Appendix – I

2017-18

director@titsbhiwani.ac.in
http://www.titsbhiwani.ac.in

Birla Colony, Bhiwani - 127 021
(HARYANA) INDIA
☎ 91+1664-242561-64
91-1664-243728

THE TECHNOLOGICAL INSTITUTE OF TEXTILE & SCIENCES

Under UGC Section 2 (f) & 12 (B)
Estd. in 1943 by Padma Vibhushan Dr. G.D. Birla

Details of Technical Research & Consultancy Services Grant received

(AY 2017-18)

Name of the Project	Name of the Principal Investigator	Amount Sanctioned (Rs in Lacs)	Name of the Funding Agency
Studies on Quality Consistency of Viscose Yarn in Kesoram Rayon Factory	Dr. Abhay Kumar Sharma	50	Kesoram Industries Ltd. Kolkata
Design and Development of union fabrics and value added products from Bamboo and Viscose filament of Kesoram Industries Ltd. (KIL)	Dr Ashvani Goyal	100 (50+50)	Kesoram Industries Ltd. Kolkata
Design and Development of Face Covering Scarves using Viscose Filament Yarn	Dr A K Patra	50	Kesoram Industries Ltd. Kolkata
Advanced Training in Connection with Excel Travel Accounting Software & Related Consultancy	Dr Mukesh Kumar	50	MSK Travels & Tour Ltd.
Studies on Comfort Characteristics of Knit Structure & Designng of Functional Accessories Using Viscose Filament Yarn	Dr. K.N.Chatterjee	50	Kesoram Industries Ltd.
TOTAL		300	

(Finance Officer /Manager Accounts)

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Director,
THE TECHNOLOGICAL INSTITUTE
OF TEXTILE & SCIENCES, BHIWANI

✉ director@titsbhiwani.ac.in
🌐 http://www.titsbhiwani.ac.in

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Estd. in 1943 by Padma Vibhushan Dr. G.D. Birla

20.07.2017

OFFICE ORDER

Dr Abhay Sharma, HOD, Department of Mechanical Engineering, will work as Principal Investigator for the project titled **"Studies on Quality Consistency of Viscose Yarn in Kesoram Rayon Factory"** sanctioned from Kesoram Industries Ltd., Kolkata.

(DIRECTOR)

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20.07.2017

OFFICE ORDER

Dr Ashvani Goyal, Assistant Professor, Department of Textile Technology, will work as Principal Investigator for the project titled **"Design and Development of union fabrics and value added products from Bamboo and Viscose filament of Kesoram Industries Ltd. (KIL)"** sanctioned from Kesoram Industries Ltd., Kolkata.

(DIRECTOR)

IQAC COORDINATOR

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20.07.2017

OFFICE ORDER

Dr. A K Patra, HOD, Department of Textile Chemistry, will work as Principal Investigator for the project titled **"Design and Development of Face Covering Scarves using Viscose Filament Yarn"** sanctioned from Kesoram Industries Ltd., Kolkata.

(DIRECTOR)
Director,
THE TECHNOLOGICAL INSTITUTE
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Estd. in 1943 by Padma Vibhushan Dr. G.D. Birla

20.07.2017

OFFICE ORDER

Dr Mukesh Kumar, HOD, Department of Computer Engineering, will work as Principal Investigator for the project titled **"Advanced Training in Connection with Excel Travel Accounting Software & Related Consultancy"** sanctioned from MSK Travels & Tour Ltd., Kolkata.

(DIRECTOR)

Director,
THE TECHNOLOGICAL INSTITUTE
OF TEXTILE & SCIENCES, BHIWANI

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Estd. in 1943 by Padma Vibhushan Dr. G.D. Birla

20.07.2017

OFFICE ORDER

Dr K.N.Chatterjee, HOD, Department of Fashion & Apparel Engineering, will work as Principal Investigator for the project titled **"Studies on Comfort Characteristics of Knit Structure & Designing of Functional Accessories Using Viscose Filament Yarn"** sanctioned from Kesoram Industries Ltd., Kolkata.

(DIRECTOR)

Director,
THE TECHNOLOGICAL INSTITUTE
OF TEXTILE & SCIENCES, BHIWANI

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COORDINATOR

(179.)

Dated: 10 May 2019

F. No. 34-55/179/RIFD/FDP/Policy-1/2017-18

All India Council for Technical Education

(A Statutory body under Ministry of HRD, Govt. of India)
Nelson Mandela Marg,Vasant Kunj, New Delhi-110070 Website: www.aicte-india.org

FDP - Sanction Letter

To
The Drawing and Disbursing Officer,
All India Council for Technical Education,
Nelson Mandela Marg,
Vasant Kunj ,
New Delhi - 110070

Sub: Release of a sum of **Rs 489000 /-**for conduct of Faculty Development Programme (FDP)– reg.

Sir,

This is to convey the sanction of the Council for payment of **Rs. 489000 /-** (Rupees **Four Lakh Eighty Nine Thousand** Only) for conduct of FDP on **Recent innovations in textile & garment design and development** to **THE TECHNOLOGICAL INSTITUTE OF TEXTILE & SCIENCES, BHIWANI**, Pin No- **127021** , **Haryana** , under the Scheme of Faculty Development Programme.

1. The amount of the grant shall be drawn by the Drawing and Disbursing Officer, All India Council for Technical Education on the grant-in-aid bill and shall be disbursed to and credited to the Registrar/ Director/Principal of the institute through RTGS.
2. This grant-in-aid is being released in conformity with the terms & conditions as well as norms of the scheme as already communicated, and also being communicated in this letter.
3. The sanctioned amount is debitable to the Major Head 602.6(a) Gen. of the Scheme of Faculty Development Programme and is valid for payment during the financial year 2019-20.

The instructions/guidelines to be followed by University/Institution

I. Release of funds and maintenance of accounts

a. The Principal of the institute and the Coordinator of the program are requested to verify the correctness of the under mentioned bank account/ RTGS details submitted by them along with the Proposal, in which the grant is being released:

Institute PAN No.	Bank Name	Bank Branch Name	Bank Branch Address	Account Holder Name	Account Type	Account Number	IFSC Code
AAATT3233A	State Bank of India	BHIWANI	S-175, Meham Chowk, Bhiwani – 127021 Haryana	Director, TIT&S	Current Account	55091893204	SBIN0050108

In case of any omission the same should be reported to AICTE immediately.

b. *The Institute shall strictly follow the provisions laid down in the scheme document and sanction order no. F. No. 34-55/ 179 /RIFD/FDP/Policy-1/2017-18 dated 10.05.2019 issued by this office*

c. Funds covered by this grant shall be kept separately and would not be mixed up with other funds so as to know the amount of interest accrued on the grant.

d. The University/College/Institute shall maintain proper accounts of the expenditure out of the grants, which shall be utilized only on approved items of expenditure.

e. The grant is intended to cover items of expenditure connected with the Faculty Development Programme such as Boarding & Lodging to the participants, TA to outstation participants, Honorarium to Course Coordinator, reading material to participants, Honorarium to resource persons, TA/DA to resource persons including two outstations resource persons & working expenses (reprographic services, postage, transport, daily wages, tea/coffee etc).

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Director,
THE TECHNOLOGICAL INSTITUTE
OF TEXTILE & SCIENCES, BHIWANI

f. The grant is subject to the adjustment on the basis of Utilization Certificate in the prescribed proforma to be submitted by the University/College/Institution. Further, the accounts of the institute will be open for test check by the Council or Controller & Auditor General of India or any other officer designated by them.

II. Disbursement of funds to institutions

a. The full amount of the grant sanctioned is being released as advance to the University/Institute.

b. The amount spent by the institute on the conduct of FDP shall be adjusted on the basis of utilization certificate and detailed expenditure statement submitted by the University/Institution on the prescribed format along with other mandatory documents viz feedback form, copy of proceedings and completion report etc.

c. The above said amount of the grant shall be released on the basis of the Letter of Approval (LOA) issued by AICTE to the institute for the academic year 2019-20.

III. Conduct of test and issuance of certificate

A test shall be conducted by Program Evaluation Committee (PEC) at the end of the program and the certificates shall be issued to those participants who have attended the program and have qualified in the test.

IV. Submission of documents by university/institution

a. The following mandatory relevant documents are required to be submitted by the university/institution within one month of the completion of the program :-

  (i) Original Statement of actual expenditure & Utilization Certificate in the prescribed proforma duly signed by the Head of the institution and countersigned by Registrar/Finance Officer/Govt. Auditor. In case of self-financing/private institutions, Statement of actual Expenditure & Utilization Certificate are required to be audited & signed and sealed by a Chartered Accountant endorsing the membership number and complete postal address. Photocopies of formats are enclosed.
  The university/institution is not required to submit bills/vouchers/invoices etc for the expenditure incurred out of recurring grants. However, such copies of bills/vouchers/invoices shall be digitized by respective institutions receiving grant and uploaded scanned copies of such bills/vouchers/invoices etc on the portal for availability and view at any point of time.

  (ii) Feedback form in the prescribed proforma.

  (iii) Copy of the proceedings and completion report.

  (iv) List of candidates who have successfully completed the program on the basis of the test conducted by Program Evaluation Committee (PEC).

  (v) Report submitted by Program Evaluation Committee (PEC).

b. The amount of the grant shall be adjusted on submission of utilization certificate & detailed expenditure statement by University/Institution. On receipt of these documents, the total amount of financial assistance, admissible as per the norms, shall be worked out and grant-in-aid shall to adjusted.

c. The university/institution is expected to submit the above said mandatory documents viz. Utilization certificate, Expenditure Statement and feedback form etc within one month of conduct of FDP. However, delay of further 2 months may be condoned by AICTE in special circumstances as explained by the institute. Delay in submission of documents after three months of the conduct of FDP shall invite a penalty of 10% of the total sanctioned amount of the FDP, to be deducted from the balance amount of 2nd installment. The entire amount of grant already released, along with interest accrued thereon shall be refunded to AICTE if mandatory documents are not submitted by the institute beyond one year.

V. General Instructions

a. **Preferably 10% of the participants may be industry professionals deputed by industry. *Further, not more than 20% participants shall be from the host institution/group of institutions.***

b. **Interest, accrued on the grant released shall be refunded back to AICTE.**

c. **If programme is not conducted in the period of nine months of the issuance of this Offer Letter, the released amount, along with interest accrued thereon, has to be returned back to AICTE.**

d. The expenditure under the Heads **'Honorarium to Course Coordinator'** and **'Honorarium to Resource Persons'** shall not exceed **1% & 20% respectively** of the total sanctioned grant for the Programme. However, overall expenditure shall not exceed the funds sanctioned for the Programme.

e. Any extra money required to complete the programme must be borne by the institute from their own resources. But the quality of the activities should not be compromised.

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Director
THE TECHNOLOGICAL INSTITUTE
OF TEXTILE & SCIENCES, BHIWANI

f. The FDP will be organized for **2 weeks with minimum 40 participants.** The approved FDP shall be conducted within nine months from the date of release of funds.

g. Any unavoidable circumstantial change in the Program with respect to name of Project Coordinator, Venue and date for organizing FDP would mandatorily require prior approval of the Council. All such requests should be addressed to AICTE, in advance, recording the specific reasons for proposed changes, failing which the offer for the grant already issued would be treated as automatically withdrawn and the financial assistance released in favour of the beneficiary institution shall be refunded immediately to the Council. Kindly mention the File No 34-55/ ______ /RIFD/FDP/Policy-1/2017-18 in your future correspondence.

h. **Program Evaluation Committee (PEC)** is required to be constituted at institutional level. The constitution of the PEC shall be as under:

(i) Principal/Director/Registrar of the institution (Chairperson),

(ii) Coordinator of the program (Member Secretary),

(iii) Two HODs and one subject expert (members).

The members of the said PEC shall not be below the rank of Associate Professor. A test shall be conducted by Program Evaluation Committee (PEC) at the end of the program and the certificates shall be issued to those participants who have attended the program and have qualified in the test. The minutes of the meetings, along with PEC report, are to be submitted to the Council at end of the program along with other mandatory documents.

i. **GOI GFR rules** (@https://doe.gov.in/order-circular/general-financial-rules2017-0) should be followed during utilization of grant.

j. This Sanction Order may be treated as Offer Letter for all purposes.

Yours sincerely,

(Dileep N. Malkhede)
Advisor-I (RIFD)
25/6/19

Copy forwarded for information and necessary action to: -

1. **Coordinator of the Program**
   Dr. YAMINI JHANJI
   THE TECHNOLOGICAL INSTITUTE OF TEXTILE & SCIENCES
   PO BIRLA COLONY
   BHIWANI 127021
   (HARYANA) BHIWANI
   BHIWANI - 127021

2. **The Registrar / Director / Principal**
   THE TECHNOLOGICAL INSTITUTE OF TEXTILE & SCIENCES
   PO BIRLA COLONY
   BHIWANI 127021
   (HARYANA) BHIWANI
   BHIWANI - 127021

3. *Guard File*

Director,
THE TECHNOLOGICAL INSTITUTE
OF TEXTILE & SCIENCES, BHIWANI

All India Council for Technical Education

Nelson Mandela Marg, Vasant Kunj, New Delhi-110070

Mandate Form For Institutes/Colleges/University/Other Organisations

1	Name of the Beneficiary Institute	The Technological Institute of Textile & Sciences
2	Permanent ID of the Institute	1-5218833
3	Head of the Institute	Director
4	Type of Institute	Self Finance
5	Address of Institute	PO Birla Colony, Bhiwani, Haryana Pin – 127021
6	PAN No. of the Institute	AAATT3233A
7	GST No., if allotted	06AAATT3233A1Z3
8	E-Mail id of the Head of the Institute	director@titsbhiwani.ac.in, info@titsbhiwani.ac.in
9	Name of the Bank	STATE BANK OF INDIA
10	Branch Name & Branch Code	RAILWAY ROAD, 50108
11	Address of the Bank with Pin Code	STATE BANK OF INDIA RAILWAY ROAD BHIWANI, HARYANA PIN – 127021
12	Telephone No. of the Bank	01664-242128, 241138
13	Name of the Account holder with Designation	Director, TIT&S
14	Account Type	Current
15	Account Number	55091893204
16	Bank Branch IFSC Code	SBIN0050108
17	Bank Branch MICR Code	127002013
18	Whether the Account is in the Name of Beneficiary Institute	Yes
19	Whether the Account is Operational	Yes
20	Whether the Account is a No-Frill Account	No
21	Whether the Account is Joint Account (if yes give details)	No

It is declared that all information provided above are true and complete in all respects.

Parmod Kumar

Signature of Account Holder with Designation
Or Authorized Signatory
with Institute Seal

Date: May 27th, 2019

IQAC
COORDINATOR

Certified that the above details are verified on (date) May 27th, 2019

Director,
THE TECHNOLOGICAL INSTITUTE
OF TEXTILE & SCIENCES, BHIWANI

(Banker's Signature with Seal)

50108

ANNEXURE – II

Name of Institute: THE TECHNOLOGICAL INSTITUTE OF TEXTILE & SCIENCES, PO BIRLA COLONY BHIWANI 127021 (HARYANA)

UTILISATION CERTIFICATE FOR THE YEAR 2019-20

Name of scheme under which grant was sanctioned:- Faculty Development Programme On Recent Innovations in Textile & Garment Design and Development.

Sl No	AICTE sanction order/letter NO and date under which grant was sanction	Amount	
1	F.No 34-55/179/RIFD/FDP/Policy-1/2017-18 dated 10-05-2019	489000/- (four lakh eight nine thousands only)	Certificate that out of the FDP Grant-in Aid of Rs 489000/-(Four lakh eighty nine thousand only) sanctioned by the AICTE during the financial year 2019-20 in favour of The Technological Institute of Textile & Sciences, PO Birla colony, Bhiwani 127021 (Haryana) as per letter mentioned in the margin Rs 489000/- and on account of unspent balance of previous year Rs.NIL/- and Rs.6153 earned as interest on unspent Grant in 2019-20 has been utilized for the purpose for which it was sanctioned and the balance of Rs. 36636/ remained unutilized at the end of the year.

Certified that I have satisfied myself that the conditions on which the amount was sanctioned have been duly fulfille and that I have exercised the following check to see that the money was actually utilized for the purpose fo which it was sanctioned.

Kinds of check exercised:

1 Audited Annual Accounts of the Institute
2 Receipts and Payment Accounts

FRN 000349N

Signature of the Chartered Accountant
Name of Chartered Accountant
R.K.Bhardwaj,FCA
Membership No 17118
Full Address with Seal
Sharma & Rishi
Chartered Accountant
537, HUDA CITY Centre
Near LIC Office, Bhiwani-127021

UDIN. 20017118AAAAAE7252

Signature of Head of Institute
Name : Prof. R K Tyagi
Designation: DIRECTOR
Full Address with Seal
The Technological Institute of Textile & Sciences
Birla Colony Bhiwani 127021 (Haryana)

Director
The Technological Institute of Textile & Sciences
BHIWANI

Signature of Finance officer
Name & Designation Mr. Vinod Sharma, Accounts officer
Full Address with Seal
The Technological Institute of Textile & Sciences
Birla Colony Bhiwani 127021 (Haryana)

Accounts Officer
The Technological Institute of Textile & Sciences
BHIWANI-127021

IQAC COORDINATOR

Place: Bhiwani
Dated: 25-02-2020

Director,
THE TECHNOLOGICAL INSTITUTE
OF TEXTILE & SCIENCES, BHIWANI

Annexure III

FACULTY DEVELOPMENT PROGRAMME ON RECENT INNOCATIONS IN TEXTILE & GARMENT DESIGN AND THE DEVELOPMENT

FORMAT FOR RECEIPT & PAYMENT ACCOUNT

S. No	Receipt	Amount (Rs.)	S.N	Payment	Amount (Rs.)
1	To Grant received From AICTE	489000/-	1	Boarding and Lodging to participants	195057/-
			2	Hon. & TA to Resource persons	93570/-
			3	TA to Outstation Participants	67320/-
			4	Hon. To Course Coordinator	4890/-
			5	Reading Material to Participants	38750/-
			6	Working expenses etc.	58930/-
3	Interest in unspent Grant	6153/-			
				Closing Balance	36636/-
	Grant Total	495153/-		Grant Total	495153/-

Signature of the Chartered Accountant
Name of Chartered Accountant
R.K.Bhardwaj,FCA
Membership No 17118
Full Address with Seal
Sharma & Rishi
Chartered Accountant
537, HUDA CITY Centre
Near LIC Office, Bhiwani-127021

FRN 000349N

UDIN-20017118AAAAAE7252

Signature of Head of the Institute
Name : Prof G. K Tyagi
Designation: DIRECTOR
Full Address with Seal
The Technological Institute of Textile & Sciences
Birla Colony Bhiwani 127021 (Haryana)

Director
The Technological Institute of Textile & Sciences
BHIWANI

Signature of the finance officer
Name & Designation Mr. Vinod Sharma, Accounts officer
Full Address with Seal
The Technological Institute of Textile & Sciences
Birla Colony Bhiwani 127021 (Haryana)

Accounts Officer,
The Technological Institute of Textile & Sciences
BHIWANI-127021

IQAC COORDINATOR

Director,
THE TECHNOLOGICAL INSTITUTE
OF TEXTILE & SCIENCES, BHIWANI

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ON DEMAND PAY MEMBER SECRETARY AICTE **Or Order**

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Rupees
रुपये THIRTY SIX THOUSAND SIX HUNDRED THIRTY SIX ONLY.

₹ 36,636.00

FOR VALUE RECEIVED

TIT&S COLLEGE

BHIWANI - HARYANA
BHIWANI - 127021

REF. No. 047913029083

6/3/20

AUTHORISED SIGNATORIES
Please sign above

⑈028508⑈ 127240002⑆ 999990⑈ 16

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COORDINATOR

Director
THE TECHNOLOGICAL INSTITUTE
OF TEXTILE & SCIENCES, BHIWANI

The Technological Institute of Textile & Sciences, Bhiwani

AICTE Sponsored Faculty Development Programme on

"Recent Innovations in Textile & Garment Design and Development"

13-25 January, 2020

COMPLETION REPORT

Department of Fashion & Apparel Engineering at The Technological Institute of Textiles & Sciences, Bhiwani organized two week AICTE sponsored Faculty Development Programme entitled "Recent Innovations in Textile and Garment Design & Development" which commenced from 13th January, 2020 and concluded on 25th January, 2020. The programme started with Inaugural ceremony on 13th January,2020 with eminent Guests from IIT, Delhi, GBTL, Bhiwani & Trident Limited. Chief guest Prof (Dr.) Kushal Sen from IIT, Delhi, Guest of honourMr B.K. Mohapatra from GBTL Bhiwani and Ms. Savita Kalwaniya from Trident Limited . Barnalagraced the occasion with their esteemed presence .

The highlights of the programme included technical sessions; hands on training, industrial visit, cultural programme and site seeing. The technical sessions included deliberations by reverent, veteran resource persons from IIT, Delhi, NIFT, Delhi and World University of Design, Sonipat apart from NITRA, NIT, Jalandhar and ATDC. Prof. Kushal Sen from IIT Delhi delivered talk on Innovations through Inspiration and Inkjet Printing Technology while Ms. Savita Kalwaniya from Trident Limited discussed about Innovations in design concepts of bathrobes. Prof. S. Dhamija from TIT&S, Bhiwani carried out his deliberations on innovative wound dressings while Dr. M.S.Parmar from NITRAhighlighted the technical and design aspects of flame retardant textiles. Dr. NavdeepPhogat and Mr. Sanjay Sharma who were industry representatives from BMD, Noida discussed the innovations associated with automotive textiles. Prof. V.K. Kothari, an EmeritusProfessor from IIT, Delhi discussed the comfort and moisture management aspects of textile structures while Prof. NoopurAnand from NIFT, Delhi delivered an impressive talk on garment sizing and fit. Prof. Deepti Gupta from IIT, Delhi delivered talk on functional clothing discussing the challenges and growth of medical textiles and smart wear. Prof. Sanjay Gupta, Vice Chancellor, WUD, Sonipat talked on a very innovative topic of assistive garments incorporating features to serve as aid for infants' mother. Prof. K.N. Chatterjee from TIT&S, Bhiwani talked on Design and Development of woven and knitted textiles. Prof. Chattopadhyay from IIT, Delhi discussed about the development of specification of textile products. Mr. Pulkit and Mr. Saurabh from Adidas and Gap respectively talked about strategic sourcing and efficient merchandising and retail concepts. Trainers from ATDC namely Ms. Gurpreet, Ms. NeeraParihar and Mr. Deepak graced the occasion and carried out very impressive deliberations on World skills, Future of Apparel Industry with advent of digital technologyand trend forecasting.

Hands on training with workshops of traditional textiles by Mr. Awadesh Pandey from Awadesh Industries, Jaipur and advanced pattern making by Dr. N. Khan from NIFT, Delhi were conducted during the programme. The embroidery and knitting workshop along with demonstration of industrial high speed sewing machines was also conducted in department's lab during the programme.

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Director,
THE TECHNOLOGICAL INSTITUTE
OF TEXTILE & SCIENCES, BHIWANI

Campus visit that included visit to departmental library, design cell, garment manufacturing and testing labs, CAD labs was organized for the participants. The demonstration of various machineries and resources in the labs was given and participants were encouraged to develop own samples.

An industrial visit for FDP participants to GBTL, Bhiwani was organized on 23rd January, 2020 with an objective to provide practical exposure and acquainting the participants with work flow and industrial practises in Textile Industry. The participants interacted with departmental heads and visited different departments namely quality assurance and testing labs, sampling department, spinning, weaving and finishing units.

Apart from technical and practical sessions, leisure activities were also planned for the participants. Sports activities were organized under the guidance of sports in charge of college followed by cultural programme and lohri celebration. An outing was planned for FDP participants and a trip was taken to Star temple, Dinode, Devsar where the participants seeked blessings of Deity and enjoyed trekking in hilly terrains of Devsar.

The programme evaluation team successfully conducted the test for the participants on 24th January, 2020 and the list of qualifying participants to be felicitated during valedictory ceremony of the programme was prepared.

The last day of the programme i.e. 25th January, 2020 was celebrated as the valedictory function of the programme. Prof. Chattopadhyay from IIT, Delhi was the Chief Guest during the event. Addressing the participants, Prof. Chattopadhyay congratulated the FDP co coordinator Dr. YaminiJhanji for successful conduct of the programme. He further extended his best wishes to participants and encouraged them to attend such programmes in near future stating that suchacademic platforms pave way foroverall personality development and provide academic and industrial exposure to the faculty.The programme was concluded by felicitation of the dignitaries and vote of thanks by Dr. Yamini, FDP co ordinator.

IQAC
COORDINATO

Director,
THE TECHNOLOGICAL INSTITUTE
OF TEXTILE & SCIENCES, BHIWANI

27th January, 2020

The Technological Institute of Textile & Sciences, Bhiwani

AICTE Sponsored Faculty Development Programme on

"Recent Innovations in Textile & Garment Design and Development"

13-25 January, 2020

Minutes of meeting

The programme evaluation committee was constituted comprising of Prof. (Dr.) G.K. Tyagi Prof. (Dr.) S.K. Sharma,Prof. (Dr.) V.K. Kaushik, Prof. (Dr.) S. Dhamija, Prof. (Dr.) K.N. Chatterjee and Dr.YaminiJhanji. The committee members conducted a meeting on 23rd and 24th January, 2020in which all the committee members were present.The membersdiscussed about the test preparation, smooth conduct of the testand evaluation of the test. DrYaminiJhanji informed the other committee members that study material has been provided to the participants. The study material was seen by the committee and the test was formulated jointly by the committee. The timings, venue, duration and sitting plan for the test was finalized by the committe members.

The commencement of the test was followed by evaluation of test by committee members and list of qualifying participants was prepared.

Programme Evaluation Committee

Prof. (Dr.) G.K. Tyagi, Chairperson
Director, TIT&S, Bhiwani

Prof. (Dr.) S.K. Sharma, Member
Professor, Department of Management Studies, TIT&S, Bhiwani

Prof. (Dr.) V.K. Kaushik, Member
Professor& Head, Department of Management Studies, TIT&S, Bhiwani

Prof. (Dr.) S. Dhamija, Member
Professor & Head, Department of Textile Technology, TIT&S, Bhiwani

Prof. (Dr.) K.N. Chatterjee, Member
Professor & Head, Department of Fashion & Apparel Engineering, TIT&S, Bhiwani

Dr.YaminiJhanji, Member Secretary
Assistant Professor, Department of Fashion & Apparel Engineering, TIT&S, Bhiwani FDP co-ordinator

IQAC
COORDINATOR

Director,
THE TECHNOLOGICAL INSTITUTE
OF TEXTILE & SCIENCES, BHIWANI

27th January, 2020

The Technological Institute of Textile & Sciences, Bhiwani

AICTE Sponsored Faculty Development Programme on

"Recent Innovations in Textile & Garment Design and Development"

13-25 January, 2020

Programme Evaluation Committee Report

The programme evaluation committee constituting of the following faculty members prepared, conducted and evaluated the programme evaluation test for the participants of FDP on 24th January, 2020. The test covered the topics like designing of bathrobes, innovative wound dressing, medical textiles, sportswear, strategic sourcing, clothing comfort, functional clothing, garment fit and sizing (to name a few). The test contents were discussed and covered extensively during the course durationand the study material was provided to participants for test preparation.

The test was conducted under the supervision of committee and based on evaluation, the qualifying participants were felicitated and provided certificates on course completion during valedictory function on 25th January, 2020.

Programme Evaluation Committee

Prof. (Dr.) G.K. Tyagi, Chairperson
Director, TIT&S, Bhiwani

Prof. (Dr.) S.K. Sharma, Member
Professor, Department of Management Studies, TIT&S, Bhiwani

Prof. (Dr.) V.K. Kaushik, Member
Professor& Head, Department of Management Studies, TIT&S, Bhiwani

Prof. (Dr.) S. Dhamija, Member
Professor & Head, Department of Textile Technology, TIT&S, Bhiwani

Prof. (Dr.) K.N. Chatterjee, Member
Professor & Head, Department of Fashion & Apparel Engineering, TIT&S, Bhiwani

Dr.YaminiJhanji, Member Secretary
Assistant Professor, Department of Fashion & Apparel Engineering, TIT&S, Bhiwani FDP co-ordinator

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Program Mode (Online/Offline): ____________

(a) Were objectives of the course clear to you? Y ☑ / N ☐

(b) The course contents were as per expectations

I. Strongly disagree ☐ 5. Strongly agree ☑

(c)The lecture sequence was well planned

I. Strongly disagree ☐ 5. Strongly agree ☑

(d) The contents were illustrated with

I. Too few examples ☐ 5. Adequate examples ☑

(e) The level of the course was

I. Too low ☐ 5. Too high ☐

Course was very Informative about new innovations.

(f) The course exposed you to new knowledge and practices

I. Strongly disagree ☐ 5. Strongly agree ☑

(g) Will you recommend the programme to your colleagues?

I. Not at all ☐ 5. Very strongly ☑

(h) The lectures were clear and easy to understand

I. Strongly disagree ☐ 5. Strongly agree ☑

(i) The teaching aids were effectively used

I. Strongly disagree ☐ 5. Strongly agree ☑

(j) The course material handed out was adequate

I. Strongly disagree ☐ 5. Strongly agree ☑

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(k)The resource persons encouraged interaction and were helpful

1. Strongly disagree ☐ 5. Strongly agree ☑

(l) The resource persons were subject experts & had full command on subject matter

1. Strongly disagree ☐ 5. Strongly agree ☑

(m) Were objectives of the course realized? Y ☑ / N ☐

Major takeaways for you from the program :
We got to know about innovation is textile. Especially I like the topics on innovation in badges, & Smart textiles.

How do you plan to implement the technical aspects & hands on training from the program in your regular academic and research work?:
During we will visit all the spinning, weaving & dyeing Conceps were refreshed. Personally I have not seen scouring, singeing & fabric finishes. Now I can make them understand in a better way. Also the working of air-jet looms and rapier looms working is quite clear now.

Please comment on the strengths of the course and the way it was conducted.
It was a brain storming session. Lot of interaction, and experiences were exchanged. Overall the technical aspects of spinning, weaving were refreshed.

Overall, how do you rate the program you attended in terms of usefulness and effectiveness? (On a scale of 1 to 5, 1 being lowest): 4.5

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STUDIES ON QUALITY CONSISTENCY OF VISCOSE RAYON IN KESORAM RAYON FACTORY

Submitted by:

DR ABHAY KUMAR SHARMA

HEAD, DEPARTMENT OF MECHANICAL ENGINEERING

TIT&S, BHIWANI

THE TECHNOLOGICAL INSTITUTE OF TEXTILE AND SCIENCES,

BHIWANI

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SECTION: 1

1.0 INTRODUCTION

Cotton plays a very important role in the textile industry. However, its limited supply cannot fulfil its demand because of increased pressure on land arising out of food grain cultivation and accommodation. Further, being a natural fibre, its production depends on climatic and soil conditions, which in turn result in fluctuation of cost and fibre quality, as a result, price of cotton has drastically increased. Viscose, a regenerated cellulosic fibre that accounted for nearly 75% of the world market in fibre industries, could be best alternative to cotton, as it exhibits similar properties except its poor wet strength. Viscose rayon as a family of fibres still enjoys the unique position of being one of the most versatile of all artificial fibres. This has resulted from the ability to engineer the fibre chemically and structurally in ways that take advantage of the properties of the cellulose from which it is made. Although the production of synthetic fibres has overtaken rayon since the 1960s, the prime attributes of rayon e.g. comfort, attractiveness, ease of processing and raw material availability will enhance its popularity for many years to come.

Although lot of experimentation and development has been done for more than 100 years, renaissance remained for viscose made from cellulose a constituent of all land growing plant life. Having a natural polymer base as raw material, viscose is an answer to the steadily increasing problems of:

(i) Higher world market cotton prices.

(ii) Greater fibre demand.

(iii) Broadening pulp industry market, including for both paper and cellophane.

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SECTION: 2

2.0 VISCOSE RAYON MANUFACTURING :

2.1 Principle of Viscose Production:

The pulp is first steeped in an aqueous solution of sodium hydroxide of appropriate concentration which causes the fibres to swell and converts the cellulose to sodium cellulosate or soda cellulose (in short alkcell, derived from the word **alk**ali**cell**ulose) that is subsequently pressed to obtain a precise ratio of alkali to cellulose . The swelled mass is then shredded to provide adequate surface area for uniform reaction in subsequent process.

The alkcell is aged under controlled time and temperature to depolymerise the cellulose by oxidation to the desired degree of polymerisation (DP) prior to reacting with carbon disulphide to form sodium cellulose xanthate. The xanthate is dissolved in dilute sodium hydroxide to yield a orange-coloured viscous solution called viscose. The solution is filtered, de-aerated, and ripened to the desired coagulation point (called salt index or Hottenroth Index) appropriate for spinning .The rayon filaments are formed when the viscose solution is extruded through the very small holes of a spinnerette into a spin bath consisting of sulphuric acid, sodium sulphate, zinc sulphate and water. Coagulation of the filaments occurs immediately upon neutralising and acidifying the cellulose xanthate followed by controlled stretching and decomposition of the cellulose xanthate to cellulose. The rayon filaments thus formed are wound in the form of cake by traversing mechanism of pot. Finally, the filaments are washed to make them free from acid, sulphur, hydro-extracted, dried, conditioned and inspected followed by packaging.

2.2 Manufacturing Process at Kesoram Rayon:

Raw material: Pulp

Kesoram Rayon at present uses two types of pulp of short and long fibre -grades received in form of bales of pulp sheets supplied by Century Pulp and Paper (Short fibre grade) and Buccai, Canada (longer fibre grade) respectively .The pulp consists of 90 -94 % α - cellulose (longer molecular chain and hence more desirable) and rest 3-4 % β and γ-gamma cellulose (shorter length and undesirable).

STEP –I Steeping:

Objective:

(a) To convert cellulose to its alkoxide derivative (alkcell). It is important to ensure that the cellulose is converted to alkoxide form both in its amorphous and crystalline regions.

(b) To remove undesirable short-chain materials present in the pulp (hemicelluloses and β-cellulose). Both these materials consume carbon disulphide (CS_2) at xanthation and deteriorate fibre quality.

(c) To cause swelling of pulp so that pulp structure opens up to enable short-chain material to be leached out.

Process:

In Kesoram Rayon steeping is carried out in batch process. A batch of around 360 kg of pulp sheet in the form of 60 nos books, each book containing 15-16 sheets, is stacked vertically in series in the compartments of steep press machine evenly so that each compartment contains 2 books . The pulp in the form of sheet is soaked in a solution of 18-19 % Sodium hydroxide (NaOH) at temperature of 20^0C.

STEP –II Pressing

Objective:

(a) To remove excess of alkali which is reused after increasing its concentration to the required level.

Process:

At the end of the steeping period, the alkali cellulose sheets are pressed under high pressure [250 -300 Kgf for Century Pulp and Paper (CPP); and 100-150 Kgf for Buccai] through a ram which forces the metal plates and pulp sheets against the opposite wall of the press for a period 7 -10 minutes depending on the requirement . The caustic from this pressing operation contains higher hemi-cellulose content. The press lye from the press goes to the dialyser where it is purified and converted into solution lye which is stored in a separate tank and sent to simplex churn. The amount of pressure applied is calculated to give a precise **press weight ratio (PWR)** [the ratio of the weight of the alkali cellulose sheet cellulose and the weight of air dried pulp] corresponding to cellulose: caustic soda ratio of around 33:15.

STEP –III Shredding:

Objective:

Shredding is performed to open up the alkcell and facilitate the penetration of oxygen and CS_2 into the alkcell. Shredding reduces the alkcell density from 250–450g /1 to 80–170 g /1 .

Process:

Shredding comprises of following three steps:

(i) Pre- breaker:

This machine contains one spike roller which rotates clock wise for first 15 second and then anti – clock wise for next 15 seconds. This roller tears apart the crumbs .The rotation in both direction helps to minimise adhesion of crumb to the roller.

(ii) **Coarse shredder**: It consists of two grooved disc mounted on shafts. One is stationary and the other one rotates. The setting between the discs is narrower than the pre breaker to further reduce the size of the crumb. The crumbed material is pneumatically transported to the next section.

(iii) **Fine Shredder**: The construction is similar to that of coarse shredder; the only difference is that space between the rollers is further reduced to achieve higher degree of shredding.

Total time for shredding is around 20 minutes.

STEP –IV Ageing:

Objective:

The pulp received from the shredder has a degree of polymerisation (D.P.) in range 850–1000. For commercial viscose processes, this must be reduced to the point at which viscose dope of an acceptable viscosity will results. However, acceptable fibre tensile properties can be achieved through the use of pulp with high degree of polymerisation. For regular staple production, the DP of the alkcell going to xanthation needs to be around 270–300.

Process:

The shredded white crumb is transferred pneumatically to jacketed drum which rotates at slow speed having rotational axis almost parallel to the ground, holding the crumb from one complete steep of the batch process. The outer jacket contains circulating hot water at required temperature being supplied from a separate hot water tank so as to increase the temperature of material (35- 38^0 C) to facilitate oxidative depolymerisation. Time required for the process is around 8.30 hours.

STEP –IV Cooling:

Objective:

Cooling reduces the temperature of the material and slow down the process of depolymerisation otherwise the chain length of the cellulose remains too small to manufacture rayon.

Process:

The material from ageing drum is transported to the cooling drum by means of conveyor belt .The construction of cooling drum is similar to that of ageing drum **.** The cold water from the cold water tank flows continuously through the outer jacket to bring down the temperature of the shredded crumb. The final temperature is around 30 -32^0 C and time required for cooling is 5.30 hours. After cooling the material transferred to a bunker (a big vessel made of cast iron) having capacity approx 1800 kg. Time required for filling is 20 -25 min.

STEP –V Xanthation

Objective:

The soluble derivative, sodium cellulose xanthate, is formed by reacting alkali cellulose with Carbon disulfide (CS2) .

Process:

In Kesoram Rayon two types of reaction vessel are used e.g.

1. **Wet churn**, whereas the alkcell is slowly agitated as the CS_2 is added. Upon completion of the xanthation (seen as a vacuum 'regain' as the residual CS_2 vapour is consumed by the alkcell), mix soda is added directly to the churn. This is a batch process.

2. **Dry churn,** where the xanthate crumb is discharged into a separate dissolving vessel upon completion of the reaction. This is also a batch process. However, this process is not in use in Kesoram Rayon at present.

The **churning** process is carried out in a hexagonal, jacketed vessel with mixer blades and a hollow perforated shaft through the centre. This centre tube is used for evacuating the churn and feeding CS_2. During operation, a weighed amount (1800 kg) of white crumb is placed into the churn through a hinged door on one side. The evacuation pump is started till the vacuum reaches 660 mm Hg column. Prior to starting of the process, the door is bolted securely. This is necessary because of the explosive nature of CS_2. The operation begins by evacuating the churn to a given negative pressure (660 mm Hg below atmospheric pressure) and then slowly admitting CS_2, over a period of time (10 minutes). The xanthation reaction is exothermic and is controlled by chilled water running through the jacket. The entire operation can be controlled automatically, and in Kesoram Rayon plant it is monitored by remotely computer stationed in control room.

As CS_2 enters the churn, the pressure rises, and as the reaction proceeds, the CS_2 is exhausted by reaction with the alkali cellulose and vacuum is restored. The operator keeps watch on the reading of pressure recorder to threshold when the reaction is complete and ready for the next step. The time of reaction depends on the temperature and the amount of CS_2 used, and vary from 60 -65 min.

The wet churn differs from the dry churn in size and in the mode in which it is used. In operation, the charging of the churn with crumb and CS_2 is similar to that for the dry churn, but the difference arises when part of the mixer caustic charge is introduced shortly after vacuum regain begins. Thus in wet churn the solution lye is added in the churn itself whereas in case of dry churn the solution lye is added in dissolver.

Process parameters for wet churn:

(a) Xantahation temperature; 30^0 C

(b) circulating water temp; 20^0C

(c) Temperature after lye addition; 18^0 C

(d) Solution lye concentration; 24 gm / lit

(e) Volume; 4800 lit (aprrox)

(f) Volume of CS_2; 145 lit

STEP –VI Simplex dissolver:

Objective:

In dissolver, the solution is homogenized.

Process:

Viscose mixing is done in a jacketed vessel with propeller blades, which is contained in an interior vessel, called a dissolver. Xanthate slurry from the wet churn is forced into the sides of the vessels in a tube and then flows down to the center through the propeller blades continuously. The heat of mixing is controlled by chilled water flowing through the outside jacket of the dissolver. Though cellulose xanthate dissolves best in cold caustic, however, for economic reasons, higher temperature of 15^0C is used in Kesoram Rayon. Few of the dissolvers in the factory are provided with homogenizer. This is .a pump which circulates the material and fastens the dissolving process. Time required for the process is 3 hrs whereas with homogenizer it is 1.30 hrs.

STEP –VII Rayon blending:

Objective:

It further homogenizes the material and reduces batch to batch quality variation in the long run by mixing different batches.

Process:

Construction of blender is simplified to that of dissolver without homogenizer. The only difference being in capacity, higher capacity to accommodate different batches. It supplies the material to a number of blender tank arranged in series.

Process parameters:

Viscosity; 45-47 seconds (ball fall)

Initial temperature of viscose; 20^0C

Final temperature; 19.5 ^{0}C

STEP –VIII Ripening:

Objective:

During ripening, chemical and physical changes occur in viscose. The solution darkens and the by-products formed affect the ease with which the viscose coagulates in subsequent spinning. The viscosity also changes, first decreasing as the solution uniformity improves and then increasing, slowly at first and then quite rapidly, as the cellulose xanthate decomposes and eventually forms a gel. Under normal conditions of viscose ripening, as CS_2 is released from the cellulose xanthate, it is consumed in reactions, forming by-products and re-xanthating the cellulose. The extent of these reactions is influenced by viscose composition and ripening conditions. The degree of ripening is controlled by time and temperature until the required ripeness is obtained. Ripeness is expressed as a salt index (SI) or Hottenroth number, which is the amount of sodium chloride solution or ammonium chloride solution, respectively, needed to coagulate the viscose. The tests measure the ease of forming a coagulated viscose filament in spinning. In Kesoram Rayon, the degree of ripening is measured in terms of Hottenroth number and the value usually maintained is around 9.5 .The cellulose DP has an inverse relationship to the SI/ Hottenroth Value, reflecting solubility–molecular weight relationship: the higher the DP, the lower the Hottenroth Value (HV). Hemi-cellulose in the viscose liable to a high Hottenroth Value. Improved solubility resulting from the redistribution of xanthate groups is required for good quality viscose rayon.

Process

In Kesoram Rayon viscose ripening is conducted in large tanks where in the filtered viscose is stored at a controlled temperature for a period of time that depends on the type of viscose. The air from viscose is also removed to avoid bubbles that would interfere with smooth spinning.

A Series blenders: It can store up to 7 number of batches. When the level goes below a certain level (say 6.5 batch), the optical sensor fitted with it start the filling pump till the level rises to the required level. Thermal sensor measures the temperature and maintains it in the temperature range of $20 – 21.5^0C$.

Filters: Regardless of how well the xanthate is brought into solution, there will always be particulate material/ impurities in the viscose. Prior to spinning, all these types of impurity needs to be removed to prevent blockage of the holes in the spinning jet.

A series Filter : Due to constant pressure difference of 1.5 Kg / sq cm in the (outlet - 4.5 kg / sq cm; and inlet - 6.5kgf / sq cm) filtration of viscose takes place through a filter of size 15 Micron . When choking of filter takes place, the internal pressure increases and if the pressure difference exceeds, a rotating piston leads to cause drainage of waste material .

From this filter, material is delivered to ***B series blender*** and filter which acts in a similar fashion. The ***B series filter*** is finer than A series filter (10 micron).

The material is then transferred to ***C series blender*** which stores the material for further ripening and act as buffer.

STEP –IX De-aeration:

Objectives:

Removal of air from viscose is essential for avoiding bubbles that may interfere with spinning process leading to the weak spot, which in many cases becomes end breakage or potential source of broken filament.

Process

To ensure continuity at spinning, the viscose must be de-aerated to remove dispersed air or other gases that might otherwise cause small bubbles to form as the viscose is extruded into filament form through the jet. .

In Kesoram Rayon process vacuum is created by converting steam to water. Water flows through the booster and high pressure steam is passed through a line. As steam comes in contact with water, condensation takes place and a high vacuum is created by pressure drop. The air present in the solution is extracted from viscose.

Feed tank: Material from de-aeration tank is delivered to the feed tank, placed just below it for further ripening. Material from the feed tank is delivered to the C series filter.

C series filter: Filtration of viscose is usually done using plate and frame filter presses. Filter materials constitute a cotton batting with a tightly woven cotton. Fabric. The filter material is strong enough to withstand the pressure applied to force the viscose through the interstices and tight enough to hold back the un-dissolved particles, fibres, partially dissolved gels and particles that would clog the fine spinnerette holes during the spinning operation. Inlet pressure is 8 kg/ sq cm and outlet pressure is 6.1 kg/ sq cm. Once blinded by impurities , cloths would be removed manually and washed for re-use or discarded.

STEP –X Spinning:

Objectives:

In spinning, the alkaline viscose solution is exposed to an acidic spin-bath under controlled conditions to form filaments of rayon

Process

Viscose after ripening and subsequent filtering is supplied from viscose department to the spinning department through different conduits by means of pump at a pressure 5.4 kgf/ sq cm. The spinning machines are supplied with viscose via a number of branch conduits by means of metering pump. Metering pump delivers a precise flow of viscose and feed to a candle filter via candle pipe. Candle filter filters the residual impurities and after filtration viscose is fed via goose neck to spin bath and finally extruded through the spinnerette contained in a glass tube and dipped in spin bath. Spinnerette are thimble-shaped and made of corrosion-resistant metal, such as platinum or gold, The viscose extruded through the spinnerette when comes in contact with the spin bath reactions takes place leading to regeneration of cellulose in form of continuous filaments .

To achieve acceptable tensile properties particularly for textile end-uses, the filament must be stretched at the earliest after extrusion. At the very early stages in regeneration, the cellulose chains can be aligned by stretching The stretch is applied in filaments by running over a pair of godets rollers placed one above the other moving at different surface speeds, the upper roller has greater speed than that of lower one . Continuous filament is collected in a rapidly rotating centrifugal pot machine through a traversing glass flannel. The rate of delivery and the spindle speed are adjusted so that the filament is given required amount of twist .Excess amount of spin bath liquor comes out through the holes in the pot. After required length of filament is wound in form of the cake, it is doffed . (weight approx 2 kg).

The filament denier is determined by the rate at which viscose is delivered to the spinnerette, the number of holes, and the degree to which the filaments are stretched.

Spin bath composition:

Sodium Sulphate; 246 -248 gm / lit

Sulphuric acid; 138.67 – 140.63 gm / lit

Zinc sulphate; 15-16 gm / lit

Temperature of spin bath; 56-57

Surface tension; 44-46 dyne / cm

STEP –XI After Treatment:

Objectives : To remove the impurities (free sulphur , zinc sulphate , sodium sulphate) present in the cake received. This is done by washing in stage wise manner followed by hydro extraction and drying .

Process

(i) Washing: For this about 310 Cakes are loaded on to the carrier. The cakes are first washed with soft water 3 times at temperatures 27, 38 and 39 C. This is followed by caustic bath washing (3.3 -3.7 gm /lit) at 65 C and washing with water at room temp. This is followed by washing in bleach bath (0.5 gpl , NaOH and available Cl_2 2 gpl) twice at room temperature . The cakes are again washed with soft water. At the next stage washing is

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done with EDTA, soft water and finally two hot washes at 50C with pH within the range 6 and TDS 1-1.0 gpl .

(ii) Hydro-extraction:

Objectives: To reduce the moisture contents of the cakes from 300% to 180%.

Process

Cakes after washing, having moisture content around 300% are placed in the rotating pots. Due to the action of centrifugal force generated because of rotation of the pots (3500 rpm) excess amount of water comes out of the cake through holes in the pot. Time taken for hydro extraction is 2 min / lot

Drying:

Objectives: Drying of cakes to reduce the moisture present in cake

Process:

After hydro- extraction the cakes are put in trolleys. The trolleys are placed inside dry chamber where the cakes dried by blowing hot air (steam coil and fan) of 80-82 C. The moisture content is reduced to 4%. Time required for drying 3 days.

(iii) **Conditioning:**

After drying the cakes are taken into conditioning room where relative humidity is maintained 85% - 87% and temperature 90^0-94^0 F .Time required is 70-72 hours. After conditioning the moisture % of the cake increased to 11%-13%.

(iii) Cone formation:

Objectives: To remove the slub like faults and to form package of suitable size and shape for viscose filaments for easier handling.

Process:

Cakes are placed on to the cone holder of precision cone winder and wound in form of cones of required weight (1kg -2.1 kg) depending on the requirement. Yarns are lubricated to reduce the coefficient of friction. The density of the cone is maintained within 65 – 70 degree shore hardness. Traverse width is 6 inch and wind per double traverse is 2.5.

(iv) Inspection:

Depending on the number of visible broken filament and appearance, cones are inspected and graded, wrapped with polythene and finally packaged as per the requirement.

SECTION: 3

QUALITY CONSISTENCY OF VISCOSE RAYON IN KESORAM RAYON FACTORY:

To make rayon, sheets of purified cellulose are steeped in caustic soda, dried, shredded into crumbs, and then aged in metal containers for 2 – 3 days. The temperature and humidity in the metal containers are carefully controlled. After ageing, the crumbs are combined and churned with liquid carbon disulphide, which turns the mix into orange-coloured crumbs known as sodium cellulose xanthate. The cellulose xanthate is bathed in caustic soda, resulting in a viscose solution that looks and feels like honey.

After the syrupy viscose solution is prepared it is forced through a spinneret into an acid bath containing sulphuric acid, sodium sulphate and, usually, Zn++ ions, causing the cellulose to be regenerated and precipitate from solution. The resulting strings or filaments are then stretched on godet wheels to strengthen them, and put into a spinning Topham box. The result is the formation of fine filaments of cellulose, or rayon.

Possible sulphur residues can generate reducing conditions – destroying or changing the shade of dyestuffs.

After initial skin formation, the core of the fibre decomposes, hardens and shrinks. Viscose fibres are therefore characterised by an irregular, serrated skin and cross section. The skin is said to consist of many small crystalline regions. The core, on the other hand, develops a coarser crystalline structure.

Differences in the ratio of skin to core impact on fibre properties and dyeing behaviour. Dye diffusion is therefore crucial to dyeing speed and extra kinetic energy is needed for dye penetration – especially when swollen to its maximum by heat.

As with most chemically oriented processes, quality control is crucial to the successful manufacture of rayon. Chemical make-up, timing and temperature are essential factors that must be monitored and controlled in order to produce the desired result.

The percentages of the various pulps used in a blended form must be controlled to optimise the good properties of blended viscose filament yarns.

The practical challenge for VFY production is the consistency of all those parameters over time, as this is the precondition for consistent yarn properties within one spool (outer versus inner part of a spool) and from spool to spool.

In order to maintain Quality consistency of Viscose Rayon Filament yarn manufactured in **Kesoram Rayon Factory**, the following areas need to be monitored:

- Broken Filament
- Tenacity

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- Shade Variation
- Denier Variation
- Coloured yarn – more range, Shade depth

i) Quality consistency of Viscose Rayon Filament yarn in terms of Broken Filament

Expectedly, filament breaks are more difficult to control. Consequently, probability to restart the total machine after minor problems increases. The optimisation of spinning speed is required to maintain a balance between efficiency and process stability.

Broken filaments are decisive for the mechanical processability in weaving, knitting and twisting. This depends on the number of physical defects associated with individual capillaries which are introduced during spinning by impurities or during after treatment due to abrasive yarn-machine contacts.

Many times, broken parts or rough surfaces of machine parts may cause broken filament. In order to control the broken filaments, excellent mechanical process ability requires less contact of yarn with machine parts, high quality guides surface, godets with a controlled drive and a safeguarded protection of the individual filaments in all process steps.

Besides the tension and pressure during extrusion of filament are other prime factors.

ii) Quality consistency of Viscose Rayon Filament yarn in terms of Yarn Tenacity

Tenacity and elongation are partially a result of the chemical parameters during spinning. Both are also strongly influenced by the stretch ratio between spinneret and winding. Yarn Tenacity can be further improved by blending imported pulp and domestic pulp. However, optimisation of blends is of paramount importance. Tenacity and elongation should be tuned by the spin bath and viscose solution parameters.

Alteration in ZnSO4 (Zinc sulphate) concentration in coagulation bath during Wet Spinning can also improve yarn tensile properties.

iii) Quality consistency of Viscose Rayon Filament yarn in terms of Shade Variation

Optical properties such as light reflection, dye uptake and brilliance depends on the morphology of the yarn i.e., porosity, skin-core ratio, which in turn are determined by the chemical parameters used during spinning.

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Possible sulphur residues can generate reducing conditions – destroying or changing the shade of dyestuffs. Hence, maintaining consistency of dope solution and proper stirring of viscose solution, filtration at several stages and viscosity of solution must be kept consistent. Stabilisers should be used.

Constant dyestuff uptake is achieved by constant skin-core relation and porosity. This suggests the use of constant process parameters namely temperatures, concentrations, and residence time throughout all process steps. For all the manufacturing stages (i.e., spinning, washing, drying and winding) the optimal processing speed and parameters need to be chosen.

iv) Quality consistency of Viscose Rayon Filament yarn in terms of Denier Variation

Filament formation takes place in a chemical process in approx. 0.1 second and during this brief span a multitude of chemical and physical parameters in and around the fibre, determines the optical and mechanical parameters. Decisive factors range from chain lengths of the cellulose over dope-viscosity to the concentration of numerous chemicals.

Equally important are the temperature of the chemicals, the reaction time and the design time of the devices.

Spinneret size in terms of their hole size and hole distribution also need to be checked out regularly. Moreover, spinning speed variation needs to be minimised.

v) Quality consistency of Viscose Rayon Filament yarn in terms of Coloured yarn, range, shade depth

With the help of most advanced package dyeing technology, more than 5000 colours can be developed. The technology can not only guarantee the quality of the products but also rich colours of the products and increased colour fastness. The depth of shade is also improved.

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SECTION: 4

OPTIMIZATION OF VARIOUS PROCESS PARAMETERS AND THEIR EFFECT ON VISCOSE QUALITY

I Steeping

Steeping conditions are optimised to ensure good formation of alkoxide, and dissolving out the hemi- and short-chain celluloses. Two main parameters to achieve optimum steeping are soda temperature and its concentration. Beside these time and degree of access of soda lye are also important.

(a) Soda temperature:

Higher soda temperature dissolves out more of the short-chain material, but reduces swelling of the pulp, the litter Swelling of pulp is favourable for removal of short length cellulose. Some depolymerisation also takes place during steeping, and its extent increases with increasing temperature.

(b) Soda concentration

Pulp swelling increases as soda concentration is reduced. A high degree of swelling is desirable because it opens up the pulp structure to enable short-chain material to be leached out, and also to enable the soda to penetrate effectively into the fibre structure. However, higher concentration is necessary to ensure that the conversion to the alkoxide derivative proceeds to an acceptable extent. In practice, around 17–19% soda is used .

(c) Time

Effective removal of hemi-cellulose and the alkali-soluble material facilitates improvement in subsequent reactions. Because alkaline hydrolysis produces short-chain material, which is desirable to continue the steeping for the shortest time needed to obtain uniform distribution of alkali in the pulp

Highly swelled pulp makes pressing difficult. Hence, as steeping proceeds, a trade-off between enhanced swelling is required to ensure good accessibility and hemi-cellulose removal, and achieving acceptable press throughputs.

(d) **Separation between the pulp sheets**:

Besides alkali concentration, temperature and time, separation between pulp sheets is important in the batch process. This is particularly so because extent of conversion is hampered by the compact nature of the cellulose sheets, and also by the accessibility of the soda into the discrete cellulose fibres if the gap maintained between the sheets is too low.

II Pressing :

The pressure applied at pressing to remove excess of liquor. But potentially excessive fibre levels in the press soda, and clumping of the cellulose fibres leads to uneven alkcell. The amount of pressure applied is calculated to give a precise press weight ratio (PWR) corresponding to cellulose (caustic soda ratio of around 33:15).

If the alkali cellulose crumb is too wet due to under pressing, or localised wetting occurred due to condensation, it will not xanthate properly. On the other hand, over pressing, drying out, and carbonate formation must also be avoided.

Press weight ratio (PWR) should be maintained precisely within a narrow range . This is because of the fact that batch to batch variation of PWR may cause serious problem in maintaining the quality of the final product .

Where fibre tensile properties are critical, it is often valuable and sometimes vital to reduce the hemi-cellulose at steeping down to 1.0–1.5%. This is usually achieved by employing a dialysis (or reverse osmosis) system, where NaOH and hemi/low-molecular weight cellulose are separated using a membrane.

III Shredding

Alkaline oxidation and hydrolysis of the cellulose, which begin when the pulp is steeped, continue during shredding. The shredding temperature and mechanical work are often used as adjuncts to aging to control the extent of depolymerisation.

Time, temperature, and rotational speed of the disc and Blade clearance in shredding are controllable variables that must be adjusted for each type of the pulp processed.

In this operation, time, temperature, blade clearance, and speed must be carefully controlled.

Blade clearance is important to avoid compacting the crumb. Each pulp type requires different conditions for optimum processing, which are determined by the fibre length of the wood species involved. Long-fibred cellulose (Buccai) needs marginally wider setting and gives a less dense, bulkier and white crumb than the short-fibred sheet supplied by CPP.

Temperature needs to be controlled because heat evolved during mechanical work done on crumb may cause depolymerisation, which affects subsequent aging requirement. The shredding temperature and mechanical work done on the alkcell together with ageing process also need to be considered to control the extent of depolymerisation.

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Excessive drying, carbonation, or localized wetting from condensation of the crumb within the shredder must also be

III Ageing:

The viscosity of viscose is an important processing parameter, and the final rayon properties are dependent on the average chain length or degree of polymerisation of the cellulose. Control of this variable is achieved by aging the alkali cellulose crumb under condition yielding the appropriate extent of depolymerisation for the type of rayon produced.

Time

The depolymerisation may be accelerated at an elevated temperature by catalysts such as Fe, Mn, and Co and by oxidants like sodium per chlorate, and sodium peroxide. In these ways, the time required for aging crumb can be reduced from 1- 2 h. However, the time, temperature and concentration of oxidants need to be optimized for actual working condition by taking trial.

Furthermore, as alkaline degradation with a high copper number (a measure of the number of carbonyl groups on cellulose) is faster than that of a pulp with a low copper number. Hence, copper number also needs to be considered during optimization.

IV Cooling

Temperature

To avoid condensation, it is important to ensure that alkcell, as it enters the xanthation vessel, has a minimal temperature difference relative to the xanthation vessel,. Any alkcell which comes into contact with water reverts substantially to cellulose from its alkoxide form, and thereafter remain unreactive at xanthation. Unreacted cellulose following xanthation causes serious filtration problems, broken filament and may at times requires rejection of the solution.

V Xanthation

The availability of free NaOH and hemicelluloses/low molecular weight cellulose encourages number of CS_2 – consuming side reactions to take place. Hence, minimising amount of these materials in the alkcell, entering the churn, plays an important role in achieving low consumption of CS_2 and NaOH.

Temperature:

At elevated temperatures, xanthation is accelerated but being by-product formation and xanthate decomposition are also affected in the same way. Being exothermic reaction, the temperature is to be maintained below 32^0 C by the use of cooling water, and excessive xanthation time is avoided.

As well therein, xanthate crumb is dissolved in a dilute aqueous solution of sodium hydroxide of about 5–8% concentration. During this step, reactions of xanthation and by-product formation continue and, in some processes, more CS_2 can be added to the mix to obtain improved viscose quality

VI Dissolution

Temperature:

Low temperature is desirable, as xanthate has greater solubility in NaOH at lower temperatures. Forced cooling of the dissolving soda down to 0–5°C allows better dissolving and can enable CS2 usage to be reduced somewhat. However, in practice slightly higher temperature is maintained for economy point of view.

The xanthate is also more soluble in higher NaOH concentrations, and it is therefore advantageous to press off as much soda as possible from the alkcell prior to the churns, and use this to increase concentration of soda at mixing.

VII Ripening:

Temperature, time, and alkali cellulose composition have considerable influence on ripening.

Even distribution of alkali cellulose composition is vital for stable spinning and acceptable filament quality. Sodium cellulose xanthate is an unstable compound and CS_2 coming off is also able to re-xanthate a previously un-xanthated part of the chain and this also helps to make the cellulose better solvated. The Hottenroth value (HV) or Salt Index (SI) tests measures the ease of forming a coagulated viscose filament in spinning. The cellulose DP has an inverse relationship to the SI reflecting solubility–molecular weight relationship: the higher the DP, the lower is the SI. Hemi-cellulose in the viscose causes a higher value of SI or HV.

It needs to mention that viscose of high Hottenroth value (HV) requires more time for complete regeneration and this enable increased stretch to be applied, with correspondingly higher tenacity .However, stuck filament and trash can be formed as a result of neighbouring poorly regenerated filaments sticking together just after extrusion.

Therefore, temperature, time, and alkali cellulose composition are adjusted in such a manner so that Hottenroth value remains within 9- 11. In Kesoram Rayon, Hottenroth value s maintained around 9-9.5. In addition, catalysts such as manganese and cobalt salt can be added to the pulp sheets and the steeping liquor to accelerate the process of ripening. However, the actual amount needs to be adjusted by trial before taking in to bulk.

VIII Spinning

In view of the effect of zinc on crystallinity, which ultimately translates to improved tensile strength, the production of high strength rayon usually involves high level of zinc in the spin bath. In practice, it is maintained between 0.5 - 1.5% with zinc sulphate in the spinbath for regular staple production. Less than 0.5% of zinc sulphate in the spinbath causes significant deterioration in filament tensile strength. To some extent this can be compensated by raising sodium sulphate concentration. This may also result in delivery of irregular filament cross-section.

Viscose dope viscosity

Higher dope viscosity expressed in terms of 'ballfalls' generally results in more stable extrusion, and consequently lower trash figures. This is kept around 40-45 sec.. Low ballfalls, particularly less than 30 ballfall seconds (as measured at 18°C), can give rise to dead viscose (DV) and stuck filament (SF) trash problems.

Spinbath acid

Reduced acid level allows more stretch to be applied, which in turn help in greater tenacity/ extension realisation. However, high DV and SF trash can result from low acid level spinning. Low acid, on the other hand, results in greater crimp formation and potentially higher fibre cohesion

Spinbath zinc

Reduced levels of zinc adversely affects tenacity, say below 0.5%.

Sodium sulphate

High level of sodium sulphate tends to increase tenacity, however, effect is insignificant with normal level of Zinc Sulphate.

SECTION 5

PROPOSED SUGGESTIONS FOR MODIFICATION OF EXISTING MANUFACTURING PROCESS

I ***Reduction of drying time*** : At Kesoram Rayon, the viscose cakes after hydro- extraction (moisture content 180%) are sent for drying till the moisture level reduces 4 %. This is followed by conditioning of the cakes where moisture level maintained is 13-14%. Thus moisture is dried and again added in the cake in Cake Conditioning Room (CCR). Instead of doing this, it is proposed that drying time of the cakes at the chamber may be reduced to get moisture level of 10- 11%. The rest amount of moisture may be added in the cake conditioning room . This is expected to reduce time, labour and heat energy consumption for drying.

For trial purpose, 10 -12 cakes may be segregated with suitable identification mark and dried till moisture content is 10 -12 %. Later, these cakes are to be transferred to CCR for adding remaining amount of moisture to get final moisture level of 14 %. The performance of these cakes needs to be monitored at the time of conning (for breakage rate) and subsequently at the inspection table and lab for quality.

II. Measurement of hemi cellulose content : In order to produce good quality viscose in terms of tenacity and higher wet modulus, the level of Hemi- cellulose in the steep soda recycling circuit (used for steeping) needs to be measured and controlled. For high-performance, high-strength rayon, the hemi- cellulose content of the steeping liquor must be maintained in the range of 0.6%- 0.8%. Where the filament properties are less demanding, higher levels of hemi- cellulose up to about 1.5 %, can be tolerated. In Kesoram Rayon lowering of hemi- cellulose content is achieved by employing a dialysis (or reverse osmosis) system, but hemi-cellulose content must be measured at regular interval.

III Use of automatic metallic filter The conventional cloth filter is prone to release deposited particulates if the system pressure or flow rate changes suddenly. These filters separate out most particulates until the filter 'blinds', the point where particulates are pushed through the cloth and efficiency starts to fall. Furthermore, these filters require frequent

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cleaning and washing. Hence, it is suggested to use Automatic Mechanical Filter (supplied by Lenzing KKF) in **C series filter** at Kesoram Rayon. These mechanical filters consist of sintered metal screens with hole of 10–20µm. These filters back flush automatically by the pressure build-up. In comparison to conventional plate type filter , this type of filter does not require frequent cleaning and washing, saves time and labour, and are more efficient and less prone to leaks . However, capital cost is higher than that of conventional plate type filter.

IV Use of metal detector: Metal detectors may be used to detect extraneous metallic particles from the alkcell especially prior to addition to the churns. This is important, because metal particles in the churn can cause spark formation, which could, in turn, lead to an explosion when the churn is vented to atmosphere upon completion of the xanthation reaction.

V. Use of modifier in the spin bath

Retarding the rate of regeneration helps to achieve improved fibre tensile properties because it allows more stretching for orientation of cellulose. Zinc sulphate in the spin bath helps to achieve this by forming a more stable intermediate compound. Surface active materials, like primary amines and polyalkenes glycols lead to formation of a more stable intermediate complex with free CS_2, zinc, and cellulose xanthate. A synergistic effect between amine and polyglycol modifiers, in conjunction with the action of zinc, enable higher stretching during spinning, This modifier system, if used with appropriate spinning conditions such as reduced primary spin-bath temperature and slower spinning speed, results in an increased of wet-modulus. This forms semi-permeable membrane and retards penetration of acid into the filament. Thus crystallization process can be delayed allowing more stretch percent available. This leads to better orientation of macro -molecules and increased strength. However, the amount of modifier needs to be optimized on the basis of actual process condition.

Reduced acid levels (lower than that used in Kesoram Rayon) may allow more stretch to be applied and consequently greater. However, **stuck filament (SF) can result from low acid spinning**. Low acid also results in greater crimp formation and potentially higher fibre cohesion. A trial may be taken to optimize the acid level in the spin bath.

VI. Use of catalyst in ageing process. In addition to temperature, time, and alkali cellulose composition, required quantity of catalysts such as salts of manganese and

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cobalt can be added to the pulp sheets and the steeping liquor to accelerate the aging process

VI. Checking of Press weight Ratio (PWR) . Both cellulose and water content in alkcell changes due to variation in press weight ratio. This may cause batch to batch variation in quality of final product (as it affect xanthation process)which may not be compensated by blending in subsequent stage. Hence PWR should be regularly checked at least for every 5-6 batches and to be maintained with in precise range (not more than mean +/_ 0.2) .

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SECTION 6

DEVELOPMENT OF MODIFIED VISCOSE RAYON:

Rayon being unique in nature, can be permanently modified for a wide variety of end uses simply by adding the appropriate material in spin bath .Relatively minor changes in the chemical and physical parameters of the spinning system can result in fibres with distinctly different properties. Due to technological developments over a period of time, rayon is in reality a family of fibres that have a common source, cellulose. It is worth mentioning that each different variety of rayon has its own particular engineered properties for a wide variety of end uses.

(A) Flame-Retardant Viscose Rayon:

Introduction

Rayon, like cotton and other cellulosic fibres, burns if ignited, and this characteristic has prevented the fibre being used alone in nightwear and other specialised dress material applications. The need for flame retardant viscose rayon has steadily increased over the last five years**.** This trend is the result of increasing safety awareness of the population especially in highly developed and industrialized countries. Consequently, a number of new processes have been developed to produce combustion and flame retardant textile products from viscose filament. . The Flame Retardant Rayons have an advantage over FR cotton as the latter needs to be after treated and most of the flame-retardant remains on the surface of the fibres. FR rayon, on the other hand, has the flame-retardant distributed uniformly throughout the interior of the fibre as the chemical is incorporated at the time of filament production itself. Furthermore, it is more durable to washing.

In general, flame retardant chemicals are selected from the family of compounds of phosphorous, antimony, sulphur, halogens etc. However, each of the process has its own drawback arising out of cost, toxicity, complexity and poor cost benefit analysis. In following section two simple process are outlined which can be made in conventional viscose rayon route (followed in Kesoram Rayon).

1. Manufacturing Process Of Flame-Retardant Viscose Rayon, based on Addition Of Phosphate Derivative:

Flame-retardancy property of rayon can be imparted by using the FR chemical, namely alkyl, aryl, and halogenated alkyl or aryl phosphates, phosphates, phosphazenes, phosphonates, and polyphosphonates for addition to the viscose.

When 18–25% of these chemical, usually in the form of finely divided powder or polymeric liquid form, is added to the viscose (on cellulose weight) the resultant viscose filament will be flame resistant as per the international standard. **Sandoflam 5060**(chemical identity : 2,2-oxybis,5,5-dimethyl-1,3,2-dioxaphosphorinane-2,2-disulphide) developed by Sandoz maybe added on the weight of cellulose to produce flame retardant viscose fibre . However the cost of this chemical is very high and thus the process becomes highly cost intensive.

2. Manufacturing Process Of Flame-Retardant Viscose Rayon Based On Addition Of Sodium Silicate :

Viscose preparation is carried out by treating cellulose pulp with 18-19% sodium hydroxide solution to convert it into alkali-cellulose which is further shredded after removing the excess of alkali. The shredded alkali-cellulose is aged to involve depolymerisation of cellulose molecules to a desired level of 300-350 DP (Degree of polymerisation). Aging is carried out in atmospheric oxygen for a period of 3-5 hours at 40-46° C. The aged alkali-cellulose is then reacted with 30-36% carbon disulphide on the basis of cellulose weight to form sodium cellulose xanthate. This xanthate is further dissolved in dilute sodium hydroxide solution in a dissolver equipped with stirrers and cooling arrangements for a period of 2-3 hours. The temperature in the dissolver is kept below 20° C. The solution of sodium cellulose xanthate is known as viscose. The viscose composition is maintained as 8-10% cellulose, 7-10% sodium hydroxide, based on blended viscose by weight, viscosity 50-60 seconds of ball fall viscosity(B F). (This is higher than the process followed in Kesoram Rayon)

The sodium silicate solution is added in the dissolver before filtration and mix well so that the sodium silicate uniformly gets mixed in the viscose. Higher concentration of silicate, if used, may be diluted with 10-15% NaOH solution to get 18-20% silica followed by filtration The viscose viscosity is nearly same to that of pure viscose.

Optionally, viscose may contain viscose additives such as condensate product of glycols and amines in the range of 0.1-1.0% on cellulose basis for proper xanthation reaction and ease of filtration.

The composition of blended solution of sodium silicate and viscose (hereinafter described as blended viscose) is in the range of 6-9% cellulose, 6-8% NaOH, 1.5-2% silicon, 2.4-2.8% CS_2 and viscosity 45-60 second B.F. All components are based on blended viscose by weight.

The blended viscose of sodium silicate and viscose is properly filtered, deaerated and ripened. The ripening of blended viscose is an important parameter since the polymeric silica precipitates only when the regeneration of fibre is slow. Hence ripening index (RI) expressed in terms Hottenroth value in the range of 16- 20 is to be achieved by adjusting the process variables. The lower RI of viscose shows reduced loading of silica in the fibre indicating that the silica gets dissolved out in the regeneration or washing zones. The metered quantity of blended viscose is passed through into an acidic spin bath. The precipitation of cellulose is carried (in the same manner as carried out in Kesoram rayon) with simultaneous a precipitation of silicon dioxide. When the blended viscose comes in contact, a solid polymer of silicon dioxide and cellulose in the form of filament is formed of acidic spin bath. The acidic spin bath contains 105-150 g/l sulphuric acid, preferably 110-140 g/l sulphuric acid, 250-380 g/l sodium sulphate, preferably 300-360 g/l sodium sulphate, 6-20 g/l, preferably 6-12 g/l aluminium sulphate at a temperature of 35^0C, preferably 40-50° C. The spin bath is free from any zinc compounds.

The diluted sodium silicate solution should be filtered through a cotton cloth/cotton pad or some other suitable filter media. The concentration of 18-20% SiO_2 in sodium silicate, before adding in viscose, is preferable to maintain the viscosity of viscose to its original state . The immersion depth of spinnerette in the spin bath is to be kept 50-60 cm (slightly different from Kesoram Rrayon) for proper precipitation of silicon dioxide in polymeric form, in the fibre matrix.

The coagulated tow from the spin bath is stretched between take up godet and stretching in air, with in the limit of 50-65%.. This is followed by the washing drying humidification and cone formation.

Flammability Assessment Test; Flammability test is carried out by LOI (limiting Oxygen Index value. And char length.

(B) High-Wet-Modulus (HWM) Rayon –

Introduction

Because of its lustre, softness and good handle properties, viscose rayon both in fibres and filaments forms has a wide acceptance. However, Viscose rayon has its own limitations. It loses up to 60% of its strength when wet. To overcome this, **High-Wet-Modulus (HWM) has been developed.** The process for manufacturing high-wet-modulus rayon is almost similar to that for making viscose rayon with following exceptions.

- Initially, when the purified cellulose sheets are bathed in a caustic soda solution, a weaker caustic soda is used while making HWM rayon.
- Neither, Alkali crumbs nor the viscose solution, is aged in the HWM process of making rayon.
- When making HWM rayon, the filaments are stretched to a greater degree than that for making viscose rayon.

1. Manufacturing Process of High-Wet-Modulus (HWM) Based on Using Modifiers:

A variety of fibres, belonging to viscose family, are possible to spin by varying the composition, concentration of chemical and temperature of spin bath. This is because of the fact that these factors determine rate of regeneration and hence skin and core proportion of viscose rayon filament.

For manufacturing of High Wet Modulus (HWM) viscose rayon, high degree of polymerization is required than that for regular viscose. To achieve this, temperature and time for ageing and ripening are lowered. As soon as viscose solution flows to the spin bath regeneration of viscose of takes place. However, in order to slow down the crystallization, the regeneration should occur slowly. For this, lower concentration of acid and Zinc salts and modifier (like polyalkylene glycols, ethoxylated fatty acids, or fatty esters and ethoxylated higher aliphatic amines) is used to reduce the rate of crystallization, which in turn, leads to higher degree of orientation. This increases the strength and abrasion resistance of viscose filament both in dry and in wet state.

The use of these modifying agents or additives significantly increases the cost of the raw materials used in production of these fibres. Furthermore, biological oxygen demand (BOD) of the effluent is also increased as the organic matters can be recovered or recycled from the spin bath unlike inorganic matter

II Manufacturing Process Of High-Wet-Modulus (HWM) Based On Modification Of Process Parameters:

Alkali cellulose is prepared by dissolving 98% alpha -cellulose rayon grade pulp with 18.5% caustic soda, pressing the steeped sheets to a press weight ratio of 2.8 – 2.9 , and then shredding and ageing at 18° C. for 20 hours the resulting alkali cellulose. Xanthation is carried out by one-step addition of carbon disulphide. The viscose thus prepared contains 7.5% cellulose and 7.5% caustic soda. It is prepared by the addition of 38% carbon disulphide, based upon the weight of the cellulose. The viscose is ripened at 18° C. for 20 hours. At the time of spinning the viscose has a salt test (using NaCl) of 15.5 and an average ball fall viscosity of 85 seconds (much higher than followed in Kesoram Rayon).The spin bath composition may be as follows

Sulphuric acid; 7.3-7.5 %

Zinc Sulphate; 3.9 – 4 %

Sodium sulphate; 12.0 - 13%

Temperature; 38 ^{0}C

Spinning speed; 30 m / min

Filaments are withdrawn from the spin bath, after immersion of 24 inches, wrapped on a godet and then passed through a hot regeneration bath, wrapped on a tow roll feeding a cutter, cut and sluiced to a process machine. The regeneration bath has to maintain specified composition and temperature. During passage of the filaments through the regeneration bath, they were stretched approximately 90 – 100%. The stretching is carried out in a hot water bath, , or a diluted spinning bath containing from 0.5 to 6.0% sulphuric acid, 0.1 to 2.0% zinc sulphate and l to 7% sodium sulphate. The spinning speed may be around 30 meters/minute.

The filaments are purified by washing and de-sulphurizing, finished with a lubricant and dried as usual .

(C) Superabsorbent Rayons: Regular rayon, with water retention as much as 80- 100% of its weight, is one of the most absorbent man-made fibres. However, by suitably modifying the spinning bath, it is possible to produce rayon of water retention capacity.

This can be achieved by including water-holding polymers like sodium polyacrylate or sodium carboxy methyl cellulose in the viscose dope prior to spinning. The result is a fibre that will soak up and retain up to as much as 150–200% of its weight in water. Super absorbent rayon is produced by American Enka and Avtex . They produce superabsorbent rayon by adding sodium polyacrylate, or copolymers of acrylic and methacrylic acids, or sodium carboxymethyl cellulose to the viscose. The biodyed rayon contains up to about 20% of the water-soluble polymer giving water imbibitions capacity almost double to that of ordinary rayon.

The superabsorbent fibres are used in medical textile where absorbency is the chief criteria for the section of the raw material

(D) Super inflated fibres:

Super inflated viscose fibres have outstanding comfort properties in terms of bulk, warmth, lightness covering power. However, inflation process makes the fibres weaker than the ordinary rayon both in dry and wet state.

In super inflated fibres, the concentration of gasses within the filament must be greater than the saturation concentration .The pressure should be higher than osmotic pressure within the filament which is in the processes of formation .Also the bubbles must be trapped within the fibres by the outer membrane or skin. When the viscose dope enters the spin bath, the normal processes of coagulation and regeneration commence. Acid penetrates the outer skin to generate carbon di oxide. Some gas escapes but more and more bubbles are generated. As the skin thickens bubbles begins to coalesce and become trapped to form a continuous stationary bubble at a certain distance from the jet face.

Inflated fibres are made by injecting a gas or gas-forming compound such as sodium carbonate into the viscose. When the regeneration conditions has been adjusted to form an impervious skin on the fibre as it emerges from the spinnerette, the gas is retained in the forming fibre and the resulting bubbles would coalesce into a tube. The resulting smooth surfaced flat filaments were highly self-bonding simply because they were deformable enough to come into intimate contact with one another as they dried, and when in contact hydrogen bonding locked them together. In the spin bath sodium sulphate and zinc sulphate level affect the degree of inflation. Higher the concentration more is the degree of inflation. The concentration of sodium carbonate and sodium sulphate are 3-4% and 18 -19 % respectively. The super inflated fibres are used where higher thermal insulation value together with greater absorbency is required. They are used in knitted fabric, surgical purpose and blending with cotton and in non woven (in form of fibre).

(E) Tyre Yarn: Tyre yarn can be manufactured in conventional viscose rayon process route by modification of process parameters. In tyre yarn manufacturing, viscosity of viscose solution is maintained at 100 poise (approx). The viscose solution containing 1- 3 % modifier (poly-oxyalkylene derivatives) on the weight of cellulose and CS_2 content of 40% is spun (salt index value 12-14) into an aqueous spinning bath of following composition:

Sulphuric acid; 8-10%

Sodium sulphate; 20 -22%

Zinc Sulphate; 6% .

The spin bath temperature is kept around 55 ^{0}C and the spinning speed is between 50 -60 m / min. The stretch applied is 75% -125 %. The tyre thus obtained has tenacity (at conditioned state) 4.5 – 5.5 g/ denier and elongation % 18-22 %. At wet condition these values are 3-4 g/ denier and 19-23 % respectively.

By products:

One of the industry's major problems, the chemical by-products of rayon have received much attention in todays environmentally conscious times. Viscose method, known as the most popular method of production, generates undesirable water and air emissions. However, particular concern is the emission of zinc and hydrogen sulphide.

At present, producers are trying various techniques to reduce pollution. Some of the techniques being used are the recovery of zinc by ion-exchange, crystallization, and the use of a more purified cellulose. Besides these, the use of absorption and chemical scrubbing is proving to be helpful in reducing undesirable emissions of gas.

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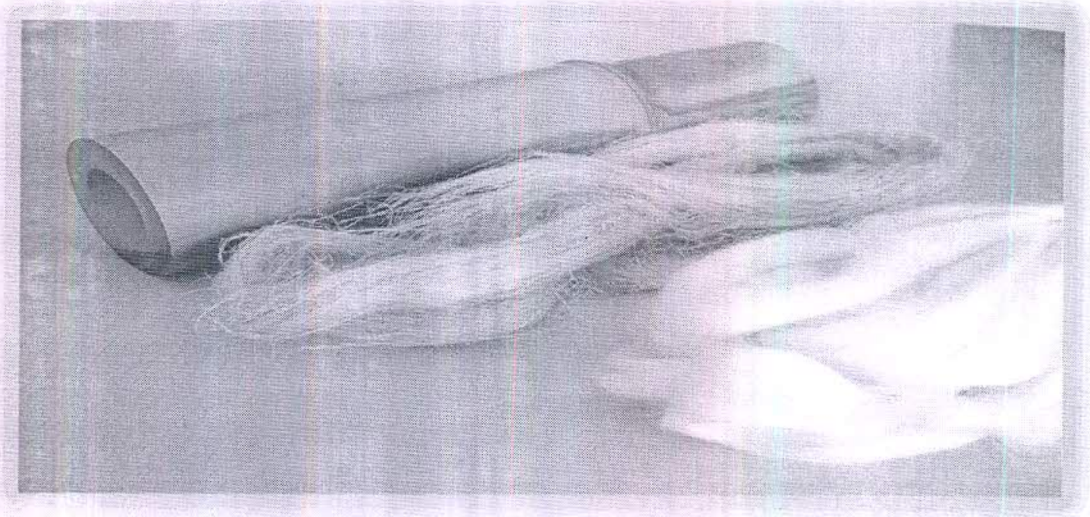
Design and Development of union fabrics and value-added products from Bamboo and Viscose filament of Kesoram Industries Ltd (KIL)



Submitted by
DR. ASHVANI GOYAL,
ASSISTANT PROFESSOR,
DEPARTMENT OF TEXTILE TECHNOLOGY
TIT&S, Bhiwani

The Technological Institute of Textile & Sciences,
Bhiwani-127021

Director,
THE TECHNOLOGICAL INSTITUTE
OF TEXTILE & SCIENCES, BHIWANI

IQAC
COORDINATOR

1. INTRODUCTION

Bamboo is a naturally occurring composite material which grows abundantly in most of the tropical countries. It is considered a composite material because it consists of cellulose fibers imbedded in a lignin matrix. Bamboo has a very long history with human kind. Bamboo chips were used to record history in ancient China.

☐ Bamboo is a type of flowering plant that belongs to the family Poaceae (grasses).

☐ There are almost 1500 species of bamboo that can be found in Asia, Australia, North and South America .

☐ Bamboo is the fastest growing plant on the planet. Sometimes the growth of the bamboo is approximately 2-3 feet over a night.

☐ It can be grown in all kind of climate and soils.

☐ Bamboo does not require replanting. The shoots are cut to their base and the bamboo re-grows from new shoots.

☐ Bamboo does not require fertilizers for optimal growth

☐ Bamboo is known as a very tough and durable plant. It is one of the oldest building materials used by human kind. Bamboo has been widely used in household products.

☐ In the market today, we will find bamboo bed sheets, bamboo non-woven, shirts, bamboo UV protective clothing and even socks.

☐ Annual bamboo fiber production is nearly 40000 tons

☐ Bamboo fiber are cellulosic fiber produced from bamboo plant, a type of grass.

☐ As a natural cellulose fiber, it can be 100% biodegraded in soil by microorganism and sunshine.

☐ Bamboo fiber comes from nature and completely returns to nature in the end.

☐ Therefore bamboo fiber is praised as "the natural green, and eco-friendly new type textile material of 21st century.

Hence, in the present project work, it is suggested that in order to utilize the best qualities of eco-friendly bamboo and viscose filament material, a systematic research should be carried out to design and develop value added products in terms of Apparels, Home Fashion and other related products.

Director,
THE TECHNOLOGICAL INSTITUTE
OF TEXTILE & SCIENCES, BHIWANI

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1.2 Aim & Objectives

The aim and objectives of present project work are as follows-

1) To design and develop union fabrics using bamboo and viscose filament yarn
2) To develop value added products made of union fabrics using bamboo and viscose filament yarn as one of the constituent material.
3) To assess comfort and other physical and mechanical properties of those materials designed and developed indigenously.

Main Objectives:

The main objectives of this research study will be as follows:

- ☐ To survey the present status of the technologies used in BAMBOO Craft and Bamboo-based products in throughout India in terms of machine & process.
- ☐ To pin point the existing technology gaps in the machines, manufacturing processes and products.
- ☐ To estimate the skill gap of the whole manpower involved in BAMBOO Craft and Bamboo-based products in the country and to formulate the steps to bridge the gap.
- ☐ To highlight the causes of the existing technological gaps, fill up the technological gaps and to introduce a guide or technology intervention plan for the up gradation of the BAMBOO Craft and Bamboo-based products in the country with respect to all forms of technology used.
- ☐ To analyse the technology gaps of BAMBOO Craft and Bamboo-based products with respect to the latest technology, processes and quality aspects and to suggest remedial measures for boosting domestic market/export potential.
- ☐ To develop the awareness amongst manufacturers regarding need of technology change in manufacturing/assembly of BAMBOO Craft and Bamboo-based products and its components
- ☐ To develop latest designs as per trends and forecasting for the BAMBOO Craft and Bamboo-based products
- ☐ To develop latest value-based Bamboo-viscose filament products in Apparel, Home Textile, Home Fashion categories and compare their properties.

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1.3 Methodology to be adopted:

Preliminary visits will be made by the project personnel from TIT&S to generate detailed information about the bamboo-based products:

- ☐ to understand the core issues related to-Raw Material at different stages of manufacturing,
- ☐ to study Infrastructure setup and work station available in developing bamboo-based value added products
- ☐ to know the details of Skill and techniques, Surface design patterns and Painting
- ☐ to understand the Product form, and shape
- ☐ to gather information about the usage of Tools and technology
- ☐ to find the Capability of manufacturing units
- ☐ to understand the problems faced by the manufacturers of bamboo-based value added products
- ☐ to develop strategies for Technology interventions in addressing the core problems associated with bamboo-based value added products

Methodology to Adopted for the Technical assessment study :

The following methodology will be used for the Technical assessment study of BAMBOO Craft and Bamboo-based products by TIT&S, Bhiwani in the country:

· Primary survey and interaction with the members of BAMBOO Craft and Bamboo-based products regarding Technological Gap Study

· Secondary survey and interaction with major manufacturers of BAMBOO Craft and Bamboo-based products in the country

· Preparation of questionnaire and its pre-testing

· Getting response from various stakeholders and manufacturers

· Analysis of the data received and finding the inferences

Methodology to Adopted for the Designing of BAMBOO Craft and Bamboo-based value-added products:

- ☐ To study latest Trends ~~and Forecasting~~ of Bamboo and Viscose filament based products
- ☐ To develop motifs for the value added Bamboo and Viscose filament based products using Traditional Textile and Embroidery designs of Indian, Asian, African and Western costumes.

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- ☐ To develop motifs for the value added BAMBOO Craft and Bamboo-based products using Traditional Textile and Embroidery designs of Indian, Asian, African and Western costumes.
- ☐ To develop designs for the value added BAMBOO Craft and Bamboo-based products using Manual and Computerised software, like Adobe Photoshop, Coreldraw, paint, etc..
- ☐ To develop product designs for the value added BAMBOO Craft and Bamboo-based articles using CAD software, like Optitex, TuckaCAD, REACH Design studio, etc..

<u>Methodology to Adopted for Developing of BAMBOO Craft and Bamboo-based value-added products:</u>

- ☐ To procure Bamboo fibre and other cellulose/re-generated cellulose fibres for the development of BAMBOO Craft and Bamboo-based products.
- ☐ To procure Bamboo yarn and other cellulose/re-generated cellulose fibres-based yarn for the development of BAMBOO Craft and Bamboo-based products.
- ☐ To develop fabrics like Hand-loom Woven fabrics, Power-loom woven fabrics, Knitted fabrics, Braided fabrics, Nonwoven fabrics for the value added BAMBOO Craft and Bamboo-based products
- ☐ To develop Apparels like Mens, womens, Kids and Home Textile Products like Bed linen, Curtains, Table-linen, Bath Linen, Kitchen Linen, and other value added BAMBOO Craft and Bamboo-based products using modern sewing machines, embroidery, printing, digital printing, etc.
- ☐ To develop Apparel and Product designs for the value added BAMBOO Craft and Bamboo-based products using Manual and Computerised software, like Adobe Photoshop, Coreldraw, paint, etc..
- ☐ To develop products for the value added BAMBOO Craft and Bamboo-based articles using CAD software, like Optitex, TuckaCAD, REACH Design studio, Digital software etc..

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2. LITERATURE REVIEW

2.1 Structure of bamboo Fiber

The surface of the viscose rayon fiber is characterized by tiny grooves, called serrations, which is a result of the way the fibers coagulate during the spinning process. This slightly uneven surface contributes to the next-to-skin contact comfort properties. This structure is similar to that observed in regenerated bamboo. According to their website, the Shanghai Tenbro Co.(2007) reports that scanning electron microscopy (SEM) images of "bamboo fibers" reveal an internal structure containing micro-gaps and micro-holes, giving the fibers the ability to absorb and evaporate human perspiration at a high rate.

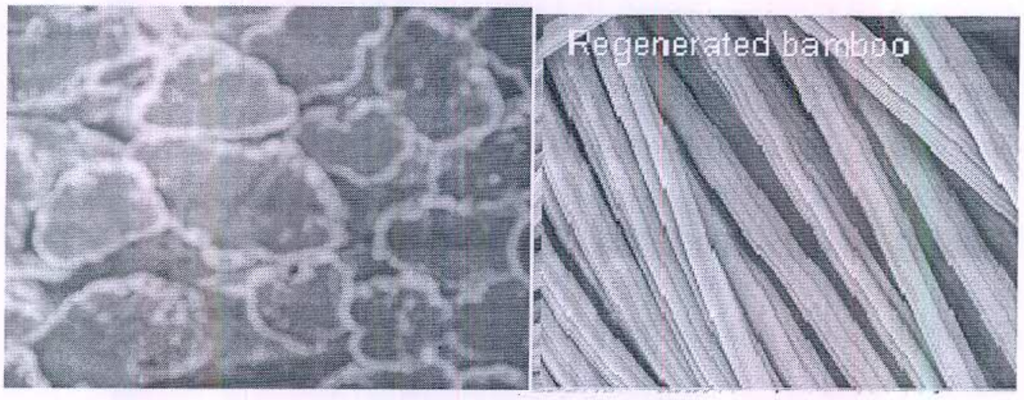

Fig. 1 Cross-sectional/ longitudinal view of bamboo fiber

Chemical composition:

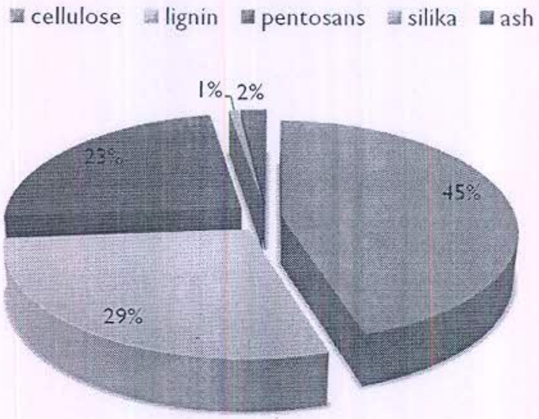

Fig. 2 Chemical composition of bamboo fiber

Physical Properties:

Table 1: Physical properties of bamboo fiber-

Property	Magnitude
Fiber Length	Short to long staple
Fiber Fineness	0.5-5 tex
Cross-sectional shape	Round
Specific gravity	1.5 gm/cm^3
Dry Tenacity	22-25cN/tex
Wet Tenacity	13-17cN/tex
Degree of polymerization	700-800
Moisture Regain (%)	13
Elongation (%) at break	14-24

Schematic diagram of bamboo plant structure

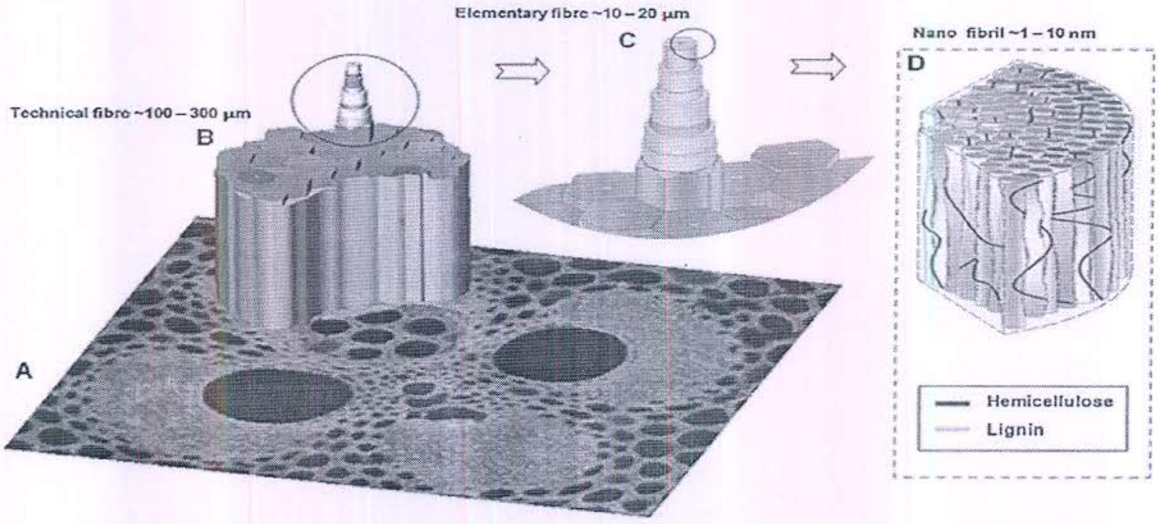

Fig. 3 Schematic diagram of bamboo plant structure

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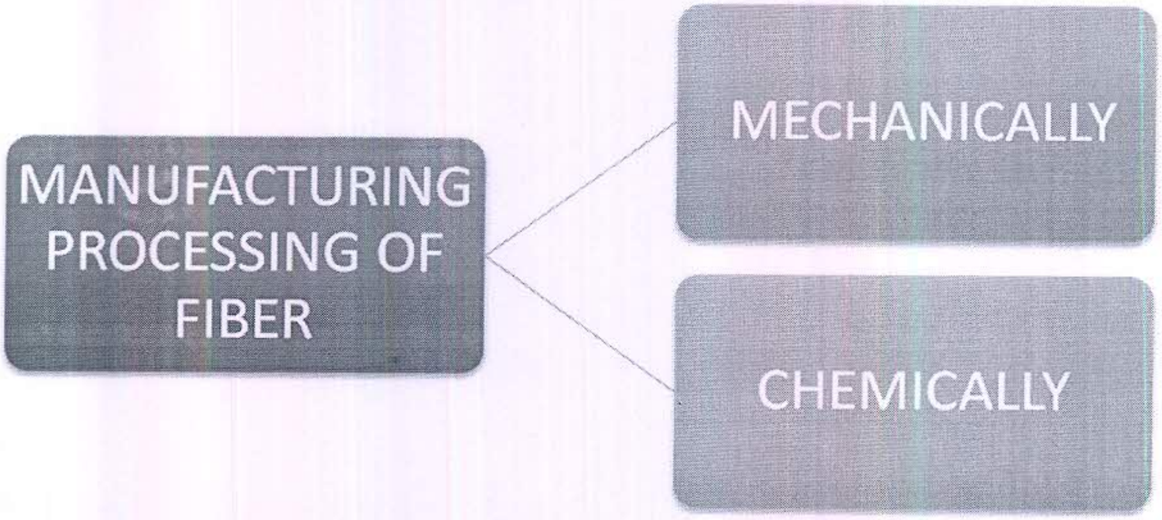
BAMBOO FIBER PRODUCTION METHOD

There are two ways to process bamboo to make the bamboo fiber.



MECHANICAL PROCESS

- ☐ The fiber extracted by mechanical process is often referred by the manufacturer as 'natural' or 'original' bamboo fiber.
- ☐ Mechanical produced bamboo fiber requires no chemical and fungicides.
- ☐ Using a process similar to the one that produces LINEN from flax, bamboo are raked and combed into long strand. Thereby preserving their anti-bacterial and anti fungal characteristics.
- ☐ Mechanical processed bamboo gives Natural bamboo fibers.

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PROCESS SEQUENCE

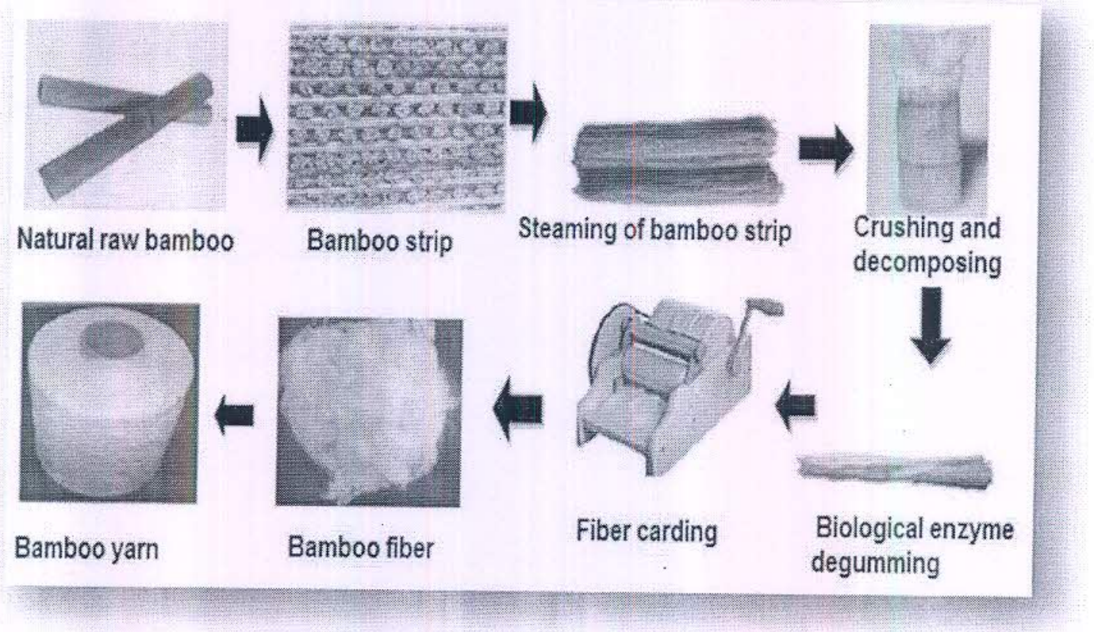

Fig. 4 Mechanical Process sequence of bamboo fiber/yarn manufacturing

☐ During the mechanical processing of bamboo fiber, the bamboo plant is first cut into small strips an then go for steaming of these strips.

☐ After steaming process, these strips are then go for crushing and decomposing.

☐ Now crushed bamboo are treated with natural enzymes, that breaks the crushed bamboo into soft, mushy and spongy mass.

☐ Subsequently, the natural fiber can be combed out mechanically to get individual fibers.

☐ These fiber can then be spun into yarn.

☐ Bamboo fiber produced by this process though considered eco-friendly is less used because it is time consuming, labor intensive, costly and serves a very specific niche of the textile market.

☐

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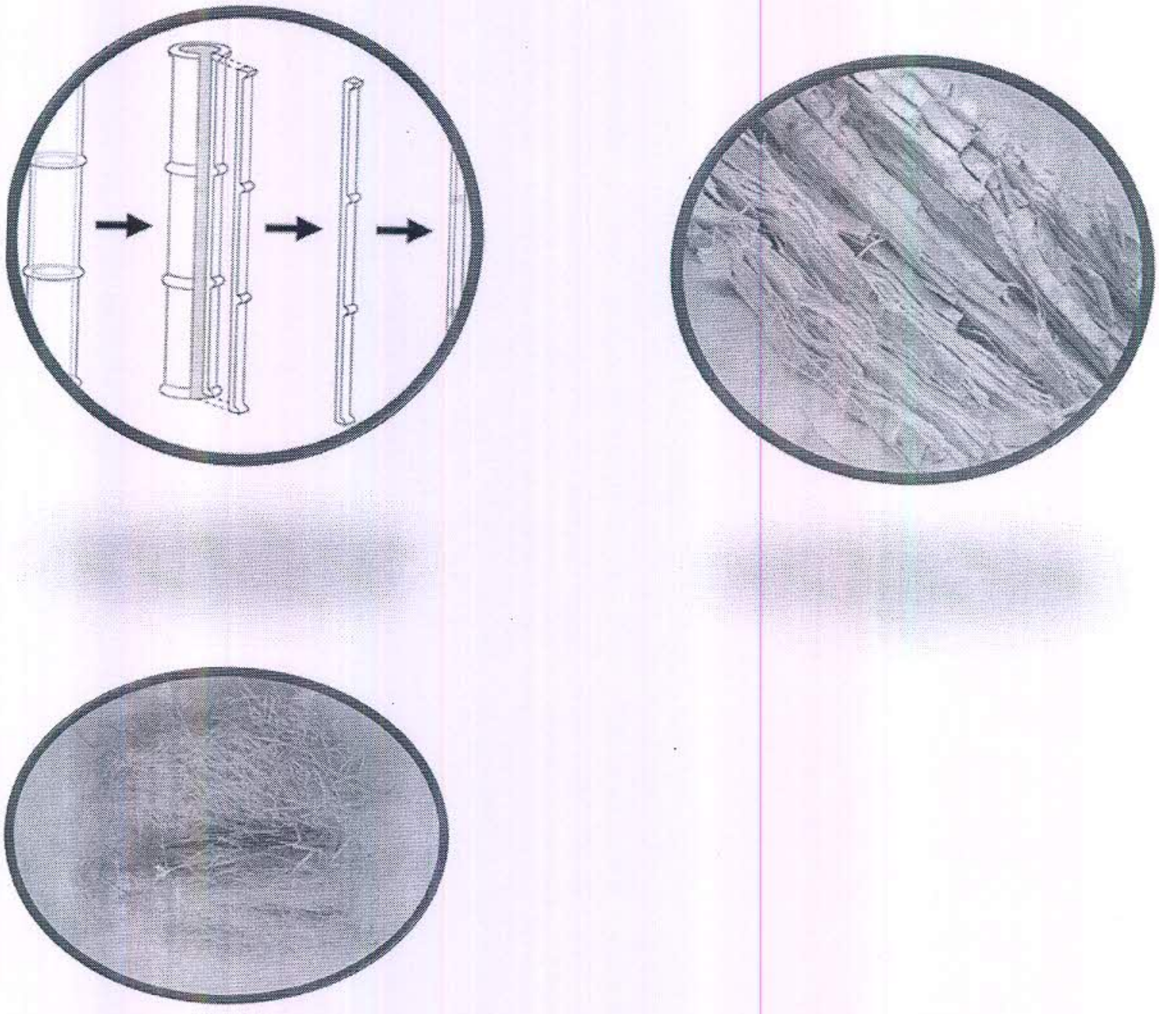

Fig. 5 Cross-sectional view of bamboo plant/ fiber

CHEMICALLY PROCESSED BAMBOO FIBRE:

- ☐ Chemical processing is the common form of bamboo fiber production.
- ☐ Chemically manufactured bamboo fiber is a regenerated cellulose fiber similar to rayon or modal.
- ☐ Chemically manufactured bamboo is sometimes called bamboo viscose rayon because of the many similarities in the way of manufacturing and similarities in its feel and hand.

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PROCESSING

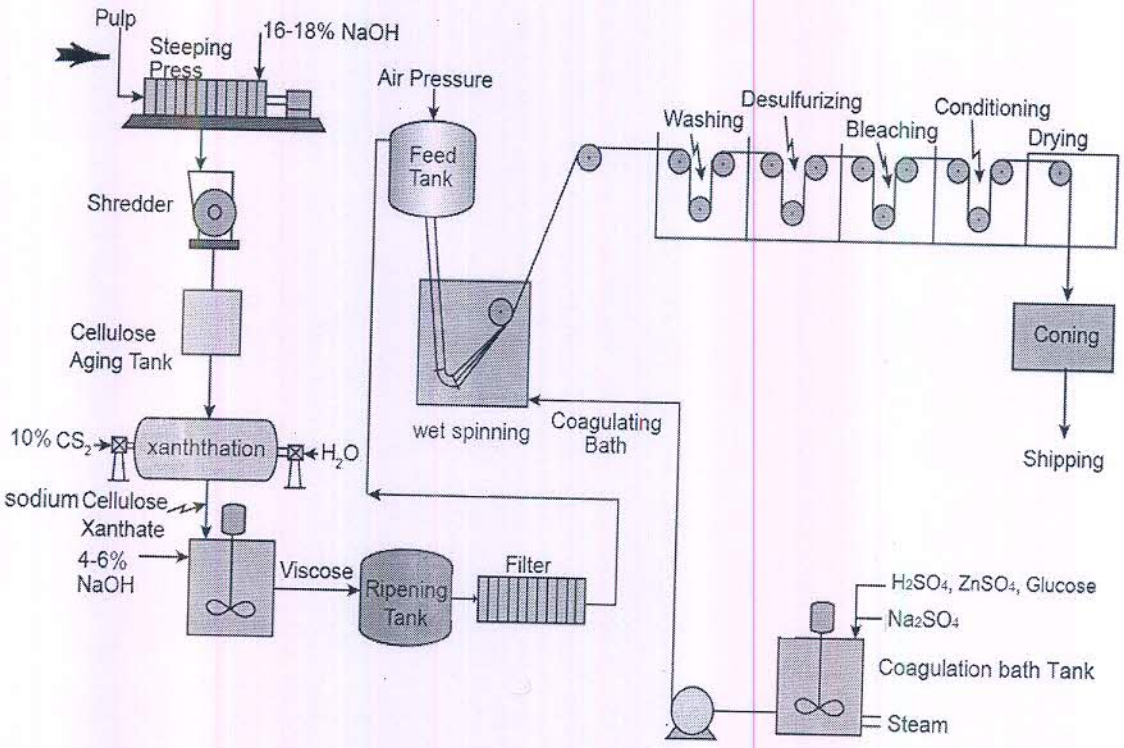

Fig. 6 Chemical Process sequence of bamboo yarn manufacturing

PREPARATION

☐ The raw material for the bamboo viscose rayon is cellulose.

☐ First of all Bamboo leaves and the soft, inner pith from the hard bamboo trunk are extracted and crushed.

☐ The crushed bamboo is bleach and pressed into sheets. This is done in the pulp mill.

STEEPING

☐ The cellulose sheets are soaked in alkali in the steeping tank.

☐ Particular for steeping

NaOH - 17-18%

Time - 30-60 minute

Temperature - 18°C.

☐ After steeping, sheets of cellulose are pressed to remove the excess alkali.

AGEING

- ☐ This is depolymerisation step in the presence of oxygen. Here the degree of polymerisation comes down from 1000 to 300.
- ☐ Ageing is carried out for 24-72 hours at 25-30°C.

XANTHATION

- ☐ The aged alkali is transferred into sealed hexagonal drums rotating at 2-4 revolution per minute.
- ☐ where 10% by weight of cellulose carbon disulphide is introduced.
- ☐ Process is carried out for 2-4 hours.
- ☐ The product at this stage is Sodium cellulose Xanthate in the form of small balls.

DISSOLUTION

- ☐ Dissolution of Sodium cellulose Xanthate is carried out in 4-6% solution of NaOH in a cylindrical vessel provided with agitator for 4-5 hours.

RIPENING

- ☐ The viscose solution is kept for 1-3 days for ripening.
- ☐ At this stage the solution is kept at controlled temperature 15-20°C.
- ☐ In this stage various change take place, here first the degree of polymerization falls and then rises to original value.
- ☐ The ripened solution is again filtered carefully to remove any foreign matters.
- ☐ Pigment can be added to produced dyed fibers.
- ☐ Delustering agent TiO2 is added for controlling the luster and other chemical for special yarn. After ripening solution is ready for spinning.

SPINNING

- ☐ In the spinning of the solution into fiber formation, the regeneration of cellulose from cellulose xanthate in the presence of acid take place
- ☐ Spinning method – wet spinning.
- ☐ Spinning particular
- ☐ spinning speed – 100 to 120 m/min
- ☐ spinneret hole dia- 0.016 to 0.05 mm
- ☐ The composition of coagulation bath is as follows,

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H2SO4 - 8 to10%

Na2SO4 - 16 to 24%

H_2O - 69%

Glucose - 2%

ZnSO4 - 1 to 2%

Coagulation Bath Temperature : **40 – 55**°C

Bamboo fiber microscopic view:

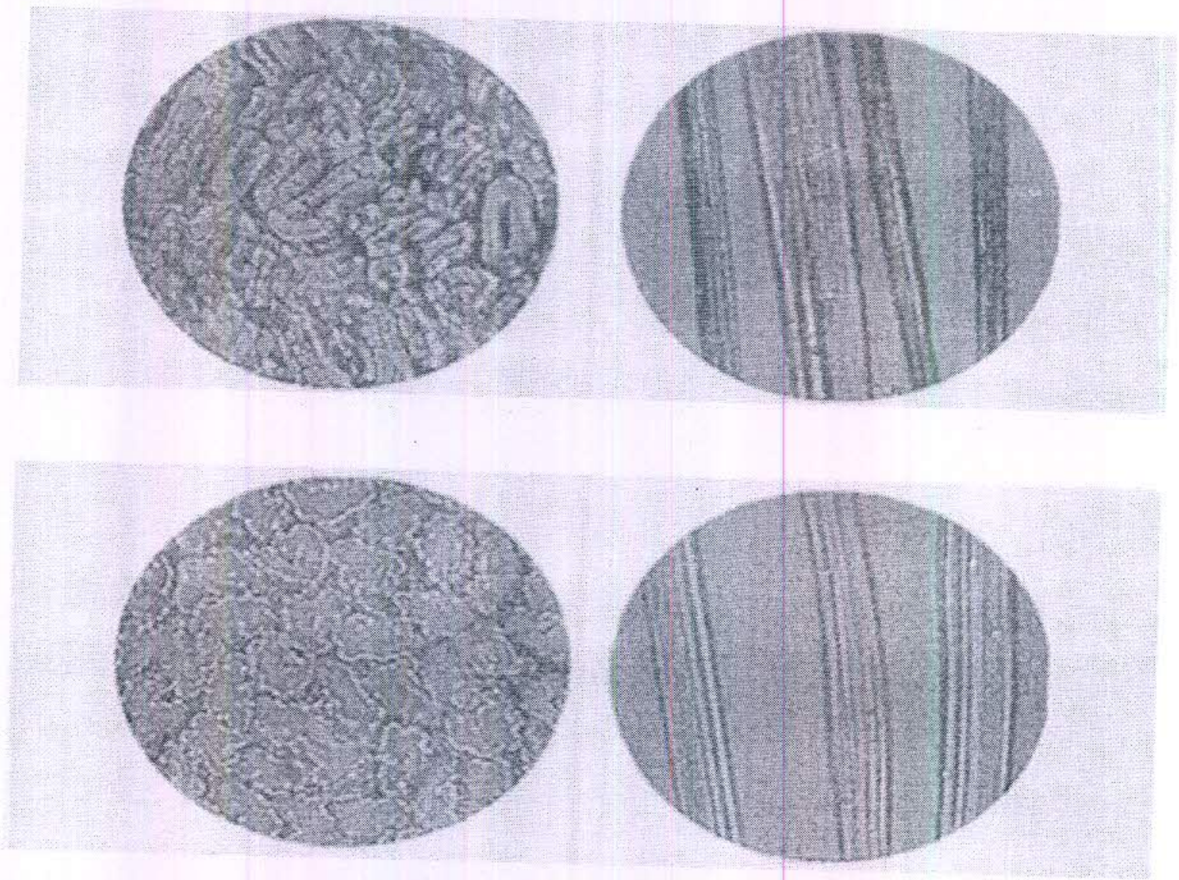

Fig. 7 Microscopic view of bamboo Yarn

2.2 Cotton

Cotton is a natural vegetable fiber and is obtained from seeds of plants of Gossypium.This type of fiber is most widely used for making denim products. The earliest evidence of using cotton is from India and the date assigned to this fabric is 3000 B.C. There were also excavations of cotton fabrics of comparable age in Southern America. Cotton cultivation first spread from India to

Egypt, China and the South Pacific. Even though cotton fiber had been known already in Southern America, the large-scale cotton cultivation in Northern America began in the 16th century with the arrival of colonists to southern parts of today's United States.

2.2.1 Structure

One of the characteristics of cotton was seen through the microscope, showing the variation in size and shape in convolutions in longitudinal view and a kidney bean in cross-section, The cotton fiber is usually creamy white or yellowish. The higher-quality cotton fiber is 2.0-2.5 inch long. The luster of cotton is relatively low but it can be increased its luster and strength by treatment of mercerization.

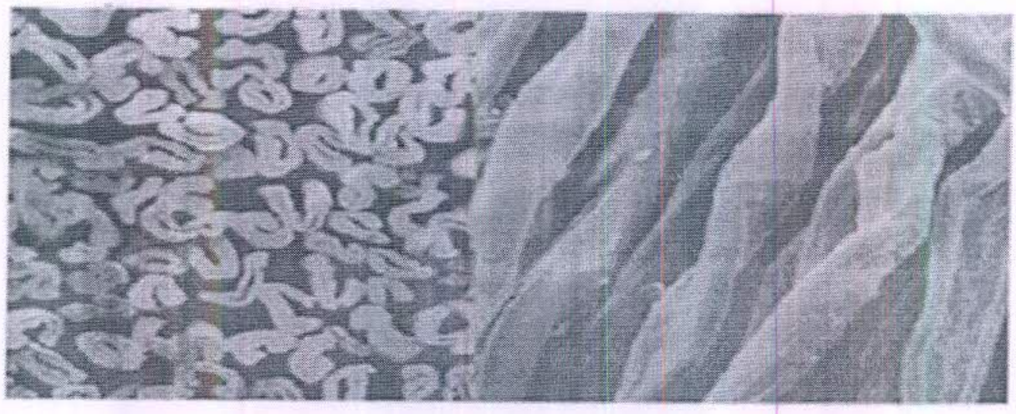

Fig-2.1 Cross section/ Longitudinal view of cotton

The layer components of cotton cell wall include the primary wall which contains 50% of cellulose, other components are small amounts of protein, pectin, wax and ash. The secondary wall contains 92-95% of cellulose with alternating S and Z-shaped twists in structure. Cellulose is a structural component for all plant fibers. The cellulose molecules group in linking with glucose units in structural formula is $(C_6H_{10}\ O_5)_n$ and forming a linear polymer of glucose molecules in repeat unit 1000. Therefore the feature is formed with larger structure and highly packed into more crystalline regions.

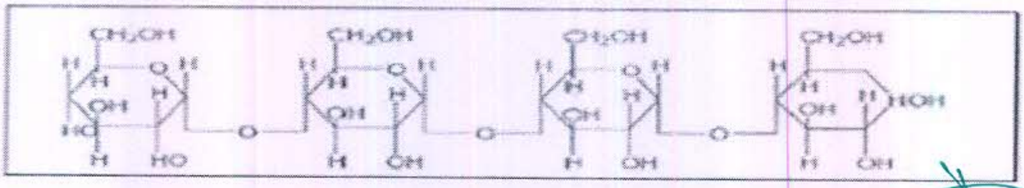

Fig 2.2 Repeat cellulose polymer chain

The high crystalline regions and associative forces linked chain in cotton. Nature of cotton is hydrophilic and hydroxyl groups of cotton hold high affinity for water. The tensile properties are affected by amount of moisture absorbed by fiber. The heat conductivity of cotton is high and it feels cool to touch.

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2.2.2 Physical properties

Table 2.2: Physical properties of cotton fiber

Property	Magnitude
Fiber Length	23-32.5 mm
Fiber fineness	2.8-4.9 micronaire
Cross-sectional Shape	Kidney bean
Specific gravity	$1.54gm/cm^3$
Dry Tenacity	20-43 cN/tex
Wet Tenacity	27-58 cN/tex
Degree of polymerization	9000-15000
Moisture Regain[9] (%)	7-8.5%
Elongation at break[9](%)	6-10%

2.3 Viscose

The process was discovered in 1891,and patented by Cross, Bevan and Beadle in 1892.Viscose is a solution of cellulose xanthate made by treating a cellulose compound with sodium hydroxide and carbon disulfide. Byproducts include sodium thiocarbonate, sodium carbonate, and sodium sulfide. The viscose solution is used to spin the fiber viscose rayon, or rayon, a soft man-made (regenerated) fiber.

2.3.1 Structure

Viscose rayon, with its semi crystalline structure (composed of crystallites together with more or less disordered amorphous regions) and high number of hydroxyl groups along the polymer chains, has a higher moisture regain and absorbency than cotton, with its more crystalline structure. Although viscose rayon does not have a complex submicroscopic structure, recent studies have shown that the fiber structure exhibits a unique "skin" and "core", which is the result of chemical conditions in the spinning bath. The different structures of the two areas are reflected in their dyeing capacity. The different characteristics of the "skin" and "core" areas were investigated by Müller et al (2000) who found that the core of the fiber appear less dense than the skin. As the skin is only a few micrometers thick, this means that more water will be absorbed into the core of the fiber, transporting water away from the fiber surface. This would lead to the surface area maintaining a dry "hand" for longer after exposure to moisture.

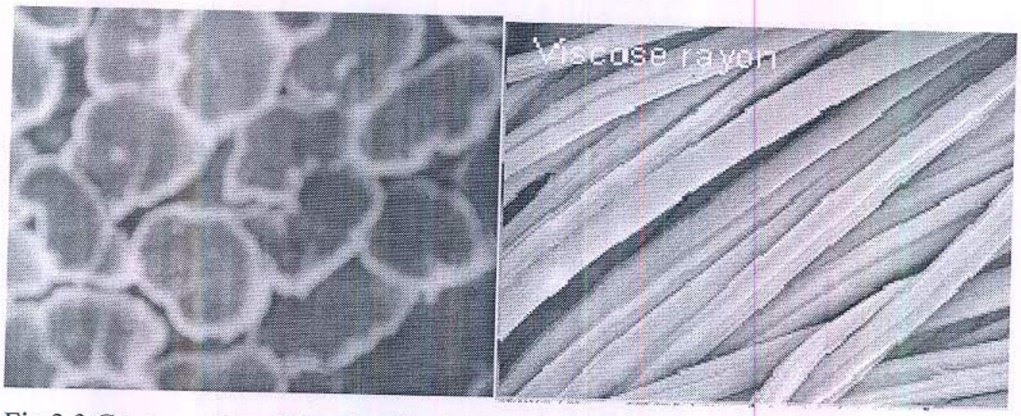
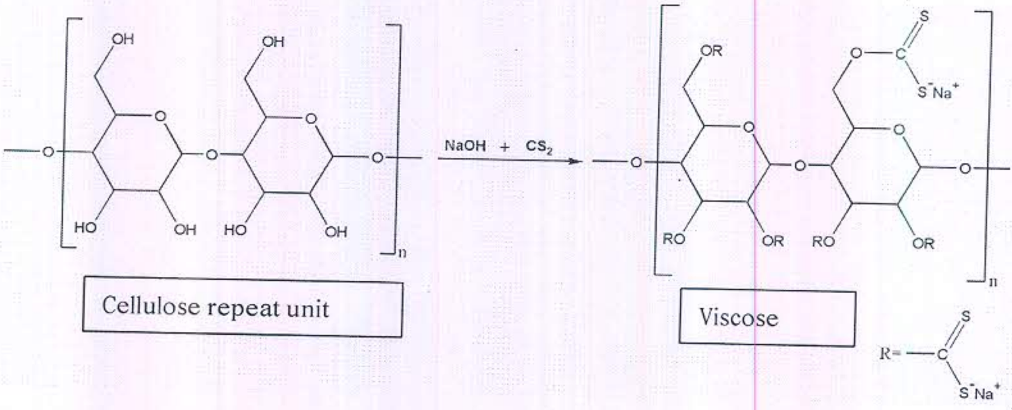


Fig 2.3 Cross-sectional/longitudinal view of viscose



2.3.2

Physical properties

Table 2.3: Physical properties of viscose fiber

Property	Magnitude
Fiber Length	51mm
Fiber fineness	0.5- 5 tex
Cross-sectional Shape	Serrated
Specific gravity	1.52 gm/cm^3
Dry Tenacity	18-26 CN/tex
Wet Tenacity	9-15 CN/tex
Degree of polymerization	300-450
Moisture Regain[9] (%)	10-14%
Elongation at break[9](%)	15-25%

2.4 Modal

Modal is a regenerated cellulose fiber and it made out of wood chips form the beech tree. Through the complex chemical process, the pulp is converted from wood pulp, reconstituted and spun into fine fibers. Modal was developed by Austria based Lenzing AG who registered in trademark fabrics name but many manufacturers make their own version nowadays. Modal is one type of regenerated fiber and is widely used in clothing. Modal is extremely smooth and soft, it is blended with cotton to help the yarn for enhancing good comfort properties. It maintains smooth characteristics after several repeated washings.

2.4.1 Structure

Similar to cotton fibers, Modal fibers are also cellulose. The majority of Modal fibers have circular cross section formed during drawing of filament. The Modal is long and straight fiber structure and it consists of 25-35% crystalline region within fiber. The average degree of polymerization of glucose unit in cellulose chains is 450-750[8]. The main structural differences between cotton and Modal can be distinguished by the degree of polymerization, crystalline regions and orientation of molecules in the filament as shown in fig-

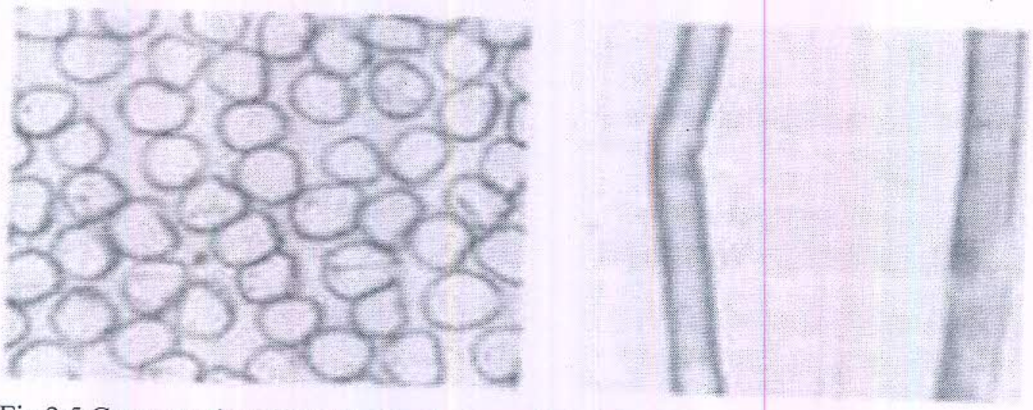


Fig 2.5 Cross-sectional/longitudinal view of Modal

2.4.2 Physical properties

Table 2.5: Physical properties of modal fiber

Property	Magnitude
Fiber Length	Short to long staple
Fiber fineness	0.1-5 tex
Cross-sectional Shape	Circular
Specific gravity	1.50gm/cm^3
Dry Tenacity	24-36 cN/tex
Wet Tenacity	12-24 cN/tex
Degree of polymerization	450-700
Moisture Regain[9] (%)	12-13
Elongation at break[9] (%)	13-25

2.5 Tencel/ Lyocell

Tencel is an eco-friendly regenerated cellulosic fiber and is the brand name of Courtaulds Lyocell fiber used in apparel fabrics and other fashion market. The very different process routes for producing tencel fiber have led to the establishment of the new generic classification for this fiber type viz. Lyocell. Tencel is the first commercially available lyocell fiber. The establishment of tencel as a completely new fiber type has meant that fiber is not viewed merely as a replacement for cellulosic fibers but as completely separate to them and as a complement to them. It is amongst the strongest and stiffest cellulosic fibers ever produced. It is claimed that lyocell combines the advantages of both natural and synthetic fiber. It has the softness of silk, strength of polyester, the absorbency of cotton and is fully biodegradable as well as highly durable too. When wet, it retains 85% of its dry tenacity, making it stronger in this state than cotton.

2.5.1 Structure:

The structural characteristics of lyocell fibers are responsible for their superior mechanical properties. Lyocell fibers have high degree of crystallinity and orientation, as well as a high average molecular mass and degree of polymerization. This enables lyocell fibers to reach high tensile strength and modulus. Even in the amorphous area there is still some degree of orientation. The degree of crystallinity of lyocell fiber is 16% higher when compared with modal fibers and significantly higher (43%) compared to viscose fibres.

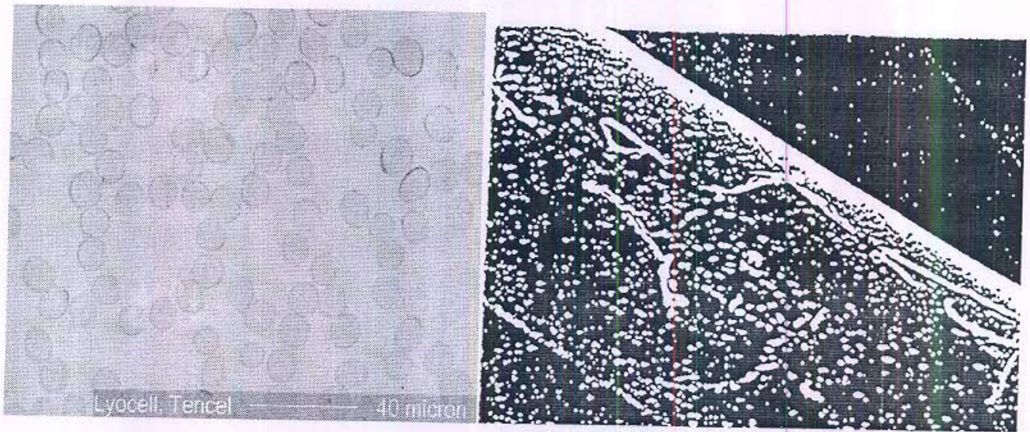


Fig-2.6 Cross-sectional/longitudinal view of tencel fiber

2.5.2 Physical properties

Table 2.6 Physical properties of tencel fiber

Property	Magnitude
Fiber Length	Short to long staple
Fiber Fineness	0.5-5 tex
Cross-sectional shape	Round

Specific gravity	1.50 gm/cm^3
Dry Tenacity	41cN/tex
Wet Tenacity	35 cN/tex
Degree of polymerization	400-700
Moisture Regain[9] (%)	11-12
Elongation at break[9](%)	12-16

2.6 Comfort Characteristics

The most important property of any apparel is comfort. Comfort is an experience that is imposed by integration of impulses passed up the nerves from a variety of peripheral receptors smell, smoothness, consistency and color etc in the brain. Comfort is a qualitative term and it is one of the most important aspects of clothing[21].

All three aspects are equally important since people feel uncomfortable if any one of them is absent. Comfort is not a property but a condition of mind.

Comfort is a situation where temperature differences between body members are small with low skin humidity and the physiological effort of thermal regulation is reduced to a minimum. Comfort is not only a function of the physical properties of materials and clothing variables, but also must be interpreted within the entire context of human physiological and psychological responses.

2.6.1 Factors affecting comfort

Comfort is condition dependent on many factors. A number of properties of fibers, yarns, fabrics and garments are significantly related to comfort and must be taken into account in producing suitable apparel items. Designers of clothing can take care of psychological and physical aspects of comfort by suitable selection of color, design, texture, style, garment fit etc. However, suitable fabrics from the comfort point of view must be developed by textile technologists by proper selection of fiber content, yarn and fabric construction techniques and finishing treatments as they influence physiological comfort level through thermal retention or transmission, moisture vapour permeability, water resistance, static charge build-up etc.

There is a general agreement that the transmission of air, heat and water vapour through a garment are probably the most important factor in clothing comfort. Comfort as felt by the user, is a complex factor depending on the above attributes. Some early studies reported various aspects of comfort related properties of fabrics.

Li et al stated that comfort is a state of multiple interactions among psychological sensations that are determined by physical, physiological and environmental factors.

Fabric properties depend on fiber properties, yarn structure, yarn properties, fabric structure and the mechanical and chemical finishing treatments given to it. Of the various fiber properties, fiber type, fineness, cross-sectional shape, crimp, length, percentage of crystalline and amorphous region and surface properties are extremely important. For a given set of fiber properties, yarn characteristics are governed by its structure. Type of yarn like filament yarn, textured yarn, and spun yarn produced on different spinning systems, twist level, unevenness, and hairiness, packing fraction, diameter of yarn have significant influence on comfort and other properties of fabric. Fabric structure includes yarn linear densities, sett, weave, crimp levels, and can influence such critical fabric properties as cover, thickness, bulk density, mechanical and surface behavior which have direct relation with fabric comfort. Finishes, which affect the properties of the fabrics and appearance, can also significantly change the performance of a fabric in clothing. Fabric properties, together with the garment design and size influence the various garment properties[23].

2.6.2 Classification of comfort

Slater defined comfort as a fundamental and universal need for consumers, is defined as a pleasant state arising out of physiological, psychological and physical harmony between a human being and the environment.

Textile comfort can be divided into three groups:

1. Psychological or Aesthetic comfort
2. Physiological or Tactile comfort
3. Thermo-physiological comfort

2.6.3 Psychological comfort

Aesthetic comfort or psychological comfort is mainly related to the garment style, proper fit, fashion and suitability for the occasion and shows no relationship with the fabric properties. Psychological comfort is mainly related to latest fashion trend and acceptability in the society and bears little relation to the properties of fabrics.

Howorth derived seven sensory descriptors, including softness and smoothness, for description of fabric hand.

Paek tested ten fabrics and revealed that the subjective perceptions of thickness and warmth were significantly correlated with objective thickness, hardness, tenacity and coefficient of friction, while stiffness and roughness were correlated with flexural rigidity and coefficient of friction respectively.

Wilson and Laing reported a study on the effect of wool fiber variables on the tactile characteristics of homogeneous woven fabrics. They examined the influence of wool fiber on the tactile characteristics of homogeneous fabrics with standardized fiber content, yarn structure, dye and finishing treatment. Results showed that there were significant differences in the ranking of roughness and prickliness among these fabrics.

Kim and Piromthamsiri carried out an experiment, involving 38 female judges, to determine the handling qualities and preferences for seven flame-retardant fabrics. Handle preferences showed significant association with smoothness, softness and gentleness.

Li found that the judgment of sensory comfort by human beings was mainly dependent on tactile and clothing fitness sensations rather than moisture sensation in cool environment. Li and Keighley carried out an investigation on consumers' psychological sensory responses in three different countries. Results showed that most of the sensory perceptions were significantly different between summer wear, winter wear and sportswear with $p<0.01$. Applying factor analysis and clustering analysis to study the relationships among 26 sensory descriptors, he identified three major sensory factors: tactile(itch, rough and prickle), thermal-wet (clammy, hot and cold) and pressure (stiff, soft and smooth).

2.6.4 Physiological comfort

Tactile comfort is the feel of the fabric when it is touched and it is directly related to fabric handle. The handle of a fabric is influenced by its mechanical and surface properties. The ease of body motion and the level of load generated in fabric during body movement are obviously related to the fabric handle properties, and therefore a study of clothing tactile comfort must take into account the fabric low-stress mechanical properties. It is concerned with the subjective judgment of roughness, smoothness, harshness, pliability, thickness etc. Many researchers have carried out extensive work on fabric handle properties.

2.6.5 Thermo-physiological comfort

Thermal comfort is the factor governed by the movement of heat, moisture and air through the fabric. The maintenance of thermal balance is probably the most important attribute of clothing and has drawn the attention of many textile research workers. The main problem associated for thermal comfort is the incompatibility between the requirement of heat conservation during low metabolic activity and heat dissipation at high energy level. There are numerous factors regarding conditions of thermal comfort, such as age, sex, adaptation, season and heat flow conditions as well as physical conditions existing next to the skin surface.

Thermo physiological comfort of a fabric is related to the fabrics ability to maintain skin temperature, allowing transfer of perspiration produced by the body. It is dependent upon the measurable factors like thermal resistance, water vapour and air permeability's of the clothing, climatic conditions and level of physical activities. In general it is found to be dependent on fiber properties, yarn structure, yarn properties, fabric geometry and chemical finishing treatments given to the fabric. Of the various yarn properties yarn bulk, packing coefficient and hairiness are especially important.

On the other hand, thermo physiological comfort relates to the ability of the fabric to maintain thermal equilibrium between the human body and the environment. Thermal, moisture and air resistance properties of the clothing material collectively contribute to the state of thermo physiological comfort of the wearer.

2.6.7 Comfort aspect in value-added bamboo related products

Comfort is something related to individual. Everyone has his/her own idea of comfortable clothing. In terms of textile clothing, comfort is defined as " The perfect interplay of skin-sensory properties such as moisture management and fineness, as well as fit."

Elizabeth M. Crowther investigates the relation between the inherent ease of stretch in the fabric and its potential extensibility when cut for seaming at a given angle of bias. To counter the discomfort resulting from shortened fork and seat seams designed to provide close fit, 100% cotton denim may be stretched at given locations to provide better body accommodation. The shaping operation on the jeans suggests that greater ease of stretch may be achieved by stretching the cloth in the shortened back-rise and upper-leg seams and also at the calf while a close fit is maintained under each ham. Stress across the crotch and thigh may be alleviated by leg-seam stretching and all shaped sections should reduce stress between contact points e.g., Knee-seat. To accommodate further the natural body contour, a curve is added to the lower leg under the knee and 'Kicks'it forward at the front. So, generally to make denim fabric comfortable stretch is imparted by varying lycra percentage into it.

Parke New York proposed Premium Active Wear had made light weight denim fabric with one way stretch to impart comfort to the fabric.

Iron Heart used the highest quality long staple cotton, the warp and weft do not have to be overly spun to keep their integrity as a result a heavy weight denim which was quite soft, heavy weight yet comfortable. People of all ages including teens and bikers etc. appreciated this type denim fabric because it protected them from accidents and had added comfort.

Lenzing is using tencel fibers to impart comfort to denim fabrics, as tencel offers aesthetics, comfort properties and naturalness at the same time.

2.6.8 Effect of weave on comfort

Vivekanandan et al found that the change in weave from plain to twill was observed to bring about significant changes not only in the low stress mechanical properties of fabrics thereby influencing the Primary and Total hand values but also played a deciding role in transport behavior of fabrics such as air permeability, moisture permeability and thermal properties. The loose structure of twill weave fabrics allows yarns and fibers to adjust and realign when deformation forces are applied, resulting in higher extensibility, lower tensile resiliency and lower bending rigidity. Tensile Energy (WT) values were noted to be lower for twill weave fabrics, which could be attributed to lower Tensile Linearity (LT) values, showing that these fabrics are easily deformable under low loads. Fewer yarn cross over's in the twill weave fabrics compared to plain weave lead to lower inter yarn friction thereby bringing about significant reduction in shear rigidity, shear hysteresis and bending hysteresis.

The reduction in surface parameters SMD and MMD for the twill weave fabrics can be attributed to fewer crossovers of the warp and weft yarns and also due to the presence of long floats resulting in less surface bumpiness. The surface roughness can thus be reduced by choosing weaves with longer surface.

2.6.9 Cool Feel: definition & review

When two objects at different temperatures are brought into contact, a transient heat flow occurs and passes from the object at the higher temperature to that at the lower. When skin is in contact with a textile material, the textile material is almost invariably at a lower temperature. The intensity of the feeling of warmth and cold is related to the rate of change in temperature sensed by the thermo receptors in the skin and to the total magnitude of change. This sensation is essentially felt under non-equilibrium conditions. If contact is maintained between the skin and an object for any length of time, the temperature of the surface increases and that of the skin decreases, until equilibrium is attained and eventually the surface ceases to feel cool.

The warm-cool feeling associated with clothing materials has been recognized by the Chinese since historical times and they found that cotton, linen and silk fabrics are good for summer clothing due to the cool feeling associated with them.

Schneider et al. found that smooth lightweight wool fabric is cooler compared to polyester fabric of similar construction. It was also observed that moisture desorbed from wool is much more compared to polyester and that the skin temperature decreased faster when woolen fabric touched the skin. The lower skin temperature lasted longer in case of wool compared to polyester.

Li et al. applied coupled heat transfer model to describe transient heat exchange when a fabric comes in contact with skin and found that woolen fabrics had greater temperature drop and also retained lowered temperature for a longer time. They concluded that the observed difference in warm-cool feeling is essentially due to the difference in moisture desorption by the fibers on the fabric surface. They have also found that moisture desorption rate has a negative non-linear relationship with fiber diameter and hence concluded that fabrics made from finer fiber would be cooler in feel. However, hygroscopicity of fiber is found to be the most important parameter related to cool feeling.

Schneider et al. found that cool feeling associated with hygroscopicity was, in general, positively related to relative humidity around the fiber.

Schneider and Holcombe^{40} studied fabric properties that influenced the coolness to touch. They developed a three-layer model of fabric structure consisting of dense core and two outer layers having protruding fibers that trapped air within them. They also showed that the thickness of outer layer had a negative influence on the coolness offered by the fabric.

Li and Brown studied a range of 20 fabrics and found that coolness to touch of a fabric is negatively related to fabric porosity, fiber diameter and fabric hairiness but positively related to fiber hygroscopicity.

Wang et al. studied perception of thermal and moisture sensations using mathematical models and showed that coolness to touch of fabrics can be predicted
with reasonable accuracy using heat and moisture transfer within the fabric.

Kawabata and Akagi explained the phenomenon of warm-cool feeling based on heat conduction from a heat source having finite heat content to a fabric specimen in contact with the hot source. They correlated the maximum value of heat flux (q-max)
during such a contact to warm-cool feeling felt when the fabric touches skin.

Yoneda and Kawabata presented a three-part paper on transient heat conduction from a body having finite heat capacity into fabrics, which provided the theoretical basis for the analysis of transient heat exchange between skin and fabric. It has been found that the values of q-max correlates well with subjective assessment of warm-cool feelings and that the measured value of q-max only depends on the surface condition of the fabric and does not depend on the thickness of the fabric.

Hes etal. studied the warm-cool to touch of fabrics based on thermal absorptivity and found this approach better than that based on peak heat flow. They introduced a new quantity called 'estimated thermal absorptivity', which characterizes the thermal handle of fabrics.

2.6.10 Factors affecting cooling behavior

The cool feel is mainly determined by the surface structure of the fabric: an ordinary sheet feels cool when one first gets into bed, but a flannelette sheet feels warm; both are 100% cotton, but the flannelette has a raised surface, giving a much smaller area of contact with the skin and therefore a slower rate of change of temperature. Other minor contributory factors include the bulk density; specific heat and moisture regain of the fiber^{40}.The smoother the fabric surface, the cooler the fabric feels to the touch. Light weight fabrics typically have a smooth finish, so that conduction between skin and fabric is maximized and thermal changes taking place in the fabric are rapidly passed on the skin.

Burton and Edholm have pointed out that in some ambient conditions, the relative humidity in the clothing microclimate can be lower adjacent to the skin than in the surrounding air, that is, there may be a relative humidity and its resulting behavior may be influenced by the moisture sorption properties of the component fibers.

G.J. Morris reached on the conclusion that the area of contact between fabric and skin (or hot body) is the major factor in determining the cold feel of the fabric and since the area of contact is the controlling factor, general statements about the cold feel of fabrics of different fibers cannot make.

Marie Jose et al observed that surface roughness and warm-cool feeling of a fabric depend on the chosen fibers, the yarn spinning method and fabric construction processes by taking plain jersey fabrics; two different varieties of cotton fibers (Pima cotton, Kaba S cotton) with similar counts (36 tex) and varying stitch length. Fabrics seem all the cooler when made from fine fibers. Fabrics made from two-ply yarns are cooler than those from single yarns. Rough fabric has a smaller contact surface and seems warmer. A hairier fabric encapsulates more air on its surface and so seems warmer.

Vivekananda et al concluded that the finer fabrics being smoother results in a higher q-max, indicating a cooler feeling. Washing finishes to denim fabrics, in general, improve q-max due to removal of size and enzymatic action. Finer count yarns give an improved q-max when used in warp direction of warp-faced woven fabrics. Thickness and bulk density show a negative correlation with q-max. Observed negative influence of cover factor of the fabrics on q-max may be attributed to the dependence of cover factor with thickness of fabrics. Pick density shows a positive correlation with q-max as the floating filling yarns on the fabric surface helps to improve area of contact between fabric surface and skin. Contribution of warp yarn is negligible. Successive washings reduce the surface roughness of fabrics (decrease in SMD). However, fabric surface friction (MIU) increases with successive washing treatments. q-max increases with the increase in smoothness of fabric surface. Four cotton denim fabrics differing in properties like weight per unit area, thickness and threads per inch were chosen for this study.

There are several factors that may influence or even distort the subjective assessment of the cool feel. Handle: the cold feel is one of the factors that contribute to the handle of a fabric and conversely any factor contributing to handle may subconsciously affect an observer's judgment of cool feel i.e.

a) Softness or hardness of the fabric;
b) Roughness or smoothness of the fabric surface
c) Coarseness or fineness of the fibers,
d) Flexibility and drape of the fabric;

e) Fullness and loftiness of the fabric;

f) Dampness or dryness of the fabric

Color of Fabric, e.g., Warm colors like red, brown etc. and cold colors: blue, grey etc. Surface reflectivity, e.g. bright shiny surfaces is cold whereas dull matt surfaces are warm[35].

2.7 Fabric handle

The term 'fabric handle' has been defined as "the subjective assessment of a textile material obtained from the sense of touch". It has been defined in more than one ways, as given below.

1. The quality of a fabric or yarn assessed by the reaction obtained from the sense of touch.
2. A person's estimation when feeling fabrics between fingers and thumbs.
3. The sum total of the sensations expressed when a textile fabric is handled by touching, flexing of the fingers, smoothing and so on.
4. The summation of the weighted contributions of stimuli evoked by fabric on the measured sensory centers.
5. What man sensorial assesses from the mechanical properties of a fabric.

'Hand' is thus a physiological phenomenon. It implies the ability of the fingers to make a sensitive and discriminating assessment and at the mind to integrate and express the results in a single valued judgment. Such a judgment cannot be obtained objectively, since the relevant mechanism of the sensory organs, the nervous system, and the brain are not known and will vary from individual to individual and with time for each individual. Strictly, it is not sufficient to express the hand of a fabric as the statistical means of the assessment of a number of observations. The very differences between assessments become important aspects of hand.

Associated with the concept of hand are quality words such as "soft", "warm", "thin", etc. which are common ideas created by communication between people. These common ideas generally involve more elemental sensory values and little variation in their assessment is to be expressed between observers. Thus, it is not unreasonable to use only statistical average in their expression. Such common ideas are sometimes called "Primary Hand expressions".

The key elements in subjective hand evaluation are given as below.

1. The judges- particularly their expertise.
2. The criteria of judgment- the choice or descriptors for fabric attributes.
3. The assessment conditions- seen or unseen, controlled temperature and relative humidity.
4. The assessment technique – free or specified fabric- manipulation technique for assessment of given attributes.
5. The method of ranking or scaling the assessment-rank order, graded standards, magnitude estimation.

6. Analysis of results- relative importance of individual descriptor for end use, correlation between descriptors, redundancy, and fabric specification profiles.

The parameters measurable under different primary hand expressions are as given in table 2.7.

Table 2.7 Influence of measured parameters on primary hand expressions

Primary Hand Expression	Measurable Parameter
1. Smoothness (NUMERI)	Surface, compression and shear
2. Stiffness (KOSHI)	Bending rigidity, weight, thickness, shear and surface
3. Fullness and softness (FUKURAMI)	Compression, surface, thickness, shear
4. Crispness (SHARI)	Surface, bending and tensile
5. Antidrape spread (HARI)	Shear, surface and bending

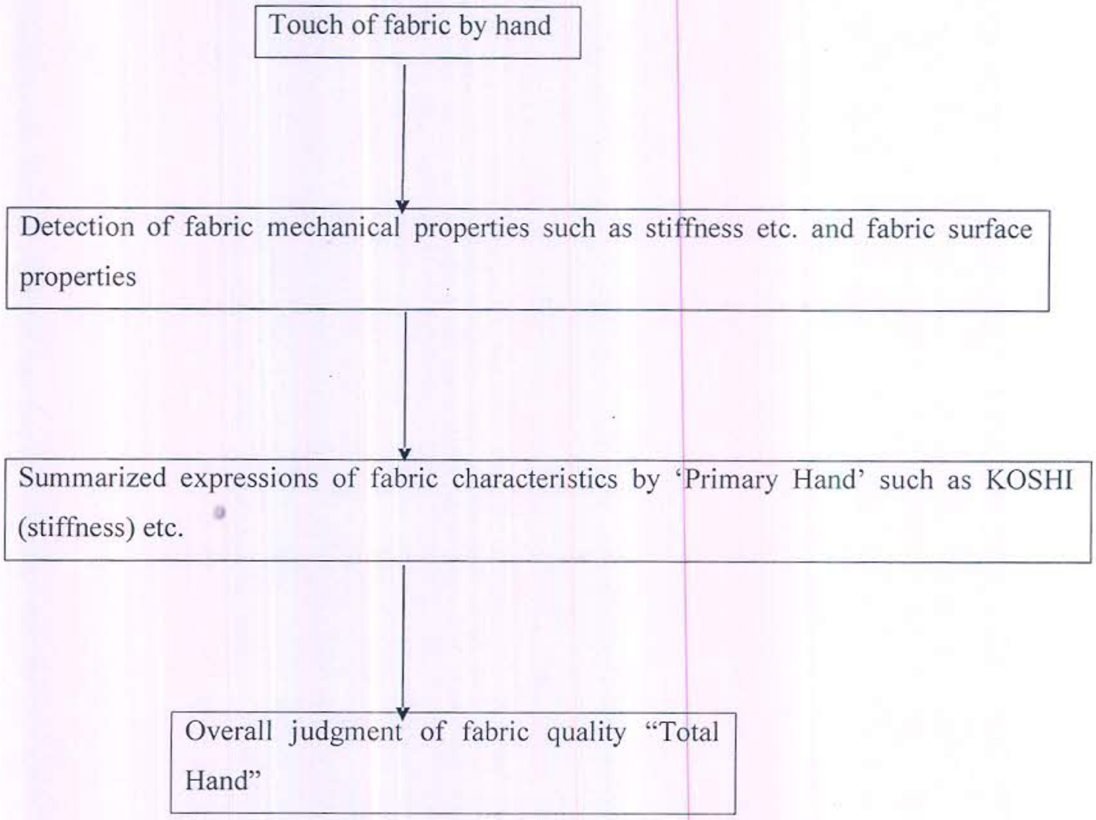
2.8 Hand evaluation techniques

2.8.1 Subjective evaluation

The HESC (Hand Evaluation and Standardization Committee), was organized by Kawabata under the sponsorship of the Textile Machinery Society of Japan. At this stage, the understanding of the 'fabric handle' that was going to be surveyed was becoming clear among the HESC members as follows-

1. The fabric handle that was used in textile mills, or, more precisely, in wool-textile finishing mills in Japan, was professional terminology for expressing the character and quality of a fabric as manifested by its performance with respect to the fitting to the human body, the feel of the surface, and comfort in wearing.
2. Visual appearance, such as the surface character and the silhouette of a garment when the fabric is tailored, was also an important factor in hand evaluation.
3. There were some important separate features of fabric character involved in the assessment of fabric handle, and it was certain that a common understanding of these features of handle existed among the experts in this area.

Important expressions for handle have to be standardized because some personal differences in the understanding of handle still remained, even among the experts. After this preliminary co-ordination of the idea of fabric handle, the selection of these important expressions for handles, together with their definition and standardization, was begun by HESC. After discussion with experts, the judgment of handle was identified as given below-



The expert touches a fabric with his hand and first detects the fabric's character from its mechanical responses, such as its bending stiffness, extensibility, etc. The expert then expresses the fabric character by some summary subjective terms, each of which is not simply a single mechanical property but combines various properties. Each of these summarized expressions certainly correlates with the fitting of the fabric to the human body and the mechanical comfort and aesthetic silhouette of the garments made from it.

Although there are many such expressions used, even by experts, in evaluating handle, the important ones are the limited number listed in Table (a). Kawabata called each of these a 'primary hand' of fabrics. They were selected in such a manner that the fabric characteristics defined by them were regarded as essential or important in clothing materials, and furthermore it was not possible to replace any of these primary hands by a combination of the others. In addition, these important primary hands could be quantified by their 'intensity' in several grades. The other less important hand terms could not be so expressed but could only be described as 'felt' or 'not felt'.

After their judgment of the primary-hand values, experts then evaluate the final and over-all impression and indicate whether the fabric handle is regarded as good or poor, on the basis of the preceding detailed, but not necessarily explicitly recognized judgment. This over-all fabric handle was called the 'total hand'.

At the beginning of the discussion on the evaluation of fabric handle, the expert did not notice this stage procedure, since they felt that they made their judgments of fabric handle in only one step. They did not agree with the separation of the judgment process into these two stages. However, the authors frequently put questions to the experts with respect to the judgment of fabric handle and asked why a particular fabric was rated as having a good or poor handle. The experts replied without exception that the fabric had a moderate 'KOSHI (stiffness)', higher 'NUMERI (smoothness)', and so on. These are the factors expressing fabric character regardless of its quality, and the important expressions used are the 'primary-hand qualities'. After many discussions, the expert agreed that they did perform a two-step judgment and accepted the separation of fabric handle into the two types, primary and total hands.

The definition of each primary hand was not exactly the same for each expert. The second stage of HESC work was therefore to select and formulate exact definitions of each of the primary hands with the concurrence of all the experts. The resulting definitions are shown in Table -2.7.

The standardization of the primary hands was carried out by the experts group of the HESC. Firstly, about 500 samples of men's winter suiting's, commercially produced mainly in Japan, were collected; every expert then judged the handle for each primary hand as follows. He divided all the samples into three groups in order of intensity of the particular primary hand, namely, strong, medium and weak. He then again divided each of the resulting three fabric groups into a further three sub-groups in the same manner as in the first grading. After this procedure, the fabrics had been separated into nine grades. Finally, those fabrics that had either an extremely strong feeling or an extremely weak feeling were separated from the strongest and the weakest groups respectively, to give a total of eleven grades, which can be ranked numerically as shown in Figure -2.7. This rating was termed the 'hand value' (HV).

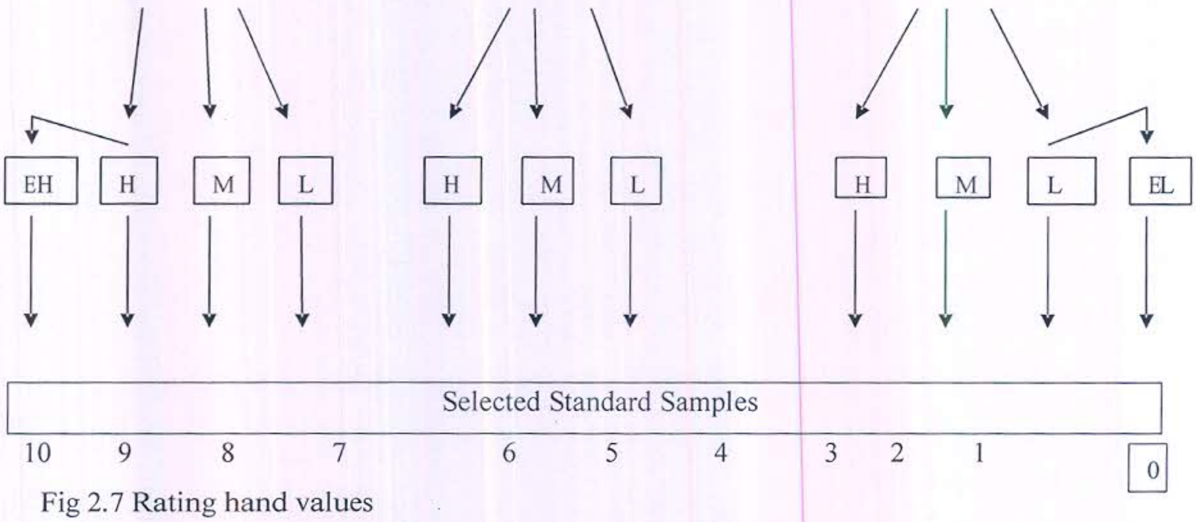


Fig 2.7 Rating hand values

A similar exercise was carried out for summer suiting's. The total hand, which is the fabric-handle aspect of the assessment of fabric quality, was also graded by the experts in the same manner as for the rating of the primary hand, but the grading of the quality levels were limited to the range from 5 to 0 as shown in Table. The grading number was termed the 'total hand value (THV).' In this exercise, 214 samples of winter suiting's and 156 samples of summer suiting's were selected from randomly collected commercial suiting samples so as to distribute their quality as widely as possible for the THV evaluation. The quality assessments were then carried out by the HESC experts for both the winter and the summer suiting samples in order to select the standard samples for the total hand.

Table-2.8 Total hand values

Grade	THV
Excellent	5
Good	4
Average	3
Fair	2
Poor	1
Not useful	0

2.8.1.1 Applicability of primary and total hand values

An important distinction must be made between the range of validity of grades of primary and total hand. Each primary hand represents an assessment by experts of a characteristic feature of the handle of a fabric, such as stiff to limp, rough to smooth, and so on. Ideally, the ranking should be the same, whoever the expert is and from wherever he or she comes. In practice, the differences should be small and could be reduced as research improves the formulation and the analysis. Thus primary hand values aim at universal validity as a way of characterizing fabric handle.

But total hand represents an assessment of the over-all quality of the fabric, which, in effect, is a measure of its value in the market, namely its selling appeal to the consumer. Its ranking will therefore reflect cultural differences and will be different in different countries owing to differences in traditions and climate, will be different depending on which market section is being aimed at, and will change as fashion changes. On the other hand, there is a possibility of the existence of some fabric properties, each of which is commonly accepted by consumers as the property related to high quality regardless of country, traditions, fashion changes etc., because the fabric quality may come from the fitting of the fabric property to the human body. Thus, THV includes both the mobility mentioned above and also the universality.

2.8.2 Objective evaluation system for fabric handle

On the basis of the standardization of fabric primary hands and total hand, a completely objective system for evaluating fabric handle has been developed. The expert subjective system is replaced by the objective expert system. In order to do this, it is necessary to translate appropriate sets of measured mechanical and surface properties into PHV and then THV.

The mechanical properties used here were determined from knowledge of the basic research on fabric mechanical properties and from observation of the mode of fabric deformation at the load level used when a fabric is evaluated by the experts. It was also desirable to choose the basic mechanical properties under simple modes of deformation because of the need to relate the fabric to fabric design in the future. The measuring system was designed by Kawabata by improving his laboratory testers in co-operation with Niwa in 1972 in order to measure these mechanical parameters. The system consists of four instruments. The basic principles of measurement by these instruments are not specialized but are well known, except for the method of surface analysis. Because the measurements must be made at very low load levels, much effort has been concentrated on instrument design in order to maintain the accuracy of the instruments at such low loads and to make the operation of measuring numerous samples easy.

2.8.3 Development of equations translating the mechanical data into hand values

In order to derive a set of equations to translate parameters from the mechanical tests into HVs, 214 winter suiting's and 156 summer suiting's were chosen by excluding the overlapping of similar fabrics; their hand values were then again evaluated subjectively by experts for each of the primary hands. Because of the smaller number of fabric samples and the existence of the standard, the evaluation became more precise than on the previous occasion. For this evaluation, ten judges were selected.

The range of mechanical parameters for good appearance and tailor ability is as shown in Table-2.9.

Table-2.9 Range of mechanical parameters for good appearance and tailorability

Mechanical Parameter	Range for Good Appearance and Good Tailor ability	Range for especially Good Appearance
EM1 (%)	4 – 6	4 – 6
EM2 / EM1 (%)	> 1	>2
RT (%)	65 – 76	72 – 78
G (gf/cm deg)	0.5 – 0.7	0.5 – 0.7
2HG5 (g/cm)	0.8 – 1.7	0.6 – 1.5

The averages of each of the primary hand values assigned by the judges were denoted by Ypk , where the suffix p indicates the fabric sample (p = 1…..N), where N is the number of fabrics in the test, and the suffix k indicates the primary hand (k = 1…3 for winter suiting; 1….4 for summer suiting). The measured values of the mechanical parameters were denoted by Xpj, where the suffix j indicates the particular parameter (j = 1…16). The mechanical parameters are grouped in six blocks: tensile, bending, shearing, compressive, surface and constructional.

In the statistical analysis for each primary-hand value, Yk, multivariable linear-regression equations are formulated between Ypk and the set of parameters in each of the blocks, in order to find which block gives the best prediction for Ypk. This gives the first regression equation for Ypk.

Secondly, the prediction errors, Epk = Ypk – Ypk', where Ypk' is the predicted value for Ypk obtained by using the first equation, are regressed with the sets of parameters in the remaining blocks in order to seek the block that is regressed with the highest accuracy. The first and second equations are then summed to obtain a single equation that includes the parameters of these two blocks. The errors Epk between Ypk and the value of Ypk' obtained by this single equation are again regressed with parameters in the remaining blocks in the same manner, and this procedure is continued until all the blocks are included.

This stepwise block regression has been developed from the requirements that:

1. The parameters included in one block must be clustered through the regression analysis, because each mechanical property can be expressed by a block.
2. The influence of the correlation between the parameters belonging to different blocks on the equation must be kept as small as possible.

3. The order of construction of the equations is important, because it shows the relative influence of each block on the primary hand value.

When the parameters have been placed in their order of importance for a particular primary hand Y_k , the suffix j is replaced by suffix i, ranging from 1 to 16 in order of decreasing importance. The complete regression equations are linear and can be expressed in the form as given below.

$$Y = C_0 + \sum_{i=1}^{16}(C_i x_i) \tag{2.1}$$

Where, C_0 and C_i are constants and Xj is the deviation of the mechanical parameter from the population mean, normalized by the standard deviation, namely

$$x_i = \frac{Xi - Mi}{\sigma i} \tag{2.2}$$

Where, X_i = absolute value of the parameter,

M_i = mean value of X_i for the population of N fabrics, and

σi = standard deviation of X_i

Equations predicting the total hand, THV, were also constructed on the basis of the subjective evaluations of THV and HV by the experts for the 214 samples of winter suiting's and 156 samples of summer suiting's. The variables of the equations are the primary hand values, and the equations consist of linear and square terms of these variables. This comes close to an optimum combination of the primary hands, HV, for predicting THV. The equation has the form:

$$THV = C_0 + \sum_{k-1}^{n}(Z_k) \tag{2.3}$$

Where C_0 is a constant, n is the number of primary hands, namely, three for winter suiting's and four for summer suiting's, and Z_k represents the contribution of the k^{th} HV to THV, given by:

$Zk = f(Y_k, Y_k^2)$

$$Zk = C_{k1}\frac{Yk - Mk1}{\sigma k1} + C_{k2}\frac{Yk^2 - Mk2}{\sigma k2} \tag{2.4}$$

Where, Y = hand values of k^{th} primary-hand value;

M_{k1} = mean value of Y_k for the population of N fabrics;

$\sigma k1$= standard deviation of Y_k;

M_{k2} = mean value of Y_k^2;

$\sigma k2$ = standard deviation of Y_k^2; and

C_{k1} and C_{k2} are constant coefficients

These regression equations were often improved during their development stage, and they are identified by numbers such as KN-101, KN-301 etc. The predictive ability of the equation for THV for fresh samples was demonstrated. The objective (calculated) THV were derived from the measured mechanical parameters by using equations (2.1) and (2.3). The subjective data, THV were correlated with the objective values and the scatter of the predicted THV was found to be small as compared to the subjective data. The objective values thus follow closely the mean value of the experts. This is why this equation is now being using widely in industry, even by experts, in addition to the equations for primary-hand values, because the quality judgment related to market value is difficult even for the experts.

2.8.4 Analysis of the total hand

It is interesting to see how the individual primary hands influence the total (or quality) of the fabric by plotting the contribution Z_k from equation (4) for each fabric against Y_k for winter suiting and for summer suiting. The influence of higher NUMERI (smoothness) on THV is remarkable for winter suiting, and it causes an increase in the THV. KOSHI (stiffness) and FUKURAMI (fullness) have the optimum zone around HV = 6.

In summer suiting, however, SHARI (crisp surface feeling) is important for THV. This is a special preference of Japanese consumers. The effect of KOSHI appears to be very small, but this probably results from the fact that the distribution of HV of KOSHI of the usual commercial summer suiting's is very narrow and converges upon HV=5. A higher SHARI and also a slightly higher FUKURAMI (fullness) around 6-7 are the preference for the handle of Japanese high-quality summer suiting's.

International comparisons between values of THV in different countries were initiated after the survey of THV in Japan for the same suiting samples had been assessed in Japan. The results show good agreement between Japan and the other countries for winter suiting, where the influence curves obtained in the assessment in western countries were very similar. The summer suiting's, however, show a difference in the quality judgments.

The ranges of mechanical properties for fabric to be rejected are as given in Table -2.10 below.

Table-2.10 Ranges of mechanical properties for fabric to be rejected

Mechanical Parameter	Range for Rejection
EM1 (%)	> 9 or < 3
EM2 (%)	<4
2HG5 (gf/cm)	<4

The interrelation between difficulties in sewing process and ranges of mechanical parameters are as given in Table -2.11 below.

Table -2.11 Interrelation between difficulties in sewing process and ranges of mechanical parameters

Range of Parameters	Difficulty Predicted in
$LT<0.55$ or >0.7	Overfeed operations
$RT > 70$	Cutting process
$RT < 55$	Steam-press operation
$LT < 0.55$ and $RT > 73$ or	Especially difficult in overfeed operations
$LT < 0.55$ and $RT < 55$	Overfeed operations
$EM1 < 3$ or > 8	Cutting operations
$EM1 > 5$	Overfeed operations
$EM2 < 4$	Sewing operations and steam press operations
$EM2 / EM1 > 3$	Overfeed operations
$G < 0.6$ or > 0.95	

The definitions of primary hand expression are as given in Table -2.12 below-

Table-2.12 Primary hand expressions

Japanese	English	Definition
KOSHI	Stiffness	A feeling related mainly to bending stiffness. A springy property promotes this feeling. A fabric having a compact weave density and made from springy and elastic yarn gives a high value.
NUMERI	Smoothness	A mixed feeling coming from a combination of smooth, supple, and soft feeling. A fabric woven from cashmere fiber gives a higher value.
FUKURAMI	Fullness and Softness	A feeling coming from a combination of bulky, rich and well-formed impressions. A springy property in compression and thickness, accompanied by a warm feeling, is closely related with this property (The Japanese word literally means swelling).
SHARI	Crispness	A feeling coming from a crisp and rigid fabric surface. This is found in a tightly woven fabric made from a hard and strongly twisted yarn. This gives a cool feeling (The Japanese word means crisp, dry and a sharp caused by rubbing the fabric Surface on itself)
HARI	Anti-drape Stiffness	The opposite of limp conformability, whether the fabric is springy or not (The Japanese word means spread)

KISHIMI	Scroop	The feeling and sound associated with some light weight fabrics.

2.9 Thermal Resistance

Thermal resistance is a measure of the resistance that a garment provides against heat loss from the body of the wearer to the external environment[51]. It is influenced by a combination of the thermal resistance provided by the clothing, by the layer of air between the skin and the clothing, and by the layer of air between the inner and outer surfaces of the fabric. The thermal resistance of a fabric is more or less proportional to the thickness of the fabric. Thermal resistance is measured in m^2 K/W, and can be converted to "tog" or "clo". One tog can be defined as a temperature difference of 0.1°C between two surfaces caused by the heat flow of 1 Watt/ m^2 (1 tog = 0.1 m2K/W) . Thermal resistance is also sometimes measured in clo (a unit of thermal insulation of clothes). One clo represents the amount of clothing required to keep a sitting man of average metabolic rate comfortable in an average
indoor atmosphere at 21°C.

2.10 Thermal absorptive

A 'warm–cool' feeling is the first sensation experienced when a human touches a fabric. This feeling is a result of heat exchange that takes place between the human hand and the fabric because of the temperature difference between the fabric surface and that of the human skin. This is referred to as thermal absorptive. If the thermal absorptive of a garment is high it can be expected to give a cooler feeling upon first contact.

2.11 Electrical Resistance

The electrical resistance of an object is a measure of its opposition to the passage of a steady electrical current. The resistance of an object determines the amount of current passing through the object for a given potential difference across the object in accordance with Ohm's law (V=IR), where R is the resistance in ohm; V, the potential difference across the object in volts; and I, the current in ampere.

Recently, some electro-physical properties of textile samples having different forms and raw material compositions were studied by Asanovic et al. For determining the electric resistance, a measuring device, based on the measurement of direct current through textile samples, was developed. The dielectric loss tangents and relative dielectric permeability were measured for some of the textile samples tested. The dielectric properties were measured using specially designed capacitance cells. Hains et al tested electrostatic properties of polyurethane coated textiles used for protective clothing.

Gonzalez et al proposed mathematical modeling of electrostatic propensity of protective clothing systems.

Ghosh and Dhawan reported the developments in the field of electronic textiles, focusing on current state-of-art of electro-textile products and the research being carried out in this field.

2.12 Air Permeability

Air permeability is the ability of air to pass through a fabric. Obviously, where opening between yarns or between fibers within yarns are large, a good deal of air will pass through the fabric. Conversely, when compact yarns are packed tightly into fabrics, with little space between them, the flow of air through the fabric is diminished. It follows, then, that fabric with compact, tightly twisted yarn will have lower permeability.

Air permeability may be affected by factors like cross sections, linear density of fiber and yarn, twist and covering power of yarn and fabric features like weave, thickness and tightness etc. Filament yarn fabrics have been found to have lower air permeability than spun yarn fabrics. Some finishes of fabrics may decrease air permeability by closing up the spaces in the fabric.

Clayton considered the permeability of a fabric in terms of these factors:

1. The cross section area of each hole.
2. The depth of each hole or thickness of fabric, and
3. The number of holes per unit area.

It is therefore, considerable that no cloth has the same permeability. He shows that air permeability increases with the increase in twist multiplier. In plain woven fabrics, air permeability value decreases at a rapid rate with increase in picks per inch up to a certain limit but for heavy picks fabric, this reduction becomes comparatively lower.

Scheifer found that closely woven fabric of short fiber with large number of threads interlacing per unit area have low permeability that of loosely woven fabrics of the same weight having lower plot and small number of interlacing. Sieminski et al discussed air permeability as plain weave, because of its maximum intersections per unit area and the shorter plot, would be impermeable than twill and the latter would be more impermeable than certain weave fabrics. Fabrics from same warp and weft yarns woven to their possible tightness for plain, 2/1 twill and satin have radically different pore space distribution. The small pores with less pore volume were found in plain than 2/1 twill and satin, this results in lower air permeability.

2.13 Water Vapour Transmission

The water vapour permeability of clothing materials is a critical property of clothing systems that must maintain thermal equilibrium for the wearer. Clothing materials with high water vapour permeability allow the human body to take advantage of its ability to provide cooling due to sweat production andevaporation[44]. When perspiration takes place to cool the body, the water exuded through skin appears initially as liquid which evaporates at once (in comfortable situations) and forms moisture vapour. This vapour is then removed from the vicinity of the body, either by convection or through the clothing worn on the person, carrying heat away with it. When the moisture vapour reaches the inner surface of the fabric, several events can take place. The vapour may pass through the fabric system to its outermost surface, which is then carried away by the air. At the other extreme, it may be prevented from escaping through the fabric system if a component of the latter is impermeable, and hence will condense at some position in the system. The fabrics should allow moisture, in the form of sensible and insensible perspiration, to be transmitted from the body to the environment in order to cool the body and reduce the degradation of the thermal insulation of the fabric caused by moisture build-up. This characteristic of fabric is commonly known as fabric breathability.

In the year 1939 Cassie et al. postulated the concept of moisture buffering in clothing and subsequently restated phenomenon to moisture sorption and desorption and exchange of heat when hygroscopic fibers are exposed to humidity transients.

During humidity transients, hygroscopic fibers can absorb or desorbs moisture from or to the adjacent air, which can delay the moisture change in the clothing microclimate. Moisture buffering during humidity transients leads to stability of clothing microclimate and thereby helps to maintain clothing comfort. Many investigations conducted to prove significance of moisture buffering in clothing comfort did not provide any conclusive proof for its existence. Works by Scheurell et al showed the importance of a fabric property named dynamic surface wetness which correlated well with wear comfort. Fabrics made of hygroscopic fibers like cotton and wool were studied to understand their influence on dynamic surface wetness.

Hong et al found that minimum moisture build up over the inner surface facing the moist skin was a minimum for cotton compared to cotton polyester blend and all polyester fabrics. Wehner et al found that the duration of humidity transient heavily depended on the moisture sorption abilities of the fabrics. While a moisture flux across an inert porous fabric can reach steady state within seconds, a similar flux across wool fabrics took over an hour to reach steady state.

Vivekanandan et al envisaged by analyzing dynamic moisture transport through both cotton and polyester-cotton blends using the CIRCOT WVTR apparatus and quantifying the moisture buffering that takes place both in cotton and cotton rich fabrics and found the CIRCOT Method, is more sensitive to dynamic environmental conditions and fabrics response to such changes during real-wear conditions. This method is also sensitive to changes in material composition of fabrics.

2.14 Drapability

Drape is an important property that decides the gracefulness of a garment as it is related to aesthetics and appearance of garment. It describes the way in which the fabric falls itself in specific shape according to its properties when part of it is supported by any surface and rest is unsupported. Drape is of much importance for the selection of appropriate fabric for intended garment, and therefore the correlation between the drape and fabric properties must be known according to Hearle the major mode of deformations in draping is fabric bending. But due to occurrence of double curvature, some shearing also occurs. There must also be some tensile and compressive deformations but because of high stiffness along the threads, these are likely to be small and ignored. Buckling behavior is also found to be important in determining the form and magnitude of drape which is again related to bending stiffness's the bending and shear properties are thought to be the main factor influencing drape and fabric handle. . According to Pandurangan et al, the factors influence the drape behavior in the following order: compression<weight<shearing<tensile<bending. The drape coefficient is the most fundamental parameter for quantifying drape and the most widely used for textile material.

2.15 Crease Recovery

Gigliardi and Grainfest et al employed an engineering approach to the mechanism of creasing and concluded that crease resistance performance of a fabric depends up on:-

(a) The inherent ability of fibers to recover from strain.

(b) The state of aggregation of fibers and yarn strain.

Laco.J. and Veer L.S.et al concluded that 2/3 twill should have much better crease recovery than plain weave and thicker the fabric better it will recover from creasing because the crease will be less sharp than that of thinner fabric. Hamburger et al confirmed these statements in their studies on fabrics made of 3- denier cellulose acetate by reporting that fabrics with decreased cover factor and long floats will exhibit increased recovery.

However, Hair and Shankaranaryanan et al while studying the effect of pick density on Crease Recovery for plain woven ring and rotor yarn fabrics stated that warp wise Crease Recovery increases and weft wise Crease recovery decreases with increase in picks per inch. They reported that this might be due to bending of yarn over weft yarn during creasing of warp and cross threads (weft) displace to relieve strain. The inter yarn movement retards recovery because of friction. Obviously, the inter yarn movement will decrease with increase in picks per inch and could lead to storage of energy because of thread compression.

2.16 Bending Length

Bending Length is that length of fabric which bends under its own weight to a definite angle 41.5^0 . Sharma et al studied the effect of different weft twist multiplier on fabric stiffness of plain woven finished fabric taking 5 weft twist multiplier in a single weft (3.1, 3.3, 3.5,4 and 4.5) and concluded that the bending length, flexural rigidity and bending modulus increases with initial increase in the twist and then falls for the twist multipliers beyond the optimum twist level. This is because the increased stiffness of yarn impedes the bending of fabric under its own weight in the fabric. Cooper et al prepared the continues filament viscose rayon fabric sample of different nominal square set from 150 denier multifilament yarn with varying twist and number of filaments and tested them for fabric stiffness. From the results, he found decrease in average bending length with increase in twist. However, by loop method, slight increase in stiffness was observed with high twist. Backer et al in their studies on the influence of yarn twist on the cotton fabrics reported an increase in stiffness at lower yarn twists and decrease at higher yarn twists.

Conclusion

From the literature review, it has been observed that no studies were made to design and develop value-added union fabrics, made of bamboo fibre/filaments.

Hence, in the present research project, an attempt will be made to design & develop value-added union fabrics for apparel, home fashion products.

3. MATERIALS AND METHODS

3.1 RAW MATERIALS

3.1.1 Fibre types and specifications

The specifications of the different eco-friendly, vegetable and re-generated cellulosic fibers to be used in the study will be as follows:

- ☐ BAMBOO FIBRES with different shapes and sizes
- ☐ COTTON FIBRES with different shapes and sizes

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☐ VISCOSE FIBRES with different shapes and sizes
☐ VISCOSE FILAMENTS with different shapes and sizes
☐ MODAL FIBRES with different shapes and sizes
☐ TENCEL FIBRES with different shapes and sizes

3.1.2 Yarn types and Specifications

Different types of spun and filament yarns sourced from spinning units will be used for study as follows:

☐ BAMBOO YARNS with different COUNT, TWIST and BLENDS
☐ COTTON YARNS with different COUNT, TWIST and BLENDS
☐ VISCOSE SPUN YARNS with different COUNT, TWIST and BLENDS
☐ VISCOSE FILAMENTS with different DENIER, TWIST and TYPE
☐ MODAL YARNS with different COUNT, TWIST and BLENDS
☐ TENCEL YARNS with different COUNT, TWIST and BLENDS

3.1.3 Fabric Samples Preparation

All fabric samples will be prepared in HANDLOOMS, POWERLOOMS, KNITTING Mills, BRAIDING UNITS, NONWOVEN UNITS and union fabric samples thus produced will be processed in the processing units as follows:

3.1.3.1 : PREPARATION OF WOVEN FABRICS:

HANDLOOM and POWERLOOM WOVEN FABRICS:

Value-added Union Handloom and Powerloom woven fabrics will be produced from Bamboo and other eco-friendly yarns with the following specifications:

☐ Using different weaves with colour and weave effect

☐ Using different fabric sett by changing Yarn and Fabric density

☐ Using different GSM and Width

☐ Using Jacquard and Dobby designs

WEFT KNITTED and WARP KNITTED FABRICS:

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Value-added Union WEFT KNITTED and WARP KNITTED fabrics will be produced from Bamboo and other eco-friendly yarns with the following specifications:

☐ Using different knit designs with grey and coloured yarns

☐ Using different loop length and stitch density by changing WPI & CPI

☐ Using different Fabric density

☐ Using different GSM and Width

☐ Using Jacquard and Dobby design

BRAIDED FABRICS:

Value-added Braided fabrics will be produced from Bamboo and other eco-friendly yarns with the following specifications:

☐ Using different braid designs with grey and coloured yarns

☐ Using different Threads per inch

☐ Using different Fabric density

☐ Using different GSM and Width

☐ Using Jacquard and Dobby designs

NONWOVEN FABRICS:

Value-added NONWOVEN fabrics will be produced from Bamboo and other eco-friendly yarns with the following specifications:

☐ Using different designs with grey and coloured fibres

☐ Using different needles per inch

☐ Using different Fabric density

☐ Using different GSM and Width

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3.2 TEST METHODS

Following Test methods will be carried out for the developed products:

- ☐ Yarn Tests
    - ☐ Actual yarn count
    - ☐ Yarn twist
    - ☐ Yarn Strength (RKM)
    - ☐ Yarn Modulus
    - ☐ Yarn to metal friction
    - ☐ Yarn Hairiness
- ☐ Fabric tests
    - ☐ Bending Length and Flexural rigidity
    - ☐ Crease Recovery
    - ☐ Air Permeability
    - ☐ Thermal absorbtivity
    - ☐ Moisture vapour transmission rate
    - ☐ Electrical resistance

Million Mega-Ohm Meter (model MM-108 D) a versatile instrument is used for the measurement of electrical resistance of textile materials. Accuracy of the test voltage within ±1.5% of full scale value i.e. ±9 volts [79]. Accuracy of mega ohms ranges within ±5% of true value on multiplier ranges up to 10^5. Multiplier range 10^6 is accurate to ±6% of true value.

Specifications: Model: MM- 108D; Multiplier: $10^1 – 10^6$; Megohm range at 500V: 10^8; Test voltage range: 65- 600V DC.

For other test voltage, test results are computed as,

$$\text{Resistance in megaohms} = \frac{\text{Meter reading*Multiplier*Test voltage}}{500}$$

3.3.7 Drape Coefficient

The Drapability of the specimen was determined by testing it in the Cusick Drape Tester according to the BS 5058:1973 test method. In the test a circular specimen is held concentrically between two smaller horizontal discs and is allowed to drape into folds under its own weight. A light falls from the top of the specimen and the shadow that the fabric casts, is traced onto an annular piece of paper, the same size as the unsupported part of the fabric specimen. To measure the areas involved, the whole paper ring is weighed and then the shadow part of the ring is cut away and weighed. The paper is assumed to have constant mass per unit area so that the measured mass is proportional to area. The drape coefficient can then be calculated using the following equation [80].

$$\text{Drape coefficient} = \frac{\text{Mass of Shaded area}}{\text{Total Mass of Paper Ring}} \text{ X } 100\%$$

3.4 Low stress mechanical properties and hand value by Kawabata evaluation system

The fabric samples were tested at Central Institute for Research on Cotton Technology, Mumbai, India. The tensile and shear properties were studied on KES-FB1 (tensile and shear tester). The tensile properties were measured by plotting the force extension curve between zero and a maximum force of 500 gf/cm and the recovery curve. Shear properties were measured by shearing a fabric sample parallel to its long axis, keeping a constant tension of 10 gf/cm on the clamp. Bending properties were measured on KES-FB2 (pure bending tester) by bending the fabric sample between the curvatures -2.5 and 2.5 cm^{-1}.

Compression properties were studied on KES-FB3 (compression tester) by placing the sample between two plates and increasing the pressure while continuously monitoring the sample thickness to a maximum pressure of 50 gf/cm^2.

The surface roughness and surface friction were measured on KES-FB4 (surface tester). The primary and the total hand values were calculated from the sixteen mechanical properties using the prescribed procedure by Kawabata and Niwa.

Kawabata low stress mechanical properties and their units are as given in Table 3.4 below.

Table 3.4 Kawabata Low Stress Mechanical Properties

Block	Symbol	Description of parameters	Unit
Tensile	LT	Linearity of load-extension curve	-
	WT	Tensile energy	gf.cm/cm^2
	RT	Tensile resilience	%
	EMT	Extensibility	%
Shearing	G	Shear rigidity	gf/cm./degree
	2HG	Hysteresis of shear force at	gf/cm

	2HG5	0.5° shear angle Hysteresis of shear force at 5° shear angle	gf/cm
Bending	B 2HB	Bending rigidity Hysteresis of bending moment	gf.cm^2/cm gf.cm/cm
Compression	LC WC RC	Linearity of pressure-thickness curve Compression energy Compression resilience	- gf.cm/cm^2 %
Surface	MIU MMD SMD	Coefficient of friction Mean deviation of MIU, frictional Mean deviation of thickness (roughness)	- - μm
Weight	W	Weight per unit area	Mg/cm^2
Thickness	T	Thickness at pressure 0.5 gf/cm^2	Mm
Thermal insulation	TIV	Thermal Insulation Value	Tog

Kawabata instrument settings are as given in Table 3.5 below.

Table 3.5 Kawabata Instrument Settings

Property		Instrument settings	
1.	Compression	Rate of compression	0.02 mm/sec.
		Maximum force	5 KPa
		Area compressed	2.0 cm^2 circle
2.	Bending	Rate of bending	0.5 cm^{-1}/sec
		Maximum curvature	+/- 2.5 cm^{-1}
		Sample size(LXW)	20 cm X 1 cm
3.	Surface	Rate of traverse	1 mm/sec
		Tension on sample	0.1 N/cm
		Normal force, friction	0.5 N
		Contact force, roughness	0.1 N
		Distance measured	3 cm
4.	Shear	Rate of shearing	0.417 mm/sec
		Maximum shear angle	+/- 140 mrad

		Tension on sample	0.1 N/cm
		Sample size(L X W)	5 cm X 20 cm
5.	Tensile	Rate of extension	0.1 mm/sec
		Maximum tensile force	5 N/cm
		Sample size(L X W)	5 cm X 20 cm

5.PRODUCT DESIGNING

5.1 Sample Design & Pattern making

User surveys will be done to carry out consumer's preferences for age group 18-65 specifically in trousers. A questionnaire will be drafted to collect information about the consumer preferences over conventional & value-added products to be developed . (Annexure-). Besides of this the selection of buttons, uppers, snaps, thread lace, tapes, braids, medallions, sequins and a variety of ornaments and closures and decorative trims will also be chosen to impart the desired design effect. To develop value-added products designs different types of software's will be used like Adobe Photoshop, Corel draw, Optitex, etc. A brief description of different software's is as under.

5.1.1 Corel Draw

Corel Draw Graphics Suite is the main tool used to create illustration and imaging. It can also be utilized for vector designs and layouts. Corel Photo-Paint is designed to retouch and edit digital photos, and other applications in the package can do tasks such as screen grabs. With the help of this program, designers can create characters, logos, shapes, different type of dresses and many other graphic objects.

5.1.2 Photoshop

Process of creating the storyboard helps in visualizing the final product. It allows analysis visually of how the products are framed in their final look or the layout. This is also an opportunity to work out the precise sequencing in the garments. It is much easier (and less expensive) to try out alternatives of the garment in this preproduction stage. A storyboard can be simple or elaborate depending on the storyboard creator. Too much detail should be avoided and the focus on just the essential details of the dress is required. Standard letter-size paper or template can be used. One can create his/her own pattern. Boxes are used for information such as fabric swatches, trims and accessories, flat sketch, final design etc. Background color or pattern must also be carefully selected and the focus of the concept and overall look and sequencing

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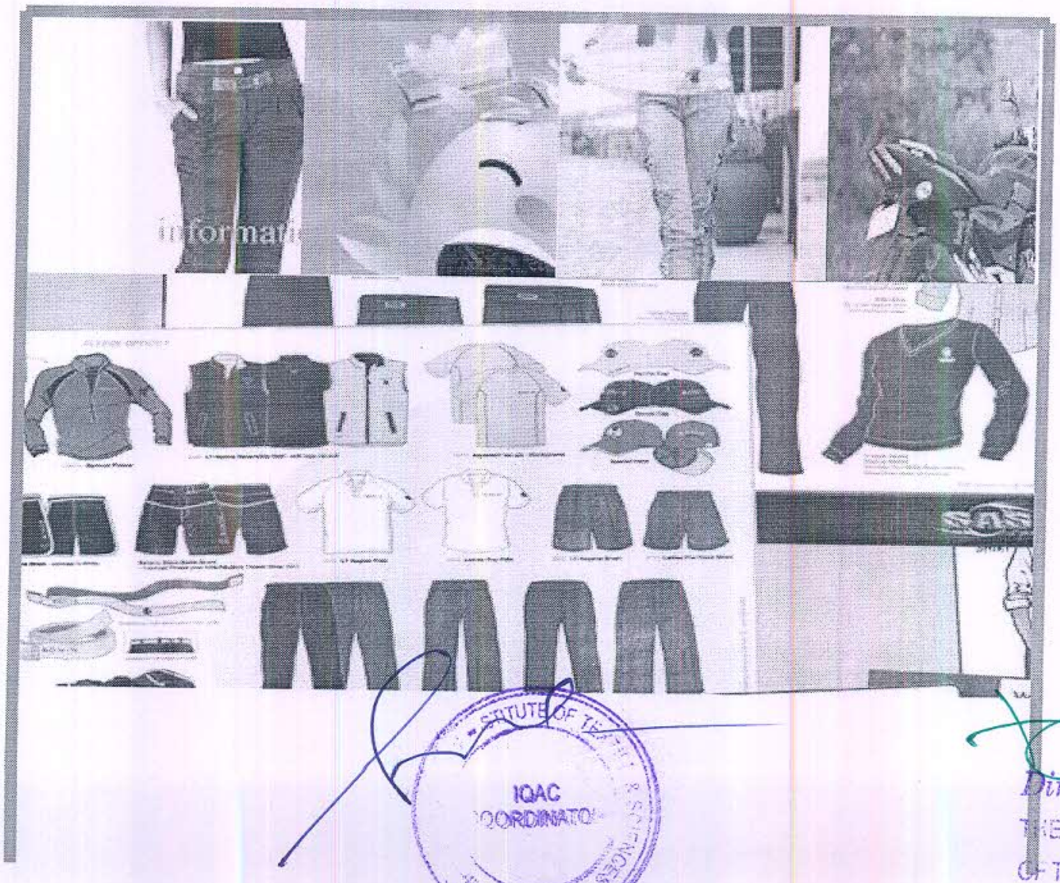
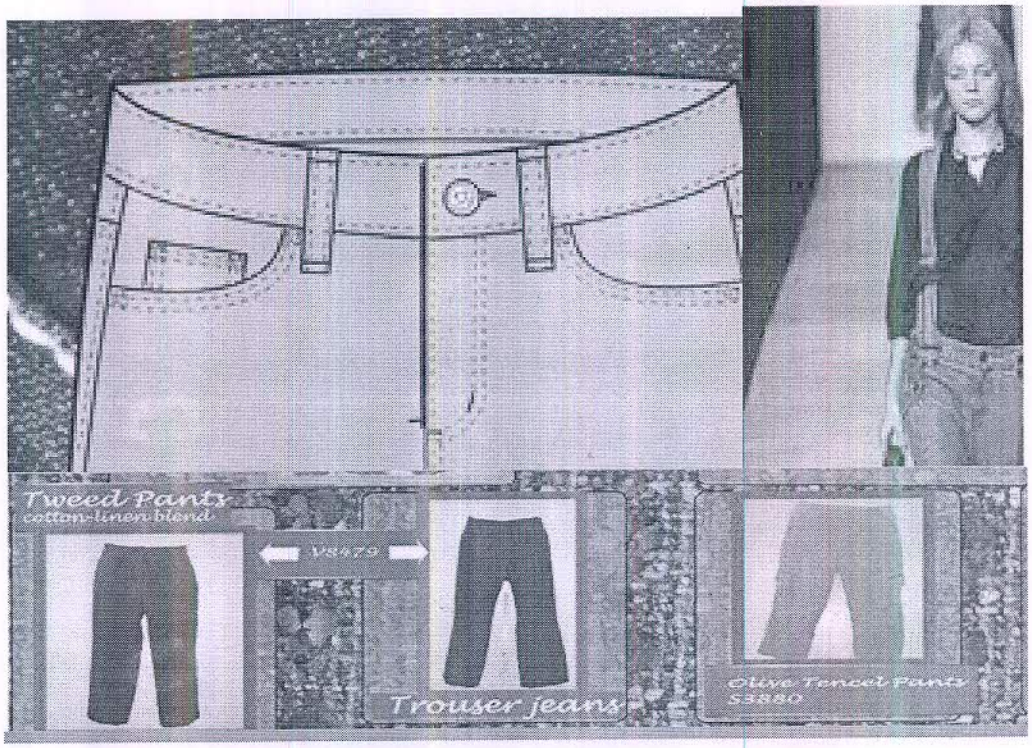
must not be compromised. According to theme, mood boards & story boards were developed shown below-

Mood boards

A mood board (sometimes called as inspiration board) is a type of poster design that may consist of a variety of objects like images, texts, colors, textures, silhouettes whose composition totally depend upon the choice of the mood board creator. Mood board is basically designed by the graphic designers to visually explain the direction of style pursuing. A rough collage of colors, textures and pictures is prepared which evoke a specific style or feeling. The sources of the picture of the mood board are magazines, newspapers, fashion designing books, internet etc. Mood board designing in the digital form is much easy and quick method as compared to when prepared with physical objects. A mood board is a tool used by designers to help them get a good idea of what their clients are looking for. Mood boards are basically collages of items such as photographs, sketches, clippings, fabric swatches and color samples. A mood board can be actual or virtual. A mood board is a type of collage consisting of images, text, and samples of objects in a composition. They may be physical or digital, and can be "extremely effective" presentation tools.

Fig-5.1 Mood Board





Story Board

Process of creating the storyboard helps in visualizing the final product. It allows analysis visually of how the products are framed in their final look or the layout. This is also an opportunity to work out the precise sequencing in the garments. It is much easier (and less expensive) to try out alternatives of the garment in the preproduction stage. A storyboard can be simple or elaborate depending on the storyboard creator. Too much detail should be avoided and the focus on just the essential details of the dress is required. Standard letter-size paper or template can be used. One can create his/her own pattern. Boxes are used for information such as fabric swatches, trims and accessories, flat sketch, final design etc. Background color or pattern must also be carefully selected and the focus of the concept and overall look and sequencing must not be compromised.

Fig-5.2 Story board

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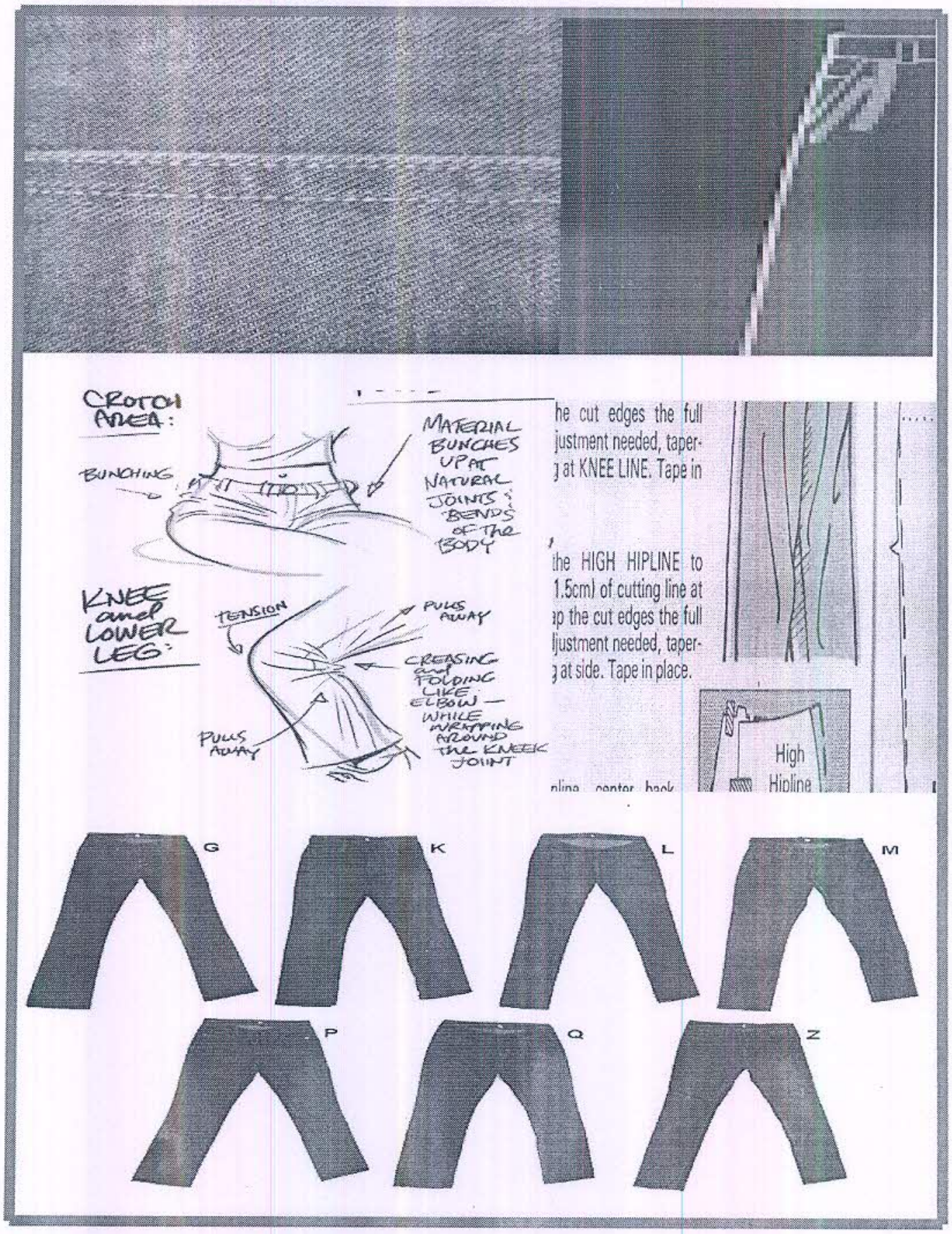
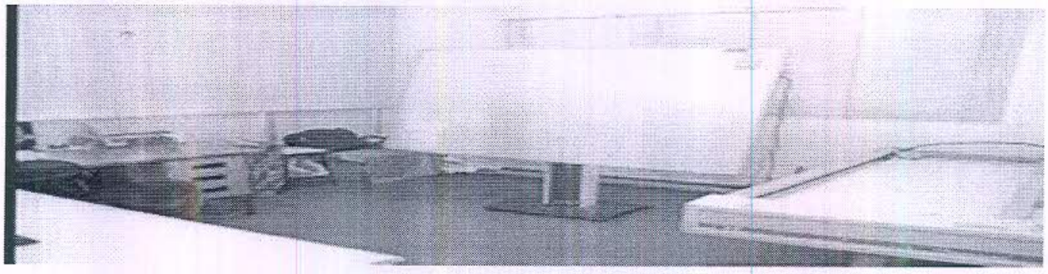


5.1.3 Pattern making :Optitex

Pattern Design System (PDS) is designed to easily create new styles or use existing patterns. Hard copy patterns can also be maintained in this system. Movable toolbars and dialog boxes allow each design engineer to create his/her own working environment. Icons and tools are organized according to functionality : the 'Compare Length' dialog box is used to compare line lengths of multiple pattern segments, while the 'Insert Toolbar' is used to add pleats, seam allowance, drill holes, notches and text. Tools such as darts, seam allowance, special corners, advanced measurement techniques, pleats, complicated curves, dimensional changing and facings, are all customizable according to specific needs.

5.2 Fabric Cutting

Cutting involves three basic operations, i.e. making the marker, spreading the fabric and chopping fabric into the marked sections. Optitex will be used for pattern making processes. There are six types of machines available to chop or cut a lay into the component parts with different types of cutting instruments like rotary blade machine, vertical reciprocal blade machines, band knives, similar to band–saws, die clickers systems with straight blades and automated computerized laser beam cutting machines. Nap cutting layout will be used for the fabric cutting.



5.3 Sewing/Stitching:

The sewing operation will be performed to join the individual cut components in to desired shape by using power operated sewing machine. Needles to be used to sew value-added products should have longer, sharper point and a longer needle eye so that it can easily penetrate into the tightly woven fabric. Its larger eye accommodates decorative topstitching thread. So the size of the sewing needle will be selected according to weight of the value-added product. Some of the needle sizes as per weight of the fabrics will be as follows-

Weight Ranges	Needle Size
12- to 14 ounce	100/16
10- to 12 ounce	80/14
6- to 8 ounce	75/11

Needles to be used for value-added products sewing has longer, sharper point, so that it can penetrate the close weave of the cloth easily. Its larger eye accommodates decorative topstitching thread. Polyester or cotton-wrapped polyester thread, and decorative threads will be used for topstitching. It is helpful, but not necessary, to have an even-feed and/or roller presser foot for sewing over multiple thick layers of fabric.

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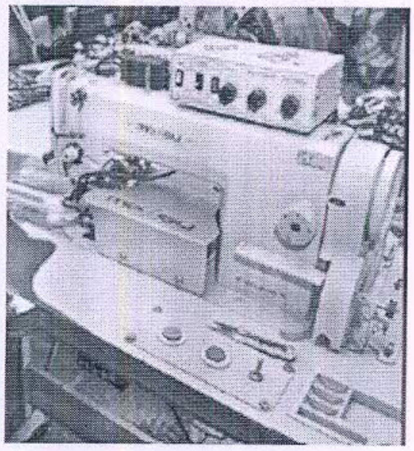


Sewing of denim is similar to other woven garments but to avoid fraying of fabric, seam finishing is essential. Some of the edges finishes used for denim trousers are as follows:

5.3.1 Pinked edge finish

It is the simplest method by trimming the seam allowance with pinking shears. For extra protection, run a straight stitch along the raw edge first and then pink it.

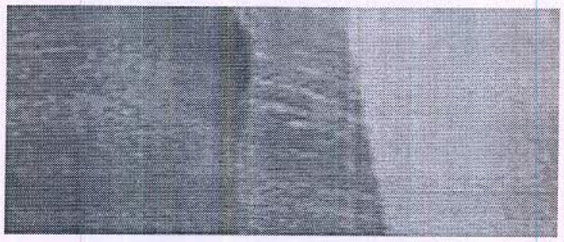


Fig 5.3 Pinked edge finish

5.3.2 Zigzag seam allowance

The allowance of the seam edge is cut in a zigzag manner to avoid fraying.

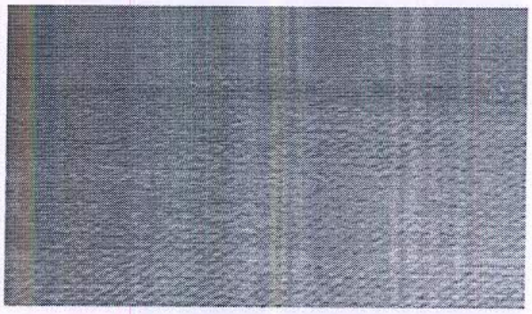


Fig- 5.4 Zigzag seam allowance

5.3.3 Serging

It the technique of binding the seam allowances with double-fold bias tape of the raw edges on unlined jackets etc. It is used in such cases where the inside of the garment is often visible. A heavy weight denim fabric requires low SPI value (10) as compared to lighter weight denims. The SPI value for light weight denim fabric is 12 (3 mm). Sewing thread tension and the presser-foot pressure reduces slightly to feed fabric plies evenly.

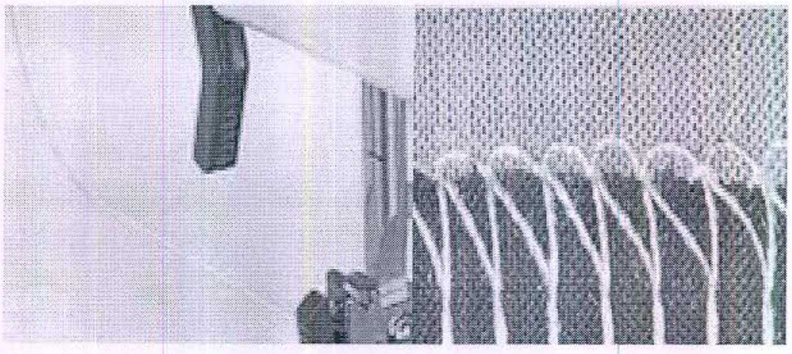


Fig 5.5 Serging of garment panel

5.3.4 Types of Seams

The most popular denim seam is the flat-fell seam; it's very durable and gives a nice, clean finish on the inside of the garment. Denim fabric is sewn with a standard seam length 5/8" (1.6 cm) with top stitching & flat felt seams.

a)Topstitching

Topstitching gives denim its trademark look, as well as decorative appeal. A heavy contrasting thread or decorative threads are used for topstitching such as buttonhole part, side seams of trousers etc. In place of regular decorative thread regular threads can also be used for topstitching.

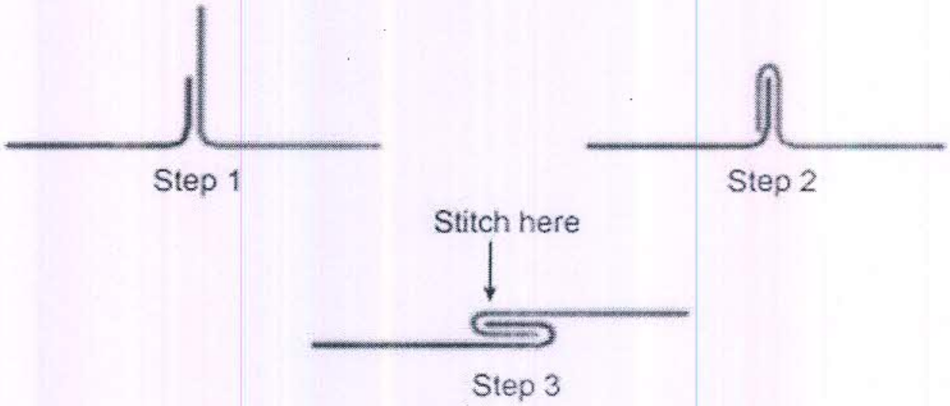


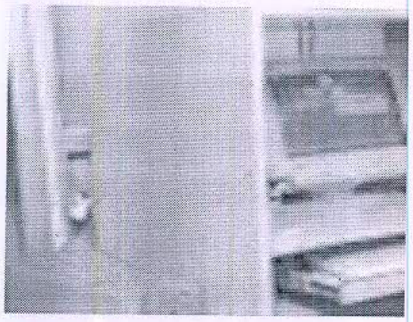
Fig 5.5 Flat felt Seam

b) Closures & Hems

Machine made buttonholes, zippers and decorative snaps are the most popular types of garment closures on denim. Hems are most often stitched by machine with one or two rows of narrow topstitching. Narrow denim hems have a tendency to curl. To reduce curling, finish the lower edge of the garment by pressing it to the wrong side or serging it. Addition of a strip of fusible web into the hem allowance, then folds and fuses the hem in place before topstitching.

5.4 Trimming &Pressing:

Trimming of extra threads, mending and pressing etc. finishing processes are exercised at this stage. Pressing has two major divisions: Buck press is a machine for pressing a garment or section between two contoured, heated pressure surfaces that may have steam vacuum systems in either or both surface.



5.5 Fabrication of Bamboo-based Value added products

Bamboo-based Value added products will be constructed for age group 18-65 in four sizes based on user survey. In the present study, Bamboo-based Value added products will be constructed as per style selected by consumers with the help of questionnaire. Steps of construction of Bamboo-based Value added products will be as follows-

FABRIC SELECTION FOR VALUE ADDED PRODUCTS

↓

FIT SELECTION FOR COMFORTABLE VALUE ADDED PRODUCTS

↓

PATTERN CONSTRUCTION AS PER MEASUREMENT

↓

FABRIC CUTTING

↓

VALUE ADDED PRODUCTS SEWING

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PRESSING & INSPECTION

5.6.1Fabric selection for Bamboo-based products

Correct fabric selection for Bamboo-based Value added products is the important criteria to impart comfort in clothing. Different types of fabric like sports cloth, corduroy, velveteen, gabardine, and a variety of medium-weight blends are suitable for pants. The fabric should be firmly woven to hold its shape and wear well. It should drape over the figure gracefully and should have good wrinkle resistance. Knits are usually a good choice for comfort, but the weight of the knit determines its success as a pants fabric, but soft, clingy knits may emphasize figure flaws. After considering all these fabric characteristics & consumer outputs from questionnaire indigenously developed Bamboo-based Value added products will be used for fabrication of products.

5.2.2 Fit selection for comfortable Bamboo-based Value added products

Fit is the second key factor to develop comfort and attractive Bamboo-based Value added product. Pants should fit comfortably at the waistline and fall smoothly over the hips and thighs. In well-fitted pants, the lengthwise grain line is perpendicular to the floor and creases in the legs are on the straight grain. Pants length will vary according to the silhouette. Some of the common problems are there in existing Bamboo-based Value added products like- Ripples at the waistline, Wrinkles at the crotch, Bagginess at the crotch, Waistline pulling down at center back or center front & Pressed creases that hang off-grain. To avoid all these problems and to make it more comfortable in every posture a Value added products will be developed

5.6.3 Pattern construction as per measurement

First step for pattern construction to take measurements from standard size chart for readymade wear and for customize Bamboo-based Value added products measurements will be taken by measuring body figure of every individual.

CHAPTER-6

Budget Estimates:

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Annexure

Questionnaire-1

Target Respondents:- Males & Females of tropical regions

"Designing and Development of union fabrics and value-added products from yarns made of Bamboo fibers/filament"

1. Name:- __________________________
2.Gender:- __________________________
3.Age Group:-
a) 18 to 25 :-
b) 26 to 35 :-
c) 36 to 45:-d)
46 to 55:-e)
56 to 65:-
f) 66 or above:
4. Occupation:- __________________________

Rate the following on a scale from 1 to 5:-

☐ 1= For Lowest Rating
☐ 5= For Highest Rating

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Q1. Which type of material do you think is the most comfortable to wear?

a) Polyester	[1]	[2]	[3]	[4]	[5]
b) Viscose	[1]	[2]	[3]	[4]	[5]
c) Wool	[1]	[2]	[3]	[4]	[5]
d) Cotton	[1]	[2]	[3]	[4]	[5]
e) Modal	[1]	[2]	[3]	[4]	[5]
f) Tencel	[1]	[2]	[3]	[4]	[5]
g) Bamboo	[1]	[2]	[3]	[4]	[5]

Q2. What kind of material do you prefer to wear in summers?

a) Cotton	[1]	[2]	[3]	[4]	[5]
b) Viscose	[1]	[2]	[3]	[4]	[5]
d) Polyester	[1]	[2]	[3]	[4]	[5]
e) Modal	[1]	[2]	[3]	[4]	[5]
f)Tencel	[1]	[2]	[3]	[4]	[5]
g)Bamboo	[1]	[2]	[3]	[4]	[5]

Q3. Why do you prefer wearing a denim trouser over formal trouser?

a) For comfort	[1]	[2]	[3]	[4]	[5]
b) For fashion	[1]	[2]	[3]	[4]	[5]
c) Inspired by peers	[1]	[2]	[3]	[4]	[5]
d) Ease of maintenance	[1]	[2]	[3]	[4]	[5]
e) Durability	[1]	[2]	[3]	[4]	[5]

Q4. In which season of would you like to wear denims?

a) Summer	[1]	[2]	[3]	[4]	[5]
b) Winter	[1]	[2]	[3]	[4]	[5]

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c) Spring	[1]	[2]	[3]	[4]	[5]
d) All seasons	[1]	[2]	[3]	[4]	[5]

Q5. In which posture do you find your denim trousers to be comfortable & to what extend?

a) Walking	[1]	[2]	[3]	[4]	[5]
b) Sitting on chair	[1]	[2]	[3]	[4]	[5]
c) Sitting on ground	[1]	[2]	[3]	[4]	[5]
d) Sleeping	[1]	[2]	[3]	[4]	[5]

Q6. What are the points of discomfort experienced by you while wearing denim trousers particularly in summers?

a) It does not absorb perspiration	[1]	[2]	[3]	[4]	[5]
b) It is suffocating	[1]	[2]	[3]	[4]	[5]
c) It hinders movement of legs	[1]	[2]	[3]	[4]	[5]

Q7. What improvements would you suggest to develop value added denim trousers?

a) Should absorb perspiration	[1]	[2]	[3]	[4]	[5]
b) Should feel cool to skin	[1]	[2]	[3]	[4]	[5]
c) Should be softer	[1]	[2]	[3]	[4]	[5]
d) Should be comfortable enough in all postures	[1]	[2]	[3]	[4]	[5]
e) Should be environmental friendly	[1]	[2]	[3]	[4]	[5]

Q8. What bottom wear do you prefer while travelling?

a) Denim trousers	[1]	[2]	[3]	[4]	[5]
b) Formal trousers	[1]	[2]	[3]	[4]	[5]
c) Capri	[1]	[2]	[3]	[4]	[5]
d) Salwar & suits	[1]	[2]	[3]	[4]	[5]
e) Bermudas	[1]	[2]	[3]	[4]	[5]

Q9. Which Color, do you like to wear mostly?

a) Blue	[1]	[2]	[3]	[4]	[5]

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b) Grey	[1]	[2]	[3]	[4]	[5]
c) Black	[1]	[2]	[3]	[4]	[5]
d) White	[1]	[2]	[3]	[4]	[5]

Q 10. On an average, how many hours a day , do you use value added products?

a) Below 8 hrs.	[1]	[2]	[3]	[4]	[5]
b) 8-10 hrs.	[1]	[2]	[3]	[4]	[5]
c)10- 12 hrs.	[1]	[2]	[3]	[4]	[5]
d) More than 12 hr.	[1]	[2]	[3]	[4]	[5]

Q11.Which type of products, listed below, do you like & how much?

a) Faded	[1]	[2]	[3]	[4]	[5]
b) Ornamentation with beads	[1]	[2]	[3]	[4]	[5]
c) Embroidered Denims	[1]	[2]	[3]	[4]	[5]
d) Printed Denims	[1]	[2]	[3]	[4]	[5]
e) Stone wash/Enzyme wash	[1]	[2]	[3]	[4]	[5]
f) Torn look	[1]	[2]	[3]	[4]	[5]

Q 12. What is the most important criteria followed by you while purchasing products?

a) Brand	[1]	[2]	[3]	[4]	[5]
b) Quality	[1]	[2]	[3]	[4]	[5]
c) Material Used	[1]	[2]	[3]	[4]	[5]
d) Color	[1]	[2]	[3]	[4]	[5]
e) Style	[1]	[2]	[3]	[4]	[5]
f) Comfort	[1]	[2]	[3]	[4]	[5]
g) Weight	[1]	[2]	[3]	[4]	[5]
h) Price	[1]	[2]	[3]	[4]	[5]

Q 13. How often do you purchase new products?

a) 1-2 times a year

b) 2-3 times in a year

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c) 3-4 times in a year

Q 14. How much would you usually spend per year on purchase of new products?

a) Rs Below2000

b) Rs 2000-4000

c) Rs 4000-7000

d) Rs 8000 or above

Q 15. Rate the quality & performance of products available in market?

a) Average

b) Satisfactory

c) Good

d) Excellent

Q16. Would you like to use products having inherent fragrance?

a) Yes b) No

Questionnaire-2

Target Respondents:- Males & Females of tropical regions

1. Name of Respondent:- ____________________

2. Gender:- ____________________

3. Age Group:-

a) 18 to 25 :-

b) 26 to 35 :-

c) 36 to 45:-

d) 46 to 55:-

e) 56 to 65:-

f) 66 or above:

4. Occupation:- ____________________

Q1. Did you find any visual difference between conventional products & value added products to you?

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a) If yes, please elaborate- ____

____

b) No

Q2. Did you find any difference in hand feel between conventional products & value added products to you?

a) If yes, please elaborate- ____

____

b) No

Q3. How did it feel to use the value added products, please elaborate-

____

____

Q4. How is the overall feel of the value added products on your skin?

____

____

Q5. Does it feel cooler than conventional products?

a)If yes, please elaborate your experience in short- ______________________

____

b) No

Q 6. Is the movement of legs comfortable for the value added products in comparison to your conventional products? Please elaborate comparative experience.

____

____

Q 7.Do you feel sweating in the value added products in hot climatic or it absorbs the sweat.

____

Q8. The new value added products have a suffocating feeling in hot climate or it is pleasant? Please share your experience.

____

____

Q 9.Is it a comfortable to sit & lie down using the value added products as compared to conventional products? Please share your experience.

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Q 10. Is there any experience of discomfort while using the value added products? Please Share your experience.

Q11. Please rate the new value added products & your conventional products on a scale from 1 to 5 for overall experience of the comfort.

a) [1]- Most Uncomfortable

b) [2]-Not very comfortable

c) [3]-Desirable

d) [4]-Satisfactory Comfort

e) [5]-Most Comfortable

Q12. Given that the new value added products has the same durability as the conventional products, how much extra would you like to pay to purchase value added products .

a)10%

b)15%

c)20%

d)30%

e) 40%

Q13. Any new styling do you prefer to use in value added products?

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TENTATIVE BUDGET FOR BAMBOO-VISCOSE FILAMENT PROJECT-2018

A. Recurring Budget:

S.N.	Items	1st Year (In Lakhs)	2nd year (In Lakhs)	3rd year (In Lakhs)	4th year (In Lakhs)	5th year (In Lakhs)	Total (In Lakhs)
1.	Manpower						
a.	Principal Investigator @Rs.20,000/-p.m.	3.00	3.00	3.00	3.00	3.00	15.00
b.	Co-PI @Rs.10,000/-pm- 2 persons	2.40	2.40	2.40	2.40	2.40	12.00
c.	PCs- 4 persons @Rs. 5,000/-p.m.	2.40	2.40	2.40	2.40	2.40	12.00
d.	PAs- 8 persons @Rs. 2,500/-p.m.	2.40	2.40	2.40	2.40	2.40	12.00
e.	PCAs- 3 persons @Rs. 2,000/-p.m.	0.72	0.72	0.72	0.72	0.72	3.60
2.	Consumables for product development.	1.00	1.00	2.00	2.00	2.00	8.00

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3.	Travel @Rs.50,000/- per year	0.50	0.50	0.50	0.50	0.50	2.50
4.	Contingencies @10%	1.20	1.20	1.20	1.20	1.20	6.00
5.	Overheads @15%	2.00	2.00	2.00	2.00	2.00	10.00
	Sub Total for 'A'	15.62	15.62	15.62	15.62	15.62	78.10
B. Capital Component (Non-Recurring)							
B.1	KES-F apparatus @Rs. 250 Lakhs				250.00		250.00
B.2	Digital printing m/c @Rs. 50 Lakhs			50.00			50.00
B.3	Knitting m/c @Rs. 30 Lakhs	30.00					30.00
B.4	Weaving m/c @Rs. 40 Lakhs	40.00					40.00
B.5	Braiding m/c @Rs. 10 Lakhs		10.00				10.00
B.6	Laptop @Rs 40,000/-		0.40				0.40
	Sub Total for 'B'	70.00	10.40	50.00	250.00		380.40
	Grand Total 'A' & 'B'	85.62	26.02	65.62	265.62	15.62	458.50

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Manpower requirement:

1. Dr. K.N.Chatterjee
2. Dr. Suman Bhattacharyya
3. Mr. Atanu Bhattacharyya
4. Mr. Kalyan Sarkar
5. Dr. Jamini Jhanji
6. Dr. Amal Chowdhury
7. Mr. Saumen Bhattacharyya
8. Dr. Ajit Pattnayak
9. Mr. Dipankar Das
10. Ms. Amit Madhu
11. Dr. Amandeep Kaur
12. Ms. Shelly Khanna
13. Mr. Ashish Bhardwaj
14. Ms. Ambika Madaan
15. Mr. Kirti Kumar
16. Mr. Ramniwas

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DESIGN AND DEVELOPMENT OF FACE COVERING SCARVES USING VISCOSE FILAMENT YARN FROM KESORAM INDUSTRIES LIMITED (KIL)

By:

DR A. K. PATRA,
HEAD, DEPARTMENT OF TEXTILE CHEMISTRY,
TIT&S, BHIWANI

Submitted to:

KESORAM INDUSTRIES LIMITED (KIL),
KOLKATA

Submitted by:

THE TECHNOLOGICAL INSTITUTE OF TEXTILE & SCIENCES,
BHIWANI

IQAC
COORDINATOR

Director,
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CHAPTER 1

INTRODUCTION & OBJECTIVES

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CHAPTER 1

INTRODUCTION AND OBJECTIVES

1.1 Introduction

Clothes play a very important role at every stage of life that's why they are also rightly termed as second skin of human being. It providing protection to our body from climatic fluctuations and also enhance the style and personality of the wearer.

Since 1920's, change in lifestyle and attitudes towards tanned skin have occurred. These changes have resulted in increased time spent outdoors and increased skin exposure to solar UV radiation.

Today's consumer is very much concerned and aware about the environment and comfort and gives priority to these two factors along with style and appearance. Many of the light weight garments used in summer do not provide enough protection for persons who spend all day in the sun.

As such the industries are also focusing on development of such garments which are attractive and stylish but also provide protection from harmful UV radiation to wear and are made from the materials which are non-toxic and have less effect on skin. Research into UV protective fabrics and fabric treatments continues as the incidence of skin cancer increases in many areas.

Exposure to small doses of UV radiation is beneficial for human beings since it contributes to bone development vitamin assimilation, etc. whereas over exposure increases the risk of permanent damage to skin that can produce premature aging of the skin (especially facial skin).

Penetration of UVR into the top layer of the skin leads to damage in the lower layer and produces premature ageing of skin and other effects including roughening, blotches, sagging, wrinkles, squamous cells and basal cell cancer. So it is important to develop a fabric that has UV blocking property to protect the facial skin with some covering to provide adequate protection against UV radiation.

Now a days, ladies use sunscreens or ordinary light weight cotton fabrics to cover their face, such fabrics only save them from dust and do not provide enough protection from the sun rays because cotton has UPF values generally in the range of 5-8, which is lesser as per required value (which is 15).

There is a dire need for development of a suitable fabric which can protect face from harmful exposure to UV rays besides saving the user from dust/ polluted air without causing difficulty in breathing.

The proposed project offers to provide a solution to the problems mentioned above by developing scarf (bandanna) made of viscose filament fabrics of Kesoram Industries Limited having UV-blocking property using Titanium dioxide Nano particles.

The innovations of novel material engineering over the years lead to commendable growth in textile industry, both in terms of productivity and quality. With the availability of wide range of fibres and textile manufacturing methods now days encourages the possibility of manufacturing fabric for customized requirements. Engineering a fabric for specific end use requires judicious combination of fibres, selection of appropriate yarn and fabric, constructional parameters together with suitable finish.

Nanoparticles are finding extremely broad application area in textiles. It opens incredible applications in materials, chemical processing, electronics, biology, medicine, transportation, energy management an d so on. The nanosize particles of Pd, Pt, Ag and Fe may be applied on textiles to impart antibacterial, conductive magnetic properties [1]. Silver has been used since long time for anti-bacterial and anti-fungal properties [1, 2]. Nanosize particles of TiO_2, ZnO, Al_2O_3 and MgO are a group of metal oxide that possesses photo catalytic ability, electrical conductivity, UV absorption and photo-oxidising capacity against chemical and biological species [1].

Carbon exists in various forms. Diamond offers very good abrasive properties, graphite provides good lubrication and electrical conduction properties and carbon fiber has extraordinary mechanical properties [4]. The two different and new forms of carbon are being recently paving major inroads in research; fullerenes (spherical closed cage carbon molecules including the basic molecule C_{60}) in 1985 and carbon nanotubes in 1991 [4-7]. Carbon nanotube (CNT) is basically hollow and seamless cylindrical tube made up of a web of carbon atoms of graphene [4]. Graphene refers to an atomic layer of graphite which has diameter less than 1nm (10^{-9}m) [4]. CNT exist in two forms namely single walled carbon nano tubes (SWCNT) and multi walled carbon nano tubes (MWCNT) [4]. Carbon black (CB) nano particles are extremely effective reinforcing material for composite fibres for improving their abrasion resistance and hence increase the durability of composite fibres [4]. CB nanoparticles can also result in high chemical resistance and electric conductivity after they are mixed with fibre polymer matrix of polyester, nylon and polypropylene as backbone. Carbon black nano particles impart abrasion resistance [1, 3], chemical resistance [1, 3], electric conductivity [1, 3, 4], soil-resistance [1], water-repellence [3], antibacterial [3], anti-static [1], anti-infrared [1, 4], electrical conductivity [1], colouration [1] and flame retardant properties [1] to some textiles.

In order to cope up with the diversity of modern generations, in terms of demand, versatility and increased flexibility, advanced techniques like Computer Aided Designing (CAD) have been developed. Process of the fashion design presentation includes designing of mood boards/inspiration boards, story boards, color boards, flat sketches etc. Fashion design presentation with the use of conventional techniques is quite unsystematic, tedious, time consuming and laborious too. The whole process of fashion design presentation is revolutionized by the introduction of CAD. Various programmes may be used for preparing various presentation boards like-

1. Corel Draw
2. Adobe Illustrator
3. Adobe Photoshop

In the present work, an attempt has been made to develop viscose filament fabrics made of Kesoram Industries Limited by incorporating multi walled carbon nano tubes (MWCNT) using conventional dyeing technique to enhance various properties like flammability, physical & wear and tear without compromising on fastness properties. In this research work, an attempt has also been made to design and develop face covering scarves using various fashion presentation tools such as mood boards, story boards and flat sketches developed with the help of CAD technique i.e. PHOTOSHOP.

1.2 Objectives

The objectives of the present research work are to develop flame and UV retardant viscose filament fabrics by application of multi walled carbon nanotubes, TNA nano particles so as to enhance various fabric properties like flammability, physical & wear and tear, as well as to design and develop face covering scarves using viscose filament yarns of Kesoram Industries Ltd.,. Hence various objectives can be summarised as under-

a) Synthesis and Characterization of MWCNT
b) To apply MWCNTs along with conventional dyeing of viscose filament fabrics
c) To study & optimise flame retardancy, UV properties of viscose filament fabrics
d) To study physical properties of modified fabric, their durability, fastness properties etc.
e) To design and develop face covering scarves made of viscose filament fabrics

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CHAPTER 2

NANO ENGINEERED TEXTILES: POSSIBLE FUNCTIONS, NANO PARTICLES (NPs) USED AND DEVELOPMENT METHODS

CHAPTER 2

NANO ENGINEERED TEXTILES- POSSIBLE FUNCTIONS, NPs USED AND DEVELOPMENT METHODS

Nanoparticles (NPs) can be applied to the textiles by various methods for value addition i.e. to enhance different functional properties which are explained below:

2.1 Conductive/ Antistatic Textiles

This functionality may be added to enhance conductivity of fibres. Synthetic fibres like polypropylene or polyethylene possess low electrical conductivity and act as insulators. To increase conductivity of these fibres, either some conductive polymers (e.g. polypyrrole, polyaniline, polythiophen etc.) can be added or carbon nanoparticles (CNTs and CB nanoparticles) can be included into their polymer matrix [8]. Polypyrrole can be applied by hand brushing, by dip or spray coating the finished textile with a nanoparticles emulsion [9] or by the solution or vapour polymerisation of the polypyrrole on the textile surface [10-12].

One more method of increasing conductivity was reported [13] in which, the addition of metal nanoparticles by the technique of copper-coating on the surface of polypropylene and polyamide fibers were carried. Same effect can be achieved by dispersing CB particles into a polymer solution and subsequent electrospinning [14] and by dip-coating hollow PP fibers with CNT containing polyaniline dispersion [15]. Increased conductivity in textiles can be achieved through dip and spray coating on the finished fabric with a dispersive CNT solution [16].

2.2 Reinforced textiles / Tear and wear resistant textiles

Nanotechnology was used to improve the mechanical properties of the textile fibers which include tensile strength, elasticity or fibre stiffness [17-19]. These properties are basically responsible for improving the tear and wear resistance of the textiles. CNTs have been found to increase significantly tensile strength of textile materials [17-18, 20-22]. It was reported that the production of CNT reinforced fibers by melt compounding CNT with polystyrene (PS) and polypropylene (PP) [17] or a masterbatch of CNT-PP can be produced [17]. Both of them follow melt spinning process. The production of reinforced polyvinyl-alcohol fibers by the co-flowing of CNT dispersion in their solution spinning process were also investigated [17]. In addition, modified solution spinning process to produce PVA-CNT composite with increased strength [20] can be achieved. Moreover, the application of CNT to fabric with the help of spray coating or simple dipping the fabric into CNT solution is also stated by Hecht et al [16].

Nanoparticles of ZnO can also be used to have increased stiffness of a fabric [22]. Application of coating by dipping the fabric into a nanodispersive ZnO solution and a subsequent dry-pad-cure process were carried out [23]. Similar process for coating of Al_2O_3 NPs on different textile materials is also reported to have increased fracture toughness [24].

Mahltig et al applied coating of SiO_2 NPs on polyester by making their dispersion to increase abrasion stability and this uses the sol-gel process [25].

2.3 Antibacterial textiles / Anti-odour textiles

According to research in a paper [25], biocidal textiles can basically be divided into three groups:

1. Textiles with photoactive properties
2. Textiles with non diffusible biocides
3. Textiles with controlled release of the embedded biocide

Textiles with photoactive properties can be produced by coating TiO_2 on fabric [26]. The absorption of light causes the valance electrons of TiO_2 to get excited into a higher energetic state which in turn produces charge carriers, an electron and a positively charged electron-hole. The positively charged holes hence produced can cause the oxidation of organic molecules while the produced electrons can react with oxygen and lead to the formation of hyperoxid radicals which also attack and oxidize the cell membranes of microorganisms [8]. This photocatalytic process can lead to the degradation of the stains. Thus TiO_2 can be used for self-cleaning textiles.

Textiles with non-diffusible biocides can be produced by immobilizing the biocides either into the textile-matrix itself or in the matrix of a coating [25]. The antibacterial effect is resulted by the interaction between positively charged biocide and the negatively charged cell membranes which damages the microorganism and inhibits their growth or reproduction.

Again, textiles with controlled release of embedded biocide can be produced by incorporation of coating where the biocides (e.g. triclosan, Ag^+, Cu^{2+}) diffuse out of the matrix [25]. In the case of metallic antibacterial agents, the nanoparticles in the matrix are oxidized by air. The formed cations, then diffuse out of the matrix and lead to the inhibition of bacterial growth. Ag and TiO_2 or their combination can be used to achieve a biocidal effect [8, 26]. The integration of ZnO NPs for achieving same desired effect is investigated by Vigneshwaran [27], while

Chitosan Core-Shell-NP was known to obtain an antibacterial coating for cotton fabrics [28]. It is possible to include different organic (e.g. Triclosan, chitosan) or inorganic biocides (Ag, Cu), into the matrix of a silica coating [25]. In most of the examined research papers, TiO_2 is applied to the textile material with the help of sol-gel processes [8].

In contrast to procedures in which NPs are applied as a coating in final stage, it is also possible to incorporate them at an earlier stage of the manufacturing process, for example through direct melt compounding of Ag and the textile polymer or the production of Ag /PP masterbatches and subsequent melt spinning [8].

2.4 "Self cleaning" textiles / textiles with antiadhesive properties

These can be produced basically by three different processes. First process is the integration of NPs that act as photocatalyst and are able to degrade organic dirt and stains [8]. Second process is the production of superhydrophobic surfaces which provide stain and grime repellency and are "self-cleaned" by the rolling water drops that collect dust and other debris [8, 29]. Third process is antiadhesive surfaces with repellent properties towards specific compounds or substances, as for example proteins, can be designed through nanoengineering [25].

1. Photocatalytic coatings

In the examined research papers, TiO_2 nanocoating on the fabric gives stain degrading properties. TiO_2 nanosol (dispersion) is applied to the fabric by dip-pad-dry-cure technique. The textile fabrics can comprise of cotton, wool-polyamide and polyester fibers [8, 26]. The absorption of light cause the valance electrons of TiO_2 to get lift into a higher energetic state which inturn produces excited charge carriers, an electron and a positively charged electron-hole. The positively charged holes hence produced can cause the oxidation of organic molecules while the produced electrons can react with oxygen and lead to the formation of superoxid and hyperoxid radicals [26] which also attack and oxidize the cell membranes of microorganisms [8]. This photocatalytic process can lead to the degradation of the stains hence TiO_2 can be used for self-cleaning textiles. As the formed radicals also attack the membranes of microorganisms, textiles which are coated with TiO_2 also show antibacterial effects.

2. Hydrophobic surfaces

Super hydrophobic textile surfaces can be produced through the integration of CNT, silica-NPs (Si-NPs) and fluoro containing polymer-NPs [29-31]. In all the three cases, coating of NPs was done on the textile fabric. The incorporation of hydrophobic properties by producing artificial lotus leaf structure on cotton fiber surface through application of CNT using dip-dry-cure method is reported [29]. Coating the emulsion containing fluoroacrylate copolymer NPs to nylon and polyester fabrics is possible [8]. The application of Si-NPs to cotton fabric by production of nanosol and then applying by dip-pad-dry-cure process is reported [8].

3. Surfaces with antiadhesive properties

Using sol-gel process, the production of antiadhesive wound dressing can be done by coating viscose fabrics with a modified SiO_2 coating [25].

2.5 Moisture absorbing textiles

By nanoengineering, the development of hydrophillic surfaces is also possible. TiO_2 can be integrated to the textiles for getting moisture absorbing properties which increases the water absorbance at the surface through photocatalytic process [25]. The phenomenon behind using TiO_2 is that when it is exposed to light, TiO_2 valance electrons are lifted to an excited state and give electron holes which oxidize lattice oxygen and leave vacancies that can be filled by absorbing water [25].

Layer by layer deposition method is also studied to obtain hydrophilic properties by the deposition of thin films of TiO_2 alternating with polydimethyldiallylammonium chloride (PDAC) on polyethylene fibers [8].

2.6 Improved colourability / enhanced bleaching resistance

In connection with the dyeing of textiles, NPs can be applied using following techniques-

1. Nanoparticulate pigments can directly be used as dyes. For example, surface modified carbon black nanoparticles on cotton, acrylic and nylon fibers [32].
2. Nanostructured coating has also been done on textile surfaces to make them hydrophilic and improve their colorability. To improve the colourability of textiles surfaces, a hydrophilic nano-thin coating can be prepared through plasma polymerization of C_2H_2mixed with ammonia. The hydrophilic coating, thus obtained with functional groups, can enable substrate independent dyeing. After coating the surface of polyester fabrics, the textile was dyed with acid dyestuffs. Without surface modification, this would be impossible due to the lack of amino groups on the polyester surface which are needed for the dye-fiber-reaction mechanism of this kind of group inherited by the dyestuffs [8].

3. Dyes are added into nano-thin coatings to improve bleaching resistance and bleaching stability. These properties can be achieved through the integration of dyes into an inorganic nanosol (silica or metal-oxid nanosols) which is then applied to the textile as a coating. The immobilization of the dye in the nanosol matrix significantly reduces the bleaching fastness. Particularly good results can be achieved by using mixed metal oxide nano-sols (e.g. aluminium or titanium oxides in a silica oxide sol) which are able to form complexes with anionic dyes. In terms of bleaching resistance, the nanosol-dye-coatings can be optimized by the addition of an organic UV-absorber to the nanosol [25].

2.7 UV-blocking textiles

These properties can be achieved with the integration of nanoparticulate ZnO finish to cotton fabrics by dip-pad-dry-cure method [23] whereas the use of soluble starch during the synthesis of ZnO NPs to inhibit their agglomeration which also result in enhanced UV-blocking [27].

The coating of nanoparticulate TiO_2 film by sol-gel process on cotton fabrics to produce fabrics with UV-blocking properties is reported in a paper [8].

2.8 Flame retardant textiles

Nanocomposites are reported to cause flame retarding effects [33]. The use of montmorillonite-nanoclay containing composites for achieving the same properties is investigated by researchers [34-37]. The use of boroxosiloxanes or Sb_2O_3 containing nano-composites to inhibit combustion process is possible [33].

The use of CNT incorporated into an ethylene-vinyl acetate (EVA) polymer-matrix can achieve enhanced flame retardence [38]. Recent researches [35, 39] report the use of nano-composites with low concentrations of conventional flame retardants to have optimized properties.

Two main methods are used for integration of nano-composites into textile fabrics one of which is the incorporation of nano-composites into textiles by melt spinning process and spun them into yarns which can subsequently be knitted or woven to textile fabrics [37]. The second possibility is to apply the produced polymer-nanoclay composite as a coating to finished textiles [36-37], as for example cotton or polyester fabrics.

2.9 Controlled release of active agents, drugs or fragrances

NPs can be used to produce fibers that act as carriers for drugs, fragrances or other active agents and thereby enable the controlled release of incorporated species. In addition, production of fibers with controlled release of different agents (e.g. drugs or insect repelling fragrances) can be done by their inclusion with SiO_2 nanosol coating [25].

2.10 Other application of nanoparticles

Nanoparticles show promising results for producing luminescent textiles and insulating textiles.

Table 2.1: Overview of functional textiles and the NPs or nanostructures used [8].

Functional textile	**NP/nanostructure**
Conductive/antistatic textile	-Carbon Black (CB) -Carbon Nano Tubes (CNT) -Cu -Polypyrrole and Polyaniline
Reinforced textiles/ tear and wear resistant textiles	-Al_2O_3 - Carbon Nano Tubes (CNT) -Polybutylacrylate -SiO_2 -ZnO
Antibacterial	-Ag -Chitosan -ZnO -SiO_2 -TiO_2
"Self-cleaning" textiles/ textiles with antiadhesive properties	- Carbon Nano Tubes (CNT) -Fluoroacrylate -SiO_2 and TiO_2
Moisture absorbing textiles	-TiO_2
Improved colourability/ enhanced bleaching resistance	-Carbon Black (CB) -Nanoporous hydrocarbon-nitrogen coating -SiO_2
UV-blocking textiles	-TiO_2 -ZnO
Flame retardant textiles	- Carbon Nano Tubes -Boroxosiloxane -Montmorillonite -Sb_3O_2
Controlled release of active agents/ drugs or fragrances	-Montmorillonite -SiO_2
Luminescent textiles	No information
Thermal conductive/ insulating textiles	No information

CHAPTER 3

LITERATURE REVIEW

CHAPTER 3

LITERATURE REVIEW

This chapter deals with the various works carried out by different researchers on the application of multi-walled carbon nanotubes in the textile field and the confirmation of presence of MWCNT in textile structure along with the evaluation of the parameters like flame retardancy, physical, wear and tear, fastness properties etc.

3.1 Introduction

Sumio Iijima, who was an electron microscopist working at the NEC laboratories in Japan, was influenced by the Krätschmer–Huffman Nature paper. Ten years earlier he had used sparingly similar arc-discharge apparatus and TEM (Transmission Electron Microscopy) to study soot formed to that used by Krätschmer and Huffman [40, 41]. He found that the formed soot contained a variety of novel carbon architectures that include tightly curved, closed nanoparticles and extended hollow needles. Initial high-resolution TEM studies by Iijima were really disappointing i.e. the soot collected from the walls of the arc-evaporation vessel appeared almost completely amorphous, with little obvious long-range structure. Eventually, Iijima gave up through the wall soot, and turned his attention to the hard, cylindrical deposit that formed on the graphite cathode after arc-evaporation. And finally here his efforts were rewarded. Instead of an amorphous mass, the cathodic soot contained a whole range of novel graphitic structures, the most striking point of which long hollow fibres, finer and more perfect than any were previously seen. Iijima founded beautiful images of carbon nanotubes which were shown first at a meeting at Richmond, Virginia in October 1991, and published a month later in Nature [42], prompted fullerene scientists the world over to look again at the used graphite cathodes, previously founded were discarded as the junk only.

Carbon which is found as one of the most abundant element on earth has uncommon properties owing to its sp^n – hybridized bonds which led to the many carbon allotropes, which ranges from zero to three dimensions on the nanoscale [43]. These allotropes of carbon (as shown in the Fig. 3.1), the zero- dimensional (0D) are known as carbon buckyballs, one-dimensional (1D) are known as carbon nanotubes, two-dimensional (2D) are known as graphene and three-dimensional (3D) are known as diamond which makes it a highly investigated material for a wide range of nanotechnology applications.

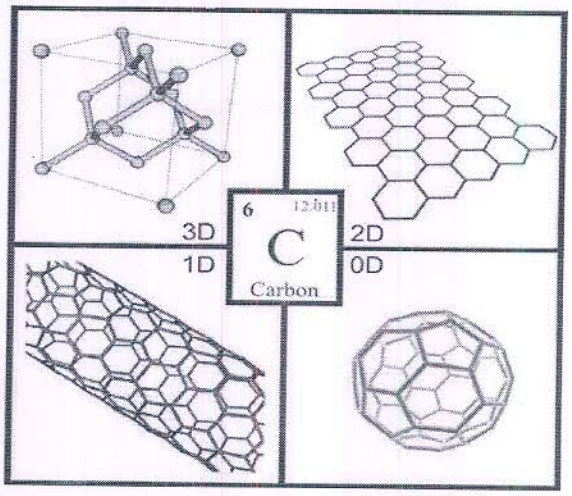

Fig. 3.1: Schematic diagram showing different allotropes of carbon: the zero- dimensional (0D) carbon buckyballs (fullerenes), one-dimensional (1D) carbon nano tubes, two-dimensional (2D) graphene and three-dimensional (3D) diamond [43]

On the nanoscale, materials behave differently from their bulk counterparts and it is attributable to the effects of quantum confinement. Table 3.1 shows the effects of dimensionality on the unique properties of different allotropes of carbon. From the perspective of material science, these materials possess different chemical, physical and electronic properties that have attracted the scientists worldwide to investigate applications of allotropes of carbon in advanced technological devices. In the allotropes of carbon, carbon nano tubes (CNTs) have led the charge since their discovery in 1991 by Iijima [42].

Table 3.1: Electronic properties of carbon-based materials [43]

	Electron Mobility ($cm^2 V^{-1} s^{-1}$)	**Bandgap (eV)**	**Thermal Conductivity ($W cm^{-1} K^{-1}$)**
Diamond	2200	5.45	22
Carbon Nanotubes	$1 x10^5$	(0 to 1)	30
Graphene	$1 x 10^4$ to $2 x 10^5$	(0 to 0.5)	40

Two different and new forms of carbon are being recently paving major inroads in research; fullerenes (spherical closed-cage carbon molecules including the basic molecule C60) in 1985 and carbon nano tubes in 1991 [9, 44-46].

Carbon nanotube is basically defined as hollow and seamless cylindrical tube made up of a web of carbon atoms of graphene [44]. Graphene refers to an atomic layer of graphite which have diameter less than 1nm. Different forms of the carbon are shown in Fig. 3.2.

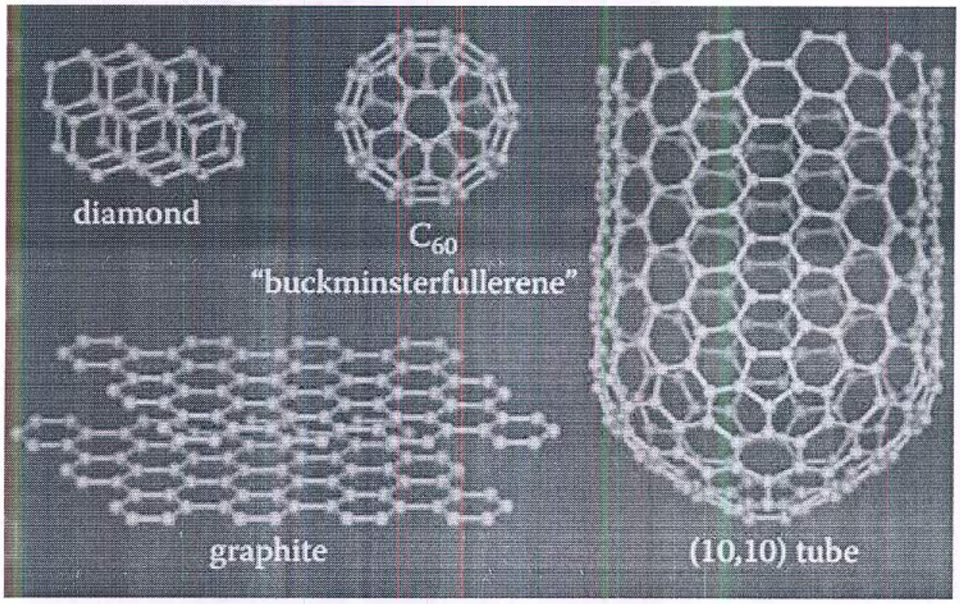

Fig. 3.2 Schematic diagram showing diamond, graphite sheet, C_{60} and carbon nano tubes [46]

Therefore, Carbon nanotubes (CNTs) are called as allotrope of carbon which has cylindrical nanostructure. Nanotubes are basically the member of the fullerene structure family. Carbon nanotubes derived their name from their long and hollow structure and their walls are formed by sheets of carbon which are called as graphene. Graphene sheets are rolled at specific and discrete angles which are called as chiral angles and the combination of the rolling/chiral angle along with the radius decides the nanotube properties. For example, whether the particular nanotube shell is a metal or semiconductor.

There are different types of carbon nanotubes (CNTs) found in the scientific research; single-walled (SW), doubled-walled (DW) and multi-walled (MW) as shown in Fig. 3.3. MWCNT have one layer of atoms sitting neatly inside another forming a multilayered structure [44].

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Director,
THE TECHNOLOGICAL INSTITUTE
OF TEXTILE & SCIENCES, BHIWANI

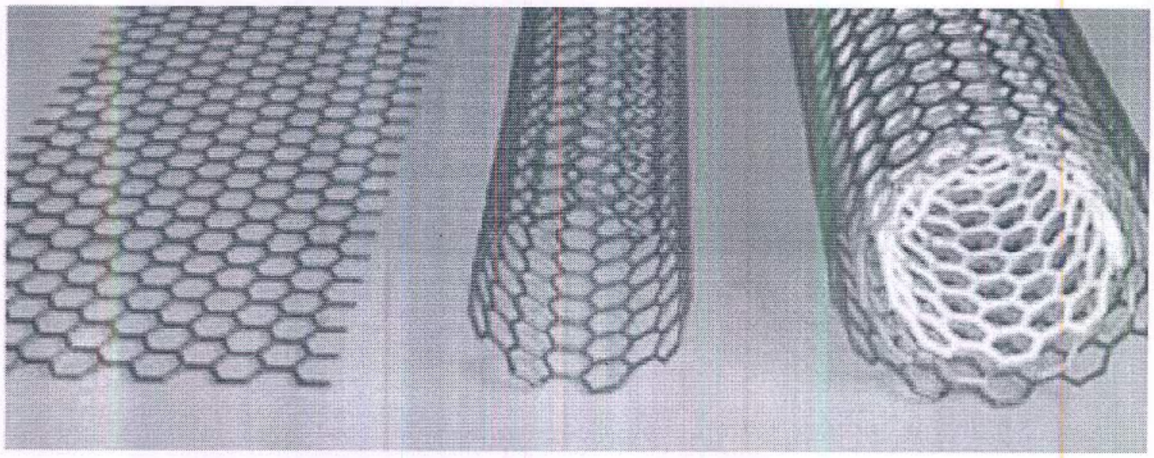


Fig. 3.3: Formation of single and multi-walled carbon nanotubes from graphene. The graphene sheet on the left is rolled to form a single walled nanotube (middle) and multi-walled carbon nanotube (right) [46]

Carbon nanotubes excite most fundamental scientists and engineers interested in applications which are all due to the unique combination of their properties.

3.2 Structure of CNT

Carbon nanotubes provide an important system for studying one-dimensional physics, theoretically and experimentally and it is all due to two parameters [47]. First of which is their small diameter which is approx to ~10 Å and second parameter is their large length to diameter i.e. aspect ratio>10^3. To understand the structure of CNTs, a sheet of 2D graphene rolled to form a 1D SWCNT is investigated and mathematically the alternate forms of chirality are identified as the traditional view of a tube is a rolled up sheet of graphene.

3.3 Single walled carbon nanotubes (SWCNT)

A SWCNT is basically a rolled graphene sheet. The way in which the graphene sheet is rolled determines the fundamental properties of the tube [46].

Most of the SWCNT typically have a diameter of close to 1 nm. However, the tube length can be many thousands times longer. As SWCNT are more pliable yet harder to make than MWCNT, they can be twisted, flattened and bent into small circles or around sharp bends without breaking. SWCNT has unique electronic and mechanical properties which can be used in numerous applications, including:

1. Electronics (wires, transistors, switches, interconnects, memory storage devices)
2. Opto-electronics (light-emitting diodes, lasers)

3. Sensors
4. Field emission devices (displays, scanning and electron probes/microscopes)
5. Batteries/fuel cells
6. Fibers, reinforced composites
7. Medicine/biology (fluorescent markers for cancer treatment, biological labels, drug delivery carriers)
8. Gas storage.

3.4 Multiwalled carbon nano tubes (MWCNT)

Multiwalled carbon nanotubes (MWNT) consist of a concentric arrangement of single walled nanotubes with the identical interlayer distance of ~0.34 Å [50, 51]. They were discovered first by Iijima [42] in 1991 via the arc discharge method. There are examples with just two nanotubes fit one into another (so called double walled nanotubes, DWNTs) as well as species with many shells (more than 50). Common MWNTs possess a smaller number of concentric tubes. The nomenclature of MWNT indicates the intercalation of the inner tubes by the notation (n1,m1)@ (n2,m2)@ (n3,m3)@ … ,starting from the central tube. Usually one cylindrical void is found in the core of these tubes which can have diameter ranging anything from 1 nm to several nanometers. The smallest void is determined by the size of the innermost single walled carbon nanotube.

In principle, the same rules apply to the atomic construction of multiwalled nanotubes like they do to single walled species [50]. Additional aspects are, however, which tubes are suitable to a concentric arrangement and what kinds of interaction exist between the components of a multiwalled carbon nanotube (MWNT).

Kinds of interaction existing between the single tubes of an MWNT are different for terminal and central regions [47]. In the middle, far away from the ends of a multiwalled nanotube, the individuals take a constant distance of 0.34 nm while there is no direct covalent or ionic bonding between them. The interaction is thus limited to vander waals exchange and to the zones where the packing enables $\pi-\pi$ interaction. The latter are usually rather small hence the overall interaction between two concentric nanotubes should be weak.

Multiwalled nanotubes (MWNT) consist of multiple rolled layers (concentric tubes) of graphene [52]. There are two models that can be used to describe the structures of multi-walled nanotubes. In the Russian Doll model, sheets of graphite are arranged in concentric cylinders e.g. (0, 8) single-walled nanotube (SWNT) within a larger (0, 17) single-walled nanotube. In the

Parchment model, a single sheet of graphite is rolled in around itself, resembling a scroll of parchment or a rolled newspaper. The interlayer distance in multiwalled nanotubes is close to the distance between graphene layers in graphite, approximately 3.4 Å.

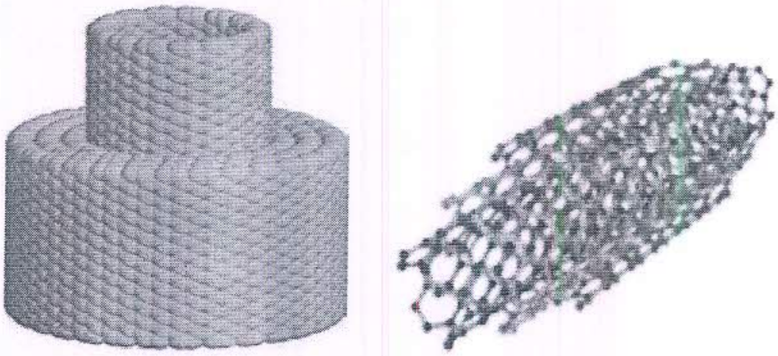


Fig. 3.9: Schematic Diagram of Multi walled carbon nanotubes [46, 52]

The diameters of MWCNT are typically in the range of 5nm to 50 nm. The interlayer distance in MWCNT is close to the distance between graphene layers in the graphite.

MWCNT are easier to produce in high volume quantities than SWCNT. However the structure of MWCNT is less well understood because of its greater complexity and variety. Regions of structural imperfection may diminish its desirable material properties.

The challenge in producing SWCNT on a large scale as compared to MWCNT is reflected in the prices of SWCNT which currently remain higher than MWCNT.

SWCNT, however, have a performance of upto ten times better and are outstanding for very specific applications.

Forms of Multiwalled carbon nanotubes

Mutiwalled nanotubes are even more complex array of forms, because each concentric singlewalled nanotube can have different structures and hence there are a variety of sequential arrangements [53]. The simplest sequence is when concentric layers are identical but not different in diameter. However, mixed variants are possible, consisting of two or more types of concentric CNTs arranged in different orders. These can have either regular layering or random layering.

3.5 Synthesis techniques of carbon nano tubes

Conventionally, CNTs are synthesized by several techniques [46] like-

1. Arc discharge method
2. Laser ablation
3. Chemical vapour deposition(CVD)

The various techniques which can be utilized to synthesize MWCNT are shown in Table 3.2.

Table 3.2: Synthesis of carbon nanotubes by various techniques [46]

Method	**Conditions**	**Temperature(Celcius)**	**Catalyst**	**Comments**
Arc discharge	50-500 Torr CH_4/Ar or He	>2500	Fe or Co in carbon	First confirmed SWCNT production
Laser ablation	500 Torr Ar	Furnace @ 1200(Target at >2500)	Ni/Co in Carbon	First laser ablation, high yield
CVD	CO @ 1.1atm	1200	Mo, Co/Ni	First SWCNT CVD growth
CVD	CH_4 @ 1.25 - atm in let	1000	Fe/Al_2O_3	First patterned-substrate growth
CVD	CH_4 @ 1.25 - atm in let	900-1000	$Fe/Mo/ Al_2O_3$	First large scale bulk CVD synthesis of SWCNT
CVD (HiPco)	CO @ 10 atm	1200	$Fe(CO)_5$vapor	Demonstration of HiPco SWCNTs (later P- 30- 50 atm)
Flame	N_2/Ar/air + C_2H_2 or C_2H_4	900-1400 in flame	Metallocene	First flame synthesis of SWCNTs
CVD	CO @ 1 atm	700	Co/Mo/silica	Demonstration of CoMoCAT : diameter control in bulk catalyst
CVD	CH_4 @ 1 atm	900	Fe/Ferritin	Diameter- selective substrate synthesis from predefined nanoparticles
CVD	$CH_4 + H_2$ @ 1 atm	900	Fe/Mo/silica	First aligned SWCNT grow the E-field alignment (substrate aligned in 2002)
CVD	C_2H_5OH or CH_3OH @ 5-10 Torr	550-900	Fe/Co (Co/Mo)	First growth from alcohol; low temperature; first proposition of amorphous carbon etchant (OH)

				during growth
CVD	$CH_4 + H_2 + C_2H_4$ @ 1 atm	900	Fe/Ferritin	First ultralong SWCNTs (>400μm)
CVD	$CO + + H_2$ @ 1 atm	900	Fe/Mo	Aligned SWCNTs from gas flow utilizing fast heating and tip growth (>1mm)
PECVD	$CH_4 + H_2$ @ 500 mT	550-850	Fe/Co/ zeolite	First PECVD of SWCNTs
Remote PECVD	CH_4 + Ar in plasma @ 500 mT	550-750	Fe	Preferntial low T growth of semiconducting SWCNTs in PECVD
CVD	C_2H_5OH in Ar/H_2	800	Co/Mo	First vertical SWCNT films (<15μm tall)
CVD	$C_2H_4 + Ar + H_2O$ @ 1 atm	750	Fe, Co/Mo, Fe/Mo	2.5 mm vertical SWCNT growth; ultrahigh yield; controlled use of H_2O as amorphous carbon etchant

3.6 Properties of CNT

Carbon nanotubes show a unique combination of stiffness, strength, and tenacity compared to other fiber materials which usually lack one or more of these properties. Thermal and electrical conductivity of carbon nanotubes are also very high when compared to other conductive materials.

3.6.1 Physical properties of MWCNT

3.6.1.1 Solubility and debundling of carbon nanotubes

Solubility of carbon nanotubes is an essential prerequisite for understanding their properties in relation to application engineering. Yet the size and structure of the nanotubes are a severe impediment to solubilization both in aqueous and organic medium [50].

Firstly, they are very big objects, which have their length ranging in the micrometer scale. Consequently any actual dissolution should better be considered a colloidal system or dispersion. Secondly, Individual nanotubes when approach one another may establish π– π-interactions and these are very pronounced as the π- electrons are easily polarized in the bent graphene layers. The exchange can take place over the whole length of the tubes. Hence the single and small energetic contributions may sum up to become a large factor which results in bundle formation.

Pure carbon nanotubes cannot be dissolved in any of the common organic or inorganic solvents. The only way to prepare fairly stable suspensions is the application of ultrasound. This method may also cause a first partial debundling [50]. Solvents with amide or amino functions, like DMF or N- methyl - 2 - pyrrolidone (NMP) proved their worth for the dispersion with ultrasound. Because the free electron pairs of the nitrogen can interact with the π- system of the tubes and in turn, enables at least partial dissolution of the bundles, which increases dispersibility. A true solution is, however, not achieved because of the reason that slow sedimentation starts after ending the ultrasound treatment. Still this simple procedure is sufficient for many investigations.

The action principle of ultrasound is based on the supply with mechanical energy. The reactive positions of the tubes, that is, their defects, are attacked first. As a result of which, shortening of the tubes occurs to some extent and the bundles get partially separated. Moreover, the amorphous carbon present in the sample is dissolved by the ultrasound treatment as amorphous carbon is less stable due to its smaller particle size and its uneven, partially unsaturated edges. Hence, it is destroyed and dispersed faster than the carbon nanotubes themselves [50].

Similar observations are found for the reaction with oxidizing substances i.e. less stable unordered material is attacked first. The solubility in aqueous media may be further increased by linking additional polar chains to the primary functional groups, especially to – COOH [50]. Suitable reagents for this may be ethylene glycols of various chain lengths or alkyl chains with terminal carboxyl groups but also peptides and proteins that can enhance solubility.

3.6.2 Mechanical properties of carbon nanotubes

3.6.2.1 Modulus of elasticity

Measurements of the Young modulus (modulus of elasticity) of single walled carbon nanotubes yields variable values between 0.4 and 4.15 Tpa. The modulus of elasticity for multiwalled carbon nanotubes range about 1.0-1.3 TPa, which is even slightly above those for single walled tubes [50].

Table 3.3: Comparison of properties of carbon based materials

Material	Specific Density	E (TPa)	Strength (GPa)	Strain at Break (%)
Carbon fiber- PAN	1.7 – 2	0.2 - 0.6	1.7 - 5	0.3 - 2.4
Carbon fiber- Pitch	2 - 2.2	0.4 - 0.96	2.2 - 3.3	0.27 - 0.6

3.6.2.2 Strength

Strength in nanotubes originates from the strongest SWNT within the respective MWNT and from a small additional contribution of the vander waals interaction between the individual tubes [50]. However, this is valid only for measurements on single MWNTs which are clamped on both ends.

3.6.2.3 Bending rigidity

Multiwalled nanotubes are normally more rigid than SWNT but strength decreases with growing diameters [50]. The mechanism of deformation under excessive strain changes with increasing load. For larger MWNT, the unordered bending at the site of highest strain turns into a system of wave-shaped defects on the concave side of the curve.

Table 3.4: Mechanical properties of nanotubes [49]

	Young's modulus (GPa)	Tensile Strength (GPa)	Density (g/cm^3)
MWNT	1200	~150	2.6
SWNT	1054	75	1.3
SWNT bundle	563	~150	1.3
Graphite (in-plane)	350	2.5	2.6
Steel	208	0.4	7.8

3.6.3 Electronic properties

Table 3.5: Electronic properties of carbon based materials- thermal and electrical conductivity

Material	Thermal Conductivity (W/m.k)	Electrical Conductivity
Carbon nanotubes	> 3000	106-107
Carbon fiber-Pitch	1000	2 - 8.5 x 106

Carbon fiber-PAN	8 – 105	6.5 - 14 x 106

Carbon nanotubes are proved to be best reinforcement material due to its high aspect ratio and very high surface area [54].

3.6.4 Confirmation and Characterisation of MWCNT in textile structure

3.6.4.1 Raman spectroscopy of carbon nanotubes

When light is scattered from a molecule or crystal, most of the photons are elastically scattered. The scattered photons have the same energy (frequency) and, therefore, wavelength, as the incident photons. However, a small fraction of light (approximately 1 in 10^7 photons) is scattered at optical frequencies different from, and usually lower than, the frequency of the incident photons. The process leading to this ***inelastic scatter*** is termed the ***Raman Effect***. If the scattering is elastic, the process is called ***Rayleigh scattering***. If it is not elastic, the process is called Raman scattering [55]. The Raman Effect arises when a photon is incident on a molecule and interacts with the electric dipole of the molecule. In quantum mechanics the scattering is described as an excitation to a virtual state lower in energy than a real electronic transition with nearly coincident deexcitation and a change in vibrational energy. The scattering event occurs in 10^{-14} seconds or less.

Numerically, the Raman shift in wave numbers (cm^{-1}), is calculated through Eq.

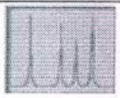
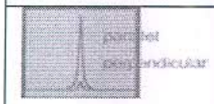
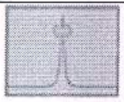
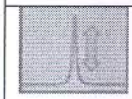
$$\bar{v} = \frac{1}{\lambda_{incident}} - \frac{1}{\lambda_{scattered}}$$

in which the λ's are the wavelengths (in cm) of the incident and Raman scattered photons respectively.

Typically, a spectrum represents intensities depending on energy. The energy scale is expressed in frequencies, wavelengths and electron volt. In vibrational spectroscopy, the energy scale is preferably expressed in wavenumbers. One advantage of the wavenumbers is that they are directly proportional to energy.

Table 3.6: Typical frequency curves explanation and their significance in Raman spectra [56]

Characteristic curve	Explanation	Significance

	Characteristic Raman frequencies	Tells about composition of material e.g. MoS_2, MoO_3
	Changes in frequency of Raman peak	Stress/Strain state e.g. Si 10 cm^{-1} shift per % strain
	Polarization of Raman peak	Crystal symmetry and orientation e.g. orientation of CVD diamond grains
	Width of Raman peak	Quality of crystal e.g. amount of plastic deformation
	Intensity of Raman peak	Amount of material e.g. thickness of transparent coating

Raman probe can prove the existence or nonexistence of carbon nanotubes in a sample. In organic molecules, particularly, certain frequencies can be associated with typical types of molecular excitations. Some examples are given in Table 3.7.

Table 3.7: Typical features in Raman spectra and their origin [55]

Frequency Range (in cm^{-1})	**Band Assignment**	**Remarks**
2700-3100	C-H alkyl free vibrations	Medium intensity in raman
2230	$C\equiv N$ stretch	Very strong band in Raman, found in most cyanide based compounds
2190-2300	$C\equiv C$ (triple bond stretch)	Very strong in raman
2100-2140	$C\equiv C$ (triple bond stretch)	Very strong in raman
1650-1750	$C\equiv O$ stretch	Ketones appear on the lower wavelength side, aldehydes appear on the higher side
1600-1675	$C\equiv C$ stretch	Very strong in raman
1580-1620	$C\equiv C$ stretch	Very strong in raman
990-1010	Aromatic ring breathing	Appears at 992 cm^{-1} for benzene, around 1004 cm^{-1} for toluene
650-850	C-Cl stretch	Strong in Raman

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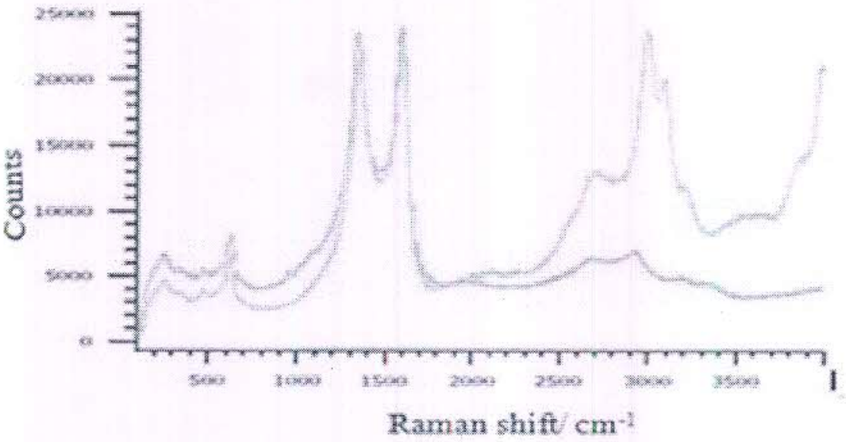


Fig. 3.10: Raman spectra of MWCNT [56]

3.6.4.2 FTIR (Fourier Transform Infra Red Spectroscopy)

In infrared spectroscopy, IR radiation is passed through a sample. Some of the infrared radiation is absorbed by the sample and some of it is passed through (transmitted). The resulting spectrum represents the molecular absorption and transmission hence creates a molecular fingerprint of the sample. This makes infrared spectroscopy useful for several types of analysis [57]. FTIR helps to identify unknown materials, determine the quality or consistency of a sample and determine the amount of components in a mixture.

FTIR, just like Raman spectroscopy, identifies molecular vibrations. However, FTIR used adsorption phenomenon.

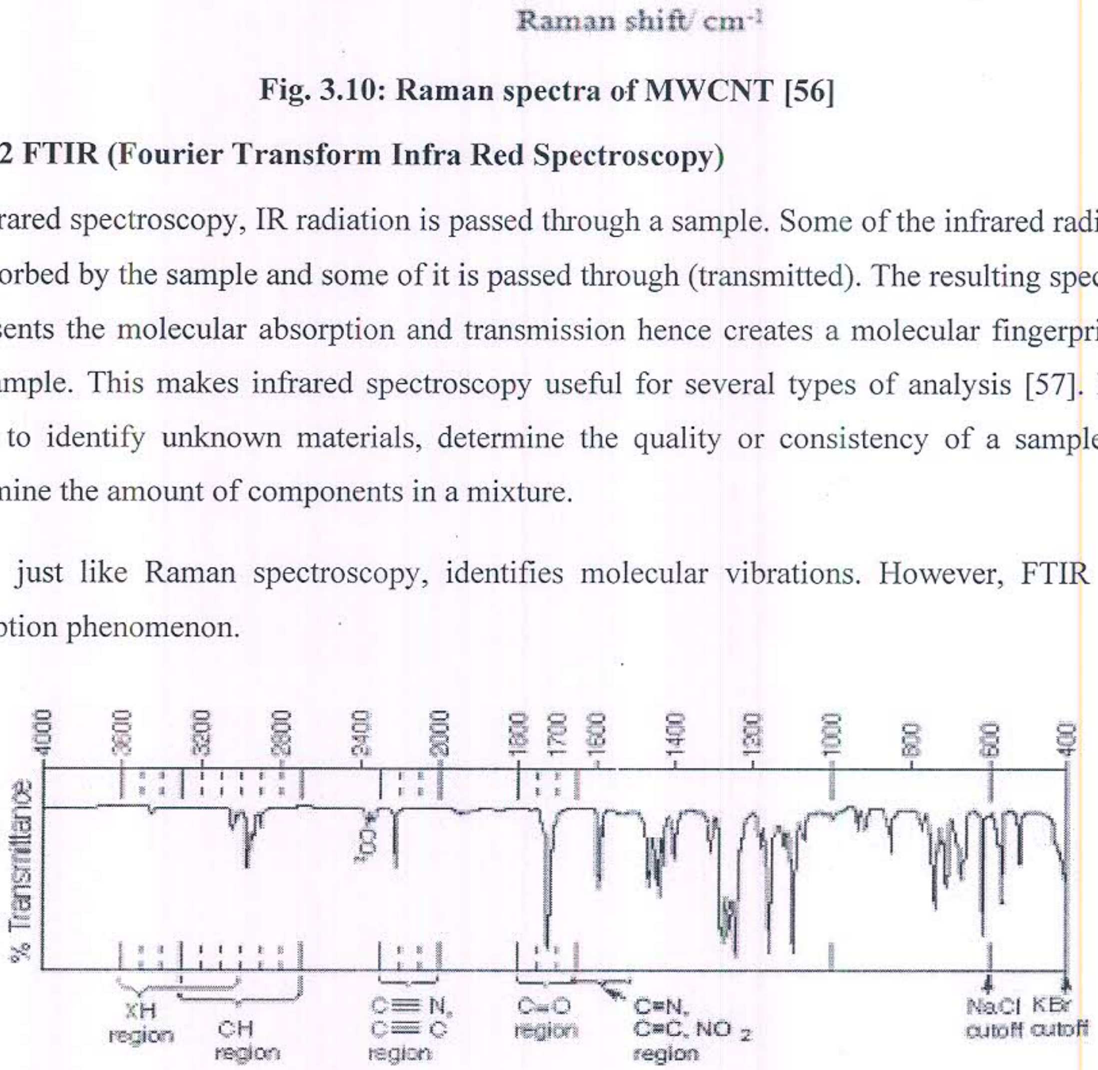


Fig. 3.11: Showing characteristics bends in FTIR plot [58]

3.6.4.3 X-ray diffraction

About 95% of all solid materials can be described as crystalline. When X-rays interact with a crystalline substance (Phase), one gets a diffraction pattern. A.W. Hull pointed out that "every crystalline substance gives a pattern; the same substance always gives the same pattern; and in a mixture of substances each produces its pattern independently of the others" [59].

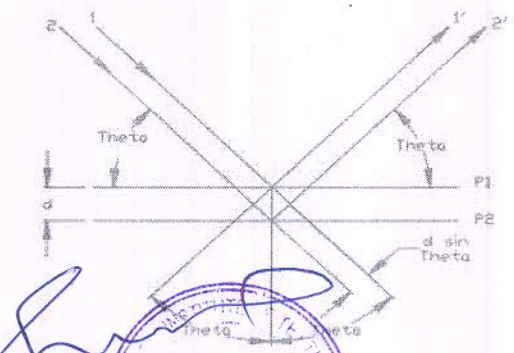
The X-ray diffraction pattern of a pure substance is like a fingerprint of the substance. Solid matter can be described as consisting of two components:

- Amorphous: The atoms are arranged in a random way similar to the disorder in a liquid. Glasses are amorphous materials.
- Crystalline: The atoms are arranged in a regular pattern.

When an X-ray beam hits an atom, the electrons around the atom start to oscillate with the same frequency as the incoming beam. In the case if the atoms in a crystal are not arranged in a regular pattern then in almost all directions it will give destructive interference, that is, the combining waves are out of phase and there is no resultant energy leaving the solid sample. However, if the atoms in a crystal are arranged in a regular pattern, and it will give constructive interference in few directions. The waves will be in phase and there will be well defined X-ray beams leaving the sample at various directions. Hence, a diffracted beam may be described as a beam composed of a large number of scattered rays mutually reinforcing one another [59].

Hence crystalline parts give sharp narrow diffraction peaks and the amorphous component gives a very broad peak (halo). The ratio between these intensities can be used to calculate the amount of crystallinity in the material.

Let us consider an X-ray beam incident on a pair of parallel planes P1 and P2, separated by an interplanar spacing d.



The two parallel incident rays 1 and 2 make an angle (Theta) with these planes. A reflected beam of maximum intensity will result if the waves represented by 1' and 2' are in phase. The difference in path length between 1 to 1' and 2 to 2' must then be an integral number of wavelengths (Lambda). We can express this relationship mathematically in Bragg's law.

$$2d*\sin T = n*\lambda$$

The process of reflection is described here in terms of incident and reflected (or diffracted) rays, each making an angle theta with a fixed crystal plane. Reflections occurs from planes set at angle theta with respect to the incident beam and generates a reflected beam at an angle 2-theta from the incident beam [59].

3.6.4.4 Spectrophotometer

The spectrophotometer is designed to measure the amount of light absorbed by a solution. Hence spectrophotometer can be used for determining a molecule's absorption spectrum (the wavelengths of light that a particular molecule absorbs). A more concentrated solution absorbs more light that a less concentrated solution [60].

A spectrophotometer works by passing the light from a lamp through a 'monochromator' (a prism or diffraction grating) that breaks it up into individual lengths. An adjustable slit is then used to allow only light of single wavelength to reach the sample, which is placed in the light path in a transparent cuvette. On the other side of cuvette is a photoelectric tube which measures the amount of light that got through the sample [60].

Spectrophotometer measures amount of light transmitted but not the amount of light which is absorbed. The percentage transmitted can be converted to absorbance using the formula given below-

$$\text{Absorbance} = \log(1/\%\text{transmittance})$$

A spectrophotometer can measure intensity as a function of the light source wavelength. Important features of spectrophotometers are spectral bandwidth and linear range of absorption or reflectance measurement. A spectrophotometer is commonly used for the measurement of transmittance or reflectance of solutions, transparent or opaque solids, such as polished glass, or gases.

3.6.5 Chemical properties

3.6.5.1 Reactivity of carbon nano tubes

There are three clearly distinct sites for reactivity of carbon nano tubes which are available for chemical reaction: the most reactive tips, the outer side wall and the cylindrical inner surface of the tube. In addition to this, there is a considerable reactivity offered by the defect sites present in carbon nanotubes [50].

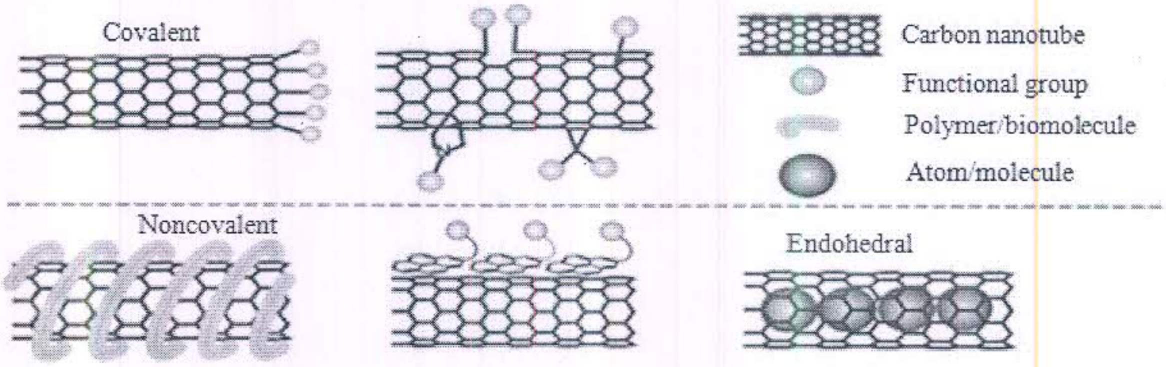


Fig. 3.12: Possible ways of carbon nanotubes functionalisation [50]

Contrary to the ideal nanotubes, nanotubes produced by any of the method possess some defective sites which must be considered while discussing about the reactivity of nanotubes. The reactivity of nanotubes markedly increases at these defective sites [50]. Different defects can be-

1. The defects may be holes in the side wall bearing sp^3- hybridized carbon atoms around their rim.
2. Stone wales defects that is resulted by rearrangement of two six-membered rings into a structure with annealed five- and seven- membered rings. Two of these defects in direct contact give rise to the 7 - 5 - 5 - 7 arrangement as shown in Fig. 3.13. Obviously the tube exhibits an increased curvature at this site and therefore the carbon atoms situated around produce such a defect that is more easily attacked by potential bonding partners.

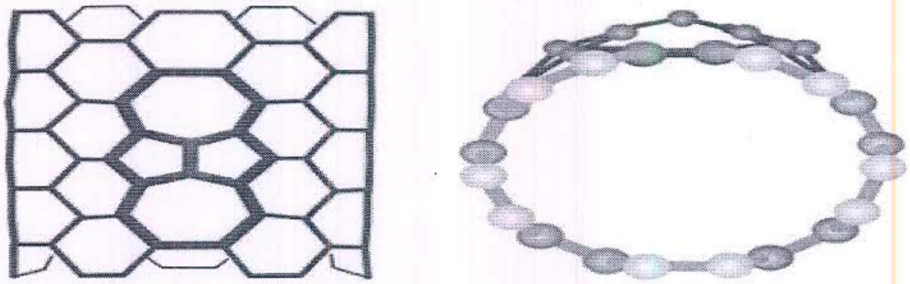


Fig. 3.13: The 7 - 5 - 5 - 7defect as site of increased reactivity [50]

Altogether, stone wales defect means a disturbance to the electronic and geometric structure and thus increase the susceptibility of chemical attack on nanotube side walls.

The reactivity of both types (SWCNT and MWCNT) differs mostly due to the curvature of the outermost wall which is normally less pronounced in MWNT.

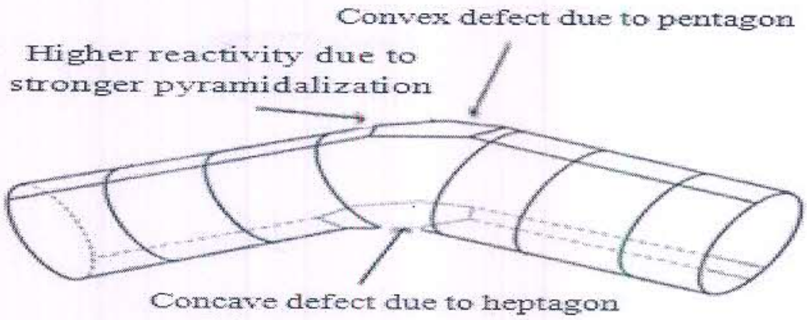


Fig. 3.14: Scheme shows a kink defect

Furthermore, there are interactions between neighbouring walls within a multiwalled tube that cause an additional stabilization.

3.6.5.2 Redox chemistry of carbon nanotubes

Carbon nanotubes can act both as electron donor or acceptor. Still oxidizing reactions mainly take place at tube's ends and at defects. On the other hand, the direct oxidation of carbon atoms in an intact side wall rarely ever occurs. It would require much harsher reaction conditions that normally cause the nanotube structure to break up, resulting in smaller fragments with functional groups containing oxygen on their rims.

The reaction with concentrated oxidizing mineral acids like nitric or sulfuric acid introduces carboxyl groups to the ends of the tubes and to defects of the side wall. Yet this reaction is not too selective and a variety of further oxidized structures is formed besides the carboxyl functions. They include keto and hydroxmethyl groups, anhydrides, and sulfonic acids. Nitration can also occur at the six-membered rings of the nanotubes.

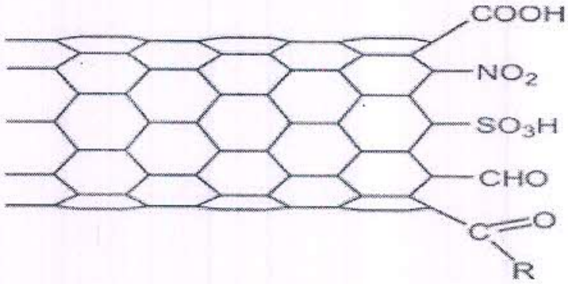


Fig. 3.15: Functional groups potentially present after an acid treatment of carbon nanotubes

Carbon nanotubes can also react with other oxidants besides nitric or sulfuric acid. These may be hydrogen peroxide, chromosulfuric or perchloric acid, $KMnO_4$, K_2IrCl_6, nitrating acid and molecular oxygen, or air at elevated temperatures [50]. Oxygen dissolved in water can also serve as oxidant.

The oxidation of nanotubes can be reversed by the reaction with reductants like $NaBH_4$ or $Na_2S_2O_4$ [50]. The reactivity of some oxidizing agents, for example, sulfuric acid, can even be enhanced by simultaneous ultrasonication [50]. This technique reduces the reaction times required and facilitates the cutting of the tubes.

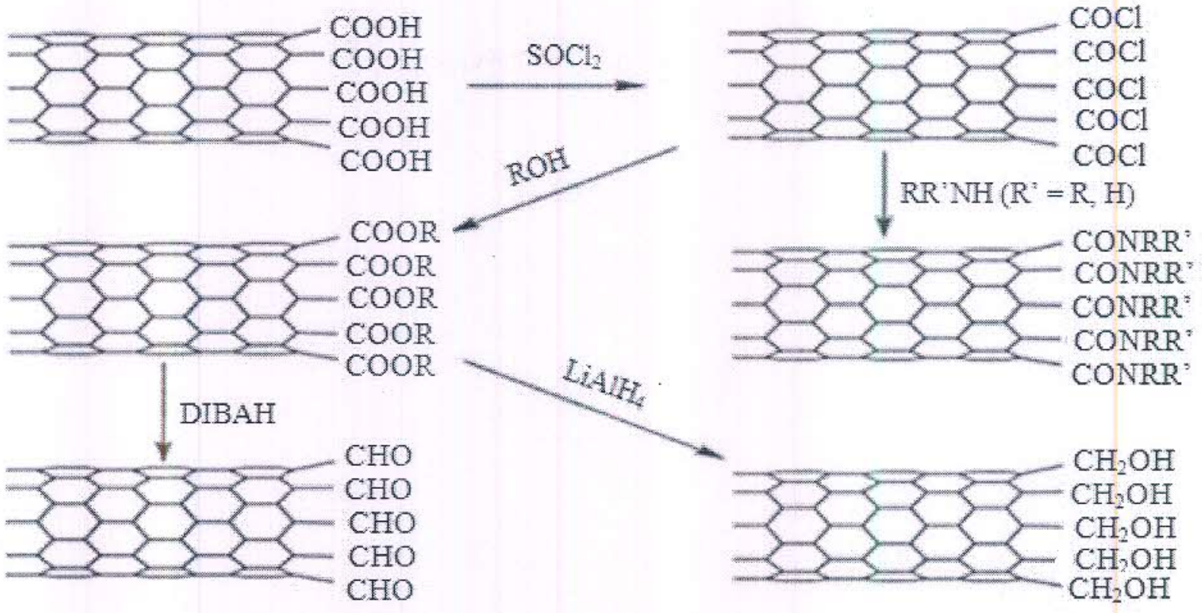
Some of these reactions are conducted in suspension while others are not. The latter variant, if applied to bundles of nanotubes, has the general drawback of accessing only the outer surface of these tightly bound aggregates. This results in a quite heterogeneous mixture of tubes, their degree of functionalization ranging from high via mediocre down to "not at all". This problem is most pronounced in reactions of nanotube powders with gases. Therefore it is crucial to employ samples with the highest possible degree of dispersion and a weak bundling.

Ozone is another reagent to attack carbon nanotubes. Supercritical water as well may bear oxidizing effect under suitable conditions.

3.6.5.3 Functionalization of open ends of carbon nanotubes

The attack of the general oxidizing reactants takes place on the ends individual tubes i.e. of both single- and multi- walled carbon nanotubes [50]. Depending upon the reaction time and the extent of reactivity, the tubes tips gives different results. Under the drastic conditions given, not only the ends but the defect sites will also react resulting in greater reactivity.

Carboxyl derivatives obtained from the oxidative opening of tubes can be further modified with the help of organic chemistry methods. The respective products after the attachment of long alkyl chains exhibit markedly increased solubility in organic solvents. Useful derivatives of nanotubes can be obtained by reacting the carboxyl units at the ends of the tubes as shown in Fig. 3.16.



R = $-C_nH_{2n+1}$, C_nH_{2n}-X, PEG etc.

(X = functional group, e.g. $-NH_2$, -OH, -halogen, -COOH, -CH=CH$_2$ etc.)

Fig. 3.16: Further reactions of carboxylated carbon nanotubes with carboxylated tips [50]

3.6.5.4 Side wall functionalization of carbon nanotubes

3.6.5.4.1 Covalent attachment of the functional groups

Hydrogenation

In the extreme conditions, a tubular and annealed nanotube is the result of Hydrogenation. However, on the extreme hydrogenation, the characteristics of carbon nanotubes are destroyed.

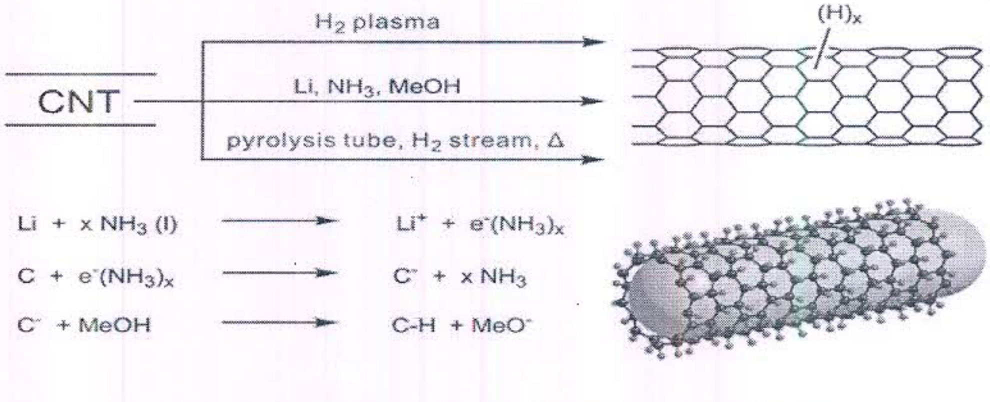


Fig. 3.17: Hydrogenation of carbon nanotubes

The theoretical structure of a completely hydrogenated nanotube is shown in the lower right corner (Fig. 3.17). The reaction with molecular hydrogen in a plasma or with alkali metals (sodium, lithium) in liquid ammonia under modified conditions give partially hydrogenated carbon nanotubes. High temperature reactions in a tube furnace under an atmosphere of hydrogen led to similar results.

Halogenation

The fluorination of carbon nanotubes is an important primary functionalization. The reaction of fluorine with SWNT, for example, can be performed in a tube furnace at about 150 ° C. It yields perfluorinated nanotubes with a degree of fluorination of up to 100%. DWNTs and MWNTs can be fluorinated too [50]. In DWNTs, only the outer wall is attacked as the inner tube is protected by its exterior counterpart.

The reverse reaction of fluorinated species being converted into unmodified nanotubes can be achieved using hydrazine. The method [50] may also be employed to remove just a part of the fluorine atoms, thus allowing for an adjustment of the degree of fluorination.

$$4\ C_nF + N_2H_4 \longrightarrow 4\ C_n + 4HF + N_2$$

Although the fluorination is a well established standard method for the primary functionalization of carbon nanotubes, little work has been done on the halogenation with chlorine and bromine [50]. Possible reasons for this may include fluorine being by far the most reactive of halogens and consequently being the most efficient in an attack to rather unreactive species.

Addition of Carbenes and Nitrenes

The addition of highly reactive electron deficient reagents like carbenes or nitrenes enables the preparation of nanotubes modified with cyclopropane or azacyclopropane rings respectively. A large variety of functionalized nanotubes can be obtained using appropriately substituted reagents here.

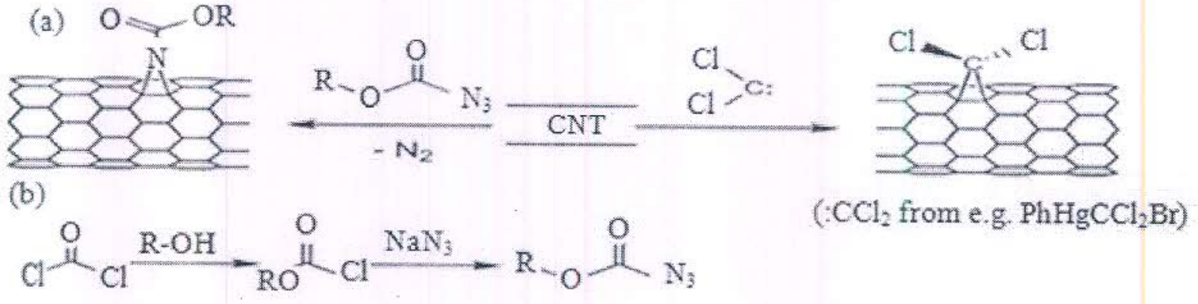


Fig. 3.18: Cycloaddition of nitrenes (a) and carbenes (b) to individual double bonds of a carbon nanotube [50]

IQAC COORDINATOR

Director,
THE TECHNOLOGICAL INSTITUTE
OF TEXTILE & SCIENCES, BHIWANI

Reactions with Ozone

The reaction with ozone proceeds with the 1, 3 - dipolar cycloaddition of an ozone to the respective double bond. The immediate product is the primary ozonide which, depending on the way of work up, can be converted into a number of functional groups. Reactions with hydrogen peroxide, dimethyl sulfide or with sodium boro-hydride have been reported in the literature. Depending on the reagent used, they allow for the generation of carboxyl, keto or hydroxyl groups respectively.

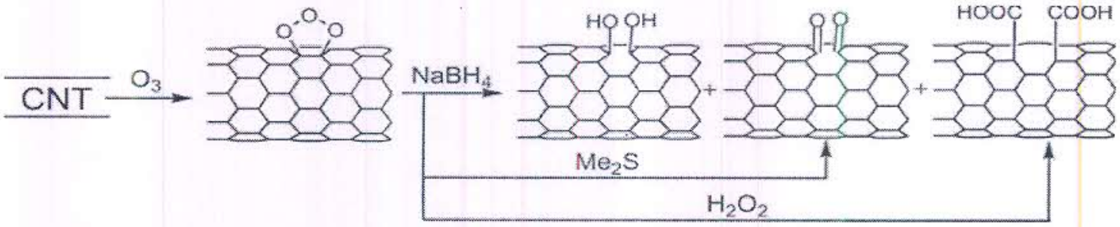
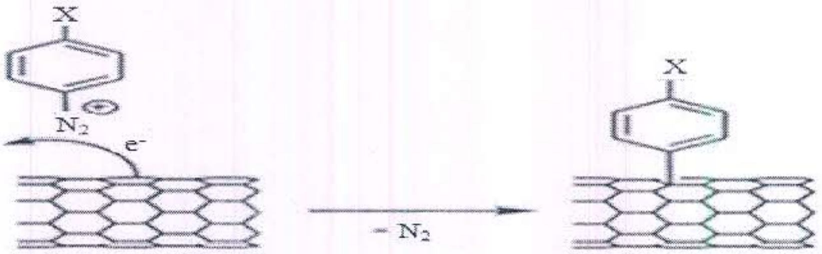


Fig. 3.19: Reaction of CNT with Ozone, hydrogen peroxide and dimethyl sulphide

Reactions with Diazonium Salts

The reaction with diazonium salts of aromatic compounds yields directly arylated derivatives of carbon nanotubes [50]. Apparently electrons are extracted from the tube and employed for bond formation. Finally the aryl radical is generated in a one - electron reduction and enters into a C-C bond with the nanotube. The disturbance of the tube's electronic structure subsequently also enhances the reactivity of adjacent carbon atoms. Up to 5% of the carbon atoms might be arylated.



X = Cl, NH_2, R etc.

Fig. 3.20: Reaction with aromatic diazonium salts [50]

Derivatization of carboxyl groups on the Side Wall

One of the most frequent functional groups on the side wall of nanotubes is the carboxyl group. The attractive way of derivatization consists in the connection with bifunctional units, which allows for a multitude of further possible reactions. Examples include amines with thiol functions. They act as a kind of spacer between the carboxyl group and the thiol. By way of the sulphur groups then the nanotubes may be deposited on or selectively bound to thiophilic substances like gold nanoparticles or respective surfaces. These self - organized structures are very important in the production of sensor devices.

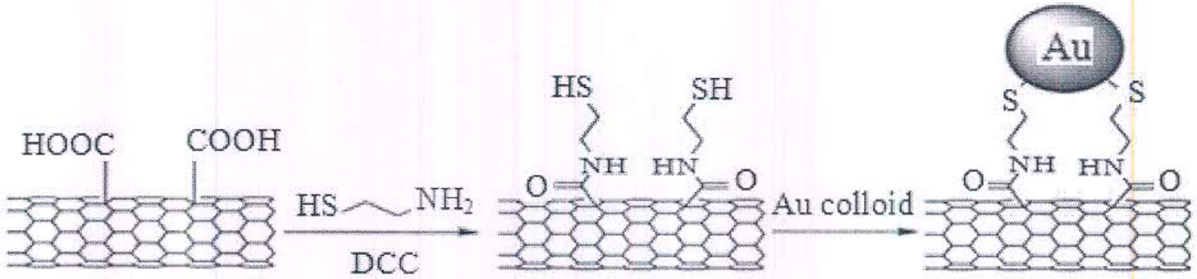


Fig. 3.21: Derivatization of carboxylated carbon nanotubes [50]

3.6.5.4.2 Non covalent attachment of functional units

Besides the covalent attachment to functional groups situated at the ends, side walls or defects of carbon nanotubes, one may also make use of their tendency to enter into strong intermolecular exchanges. Nanotubes tend to form solid bundles. These are held together by non covalent interactions alone and hence replace this exchange with neighbouring tubes by another one of at least the same strength would mean a non covalent attachment of molecules to the nanotube surface.

Wrapping with long - chain molecules

A very simple, but extremely efficient, method for carbon nanotube functionalization consists of establishing an interaction with long chain molecules that wind around individual tubes. These are not covalently bound to the nanotube, but only by Vander Waals interactions. Usually, they are polymeric compounds featuring an ever recurring pattern of functionalities that enables a regular wrapping around the nanotube.

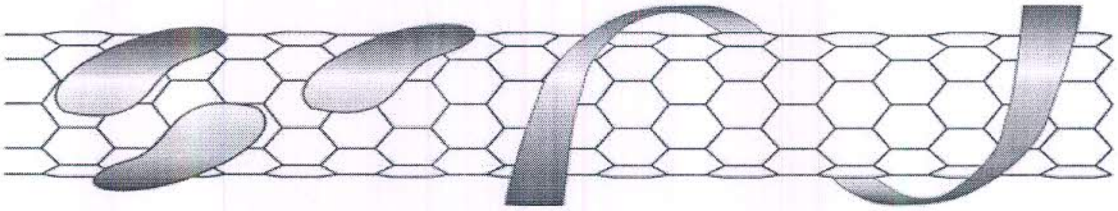


Fig. 3.22: Possible ways of non covalent functionalization carbon nanotubes [50]

Polymers featuring a helical shape are especially apt to wind around nanotubes. Hence peptides with an α- helical structure are frequently used to this purpose.

Interactions with larger aromatic systems

Carbon nanotubes possess an extended system of delocalized π- electrons. Aromatic compounds may hence interact with this π- system by way of a so called π- stacking. However, as might be seen from the insolubility of nanotubes in aromatic solvents like benzene or toluene, the interaction with single benzene rings is not sufficient here. It rather takes larger π- systems to achieve a sufficient effect.

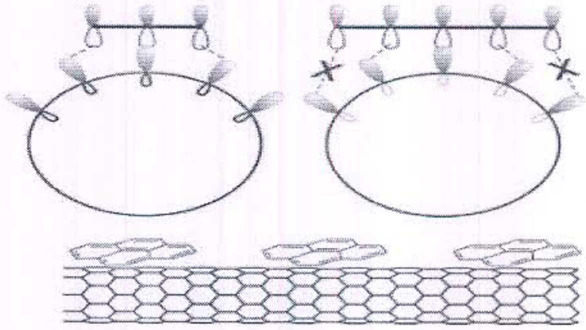


Fig. 3.23: Strength of interaction depends on the size of the complexing agent's aromatic system just up to a certain extent [50]

3.7 Potential applications of CNT

The strength and flexibility of carbon nanotubes makes them of potential use in controlling other nanoscale structures, which suggests that they will have an important role in nanotechnology engineering. The highest tensile strength of an individual multiwalled carbon nanotube has been tested to be is 63 GPa [61].

3.7.1 Hydrogen storage

There has been some research in using carbon nanotubes to store hydrogen which is to be used as a fuel source in addition to being able to store electrical energy [52]. The capillary effects of the small carbon nanotubes proved to be their advantage as it make possible to condense gases in high density inside the single-walled nanotubes. And which allows for gases, most notably hydrogen (H_2), to be stored at high densities without being condensed into a liquid. Effectively, this storage method could be used for a hydrogen-powered car in place of gas fuel tanks. A latest emerging issue regarding hydrogen-powered vehicles is the onboard storage of the fuel. Current storage methods involve cooling and condensing of the H_2 gas to a liquid state for storage which causes a loss of potential energy (25–45%) when compared to the energy associated with the gaseous state. Storage using SWNTs would allow one to keep the H_2 in its gaseous state, thereby increasing the storage efficiency. This method allows for a volume to energy ratio slightly smaller to that of current gas powered vehicles, allowing for a slightly lower but comparable range [62].

3.7.2 Ultra capacitors

MIT Laboratory for Electromagnetic as well as Electronic Systems used nanotubes to get improved ultra capacitors [52]. The problem in the conventional ultra capacitors is the use of the activated charcoal which has many small hollow spaces of varying sizes, which together create a large surface to store electric charge. But at the moment when the charge is quantized into elementary charges, i.e. electrons, and when each such electron needs a minimum space, a significant part of the electrode surface is not made available by them for storage because the hollow spaces of activated charcoal are not compatible with the electron's requirements. But with a nanotube electrode, these spaces may be tailored to size-few too large or too small and consequently the capacity should be increased considerably [52].

3.7.3 Radar absorption

Radars work in the microwave frequency range, which can be absorbed by MWNTs [52]. So the application of MWNTs to the aircraft would cause the radar to get absorbed and therefore seem to have a smaller signature. One similar application of nanotubes could be to paint the nanotubes onto the plane. Recently some work has been done at the University of Michigan regarding carbon nanotubes usefulness as stealth technology on aircraft. One added advantage of nanotubes has been found that in addition to the radar absorbing properties, the nanotubes does not either reflect or scatter visible light, which makes it invisible at night [52].

3.7.4 Medical

In the current research in the Kanzius cancer therapy, SWNTs are introduced around cancerous infected cells and then excited with the help of radio waves which causes the infected cells to heat up and ultimately kill the surrounding cells [52].

Another study made by the researchers at Rice University, University of California, Riverside and Radboud University Nijmegen Medical Centre have shown their result that carbon nanotubes and their polymer nanocomposites are suitable scaffold materials for bone cell proliferation and bone formation [52].

3.7.5 Optical power detectors

A spray of the mixture of CNT and ceramic demonstrated excellent ability to resist damage while absorbing laser light [52]. Such coatings that absorb the energy of high-powered lasers without breaking down are essential for optical power detectors which are responsible for measuring the output of such lasers. One such application is their use in military equipments for defusing unexploded mines.

3.7.6 Electrical cables and wires

Wires used for the purpose of carrying electrical current may be fabricated from either pure nanotubes or nanotube-polymer composites [52]. According to the recent reports, small wires have been fabricated with specific conductivity that exceeds to that of copper and aluminium [52]. These cables are found to be the highest conductivity carbon nanotube and also highest conductivity non-metal cables.

3.7.7 Paper batteries

In the reports, a paper battery is a battery engineered to use a paper-thin sheet of cellulose (which is the major constituent of regular paper, among other things) infused with aligned carbon nanotubes [52]. The nanotubes act as electrodes and hence allow the storage devices to conduct electricity. The battery, which functions as a lithium-ion battery and a super capacitor both, can provide a long as well as steady power output comparable to a conventional battery. Along with this, a super capacitor's quick burst of high power is also achieved and whereas a conventional battery contains a number of separate components, the advantage of the paper battery combines all of the battery components in a single structure, which makes it more energy efficient.

3.7.8 Solar cells

One of the exciting and promising applications of carbon nanotubes (CNTs) is their use in solar panels, owe to their strong UV/Vis-NIR absorption characteristics [52]. Research has shown that inclusion of CNTs can provide a sizeable increase in efficiency, even at their current unoptimized state. New Jersey Institute of Technology developed Solar cells which uses a carbon nanotube complex which in turn is formed by a mixture of carbon nanotubes and carbon buckyballs/fullerenes to form snake-like structures. Fullerenes trap electrons, but they can't make electrons flow. Electrons will be absorbed by the fullerenes by adding sunlight to excite the polymers. Nanotubes, behaving like copper wires, will then be able to make the electrons or current flow [52].

3.7.9 Chemical and Physical sensors

CNTs have a large surface-to-volume ratio along with high aspect ratio with a few nanometers diameter and length up to 100 μm due to which they form an extremely thin wire which is unique in the carbon family and possess the hardness of diamond and the conductivity of graphite [52]. Diamond is the found to be the hardest substance in nature and is an insulator, but graphite is found to be one of the softest conducting materials. As the electronic property of CNTs is strongly influenced by their atomic structure and mechanical deformations which makes it useful for developing extremely small sensors which are sensitive to the changes in chemical and mechanical or physical environment.

3.7.10 Optical sensors

Optical sensors works on the principle of the interaction between the sensing material and the chemical species which causes the change in optical properties [49]. In the case of optical sensors, the optical beam is allowed to come out of the spectrophotometer and made to incident on the sample, and then redirected towards the spectrophotometer for further processing.

3.7.11 Biosensors

Nucleic acids and the proteins which act as bio molecules in the body carry very important information of biological processes [49]. In the area of medical research and healthcare, at molecular level, to measure extremely small amounts of particular biomarkers is most desirable. Carbon nanotubes which have defined nanoscale dimension and unique molecular structure proves to be a good bridge which links bio molecules which in turn gives the information of bio events transduced into measurable signals.

3.7.12 Composites

There are few newly emerged materials being processed in near term opportunities which are new conducting polymers, metal matrix composites, high fracture-strength ceramics and multifunctional polymer composites [49]. Moreover, highly conducting materials, highly anisotropic insulators and high-strength, porous ceramics are some examples of the newly emerged materials from nanotubes.

3.7.13 Applications in Integrated Circuit Manufacturing

According to Moore's law, Carbon nanotubes based electronics may be a long term aspect which need for further development and the end of the silicon complementary metal–oxide–semiconductor (CMOS) scaling [49]. There are several areas where CNTs can provide better solutions to forecasted problems in the future generations of Si CMOS integrated circuit (IC) manufacturing.

3.7.14 Membranes and separation

The CNTs two aspects- nanoscale size and the hollow core have resulted into applications like separation membranes, nanofluidic channels, and drug and other molecule delivery systems [49].

3.8 Applications of CNT in textiles [8]

1. Conductive / Antistatic textiles
2. Self cleaning textiles
3. Flame retardant for ethylene-vinyl acetate (EVA) only and applied by melt blending of CNT and EVA
4. Reinforced textiles / Tear and wear resistant textiles

3.9 CNT resulted flame retardant fabric- possible uses [8]

The CNT resulted flame retardant fabric can be used in numerous applications some of these are listed in Table 3.8.

Table 3.8: CNT resulted flame retardant fabric possible uses

Product group	Product description
Apparel	Clothing made of synthetic as well as natural fibres
Protective clothing	Flame resistant suits, Gloves etc.
Interior trim and Upholstery	Flame retardant furniture textiles, Carpets, Curtains.
Automotive interiors	Flame retardant seat cushions, Linings
Auxiliary / Intermediate products	Flame retardant textile additive for synthetic

for industrial processes	polymers
	Industrial coating agent

3.10 Early investigations on application of CNT in textiles

Dapeng and Gang [63] studied the NPs dyeing of textiles; CB (carbon black) nanoparticles were dispersed in aqueous system by using different surfactants in varying concentrations. The nanoparticle suspension was directly applied to both polyester and acrylic fabrics for coloration purpose through a dip-pad-cure operation. K/S values of the treated fabrics were determined. The results indicated that carbon NPs can dye polyester and acrylic fabrics directly when the treatment temperature was at 180 degree Celsius. Different surfactants and concentrations of both NPs and surfactant affect the dyeing process.

According to Dapeng and Gang [32], cotton, wool, acrylic and nylon fabrics can also be directly dyed by using surface modified CB and self-dispersible CB (SDCB) NPs through an exhaustion process. The SDCB NPs were prepared by refluxing CB particles in nitric acid for certain time to result in hydrophilic carboxylic groups on their surfaces. They reported that SDCB NPs behaved similarly to direct or acid dyes in dyeing cotton, acrylic and nylon fibers. The SDCB-dyed fabrics showed good color fastness against crocking. However, wash fastness of the NPs-dyed cotton fabrics is relatively lower than the crocking fastness. The exhaustion rate of the NPs by the fabrics was found to be very low which was explained as that only a small portion of the NPs was dispersed in singular particle form.

Liu and co-workers [64] investigated upon the functionalization of cotton textiles with CNTs. CNT network armours have been fabricated on the surface of cotton textiles using a simple dipping coating method. They reported that due to the reinforcement and protection of CNTs, the cotton textiles exhibit enhanced mechanical properties, extraordinary flame retardancy, improved UV-blocking and super water repellent properties.

In another study, Gang and Dapeng [65] stated the use of nanotechnology to textile coloration. In one embodiment of their patent, they reported a textile material having embedded NP. The NP can be an organic NP or inorganic NP. In another embodiment, researchers reported the process of diffusing a NP into a polymer matrix, thereby making the NP processed polymer composition. They concluded the benefits of this invention over conventional techniques as fewer environmental concerns arise compared to traditional dyeing techniques in terms of waste water release, cost of treatment of waste water etc.

Study of Mani et al [66] emphasize on reducing the NP size, narrowing the NP size distribution of clay particles to improve the results of dyeable polypropylene nanocomposite. They opted ultrasonication for enhancing particles size distribution. The amplitude and time of ultrasonication process were investigated with respect to particle size distribution. They observed when the amplitude was increased from 80% to 90%, the specific surface area (SSA) increased from 40.38 m^2/g to 45.48 m^2/g in 1 hr and to 46.98 m^2/g in 4hr. They found time as the vital factor for getting better results. When the sonication time was changed from 15min to 1 hr and 4 hr, the SSA increased from 38 m^2/g to 45.4 m^2/g and 46.9 m^2/g. Along with this, they found that when specific surface area of the particles is more uniformly distributed throughout the polypropylene matrix, the dyeing would be even in the nanocomposite polypropylene.

Jhala [67] suggested in his paper that in the process of dyeing of polypropylene, the uniformity of NPs distribution influences the dye levelness in the polypropylene matrix to a large extent.

Patel et al [68] investigated that CB NPs can improve abrasion resistance and hence the durability of the fibers. They also reported that Nylon-6, when infused with MWCNT, yielded most promising results. Tension test on individual filament of this system showed about 150-300% improvement in strength and stiffness with 1% MWCNT loading.

They also stated that NPs added on textile materials cannot be detected by the naked eye; therefore the original colour of the products will not be altered. Textile products, which have been processed with NPs, are more durable than the traditional finishes with repeated washings. They concluded with the statement that the nanosize materials are able to enhance the physical properties of conventional textiles in areas such as anti-microbial properties, water-repellancy, soil-resistance, anti-static, anti-infrared and flammability properties, dyeability and strength of the textile materials.

Kshiwagi et al [69] studied the flammability properties of polypropylene and MWCNT nanocomposites. They found increase in flammability properties with increase in MWCNT content.

Beyer [70] used carbon nanotubes (MWCNTs or SWCNTs) as nanofillers in polyethylene and researcher found that nanofillers based on MWCNTs acted as efficient flame retardants at low filler contents in the non-polar polymer polyethylene. In contrast SWCNTs did not show any improvements on flame retardancy.

Shahvazian et al [71] investigated the effects of MWCNTs on flame retardation as well as thermal stabilization efficiency of two phosphorus-containing flame retardant systems i.e., ammonium polyphosphate/pentaerythritol (APP/PER) and red phosphorus (RP) in polypropylene (PP). They found that the addition of MWNTs alone improves thermal stability of PP considerably without any undesirable effect on its flow-ability and mechanical properties. Moreover, addition of MWNTs alone resulted in a slight improvement of flammability of the polymer. However, comparison between thermal stability and flame retardancy of PP samples containing a combination of MWNTs and APP/PER or RP and those of the samples containing APP/PER or RP alone proved that MWNTs interfere with thermal stabilization and flame retardation efficiency of both APP/PER and RP in the polymer.

While studying flame retardancy of MWNTs and clay on acrylonitrile–butadiene–styrene (ABS) resin, Ma et al [72] found that the flammability properties of the nanocomposite of clay and MWNTs into ABS resin was strongly affected by the formation of a network structure.

Dittrich et al [73] studied the influence of adding functionalized graphene (FG), distinct expanded graphites and carbon nanofillers such as CB and MWCNTs on mechanical properties, morphology, pyrolysis, response to small flame and burning behavior of polypropylene (PP). They found that addition of layered carbon NPs lowers the time to ignition and increase the flame retardancy of the composite.

Zhuo et al [74] used carbon nanotube/graphene nanoplatelet (MWCNT/GNP) membranes to improve the flame retardancy of carbon fiber reinforced polymer (CFRP) composites. Results show that incorporation of MWCNT/GNP membranes on CFRP composite plates can remarkably improve the flame retardancy of CFRP composites.

Atieh [75] reported the investigation carried out on styrene butadiene rubber (SBR) matrices filled with functionalized MWNTs which in turn were functionalized with amine group and this was done to obtain increased mechanical and thermal properties. Results obtained show significant improvement in the mechanical as well as thermal properties of the nanocomposites. For example the tensile strength increased from 0.16 MPa (blank SBR) to 0.45 MPa (10% CNT).

WQ et al [76] synthesized nanocomposites based on different concentrations of graphene with thermotropic liquid crystalline polyester (TLCP) material and this nanocomposite material was found to exhibit excellent thermal properties.

Wong et al [77] stated different techniques of applying NPs to textiles which are spraying, dipping and soaking, transfer printing, washing, padding etc. ***They also reported that coating of NPs does not affect the breathability and hand feel of the textiles***.

Jirsak et al [78] found that majority of the work has been focused on composite materials reinforced by carbon nano-fibers or nanotubes. Qian et al [79] reported CNT composite fiber (SWNT- polyvinyl alcohol fiber) produced by using a coagulation based spinning process. The fiber exhibits twice the stiffness and strength, and 20 times the toughness of steel wire of the same weight and length.

Costa et al [80] in their study found raman spectroscopy as a quick measurement technique to characterize the presence of single walled, double walled and multi walled CNTs.

Jagdap and Ratna [81] prepared epoxy and MWCNTs composites and used Raman and FTIR spectroscopy to explain cation-π interaction between sodium salt of 6-aminohexanoic acid (SAHA) with MWCNT and chemical bonding of SAHA with epoxy resin confirmed the presence of MWCNT by confirming their characteristic peaks in raman spectroscopy.

Wepasnick et al [82] applied six different chemical oxidants to MWCNTs and studied their effects on surface chemistry and structure of MWCNT using raman spectroscopy.

Manocha and co-workers [83] characterize MWCNTs using raman spectroscopy owing the presence of the peaks corresponding to the functional groups present in the MWCNT. They found it one of the most convenient techniques to confirm the presence of MWCNT.

Kopaieemalek [84] used FTIR in his work to characterize the mesoporous CNT materials and showed the formation of oxygen containing groups such as C=O and COOH and used to characterize surface of functionalized MWCNTs.

Singh et al [85] studied the change in nature of bonding after functionalisation of CNT and impurities in CNT using FTIR spectroscopy. They also studied the changes in structure and morphology after functionalisation of CNTs using X-Ray diffraction method. The changes in the intensities of the peaks and hence in the XRD pattern were studied.

Dubey et al [86] synthesized CNT by mustard oil and characterized using XRD by the presence of intense peak at 25.6 degree. Saraf [78], in his research work, used XRD to characterize crystallinity of the compound. XRD pattern of purified MWCNT sample showed prominent peak at about $2\theta = 26$ degree and 54 degree. They concluded this as the indication of high degree of crystallinity in the pattern which suggests low content of amorphous carbon and impurities.

Buyle et al [88] stated that when coating textiles with formulations including NPs, an important issue is to control the dispersion of the NPs because these particles often have the tendency to agglomerate. If agglomeration occurs, the actual particle size lies in the range of μm or even higher, so the typical properties of nanosized objects might be lost. Apart from this, they also stated for the environmental, health and safety aspects as ***once the NPs are in dispersion, the risk of exposure is very low as they can no longer move freely***. This means that after application of NPs into the textiles when they cannot move, the exposure risk is very low.

Gonçalves et al [89] functionalized MWCNTs with oxygen-containing surface groups and subsequently incorporated in cotton and polyester fabrics by a process that mimics the traditional industrial dyeing process. The washing fastness, hydrophobicity and flame retardancy of the functional textiles were evaluated. The scanning electron microscopy images and the whiteness degree values of the functional textiles before and after washing indicated that the incorporation efficiency was higher for the textiles containing the most acidic MWCNTs, especially for the polyester textiles. The immobilization of the less acidic MWCNTs in polyester imparted hydrophobic properties to the fabrics surface; in particular, the polyester samples functionalized with unmodified and O_2-oxidized MWCNTs presented an almost superhydrophobic behaviour. In the case of the cotton-based samples, a hydrophobic behaviour was not achieved. Finally, the flame-retardant properties of both substrates improved upon the MWCNTs immobilization.

CNTs must be dispersed well by sonication methods to achieve limited scalability and damage to the SWNT structure. Linde [90] has used liquid ammonia to produce dispersed CNTs instead of sonication. He stated that negative charge on the SWNTs allows for further functionalisation which extends the field of potential applications to composites, sensors and biology.

Number of researchers has stated that the use of CNT was limited just for textile functionalisation of fiber spinning for enhancement of their physical and mechanical properties [91-93] but recently CNT is coated on the textile fabrics using several methods for modification of fabric characterstics. It is also investgated in a paper that intelligent electronic textiles are also produced for human biomonitoring using a polyelectrolyte-based coating with CNTs [94]. Additionally, Panhuis et al. [95] dyed textile material by immersing in an aqueous sulfonated polyaniline-CNT dispersion which resulted in increased conductivity and capacitance. In another study, Hu and co-workers [96] gave coating of single SWCNT using the simple technique "dipping and drying" for wearable electronics and energy storage applications. CNTs have an aligned nanotube structure and a negative surface charge so the exhaustion method is applied for coating and absorbing CNTs on the fiber surface for preparing multifunctional fabric including antibacterial, electric conductive, flame retardant and electromagnetic absorbance properties [77, 94, 96].

CNT can be entrapped into the textile structure either during spinning process or with the help of textile finishing methods [68]. Surface coating is the common technique of creating layers of thin films on the surface which includes coating by spraying, transfer printing, washing or rinsing and padding [68, 97-99] but makes the fabric unbreathable and also gives unsatisfactory durability of the treatments as the effect of treatment get worn off either through abrasion or cleaning [100]. In addition to this, surface treatments adversely affect the handle properties of the fabrics and gives non-uniform deposition of the NPs over the entire textile surface [100].

Black [100] stated that chemical bonding achieved at nanoscale is far more durable than conventional finishing processes, reducing the amount of pollution caused when finishing treatments breakdown. For example, specific NPs may be embedded into the molecular surface structure, chemical bonding with the fiber molecules to create new, stable and therefore permanent structures.

Application of special flame retarding treatments on cotton like coating with Pyrovatex and Pyroguard [101] suffers from the limitation of being expensive, reduced fabric strength, technical complicacy in their application and used where washing is not so frequent e.g. curtains, upholstery and other home textile products.

Hence it is advisable to use CNTs for imparting flame retardant properties.

3.11 Summary

The following points can be summarized from the literature survey made-

1. Cotton is one of the most popular raw materials for textile and clothing applications. Compared with some synthetic fibers, the main drawback of cotton fiber is its poor mechanical properties and its high flammability, and therefore it cannot be used for special applications.
2. It is also observed that NPs have some affinity to the textiles subject to the condition that they should be properly dispersed.

3. Much of the work has been done on producing nanocomposites and then various properties of the carbon NPs are exploited.
4. CBNPs functionalised polyester and acrylic fabric can be produced with the help of pad-dry-cure method but the washing fastness is not found to be satisfactory.
5. Oxidising agents can be used to disperse CB NPs but after this treatment, NPs do not come in singular particle form. Also, CNTs can be dispersed by sonication methods.
6. Increase in the ultrasonication time increases the specific surface area (SSA) and SSA of the particles is more uniformly distributed. Also uniformity of NPs distribution influences the dye levelness.
7. MWCNT shows significant improvement in the mechanical as well as thermal properties.
8. Application of special flame retarding treatments on cotton has its own limitations such as high cost, reduction in fabric strength, technical difficulties in their application and used where washing is not so frequent e.g. curtains, upholstery and other home textile products.
9. Different techniques of applying NPs to textiles are spraying, dipping and soaking, transfer printing, washing, padding etc. but make the fabric unbreathable and also give unsatisfactory durability of the treatments as the effect of treatment gets diminishes on abrasion or cleaning.
10. Chemical bonding achieved at nanoscale is far more durable than conventional finishing processes and reduces the extent of pollution as compared to conventional finishing finishing treatments. For example, specific NPs may be embedded into the molecular surface structure, bonding with the fiber molecules to create new, stable and therefore permanent structures.
11. Environmental, health and safety hazards are not there as once the NPs are in dispersion, the risk of exposure is very low as they can no longer move freely.
12. MWCNT can improve various properties of textiles such as thermal stability, flame retardancy, anti-microbial properties, water-repellence, soil-resistance, anti-static, anti-infrared, dyeability and strength of the textile materials.
13. NPs added on textile materials cannot be detected by the naked eye and therefore the original colour of the products will not be altered.
14. Raman and FTIR spectroscopy are found to be important techniques to characterise CNT. These confirm the presence of different functional groups corresponding to various frequency peaks. XRD is also found to be powerful technique for analysing

crystalline compounds. Confirmation of the presence of CNT upto the molecular level can be done with the help of these techniques.

Therefore, a systematic study could entail proper development of MWCNT functionalised cotton fabric. There is limited information available on MWCNT incorporated cotton fabric produced with the help of conventional dyeing technique. Hence, in present study, an effort has been made to apply sonicated MWCNT (without any use of surfactant or oxidising agent) along with the reactive dye on the cotton fabric and to study flammability behaviour of the cotton fabric along with other physical as well as wear and tear properties. Use of any dispersant or oxidising agent to disperse CNT has been avoided as the presence of these molecules in the solution can interfere with the dyeing conditions.

Considering the exceptional properties of MWCNTs, these CNTs functionalized cotton fabrics can find a variety of applications in today's world.

Ultra Violet Radiation

Ultraviolet radiation is part of the electromagnetic spectrum and lies between the visible spectrum and the x-ray region. The electromagnetic radiations of wavelength between 150 and 400 nm coming out from sun rays are termed as Ultra-Violet Rays (UVR).

The term **UVA** represents the region **320 – 400 nm**, the term **UV B** represents the region between UV C and UV A, i.e. **290 – 320 nm**, and **UV**C region represents the region **below 290 nm**. Part of this radiation, UVC (100–290 nm), is filtered off from the atmosphere mainly because wavelengths smaller than 242 nm are absorbed by stratospheric molecular oxygen to produce ozone. This stratospheric ozone can partly absorb UVB (290–320 nm) rays. But most of the remaining UVB together with UVA (UVA-2, 320–340 nm; and UVA-1, 340–400 nm) rays reach our skin and cause biological and metabolic reactions.

UV protection by fabric engineering

Composition of the fibers (most natural fibers transmit UV radiation more than synthetic ones), Tightness of the weave (the more closely woven fabric, the less of UV radiation is transmitted), Color (dark colors of the same fabric type will absorb UV radiation more strongly than light pastel shades and will consequently have higher UPFs), Stretch (the greater the stretch the lower the UPF rating), Moisture (wet fabrics provide less UVR protection)

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UPF range	UVR protection category	Effective UVR transmission, %	UPF ratings
15 to 24	Good protection	6.7 to 4.2	15, 20
25 to 39	Very good protection	4.1 to 2.6	25, 30, 35
40 to 50, 50+	Excellent protection	≤2.5	40, 45, 50, 50+

Nano particles as UV absorbers

Nanoparticles are particles with lengths in at least one dimension between 1 and 100 nanometers (1.0 nm = 10^{-9} m). At these length scales, materials begin to exhibit distinct properties that affect biological, chemical, and physical behaviours. “Nano-particles” which in general terms are defined as engineered structures with diameters of < 100 nm, are devices and systems produced by chemical and/or physical processes having specific properties.

A wide variety of nanoparticles exists with organic or inorganic composition, most being metals. Examples include: Silica (SiO_2), Silver, Iron Nanoparticles, Carbon Black, Aluminum, Cerium, Zinc Oxides, Titanium Dioxide (TiO_2), Polystyrene, Nano-clays. UV absorbers are organic or inorganic colorless compounds with strong absorption in the UV range of 290 – 360 nm. UV absorbers convert UV energy into harmless heat energy.

Generally Inorganic UV blockers (TiO_2, ZnO) are more preferable to organic UV blockers as they are non-toxic and chemically stable under exposure to both high temperatures and UV radiations. Nano particles are most efficient at absorbing and scattering UV radiation than the conventional size because Nano particles have large surface area per unit mass and volume.

According to the Rayeigh’s Scattering theory, the scattering is strongly dependent upon the wavelength, where the scattering is inversely proportional to the wavelength of fourth power. This theory predicts that in order to scatter UV radiation between 200 to 400 nm, the optimum particle size will be in between 20 and 40 nm.

Photo-catalytic mechanism of TiO_2 nanoparticles

The catalytic activity of TiO_2 is based on the electron-hole pair formation due to photo-excitation. TiO_2 Nano particles when illuminated by light with energy higher than its band gap (3-3.2 eV) electrons in TiO2 will jump from valence band to conduction band and the electron (-e) & electric hole (h+) pairs will form on the surface of the photo-catalyst.

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The negative electrons and oxygen will combine to form O_2^- radical ions, whereas the positive electric holes & water will generate hydroxyl radicals OH. Since both products are unstable chemical entities, when the organic compound falls on the surface of the catalyst it will combine with O_2^-& OH radicals, turned into carbon dioxide and water

Titanium dioxide (TiO_2) Nano particles and its applications in textile sector

- A. AbouOkeil et al (2008), worked with TiO_2 as a catalyst for cross linking of cellulose using citric acid by pad-dry-cure method. Results obtained indicate that TiO_2 has the ability to catalyze cross linking of cellulose with citric acid. Crease recovery angle increases with increasing TiO_2 concentration; the optimum concentration was 0.6% TiO_2. Also, crease recovery angle increases with increased curing time, curing temperature, and citric acid concentration.

- Ye Zhang et al (2012), made a research on cotton fabric treated with nano TiO2 (as photo-catalyst) and BTCA (as cross-linker) in an ultrasonic bath. Self-cleaning, hydrophobicity, crease recovery angle (CRA). The results indicate a reasonable hydrophobicity along with photo-activity and cross-linking. Creasing property decreases considerably and photo-activity decreases after repeated laundering.

- Mohamed Gouda et al (2012) worked on Synthesis and characterization of TiO2 NPs (5-10 nm) and their application on cotton fabric using Pad-Dry-Cure method. The results shows excellent Anti-bacterial property (96.6% +ve& 95.2% -ve), enhanced the self-cleaning and UV protection than untreated cotton fabric. TiO2 NPs treated fabrics are durable in-situ even after 20 laundering wash cycles.

- Shui-Lin Chen et al (2005), Titanium hydrosol was prepared to enhance the UPF of cotton fabrics using Pad-Dry-Cure method. SEM, AFM (Atomic force microscopy), UPF property, tensile and tear strength. UV transmittance decreased after sol treatment. Use of adhesive treatment increased washing durability and UV protection property. No negative effect on strength of fabric.

- Luis Cabrales et al (2009); Cotton fabric was padded with titania nano sols solution prepared by means of sol-gel process. SEM, evaluation of stain removal efficiency, UV protection measurement and durability. Stains of coffee and red wine were successfully decomposed by exposure to UV radiation. Good protection against UV radiation and no effect of laundering on UV protection efficiency.

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- K.K. Gupta et al (2002); prepared coating formulations containing ZnO, TiO2 and their various combinations applied on Nylon and cotton substrate by Pad-Dry-Cure method. UV protection has been measured. Combinations of ZnO and TiO2 NPs provide high UV absorption.

- Roshan Paul et al (2010);made a research with Cotton yarns and fabrics which were treated with TiO2 and ZnO NPs for imparting UV protection. Cotton yarns treated with ZnO NPs were found to withstand the knitting operation. Zno treated fabric shows moderate to high UPF values whereas TiO2 treated fabric shows 50+ UPF values.

- A. Sivakumar et al (2013); treated cotton fabric with ZnO and TiO2 NPs with acrylic binder using Pad-Dry-Cure method. TiO2 (35nm) treated fabrics exhibit better UPF values than ZnO (9nm) treated fabrics. ZnO (9nm) treated fabrics show better results regarding Self-cleaning action. Washing durability is found to be in between 28 – 48 washes for UV protection.

MAIN OBJECTIVES

The main objective of the present research work is to develop face covering scarves treated with tio_2 nano-particles having ultraviolet blocking properties.

The objectives are as follows:

- To select and develop experimental light weight 100% viscose filament fabric, 100% cotton fabric and union fabric using cotton as warp and vscose filament as weft, to be used as ladies' scarf or face covering fabric which is comfortable for breathing in summer season.

- To evaluate and optimise Ultraviolet protection property and crease recovery angle of Titanium dioxide nanoparticles coated fabric and uncoated fabric.

- To compare the performance of fabric treated with optimized parameters with raw fabric.

- To develop designs for ladies' face covering scarves using CAD techniques i.e. Corel draw and Adobe Photoshop.

- To assess the developed face covering scarves subjectively by the consumers using questionnaire.

CHAPTER 4

MATERIAL AND EXPERIMENTAL PLAN AND METHODS

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Material:

Fabrics:

- *Cotton Fabric*

100% pure cotton fabric woven with following details will be used in present study:

- *Viscose Filament Fabric*

100% pure *Viscose Filament* fabric woven with following details will be used in present study:

- *Union Fabric*

Union fabric woven with following details will be used in present study:

Features	**Details**
Fibre/Filament	100% cotton, 100% *Viscose Filament, Union fabricusing cotton as warp and weft as viscose filament*
Weave	Plain, twill and sateen
Yarn count	60-80 Ne^s warp & 60-80 Ne^s weft for cotton fabric 120-150 denier viscose filament as warp and weft for filament fabric 60-80 Ne^s warp & 150 denier viscose filament weft for union fabric
EPI/PPI	104/ 92
GSM	70-80

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- *Titanium dioxide nano-particles*

Titanium dioxide nano-particles will be procured from Nanobeach, G-25, East Gokalpur, Loni road, Delhi-110094 (India). The nano-particle details are given below:

Features	**Details**
Molecular weight	79.86 g/mol
Purity	99 %
APS	20nm – 40nm
CAS	13463-67-7

- *Other additives*

Citric Acid (CA) as cross-linking agent, Non-ionic detergent (NID) as surfactant and di-sodium hydrogen phosphate (SHP) as co-catalyst will be used and procured from SD Fine Chemicals, Mumbai.

Experimental Plan:

Collection of Samples

Evaluation of Air Permeability, Bending length, Crease Recovery angle and Ultra-violet Protection Factor (UPF)

Selection of fabric as per desirable criteria

Weaving of fabric

Preparation of nano TiO_2/CA/NID suspension

Treatment of fabric with TiO_2 nanoparticles as per Box-n-Behnkan Experimental plan

Evaluation in terms of Ultra-violet Protection Factor (UPF) and Crease Recovery angle

Optimization of process parameters w.r.t. desirability criteria

Validation of optimized parameters

Conclusion

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The Experimental Design:

* The Box-n-Behnkan design will be applied for experimental plan with three independent variables TiO_2 nanoparticles concentrations (1%, 3%, 5%), citric acid concentrations (1%, 3%, 5%) and Non-ionic detergent concentrations (0.5%, 1%, 1.5%) using Design Expert software (version 7.0). The respective parameters are shown in given table.

Independent Variables	Levels			Dependent variables
	-1	0	+1	
TiO_2 nanoparticles	1%	3%	5%	• UPF value • Crease recovery angle (CRA)
Citric acid	1%	3%	5%	
Non-ionic detergent	0.5%	1%	1.5%	

Run	TiO_2 %	Citric Acid %	NID %
1	1	3	0.5
2	5	5	1
3	1	3	1.5
4	3	3	1
5	3	1	1.5
6	3	3	1
7	1	5	1
8	5	1	1
9	5	3	1.5
10	3	1	0.5
11	3	5	0.5
12	3	5	1.5
13	3	3	1
14	5	3	0.5
15	3	3	1
16	1	1	1
17	3	3	1

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Preparation of Nano TiO_2/ CA/ NID suspension.

The aqueous suspension of finishing will be prepared with mixture of TiO_2 nanoparticles, citric acid, non-ionic detergent as per Box-n-Behnkan experimental runs (as shown in above table) and 5% di-sodium hydrogen phosphate (SHP) with required distilled water in ultrasound bath for 30 minutes.

Treatment of fabric with TiO_2 suspension.

The cotton fabrics will be immersed in freshly prepared TiO_2 suspension (MLR 1:40) for 5 min., padded with wet-pick-up of 100±1% at pressure of 35 lb/in^2 and dried at 80°C temperature for 4 min. followed by curing at temperature 140°C for 3 min. Then, the finished samples were washed at 75°C for 20 min. with 2gpl Na_2CO_3 and 1gpl Non-ionic detergent (NID) and finally dried at room temperature.

Testing Methods

1. Fabric Weight [GSM (grams per meter square)]:
2. Thickness
3. Ultra-Violet Protection Factor (UPF) test of fabric
4. Air permeability of fabric
5. Bending Length of fabric
6. Dry Crease Recovery Angle (DCRA) of fabric
7. Scanning Electron Microscopy (SEM) Test
8. Fourier-transformed infrared spectroscopy (FTIR) Test
9. Whiteness Index
10. Assessment of Durability of Finish to Washing

CHAPTER 5

DESIGNING AND DEVELOPMENT OF SCARVES

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Designing and Developing scarves

Fashion design presentation tools

Flat sketches

Flat sketch (also called Flats in the fashion industry) is basically black and white apparel sketch that show a garment as if it was laid "flat" to display all seams, topstitching and any other design details. The Illustration may show either front or the ¾ view of the design. In a flat sketch the back of the garment can also be drawn along with the front. And these are rendered with colors and fabrics after finalizing the design. Flat sketches (in black and white & colored) can be drawn free hand or by using computer graphics. Sketches can quickly and easily be created to convey design information. In the apparel industry, flat sketches are an important reference for pattern makers, technical designers, merchandisers, manufacturers, production and sales teams. Flats are the must-haves to be included in presentation boards, tech packs and fashion design portfolio.

Freehand sketching

The informal drawing of shapes using freeform lines and curves, has remained one of the most powerful and intuitive tools used at the conceptual design stage. Sketches, in contrast to typical Computer Aided Designs, can quickly and easily be created to convey shape information.

Mood boards

A mood board (sometimes called as inspiration board) is a type of poster design that may consist of a variety of objects like images, texts, colors, textures, silhouettes whose composition totally depend upon the choice of the mood board creator. Mood board is basically designed by the graphic designers to visually explain the direction of style which he/she is pursuing. A rough collage of colors, textures and pictures is prepared which evoke a specific style or feeling. The sources of the picture of the mood board are magazines, newspapers, fashion designing books, internet etc.

Mood board designing in the digital form is much easy and quick method as compared to when prepared with physical objects. In short, mood boards are not limited to visual subjects, but serve as a visual tool to quickly inform others of the overall feel or flow that a designer is trying to achieve.

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Storyboards

Storyboard basically tells the story of the designer's idea. A storyboard shows not only the individual garment, but the sequence of making garment as well. The storyboard should include original illustrations and flats as well as additional materials (such as images from the Internet or magazines, paper, color palette, fabric swatches, patterns, all the trims and accessories etc. which have some influence on the unique design). Storyboard enhances the creativity and originality in the designer's ideas and makes the visual communication of the design possibilities.

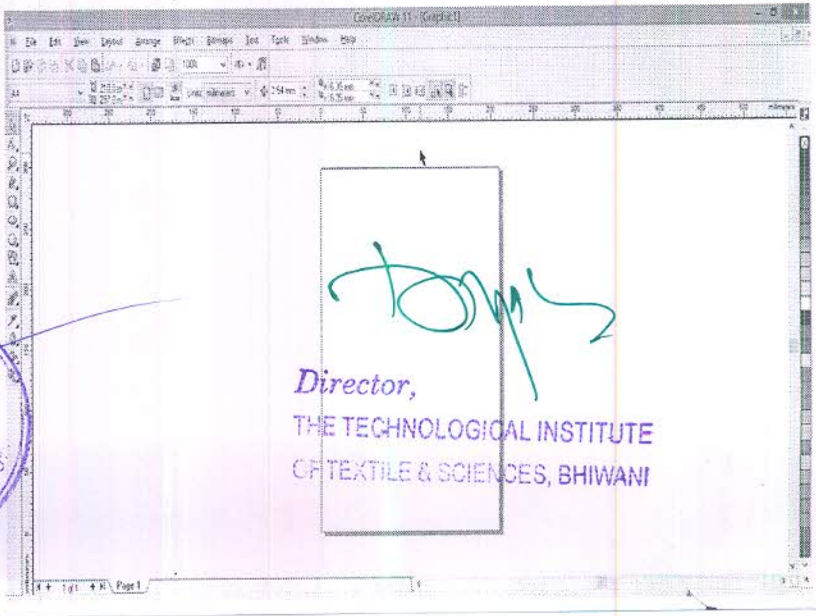
Process of creating the storyboard helps in visualizing the final product. It allows analysis visually of how the products are framed in their final look or the layout. This is also an opportunity to work out the precise sequencing in the garments. It is much easier (and less expensive) to try out alternatives of the garment in this preproduction stage.

A storyboard can be simple or elaborate depending on the storyboard creator. Too much detail should be avoided and the focus on just the essential details of the dress is required. Standard letter-size paper or template can be used. One can create his/her own pattern. Boxes are used for information such as fabric swatches, trims and accessories, flat sketch, final design etc. Background color or pattern must also be carefully selected and the focus of the concept and overall look and sequencing must not be compromised.

DESIGNING OF SCARVES

Application of CAD software in designing

In order to cope up with the diversity of modern generations, in terms of demand, versatility and increased flexibility, advanced techniques like Computer Aided Design have been developed. Fashion design presentation with the use of conventional techniques is quite tedious, time consuming and laborious too. The whole process of fashion design presentation is revolutionized by the introduction of CAD. Various programmes may be used for preparing various presentation boards like-



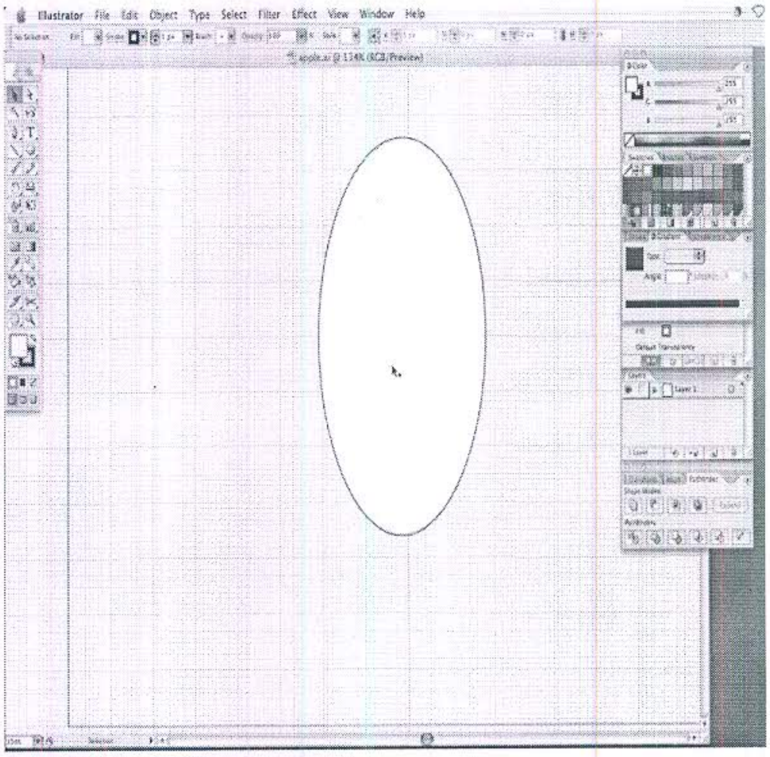
1. Corel Draw
2. Adobe Illustrator
3. Adobe Photoshop

Corel draw

Corel Draw Graphics Suite is one of the most popular packages of illustration and imaging tools. With the help of this program, designers can create characters, logos, shapes and many other graphic objects. The main application in Corel Draw Graphics Suite package is CorelDraw, which is used for vector designs and layouts. Corel Photo-Paint is designed to retouch and edit digital photos, and other applications in the package can do tasks such as screen grabs, and more.

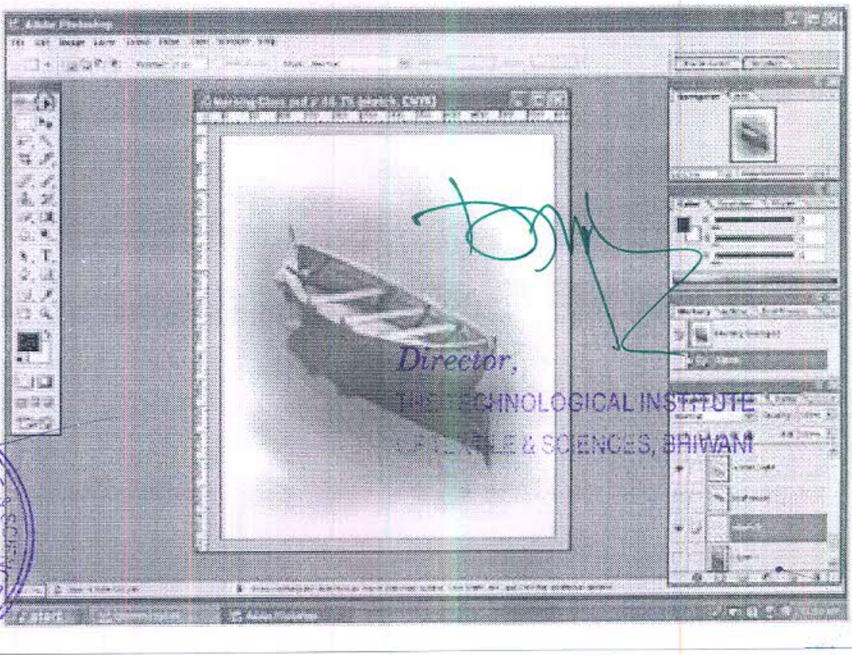
Adobe Illustrator

Adobe Illustrator is a vector-based program. All images in Adobe Illustrator are created in vector, including type. A vector graphic is resolution independent. This means it can be scaled to any size and printed on any output device. The clarity of the image is dependent on quality of the output device. This makes vector graphics and hence Adobe Illustrator the perfect format for creating detailed technical drawing and fashion illustrations.



Adobe Photoshop

Adobe Photoshop is a raster-based program. It is a complex and premier tool that has now become a “verb”. Photoshop programme is found to be an extremely effective programme to work with. This programme has been exploited in various



fields like interior designing, advertising, textiles and apparels but textile and apparel are the most challenging and creative field to work with. Process of the fashion design presentation includes designing of mood boards/inspiration boards, story boards, color boards, flat sketches etc. Photoshop programme contribute in making mood boards, story boards, flat sketches to a large extent. The possibilities of variations in presentation techniques become endless with the introduction of CAD.

Bitmaps (Raster) are made up of individual pixels. Pixels are defined by a grid- the amount of pixels in an image make up the overall "dpi" of the image or the resolution of the image- 300 dpi means a resolution of 300 dots per inch. Higher the dpi, higher will be the resolution. Bitmap images are good for reproducing subtle gradations of color and air brushing techniques. The final image has a softer, more realistic look than a vector image. So in the present study, the raster images are used to make fashion design presentation tools and to create more realistic effects.

Photoshop provides creating the photo background, photo editing, producing effects to texts & objects, cropping images, composting (putting several images together), ghosting images (for use as web page backgrounds), using layers, creating masks, applying filters, formatting text and other effects. Hence it results in various activities of fashion design presentation like creation of the silhouette of the garment, experimentation with illusions of silhouettes and colors along with balance (vertical/horizontal or symmetric/asymmetric) in the garment, producing various effects like LED, tie and dye, batik, denim effect etc.

Product designing process involves preparation of mood boards, story boards, flat sketches etc. Photoshop graphics software program is used to create fashion presentation boards. With a couple of clicks, flat sketches, mood boards and storyboards can be created.

Application of Adobe Photoshop

Making Mood boards and Story boards with Adobe Photoshop

Collect images that pertain to the theme. Prepare images if they are not in digital form. Open images in Photoshop. Alter the images, as necessary, for color, resolutions and so on. Prepare a document to be the main document i.e. mood board/story board. One should know working with layer effects before making these boards which are:

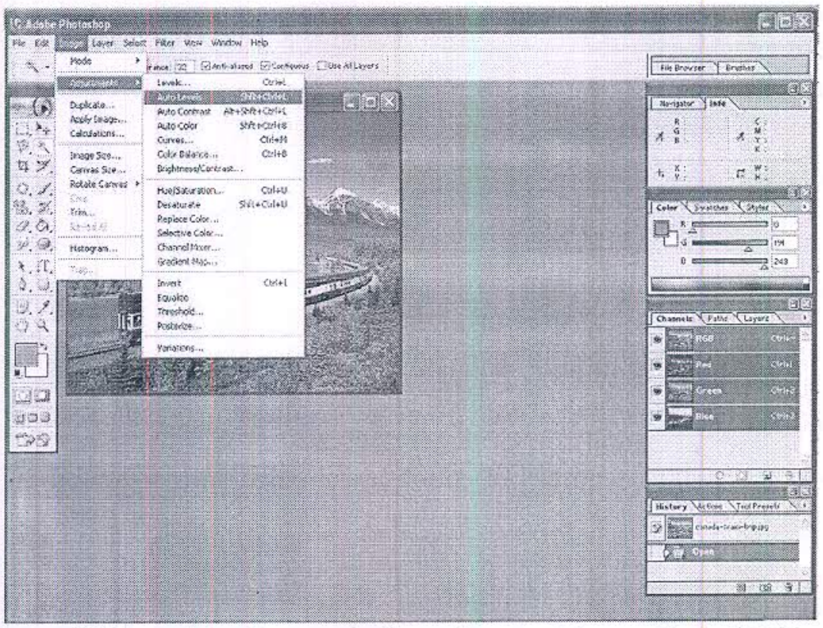
Layer order- Images in the Photoshop come in the order of their layers present in layer palette. In the picture, layer 2 will be displayed over layer 1 and the order of layers can be changed by simply dragging and dropping the layer in layer palette to adjust which layer appears over another.

Grouping- layers menu>group or layers menu>ungroup. If one wants to make one image out of several layers and want them to separate later on then group and ungroup is the best option.

Flattening- (layer>flatten)This is similar to grouping option but the main difference is that one cannot separate them later on as the layers are permanently compressed into one image.

Blending options- Layer menu> Blending options. Blending options like drop shadow, inner glow, outer glow, embossing etc. gives interesting effects.

Adjustment layer- This is an image based effect. Adjustment effect can be selected by double clicking on the adjustment layer icon in the layers palette or Image>adjustments which bring up a menu in which one can adjust levels, brightness/contrast or color balance associated with the particular layers.



Arrangement- Layers menu> arrange. It is used in the reordering of several layers in a single photoshop picture. It provides 4 options. "Send to back" send the selected layer to bottom most position. "Send backward" send the selected layer one space backward. "Bring forward" bring the selected layer one space forward. "Bring to front" bring the selected layer to the topmost position.

Making Flat sketches with Adobe Photoshop

Scanning the hand drawn flat sketch or drawing flat sketch using paint-oriented tools and then adding color into it.

Cleaning the scanned Picture: One can convert the images-

- **Black & White image to color images:** First open the image (Ctrl + O). Next make the image into duplicate. Next select image. Go to image menu> mode> RGB mode. Next go to image menu> adjustment> variations. Select any color. Click on ok.

- **Color to black & white image:** First open any image. Make in to duplicate. Go to image menu> mode> gray scale option.
- **Removing patches:** First open the image. Next make the image into duplicate. Next select any patch tools. Next select the patch. Next click & drag on the clean area. Like this remove all patches.

Note: Press Ctrl + shift + I for inverse selection. Ctrl + shift + U for B & W or go to image menu→adjustment→click on desaturate.

Adding color to scanned picture according to the desired color scheme

- **Filling solid color**: First select the area using any one of the selection tools. Next fill the color using painting tools after selecting color in foreground square. Right click on the image> dialog box opens (alter the size of the tool) and fill the color in the image. Eyedropper tool can be used to pick colors from any of the images.
- **Filling pattern**: One can use pre-defined pattern or can create new patterns (Edit menu>Define pattern).

In the present study, Adobe Photoshop techniques will be used and which are found to be better in comparison to Corel Draw and Adobe Illustrator in terms of-

- Quick response
- High resolution
- More user friendly
- Variety
- Compatibility with various soft wares

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Designing and development of scarves

In men's and women's fashion, there is one accessory that is often completely overlooked, yet can offer endless possibilities for enhancing the look of your wardrobe. That accessory, of course, is the scarf. A scarf is a piece of fabric worn around the neck, or near the head or around the waist for warmth, cleanliness, fashion or for religious reasons. It is also known as a Kremer, muffler or neck-wrap.

Ancient Rome is one of the first origins of the scarf, where it was used to keep clean rather than warm. It was called the '*Sudarium*', which translates from Latin to English as "sweat cloth", and was used to wipe the sweat from the neck and face in hot weather. They were originally wrapped by men around their neck or tied to their belt. Afterwards women started using the scarves, which were made of cloth but not made of wool, pashmina, or silk, and ever since the scarf has been fashionable among women.

Categorization of scarves:

By season and material: Wool, Cashmere, Pashmina, Mohair, Cotton, Linen, Jersey, Silk, Polyester etc.

By shape and length: Square scarf, Rectangle scarf, Infinity scarf and Shawl or Wrap

By function: Head Scarves, Winter Scarves, Beach Scarves, Neck Scarves

By design: Hand Painted Scarves, Printed Scarves, Beaded Scarves, Embroidered Scarves

Sizes of Scarves:-

Bandannas & Neckerchiefs - commonly 22"x22" (56x56cm) squares of cotton, but can be of any fabric.

Shawls - rectangles (generally length is 1-1/2 times the width) or large squares folded as triangles.

Stole - presumed a rectangle significantly longer than it is wide and well covers the arms and shoulders.

Wrap - fully wraps the figure, generally twice the length of the width.

Blanket - as wide as the manufactured goods allow.

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In this research work, an attempt will be made to develop fashionable face covering scarves using various fashion presentation tools such as mood boards, story boards and flat sketches developed with the help of CAD technique i.e. Adobe Photoshop and Corel Draw.

Methodology:

Cotton, viscose filament and union fabrics face covering scarves are pretreated with optimized parameters. After that these face covering scarves are to be painted or printed with different techniques like hand painting, stencil printing, tie & dye etc. This section mainly covers the elegant motif designing process suitable to scarves. Different steps which are followed for scarves designing are:

Design Research (Questionnaire)
Selection of theme based on the questionnaire
Selection of mood board for further designing
Designing of story board
Implementation of final designs on scarves.

On the basis of questionnaire results from respondent, different themes and designs will be selected. After selection of themes, mood boards will be developed. Finally, scarves article will be designed as per the final story board.

Flat sketches

Rectangular scarf flat sketch

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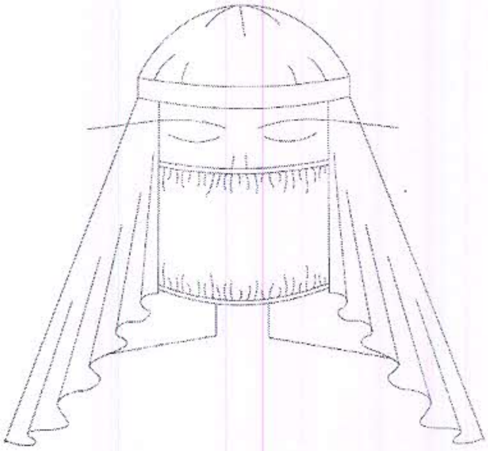
Square scarf flat sketch



Face covering article 'A' flat sketch, front

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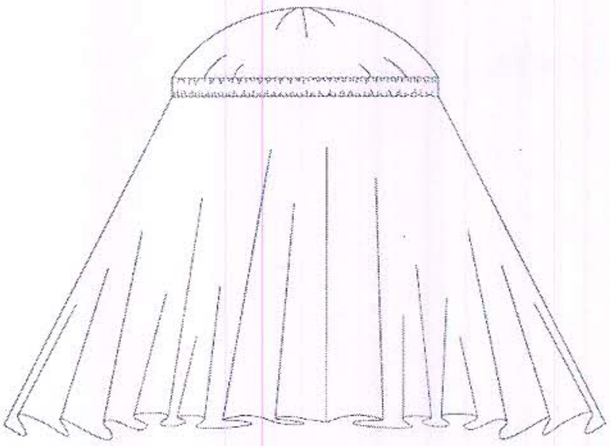
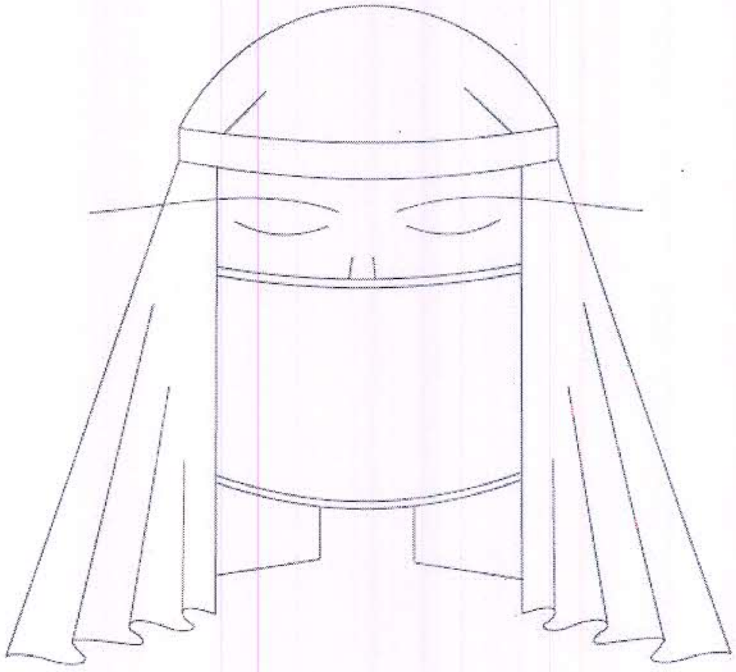


Face covering article 'A' flat sketch, back



Face covering article 'B' flat sketch, front

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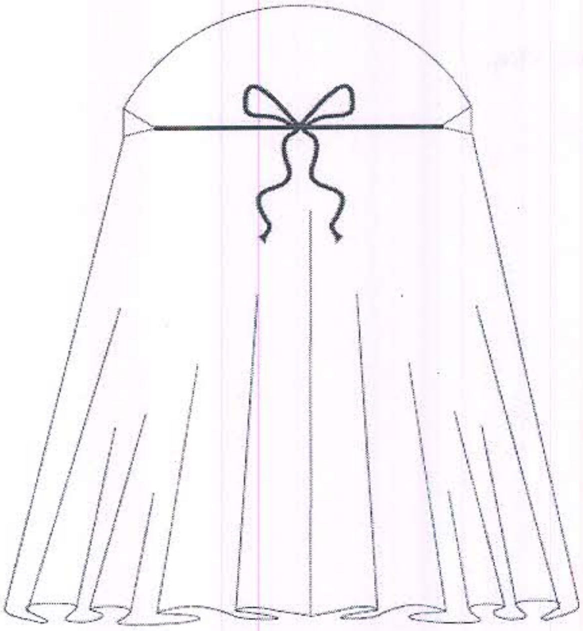
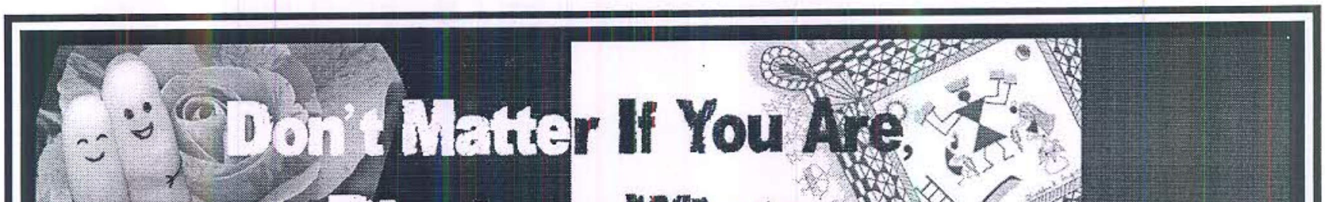


Face covering article 'B' flat sketch, back

Mood Boards



Mood board for theme Black-n-White with Orange

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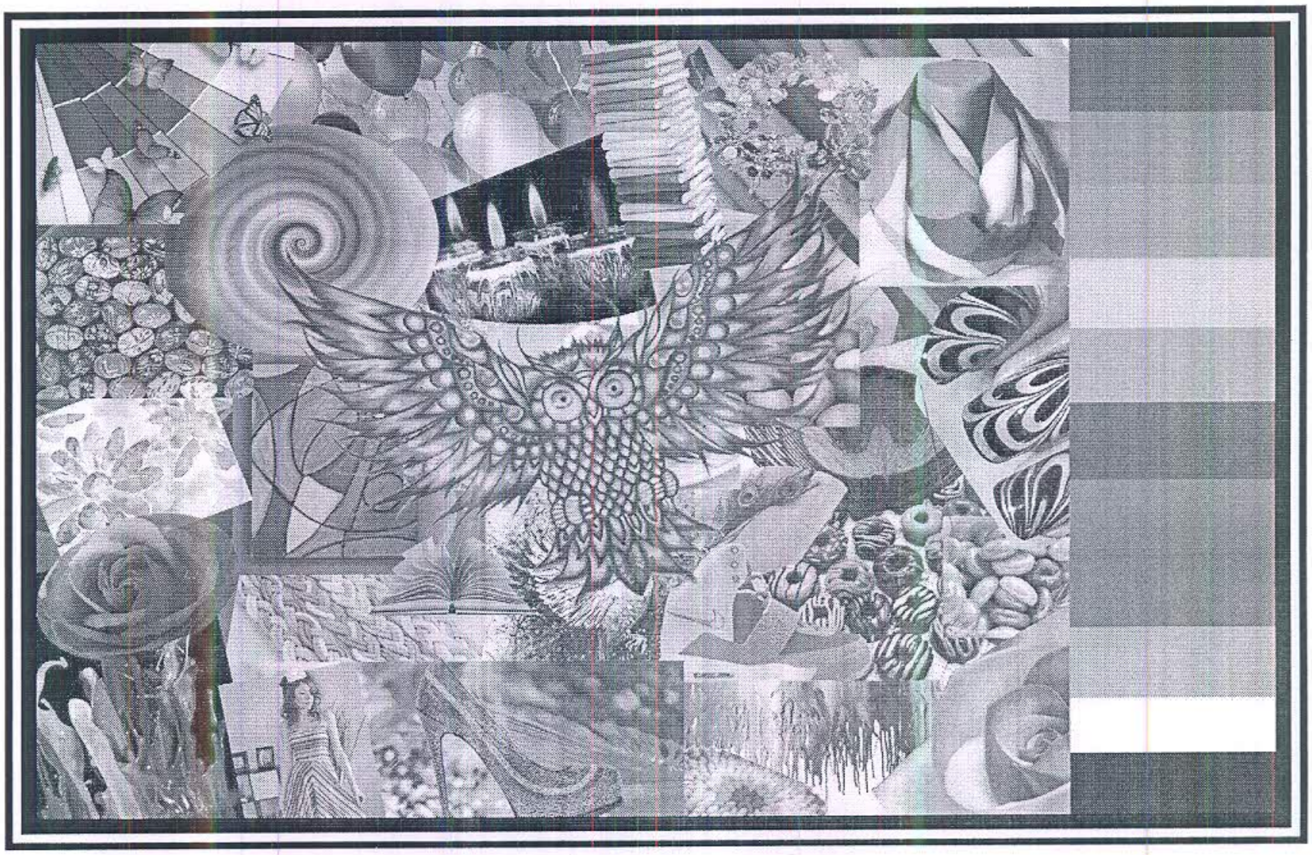

Mood board for theme Rainbow

Story Board:

Story board with white-n-black & orange color theme

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APPENDIX

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APPENDIX: PHOTOSHOP PROGRAMME DETAILS

To start

Start→programs→Adobe Photoshop

Shortcut keys

Ctrl + N	:	New document
Ctrl + shift+ N	:	Layer creation
F7	:	Layer palette
G	:	Gradient tool
Ctrl+ T	:	For free transform
Ctrl + backspace key	:	To apply background color
Alt+ backspace key	:	To apply foreground color

Note: instead of backspace key we can use delete button.

Ctrl+ D	:	For deselect
Ctrl + J	:	For duplicate.
Ctrl + E or ctrl+ shift+ E	:	Merge layers
Ctrl+ enter	:	For selection
Ctrl+ alt+ D	:	For feather
D	:	To apply black & white color to foreground &background
X	:	Swap to foreground to background
V	:	For move tool
Tab key	:	To hide all tool boxes
Ctrl+ {	:	To get back object
Ctrl+}	:	To get front object for full screen mode (3 times F)
Ctrl+Alt+ Z	:	For undo (10 times)

New Document

First press Ctrl + N for new document or Go to file menu> new (Set the page size: A4 or 800 * 600, width: 800 pixels, height: 600pixels, resolution: 72, color mode: RGB, background contents: white). Click on ok.

Duplicate an image

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One can duplicate an entire image (including all layers, layer masks, and channels) into available memory without saving to disk.

Procedure

a. Open the image you want to duplicate.
b. Choose Image →Duplicate.
c. Enter a name for the duplicated image.
d. Click OK.

Layer Palette (F7)

To modify any created objects one has to create the layers. One can take number of layers.

Window menu→ layer palette.

Note

- One layer should be for one object only
- One can hide the layer by pressing eye button in layer palette

Free Transformation (Ctrl + T)

This option is used to change the size of the object and also flip the object in different angle, rotate, skew, distort etc. Edit menu→free Transform.

Photoshop tools and functions

Move tool (V)

This tool is used to move the created object & image. It is also used to select the images & objects. This tool is also called as pointer tool & pick tool.

Marquee tools

This tool is used to create the object in the document. Four types of marquee tool are there which are-

- Rectangle marquee tool (M)
- Elliptical Marquee tool (shift+ M)
- Single row marquee tool
- Single column marquee tool

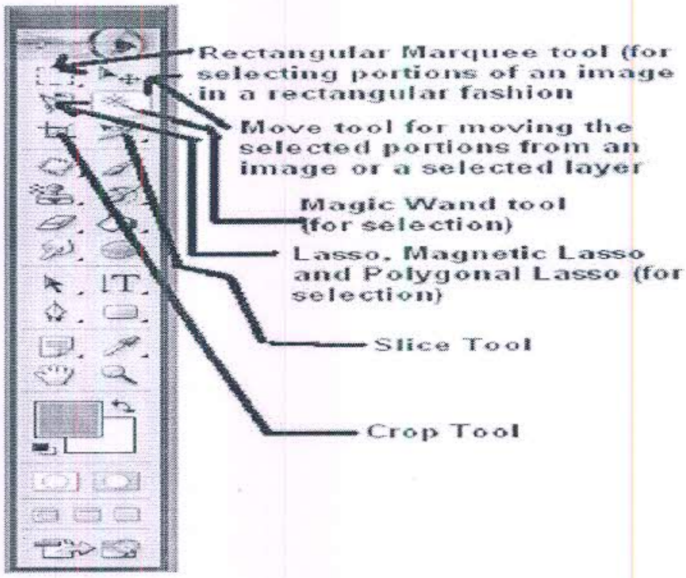
For this tool, the shaping option in optional bar is available. They are: New selection, Add to selection, Subtract from selection and Intersect with selection. To select this option, go to optional bar.

Lasso Tool (L)

This option is used to select the images without background. In this option, three types of tools are available which are-

Lasso tool (L): This tool is used to select the image with free hand.

Polygonal Lasso tool (shift+ L): This tool is used to select the image with straight line only. To delete any selection press backspace key.



Magnetic Lasso tool (shift+ L): This is also used to select the image based on the pixels. One can delete the selection by pressing the backspace key.

Magic Wand tool (W)

This is also used to the images without the background. To use this tool, select the image single color background only.

Crop tool

This tool is mostly for a stamp size photo purpose or to cut the images from the document or to select the particular part from images.

Eraser tool

This option is used to erase the created object in your document. Three types of eraser tool are available which are-

Eraser tool (E): This option is used to erase the object of created in the document.

Background eraser tool (shift +E): This option is used to erase the background of the document. It displays the transparent document.

Magic eraser tool (shift+ E): This tool is just the magic wand tool. This tool is also used to erase the single color background of images of any document.

Text tool

In this application, four types of text tool are available which are Horizontal Text tool (T), Vertical text tool (shift+ T), Horizontal mask text tool (shift+ T) and Vertical mask text tool (shift +T).

Toolbox overview

A Selection tools
- ■ Move (V)*
- ■ Rectangular Marquee (M)
- Elliptical Marquee (M)
- Single Column Marquee
- Single Row Marquee
- ■ Lasso (L)
- Polygonal Lasso (L)
- Magnetic Lasso (L)
- ■ Quick Selection (W)
- Magic Wand (W)

B Crop and slice tools
- ■ Crop (C)
- ■ Slice (K)
- Slice Select

C Retouching tools
- ■ Spot Healing Brush (J)
- Healing Brush (J)
- Patch (J)
- Red Eye (J)
- ■ Clone Stamp (S)
- Pattern Stamp (S)
- ■ Eraser (E)
- Background Eraser (E)
- Magic Eraser (E)
- ■ Blur (R)
- Sharpen (R)
- Smudge (R)
- ■ Dodge (O)
- Burn (O)
- Sponge (O)

D Painting tools
- ■ Brush (B)
- Pencil (B)
- Color Replacement (B)
- ■ History Brush (Y)
- Art History Brush (Y)
- ■ Gradient (G)
- Paint Bucket (G)

E Drawing and type tools
- ■ Pen (P)
- Freeform Pen (P)
- Add Anchor Point
- Delete Anchor Point
- Convert Anchor Point
- ■ Horizontal Type (T)
- Vertical Type (T)
- Horizontal Type Mask (T)
- Vertical Type Mask (T)
- ■ Path Selection (A)
- Direct Selection (A)
- ■ Rectangle (U)
- Rounded Rectangle (U)
- Ellipse (U)
- Polygon (U)
- Line (U)
- Custom Shape (U)

F Annotation, measuring, and navigation tools
- ■ Notes (N)
- Audio Annotation (N)
- ■ Eyedropper (I)
- Color Sampler (I)
- Ruler (I)
- Count (I)†
- ■ Hand (H)
- ■ Zoom (Z)

Horizontal & vertical text tool

This tool is used to type the text in the document. For these two tools, no need to create a layer, it automatically displays layer.

Horizontal &Vertical text mask tool

It is also used to type the text. For these tools, create a layer & then type the text.

Boarder text

It is used to type only the outline text. To type the boarder texts select the masking text tools.

Brush tools

In this option one can apply painting to the document. Three types of brush tool are available which are-

Brush tool (B)

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This tool is used to paint the image in the document. To apply any color to brush, select the foreground color & background color.

Pencil brush tool (Shift + B)

This tool is also same like the brush tool. But it display in the hard type of brushes.

Color replacement tool (Shift + B)

It is also used to apply the painting to the images. In this option one can apply single color.

Pen tool

This tool is used to select the image without any background. It is same like the lasso tools. Two types of pen tools are available which are-

Pen tool (P)

It is used to select the image with any background. To convert into selection mode→press ctrl+ enter key. To delete any selection press backspace key.

Free from pen tool (Shift+ P)

This tool is just like the lasso tool. This is also used to select the image with free hand.

Magnetic pen tool is the extra added advantage under this tool. To select this tool, go to optional bar & tick mark to magnetic option. With this tool, one can select the image automatically.

Custom shape tool (U)

In this one can create a different shape in the document. To select different shape, go to optional bar. Next click & drag on the document. In this tool, six options are provided which are-

a. Line tool (U)
b. Rectangle tool (Shift+ U)
c. Ellipse tool (Shift+ U)
d. Polygon tool (Shift+ U)
e. Rounded rectangle tool (Shift + U)
f. Custom shape tool. (Shift+ U)

Spot healing brush tool

This option is used to delete the patches from the images. To delete any patches, first click on clean area. Then click on patch area.

Healing brush tool

This tool is also used to delete the patches from images by holding the alt key.

Patch tool

This tool is used to delete the patches by selecting the patches & dragging into clean area.

Clone stamp tool

This tool is same like the healing brush tool. For this tool also hold the alt key & click on clean area. Then click on patch area.

Blur Tool (R)

This is to delete the edge part of the objects & images. It can be used for only the selected part.

Sharpen tool (Shift+ R)

This tool is used to apply on the jewellary to get the shining in the necklace.

Smudge tool (Shift +R)

This tool is used to expand the objects.

Dodge tool (O)

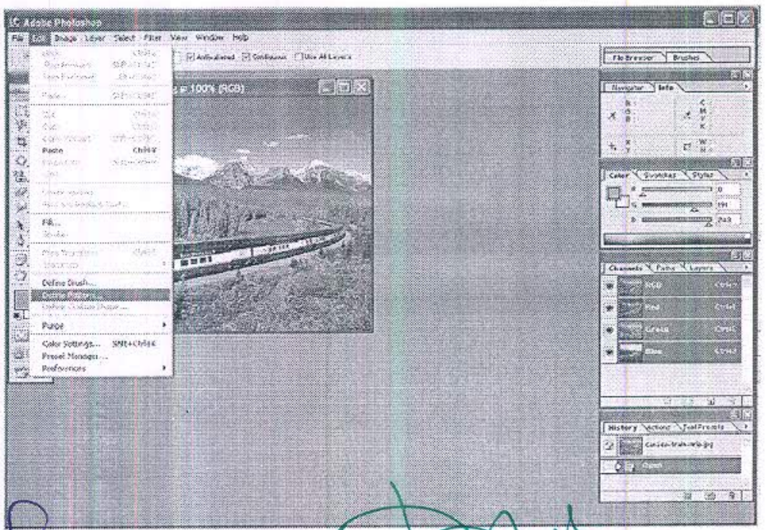
It is used to delete the dark color from the image & it will apply the lighting to images.

Burn tool (Shift+ O)

This tool is used to apply the dark color to the images.

Sponge tool (Shift+ O)

This tool is used to convert the images into white. It will delete the reddish colors from the images.



Pattern stamp tool (s)

In this tool, two types of patterns are there which are:

Define pattern tool- This option is used to create the patterns in the document. This tool can be accessed by Edit> Define Pattern.

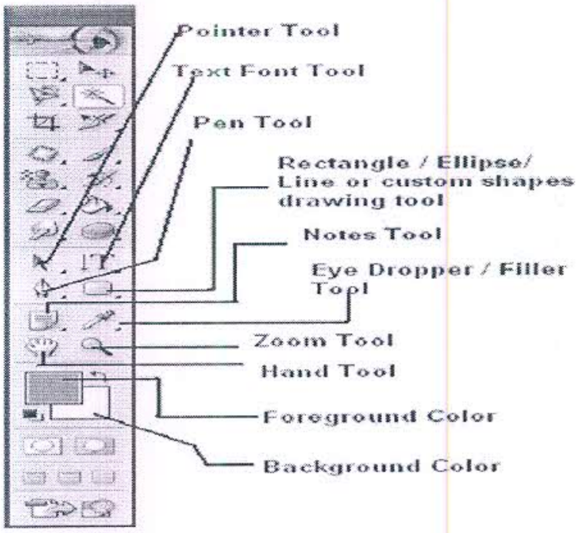
Pre-define pattern tool- In this option one can get already created pattern in the document.

Notes tool

This tool is used to write the notes of the design. To select this tool, go to property bar.

Eyedropper tool

This tool is used to select the colors from the images & apply the selected color to the objects & back ground.



Color sampler tool

It is used to display the sampler pointer in the images.

Measure tool

It displays the measurement of the created objects in property bar.

Hand tool (H)

It is used to move the total document.

Zoom (Z)

It is used to increase the size of the document or image. To get normal window. press Ctrl + 0 (Zero).

Art history brush tool (shift+ Y)

This option is used to convert the image into painting images.

History brush tool (Y)

This option is used to clear the images. It will convert into normal image.

Path selection tool

This tool is used to select the object. To use this tool create the object with pen tools & custom shape tools only.

Direct selection tool

This tool is also same like selecting the objects & also one can modify the objects without any layers.

Slice tools

In this option one can crop the image into a number of copies. They are of two types:

1. Slice tool- It is used to crop the images.

2. Slice select tool- It is used to adjust the selected parts.

Main Filter effects in fashion design presentation boards

Multiple filter effects can be applied to a single layer. First select a layer. a) Filter menu> Liquify to experiment with the silhouettes and flow of the garment, b) Artistic effects: Filter>artistic>select an effect, c) Rendering effects: Filter>render>lens flare or Filter>render>lighting effects (adjusting the focus of the viewer). One can experiment with other filter effects like blur, brush stroke, pixelate, sharpen, sketch, texture video etc. to create magical and interesting effects.

TENTATIVE BUDGET FOR COTTON-VISCOSE FILAMENT FACE COVERING SCARVES PROJECT-2018

A. Recurring Budget:

S.N.	Items	1st Year (In Lakhs)	2nd year (In Lakhs)	3rd year (In Lakhs)	4th year (In Lakhs)	5th year (In Lakhs)	Total (In Lakhs)
1.	Manpower						
a.	Principal Investigator @Rs.20,000/-p.m.	3.00	3.00	3.00	3.00	3.00	15.00
b.	Co-PI @Rs.10,000/-pm- 2 persons	2.40	2.40	2.40	2.40	2.40	12.00
c.	PCs- 4 persons @Rs. 5,000/-p.m.	2.40	2.40	2.40	2.40	2.40	12.00
d.	PAs- 4 persons @Rs. 2,500/-p.m.	1.20	1.20	1.20	1.20	1.20	6.00
e.	PCAs- 3 persons @Rs. 2,000/-p.m.	0.72	0.72	0.72	0.72	0.72	3.60
2.	Consumables for product development.	1.00	1.00	2.00	2.00	2.00	8.00
3.	Travel @Rs.50,000/- per year	0.50	0.50	0.50	0.50	0.50	2.50
4.	Contingencies @10%	1.20	1.20	1.20	1.20	1.20	6.00
5.	Overheads @15%	2.00	2.00	2.00	2.00	2.00	10.00

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	Sub Total for 'A'	**14.42**	**14.42**	**14.42**	**14.42**	**14.42**	**72.10**
B. Capital Component (Non-Recurring)							
B.1	KES-F apparatus @Rs. 250 Lakhs				250.00		250.00
B.2	Digital printing m/c @Rs. 50 Lakhs			50.00			50.00
B.3	Knitting m/c @Rs. 30 Lakhs	30.00					30.00
B.4	Weaving m/c @Rs. 40 Lakhs	40.00					40.00
B.5	Braiding m/c @Rs. 10 Lakhs		10.00				10.00
B.6	Laptop @Rs 40,000/-		0.40				0.40
	Sub Total for 'B'	**70.00**	**10.40**	**50.00**	**250.00**		**380.40**
	Grand Total 'A' & 'B'	**84.42**	**25.82**	**64.42**	**264.42**	**14.42**	**452.50**

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Manpower requirement:

1. Dr. K.N.Chatterjee
2. Dr. Suman Bhattacharyya
3. Dr. Amandeep Kaur
4. Ms. Shelly Khanna
5. Dr. Jamini Jhanji
6. Mr. Ashish Bhardwaj
7. Dr. Amal Chowdhury
8. Mr. Saumen Bhattacharyya
9. Dr. Ajit Pattnayak
10. Mr. Dipankar Das
11. Mr. Amit Madhu
12. Ms. Ambika Madaan
13. Mr. Kirti Kumar
14. Mr. Ramniwas

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STUDIES ON COMFORT CHARACTERISTICS OF KNIT STRUCTURES & DESIGNING OF FUNCTIONAL ACCESSORIES USING VISCOSE FILAMENT YARN FROM KESORAM INDUSTRIES LIMITED (KIL)

By:

Dr. K.N.CHATTERJEE,
PROF. & HEAD, FASHION & APPAREL ENGINEERING,
TIT&S, BHIWANI

Submitted to:

KESORAM INDUSTRIES LIMITED (KIL) ,
KOLKATA

Submitted by:

THE TECHNOLOGICAL INSTITUTE OF TEXTILE & SCIENCES,
BHIWANI

Director,
THE TECHNOLOGICAL INSTITUTE
OF TEXTILE & SCIENCES, BHIWANI

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Contents:

- **Introduction**
- **Objective**
- **Literature review**
- **Materials and methods**
- **Results and discussion**
- **Designing and development of functional accessories**
- **Conclusions**
- **Scope of work**
- **Questionnaire survey and feedback from respondents**
- **Bibliography**

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CHAPTER 1

INTRODUCTION & OBJECTIVES

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INTRODUCTION:

- **Knitted fabrics owing to their excellent stretch ability, good handle and comfort properties.**
- **Clothing comfort depends on several factors, one of them being thermal comfort.**
- **Moreover knitted fabrics are also finding wide spread application in accessory industry parts particularly those intended for next to skin application fulfilling the requirement of ease of passage of air, moisture vapor, liquid moisture and heat through them.**
- **Next to skin accessories like socks, gloves, hats etc have to be designed with appropriately engineered fabrics so as to achieve comfort as well aesthetic characteristics.**
- **The fibers, yarn and fabric variables (finishing and printing technique) affect the fabric structure and hence the overall physical and comfort properties of apparel and accessories designed from the engineered fabrics.**
- **Finishing treatments influence not only the fabric properties like porosity, air passage but also the aesthetic appeal.**
- **Today's aware consumer gives weightage to performance, functionality as well as aesthetic appeal and surface ornamentation of end products.**

1. The role of physiological comfort in clothing functionality

The relationship between clothing and comfort sensation is a vast and complex subject as it involves both physiological and psychological dimensions. During the last two centuries social, economic, political and technological developments have honed the functionality of clothing and what it means to feel 'comfortable' in one's attire.

1.1 Comfort and the functionality of clothing

The fundamental role of clothing is to satisfy both psychological and physiological needs of the wearer independent of culture, time and activity. These motives were originally identified in the 1930's as decoration, protection and modesty by English academic psychologist John Flügel. Although it is unclear whether it was psychological or physiological pressures that drove the invention of the first clothing (Flügel, 1971, Ryder, 2000), there is no doubt that the two are inextricably linked.

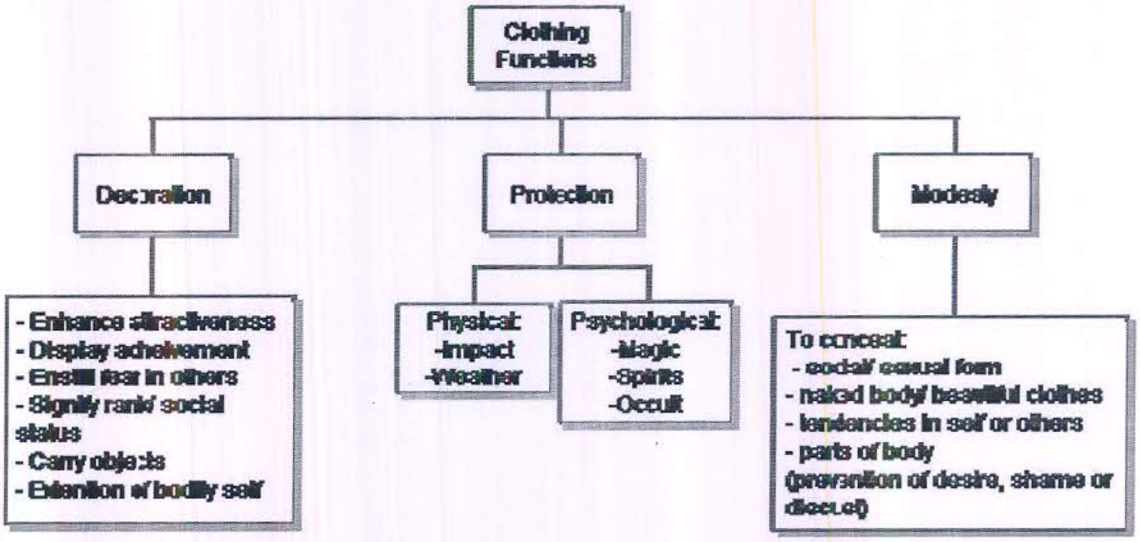

Figure 1: Map of clothing functionality

Figure 1 illustrates the complex nature of clothing functionality but is by no means exhaustive; this study is concerned only with the physiological functionality and in particular the factors that affect comfort, so for purposes of simplicity I will not reference work conducted in the psychological sector.

1.1.1 Physiological comfort

The sensation of comfort from clothing was the subject of great debate (Renbourn, 1971, Kemp, 1971, Greenwood, 1971) among the textile sectors in the 1970's; its vague nature made it impossible to define. It was, however, agreed that there are both psychological and physiological dimensions to the experience (Slater, 1977).

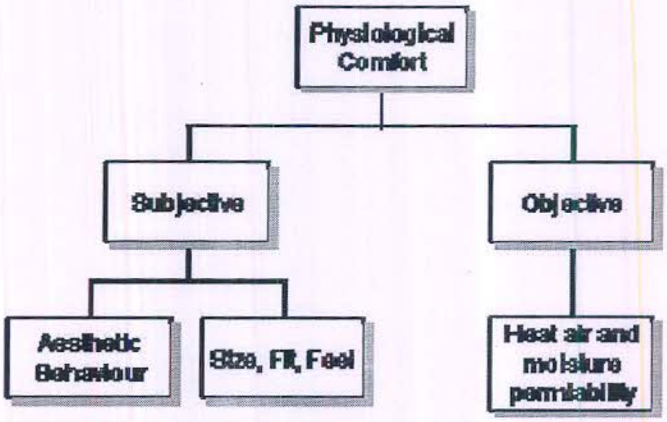

Figure 2: Physiological comfort: effect of textile properties

Physiological comfort, which is the focus of this study, is further defined by both objective and subjective factors as illustrated in figure 2. The subjective factors include the size, fit and aesthetic behaviour of the garment such as drape [1]. The objective aspect is defined by the garment's performance in relation to the external conditions and activity of the wearer and particularly the clothing's permeability to heat, moisture and air (Slater, 1977).

Objectives:

To study the effect of fiber, yarn, fabric variables and finish application on physical and comfort properties of rib knit structure and design and development of functional accessories.

- The above stated objective was fulfilled by:
- Varying fiber type
- Varying filament denier
- Varying loop length
- Varying knit structure
- Application of hydrophilic/hydrophobic finish and antimicrobial finish
- Digital printing on developed fabric sample
- Design and development of functional accessories
- Subjective evaluation of developed accessories

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CHAPTER 2

LITERATURE REVIEW

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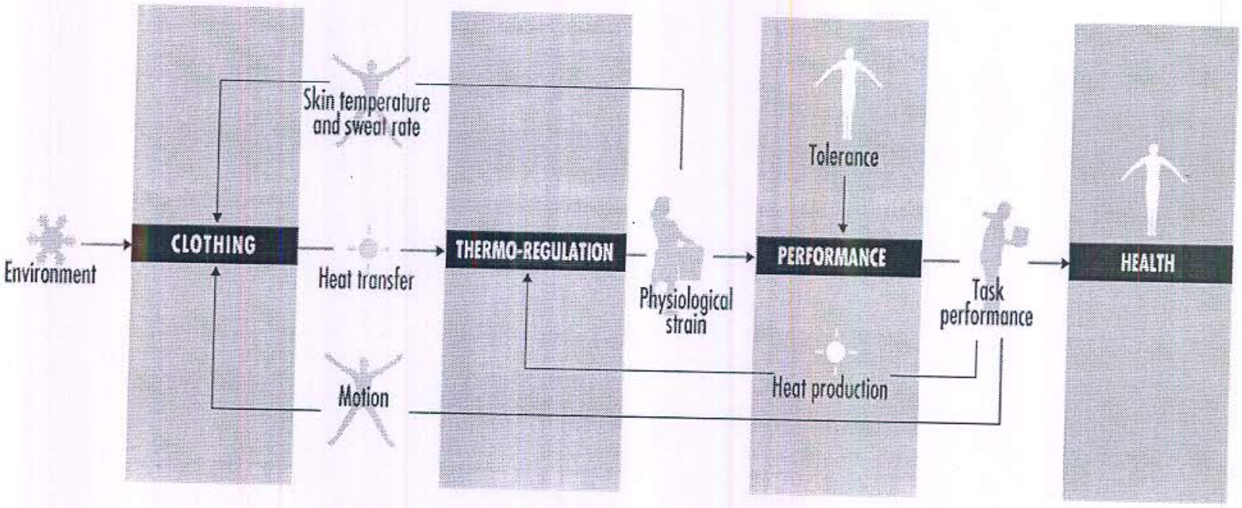
Chapter 2

Literature review

Comfort:

Comfort is related to how an individual feels. There are three main aspects for analyzing comfort of any fabric

- The first aspect of comfort is thermal comfort
- Tactile sensation is second aspect of comfort
- Third component of comfort is related to the fit of the garment.



Heat Loss:

- There are 4 mechanism that allow the body to lose heat to the environment in order to maintain its thermal balance.
- The way the heat loss is divided between the mechanism depends on the external environment.
- Conduction
- Convection
- Radiation

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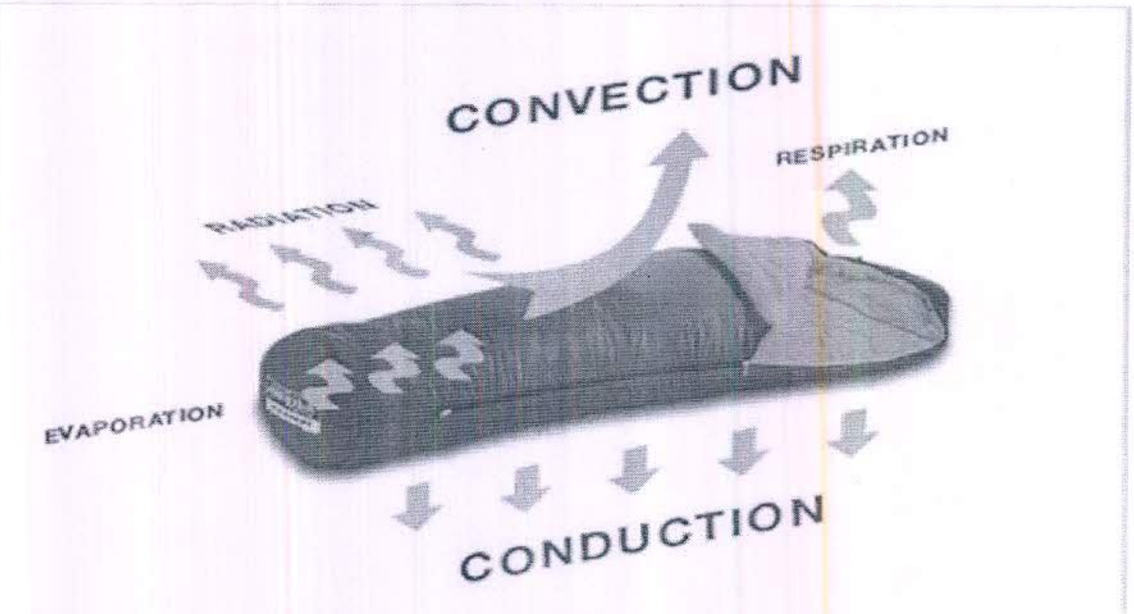
- **Evaporation**



Heat Generated= Heat loss through convection, conduction, evaporation and radiation

Now a days, people are paying more attention to sports activity and that the market for sportswear continues to expand, those engaged in developing sportswear solutions in this field must therefore feel encouraged to produce an adequate response to these increasingly demanding expectations. The consumers seem to be prepared to spend considerable amounts of money on sportswear and other functional fabrics, which have made the market attractive to many producers. Many researchers and industries are engaged to develop the functional wear e.g., active sportswear.[9]

Recently more numbers of sports have been invented and also many of the old sports have been again popular. The highly competitive world of sports has increased awareness among the professional sports persons, who use to demand more specific functions to be performed by sportswear in real time to increase their efficiency. Consumers demand high levels of comfort, design and easy care in all types of clothing. But the performance requirements of many sports goods often demand widely different properties from their constituent fibres and fabrics, such as barrier to rain, snow, cold, heat and strength and at the same time these textiles must fulfill the consumer requirements of drape, comfort, fit and ease of movement. The main requirements for active sportswear can be classified in two main categories:

2.2: Requirement of active sportswear :-

- Functional requirements:
  - Super lightweight
  - Super high tenacity
  - Stretchability to provide the freedom of movement necessary in sports
  - Good water vapour permeability to ensure that the body vapour passes outward through all layers of the clothing system, prevention of feeling of dampness
  - Optimum heat regulation to maintain body temperature
  - Dimensional stability, even when wet
  - Protection from wind, cold and adverse weather conditions
  - Quick drying to prevent catching cold
  - Water proofing
  - UV resistance
- Aesthetical requirements:
  - Soft and pleasant to skin
  - Lustre, color variation
  - Comfort in wear

A functional requirement of performance sportswear depends on nature of sport, climatic conditions and amount of physical activity. Sportswear must protect the human body from the environment and at the same time, support mobile functionality and comfort, when worn by the wearer. Garments worn in sporting activities have different properties and performances attributes according to the activity carried out (as shown in Table- 2.1). For example, in sports like football and basketball where there is intense multi-directional activity, loose-fitting and comfortable clothes are required; in activities such as swimming and cycling where speedy body movements are important, skin-tight or well-fitting clothes are preferred. And also if the weather is cold, the clothing must exhibit a high level of thermal insulation, but when the wearer is hot the level of thermal insulation must be low.[8, 9]

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Table- 2.1: Required functions of the main sportswear [8]

Sportswear	Required Function
Shirts for tennis, volleyball, golf, football, rugby, baseball uniform, tracksuits etc.	Sweat absorption and transfer, fast drying, cooling.
Skiwear, wind breakers, rainwear	Vapour permeability, water proofing
Skiwear, wind breakers, tracksuits	Sunlight absorbing and thermal retention
Swimming race and skating costume, ski jump and downhill skiing suits, cycling costumes	Low fluid resistance (for water and air)
Skiwear, snowboard wear, football and baseball uniform	High tenacity, water vapour permeability, evaporative heat transfer, quick drying and maintaining body core temperature.
Swimwear, leotards, skating costume	Stretchability, opacity

The latest sports textile materials are much more functional in fulfilling specific needs in different sports activities. Developments in active sportswear fabrics has been progressing to perform high functions and to achieve comfort. The sportswear manufacturing textile industries use the innovative textile science and technology in the manufacturing of active sportswear fabrics to fulfill the requirements for athletics and leisure activities for their better performance in the sports.

Comfort, design and easy care are the main expectations from sportswear cloths. But garments worn in sporting activities have different properties, and performances attributes according to the activity carried out. The required functions of sportswear fabrics differ in different situations such as type of sport, environmental conditions and level of activity.

2.3: Comfort characteristics:-

The most important property of any apparel is comfort. It is a qualitative term and it is one of the most important aspects of clothing. Comfort plays a vital role in the selection of apparel. Comfort is one of key requirement of sportswear. Comfort as a fundamental and universal need for consumers. It is defined as a pleasant state arising out of physiological, psychological and physical harmony between a human being and the environment.

All three aspects are equally important since people feel uncomfortable if any one of them is absent. Comfort is not a property but a state or condition of mind. Clothing comfort is an extremely complex phenomenon resulting from the interaction of various physical and nonphysical stimuli on a person wearing given clothing under given environmental conditions.[10]

2.4: Classification of comfort:-

The clothing comfort can be divided into three groups that are as follow:-

1. Physiological or Tactile comfort
2. Psychological or Aesthetic comfort
3. Thermo-physiological comfort

2.4.1: Physiological comfort:-

Tactile/Sensorial comfort deals with the mechanical sensations caused by textiles as it is in direct contact with the skin. Garments should be soft and pliable during wear and especially when damp, should not prickle/ irritate or cling to the body. To a lesser extent, sensorial comfort can be improved by the control of odour and by the use of UV resistant materials. Waterproofing can improve sensorial comfort but may impair. The ease of body motion and the level of load generated in fabric during body movement are obviously related to the fabric handle properties, and therefore a study of clothing tactile comfort must take into account the fabric low-stress mechanical properties. It is concerned with the subjective judgment of roughness, smoothness, harshness, pliability, thickness etc[12,13]

2.4.2: Psychological comfort:-

Aesthetic comfort or Psychological comfort implies that individuals need specific garments, fabrics, colors and design features to help them feel confident. It is mainly related to the latest fashion trend and the acceptability in society and bears little relation to the properties of the fabrics Where garments are worn during strenuous activity, psychological comfort also occurs when the garment is extensible and does not restrict mobility. Body movement is characterized by the fit of the clothing and the freedom of movement it allows. The garment's construction and the elasticity of the materials are the main aspects.[12]

2.4.3: Thermo physiological comfort:-

The thermal comfort is related to the ability of a fabric to maintain the temperature of the skin through transfer of heat and perspiration generated within human body whereas tactile comfort has relationship with fabric surface and mechanical properties. Distinguished aspect of wear comfort of clothing is "thermo physiological wear comfort" which concerns the heat and moisture transport properties of clothing and the way it helps the clothing to maintain the heat balance of the body during various levels of activity. Moisture management often refers to the transport of both moisture vapour and liquid away from the body. So moisture management can be defined as the controlled movement of water vapour and liquid water (perspiration) from the body to the atmosphere through the fabric[8,9&10]

When sports persons are engaged in physical activities under dynamic/transient conditions, liquid water appears in the clothing systems due to sweating and/or condensations, which can cause significant changes in the thermal properties of clothing materials and temperature/moisture distributions in the clothing system. Hence, the management of water vapor transfer and liquid water transfer can become critically important in the design of clothing systems. The performance of sportswear can be greatly improved if it is systematically designed. The water vapor permeability and moisture management of fabrics are indeed very important to prevent water condensation in the clothing and ultimately ensure improved superior thermal functional and comfort performance.[8]

Sportswear garments that perform or function for some purpose help active people to keep cool, comfortable and dry through moisture management and other techniques. In a normal situation, human beings restore a correct balance of heat exchange, modifying the environment. However, outdoor activities are more demanding in terms of thermal balance, and the ability of recovering the thermal balance is more difficult to achieve.

For that reason, active sportswear should provide sufficient heat transfer so that the skin temperature remains within comfortable range.[13]The thermo physiological (thermal) comfort depends on thermal, moisture and air permeability properties.[14] This comprises heat and moisture transport processes through the clothing and directly influences a person's thermoregulation. Thermal interaction between man and environment is highly complex, because the person's perception of thermal comfort is affected by several parameters, such as air temperature, air movement (speed), humidity, clothing, activity level and many other factors. So, thermal comfort stands for the proper relationship between body heat production and loss.[13]

It is expected from a garment to help to protect thermal balance of the body, and to maintain the body temperature and humidity. Garments work as a tampon to conserve body temperature of a human being in different atmospheric conditions.[15] The human body has an operating temperature of 37°C, which it attempts to maintain under varying circumstances. During heavy activities the body produces lots of heat energy and the body temperature increases. Thus, it is necessary to transport heat from the body to the environment so as to maintain the body temperature at 37°C. To reduce the high temperature, the body perspires a lot in liquid and vapour. The insulation properties of a fabric usually decline when the fabric is wet resulting in rapid heat loss from the wearer. This wetting can be both from outside a garment and from inside a garment. During strenuous activity wet fabric can aid in the cooling of hot skin surface. However, once the activity and the excessive heat production stop, this heat loss must be restricted. A wet body cools very quickly leading to post-exercise "chill" or, in extreme cases hypothermia.

Garments that are designed for sportswear and active wear should be dynamic or responsive. Through effective thermoregulation and moisture management a clothing system can maximize heat loss when the wearer is hot, then increase thermal insulation when perspiration stops. In a sports arena, dynamic or responsive garments can enhance performance, control weight build-up in clothing and reduce the potential for skin damage.[16]

In present research work, the thermal comfort parameters (thermal conductivity, thermal resistance, water vapor permeability and air permeability) of fabrics were measured.

2.5: Terms related to comfort:-

2.5.1: Thermal Conductivity:-

Thermal conductivity is a phenomenon which indicates the capability of material to conduct heat from one point to another point. It presents the amount of heat, which passes from 1 m^2 area of material through the distance 1m within 1 sec and create the temperature difference of 1Kelvin (K)

It can be expressed in equation(1) as:

$$Q= \{ \lambda A (t_2-t_1)t\}/ d..........(1)$$

Where, Q= Quantity of heat conducted

λ = Thermal conductivity of the material

(t_2-t_1) = Temp. differential across the material

A = area of surface and d = Thickness of the material

The amount of fiber per unit area increases and the amount of air layer decreases as the weight increases. Thermal conductivity values of fibers are higher than the thermal conductivity of entrapped air. The lower thermal conductivity of fabrics made from the finer counts could be ascribed to the higher porosity value of the fabrics made from finer yarns.

2.5.2: Thermal Resistance:-

Thermal resistance is an important parameter, which is relevant to thermal insulation. It is directly proportional to thickness and inversely proportional to thermal conductivity. It is an indication of how well a material insulates. It is calculated by using equation (2) as:

$$R = d/\lambda......(2)$$

Where, R = thermal resistance offered by the material (m^2K/W), d= Thickness of the material (m) & λ = thermal conductivity of the material (W/mK)

Thermal resistance is a measure of the body's ability to prevent heat from flowing through it. Under a certain condition of climate, if the thermal resistance of clothing is small, the heat energy will gradually reduce with a sense of coolness. If the fabric thickness increases than the thermal resistance is also increases.[15]

2.5.3 Thermal absorptivity:-

Thermal absorptivity (B) is a factor that indicates the ability of the material to regulate as per thermal condition. It allows the objective measurement of warm–cool feeling and determines the contact temperature of two materials.

It can be expressed in equation (3) as:

$$B=(\lambda pc)^{\frac{1}{2}}, (Ws^{\frac{1}{2}}/m^2K)\ldots\ldots(3)$$

Where λ= thermal conductivity (w/MK), p= fabric density (kg/m^3), and c = specific heat of fabric (j/kg k).

When a human touches a garment that has a different temperature than the skin, heat exchange occurs between the hand and the fabric. If the thermal absorptivity of clothing is high, it gives a cooler feeling at first contact. Fabrics with a low value of thermal absorption give us a ''warm'' feeling. Thermal absorption is a surface property and can be changed during finishing processes.[17]

2.5.4: Water vapour permeability:-

Water vapour permeability is the ability to transmit vapour from the body. If the moisture resistance is too high to transmit heat, by the transport of mass and at the same time the thermal resistance of the textile layers considered by us is high, the stored heat in the body cannot be dissipated and causes an uncomfortable sensation Relative water vapor permeability is the rate of water vapor transmission through a material.[52]

2.5.5: Air permeability:-

Air permeability is the rate of air flow passing perpendicularly through a known area under a prescribed air pressure differential between the two surfaces of a material. Air permeability is an important factor used for evaluating and comparing the breathability.[16]

2.6: Textile material and fabric structure for Sportswear:-

2.6.1: Textile fibrous material:-

It is not possible to achieve all required properties for sportswear in a simple structure of any single fiber. The right type of fiber should be in the right place. The behavior of the fabric is mainly depending on its base fibers properties. The most important properties are: fiber type; weave construction; weight or thickness of the material and presence of chemical treatments

2.6.1.1: Types of fibres used in sportswear:-

Selection of fibres or fabrics for manufacturing active sportswear is one big factor influencing performance, efficiency, ensuring protection, and physical comfort. Technological developments have lead sportswear to a state of virtual insanity. There are number of textile fibres used in sportswear both natural and synthetic.

2.6.1.1.1: Synthetic fibres:-

For every active sport, synthetic fibres preferred because they do not retain moisture and therefore do not get heavy upon sweating like cotton does. Synthetic sports uniforms also have better dimensional stability. Synthetic fibres offer the three major requirements in today's high technology sports uniforms:

- Warmth, wind resistance, moisture wicking and lightness
- Comfort and feel of natural fibres
- Style and a variety of colours

2.6.1.1.1.1: Polyester:-

Polyester has outstanding dimensional stability and offer excellent resistance to dirt, alkalies, decay, mold and most common organic solvents. Excellent heat resistance or thermal stability is also an attribute of polyester. It is the fibre used most commonly in base fabrics for active wear because of its low moisture absorption, easy care properties and low cost. Polyester is essentially hydrophobic and does not absorb moisture. However, most polyester used in base layer clothing is chemically treated so that they are able to wick moisture.

2.6.1.1.1.2: Nylon:-

Nylon fibre characteristic include lightweight, high strength and softness with good durability. Nylon also quickly when wet. Nylon is good fabric choice when combined with PU coatings. Nylon has a much higher moisture regain than polyester and therefore has better wicking behaviour. It is most often used in tightly woven outerwear, which can trap heat because of low air permeability. It is also used in more breathable knitted fabrics, where it can perform well. However, it is much more expensive than polyester and is therefore only used in premium applications such as swimwear and cycling wear. Also, because of its higher moisture regain, it dries more slowly than equivalent fabrics made from polyester. Teijin DuPont Nylon has developed a waterproof fabric, Polus-Ex that is permeable to moisture. The material is made by laminating a multi-porous film to a nylon fabric and a moisture permeability of 8000 g/sq.m/24 hours, as well as 20 m head of water.[16]

2.6.1.1.1.3: Polypropylene:-

Polypropylene fibres have very low moisture absorbency but excellent wicking ability. It has good moisture management property due to its hydrophobic nature as polypropylene does not wet out, its thermal insulation is retained during and after strenuous activity which keeping the wearer warm in cold weather and cold in warm weather.

2.6.1.1.1.4: Elastomeric fibres:-

These fibres are frequently used in small quantities in garments to increase stretch and support. For example knitted sportswear contains 3-10 per cent of Elastomeric fibres. It will not affect the Thermo-physiological comfort of garments that contain them.

2.6.1.1.2: Natural fibres:-

2.6.1.1.2.1: Cotton: -

Cotton garments provide a good combination of softness and comfort. However, cotton is not recommended for use in base layer clothing because of its tendency to absorb and retain moisture. When cotton becomes wet, it dries out slowly. This can lead to rapid and undesired heat loss once activity has stopped. However, cotton fabrics are easier to clean than those based on many synthetic fibres.

2.6.1.1.2.2: Wool:-

Wool has good wicking ability and is a good insulator even when wet. However, wool is slow to dry and has a high wet surface coefficient of friction. It also has higher heat releasing and heat absorption properties accompanying moisture absorption and desorption respectively, which strengthens the buffering effect of the clothing between the human body and the surrounding environment.

2.6.1.1.2.3: Silk:-

Silk has good wicking ability and it breaths well because of its hollow structure. Silk also has high thermal conductivity and therefore feels cool to the touch. Silk is not, however, an easy fibre to care for, which is a disadvantage in sportswear that is worn frequently.

2.6.1.1.3: Regenerated fibres for Sportswear:-

2.6.1.1.3.1: Viscose:-

Viscose is more absorbent, 2-3 times more than cotton due to the presence of higher proportion of amorphous material. In addition, the slightly irregular surface of viscose fibres contributes to comfort against the skin when worn. Fabrics composed of viscose fibres, difficult to launder.

2.6.1.1.3.2: Tencel:-

Tencel is the generic name of Lyocell. Lyocell is a natural, manmade fibre produced in an environment friendly process from wood pulp that has become popular in clothing. The moisture management of tencel is unique when compared to synthetic fibres and allows for peak performances in sports. The excellent moisture absorption is perfect for the skin and thus guarantees well being at a very high level.

2.6.1.1.3.3: Bamboo:-

Bamboo fabrics are made from pure bamboo fibre yarns which have excellent wet permeability, moisture vapour transmission property, soft hand, better drape, easy dyeing, splendid colours. It is newly founded, great prospective green fabric. Bamboo fibre has a unique function of anti bacteria, which is suitable to make underwear, tight t- shirt and socks. Its anti – ultraviolet nature is suitable to make summer clothing

2.6.1.1.3.4: Modal:-

It is harmless to the human body, and can decompounds naturally green environmental protection. Modal yarn is the best choice for the top-grade knitting and machine weaving face fabrics. Because of its splendid gas permeability, it is become more and more useable in ladies suit, underwear, sportswear and household textiles fields. Modal yarn fabric's characteristics:

1. Soft, smooth and strong silk feeling

2. Silk like gloss
3. Feel smooth and soft after repeating laundering
4. Wonderful hygroscopicity and gas permeability
5. Flamboyant colour
6. No fibrillation

2.6.1.1.3.5: Soybean:-

Soybean protein contained in the fibre remakes a superior, soft hand endowed with both moisture absorbency and permeability, which makes best application in knits and innerwear. Finishes with an antibacterial agent, health-care functionalities are also given. It has great potential in its use in high-grade knits and innerwear.

2.6.1.1.4: Widely used fibres for sportswear:-

In the past, cotton was widely preferred for a wide range of garments, however with the advent of synthetic fibres, such as polyester, nylon, polypropylene, acrylic, etc. During 1970s created pre-dominant use of polyester fibres in sportswear, which retained its prominence in 80s and 90s.[17]

2.6.1.1.4.1: Polyester:-

It is preferred in sportswear due to its following characteristics:-

- Light Weight
- Cheap To Produce
- Dye Fastness
- Durability
- Easy Care Properties
- Quick Drying
- Hydrophobic In Nature
- Wicking Ability

In addition, the polyester filament fabrics can be given hydrophilic coating. Hence, polyester fibre based fabrics with its hydrophobic core and hydrophilic coating enables it to wick moisture away from its contact from the skin to outer surface to the environment. Polyester is often blended with other natural fibres mainly to extract its benefits to maintain moisture management and durability. European man-made fibres association reported that among man-made fibres polyester is a dominant fibre (WSA, 2012).

Many sportswear brands are progressively moving toward recycled polyester, Adidas was one of the companies who carried out a life cycle analysis by conducting research on the environmental impact of polyester. Mechanically recycled polyester has better environmental profile than the chemical recycled, however chemically recycled fibres have a wide range of applications in the industry[14]

2.6.1.1.4.2:Elastane

It is another synthetic fibre widely preferred for its elasticity mainly for stretch and recovery. The elastic nature of filaments is used in sportswear to compress muscles, offer stretch for body movements, and support in recovering from muscle soreness. A wide range of sportswear products such as foundation garments, swimwear, base layer products, compression tights, etc., are widely made of elastane.

2.6.1.1.4.3: Merino wool

It is widely used in sportswear, for instance, superfine merino wool possess superior water vapour permeability and quick drying properties. Advansa's Thermo° Cool were blended with merino wool (50/50% or 70/30%), for better thermo regulation and comfort.Merino fibre can absorb up to 35% of its dry weight in moisture vapour. During strenuous exercise or hot conditions, a Merino wool garment closer to the skin actively transfers moisture vapour away from the body. This causes the micro-climate above the skin to become less saturated with vapour, thereby making the wearer less clammy and it is less likely for the vapour to form sweat droplets on the skin's surface. Recently Pearl Izumi a Japanese cycling and sports apparel promoted its cycling jersey with merino perform technology developed by Australian Wool Innovation using 19.5 micron wool that promotes comfort and warmth.

2.6.2 Type of fabrics for sportswear

A wide range of woven, knitted and nonwoven fabrics are commercially available for sportswear and normal wear. These fabrics differ in their structure such as entrapped air, pore shape and size, bulk and surface properties etc. which may affect the heat and moisture transmission characteristics of the fabrics.

Generally, knitted fabrics are widely used for sportswear. Knitted fabrics are known to possess excellent comfort properties. knitted fabrics are preferred as these fabrics have greater elasticity and stretch ability compared to woven fabrics, which provide unrestricted freedom of movement. They not only allow for stretching and ease of movement, but they also have good handling characteristics and facilitate the easy transmission of water vapour from the body. These attributes make knitted fabrics the commonly preferred choice for sportswear, casual wear and underwear. Knitted structures offer several advantages. Physically, they present properties of comfort such as high stretch and elasticity, a snugness of fit to body shape, they are soft and pleasing to touch, offer a feeling of freshness and the like. Knitted fabrics have therefore long been preferred as fabrics in many kinds of clothing. Efforts have been made to make knitted fabrics more comfortable by incorporating different fibres, altering yarn parameters, like twist, bulk, count, and finishing treatments, and knitting factors/ knitting parameters, like stitch length, different type of stitches, CPI, WPI and fabric weight and by adopting new or different finishes. Knit fabrics are produced on different machines with different knit stitches and conditions to create different patterns and fabric types.[8-10]

Knit Structures

- **Knitting is a process of fabric manufacturing by interlocking series of loops of one or more yarns.**
- **Single Jersey Structures Rib Structures Interlock Rib Structure**

2.6.2.1 Basic knit stitches

The knitting parameters and the type of structure not only affect the comfort but also the performance properties of the knitted fabrics. There are three basic knitted stitches;

- Knit,
- Tuck and
- Miss (float or non-knit)

2.6.2.1.1 Knit, Tuck & Float Stitches and their uses:-

2.6.2.1.1.1: Knit Stitch:-

Fig. 2.1 illustrates Knit Stitches

- The knit stitch is the basic stitch. It is also called the plain stitch.
- Knit stitch is formed when the needle carries out a complete stroke, reaching the maximum height on the looping plane.

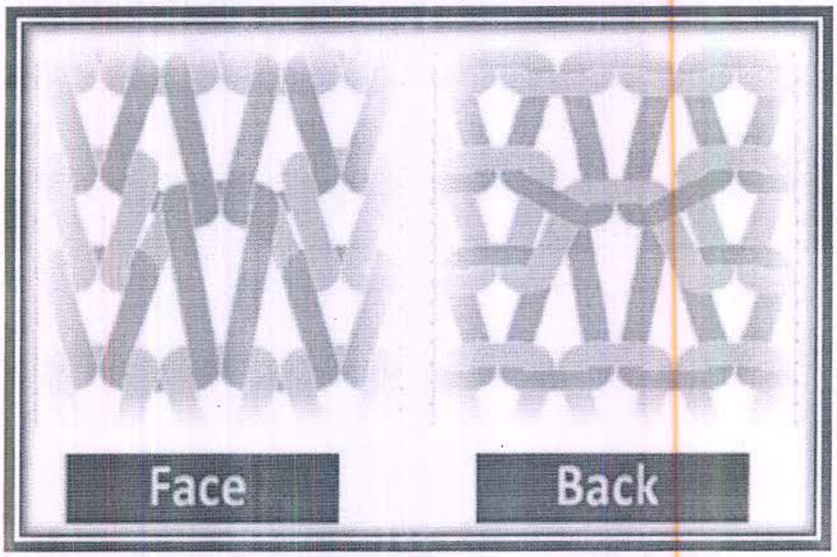

Fig.2.1: Illustration of face & back knitted fabric made up of knit stitches[18]

2.6.2.1.1.2: Tuck Stitch:-

Fig. 2.2 illustrates Tuck Stitches

- A tuck stitch is composed of a held loop, one or more tuck loops and knitted loops. It is produced when a needle holding its loop also receives the new loop.
- The tuck loop assumes an inverted U-shaped configuration. Tuck loops reduce fabric length and length-wise elasticity because the higher yarn tension on the tuck loop causes then to rob yarn from adjacent knitted loops, making them smaller and providing greater stability and shape retention.[17]

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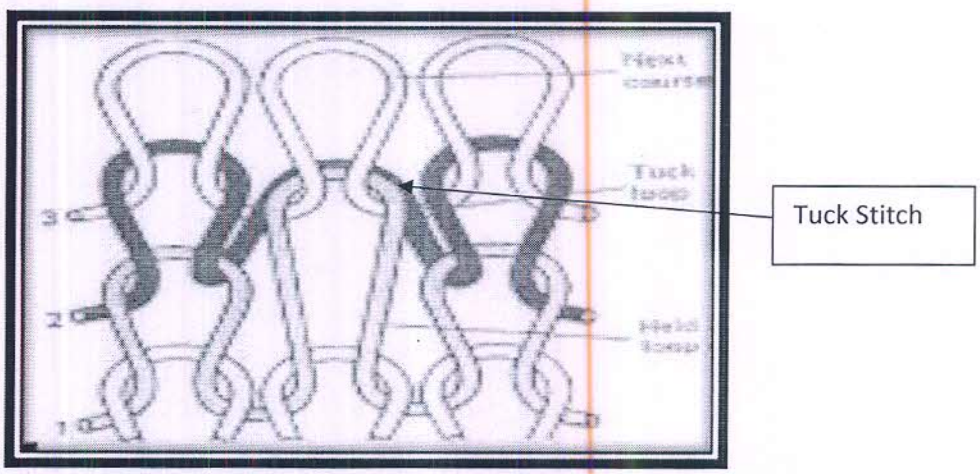

Fig. 2.2: Illustration of technical face of Tuck stitches

2.6.2.1.1.3: Miss/Float Stitch :-

Fig. 2.3 illustrates Miss Stitch

- A miss stitch or float stitch is composed of a held loop, one of more float loops and knitted loops. It is produced when a needle holding its old loop fails to receive the new yarn that passes, as a float loop to the back of the needle, and to the reverse side of the resultant stitch.
- A single float has the appearance of a U-shape on the reverse of the stitch.
- Miss stitch (float stitch) fabrics are narrower than equivalent all-knit fabric because the wales are drawn closer together by the floats, and reducing widthwise elasticity and improving fabric stability.
- A floating thread is useful for hiding unwanted coloured yarn when producing Jacquard designs.[17-20]

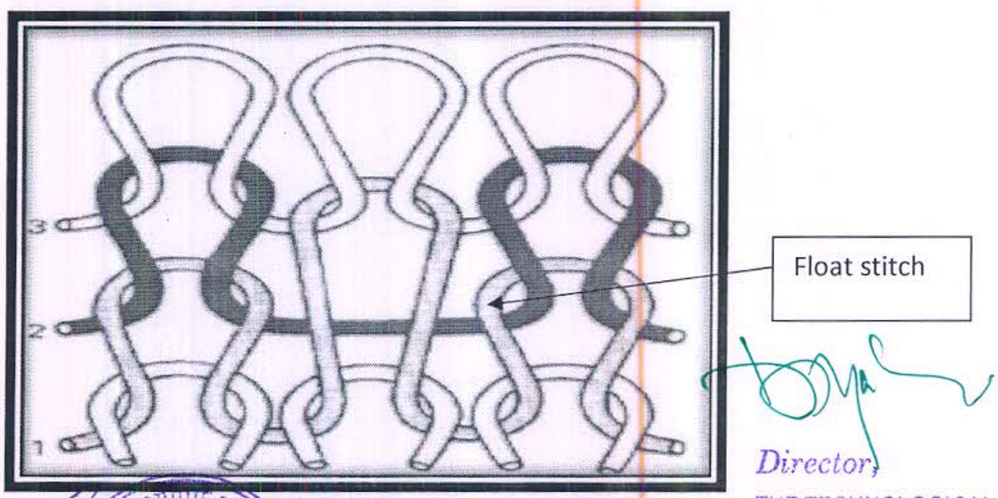

Fig. 2.3: Illustration of technical face of Float stitch[17]

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2.6.3: Effect of knit stitches to the plain jersey construction:-

- Tuck stitch makes the fabric wider, more porous and thicker
- Float stitch makes the fabric narrower, thinner and more rigid in the course Direction
- Effect of tuck and float stitches on the areal density of fabric would depend critically on the actual change in fabric width although presumably the effect may be marginal

Some fabrics have a combination of two or even three of the loop types. As might be expected fabric properties change as different loop types are knitted. All the various shapes and sizes of loops are made by controlling the height that a given needle is raised. Fabrics containing different types of loops will have one appearance on the technical face and another appearance on the technical back.[17-20]

2.7: Classification of knitting:-

Fig. 2.4 demonstrates a flow chart of classification of Knitting

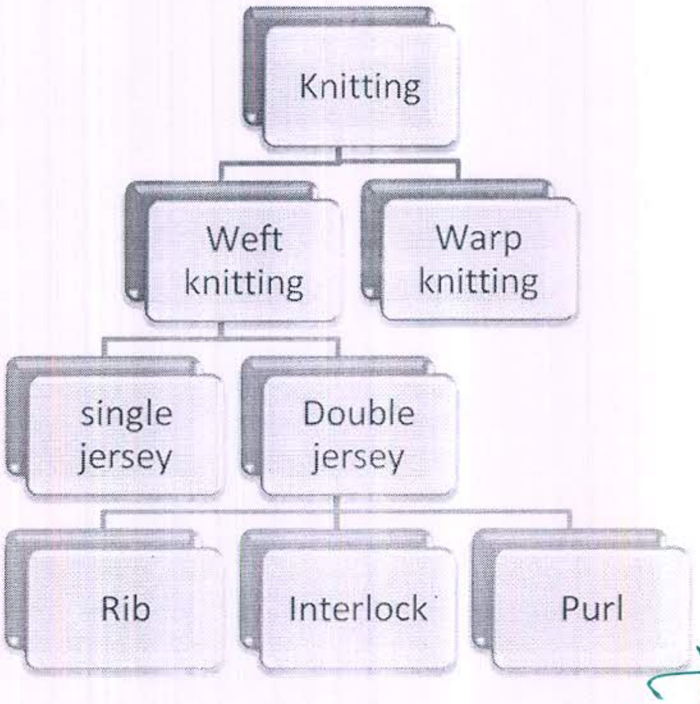

Fig. 2.4: Flow chart of classification of knitting

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2.7.1: Double jersey structures to be used:-

Double jersey structures are made with two sets of yarns, this double-constructed fabric has fine ribs running lengthwise on both sides. Usually looks same on fabric's face and reverse, making it reversible. Fancy double knits may have novelty stitch on fabric's face and fine ribs on reverse.[18]

2.7.1.1: Rib fabric: -

Fig. 2.5 illustrates technical faces of Rib fabric

- A double-knit fabric in which the rib wales or vertical rows of stitches intermesh alternatively on the face and the back of the fabric.
- Rib knit fabrics have good elasticity and shape retention, especially in the width.[21]

Properties

- The appearance of face and back are identical.
- Fabric length wise and width wise extensibility is approximately that of single jersey.
- Fabric does not curl at edges.
- Fabric thickness is approximately twice than single
- There are two series of knitted loops arranged into two parallel in a course.
- Combination of wales of face loop and back loop are present on the both side of the fabric.
- Suitable for extremities of garments

Fig. 2.5: Illustration of technical face Rib knitted Fabric

Uses:

- Ideal for trimming other knits (and wovens) because of its elasticity,

- Garments made from rib knits are usually close-fitting and therefore use a pattern designed for knits

2.7.2: Derivatives of Rib Structure to be used:-

- 1x1 Rib
- Half cardigan
- Full cardigan
- Half Milano
- Full Milano

2.7.2.1: 1 x 1 Rib:-

Fig. 2.6 illustrates diagram and notation of 1x1 Rib fabric[21]

- The simplest rib in 1 x 1 rib
- It is now normally knitted with two sets of latch needles and known as double jersey fabric.
- Rib has a vertical cord appearance
- Relaxed 1 x 1 rib is twice as thick and half the width of an equivalent plain fabric.
- 1 x 1 rib normally relaxes by 30% compound with its knitting width.
- Rib cannot be unroved from the end knitted first because the sinker loops are securely anchored by the cross meshing between face and reverse loop.
- It is used for loops for socks, cuffs of sleeves, rib border for garments.[22]

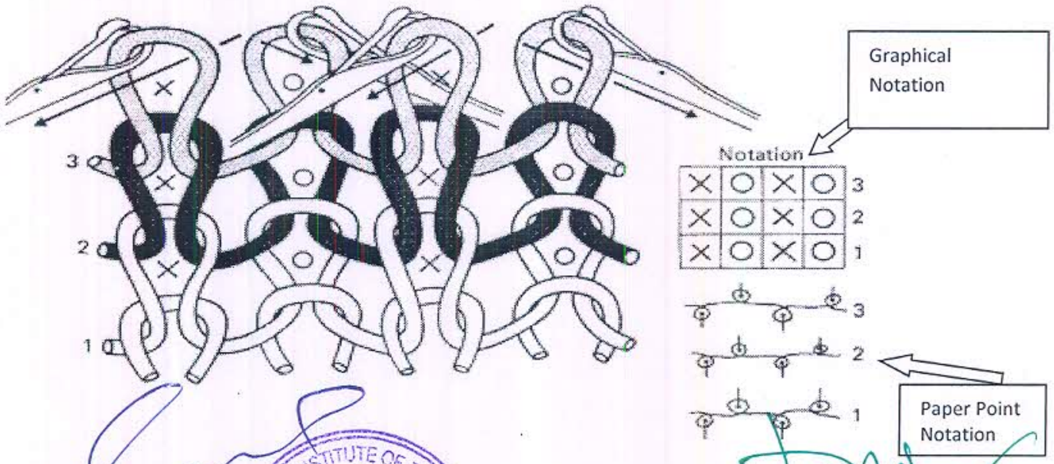
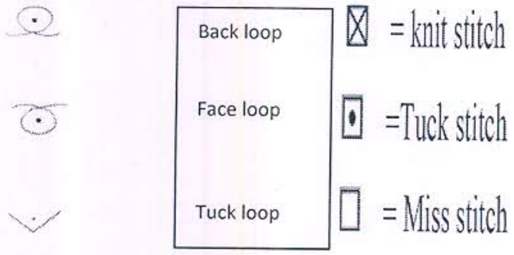


Fig. 2.6: Diagram & Notation of (1x1) Rib knitted structure



2.7.2.2: Half Cardigan (Royal rib):-

Figs. 2.7 & 2.8 illustrates diagram and notation of Half Cardigan (Royal Rib) fabric.

- ❖ The cardigans are the rib structures with tuck loops.
- ❖ The first type is the half cardigan or royal rib. This is two courses per repeat, with one course of 1x1 rib and the other course of all needles knit one side and all needles tuck of the other side of the fabric.
- ❖ Half cardigan is a wide fabric, the large amount of tuck loops reduce the side way contraction.
- ❖ If a 1x1 rib shrinks for 30% after relaxation on its width, then the half cardigan will shrink only about 8%.
- ❖ The structure is mainly produced on coarse gauge V-bed machines for fully fashion or cut and sewn pullovers or cardigans.
- ❖ Half cardigan is not a balanced structure; the number of courses per inch is different on both sides of the fabric.[22-23]

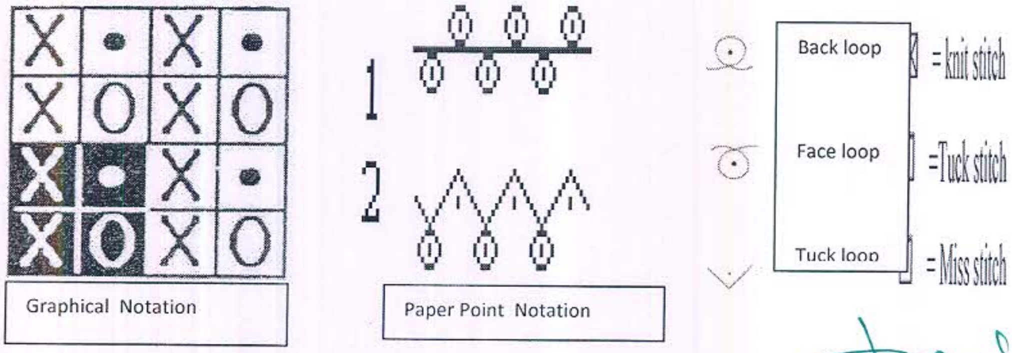


Fig. 2.7: Notation of Half cardigan Knitted structure

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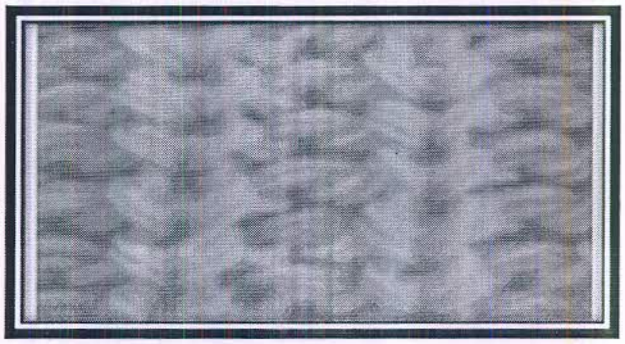


Fig. 2.8: Illustration of Half cardigan

2.7.2.3: Full Cardigan (Polka Rib):-

Figs. 2.9 & 2.10 illustrate diagram and notation of Full Cardigan (Polka Rib) fabric.

- Full cardigan has the same appearance on both sides of the fabric (half cardigan has different appearance on both sides)
- Although full cardigan is also two courses per repeat, it contains no rib course. The structure has 50% tuck loops and 50% knit loops.
- The excessive tuck loops make the fabric bulky and heavy, therefore the structure is suitable for chunky knitwear.
- Full cardigan is normally knitted on 3-12 gauge V-bed machines with wool or acrylic yarns,[23]

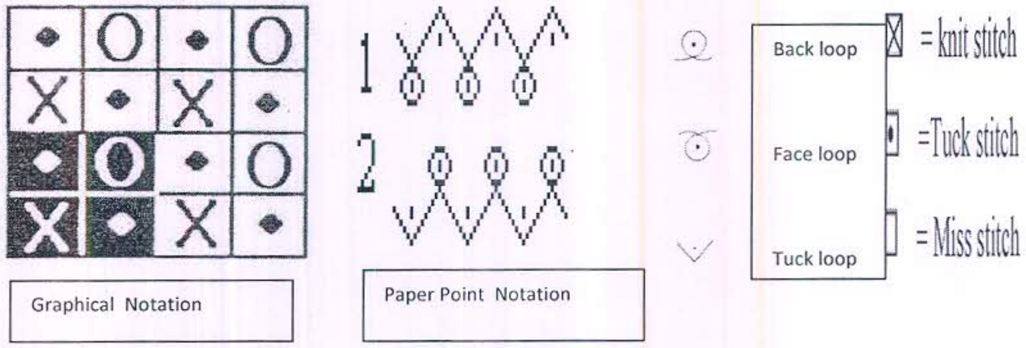


Fig. 2.9: Notation of Full cardigan knitted structure

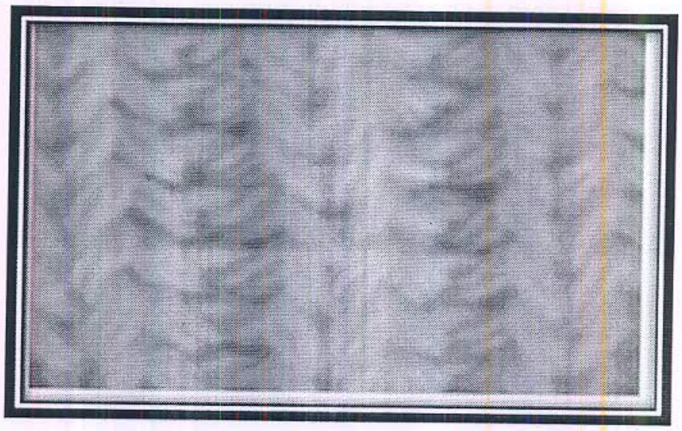
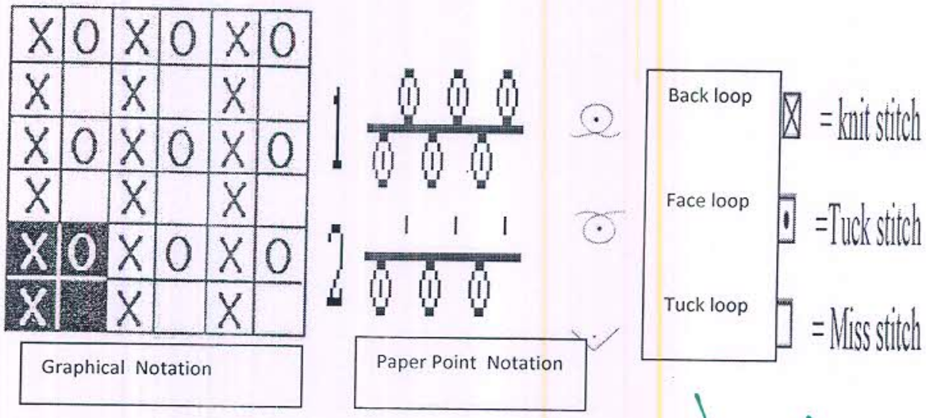


Fig. 2.10: Illustration of Full cardigan fabric

2.7.2.4: Half Milano Rib:-

Fig. 2.11 illustrates notation of Half Milano Rib fabric.

- There are two types of Milano ribs, namely Half Milano and Full Milano.
- Half Milano is two courses per repeat, with first course knits on all needles (front and back) and the second course on front needles only.
- Half Milano is made up of 1 rib course and 1 plain course; with plain course always on the face side of the fabric.
- The resultant fabric is an unbalanced structure, with different appearance on both sides.
- Half Milano is seldom knitted as piece goods, it is used for sweaters of coarser gauge (5 to 7 gauge V-bed machine with woollen or acrylic yarns)[22]



X	O	X	O	X	O
X		X		X	
X	O	X	O	X	O
X		X		X	
X	O	X	O	X	O
X		X		X	

Fig. 2.11: Notation of Half Milano knitted structure

Director,
THE TECHNOLOGICAL INSTITUTE
OF TEXTILE & SCIENCES, BHIWANI

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2.7.2.5: Full Milano Rib:-

Fig. 2.12 illustrates notation of Half Milano Rib fabric.

- Full Milano has three courses per repeat; with one course of 1x1 rib; one course of plain on one side of fabric and another course of plain on the other side.
- Although Full Milano is slightly modified from half milano, the fabric property is entirely different
- Full Milano is normally knitted in higher density to give a firm fabric.
- The two plain courses of Full Milano reduces most of the width way elasticity.
- As a result, Full Milano is a fabric with much better dimensional stability.
- Full Milano is produced mainly on medium gauge machines as piece goods for suiting fabrics[21-23]

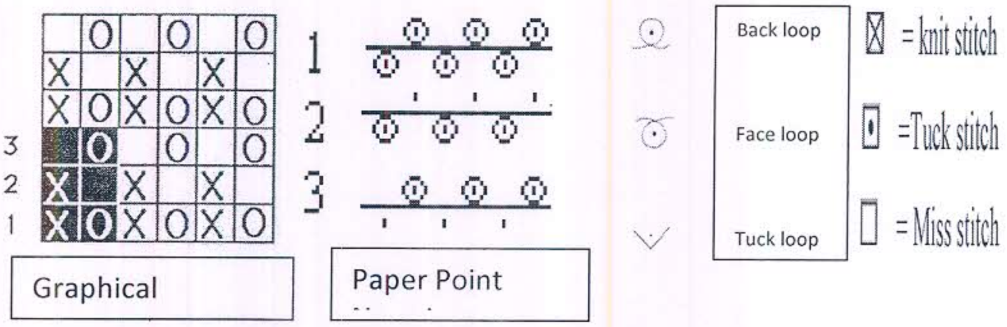

Fig. 2.12: Notation of Full Milano knitted structure

2.8: Effect of Fabric structure on physical & comfort properties:-

Extensive research has been carried out by many researchers to investigate the contribution of various variables on physical/dimensional & comfort characteristics of knitted fabrics. The thermal and moisture management properties of knitted fabrics depend on several factors which may take into account the fibre characteristics, the structure and properties of the resulted yarn as well as the design characteristics of the fabrics itself. The fabric structure is one of basic variable that has great influence on dimensional & comfort characteristics. Some of studies by researchers are given below:-

Renu et al.[25] investigated the effect of knit stitches- plain & tuck on the physical & comfort properties of machine knitted cotton fabrics. Stitch density, fabric thickness, moisture content and wicking ability tests were carried out for determination of comfort level provided by each fabric. The results obtained are shown in Table- 2.2.

Table- 2.2: Physical & comfort properties of plain & tuck knitted fabrics[24]

S. No.	Knit stitches	Stitch density (loops /inch^2)	Fabric thickness (mm)	Fabric weight (g/m^2)	Moisture content (%)	Wicking ability (%)
1.	Plain	504.4	0.86	168.8	4.35	125.99
2.	Tuck	452.2	1.22	230.0	3.98	24.95

2.8.1: Effect of knit stitches on Stitch density: -

The stitch density is expressed in terms of courses per inch and wales per inch. As illustrated in Table- 2.2, tuck fabric has lower stitch density among both the stitches. Maximum density of plain stitch indicates its maximum covering power.

2.8.2 Effect of knit stitches on Fabric thickness: -

Table- 2.2 indicated that thickness value was lower for plain fabric as compared to tuck fabric. As thicker fabric creates warmth in the body thus tuck fabric will be more comfortable in cold weather while plain knitted fabric will better choice for summer clothing.

2.8.3: Effect of knit stitches on fabric weight:-

As shown in Table- 2.2, average weight of plain knit fabric is less as compared to knitted fabric containing tuck stitches. Because of less fabric weight, the plain knitted fabric is finer & easy to put on & put off.

2.8.4. Effect of knit stitches on Moisture content: -

From the Table- 2.2, it can be observed that moisture content values were 4.35 %, and 3.98 % for plain, and tuck knitted fabrics respectively. It was found that according to mean values, plain construction had maximum moisture content followed by tuck fabric. Knit construction has significant effect on the moisture content of the fabric.

2.8.5 Effect of test Results of Stitch density, fabric weight & thickness on comfort properties of plain & tuck knitted fabric

The results showed that stitch density of tuck fabric is low which shows low coverin power of fabric. It showed higher value in fabric weight and minimum value in moistur content that indicates fabric containing this stitch is less durable and comfortable to wea in hot weather. Results emphasize that fabric containing Plain stitch was thinner an lighter in weight which will make the fabric more comfortable and more economical Higher moisture content and wicking ability of plain fabric will not encourage generatio of static charge. Plain fabric showed more moisture content than tuck fabric because it ha more number of loops of yarn floats on the surface than rib fabric. It results in penetratio of more water molecules onto the surface of plain fabric so water vapour permeability o more as compared to tuck knitted fabrics. These properties will make it comfortable t wear specially in hot weather. Visual investigation showed that tuck stitch was the mos beautiful and decorative stitch.

El-Hady^{25} analyzed the effect of fabric structure with different stitch type on air permeability property, which is important factor in the people's perception of wear comfort. The test results are as cited in Table- 2.3.

Table- 2.3: Dimensional properties of weft knitted structure made by combination of Plain, Tuck & Float stitches[25]

<table>
<tr><th>Sample No.</th><th>Notation diagram</th><th>Types of stitches</th><th>Fabric Weight (g/m^2)</th><th>Fabric Thickness (mm)</th><th>CPI (courses per inch)</th><th>WPI (Wales per inch)</th></tr>
<tr><td>1</td><td><table><tr><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td>All Feeders</td></tr></table></td><td>Only knit stitches</td><td>146</td><td>0.62</td><td>48</td><td>29</td></tr>
<tr><td>2</td><td><table><tr><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td>.</td><td>F. 5-9</td></tr><tr><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td>F. 1-4</td></tr></table></td><td>91% Knit Stitches
9 % Tuck Stitches</td><td>151</td><td>0.64</td><td>50</td><td>27</td></tr>
<tr><td>3</td><td><table><tr><td>.</td><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td>F.7-12</td></tr><tr><td>x</td><td>x</td><td>x</td><td>.</td><td>x</td><td>x</td><td>F.1-6</td></tr></table></td><td>83 % Knit Stitches
17 % Tuck Stitches</td><td>158</td><td>0.68</td><td>53</td><td>24</td></tr>
<tr><td>4</td><td><table><tr><td>.</td><td>x</td><td>.</td><td>x</td><td>.</td><td>x</td><td>F. 4</td></tr><tr><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td>F. 3</td></tr><tr><td>x</td><td>.</td><td>x</td><td>.</td><td>x</td><td>.</td><td>F. 2</td></tr><tr><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td>F. 1</td></tr></table></td><td>75 % Knit Stitches
25 % Tuck Stitches</td><td>166</td><td>0.72</td><td>56</td><td>22</td></tr>
<tr><td>5</td><td><table><tr><td>.</td><td>x</td><td>.</td><td>x</td><td>.</td><td>x</td><td>F. 2</td></tr><tr><td>x</td><td>.</td><td>x</td><td>.</td><td>x</td><td>.</td><td>F. 1</td></tr></table></td><td>50 % Knit Stitches
50 % Tuck Stitches</td><td>175</td><td>0.77</td><td>59</td><td>19</td></tr>
<tr><td>6</td><td><table><tr><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td></td><td>F. 5-9</td></tr><tr><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td>F. 1-4</td></tr></table></td><td>91% Knit Stitches
9 % Miss Stitches</td><td>142</td><td>0.6</td><td>53</td><td>32</td></tr>
<tr><td>7</td><td><table><tr><td></td><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td>F.7-12</td></tr><tr><td>x</td><td>x</td><td>x</td><td></td><td>x</td><td>x</td><td>F.1-6</td></tr></table></td><td>83 % Knit Stitches
17 % Miss</td><td>138</td><td>0.58</td><td>57</td><td>34</td></tr>
</table>

☒ Knit stitch
⊡ Tuck stitch
☐ Miss stitch

From the obtained results, it was clear that stitch type had explicit impact on air permeability property of knitted fabrics. Loose knitted structure and porous structure with high percent of tuck stitches showed maximum air permeability compared with knit and miss stitches structures. The higher air permeability rate the quickest heat-loss obtained from a textile material. For summer wear, structures with tuck stitches could be used as it is characterized by higher air permeability, creating a cool feeling to the wearer by allowing more cold air to penetrate through to bring the heat away from the body and accelerate the sweat evaporation at the skin and fabric surface.

2.8.6: Relationship between stitch type percent & Air Permeability (l/m2/s):-

Fig. 2.13 showed that there is direct relationship between stitch type percent in the structure (from 0% to 50%) and air permeability. It is clear that, the air permeability of the single knitted fabric increases with the increase of tuck stitches percent in the structure. Loose knitted structures with tuck stitches are more permeable to air owing to their higher porosity compared with knit or miss stitches. Tuck stitched structure is more open and porous than knit stitched fabric.

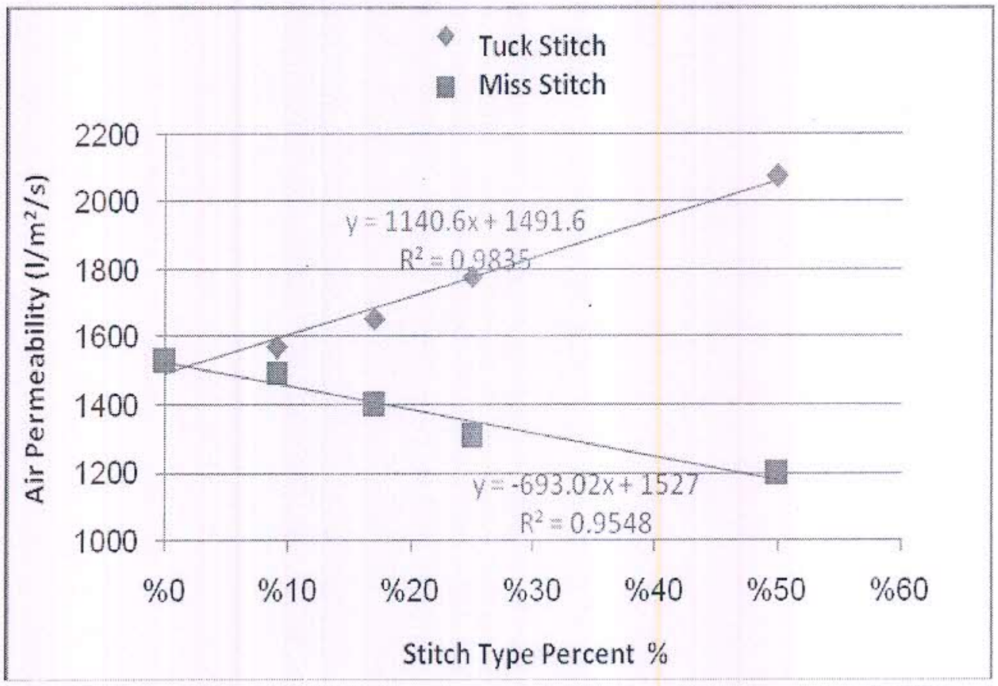

Fig. 2.13: The Relationship between the air permeability(1/m^2/sec) Stitch Type % for Single Weft-Knitted Structures

2.9: Thermal comfort properties of knitted fabrics:-

Nida and Arzu [26] had investigated the thermal properties of cotton and polyester based knitted fabrics with single jersey, 1×1 rib and interlock structures were discussed. The thermal resistance, thermal absorptivity, thermal conductivity, water vapour permeability of the samples were measured with the aid of Alambeta and Permetest devices respectively. The specification and results obtained are shown in Table- 2.4. All results indicated similar trends in both cotton and polyester groups.

Table- 2.4: Thermal properties of basic knitted structures[26]

Materia	Fabric type	Thickness (mm)	GSM	Water vapor permeability (%)	Thermal conductivity (W/mK)	Thermal resistance (m^2K/W)	Thermal absorptivity $Ws^{1/2}/m^2K$
100% Cotton carded	Single Jersey	0.84	102	45.05	0.035	0.023	87
	1x1 rib	1.14	169	40.51	0.043	0.027	102
	Interlock	1.40	225	38.75	0.047	0.030	114
100% PET (Staple fibre)	Single Jersey	0.83	114	45.37	0.032	0.026	69
	1x1 rib	1.09	147	44.79	0.038	0.029	92
	Interlock	1.37	205	40.51	0.042	0.033	98

2.9.1: Effect of structural properties on thermal comfort :-

As illustrated in Table- 2.4, Because of their structural properties, single jersey fabrics have remarkably lower thermal conductivity and thermal resistance values as well as higher relative water vapour permeability values than 1×1 rib and interlock fabrics. It can be seen that interlock structures have higher thermal conductivity and less water vapour permeability values than 1×1 rib structures. This situation can be explained by the amount of fibre per unit area. While the amount of fibres increases, the amount of entrapped air decreases. Therefore, thermal conductivity values will be higher for heavier and thicker fabrics, such as interlock fabrics.

According to the results, it had been proven that different knitting structures have different comfort properties. The different knitted fabric structure had significant impact on comfort properties. Therefore, in order to achieve the ideal clothing comfort, it is necessary to consider the end use of the garment while selecting the fabrics.

Bedek et al.[27] had earlier studied the thermal & WVTR properties of different knitted structures simple rib, 1 × 1 Interlock and Double rib having different fabric content & also analysed the relationship between the textile properties (thickness, porosity, moisture regain etc) and comfort-related properties. The sweating guarded hot plate apparatus was used to measure the thermophysiological comfort of clothing, i.e. the thermal and vapour resistances of fabrics under steady-state conditions, Rct and Ret, respectively

2.9.2: Water-Vapour Transmission Rate (WVTR):-

Water-Vapour Transmission Rate (WVTR) provides some relevant information on the fabric "breathability". As cited in table8, Water-vapour transmission rate indicated that all the fabrics exhibited high water transmission irrespective to their construction design since no significant difference have been observed for the various samples, excepted for the fabric labelled D.

From Table-2.6, it seemed that Ret values did not correspond to the WVTR values. One of the possible explanations was the presence of air layers which led to different water-vapour pressure gradient through the fabrics.

Sample code	Fabric Content	Fabric design	Fabric weight(g $/m^{2)}$	Thickness (mm)	Relative porosity p(%)	Moisture Regain (%)	Air permeability ($1/m^2$/ sec)	WVTR (g/m^2.day)
A	38% cotton, 31% polyester and 31% rayon	Simple rib	215.7±2.1	0.99±0.02	85.4	4.2±0.9	727.80 ± 74.55	16864.10±832.12
B	100% cotton	1 × 1 Interlock	216.4±6.4	1.19±0.01	87.4	4.6±0.3	706.20 ± 2186	15582.21±253.49
C	70% cotton and 30% viscose	1 × 1 Interlock	226.7±51	1.16±001	86.8	5.6±0.1	917.20 ± 2334	15771.91±538.59
D	100% polyamide	1 × 1 Interlock	166.6±5.2	0.73±0.03	78.7	2.3±0.1	1224.0 ± 140.0	19836.83±571.66
E	68% polyester and 32% hydrophilic polyester (filament	Double rib	207.2±7.6	0.86±0.02	83	0.3±0.1	2060.0 ±76.15	16503.59±242.38
F	69% polyester and 31% hydrophilic polyester (multifilament)	Double rib	187.8±2.5	0.86±0.02	84.1	0.3±0.1	2660.0 ±65.90	15175.72.±406.49

Table 2.5: Physical and comfort properties of weft knitted structures

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Table 2.6 Test results of Thermal, Moisture management properties[27]

Sample code	Thermal Conductivity λ_T (W m K^{-1}) × 10^{-3}	Rct (m^2 K W^{-1})	Ret (m^2 Pa W^{-1})	ImT	Drying time (min)	WVTR (g m^{-2} day^{-1})	OMMC
A	76.70 (±3.6)	0.0260 (±0.0002)	3.96 (±0.35)	0.39	87 (±3)	16864.10 (±832.12)	0.27 (±0.09)
B	81.60 (±2.4)	0.0246 (±0.0002)	4.74 (±0.05)	0.31	115 (±2)	15582.21 (±253.49)	0.22 (±0.05)
C	81.50 (±2.9)	0.0258 (±0.0001)	4.82 (±0.25)	0.34	128 (±3)	15771.91 (±538.59)	0.27 (±0.02)
D	77.10 (±1.6)	0.0272 (±0.0001)	3.20 (±0.30)	0.50	23 (±2)	19836.83 (±571.66)	0.72 (±0.04)
E	48.20 (±3.3)	0.0256 (±0.0002)	2.68 (±0.10)	0.58	16 (±1)	16503.59 (±242.38)	0.35 (±0.01)
F	49.60 (±2.4)	0.0296 (±0.0001)	3.43 (±0.20)	0.52	21 (±1)	15175.72 (±406.49)	0.34 (±0.01)

2.9.3: Influence of textile properties (Porosity & thickness) on Moisture management & WVTR:-

The moisture management Properties & WVTR were also found to be dependent to relative porosity. As illustrated in Table- 2.6 , OMMC are strongly correlated to fabric relative porosity thus low porosity leads to high liquid moisture management capacity. Water-vapour transmission rate was correlated to relative porosity, and lower relative porosity value led to higher WVTR value. The fabric having the lowest relative porosity and thickness values has the highest water-vapour transmission rate and a very good moisture management capability.

2.10: Advancements in sportswear:-

In the first half of 20th century sportswear was not scientifically designed due to the non-availability of specialty fibres. However, later on designing of sportswear has received scientific inputs by utilizing the knowledge synthetic polymer, fibre, fabric, finished, and smart garment design for advanced sportswear suitable for specific application. A number of technological progresses have been made in the past to develop speciality polymer with micro-porous to hydrophilic characteristic, speciality fibres with different shapes and diameter, and single to multi-layer fabrics with different fabric structure to improve the fabric comfort and functionality. Extensive research had been carried out in order to enhance the performance of sportswear. A lot of advancements takes place in sportswear.[8-11] Some are listed below:-

- Use of specialized synthetic fibres
- Use of Specialized fabric structure
- Development in finishing technology

- Use of Smart textile/wearable technology----*Main focus of Present research work*

2.10.1: Specialised synthetic fibres:-

Synthetic fibre can be modified during manufacture to improve its thermo physiological and sensory properties. A number of different techniques are available for producing such fibres, including the following:

- Block copolymers can be added to the base polymer before extrusion
- Fibres can be extruded with different cross sections.
- Fibres can be coated after treatment[35,36]

2.10.1.1: Special Fibres used:-

2.10.1.1.1: Microfibres:-

One of the most common modifications made in order to provide improved comfort is the use of superfine fibres or microfibers with the filaments having a linear density well below 1decitex. The use of these fibres enables very dense fabrics to be created in which the fibre surface is significantly increased and the space between the fibres is reduced. This leads to the increase of capillary action for better thermal regulation. Micro fibre exhibits better moisture transport and ensures better moisture control. Microfibers have higher breathability and moisture transport properties and because they are wind- and water proof, these fabrics are widely used in rainwear and active sportswear. Specialised polyester fibres (Modified polyester) have been developed in order to produce a more natural handle, to increase absorbency, to provide better thermal resistance and to reduce static charges.

2.10.1.1.2: Hygra:-

Unitika Limited has launched Hygra, (Fig. .2.14) which is a sheath core type filament yarn composed of fibre made from water absorbing polymer and nylon. The water-absorbing polymer has a special network structure that absorbs 35 times its own weight of water and offers quick releasing properties that the conventional water absorbing polymer cannot do. On the other hand, nylon in the core gives tensile strength and dimensional stability. Hygra also has superior antistatic properties even under low wet conditions. The main apparel applications include sportswear like athletic wear, skiwear, golf wear etc.

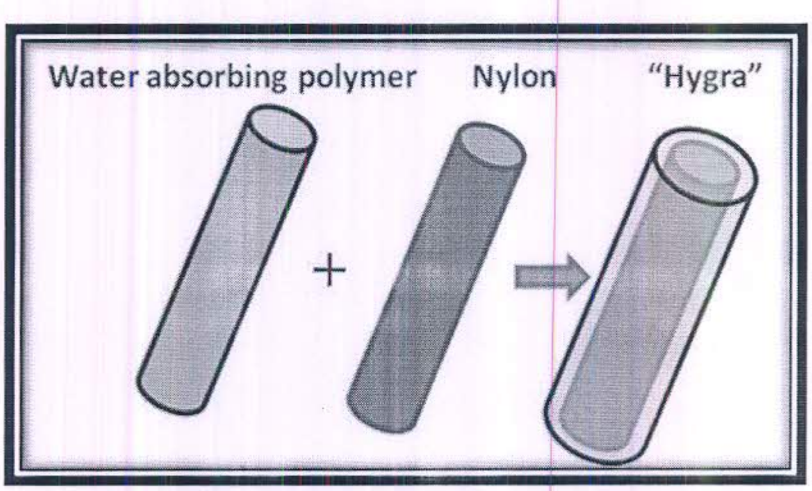


Fig. 2.14: Schematic of mechanism of Hygra fibre[35]

2.10.1.1.3: Lumiace:-

Lumiace is also a product from Unitika. It is a collection of polyester filaments having different fineness (0.5 - 2.0 denier per filament) and irregular cross sections. Hygra - Lumiace combination in knitted fabric is very popular in top Japanese athletes.

2.10.1.1.4: Coolmax:-

Coolmax is a four-channel modified polyester fibre with a cross section that resembles a double scallop. It offers improved wicking capability and moisture vapour permeability. It dries significantly more quickly than many other fabrics used in sportswear.

2.10.1.1.5: Dryarn:-

Dryarn is the new fibre obtained from Aquafil. It is a completely recyclable polypropylene microfibre. Fabric from Dryarn is very lightweight and comfortable and used in different sports. In addition it has a soft handle and a high thermoregulatory capacity and also dries quickly. Bacteria cannot settle on smooth surface of the fibre which avoids unpleasant odour associated with decomposition of bacteria.

2.10.1.1.6: Killat N :-

Killat N from Kanebo Ltd is a nylon hollow filament. The hollow portion is about 33 per cent of the cross section of each filament due to which it gives good water absorbency and warmth retentive property. The manufacturing technology of Killat N is very interesting. The yarn is spun as bi component filament yarn with soluble polyester copolymer as the core portion and nylon as the skin portion. Then by giving alkali weight loss treatment the soluble polyester copolymer of the bicomponent filament will dissolve and a large hollow portion (exceeding 30 per cent of the cross section) will be created as shown is Fig. 2.15.

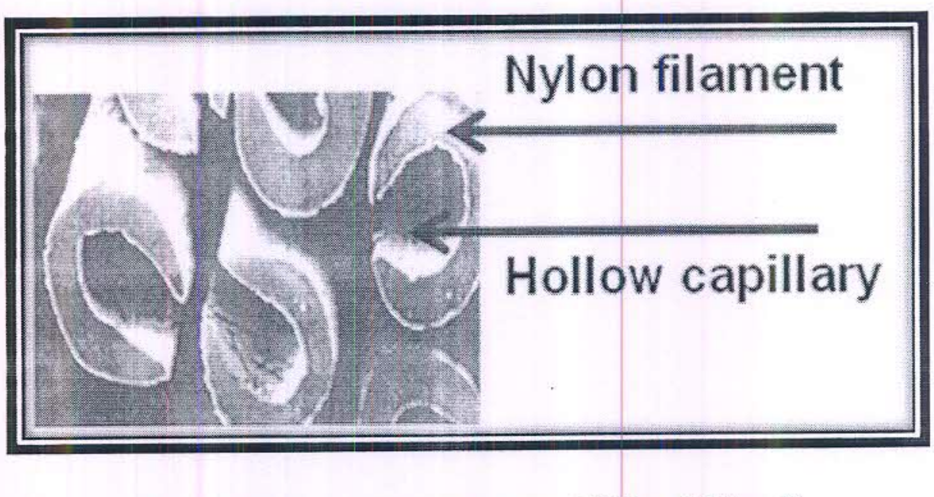


Fig. 2.15: Cross sectional view of Killan N fibre[36]

2.10.1.1.7: Triactor

Toyoba Co Ltd has developed Triactor, which is a perspiration absorbing/quick drying polyester filament as shown in Fig..2.16. Polyester is hydrophobic and does not absorb moisture but by changing the filaments to Y shaped cross section Toyobo has realized quick perspiration absorbency by capillary action. The hydrophobic nature and large filament surface of polyester filaments realize quick drying and refreshing properties at the same time. There are many other fibres, which have good sweat absorption and fast drying property. Most of them are either nylon or polyester.

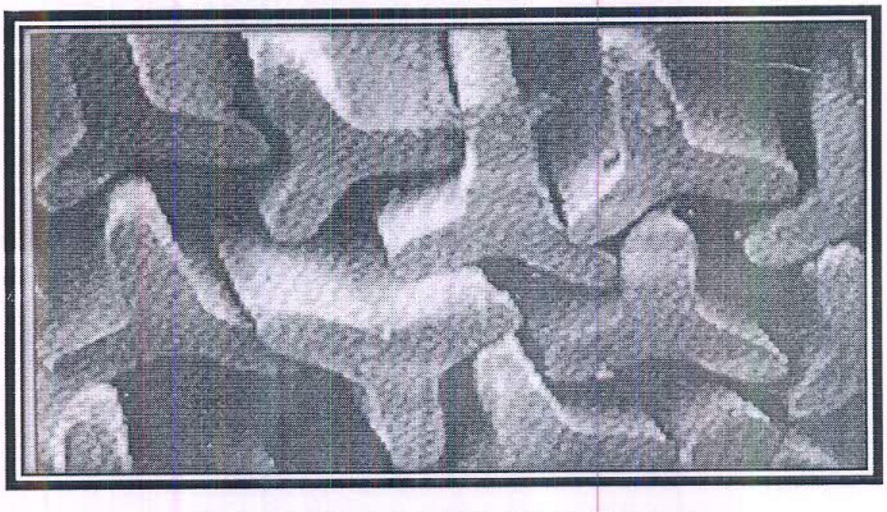


Fig. 2.16: Structural model of Triactor

2.10.1.1.8: Hydrofilia (Modified polyamides):-

Hydrofilia is a polyamide block copolymer containing 85% nylon 6 and 15% polyethylene oxide diamine which provides significantly improved water absorbency, up to the levels associated with cellulosic fibres. Polyamide microfibres such as Tactel Micro, Microfine, Supplex and Microfibre, are used in fabric to produce superior wind protection, a soft feel and good moisture vapour transmission.

2.10.1.1.9: Lycra:-

Lycra, a truly synthetic fibre of long chain polymer composed of at least 85% segmented polyurethane, finds wide range of end uses such as swimwear, active sportswear, floor gymnastics because of its comfort and shape fitting properties. Adding Lycra to a fabric gives it stretch and recovery, particularly in gymnastics and swimwear where body skin flexing and stretching are inevitable. Lycra T-9026 requires still effort for the same extensibility.

2.10.1.1.10: Roica and Leofeel:-

Roica is a polyether type spandex made by dry spinning method and Leofeel is a soft nylon-66 yarn developed by Asahi Chemical. The combination of Roica and Leofeel in mixed knitted tricot fabric gives a soft touch and excellent stretch. It is mainly used in swimwear. Various other fibres like Elite from Nylstar Co, Linel Ac from Fillattice Co, Elastil and Sens from Miroglio etc also have good stretchability and are effectively used in swimwear.

1.1.2 Requirements of a clothing system

A system of clothing can be made of one or more layers (base, mid, external) providing a portable environment (Watkins, 1995) of fibrous material and air extending from the surface of the skin to the outer face of the external garment. The role of the system is to satisfy the physiological and psychological needs (outlined in section 1.1.1) necessary for the individual to function within the physical and social environment. A dynamic micro-climate is created within the system and is influenced by external factors (climate, activity of wearer, etc.) and internal factors (fibre properties, textile structure, design of garment, etc)(Black et al., 2005).

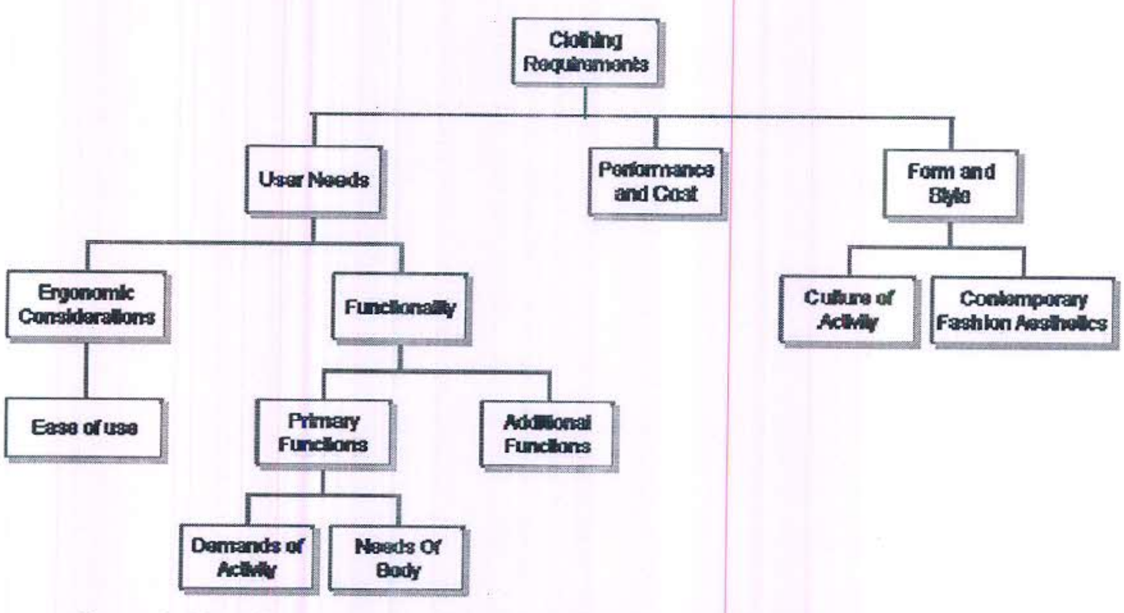


Figure 3: Functional requirements of clothing (Black et al., 2005)

The end use of the clothing system dictates whether emphasis during the design and development is placed on the physiological or psychological functionality of the clothing, however all garments must satisfy some basic requirements (fig 3). The form and style of each item within a system must suit the culture of the activity and meet basic contemporary design aesthetics. Although this may appear more important to the fashion sector, Black (2005) identified several cases where individuals working in hazardous environments rejected their protective clothing because they were deemed unsuitable in terms of look and design.

Clothing needs to balance performance with cost; a successful design convinces the consumer that its price is suitable to the performance of the garment. Clothing must also satisfy basic ergonomic considerations to avoid inhibiting general life activities and functions. It is vital that a clothing system is easy to use (adding and removing garments) and does not restrict movement.

Fire fighters require their clothing to protect them from flames yet prevent them from overheating when exposed to extremely high temperatures and the metabolic heat produced during activity. Cold water diving suits need to sustain the core temperature of the wearer to prevent hypothermia. Urban dwellers in cities such as London or New York require insulating coats and jackets that protect them from exposure to short periods of cold experienced during the winter months. These items of clothing also need to be light and durable and easily removed when they are within an enclosed environment such as a public transport system, place of work or residence.

Additional functional requirements represent possible future demands from clothing enabled by new and emerging technologies. The advancing fields of bio-, nano-, electro- textiles are introducing new properties to apparel that could supplement the functionality of conventional clothing to meet changing needs of the consumer's lifestyle. Remote connectivity, for instance, enabled by innovations in wearable electronics, offers clothing able to take on additional roles currently performed by devices such as mobile phones, PDA's and satellite tracking devices. This sector of the clothing industry is very new and the first innovations, pioneered mainly by the sportswear and performance sectors, have begun to appear on the mass market.

1.2 Factors effecting the role of physiological comfort

The literature review revealed that the history of sensory experience from clothing and in particular physiological comfort has never been documented, it also suggests that role of physiological comfort and consumer expectations in

Western dress from the Victorian era to the present is honed through social, political and technological pressures.

1.2.1 Physiological comfort in the Victorian era

The clothing of wealthy Victorian men and women included tight corsets, stiff collars, cuffs and multiple layers of heavy cloth that heavily restricted the mobility of the wearer (Newton, 1974). These cumbersome systems functioned as a symbol of wealth and status, the individual was not required to participate in any strenuous physical activities as these tasks were performed on their behalf by staff who were part of the lower classes (Cunnington, 1990).

A lady in Victorian times felt comfortable in her clothing when she was admired for her physical appearance by peers. The female silhouette and in particular the shape of a lady's waist was of key importance to the overall appearance. Designer corsets ensured highly desirable tiny waistlines; this was especially evident in the advertising of the time. Various corset brands would promote their designs by combining before and after imagery in their promotional material. The before images would usually display women complaining about how ugly and unhappy they felt in their old corsets. These would be followed by imagery of the female stating how comfortable and happy she felt after she had replaced her old corset with a new one because of all the complements she received from her peers (Steele, 1999).

Comfort in Victorian times held a very different meaning to the one we know today. There was no distinction between the physiological and psychological dimensions of the sensation and value was placed solely on the symbolic/ decorative role of clothing. There was in fact no knowledge of the physiological effects of textile and garments on the body until the mid 1800's where a movement known as the 'dress reform' or 'rational dress movement' (Newton, 1974) exposed the health hazards directly associated with upper class Victorian dress.

Emily King (a member of the Rational Dress Society founded in 1881) published 'Rational Dress or the Dress of Women and Savages' in 1882. The work examined the physical damage caused by body mutilation practiced in Africa (tattoos and scaring) and China (foot restriction) and drew parallels to the use of corsetry which was found to cause permanent disfiguration to female bone structure and vital organs.

The physiological impact of civilian clothing was brought to the attention of the public for the first time in an attempt to improve the individual's experience of clothing wear. The rational dress movement scrutinised dress etiquette of both western and eastern cultures and exposed factors that threatened the health and wellbeing of the wearer. Emily King revealed the true price of a 'beautiful' silhouette while the work of other dress reformers such as Dr Wilson and Dr Jaeger exposed the deadly effect certain dyes used to colour cloth as their poison could be absorbed through the skin, other significant factors identified were the weight and shape of clothing as they burdened the wearer and restricted movement (Cunningham, 2003).

Ease of movement was a key feature in the dress reform mantra which contradicted the stiff and restrictive nature of upper class dress etiquette. However, it wasn't till the end of the 19th century that lifestyle changes helped ensure the 'relaxing' of Victorian dress. Individuals became increasingly interested in the pursuit of leisure and outdoor adventure, both men and women began to engage in various physical activities such as cycling, tennis and swimming. The new lifestyle demands placed pressure on the existing clothing systems and eventually modifications were introduced that enabled participation in such activities. This shift in clothing functionality meant that garments became more practical; men's shirts for instance, lost their stiff collars and cuffs. Although these changes were originally restricted to the countryside, during the early twentieth century more relaxed clothing styles permeated city wear (Willett and Cunnington, 1981).

IQAC
COORDINATOR

Director,
THE TECHNOLOGICAL INSTITUTE
OF TEXTILE & SCIENCES, BHIWANI

1.2.2 Physiological comfort in the 20th Century

Textile technology of the early twentieth century was able to deliver sophisticated clothing functionalities to accommodate an outdoor lifestyle. Complex garment systems were engineered to enable the exploration of extreme and hostile environments. George Mallory and Andrew Irvine set out to climb Mount Everest in 1924, although it is not certain whether they reached the summit or not and the attempt cost them their lives. Originally it was assumed that the climbers died because they lacked specialist skills and equipment. However Mallory's body was discovered in 1999 and his garments were analysed by a team at Lancaster University who found carefully engineered layers of silk cotton and wool using construction methods to ensure optimal insulation and wind proof functionality. The team concluded that the clothing system was very efficient (much lighter than modern equivalent climbing attire) and would not have caused death (Phillips, 2005).

The twentieth century also saw the birth of the man-made fibre industry that altered the functionality of clothing once more. Driven by the age old desire to create artificial silk, Rayon was the first man-made fibre to be commercially produced in 1910. Rayon is a regenerated cellulose fibre made from wood pulp or cotton linters (Cook, 1984a). The fibre was originally extruded into filaments that were smooth, straight and imitated the lustre of silk. Rayon soon became a cheap alternative to silk and took its place in dresses, lingerie and coat linings.

The first synthetic fibre was commercially produced in 1939 by E.I. du Pont de Nemours and Company. Following an extensive research program, the company synthesised a polyamide fibre they branded Nylon. Nylon fibres were long, smooth and offered a silk like handle to textiles but with much superior tensile strength. Prior to the invention of Nylon, silk was the finest fibre available in filament form that was strong enough to be used in sheer, fine denier stockings. Silk stockings were expensive and available exclusively to the rich, however, stockings made from Nylon (known as Nylons) were a fraction of the cost and therefore available to all (Handley, 1999).

By the 1950's more synthetic fibres were commercially produced such as polyester and acrylic. These fibres offered an entirely new set of functionality to clothing. Unlike natural and regenerated fibres [2], synthetic counterparts absorbed nominal quantities of moisture (Cook, 1984a) creating quick drying textiles that require little or no ironing. This presented many new opportunities for the swimwear industry and promised to liberate women from household chores such as ironing and washing (Handley, 1999). Even natural fibres were treated with various resins to imitate the performance of synthetic textiles (Kemp, 1971, Smith, 1993).

Crisis hit the synthetic fibre industry in the 1970's as consumers rejected products made from these materials and sales plummeted. This rejection was believed to be fuelled by consumer perception that synthetic textile products had saturated the market (Handley, 1999) and the nature of the fibres themselves caused a range of new sensations such as clingy, damp, clammy, static and various skin irritations (Kemp, 1971). The hydrophobic nature of synthetic materials that created a revolution in the 1950's was the cause of their demise twenty years later as consumers began to favour the properties of natural fibres over their synthetic counterparts.

The 1970's was a very important time for the textile industry. During this decade great losses were made in the man made fibre sector which drove scholars to unravel the meaning of comfort/ discomfort and technologists to find ways of manipulating the performance of synthetic materials to imitate the properties of natural fibres. By the end of the 20th century synthetic fibres had made a total recovery in the clothing sector and in some cases, synthetic textiles could command higher prices than those made of natural fibres (Handley, 1999).

1.2.3 Physiological comfort in the 21st Century

The functional profile of clothing is undergoing yet another reform. Driven by changes in work patterns/ lifestyle and coupled with the experimental application of technology from other areas such as the medical, aviation and military textiles to clothing. New functionalities are gradually finding applications in commercial clothing which is enabled by innovations in production methods such as 3D construction, digital printing and the use of nanotechnology. As these new properties offer non-conventional roles to garments, the boundaries between clothing and the body are shifting. Textiles in the medical sector, for instance, can be used for drug delivery and are integrated into the body; telemedicine uses items of clothing to monitor a patient's body functions remotely.

Bolton (2002) reviewed current social and technological trends. The work suggests that some aspects of cutting edge fashion design is tailored to deliver psychological comfort in a modern urban environment (Bolton, 2002). Bolton draws upon the work of Augé (1995), who describes the nature of contemporary urban spaces as busy, transitional spaces or 'non-places'. Individuals travelling through such spaces do not develop emotional bonds
(such as history or memory) with the area and are inflicted with sensations of isolation, confusion and fear (Augé, 1995). The works of the fashion designers reviewed in Bolton's work develop products to accommodate changes in lifestyle and combat these sensations.

The 'New Nomad' is a term coined by Philips Design to describe a lifestyle enabled by portable and wearable technology (Philips, 2000). Devices such as mobile phones and laptops have released some individuals from spending the whole of their working life in a particular place such as an office or studio. Philips took this one step further and developed a range of prototype garments with integrated electronic circuitry that incorporates the functions of a mobile phone, PDA or laptop into that of the clothing system. Other electronic devices that have been incorporated into the structure of clothing are MP3 players, satellite navigations systems and various visual recording devices. These developments are mainly prototypes to illustrate the types of functionality that electronic textile circuitry can introduce to clothing; products have yet to reach the mass market.

The question is do consumers need clothing to perform theses tasks. Bolton's

(2002) work highlights that the needs of individuals alter during the course of any particular day and most current garments do not necessary cater for such requirement changes. The adaptation of the properties of a clothing system is achieved manually by the addition, removal or compression/ extension of items. Modular clothing is a new adaptive concept pioneered by design companies such as Mandarina Duck and C.P. Company (fig 4) who have developed clothing products that can alter their shape, silhouette and functionality by adding/ removing, compressing/ elongating elements to accommodate changing circumstances.

So far, such products command high price tags, are generally considered a novelty or have niche applications (ski jackets, military/ police uniforms). The field of wearable electronics or e-textiles has received heavy investment in the last decade; in fact the market value for Smart Fabrics and Interactive Textiles (SFITs) in 2008 was estimated at US$640M with an annual growth rate of 76% [source: Textile intelligence (2007)], these figures however are inflated because of the large market for heated car seats which use e-textiles and do not represent clothing consumption.

Sensory management is a sub-field of adaptive clothing. Apparel in this category has the ability to manage the wearer's senses in response to psychological or physiological changes in the individual. Dr J. Tillotson [3] has created a prototype garment able to manage the wearer's mental and physical wellbeing by emitting various aromas into the individual's proximate environment. The Woolmark Company have also launched a product that uses microencapsulation to embed various substances into textiles that offer functions such as aromatherapy, insect repellents etc as part of a range branded Sensory Perception Technology ™ [4]. Embedded audio and visual devices also promise sensory management properties to protect the individual from feeling isolated, lonely and provide a protective barrier from the bombardment of audio and visual advertising cues characteristic of 'non-places'.

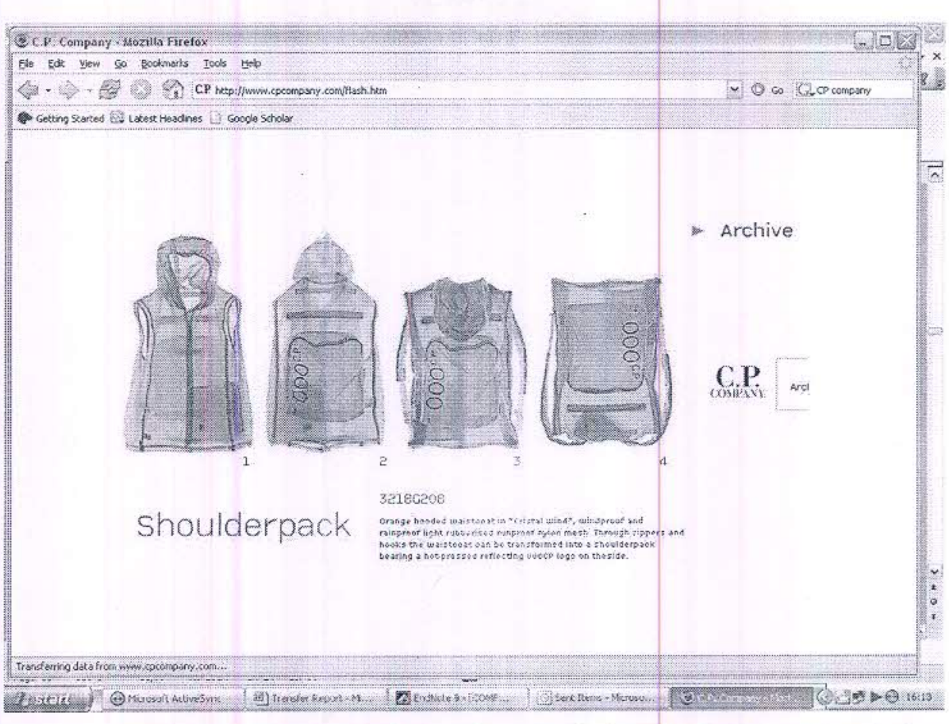


Figure 4: Adaptive modular clothing – a hooded jacket that can transform into a shoulder pack (source: C.P. Company)

Comfort is a key factor in the design requirements of 21st Century clothing. New technologies offer novel methods with which to achieve the desired functionality, however most new developments operate on a psychological platform. This project focuses on the experience of physiological discomfort during travel through an urban environment such as London or New York in winter. The multilayered over and underground networks that lace a modern metropolis form vital passages that lead the traveller though a multitude of natural and artificial spaces each defined by unique conditions (i.e. ambient temperature and humidity) and possibilities (e.g. activity). The plethora of eventualities presented to each individual before embarking on such a journey is impossible to predict and consequently to accommodate in a selection of clothing to ensure physiological comfort. The next section will review current textile technology that aims to enhance comfort relevant to this project.

1.3 The technology of physiological comfort

The physiological comfort of a clothing system is determined by the structure's ability to insulate effectively as well as diffuse excess water vapour emitted from the surface of the skin (see section 1.1.1). Insulation is an important factor in the context of urban travel during winter. The individual however is not likely to be exposed to extreme weather conditions such as those found in the arctic, nor is it likely that the individual would be exposed to cold weather, rain, wind and snow for extended periods. Instead, the urban traveller faces frequent and abrupt changes varying from cold to hot, dry to damp. The type of discomfort experienced in this situation is from inappropriate ventilation and adaptation of the clothing system is often described as clammy or damp.

1.3.1 Sensory perception

Sensation is an important mechanism for living organisms as it provides vital information on the chemical and physical aspects of the surrounding environment (Gescheider, 1997). Cabanac (1979) states that there are two dimensions to the experience of a sensation: discriminative and affective.
Discriminative aspect reflects the quantitative (nature) and qualitative (intensity) of the stimuli while the affective dimension refers to the amount of pleasure or displeasure caused by the experience (Cabanac, 1979). Figure 5 illustrates a set of scales representing the affective dimension of sensation according to Cabanac's theory. For purposes of this study modifications have been made to the original wording where the term 'displeasure' has been replaced with 'discomfort'. The term 'comfort' has been also been introduced to the scales to represent a neutral state (Renbourn, 1971).

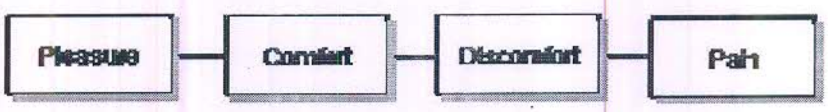


Figure 5: Sensation affective scale

Cabanac's (1979) work suggests that the affective outcome of a stimuli, i.e. whether it instigates pleasure or displeasure, depends on the internal state of the subject; if an individual is hot, physical contact with a cold object would cause pleasure whereas a hot object would cause displeasure. This mechanism is believed to help the individual identify what conditions are required to achieve a type of homeostasis. Sensory pleasure from clothing is unusual, yet not impossible. Flügel (1971) identified certain types of individual that are capable of experiencing sensory pleasure from their clothing. Such individuals demonstrate strong emotional relationships with their apparel and are more sensitive to the psychological aspects of discomfort. The texture of textiles in some extreme cases can elicit sensations of pain to sufferers of Asperger Syndrome [5] or to victims of post-stroke pain syndrome.

The two sensations important to this project are those of temperature and moisture. The mechanism responsible for the detection of temperature in the human skin is well documented. Specialised nerve endings found in the inner layers of the skin are designed to detect either hot or cold. These nerve endings are stimulated by changes in temperature which cause an increase in the impulse frequency. In the case of heat sensitive nerves, an increase in frequency will be triggered by increase in temperature, similarly a decrease in temperature will stimulate the nerves sensitive to cold (Edholm, 1975).

The sensation of moisture requires a more complex mechanism, Bentley (1900) was the first to identify that there were no direct sensory organs in the skin responsible for the detection of moisture and in fact the nature of the sensation is 'synthetic' (Bentley, 1900) meaning that it is generated by a combination of conditions. Experimental work suggested that changes in temperature and pressure at the skin surface created the conditions we perceive as damp or wet. Kerslake (1972) suggested that the perception of dampness is identified through the combined sensation of swelling of the skin from moisture absorption and a change in skin temperature (Kerslake, 1972). While Gagge (1973) found that in a warm environment the sensation is attributed to the increasing strain between two opposing forces: the body's drive to secrete sweat and the peripheral resistance at the skin's surface to the expulsion of sweat caused by hydromiosis (reduction of sweat associated by wetting of skin) (Gagge and Gonzales, 1973).

The findings of experimental work conducted by the textile sector aiming to understand the relationship between physiological comfort and the hygroscopic properties of textile fibres reflected aspects of the above theories. It is clear that changes in temperature and pressure at the skin surface create the stimulus humans perceive as damp. Garments made from highly hygroscopic fibres such as wool are conceived as more comfortable than items made from less absorbent fibres such as polyester. Due to their ability to absorb excess moisture into their core, hygroscopic fibres manage the migration of moisture away from the skin (Holcombe and Barnes, 1996) and reduce the vapour pressure in the microclimate (the space between the surface of the individual's skin and the surface of the external layer of clothing) (Spencer-smith, 1971, Hong et al., 1988, Ha et al., 1999, Scheurell et al., 1995) and thus maintaining positive comfort conditions for a longer period of time Textiles made from highly hygroscopic fibres are also perceived to be dryer (Li et al., 1992b, Plante et al., 1995a); fibres such as wool demonstrate a lower rate of ambient moisture exchange and maintain higher temperature prior to contact with skin than less hygroscopic textiles. Upon initial contact between the skin and the surface of the textile, Plante et al (1995) noted a drop in temperature, the significance of which was directly related to the sensation of damp or dry. The greater the drop in temperature during initial contact the more damp the fabric was perceived to be.

1.3.2 Product & technology review

Slater (1977) identified that the objective factors governing the performance of a textile system, in this case, is the structure's permeability to heat, moisture and air (fig 2). Other factors are the activity of the individual and the conditions of the external environment. This section will focus on technology and products that affect the heat, air and moisture permeability properties in the management of clothing microclimate conditions.

The temperature and moisture concentration in a clothing system's microclimate generates the stimulus that triggers physiological discomfort. These conditions (temperature and moisture) are greatly affected by the design and the properties of the components that constitute the clothing system.

The product review is indicative and by no means exhaustive. Trade names and companies frequently re-brand therefore names often change. Every effort has been made to ensure that the naming is accurate. Information on the products has been collected from visits to trade fairs (e.g. Premiere Vision) and industry publications (e.g. Techstyle). Although it has not always been possible to obtain technical data supporting the product claims published in the marketing literature due to the protective nature of the industry, every attempt has been made to identify the nature of the mechanisms employed.

Permeability to heat (Insulation)

The thermal performance of a textile or garment is defined by its ability to resist the passage of conductive heat (thermal resistance). It is well known that fibres are generally good but air is a poor conductor of heat. Accordingly, the greater the volume of trapped air within a textile system, the higher its resistance to the passage of heat and the greater insulation it provides. The unit used to measure the insulation value of textiles is tog (1 tog = 0.1 m^2 K/W) or clo (clo = 0.645 togs). The tog is a system developed by the Shirley Institute in the 1960's as a simple alternative to the S.I. m^2K/W. The standard method for measuring the thermal resistance of a textile is by placing a textile sample in between a board with known thermal resistance and 'a cold plate'. The thermal resistance of a clothing system is measured by adding the tog values of the component layers; or by applying the above test to a section of all the fabrics incorporated in the system (Taylor, 1990).

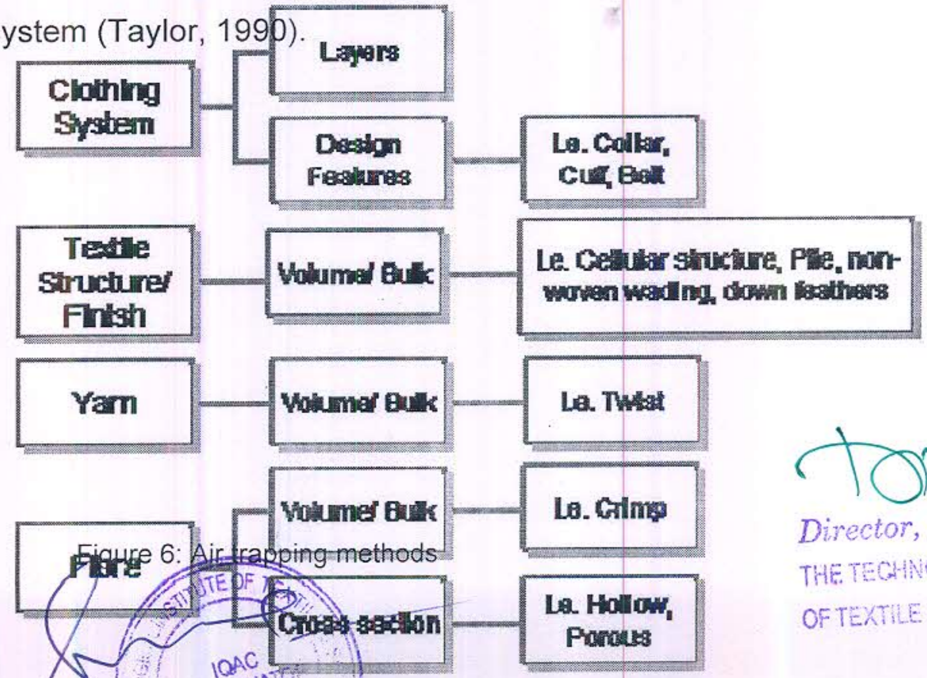


Figure 6: Air trapping methods

There are several methods used to manipulate the insulation properties of textiles, figure 6 illustrates some techniques currently used by the textile industry. It is evident that this property can be engineered into various levels of the hierarchy from fibre to finished garment.

The shape of the fibre is a key factor in the insulation properties of a textile because this influences how closely individual fibres can pack together when spun into a yarn. A wool fibre for instance has a characteristic natural crimp along its length. When packed together into yarns, the crimp structure prevents the fibres from lying close together thus creating pockets of air. Man-made fibres are straight when extruded, but crimp can be introduced at a later stage using bicomponent technology, which will be discussed in greater detail in chapter 5. The cross section of man-made fibres can also be manipulated to increase their capacity to trap air. The design of fibres with hollow cross sections (hollow fibres) is one popular technique which allows for straight fibres to trap greater volumes of air. Thermolite [6] by DuPont and Meryl® Nexten [7] by Nylstar are commercial fibres that use a hollow cross section to improve their insulation properties.

The volume of air trapped within a yarn made from staple fibres [8]can vary depending on the amount of crimp demonstrated by the fibres and/or the amount of twist. Filament yarns can have bulk engineered into them as they are inherently straight. Using the thermoplastic properties of synthetic materials there are a range of methods used such as false twist, knit-deknit, gear crimping, air-jet texturing, etc (Taylor, 1990). Fancy yarns are also quite voluminous, traditional examples are chenille and boucle (Collier and Tortora, 2001).

Volume can be engineered into the structure of a textile using conventional methods such as quilting, cellular knit or weaves, double woven or knitted fabrics all of which introduce additional air pockets into the fabric structure (Humphries, 1996). Advances made in knitting and weaving technology have yielded new hi-tech structures; a prime example is the Spacetech product produced by Heathcoat Ltd. Heathcoat have developed a knitting system that creates three dimensional textiles known as spacer fabrics, where a web of interconnecting yarns is engineered to bind two layers of fabric. The distance between the two layers of textile determines the volume of air trapped and in effect the insulation properties.

Pile structures such as velvets, velour and synthetic furs also trap air at the surface of the fabric. Additionally, composite textile structures combine layers of textiles with different properties by bonding them together to produce multifunctional textiles with high insulation values; wadding [9] or feathers are commonly trapped between two layers of fabrics to increase the volume of trapped air. Nap'tural by Naptural SAS [10] produce insulation sheets composed of 60% natural down and/or feather and 40% synthetic fibre whose main application currently is the construction industry.

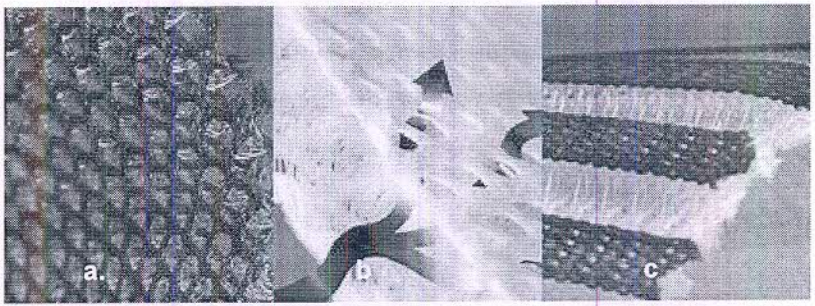


Figure 7: Cross sections of Spacetech textiles by Heathcoat, a and c are two design variations and b illustrates the air flow through the textile.

Composite textiles such as membrane/textiles laminates can manipulate thermal performance by incorporating a metal such as aluminium into the textile system, thereby giving it the ability to reflect heat generated by the body (Tastuya and Glyn O., 1997). The Reflect' line by HT Concept Diffusion [11] is a textile system comprising of a hydrophobic polyurethane membrane containing aluminium particles laminated onto a textile. Similarly, Sympatex Reflexion [12] by Sympatex Technologies is a non-porous polyester membrane with an aluminium coating; the company claims that their products reflect 75% of infrared radiation emitted by the body.

Indetex claim that their Cool & Fresh textiles draw away from the body heat produced by muscular activity, far-infrared radiation from the sun and environmental heat through the incorporation of Sophista and Lonwave fibres into the face of the fabric and multilayer knit construction. Sophista is a bicomponent fibre made from ethylene vinyl-alcohol and polyester. Lonwave is a polyester staple fibre with a hollow cross section that contains ceramic particles believed to reflect far-infrared rays.

Aerogels are used as an alternative thermal insulator to air; this technology has migrated from the medical industry. Manufactured by Aspen Aerogels Incorporated, this is a nanoporous material that has greater free void volume (<90%) than textiles conventionally used for insulation. This increase in pore volume has been found to produce twice the thermal resistance of air (English, 2003), and five times that of Thinsulate by 3M, which is a well established brand of non-woven microfibre insulation materials used for outdoor clothing and accessories. Water and helium are other media that have also been applied experimentally to the management of heat energy in garments by trapping them into non-porous structures used as garment inserts.

Design and assembly of the garments are structural features that effect the insulation properties of the clothing system. The incorporation of collars, cuffs and belts in the structure of a garment, for instance, encapsulates volumes of air into the microclimate. The layering method is another technique used to manage the amount of trapped air between layers of garments; more clothing layers = more warmth. This is currently the most practical technique for the wearer to accommodate changes in activity and external conditions. The individual can put on or take off items of clothing in response to his/her assessment of personal comfort level at any point.

Permeability to moisture

The diffusion of moisture vapour through the matrix of a textile system involves many complex interactions that depend mainly on the chemical composition of the fibre and the structure of the textile. During perspiration, the body uses the evaporation of moisture at the skin surface to cool itself. This moisture is stored in the clothing system's microclimate. Water molecules penetrate the textile matrix and can interact with it in a variety of ways: they can stick to the surface of the fibres, penetrate the core and/ or congregate in the capillary spaces created between fibres. Water molecules can also migrate from the interior of the system to the surface where they evaporate into the atmosphere.

When moisture builds up high concentrations in the microclimate of a clothing system, it condenses into water droplets. This is directly associated with sensations of discomfort and in particular a sensation described as damp or clammy (Gagge and Gonzales, 1973, Plante et al., 1995a, Li, 2005).
Permeability to moisture is measured in terms of water vapour resistance. The lower the vapour resistance of a particular textile the more comfortable the textile is considered to be (Taylor 1990). Textile systems with high vapour resistance properties prevent the diffusion of moisture through the fabric resulting in the development of a high concentration of moisture in the microclimate. It is therefore important for a system to maintain low moisture content in the microclimate.

There are several methods used to measure the water vapour resistance of a textile; each uses a different apparatus but all generate a value through the measurement of latent mass change in a textile that has been subjected to high humidity conditions. The main unit used to measure water vapour resistance is g/24h/m^2. A comparative study of these methods was conducted by McCulloch et al (2003), who found that same fabrics ranked differently in the various test and each method is relevant to a particular range of textile construction, however companies often use the method that yields the most favourable results for a particular product.

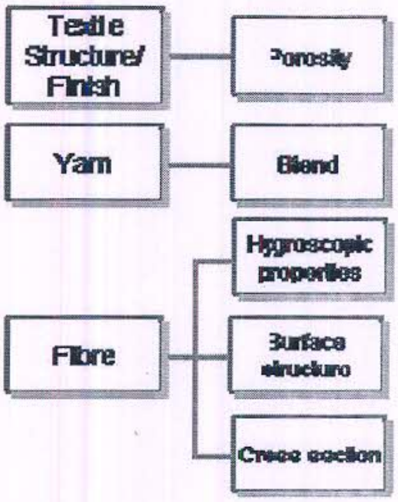


Figure 8: Moisture diffusion methods applied at various levels of hierarchy. Structure porosity affects the passage of air through the textile; yarn blend refers to the combination of fibres used to create the yarn. Natures of fibres plays significant role main factors are hygroscopic properties (a hygroscopic fibre allows penetration of moisture), can moisture adhere to the surface of the fibre, this is influenced by the structure of the fibre surface. The shape of the cross section effects the amount of moisture that can attach onto the surface of the fibre.

A key term often used in marketing literature to describe the water vapour resistance properties of a textile is *breathable*, which refers to a fabric that offers high resistance to liquid water yet low resistance to water vapour (Denton and Daniels 2002). This term is frequently used in the marketing of composite textiles used in outer layer garments especially when one component is a membrane. Another is the *wicking* properties of a fibre or fabric which describe the rate at which the absorbed moisture is dispersed across the volume of the textile and is driven by capillary forces (Denton and Daniels 2002). The term is often used in the marketing to describe a textile's ability to draw moisture away from the skin, sometimes to the face of a textile where it evaporates into the atmosphere.

Similar to the management of heat movement within a textile system discussed in the previous section, there are several factors that affect the moisture diffusion properties of a textile as illustrated in figure 8. The various mechanisms involved are highly complex and have been studied in great detail (Spencer-Smith, 1977, Gibson and Pan, 2006, Li, 2001), this section will provide a simplified overview of the key factors.

The hygroscopic properties (how readily they absorb moisture into their core) of fibres is possibly the most significant contributor the moisture diffusion performance of a textile and in effect the sensation of comfort. As discussed in section 1.3.1 garments made from highly hygroscopic fibres are perceived to be dryer and more comfortable than their less absorbent counterparts.

Hygroscopic fibres also attribute a 'buffering effect' to clothing that improves the comfort of the wearer during transition from a dry environment to a damp one. It was found that the fibres absorb excess moisture delaying the sensation of damp by the wearer. Accordingly, when stepping from damp to a dry environment, the moisture in the fibres is released and the wearer experiences a cooling sensation (Dear et al., 1989, Li et al., 1992a).

Hygroscopic behaviour is affected by the alignment of molecules in the fibre. Fibres are made up of a combination of crystalline and amorphous regions; the ratios vary depending on the type of fibre. Water can penetrate only the amorphous areas because the molecules in the crystalline sections are bound tightly together by chemical bonds (Cook 1984). Natural and regenerated fibres have high ratios of amorphous regions compared to their synthetic counterparts, this is due to the stretching processes the filaments (fibre of indefinite length) are exposed to during manufacture which creates greater areas of aligned molecules (Latta 1977).

The nature of the fibre surface can encourage or discourage the adhesion of water molecules. In the first case, the fibre is classified as hydrophilic and associated with comfort. Natural and regenerated fibres fall into this category.

The latter are known as hydrophobic and are generally considered uncomfortable. Synthetic fibres are hydrophobic by nature despite the presence of hydrophilic monomers in their polymer chains because they are submerged into the layers of the fibre skin during manufacture. Other contributing factors to the hydrophobicity of synthetic fibres are the smooth surface and lack of bulk generated in the filament yarns (Latta 1977). Coolest Comfort by Nano-Tex and Intera by Intera Corporation both use nanotechnology to mask the hydrophobicity of synthetic fibres by grafting hydrophilic groups to the surface of the fibre.

The commercialisation of microfibre technology in the 1990's demonstrated that structures made of synthetic fibres could be breathable. Due to their fine structure, which is less than 1 denier (the mass in grams of 9000m of a fibre, filament or yarn), tiny holes are created between the fibres when spun into a yarn and constructed into a textile, they allow the passage of water vapour, therefore creating a breathable structure e.g. Micro Supplex by Invista [13].

Hydrophobic properties enable textiles to achieve rapid capillary wicking rates, meaning that they dry quicker. This can be further improved by manipulating the cross section of a fibre to increase the overall surface area which in turn results in even quicker evaporation of the excess moisture (Patnaik et al., 2006). DuPont's Coolmax [14] range employs this method, made from a hydrophobic copolymer; the cross section has 4 grooves running along the length of the fibre revealing a cross section often referred to as 'Mickey Mouse ears'. This is believed to increase the surface area of the fibre by 20% compared to a standard round cross section. Similarly, Technofine [15] by Asahi Kasei have developed a w-shaped cross section. Another fibre that uses cross section design to increase wicking is Becool [16] by Condamin et Prodon

Textiles made from hygroscopic fibres such as cotton and viscose (rayon) help maintain lower vapour pressure in the microclimate by absorbing moisture into their core. However, once saturated these textiles become very uncomfortable and difficult to dry when compared to their synthetic counterparts. It is possible to combine the positive properties of the two fibre types and minimize negative effects by blending natural or regenerated with synthetic fibres in a yarn. Sportwool by the Woolmark Company uses yarns composed of both wool and synthetic fibres whose functionality and comfort properties have been found to surpass those of cotton in base layer garments such as T-shirts (Holme, 2003).

The density of a textile structure can play a significant role in the diffusion of moisture but the nature of the fibres is the key factor. Fort and Harris (1947) conducted a comparative study of a range of natural, regenerated [17] and synthetic textiles; the findings revealed that diffusion occurs in textiles made from either natural or regenerated fibres in spite of the density of the structure. Synthetic fibres, however, increase their vapour resistance in denser structures. The hygroscopic properties of natural and regenerated fibres allow the moisture to be drawn into the fibre whereas textiles made from synthetic fibres rely solely on capillary wicking to diffuse moisture which only occurs in higher humidities (Adler and Walsh, 1984).

Perseverance Mills have developed a woven textile called Pertex [18] that controls the direction of the water vapour diffusion by using a denier gradient structure. Thicker polyamide yarns are engineered into the inside of the weave while the face of the fabric is made of microfibres; this is claimed [19] to draw moisture from the microclimate to the surface of the garment. 3XDry by Schoeller also demonstrates a similar functionality however; the mechanism includes hydrophobic treatments.

During the 1990's breathable, water resistant membranes and coatings started to find applications in the casual clothing sector. The basic principle supporting this technology is that water in the form of vapour is able to pass through the membrane whereas drops are not. There are two types of products available, the first is expanded PTFE whose surface is characterised by micropores permeable to water vapour, Goretex by Gore and Associates were the first to develop this technology [20]. The second type is known as a hydrophilic/phobic membrane and was originally developed by Sympatex Technologies [21]. The hydrophilic side of the membrane faces the interior of the clothing system and draws the moisture away from the skin toward the surface of the textile, while the hydrophobic layer prevents moisture in the form of droplets from entering the system. Several variations of these have been developed over the years but operate on the same principles.

Permeability to air (Ventilation)

Fibre hygroscopicity and good moisture diffusion can help maintain steady vapour pressure in the microclimate when excess moisture is introduced, the enclosed air will eventually become saturated thus eliciting discomfort sensations. In order to prolong or prevent this it is necessary to replenish the air trapped in the clothing system. This can be instigated by the wearer with the aid of design features and/or by the properties of the textiles. The key factors affecting the permeability of a textile to air are the thickness and porosity of the structure. The shape of the fibre (amount of crimp) can contribute to these properties but it is the yarn and textile structure that play the most significant role in this aspect of textile performance (Kullman et al., 1981, Backer, 1951).
Periodic ventilation is the main method used to manually manage air renewal in the microclimate. Ancient Inuit clothing was made of insulating and waterproof furs and feather pelts yet the garment's design enabled extremely efficient ventilation (Ammitzboll et al., 1991, Humphries, 1996). The traditional Inuit hood was closely fitted around the face with no front opening and air was trapped in the system at the chin and waist. The sleeves on the parka were long enough to cover the hands and fitted to prevent cold wind from penetrating the system. During periods of activity when the microclimate was threatened by saturation, ventilation was achieved by pulling the garment forward at the front of the throat, pushing the hood back or loosening the closure at the waist (Humphries, 1996). Conventional clothing uses design features such as zips and openings to enable the renewal of saturated air in the microclimate (Ruckman et al., 1999).

The physical factors affecting the permeability of textiles will be discussed in greater detail in chapter 5. As a rule of thumb, fabrics that demonstrate firm texture, close structure and short floats (e.g. plain weave) are generally less permeable to air. Whereas open structured, fine fabrics with long floats (e.g. sateen weave) demonstrate higher permeability. Various finishing processes can also effect the performance of a textile (Schiefer et al., 1933).

Textiles with low air permeability are important for use in clothing systems designed for cold weather conditions as they keep warm air in and prevent cold air from penetrating the system. However, physiological comfort depends on the system's ability to adapt its permeability properties in accordance to changes in the wearer's activity. Even clothing designed for extreme cold conditions must take this into account, which is why the Inuit system is a successful example. Textiles with high air permeability are used for clothing systems designed for hot weather climates because they allow for constant air renewal necessary when the individual is sweating regardless of activity levels.

Wind resistance

Tightly woven structures, felting/ milling techniques, and natural skins were traditional methods used for protection against wind and cold. Today, advances in knitting technology coupled with the development of microfibres, have enabled the production of tightly knitted fleece structures such as Polartec Wind Pro [22] by Malden Mills which is a 100% polyester fleece whose tight knit construction increases its resistance to wind penetration.

Wind resistant membranes or coatings are commonly incorporated into a composite textile system to offer a host of functionalities. Sympatex Windmaster [23] by Sympatex Technologies is a 100% polyester membrane with aluminium which reflects body heat and increases wind resistance. Windstopper Soft Shell [24] by Gore & Associates is made of an expanded PTFE membrane designed to act as a barrier against wind when combined with fleece or other materials.

1.3.3 Adaptive/ smart technology

Conventional clothing systems rely on wearer intervention to adapt insulation and ventilation properties of a garment system. Consumer trends suggest that expectations from apparel are changing and that individuals may require their clothing in the future to alter its functionality without the wearer's intervention (see section 1.2.3). The textile industry is currently seeking systems that offer alternative methods of adapting the performance of a clothing system; this section will review key commercially available developments.

The manipulation of insulation properties through the control of the volume of trapped air in a clothing system is known as Variable Geometry. Some development has been carried out by N. & M.A. Saville Associates (fig 9). The structure consists of two layers of fabric, which are joined together by strips of textile at a vertical angle to the plane of the two fabrics. By skewing the parallel layers the volume of air between them reduces. This results in the reduction of the insulation value. The idea was used in the design of military uniform systems that can be adapted to function in both extreme cold and hot conditions. This product is still in development; however Alex Soza (fig 10) developed the *Bionic Jacket* concept. This design employs the principles of variable geometry for the manipulation of insulation values but the mechanism is incorporated into the shape of the garment and not isolated to the textile system.

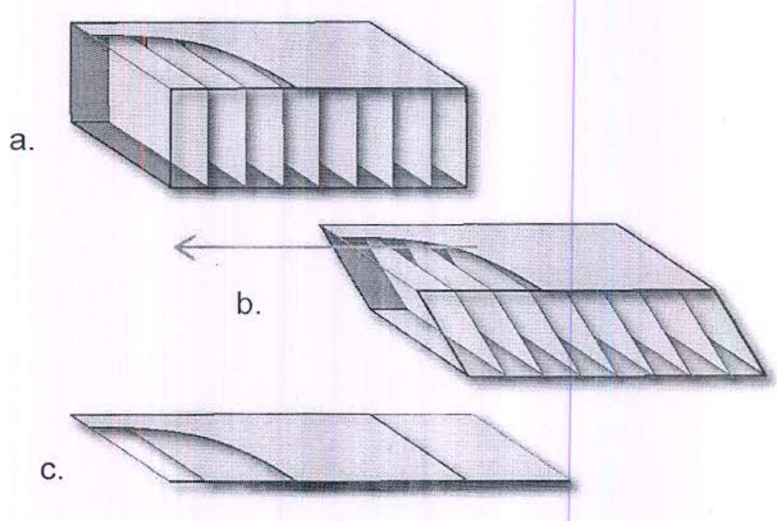


Figure 9: Variable geometry concept (source: N. & M.A. Saville Associates). Textile system comprising of two layers joined together by textile strips at 90° angles. 9a. Configuration allowing the maximum volume of trapped air between top and bottom layers thus providing maximum insulation. 9b. By skewing system volume of trapped air is reduced. 9c. System fully compressed trapping the minimum volume of air.

A commercial version of this concept is Airvantage by Gore & Associates. This adaptive insulation mechanism allows the wearer to adjust the volume of trapped air, thus managing the heat resistance of the garment. In the form of an inflatable lining insert, the structure is made from two layers of expanded polytetrafluoroethylene (ePTFE) membrane and polyester membranes (76%PE 24%PTFE) that are bonded together at points that form a network of tubes (fig 11); this product allows the user to inflate/deflate the jacket thus controlling the necessary amount of air for the provision of adequate thermal resistance.

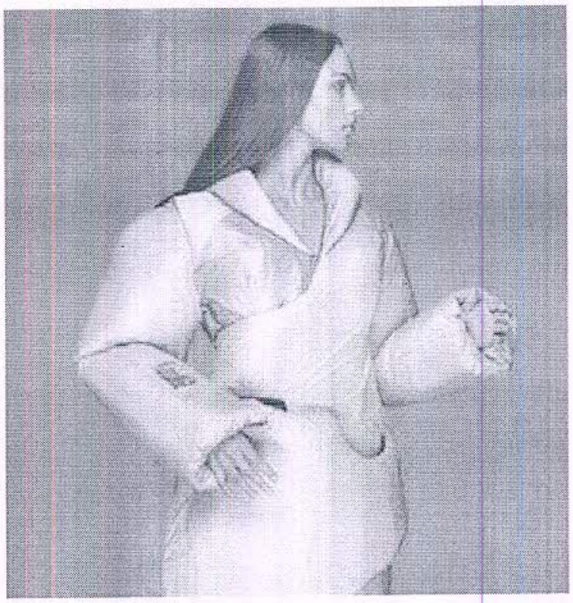


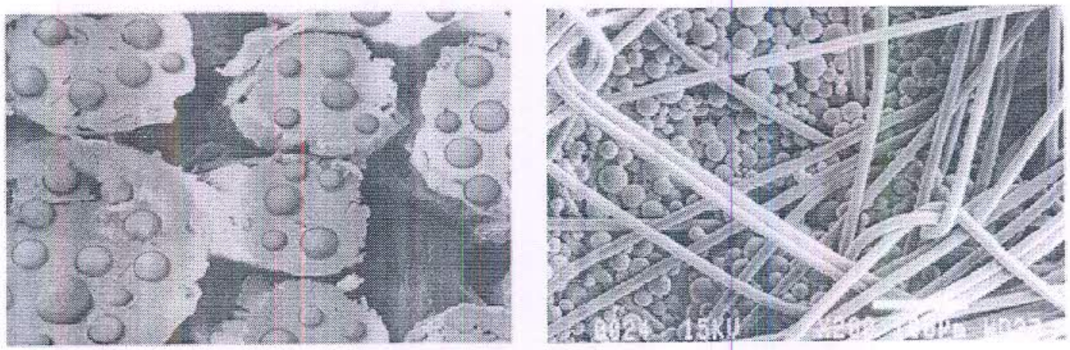
Figure 10: Bionic Jacket: Image shows jacket in inflated state, inflation is managed by integrated control pad on sleeve (left). (source: Alex Soza)

Shape memory polymer (SMP) membranes are the main technology used to introduce adaptive moisture vapour resistance properties to clothing. Mitsubishi Industries originally developed a smart membrane branded Diaplex [25] in the 1990's. Recently Schoeller launched a product into the European market that uses a similar membrane technology under the brand C-change [26]. According to the marketing literature the mechanism that enables this functionality is based on micro-Brownian movement which is a temperature related phenomenon. At lower temperatures the molecules in the membrane obstruct the diffusion of air and vapour through the membrane and at higher temperatures the bonds loosen enabling the passage of air and moisture. Mitsubishi Industries claim that the temperature at which the functionality change occurs can be engineered into the polymer. These products will be discussed in greater detail in chapter 5.

Figure 11: Jacket lining with Airvantage lining inserts (source: Gore and Associates)

Phaseable [27] by Sympatex is a hydrophilic/ phobic membrane lined with a black film that forms the base of the system. The side adjacent to the skin features printed motifs using a foam based substance that swells as it absorbs moisture. Originally printed in triangle shapes, these sections raise the surface of the textile away from the skin and Sympatex claim they pump moisture out of the system. The benefits and nature of the mechanism are unclear from the available literature and Sympatex were unable to disclose any information due to a confidentiality agreement with Nike at the time of this research. It may be that the swelling foam absorbs moisture from the microclimate thus maintaining low vapour pressure for longer.

Phase change microcapsule (PCM) technology has introduced adaptive heat storage/ production properties into clothing. Originally funded by NASA and carried out by Triangle Research Group the technology was intended for use in space applications. Triangle was later renamed Outlast Technologies Inc and focused on applications in the textile and apparel sector. The technology involves the use of tiny ceramic capsules that are filled with paraffin-hydrocarbon which convert to liquid form in warm conditions and solidify in cool conditions. The PCMs can be applied to the textile either directly into the fibre (fig 12a) or as a coating (fig 12b) onto the finished fabric.



a: in fibre b: in coating Figure 12: Phase change microcapsules (source: Outlast)

The adaptive nature of the product lies in its phase change mechanism. When the microclimate is hot, the paraffin absorbs the excess energy and stores it as in liquid state; the effect on the wearer is a cooling sensation. When the temperature of the microclimate drops the paraffin releases the heat energy by becoming solid state, thus heating the wearer (Pause, 2003, Holman, 1999).

This chapter has examined the impact that lifestyle and technology have on consumer expectations and the requirements of clothing. It is very likely that clothing of the future will incorporate novel functionalities additional to those of conventional clothing. Already smart and adaptive textile technologies are finding their way to consumers through the garments they purchase, but these are focused on the psychological dimension of clothing functionality. The physiological needs of individuals in urban environments have not received much attention from new developments but are a persisting problem. Modular clothing systems are used to manage physiological discomfort but the problem with these is that they involve adding and removing layers or opening and closing zips and fastenings, this is not always ideal for the individual who may be in transit or in confined space.

The focus on current smart developments pivots around the use of temperature changes as stimuli for adaptation; however there is no data to support the marketing claims. This raises questions on the suitability of temperature as trigger for an adaptive system designed to combat physiological discomfort. The next chapter will review the literature on methods used to link damp sensation with microclimate temperature and humidity and the effect of textile properties, to map existing work and knowledge. This is followed by a description of the design and execution of a trial designed specifically for the identification of ideal stimulus and comfort conditions.

Physiological discomfort and the role of clothing

Pressures from the changing relationship between the city dweller/ commuter and the nature of urban cityscapes in conjunction with advances in novel technologies are gradually altering consumers' expectations from their apparel. Already clothing systems are available that offer additional, non-conventional functionalities such as remote communication (embedded Bluetooth, GPRS and mobile phone technology) and entertainment (integrated audio equipment).

As a consequence, expectations of conventional properties of clothing are also being driven forward; novel technologies promise to alter the performance of a clothing system to meet the wearer's physiological needs. The product review in the previous chapter showed that current developments in smart and/or adaptive textile technology employ temperature as a stimulus in mechanisms such as latent heat storage (PCM) and variable moisture vapour resistance (SMP membranes). However, it is questionable whether these developments are designed to work in partnership with the microclimate of the wearer (despite claims in the marketing literature) and adapt to the individual's *actual* physiological needs.

Cities such as London or New York are hives of activity whose lifeline is an intricate system of under and over ground transport networks. These networks are composed of many isolated environments whose climatic conditions vary greatly in terms of temperature and moisture. In the winter months, individuals can step from a cold to a hot environment or damp to dry (and opposite in the summer), several times before they reach their destination as well as alter the level of their activity (slow walk to run). Modular clothing and layering assemblies are capable of adjusting their insulation and moisture resistance properties, but this needs to be done manually by the individual by unbuttoning their coat, etc. This method is often compromised by limited availability of space in public transport vehicles and the luggage carried by individuals. Also the wearer's ability to sense the onset of discomfort in time limits his/her success at adapting the properties of the outfit.

2.1 The study and measurement of discomfort from moisture

The combined effects of changes in microclimate temperature and vapour pressure at the skin of the individual cause the physiological discomfort (Bentley, 1900, Plante et al., 1995a) relevant to this project. Until clothing made from synthetic fibres entered the market on a mass scale during the 1960's and 70's, these sensations were virtually unknown. Terms relating to the conventional properties of textiles of the time such as hot, cold, tight, heavy etc failed to reflect the nature of the discomfort consumers were experiencing. (Hollies, 1977) studied this new form of discomfort and noticed that the same sensory descriptors such as clammy, damp and clingy reappeared in numerous independent subjective studies. These terms have since been used by the industry to describe the sensation caused by the concentration of moisture in the microclimate of clothing.

Subjective measurements are a valuable tool for the study of the experience of the wearer, but they can be problematic. Slater (1986) identified that this kind of data usually is inconsistent due to the influence of psychological, physiological, social and environmental factors and rely upon the honesty and subjective opinion of the individual. Subjective trials also produce non-numerical results that are difficult to analyse statistically, while trials that focus on objective factors produce reliable and consistent data (Slater, 1986).

The instruments used to measure the moisture resistance of textiles were discussed in section 1.3.2 and provide information used widely in the textile industry especially for testing industry standards. The numerical data produced can predict the sensory influence of a textile during use (Slater 1986); generally a textile with low resistance to moisture would be more comfortable than one with high resistance.

Other devices imitate the behaviour of human organs such as skin. Holcombe and Barnes (1996) used an apparatus designed to simulate sweating skin to study the impact of fibre hygroscopicity on the migration of moisture vapour. Textiles made from 100% wool and 100% polyester were tested and the results indicated that 30% more moisture is transported from the skin by the wool fabric than the polyester and therefore should be more comfortable. This type of data provides useful information on the performance of a particular textile and how it compares with others, but is not directly linked with the sensory experience of an individual and therefore poses limitations to the purposes of this study.

2.1.1 Psychophysics and moisture sensation

The link between sensation and physical stimulus is enabled through the field of psychophysics which has its origins in the 1860's and describes the relationship between experience and stimulus (Gescheider, 1997) by measuring the strength of sensory experience. Psychophysics was originally applied to senses such as smell and touch, and the textile industry adopted some of the principles to the study of tactile sensation from textiles and later physiological comfort. Sweeny and Branson (1990a) where the first to demonstrate that psychophysical techniques can be applied to the study of moisture sensation in relation to textile properties (Sweeney and Branson, 1990) and produce reliable results. The mathematical tools of psychophysics are used to quantify the intensity of the stimulus and identify the threshold or the minimum amount of stimulus necessary for the subject to detect a difference. An in depth account can be found in the work of Li (2001). These are not relevant to the purposes of this work and will not be further discussed. It is the scaling techniques that are useful to this study.

In indirect scaling the subjects are asked to compare several pairs of stimuli and place them in order of intensity or on a rank in a scale. Plante et al (1995a) exposed a group of subjects to four types of fabric at different humidities in order to study the effect of fibre hygroscopicity and the perception of damp (Plante et al., 1995b). A scoring scale was used to rank the perceived dampness of each textile. Fabrics made from highly hygroscopic fibres such as wool felt drier than those made from polyester.

Direct scaling requires the subject to make estimates of the stimuli's sensory magnitude with reference to a standard value. Sweeny and Branson (1990b) used a 50/50 blend of polyester and cotton single jersey textile swatches that contained different amounts of moisture (Sweeney and Branston, 1990). Subjects were asked to assign numbers to each sample that reflected the amount of moisture perceived in the textile.

Psychological scaling is another technique used to link sensations with numerical values. Although there are several different types, the scales used to study comfort, function as measures of attitude [28] (Li, 2001). Attitude scales were pioneered by Hollies et al (1979) as part of a method developed to analyse human perception where subjects were asked to rate the intensity of sensations from a list given to them during the trial (Hollies, 1979). Li et al (1992) developed subjective rating scales to measure clamminess and thermal sensations in order to study the moisture buffering behaviour of hygroscopic fabrics (Li et al., 1992b) and further developed this tool (fig 13) to include perceived comfort (Li, 2005).

2.1.2 Psychophysical methods applied to clothing microclimate

Studies employing psychophysical methods for the investigation of moisture sensation have focused exclusively on various specific locations such as areas of skin on the back and inner forearm. The most relevant study by Li (2005), conducted a series of trials to study the perception of moisture and temperature from the clothing system and the relationship to comfort. Focusing on the microclimate, the data included subjective measurements of comfort (thermal and moisture sensations) which were recorded using psychological rating scales illustrated in fig 13, while objective data on the temperature and moisture content of the microclimate was recorded simultaneously.

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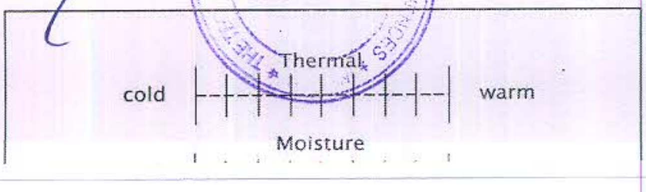

Figure 13: Subjective rating scales (Source Li ,2005)

The trials were conducted in a controlled environment of 20^{O}C and 80% RH; rain simulations were included in the protocol. The subjects felt comfortable, warm and dry when $T_{skin} > 34.4\ ^{O}$C. Uncomfortable and damp sensations occurred around $T_{skin} = 34\ ^{O}$C. The subjects also felt a sharp increase in the sensation of dampness and decrease in comfort around 50-55% relative humidity. Although the work of Li (2005) was not designed to identify the boundaries of comfort in the given climatic conditions, valuable information has been extracted from the work.

This project further explores the sensation of discomfort using inexpensive and non-lab based methods to pilot the study of the physiological comfort threshold in a cold and dry environment and distinguish between temperature and moisture for the stimulus most representative of the onset of clammy/ damp sensations.

2.2 Experimental trials: The Journey

The Journey is a name coined to describe the process of data collection designed to identify the changes in microclimate temperature and moisture
content that trigger the sensation of discomfort during 'real time' urban travel.

This was achieved through the simultaneous collection of both subjective and objective data in a real environment and the subsequent analysis of their relationship.

The work began in October 2003 and evolved over two phases, the second building and improving on the first. The first stage was speculative and occurred before any review of literature had been conducted. A single thermocouple with two sensors was used to measure skin and external temperatures and the subjective data was recorded in a note book noting the time with a stopwatch that had been synchronised with the thermocouple's clock. The timeline functioned as a link between sensation and actual skin temperature. During the analysis of the data, it became apparent that the findings were not representative of the sensations experienced. Temperature measurements alone did not provide an accurate representation of the microclimate conditions.

This stage also helped develop the method and protocol of the final trials; it became apparent that the language used needed refining and that a set of sensory descriptors, independent of psychological factors were necessary. The lack of consistent psychological scaling produced inconsistent data, that was influenced by factors such as those described by Slater (1986).

The location of the ideal position for the sensors was also an important outcome of the first phase. Various locations on the chest and back were tested, but during the trials it became apparent that moisture discomfort would start at the nape of the neck and slowly progress down the back and spread down and around the armpits toward the front of the body.

Overall, the first phase did not produce any reliable data but was crucial to the design of the journey trials because it provided an understanding for the nature of the experience and the type of data that was necessary to collect. The initial trial also indicated that the most prominent sensation that caused discomfort was the build-up of dampness which instigated the acquisition of a humidity recorder for the second series of trials.

2.3: VISCOSE RAYON:

Rayon, a manufactured fiber composed of regenerated cellulose, can be made to be quite lustrous and strong, dependent upon the number and size of the filaments in the yarn.

Four basic technology concepts are applied today to produce the majority of all Viscose Filament Yarn (VFY) worldwide. Technological developments focus more and more on either "low cost ↔ mass products" or on "high value ↔ demanding quality".

Drivers for Viscose Filament Yarn (VFY) Technology

Viscose Filament Yarns for textile applications have been produced for more than 80 years and still display the best available properties in moisture adsorption, colour brilliance, comfort and drape. Future developments of the VFY technologies are driven by two market trends:

- low cost ↔ high volume
- high value ↔ demanding quality.

Those market trends will also lead to differentiated technological concepts. Mass production for low cost ↔ high volume has predominantly a focus on the cost drivers:

- Investment & running costs

- Large volume products

- Yield without neglecting quality and service.

Engineering companies are offering complete investment concepts at competitive costs because there is an economy of scale when one machine concept can be offered to numerous companies.

Producers in high wage countries are forced to excel on high value ↔ demanding quality and consequently developed their proprietary technologies.

Key factors for success are highest quality and new products:

- Fluff level
- Evenness of dye affinity
- Fine denier
- Fine denier per filament
- Specialities (e.g. triangular shape) without neglecting costs, production volumes and yield.

Sensitive Points for VFY Technologies Filament formation is done in a chemical process in approx. 0.1 second. During this brief moment a multitude of chemical and physical parameters in and around the fibre are determining the optical and mechanical properties. Decisive factors range from chain lengths of the cellulose over dope-viscosity to the concentrations of numerous chemicals.

Equally important are the temperature of the chemicals, the reaction time and the design of the spinning devices. Optical properties such as light reflection, dye uptake and brilliance depend on the morphology of the yarn (porosity, skin-core ratio), which in turn are determined by the chemical parameters during spinning. Tenacity and elongation are partially a result of the chemical parameters during spinning and also strongly influenced by the stretch ratio between spinneret and winding. The number of fluffs and breakages of the yarn are decisive for the mechanical processability in weaving, knitting and twisting. This depends on the number of physical defects in individual capillaries which can be introduced during spinning (e.g. by impurities) or during textile after-treatment (abrasive yarn-machine contacts). The practical challenge for VFY production is the constancy of all those parameters over time, as this is the precondition for consistent yarn properties within one spool (outer versus inner part of a spool) and from spool to spool. Basic Technologies Available Today The processes applied today on large scale can be divided into the following basic technologies The Centrifugal (or Pot) and the Spool technologies are both discontinuous processes. For all process steps (spinning, washing, drying and winding) optimal processing speed and parameters can be chosen. Disadvantages are the high labour intensity and long processing times.

Centrifugal is the standard batch technology for VFY spinning used all over the world. The limits of the centrifugal technology (control over yarn speed and stretching conditions) can be overcome with the Spool technology. As a result, coagulation, stretching and the yarn morphology are fully controlled, allowing the manufacturing of fine denier yarns and yarns with superior dye uniformity. The Warp Type technologies are both continuous processes with very short cycle times. The process is very compact needing low space requirements. This results in comparatively low investment costs. But variances of physical and chemical parameters within one machine and between machines are creating variances in physical and dyeing properties of the yarn. The technically more sophisticated process has a parallel yarn treatment. Nearly 500 yarn strands are spun at the same moment, in one machine, under the same physical and chemical conditions, therefore displaying identical yarn to yarn properties. High Quality The superiority of the spool and Warp Type technology over standard designs can be demonstrated with the following examples: Fluff level determines the efficiency during weaving, knitting and twisting, especially when using automated and high speed equipment. Evenness of dye affinity was always highly esteemed by lining weavers and is now increasingly demanded by circular knitters as it supports just-in-time production. The practical data of a mass production (2,300 tons of 75 den) show the high and constant quality level with respect to fluff level and evenness of dye affinity.

Fine Deniers – Market Driven Solutions

While standard technologies are concentrating on the titer range between 75 and 500 denier, fine denier range covers next to 75 den also 60 den and now even 40 and 30 den. The latter presently marks limit for the large scale production of a flawless yarn (30 den Spool spinning). Utmost regularity in finest cross sections is the prerequisite for this achievement and only made possible by the advanced spinning technologies. It leaves the traditional product range of VFY far behind and penetrates the markets for silk and silk-like products. The next challenge is the commercial breakthrough to real micro yarns with denier per filament (dpf) below 1. 75 den f 90 are delivered to customers applying this product in lining fabrics. First reactions are very promising. Fine dpf such as 75 den f 90 already have quite a history. In 2000, started commercial deliveries in 75 den f 60, followed by first deliveries of 100 den f 90 in 2001. Fine dpf gives high softness and exclusive touch to garments. Cupro-like fabrics (weaving) and light-weight knitted fabrics are the main applications showing the exquisite touch and luster of this sophisticated yarn.

Steady Growth and Market Success

The steady growth and market success of fine denier and fine dpf products gives testimony to the fact that spinning technology sets the standard for "high value ↔ demanding quality" in the VFY industry.

The World of Specialities in VFY

Observes technological trends (e.g. Triangular Yarns) as well as market trends (e.g. Yarn-dyed). But the biggest challenge is posed by the ever increasing demand for fine deniers in VFY displaying the same quality characteristics as the standard yarns. More than 80 years since its invention, VFY is one of the oldest man made fibres. Despite that respectable history, further progress in spinning technology is to be expected. Main focus will be either on "low cost ↔ high volume" or on "high value ↔ demanding quality" standards. as the leading European producer for VFY will further push technological barriers of its proprietary technologies to offer new and exciting products.

Rayon fiber offers:

- Highly absorbent
- Soft and comfortable
- Drapes well

Sample rayon applications:

- Clothing
- Tire cord
- Industrial products

Blends with other fibers to enhance functional and aesthetic qualities of the resulting fabric

The viscose technology is the origin of the man-made fiber industry. The current basic technologies were developed in the years 1950 to 1960. These technologies are known as

- Spool process
- Pot – or centrifuge process
- Continuous process.

The technology of high speed spinning to be prepared for the various developments in the textile market. The continuous spinning process according the latest technology can now be operated at 500 m/min spinning speed. At this speed, the production stability and the product properties are at an optimal level. Especially the level and the constancy of all important yarn properties, such as dye uptake and shrinkage, are excellent. Also at manifolded spinning speed, the special continuous spinning process shows the advantages in product properties in comparison to the old -type technologies. Further increase in spinning speed is limited by mass-transfer in the yarn forming step and the washing units. Technically, a spinning above 1000 m/min is possible, but sees no economical benefit at this high speed.

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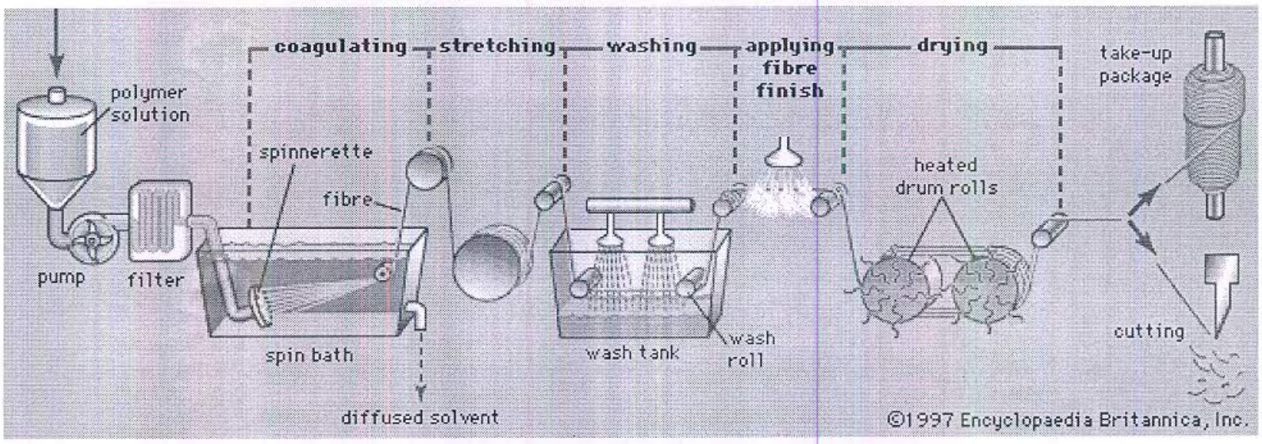

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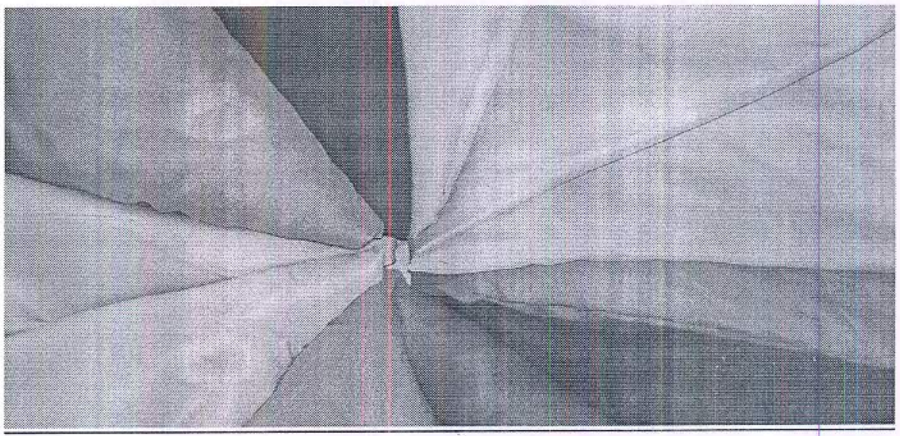
- Rayon is a manufactured regenerated cellulose fiber. It is made from purified cellulose, primarily from wood pulp, which is chemically converted into a soluble compound.
- Has many of the same characteristics as cotton. It was the first manufactured fiber. Often found in lingerie, shirts, blouses, dresses, slacks, coats, and work clothes.



Advantages & Disadvantages Rayon

Advantages

- Soft
- Comfortable
- Absorbent
- Inexpensive
- Versatile

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Disadvantages

- Shrinks & wrinkles easily
- Low Resiliency
- Heat sensitive
- Mildews
- Dry Clean or Hand Wash Only.

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Quality requirements for viscose filament yarns

The textile applications for viscose filament yarns have remained basically unchanged over the past decades. In the apparel segments, viscose filament yarns are used for crepe fabrics, knitwear, embroideries and yarn blends together with wool or synthetics. For garment lining fabrics, viscose filament yarns are still the most favorable materials to get the right fabric properties.

Dependent on the fashion cycles, these various segments are characterized by strong fluctuations in demand. A successful yarn process for these markets has to be designed for high flexibility to cover all these applications. The titer range has to cover all segments; the technical performance of the yarns has to be suitable for these various textile-processing steps. For Kesoram Rayon, which serves all these textile segments, the basic yarn properties

- Constant dye uptake,

- Consistency in all physical properties,

- Excellent mechanical processing properties have to be the premises for the high-speed spinning process.

In the current textile industry, where time to market is the ultimate requirement, product deviations influencing the processability or fabric characteristics are not tolerated.

Technical requirements for the high-speed spinning process

Based on the market demands, the technical requirements can be defined. Constant dyestuff uptake is achieved by constant skin-core relation and porosity. This means constant process parameters, such as temperatures, concentrations, and residence time throughout all process steps. Excellent mechanical processability requires a low number of contacts of yarn and machine parts, high quality of the surface of yarn guides, godets with a controlled drive and a safeguarded protection of the individual filaments in all process steps. Basic tenacity and elongation is tuned by the spin bath and viscose solution parameters.

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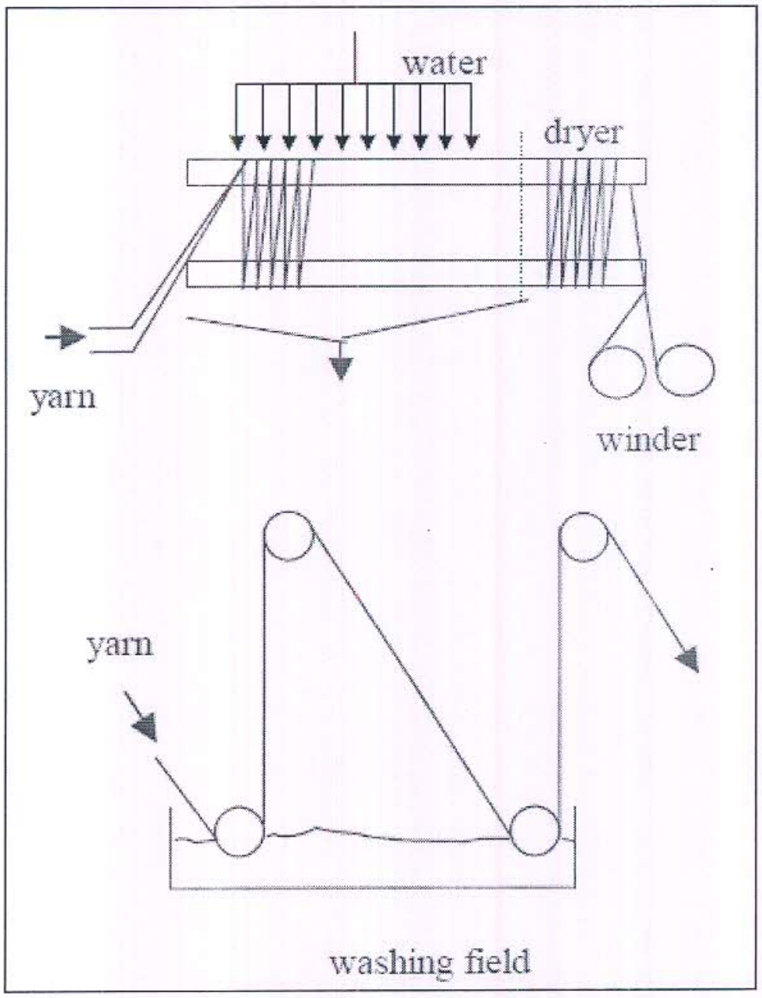
Comparison of existing technologies

The known processes can be divided into four basic technologies. Spool and pot-processes are both discontinuous types. For all the various steps (spinning, washing, drying and winding) the optimal processing speed and parameters can be chosen. The disadvantage is the high labor intensity and high processing times. Within these two discontinuous technologies, the spool process covers a titer range from 67 dtex to 660 dtex at top quality; the pot processis more restricted to the heavy deniers.



The above technology are both continuous processes with short production time (Figure 1). The compact process realizes the post-coagulation step and the yarn washing with low space requirements. This results in comparatively low investment costs. This benefit in investment leads to a weakness in parameter constancy during these process steps.
Result is the broad variance in physical yarn properties and dyeing characteristics.
The technical more sophisticated process has a parallel yarn treatment. The different washing steps are fully separated and can be operated at optimal conditions. As a result, the quality of the yarns is fully comparable to the spool spun yarns.

Development of high-speed spinning viscose filament

The development of high speed spinning to reduce the specific investment cost of the process, which were clear higher than for old process. The product portfolio had to cover the titer range from 40 dtex to 167 dtex at the established ENKA quality level.
Especially the yarn shrinkage of max. 5 % was to be kept beyond this limit. The target spinning speed was defined as 500 m/min, which meant a factor of 3 to 5 in comparison to the established speed.

Process principle for high-speed spinning

In a continuous spinning process, the yarn speed in every step has to be identical. The dimensions of each unit are determined by the necessary residence time. For a minimized investment and therefore the optimal economics, the target is to reduce these residence times as much as possible. An alternative to operate the process steps of a continuous spinning at different speeds was developed by Asahi. The high-speed yarn formation was followed by a low speed washing, where the yarn was folded on a sieve belt. The mass transfer mainly determines the residence times of the processing steps. The time limiting mass transfer is of course different during coagulation, degradation of the xanthate, washing and drying.

The first step, the chemical reaction, is a fast neutralization of sulphuric acid and caustic. The reaction rate depends only on the acid diffusion to the reaction zone. The washing process is only controlled by diffusion. The limiting mass transfer coefficients of e.g. sodium sulphate in cellulose and in the laminar film are constant.Drying is also a diffusion process where heat transfer and the diffusion coefficient of water in cellulose are the determining items. Common for these types of diffusion processes are the limited possibilities for acceleration of mass transfer.

This topic and the item are originally compiled for the students of clothing technology and the objective was to present a restated selection of the literature available under this assignment.

Narrow woven fabrics are as much subjected to fashion as other fabrics, thousands of new designs being introduced in the market every season, hence the designer must be equally competent in his profession as the designer for men's wear, dress goods, upholstery goods, carpets, rugs, etc., is, in fact more so, since in many instances he deals with weaves and fabric structures not known by the other branches of the textile industry referred to.

The various narrow woven fabrics we come in contact with are:

Smooth Ribbons for all purposes interlaced with Taffeta-, Twill-, Satin-, Rib-, etc., weaves made from Cotton, Silk, Worsted, Linen, Ramie, etc., Yarns, used by itself or in combination with each other.

Gents' and Ladies' Hat-bands, Belts, etc.
Tube-ribbons and Tube-ties, Ribbons for Buttons.
Ribbons with Initials or Names, Badges.
Wash-ribbons, Corset and Apron-trimmings.
Embroidered-ribbons, figured in warp or filling.
Suspenders, Garters, Elastic-webbings.
Ribbons for Curtains and Point-laces.
Velvet-ribbons, Carriage-trimmings, Reins, Girdles.
Furniture-passementerie.
Upholstery-trimmings.
Ribbons for Venetian-blinds.
Ribbon-loom-embroidery.
Church-trimmings.
Dress-protectors.
Collar- and Coat-stiffenings.
Boot-straps.

Fancy-ribbons and Figured-trimmings, made of various yarns, interlaced with the greatest variety of weaves and fancy effects possible, as the constant change in fashion dictates.

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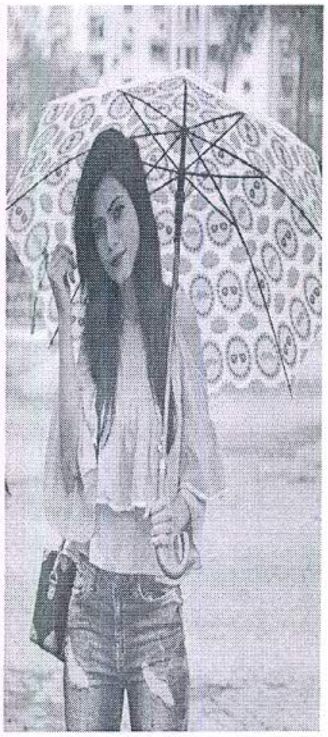
Sensation Scales

Comfort Level		Humidity		Thermal	
		Saturated	4	Boiling	4
		Very damp	3	Very hot	3
		Bit damp	2	Hot	2
		Evaporation	1	Warm	1
comfortable	0	Dry	0	Neutral	0
slight discomfort	-1			Cool	-1
uncomfortable	-2			Cold	-2
very uncomfortable/ sick	-3			Very cold	-3
				Freezing	-4

Table 1: Journey sensation scales

Knitted Accessories

- Accessories are additional components worn to complement overall look of garment both functional and ornamentation purposes.



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TENTATIVE BUDGET FOR FUNCTIONAL ACCESSORIES -VISCOSE FILAMENT PROJECT-2018

A. Recurring Budget:

S.N.	Items	1st Year (In Lakhs)	2nd year (In Lakhs)	3rd year (In Lakhs)	4th year (In Lakhs)	5th year (In Lakhs)	Total (In Lakhs)
1.	Manpower						
a.	Principal Investigator @Rs.20,000/-p.m.	3.00	3.00	3.00	3.00	3.00	15.00
b.	Co-PI @Rs.10,000/-pm- 2 persons	2.40	2.40	2.40	2.40	2.40	12.00
c.	PCs- 4 persons @Rs. 5,000/-p.m.	2.40	2.40	2.40	2.40	2.40	12.00
d.	PAs- 8 persons @Rs. 2,500/-p.m.	2.40	2.40	2.40	2.40	2.40	12.00
e.	PCAs- 3 persons @Rs. 2,000/-p.m.	0.72	0.72	0.72	0.72	0.72	3.60
2.	Consumables for product development.	1.00	1.00	2.00	2.00	2.00	8.00
3.	Travel @Rs.50,000/- per year	0.50	0.50	0.50	0.50	0.50	2.50
4.	Contingencies @10%	1.20	1.20	1.20	1.20	1.20	6.00
5.	Overheads @15%	2.00	2.00	2.00	2.00	2.00	10.00
	Sub Total for 'A'	**15.62**	**15.62**	**15.62**	**15.62**	**15.62**	**78.10**

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B. Capital Component (Non-Recurring)							
B.1	KES-F apparatus @Rs. 250 Lakhs				250.00		250.00
B.2	Digital printing m/c @Rs. 50 Lakhs			50.00			50.00
B.3	Knitting m/c @Rs. 30 Lakhs	30.00					30.00
B.4	Weaving m/c @Rs. 40 Lakhs	40.00					40.00
B.5	Braiding m/c @Rs. 10 Lakhs		10.00				10.00
B.6	Laptop @Rs 40,000/-		0.40				0.40
	Sub Total for 'B'	**70.00**	**10.40**	**50.00**	**250.00**		**380.40**
	Grand Total 'A' & 'B'	**85.62**	**26.02**	**65.62**	**265.62**	**15.62**	**458.50**

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Manpower requirement:

1. Dr. K.N.Chatterjee
2. Dr. Suman Bhattacharyya
3. Mr. Atanu Bhattacharyya
4. Mr. Kalyan Sarkar
5. Dr. Jamini Jhanji
6. Dr. Amal Chowdhury
7. Mr. Saumen Bhattacharyya
8. Dr. Ajit Pattnayak
9. Mr. Dipankar Das
10. Ms. Amit Madhu
11. Dr. Amandeep Kaur
12. Ms. Shelly Khanna
13. Mr. Ashish Bhardwaj
14. Ms. Ambika Madaan
15. Mr. Kirti Kumar
16. Mr. Ramniwas

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PROJECT REPORT

ON

ADVANCED TRAINING IN CONNECTION WITH EXCEL TRAVEL ACCOUNTING SOFTWARE & RELATED CONSULTANCY

Compiled and submitted by:

Dr Mukesh Kumar

(HEAD, DEPARTMENT OF COMPUTER ENGINEERING)

TIT&S, BHIWANI

THE TECHNOLOGICAL INSTITUTE OF TEXTILES AND SCIENCES

BHIWANI, HARYANA – 127021 (INDIA)

2016-17

Chapter- 1

INTRODUCTION

1.1 React Js

React (also known as **React.js** or **ReactJS**) is an open-source JavaScript library for building user interfaces. It is maintained by Facebook and a community of individual developers and companies.

React can be used as a base in the development of single-page or mobile applications. However, React is only concerned with rendering data to the DOM, and so creating React applications usually requires the use of additional libraries for state management and routing. Redux and React Router are respective examples of such libraries.

1.1.1 Why React Js?

ReactJS is a stronger framework because of its ability to break down the complex interface and allow users to work on individual components. ReactJS comes with the core objective is to deliver the best rendering performance possible. Its strength stems from the emphasis on individual parts. ReactJS helps a developer to break down the complicated UI into smaller components, rather than operating on the entire web framework.

1.1.2 Features of React Js

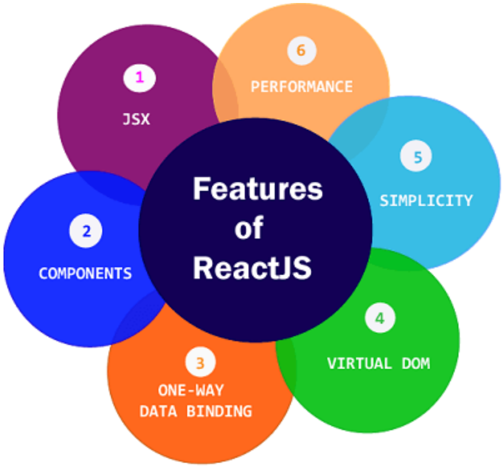


Fig 1.1 Features Of ReactJs

- JSX
- Components
- One-way Data Binding
- Virtual DOM
- Simplicity
- Performance

1.1.3 Introducing JSX

```
const element = <h1>Hello, world!</h1>;
```

The above syntax is called JSX, and it is a syntax extension to JavaScript. It is used with React to describe what the UI should look like. JSX may remind you of a template language, but it comes with the full power of JavaScript. JSX produces React “elements”.

1.2. Why JSX?

React embraces the fact that rendering logic is inherently coupled with other UI logic: how events are handled, how the state changes over time, and how the data is prepared for display.

Instead of artificially separating technologies by putting markup and logic in separate files, React separates concerns with loosely coupled units called “components” that contain both.

React doesn’t require using JSX, but most people find it helpful as a visual aid when working with UI inside the JavaScript code. It also allows React to show more useful error and warning messages.

1.3 Embedding Expressions in JSX

In the example below, we declare a variable called name and then use it inside JSX by wrapping it in curly braces:

```
const name = 'Josh Perez';

const element = <h1>Hello, {name}</h1>;

ReactDOM.render(
```

```
  element,
  document.getElementById('root')
);
```

You can put any valid JavaScript expression inside the curly braces in JSX. For example, 2 + 2, user.firstName, or formatName(user) are all valid JavaScript expressions.

In the example below, we embed the result of calling a JavaScript function, formatName(user), into an <h1> element.

```
function formatName(user) {
  return user.firstName + ' ' + user.lastName;
}

const user = {
  firstName: 'Harper',
  lastName: 'Perez'
};

const element = (
  <h1>
    Hello, {formatName(user)}!
  </h1>
);

ReactDOM.render(
  element,
  document.getElementById('root')
);
```

1.3.1 JSX is an Expression Too

After compilation, JSX expressions become regular JavaScript function calls and evaluate to JavaScript objects.

This means that you can use JSX inside of if statements and for loops, assign it to variables, accept it as arguments, and return it from functions:

```
function getGreeting(user) {
  if (user) {
    return <h1>Hello, {formatName(user)}!</h1>;
  }
  return <h1>Hello, Stranger.</h1>;
}
```

1.3.2 Specifying Attributes with JSX

You may use quotes to specify string literals as attributes:

```
const element = <div tabIndex="0"></div>;
```

You may also use curly braces to embed a JavaScript expression in an attribute:

```
const element = <img src={user.avatarUrl}></img>;
```

1.4 Rendering Elements

Elements are the smallest building blocks of React apps.

An element describes what you want to see on the screen:

```
const element = <h1>Hello, world</h1>;
```

Unlike browser DOM elements, React elements are plain objects, and are cheap to create. React DOM takes care of updating the DOM to match the React elements.

1.4.1 Rendering an Element into the DOM

Let’s say there is a <div> somewhere in your HTML file:

```
<div id="root"></div>
```

We call this a “root” DOM node because everything inside it will be managed by React DOM.

Applications built with just React usually have a single root DOM node. If you are integrating React into an existing app, you may have as many isolated root DOM nodes as you like.

To render a React element into a root DOM node, pass both to ReactDOM.render():

```
const element = <h1>Hello, world</h1>;
ReactDOM.render(element, document.getElementById('root'));
```

1.4.2 Updating the Rendered Element

React elements are immutable. Once you create an element, you can’t change its children or attributes. An element is like a single frame in a movie: it represents the UI at a certain point in time.

With our knowledge so far, the only way to update the UI is to create a new element, and pass it to ReactDOM.render().

Consider this ticking clock example:

```
function tick() {
  const element = (
    <div>
      <h1>Hello, world!</h1>
      <h2>It is {new Date().toLocaleTimeString()}.</h2>
    </div>
```

```
  );

ReactDOM.render(element, document.getElementById('root'));
}
setInterval(tick, 1000);
```

1.5 Component and Props

Conceptually, components are like JavaScript functions. They accept arbitrary inputs (called “props”) and return React elements describing what should appear on the screen.

1.5.1 Function and Class Components

The simplest way to define a component is to write a JavaScript function:

```
function Welcome(props) {
  return <h1>Hello, {props.name}</h1>;
}
```

This function is a valid React component because it accepts a single “props” (which stands for properties) object argument with data and returns a React element. We call such components “function components” because they are literally JavaScript functions.

You can also use an ES6 class to define a component:

```
class Welcome extends React.Component {
  render() {
    return <h1>Hello, {this.props.name}</h1>;
  }
}
```

The above two components are equivalent from React’s point of view.

1.5.2 Rendering a Component

Previously, we only encountered React elements that represent DOM tags:

```
const element = <div />;
```

However, elements can also represent user-defined components:

```
const element = <Welcome name="Sara" />;
```

When React sees an element representing a user-defined component, it passes JSX attributes and children to this component as a single object. We call this object “props”.

For example, this code renders “Hello, Sara” on the page:

```
function Welcome(props) {
 return <h1>Hello, {props.name}</h1>;
}

const element = <Welcome name="Sara" />;
ReactDOM.render (
  element,
  document.getElementById('root')
);
```

1.5.3 Composing Components

Components can refer to other components in their output. This lets us use the same component abstraction for any level of detail. A button, a form, a dialog, a screen: in React apps, all those are commonly expressed as components.

For example, we can create an App component that renders Welcome many times:

```
function Welcome(props) {
  return <h1>Hello, {props.name}</h1>;
}

function App() {
  return (
    <div>
```

```
    <Welcome name="Sara" />
    <Welcome name="Cahal" />
    <Welcome name="Edite" />
  </div>
 );
}

ReactDOM.render(
 <App />,
 document.getElementById('root')
);
```

1.5.4 Extracting Components

Don’t be afraid to split components into smaller components.

For example, consider this Comment component:

```
function Comment(props) {
 return (
  <div className="Comment">
   <div className="UserInfo">
    <img className="Avatar"
     src={props.author.avatarUrl}
     alt={props.author.name}
    />
    <div className="UserInfo-name">
     {props.author.name}
    </div>
   </div>
   <div className="Comment-text">
    {props.text}
   </div>
```

```
      <div className="Comment-date">
        {formatDate(props.date)}
      </div>
    </div>
  );
}
```

1.6 Converting a Function to a Class

You can convert a function component to a class in five steps:

1. Create an ES6 class, with the same name, that extends React.Component.
2. Add a single empty method to it called render().
3. Move the body of the function into the render() method.
4. Replace props with this.props in the render() body.
5. Delete the remaining empty function declaration.

```
class Clock extends React.Component {
  render() {
    return (
      <div>
        <h1>Hello, world!</h1>
        <h2>It is {this.props.date.toLocaleTimeString()}.</h2>
      </div>
    );
  }
}
```

1.7 Adding Local State to a Class

We will move the date from props to state in three steps:

1. Replace this.props.date with this.state.date in the render() method:

```
class Clock extends React.Component {
  render() {
    return (
      <div>
        <h1>Hello, world!</h1>

       <h2>It is {this.state.date.toLocaleTimeString()}.</h2>
     </div>
    );
  }
}
```

2. Add a class constructor that assigns the initial this.state:

```
class Clock extends React.Component {
  constructor(props) {
    super(props);

   this.state = {date: new Date()};
 }

  render() {
    return (
      <div>
        <h1>Hello, world!</h1>
        <h2>It is {this.state.date.toLocaleTimeString()}.</h2>
      </div>
    );
  }
}
```

Note how we pass props to the base constructor:

```
 constructor(props) {


   super(props);
   this.state = {date: new Date()};
  }
```

Class components should always call the base constructor with props.

3. Remove the date prop from the <Clock /> element:

```
ReactDOM.render(
 <Clock />,
 document.getElementById('root')
);
```

The result looks like this:

```
class Clock extends React.Component {
 constructor(props) {
   super(props);
   this.state = {date: new Date()};
 }
  render() {
    return (
      <div>
        <h1>Hello, world!</h1>
       <h2>It is {this.state.date.toLocaleTimeString()}.</h2>
     </div>
    );
  }
}
```

```
ReactDOM.render(
 <Clock />,
 document.getElementById('root')
);
```

1.7.1 Using State Correctly

There are three things you should know about setState().

Do Not Modify State Directly

For example, this will not re-render a component:

```
// Wrong
this.state.comment = 'Hello';
```

Instead, use setState():

```
// Correct
this.setState({comment: 'Hello'});
```

The only place where you can assign this.state is the constructor.

State Updates May Be Asynchronous

React may batch multiple setState() calls into a single update for performance.

Because this.props and this.state may be updated asynchronously, you should not rely on their values for calculating the next state.

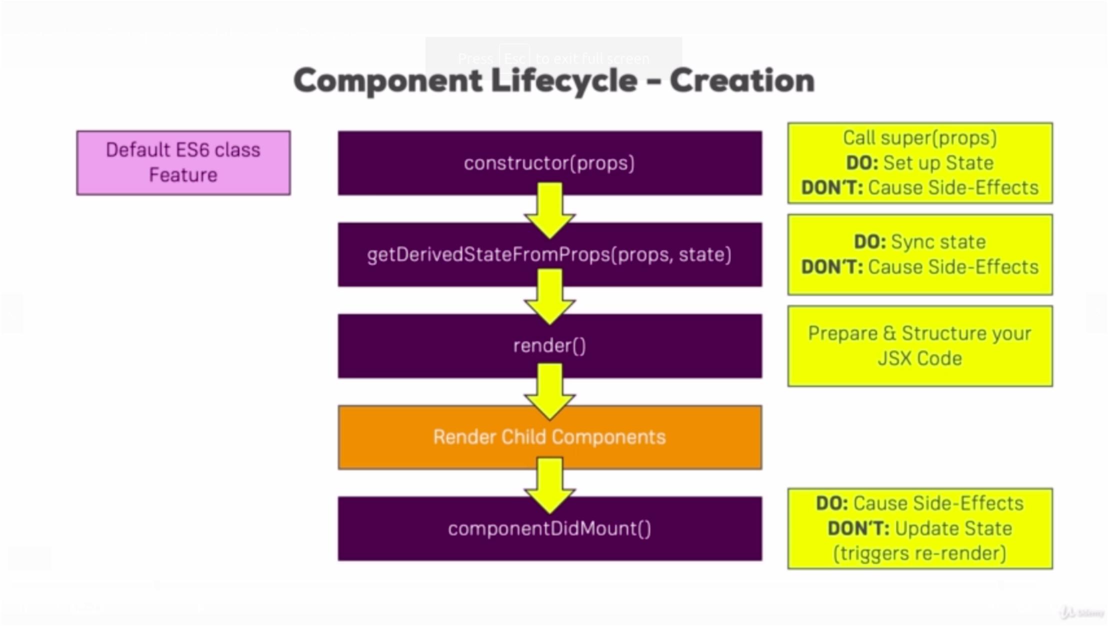
When you call setState(), React merges the object you provide into the current state.

1.8 Lifecycle of Components

Each component in React has a lifecycle which you can monitor and manipulate during its three main phases.

The three phases are: Mounting, Updating, and Unmounting.

1.8.1 Mounting



Component Lifecycle – Creation

Default ES6 class Feature

constructor(props)

Call super(props)
DO: Set up State
DON'T: Cause Side-Effects

getDerivedStateFromProps(props, state)

DO: Sync state
DON'T: Cause Side-Effects

render()

Prepare & Structure your JSX Code

Render Child Components

componentDidMount()

DO: Cause Side-Effects
DON'T: Update State (triggers re-render)

Fig: 1.2 Component Lifecycle Creation

Mounting means putting elements into the DOM.

React has four built-in methods that gets called, in this order, when mounting a component:

1. constructor()
2. getDerivedStateFromProps()
3. render()
4. componentDidMount()

The render() method is required and will always be called, the others are optional and will be called if you define them.

1.8.1.1 constructor

The constructor() method is called before anything else, when the component is initiated, and it is the natural place to set up the initial state and other initial values.

The constructor() method is called with the props, as arguments, and you should always start by calling the super(props) before anything else, this will initiate the parent's constructor method and allows the component to inherit methods from its parent (React.Component).

```
class Header extends React.Component {
  constructor(props) {
    super(props);
    this.state = {favoritecolor: "red"};
  }
  render() {
    return (
      <h1>My Favorite Color is {this.state.favoritecolor}</h1>
    );
  }
}
```

1.8.1.2 getDerivedStateFromProps

The getDerivedStateFromProps() method is called right before rendering the element(s) in the DOM.

This is the natural place to set the state object based on the initial props.

It takes state as an argument, and returns an object with changes to the state.

The example below starts with the favorite color being "red", but the getDerivedStateFromProps() method updates the favorite color based on the favcol attribute:

Example:

The getDerivedStateFromProps method is called right before the render method:

```
class Header extends React.Component {
  constructor(props) {
    super(props);
```

```
    this.state = {favoritecolor: "red"};
  }
  static getDerivedStateFromProps(props, state) {
    return {favoritecolor: props.favcol };
  }
  render() {
    return (
      <h1>My Favorite Color is {this.state.favoritecolor}</h1>
    );
  }
}
```

1.8.1.3 render

The render() method is required, and is the method that actual outputs HTML to the DOM.

Example:
A simple component with a simple render() method:

```
class Header extends React.Component {
  render() {
    return (
      <h1>This is the content of the Header component</h1>
    );
  }
}
```

1.8.1.4 componentDidMount

The componentDidMount() method is called after the component is rendered.

This is where you run statements that requires that the component is already placed in the DOM.

Example:
At first my favorite color is red, but give me a second, and it is yellow instead:

```
class Header extends React.Component {
  constructor(props) {
    super(props);
    this.state = {favoritecolor: "red"};
  }
  componentDidMount() {
    setTimeout(() => {
      this.setState({favoritecolor: "yellow"})
    }, 1000)
  }
  render() {
    return (
      <h1>My Favorite Color is {this.state.favoritecolor}</h1>
    );
  }
}
```

1.8.2 Updating

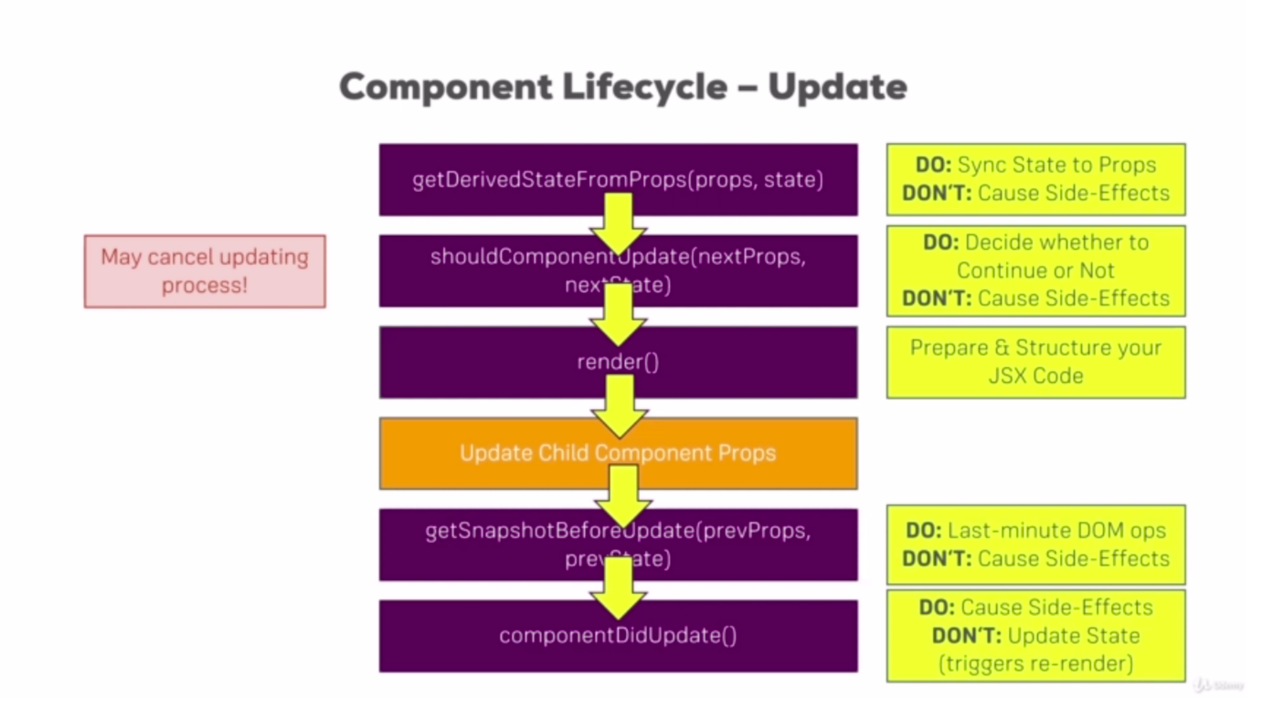


Fig 1.3 Component Lifecycle Update

The next phase in the lifecycle is when a component is updated.

A component is updated whenever there is a change in the component's state or props.

React has five built-in methods that gets called, in this order, when a component is updated:

1. getDerivedStateFromProps()
2. shouldComponentUpdate()
3. render()
4. getSnapshotBeforeUpdate()
5. componentDidUpdate()

The render() method is required and will always be called, the others are optional and will be called if you define them.

1.8.2.1 getDerivedStateFromProps

Also at updates the getDerivedStateFromProps method is called. This is the first method that is called when a component gets updated.

This is still the natural place to set the state object based on the initial props.

The example below has a button that changes the favorite color to blue, but since the getDerivedStateFromProps() method is called, which updates the state with the color from the favcol attribute, the favorite color is still rendered as yellow:

Example:

If the component gets updated, the getDerivedStateFromProps() method is called:

```
class Header extends React.Component {
  constructor(props) {
    super(props);
    this.state = {favoritecolor: "red"};
  }
  static getDerivedStateFromProps(props, state) {
    return {favoritecolor: props.favcol };
  }
  changeColor = () => {
    this.setState({favoritecolor: "blue"});
  }
  render() {
    return (
      <div>
      <h1>My Favorite Color is {this.state.favoritecolor}</h1>
      <button type="button" onClick={this.changeColor}>Change color</button>
      </div>
    );
  }
}
```

1.8.2.2 shouldComponentUpdate

In the shouldComponentUpdate() method you can return a Boolean value that specifies whether React should continue with the rendering or not.

The default value is true.

The example below shows what happens when the shouldComponentUpdate() method returns false:

Example:

Stop the component from rendering at any update:

```
class Header extends React.Component {
  constructor(props) {
    super(props);
    this.state = {favoritecolor: "red"};
  }
  shouldComponentUpdate() {
    return false;
  }
  changeColor = () => {
    this.setState({favoritecolor: "blue"});
  }
  render() {
    return (
      <div>
      <h1>My Favorite Color is {this.state.favoritecolor}</h1>
      <button type="button" onClick={this.changeColor}>Change color</button>
      </div>
    );
  }
}
```

1.8.2.3 render

The render() method is of course called when a component gets updated, it has to re-render the HTML to the DOM, with the new changes.

The example below has a button that changes the favorite color to blue:

Example:

Click the button to make a change in the component's state:

```
class Header extends React.Component {
  constructor(props) {
    super(props);
    this.state = {favoritecolor: "red"};
  }
  changeColor = () => {
    this.setState({favoritecolor: "blue"});
  }
  render() {
    return (
      <div>
      <h1>My Favorite Color is {this.state.favoritecolor}</h1>
      <button type="button" onClick={this.changeColor}>Change color</button>
      </div>
    );
  }
}
```

1.8.2.4 getSnapshotBeforeUpdate

In the getSnapshotBeforeUpdate() method you have access to the props and state before the update, meaning that even after the update, you can check what the values were before the update.

If the getSnapshotBeforeUpdate() method is present, you should also include the componentDidUpdate() method, otherwise you will get an error.

The example below might seem complicated, but all it does is this:

When the component is mounting it is rendered with the favorite color "red".

When the component has been mounted, a timer changes the state, and after one second, the favorite color becomes "yellow".

This action triggers the update phase, and since this component has a getSnapshotBeforeUpdate() method, this method is executed, and writes a message to the empty DIV1 element.

Then the componentDidUpdate() method is executed and writes a message in the empty DIV2 element:

Example:

Use the getSnapshotBeforeUpdate() method to find out what the state object looked like before the update:

```
class Header extends React.Component {
  constructor(props) {
    super(props);
    this.state = {favoritecolor: "red"};
  }
  componentDidMount() {
    setTimeout(() => {
      this.setState({favoritecolor: "yellow"})
    }, 1000)
  }
  getSnapshotBeforeUpdate(prevProps, prevState) {
    document.getElementById("div1").innerHTML =
    "Before the update, the favorite was " + prevState.favoritecolor;
  }
  componentDidUpdate() {
    document.getElementById("div2").innerHTML =
    "The updated favorite is " + this.state.favoritecolor;
  }
  render() {
    return (
      <div>
        <h1>My Favorite Color is {this.state.favoritecolor}</h1>
        <div id="div1"></div>
```

```
        <div id="div2"></div>
      </div>
    );
  }
}
```

1.8.2.5 componentDidUpdate

The componentDidUpdate method is called after the component is updated in the DOM.

The example below might seem complicated, but all it does is this:

When the component is mounting it is rendered with the favorite color "red".

When the component has been mounted, a timer changes the state, and the color becomes "yellow".

This action triggers the update phase, and since this component has a componentDidUpdate method, this method is executed and writes a message in the empty DIV element:

Example:

The componentDidUpdate method is called after the update has been rendered in the DOM:

```
class Header extends React.Component {
  constructor(props) {
    super(props);
    this.state = {favoritecolor: "red"};
  }
  componentDidMount() {
    setTimeout(() => {
      this.setState({favoritecolor: "yellow"})
    }, 1000)
  }
  componentDidUpdate() {
    document.getElementById("mydiv").innerHTML =
    "The updated favorite is " + this.state.favoritecolor;
```

```
  }
  render() {
    return (
      <div>
      <h1>My Favorite Color is {this.state.favoritecolor}</h1>
      <div id="mydiv"></div>
      </div>
    );
  }
}
```

1.8.3 Unmounting

The next phase in the lifecycle is when a component is removed from the DOM, or unmounting as React likes to call it.

React has only one built-in method that gets called when a component is unmounted:

- componentWillUnmount()

1.8.3.1 componentWillUnmount

The componentWillUnmount method is called when the component is about to be removed from the DOM.

Example:

Click the button to delete the header:

```
class Container extends React.Component {
  constructor(props) {
    super(props);
    this.state = {show: true};
  }
  delHeader = () => {
```

```
    this.setState({show: false});
  }
  render() {
    let myheader;
    if (this.state.show) {
      myheader = <Child />;
    };
    return (
      <div>
      {myheader}
      <button type="button" onClick={this.delHeader}>Delete Header</button>
      </div>
    );
  }
}

class Child extends React.Component {
  componentWillUnmount() {
    alert("The component named Header is about to be unmounted.");
  }
  render() {
    return (
      <h1>Hello World!</h1>
    );
  }
}
```

1.9 Handling Events

Handling events with React elements is very similar to handling events on DOM elements. There are some syntax differences:

- React events are named using camelCase, rather than lowercase.
- With JSX you pass a function as the event handler, rather than a string.

For example, the HTML:

```
<button onclick="activateLasers()">
  Activate Lasers
</button>
```

is slightly different in React:

```
<button onClick={activateLasers}>
 Activate Lasers
</button>
```

Another difference is that you cannot return false to prevent default behavior in React. You must call preventDefault explicitly. For example, with plain HTML, to prevent the default link behavior of opening a new page, you can write:

```
<a href="#" onclick="console.log('The link was clicked.'); return false">
  Click me
</a>
```

In React, this could instead be:

```
function ActionLink() {
 function handleClick(e) {
   e.preventDefault();
   console.log('The link was clicked.');
 }
  return (
   <a href="#" onClick={handleClick}>
```

```
      Click me
    </a>
  );
}
```

Here, e is a synthetic event. React defines these synthetic events according to the W3C spec, so you don’t need to worry about cross-browser compatibility. See the SyntheticEvent reference guide to learn more.

When using React, you generally don’t need to call addEventListener to add listeners to a DOM element after it is created. Instead, just provide a listener when the element is initially rendered.

When you define a component using an ES6 class, a common pattern is for an event handler to be a method on the class. For example, this Toggle component renders a button that lets the user toggle between “ON” and “OFF” states:

```
class Toggle extends React.Component {
  constructor(props) {
    super(props);
    this.state = {isToggleOn: true};
   // This binding is necessary to make `this` work in the callback
   this.handleClick = this.handleClick.bind(this);
 }

 handleClick() {
   this.setState(state => ({
     isToggleOn: !state.isToggleOn
   }));
 }

  render() {
    return (
     <button onClick={this.handleClick}>
       {this.state.isToggleOn ? 'ON' : 'OFF'}
```

```
      </button>
    );
  }
}

ReactDOM.render(
  <Toggle />,
  document.getElementById('root')
);
```

1.10 Router

React Router is a standard library for routing in React. It enables the navigation among views of various components in a React Application, allows changing the browser URL, and keeps the UI in sync with the URL.

Let us create a simple application to React to understand how the React Router works. The application will contain three components: home component, about a component, and contact component. We will use React Router to navigate between these components.

1.10.1 Installing React Router:

React Router can be installed via npm in your React application. Follow the steps given below to install Router in your React application:

- Step 1: cd into your project directory i.e geeks.
- Step 2: To install the React Router use the following command:

```
npm install react-router-dom –save
```

After installing react-router-dom, add its components to your React application.

1.10.2 Adding React Router Components:

The main Components of React Router are:

- **BrowserRouter:** BrowserRouter is a router implementation that uses the HTML5 history API(pushState, replaceState and the popstate event) to keep your UI in sync with the URL. It is the parent component that is used to store all of the other components.
- **Route:** Route is the conditionally shown component that renders some UI when its path matches the current URL.
- **Link:** Link component is used to create links to different routes and implement navigation around the application. It works like an HTML anchor tag.
- **Switch:** Switch component is used to render only the first route that matches the location rather than rendering all matching routes. Although there is no defying functionality of SWITCH tag in our application because none of the LINK paths are ever going to coincide. But let’s say we have a route (Note that there is no EXACT in here), then all the Route tags are going to be processed which start with ‘/’ (all Routes start with /). This is where we need a SWITCH statement to process only one of the statements.

To add React Router components in your application, open your project directory in the editor you use and go to **app.js** file.

//App.js:

```
import {
   BrowserRouter as Router,
   Route,
   Link,
   Switch
} from 'react-router-dom';
import {
   BrowserRouter as Router,
   Route,
   Link,
   Switch
} from 'react-router-dom';
```

1.10.3 Using React Router :-

To use React Router, let us first create a few components in the react application. In your project directory, create a folder named component inside the src folder and now add 3 files named home.js, about.js and contact.js to the component folder.

//Home.js:

```
import React from 'react';


function Home (){
        return <h1>Welcome to the Unthinkable Solutions!</h1>
}


export default Home;
```

//About.js:

```
import React from 'react';


function About () {
return <div>
                <h2>We provide you best solutions!</h2>
         </div>
}
export default About;
```

//Contact.js:

```
import React from 'react';


function Contact (){
return <address>
                You can find us here:<br />
```

```
                Unthinkable Solutions<br />
                9th Floor Sector 30 <br />
                Silokhera NH 9 Gurgaon (Haryana)
            </address>
        }
        export default Contact;
```

Now, let us include React Router components to the application:

- **BrowserRouter:**
  Add BrowserRouter aliased as Router to your app.js file in order to wrap all the other components. BrowserRouter is a parent component and can have only single child.

```
            class App extends Component {
            render() {
                return (
                <Router>
                    <div className="App">
                    </div>
                </Router>
                    );
                }
            }
```

- **Link:**
  Let us now create links to our components. Link component uses the to prop to describe the location where the links should navigate to.

```
            <div className="App">
                <ul>
                <li>
                    <Link to="/">Home</Link>
```

```
        </li>
        <li>
                <Link to="/about">About Us</Link>
        </li>
        <li>
                <Link to="/contact">Contact Us</Link>
        </li>
        </ul>
</div>
```

Now, run your application on the local host and click on the links you created. You will notice the url changing according to the value in to props of the Link component.

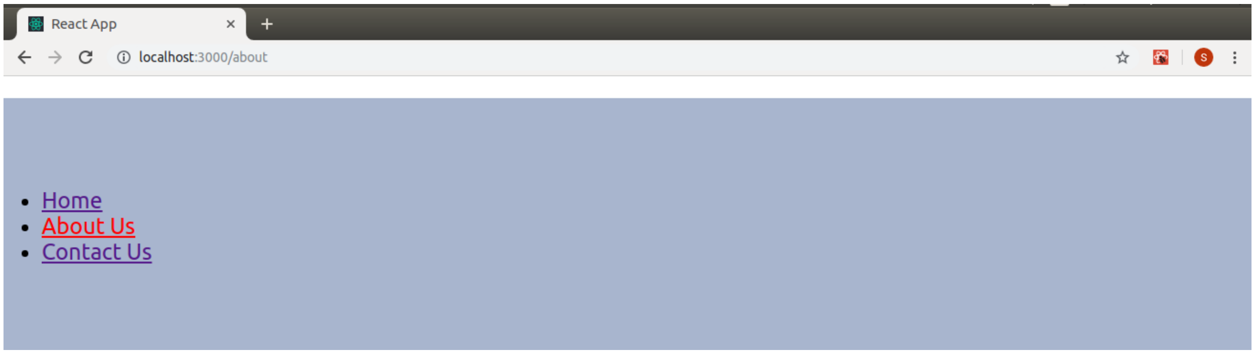


Fig 1.4 Routing

- **Route:**

Route component will now help us to establish the link between the component's UI and the URL. To include routes to the application, add the code given below to your app.js.

```
<Route exact path='/' component={Home}></Route>
<Route exact path='/about' component={About}></Route>
<Route exact path='/contact' component={Contact}></Route>
```

Let us now try to understand the props associated with the Route component.

1. **exact:** It is used to match the exact value with the URL. For Eg., exact path='/about' will only render the component if it exactly matches the path but if we remove exact from the syntax, then component will still be rendered even if the structure is like /about/10.
2. **path:** Path specifies a pathname we assign to our component.
3. **component:** It refers to the component which will render on matching the path.

- **Switch:**
  To render a single component, wrap all the routes inside the Switch Component.

```
<Switch>
        <Route exact path='/' component={Home}></Route>
        <Route exact path='/about' component={About}></Route>
        <Route exact path='/contact' component={Contact}></Route>
</Switch>
```

Switch groups together several routes, iterates over them and finds the first one that matches the path. Thereby, the corresponding component to the path is rendered.

After adding all the components here is our complete source code:

```
import React, { Component } from 'react';
import { BrowserRouter as Router, Route, Link, Switch } from 'react-router-dom';
import Home from './component/home';
import About from './component/about';
import Contact from './component/contact';
import './App.css';

class App extends Component {
render() {
        return (
```

```
        <Router>
            <div className="App">
                <ul className="App-header">
                <li>
                    <Link to="/">Home</Link>
                </li>
                <li>
                    <Link to="/about">About Us</Link>
                </li>
                <li>
                    <Link to="/contact">Contact Us</Link>
                </li>
                </ul>
                <Switch>
                <Route exact path='/' component={Home}></Route>
                <Route exact path='/about' component={About}></Route>
                <Route exact path='/contact' component={Contact}></Route>
                </Switch>
            </div>
        </Router>
    );
    }
    }
    export default App;
```

1.11. Redux

Redux is a predictable state container for JavaScript apps. As the application grows, it becomes difficult to keep it organized and maintain data flow. Redux solves this problem by managing the application's state with a single global object called Store. Redux fundamental principles help in maintaining consistency throughout your application, which makes debugging and testing easier.

More importantly, it gives you live code editing combined with a time-travelling debugger. It is flexible to go with any view layer such as React, Angular, Vue, etc.

Principles of Redux

Predictability of Redux is determined by three most important principles as given below −

- **Single Source of Truth**

The state of your whole application is stored in an object tree within a single store. As the whole application state is stored in a single tree, it makes debugging easy, and development faster.

- **State is Read-only**

The only way to change the state is to emit an action, an object describing what happened. This means nobody can directly change the state of your application.

- **Changes are made with pure functions**

To specify how the state tree is transformed by actions, you write pure reducers. A reducer is a central place where state modification takes place. Reducer is a function which takes state and action as arguments, and returns a newly updated state.

1.11.1 Installation

Run the following command in your command prompt to install Redux.

```
npm install --save redux
```

To use Redux with react application, you need to install an additional dependency as follows −

```
npm install --save react-redux
```

1.11.2 Core Concepts

Let us assume our application’s state is described by a plain object called initialState which is as follows −

```
const initialState = {
  isLoading: false,
  items: [],
  hasError: false
};
```

Every piece of code in your application cannot change this state. To change the state, you need to dispatch an action.

What is an action?

An action is a plain object that describes the intention to cause change with a type property. It must have a type property which tells what type of action is being performed. The command for action is as follows −

```
return {
  type: 'ITEMS_REQUEST', //action type
  isLoading: true //payload information
}
```

Actions and states are held together by a function called Reducer. An action is dispatched with an intention to cause change. This change is performed by the reducer. Reducer is the only way to change states in Redux, making it more predictable, centralised and debuggable. A reducer function that handles the ‘ITEMS_REQUEST’ action is as follows −

```
const reducer = (state = initialState, action) => { //es6 arrow function
  switch (action.type) {
    case 'ITEMS_REQUEST':
      return Object.assign({}, state, {
        isLoading: action.isLoading
      })
    default:
      return state;
  }
}
```

Redux has a single store which holds the application state. If you want to split your code on the basis of data handling logic, you should start splitting your reducers instead of stores in Redux.

Redux components are as follows −

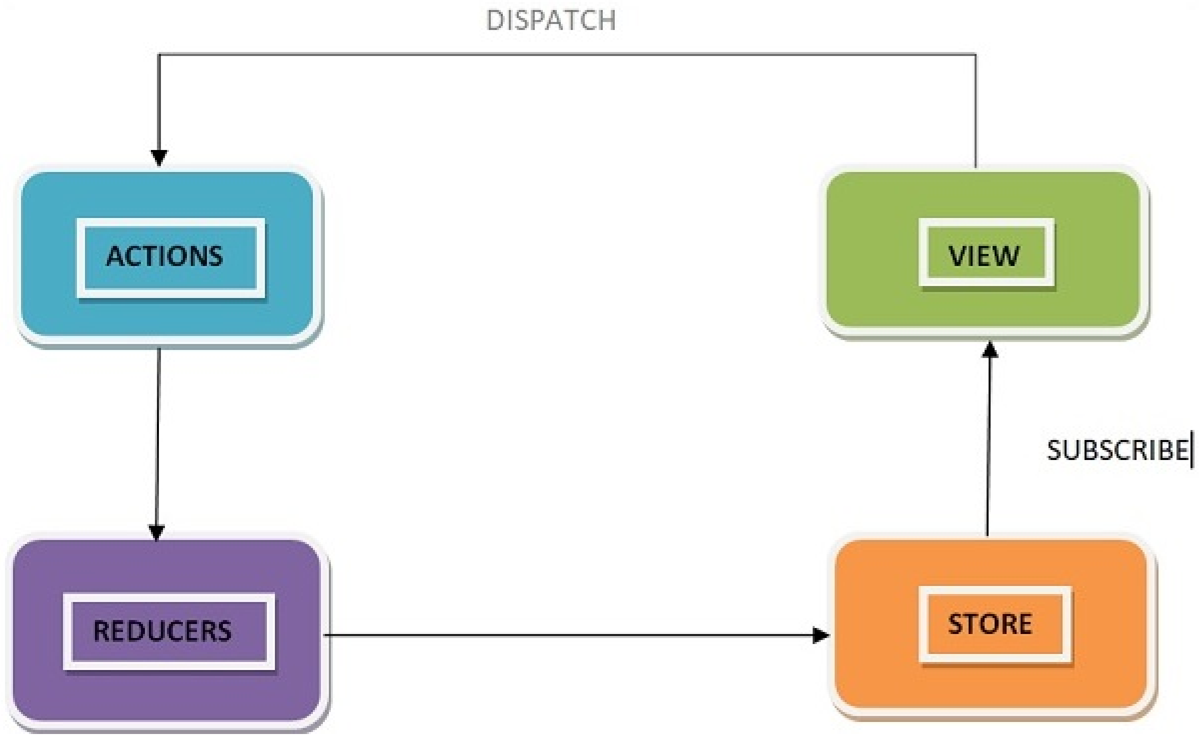


Fig 1.5 Redux Components

1.11.3 Data Flow

Redux follows the unidirectional data flow. It means that your application data will follow in one-way binding data flow. As the application grows & becomes complex, it is hard to reproduce issues and add new features if you have no control over the state of your application.

Redux reduces the complexity of the code, by enforcing the restriction on how and when state update can happen. This way, managing updated states is easy. We already know about the restrictions as the three principles of Redux. Following diagram will help you understand Redux data flow better −

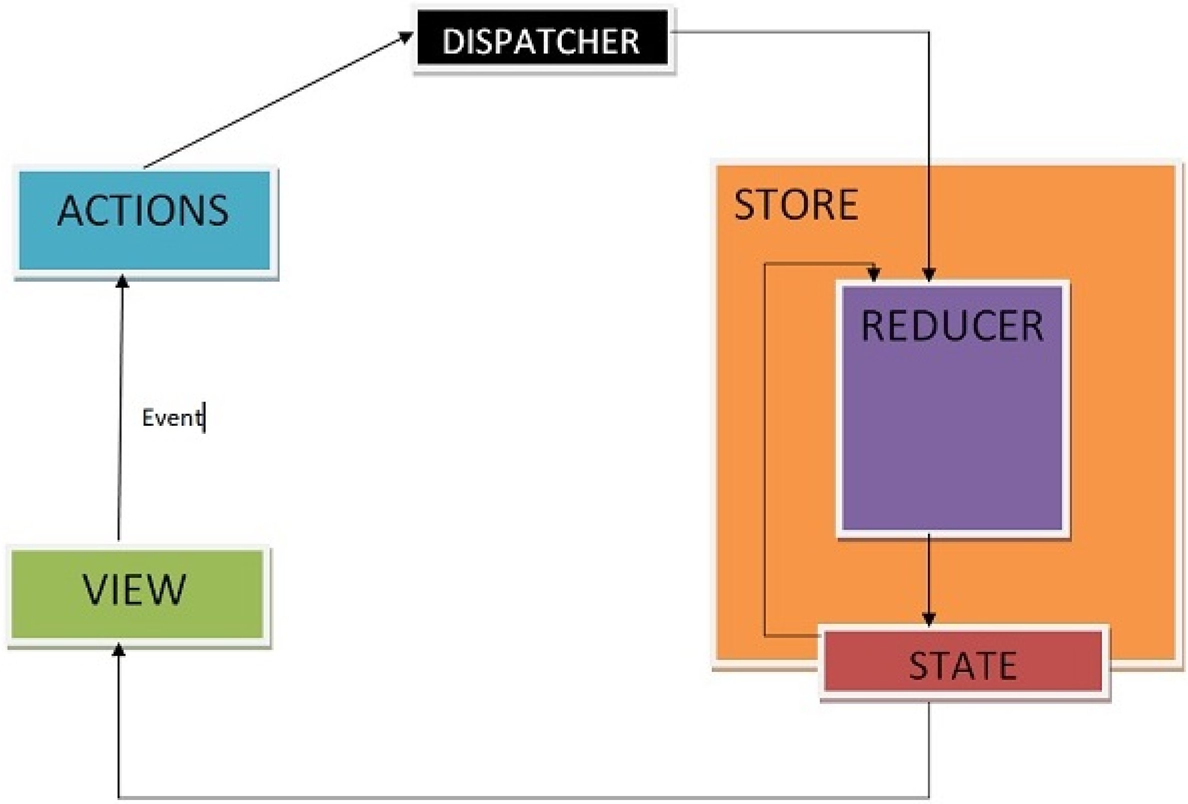


Fig 1.6 Data Flow

- An action is dispatched when a user interacts with the application.
- The root reducer function is called with the current state and the dispatched action. The root reducer may divide the task among smaller reducer functions, which ultimately returns a new state.
- The store notifies the view by executing their callback functions.
- The view can retrieve updated state and re-render again.

1.11.4 Store

A store is an immutable object tree in Redux. A store is a state container which holds the application's state. Redux can have only a single store in your application. Whenever a store is created in Redux, you need to specify the reducer.

Let us see how we can create a store using the createStore method from Redux. One need to import the createStore package from the Redux library that supports the store creation process as shown below −

```
import { createStore } from 'redux';
          import reducer from './reducers/reducer'
          const store = createStore(reducer);
```

A createStore function can have three arguments. The following is the syntax −

```
createStore(reducer, [preloadedState], [enhancer])
```

A reducer is a function that returns the next state of app. A preloadedState is an optional argument and is the initial state of your app. An enhancer is also an optional argument. It will help you enhance your store with third-party capabilities.

A store has three important methods as given below −

- **getState**

  It helps you retrieve the current state of your Redux store.

  The syntax for getState is as follows −

  ```
  store.getState()
  ```

- **dispatch**

  It allows you to dispatch an action to change a state in your application.

  The syntax for dispatch is as follows −

  ```
  store.dispatch({type:'ITEMS_REQUEST'})
  ```

- **subscribe**

  It helps you register a callback that Redux store will call when an action has been dispatched. As soon as the Redux state has been updated, the view will re-render automatically.

  The syntax for dispatch is as follows −

  ```
  store.subscribe(()=>{ console.log(store.getState());})
  ```

Actions are the only source of information for the store as per Redux official documentation. It carries a payload of information from your application to store.

As discussed earlier, actions are plain JavaScript objects that must have a type attribute to indicate the type of action performed. It tells us what had happened. Types should be defined as string constants in your application as given below −

```
const ITEMS_REQUEST = 'ITEMS_REQUEST';
```

Apart from this type attribute, the structure of an action object is totally up to the developer. It is recommended to keep your action object as light as possible and pass only the necessary information.

To cause any change in the store, you need to dispatch an action first by using store.dispatch() function. The action object is as follows −

```
{ type: GET_ORDER_STATUS , payload: {orderId,userId } }

{ type: GET_WISHLIST_ITEMS, payload: userId }
```

Actions Creators

Action creators are the functions that encapsulate the process of creation of an action object. These functions simply return a plain Js object which is an action. It promotes writing clean code and helps to achieve reusability.

Let us learn about action creators which lets you dispatch an action, ‘ITEMS_REQUEST’ that requests for the product items list data from the server. Meanwhile, the isLoading state is made true in the reducer in ‘ITEMS_REQUEST’ action type to indicate that items are loading, and data is still not received from the server.

Initially, the isLoading state was false in the initialState object assuming nothing is loading. When data is received at browser, isLoading state will be returned as false in ‘ITEMS_REQUEST_SUCCESS’ action type in the corresponding reducer. This state can be used as a prop in react components to display loader/message on your page while the request for data is on. The action creator is as follows −

```
const ITEMS_REQUEST = ‘ITEMS_REQUEST’ ;

const ITEMS_REQUEST_SUCCESS = ‘ITEMS_REQUEST_SUCCESS’ ;

export function itemsRequest(bool,startIndex,endIndex) {
```

```
  let payload = {
    isLoading: bool,
    startIndex,
    endIndex
  }
  return {
    type: ITEMS_REQUEST,
    payload
  }
}
export function itemsRequestSuccess(bool) {
  return {
    type: ITEMS_REQUEST_SUCCESS,
    isLoading: bool,
  }
}
```

To invoke a dispatch function, you need to pass action as an argument to the dispatch function.

```
dispatch(itemsRequest(true,1, 20));
dispatch(itemsRequestSuccess(false));
```

You can dispatch an action by directly using store.dispatch(). However, it is more likely that you access it with the react-Redux helper method called connect(). You can also use bindActionCreators() method to bind many action creators with dispatch functions.

1.11.5 Pure Functions

A function is a process which takes inputs called arguments, and produces some output known as return value. A function is called pure if it abides by the following rules −

- A function returns the same result for the same arguments.

- Its evaluation has no side effects, i.e., it does not alter input data.
- No mutation of local & global variables.
- It does not depend on the external state like a global variable.

Let us take the example of a function which returns two times of the value passed as an input to the function. In general, it is written as, f(x) => x*2. If a function is called with an argument value 2, then the output would be 4, f(2) => 4.

Let us write the definition of the function in JavaScript as shown below −

```
const double = x => x*2; // es6 arrow function
console.log(double(2));  // 4
```

Here, double is a pure function.

As per the three principles in Redux, changes must be made by a pure function, i.e., reducer in Redux. Now, a question arises as to why a reducer must be a pure function.

Suppose, you want to dispatch an action whose type is 'ADD_TO_CART_SUCCESS' to add an item to your shopping cart application by clicking the add to cart button.

Let us assume the reducer is adding an item to your cart as given below −

```
const initialState = {
  isAddedToCart: false;
}
const addToCartReducer = (state = initialState, action) => { //es6 arrow function
  switch (action.type) {
    case 'ADD_TO_CART_SUCCESS' :
      state.isAddedToCart = !state.isAddedToCart; //original object altered
      return state;
    default:
      return state;
  }
}
export default addToCartReducer ;
```

Let us suppose, isAddedToCart is a property on state object that allows you to decide when to disable the ‘add to cart’ button for the item by returning a Boolean value ‘true or false’. This prevents user to add same product multiple times. Now, instead of returning a new object, we are mutating isAddedToCart prop on the state like above. Now if we try to add an item to cart, nothing happens. Add to cart button will not get disabled.

The reason for this behaviour is as follows −

Redux compares old and new objects by the memory location of both the objects. It expects a new object from the reducer if any change has happened. And it also expects to get the old object back if no change occurs. In this case, it is the same. Due to this reason, Redux assumes that nothing has happened.

So, it is necessary for a reducer to be a pure function in Redux. The following is a way to write it without mutation −

```
const initialState = {
  isAddedToCart: false;
}
const addToCartReducer = (state = initialState, action) => { //es6 arrow function
  switch (action.type) {
    case 'ADD_TO_CART_SUCCESS' :
      return {
        ...state,
        isAddedToCart: !state.isAddedToCart
      }
    default:
      return state;
  }
}
export default addToCartReducer;
```

1.11.6 Reducers

Reducers are a pure function in Redux. Pure functions are predictable. Reducers are the only way to change states in Redux. It is the only place where you can write logic and calculations. Reducer function will accept the previous state of the app and action being dispatched, calculate the next state and returns the new object.

The following few things should never be performed inside the reducer −

- Mutation of functions arguments
- API calls & routing logic
- Calling non-pure function e.g. Math.random()

The following is the syntax of a reducer −

```
(state,action) => newState
```

Let us continue the example of showing the list of product items on a web page, discussed in the action creators module. Let us see below how to write its reducer.

```
const initialState = {
  isLoading: false,
  items: []
};
const reducer = (state = initialState, action) => {
  switch (action.type) {
    case 'ITEMS_REQUEST':
      return Object.assign({}, state, {
        isLoading: action.payload.isLoading
      })
    case ‘ITEMS_REQUEST_SUCCESS':
      return Object.assign({}, state, {
        items: state.items.concat(action.items),
        isLoading: action.isLoading
      })
    default:
      return state;
  }
}
```

```
export default reducer;
```

Firstly, if you do not set state to ‘initialState’, Redux calls reducer with the undefined state. In this code example, concat() function of JavaScript is used in ‘ITEMS_REQUEST_SUCCESS', which does not change the existing array; instead returns a new array.

In this way, you can avoid mutation of the state. Never write directly to the state. In 'ITEMS_REQUEST', we have to set the state value from the action received.

It is already discussed that we can write our logic in a reducer and can split it on the logical data basis. Let us see how we can split reducers and combine them together as root reducer when dealing with a large application.

Suppose, we want to design a web page where a user can access product order status and see wishlist information. We can separate the logic in different reducers files, and make them work independently. Let us assume that GET_ORDER_STATUS action is dispatched to get the status of order corresponding to some order id and user id.

/reducer/orderStatusReducer.js:

```
import { GET_ORDER_STATUS } from ‘../constants/appConstant’;

export default function (state = {} , action) {

  switch(action.type) {

    case GET_ORDER_STATUS:

      return { ...state, orderStatusData: action.payload.orderStatus };

    default:

      return state;

  }

}
```

Similarly, assume GET_WISHLIST_ITEMS action is dispatched to get the user’s wishlist information respective of a user.

/reducer/getWishlistDataReducer.js:

```
import { GET_WISHLIST_ITEMS } from ‘../constants/appConstant’;

export default function (state = {}, action) {

  switch(action.type) {

    case GET_WISHLIST_ITEMS:
```

```
              return { ...state, wishlistData: action.payload.wishlistData };
            default:
              return state;
        }
      }
```

Now, we can combine both reducers by using Redux combineReducers utility. The combineReducers generate a function which returns an object whose values are different reducer functions. You can import all the reducers in index reducer file and combine them together as an object with their respective names.

/reducer/index.js:

```
import { combineReducers } from ‘redux’;
import OrderStatusReducer from ‘./orderStatusReducer’;
import GetWishlistDataReducer from ‘./getWishlistDataReducer’;

const rootReducer = combineReducers ({
  orderStatusReducer: OrderStatusReducer,
  getWishlistDataReducer: GetWishlistDataReducer
});
export default rootReducer;
```

Now, you can pass this rootReducer to the createStore method as follows −

```
const store = createStore(rootReducer);
```

1.11.7 Integrating with React

In the previous chapters, we have learnt what is Redux and how it works. Let us now check the integration of the view part with Redux. You can add any view layer to Redux. We will also discuss the React library and Redux.

Let us say if various react components need to display the same data in different ways without passing it as a prop to all the components from top-level component to the way down. It would be ideal to store it outside the react components. Because it helps in faster data retrieval as you need not pass data all the way down to different components.

Let us discuss how it is possible with Redux. Redux provides the react-redux package to bind react components with two utilities as given below −

- Provider
- Connect

Provider makes the store available to the rest of the application. Connect function helps the react component to connect to the store, responding to each change occurring in the store’s state.

Let us have a look at the root index.js file which creates a store and uses a provider that enables the store to the rest of the app in a react-redux app.

```
import React from 'react'
import { render } from 'react-dom'
import { Provider } from 'react-redux'
import { createStore, applyMiddleware } from 'redux';
import reducer from './reducers/reducer'
import thunk from 'redux-thunk';
import App from './components/app'
import './index.css';

const store = createStore(
  reducer,
  window.__REDUX_DEVTOOLS_EXTENSION__ && window.__REDUX_DEVTOOLS_EXTENSION__(),
  applyMiddleware(thunk)
)
render(
  <Provider store = {store}>
    <App />
  </Provider>,
  document.getElementById('root')
)
```

Whenever a change occurs in a react-redux app, mapStateToProps() is called. In this function, we exactly specify which state we need to provide to our react component.

With the help of connect() function explained below, we are connecting these app's state to the react component. Connect() is a high order function which takes component as a parameter. It performs certain operations and returns a new component with correct data which we finally exported.

With the help of mapStateToProps(), we provide these store states as prop to our react component. This code can be wrapped in a container component. The motive is to separate concerns like data fetching, rendering concern and reusability.

```
import { connect } from 'react-redux'
import Listing from '../components/listing/Listing' //react component
import makeApiCall from '../services/services' //component to make api call

const mapStateToProps = (state) => {
  return {
    items: state.items,
    isLoading: state.isLoading
  };
};
const mapDispatchToProps = (dispatch) => {
  return {
    fetchData: () => dispatch(makeApiCall())
  };
};
export default connect(mapStateToProps, mapDispatchToProps)(Listing);
```

The definition of a component to make an api call in services.js file is as follows −

```
import axios from 'axios'
import { itemsLoading, itemsFetchDataSuccess } from '../actions/actions'
```

```
export default function makeApiCall() {
  return (dispatch) => {
    dispatch(itemsLoading(true));
    axios.get('http://api.tvmaze.com/shows')
    .then((response) => {
      if (response.status !== 200) {
        throw Error(response.statusText);
      }
      dispatch(itemsLoading(false));
      return response;
    })
    .then((response) => dispatch(itemsFetchDataSuccess(response.data)))
  };
}
```

mapDispatchToProps() receives dispatch function as a parameter and returns you callback props as plain objects that you pass to your react component.

Here, you can access fetchData as a prop in your react listing component, which dispatches an action to make an API call. mapDispatchToProps() is used to dispatch an action to store. In react-redux, components cannot access the store directly. The only way is to use connect().

Let us understand how the react-redux works through the below diagram −

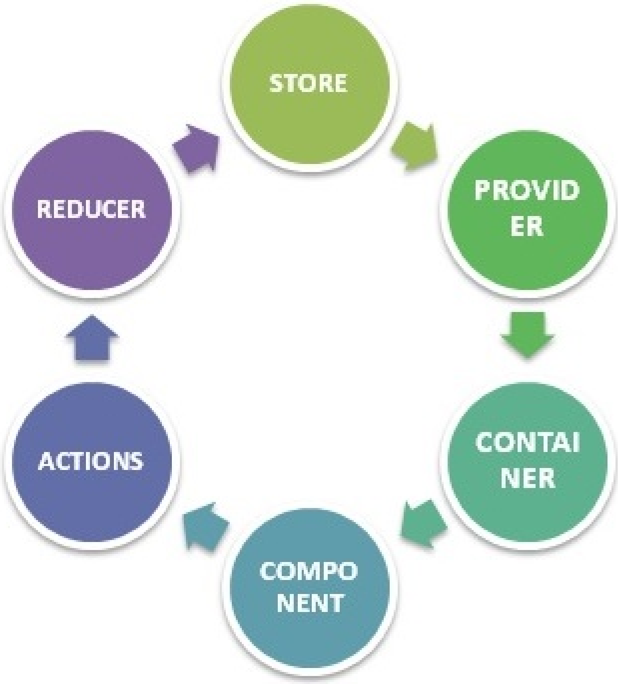


Fig 1.7

Chapter 2-
PROJECT ANALYSIS

2.1 What is supportSME

SupportSME Community Inc. has launched a marketplace platform to help small businesses mitigate potentially catastrophic effects of coronavirus-related closures, lockdowns and other restrictions. According to a new survey, one in three businesses in Canada say that they cannot survive the current coronavirus pandemic conditions for more than a month. According to the Canadian Federation of Independent Business, 60 percent of small businesses have seen a significant drop in sales, with more than a third reporting a reduction greater than 75 percent. In these uncertain and chaotic times, the SupportSME platform targets all small and medium businesses including restaurants, spas, beauty salons, barber’s shops, dental offices, physiotherapy/massage clinics, fitness centers, shops, and arts and entertainment venues that are directly or indirectly dependent on free movement of buyers arriving in-person to physical business locations. The platform provides a “natural” community-based financing solution to help businesses meet their liquidity and operating expense requirements by channeling immediately available cash funds from buyers who are willing to support their favorite service providers now in lieu of the services delivered later. The governments of all levels may benefit from the platform by leveraging it to channel available consumer cash in a form of pent-up demand for small business products and services instead of directly subsidizing business operational expenses during the COVID-19 economic downturn. Supportsme’s marketplace platform allows local suppliers to list their businesses and offer services by issuing certificates. Customers will be able to purchase these certificates during the restrictions, making the funds immediately available for the businesses, and redeem them after the restrictions are lifted at the issuer-specified premium.

2.2 Technology Stack:-

- **Frontend:-** ReactJs for web App , react native for mobile app.
- **Backend:-** NodeJs.
- **DataBase:-** Postgresql
- **Other Technologies:-** AWS Elasticsearch, S3 bucket, Microservices Architecture

2.3 Features Of Project:-

Admin Portal:-

- SignUp
- SignIn
- Adding Categories
- Adding Certificate Plans.
- Showing Business List
- Verifying / Reject Business
- Giving the default amount to businesses to publish certificates.

Business portal:-

- SignUp
- SignIn
- OnBoard Business
- View Profile
- Edit Profile
- Business Verification
- Create and Publish Certificates with his preferred offer.
- Redeem Certificate
- View Certificate History
- View Donation History
- Onboard multiple business
- Displaying Business Listing
- Edit Business

Customer portal:-

- SignUp
- SignIn
- OnBoard Customer.
- Edit profile
- Display of All Businesses with their certificates.
- Display of Nearby Businesses.
- Purchase Certificate
- Checkout Payment
- Showing Purchase History
- Make Donation
- Showing Donation list
- Showing Top Donors
- Showing Trending Business
- Giving Rating and Feedback to business
- Displaying Feedback List

2.4 Hardware Configuration

Table 2.1 Hardware configuration

RAM	8 GB
Processor	Intel® Core™ i5-8265U CPU
Clockspeed	1.60GHz
No of cores	8
OS Type	64 bit

Harddrive	251.0 GB

2.5 Software Configuration

Table 2.2 Software configuration

Package Manager	npm
Architecture	create-react-app
Editor	VS Code
Repository	Bitbucket
OS	Linux

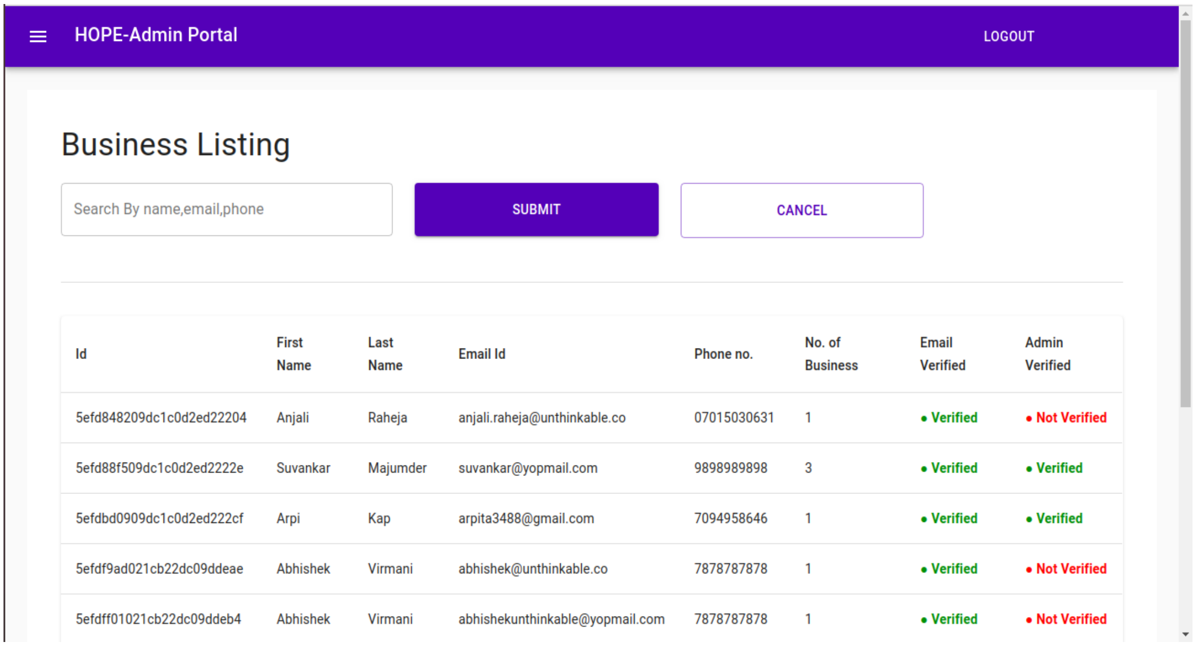
2.6 Roles & Responsibilities

- UI Designing of multiple Components.
- API Integrations.
- Business DashBoard.
- Customer Purchasing Certificate.
- Making reusable Components.
- Adding Multiple Business.
- Certificates Redemption.
- Integrating Payment Checkout
- Solving UAT Issues.

Chapter- 3

RESULTS AND DISCUSSIONS

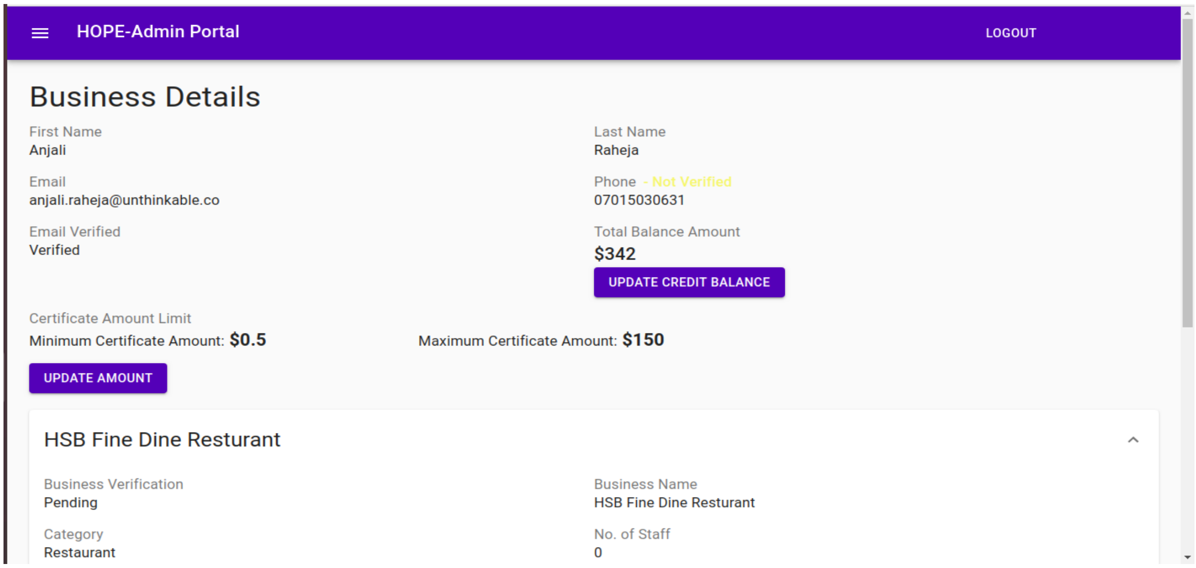
3.1 Admin portal:-



Business Listing

Id	First Name	Last Name	Email Id	Phone no.	No. of Business	Email Verified	Admin Verified
5efd848209dc1c0d2ed22204	Anjali	Raheja	anjali.raheja@unthinkable.co	07015030631	1	● Verified	● Not Verified
5efd88f509dc1c0d2ed2222e	Suvankar	Majumder	suvankar@yopmail.com	9898989898	3	● Verified	● Verified
5efdbd0909dc1c0d2ed222cf	Arpi	Kap	arpita3488@gmail.com	7094958646	1	● Verified	● Verified
5efdf9ad021cb22dc09ddeae	Abhishek	Virmani	abhishek@unthinkable.co	7878787878	1	● Verified	● Not Verified
5efdff01021cb22dc09ddeb4	Abhishek	Virmani	abhishekunthinkable@yopmail.com	7878787878	1	● Verified	● Not Verified

Fig 3.1:- Business List



Business Details

First Name
Anjali

Last Name
Raheja

Email
anjali.raheja@unthinkable.co

Phone - Not Verified
07015030631

Email Verified
Verified

Total Balance Amount
$342

Certificate Amount Limit
Minimum Certificate Amount: **$0.5**
Maximum Certificate Amount: **$150**

HSB Fine Dine Resturant

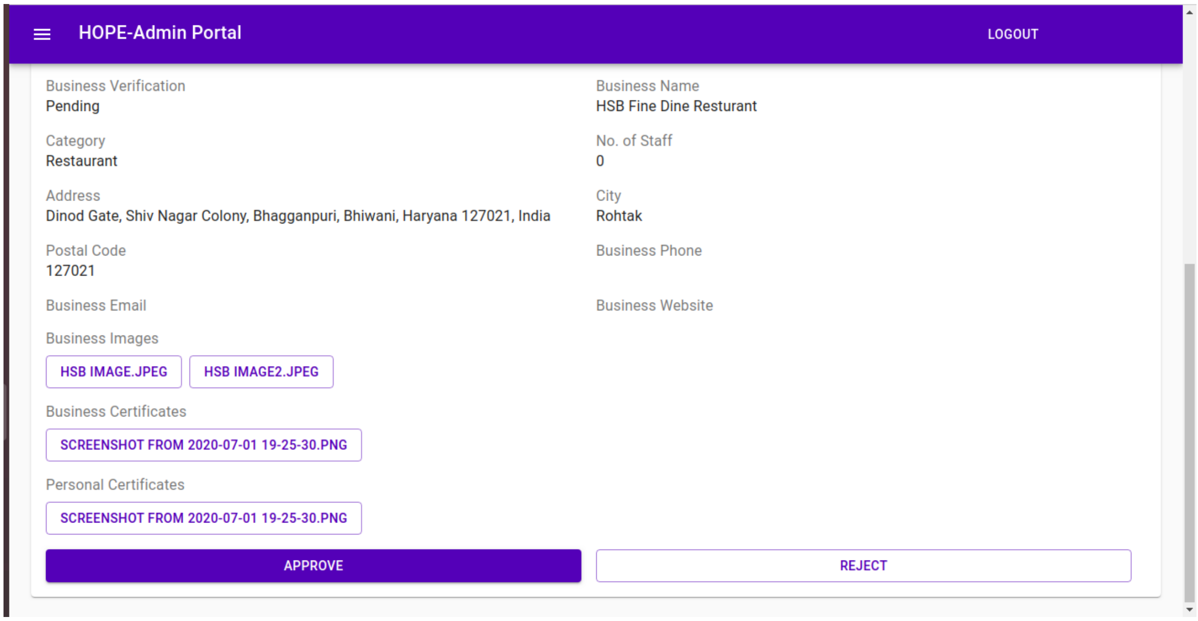
Business Verification
Pending

Business Name
HSB Fine Dine Resturant

Category
Restaurant

No. of Staff
0

Fig 3.2:- Business Details



Business Verification
Pending

Business Name
HSB Fine Dine Resturant

Category
Restaurant

No. of Staff
0

Address
Dinod Gate, Shiv Nagar Colony, Bhagganpuri, Bhiwani, Haryana 127021, India

City
Rohtak

Postal Code
127021

Business Phone

Business Email

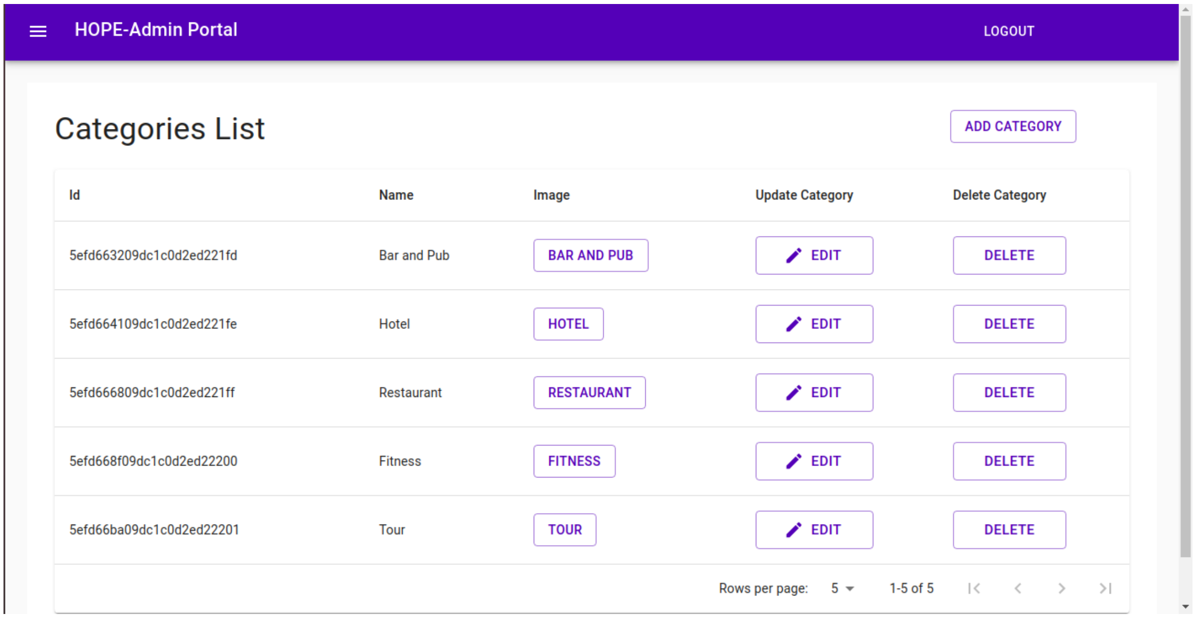
Business Website

Business Images
HSB IMAGE.JPEG
HSB IMAGE2.JPEG

Business Certificates
SCREENSHOT FROM 2020-07-01 19-25-30.PNG

Personal Certificates
SCREENSHOT FROM 2020-07-01 19-25-30.PNG

Fig 3.3:- Business Approve/Reject

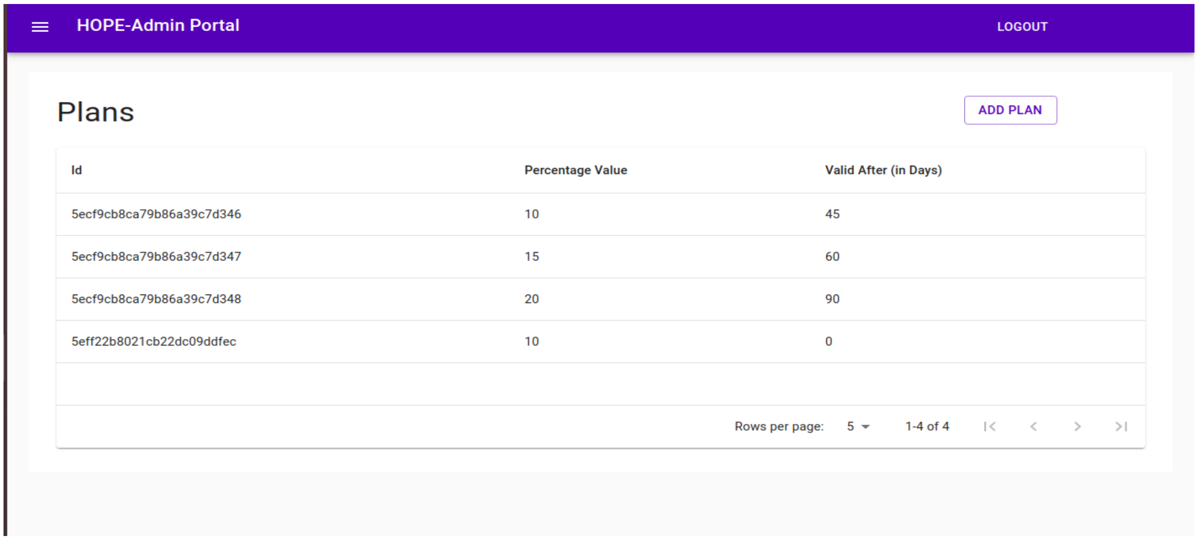


Categories List

Id	Name	Image	Update Category	Delete Category
5efd663209dc1c0d2ed221fd	Bar and Pub	BAR AND PUB	EDIT	DELETE
5efd664109dc1c0d2ed221fe	Hotel	HOTEL	EDIT	DELETE
5efd666809dc1c0d2ed221ff	Restaurant	RESTAURANT	EDIT	DELETE
5efd668f09dc1c0d2ed22200	Fitness	FITNESS	EDIT	DELETE
5efd66ba09dc1c0d2ed22201	Tour	TOUR	EDIT	DELETE

Rows per page: 5 1-5 of 5

Fig 3.4:- category List



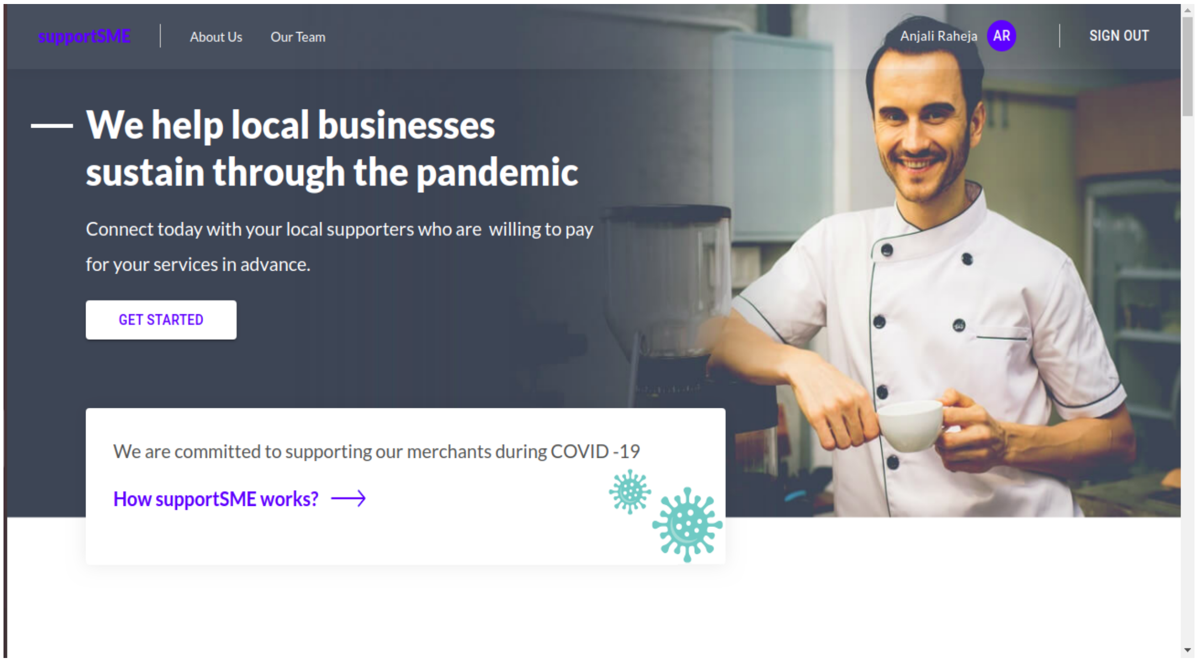
Plans

Id	Percentage Value	Valid After (in Days)
5ecf9cb8ca79b86a39c7d346	10	45
5ecf9cb8ca79b86a39c7d347	15	60
5ecf9cb8ca79b86a39c7d348	20	90
5eff22b8021cb22dc09ddfec	10	0

Rows per page: 5 1-4 of 4

Fig 3.5:- Certificates Issuing Plans

3.2 Business portal:-



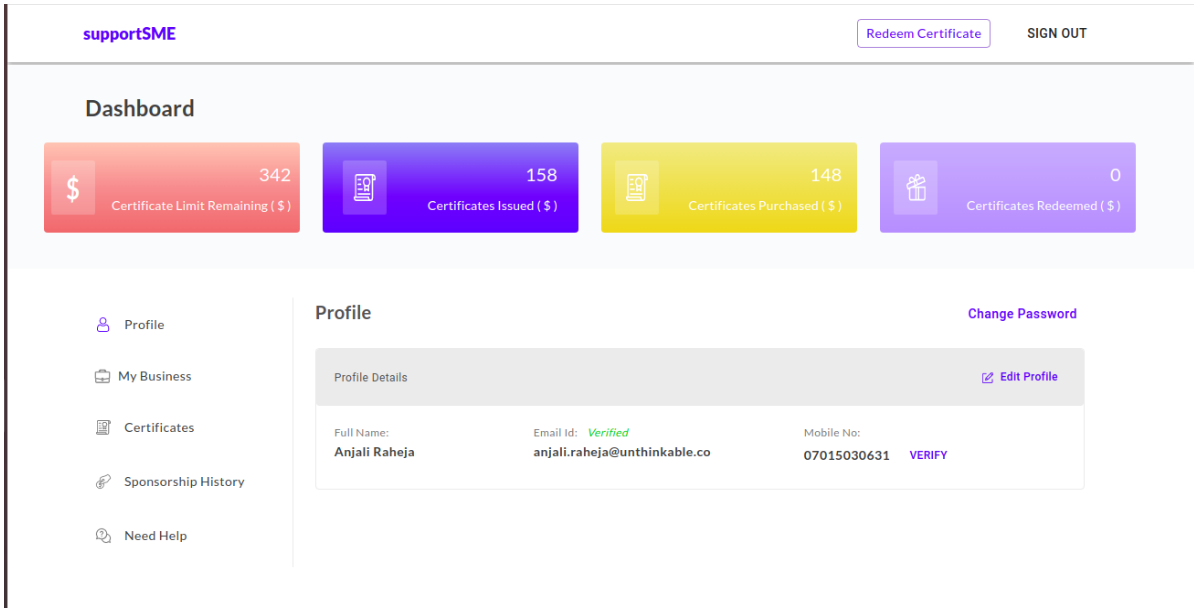
We help local businesses sustain through the pandemic

Connect today with your local supporters who are willing to pay for your services in advance.

We are committed to supporting our merchants during COVID -19

How supportSME works?

Fig 3.6:- Business Home Page



342 Certificate Limit Remaining ($)

158 Certificates Issued ($)

148 Certificates Purchased ($)

0 Certificates Redeemed ($)

Full Name: Anjali Raheja

Email Id: Verified anjali.raheja@unthinkable.co

Mobile No: 07015030631

Fig 3.7:- Business Profile

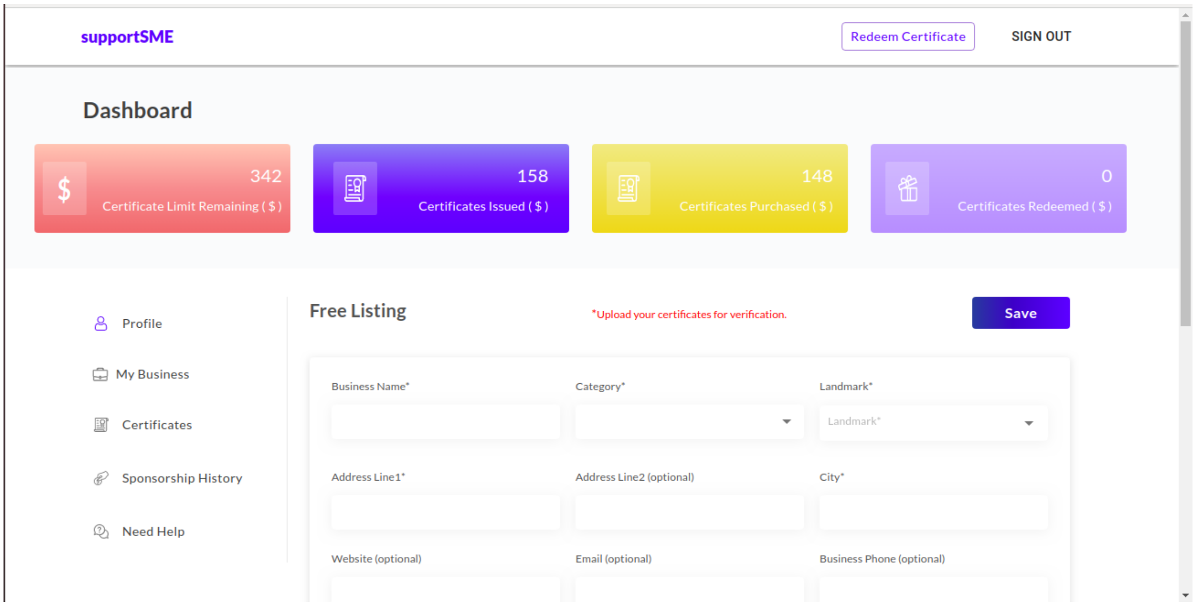


Fig 3.8:- Edit Business

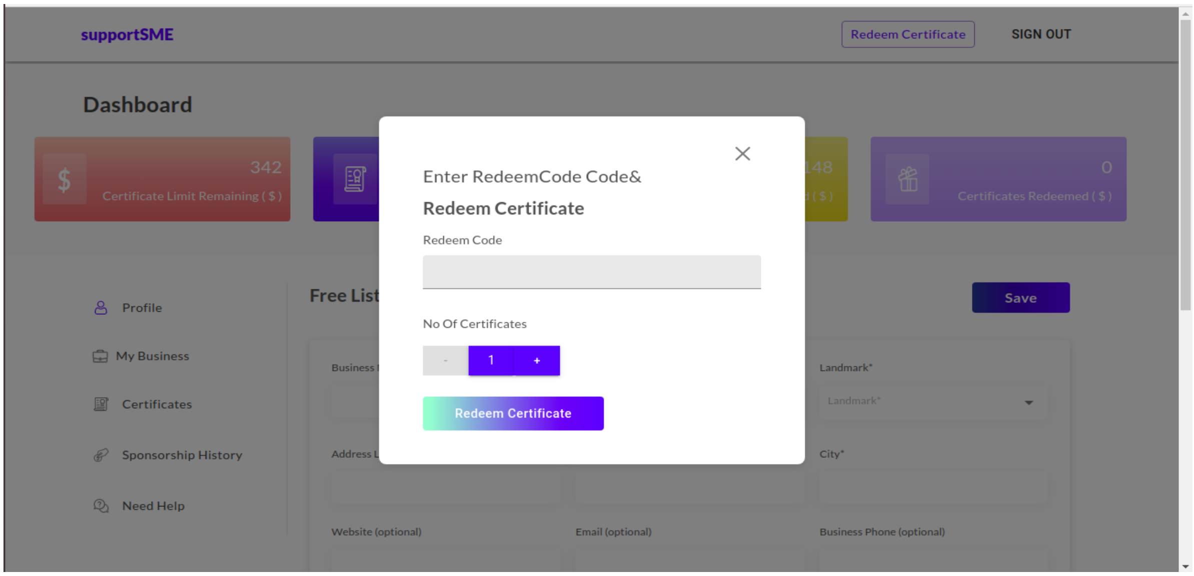
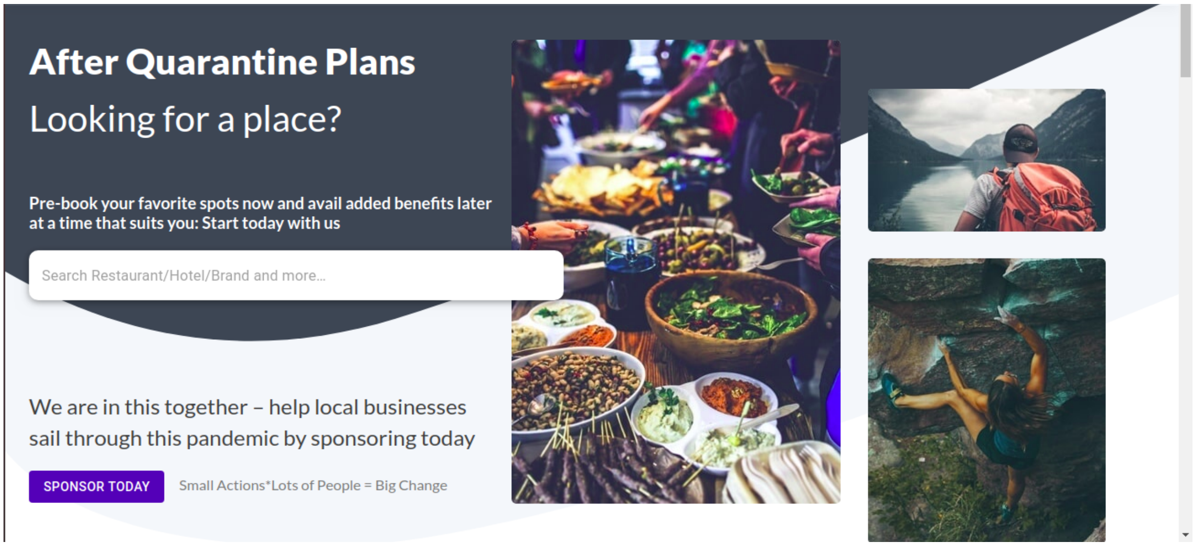


Fig 3.9:- Redeem Certificate

3.3 Customer portal:-



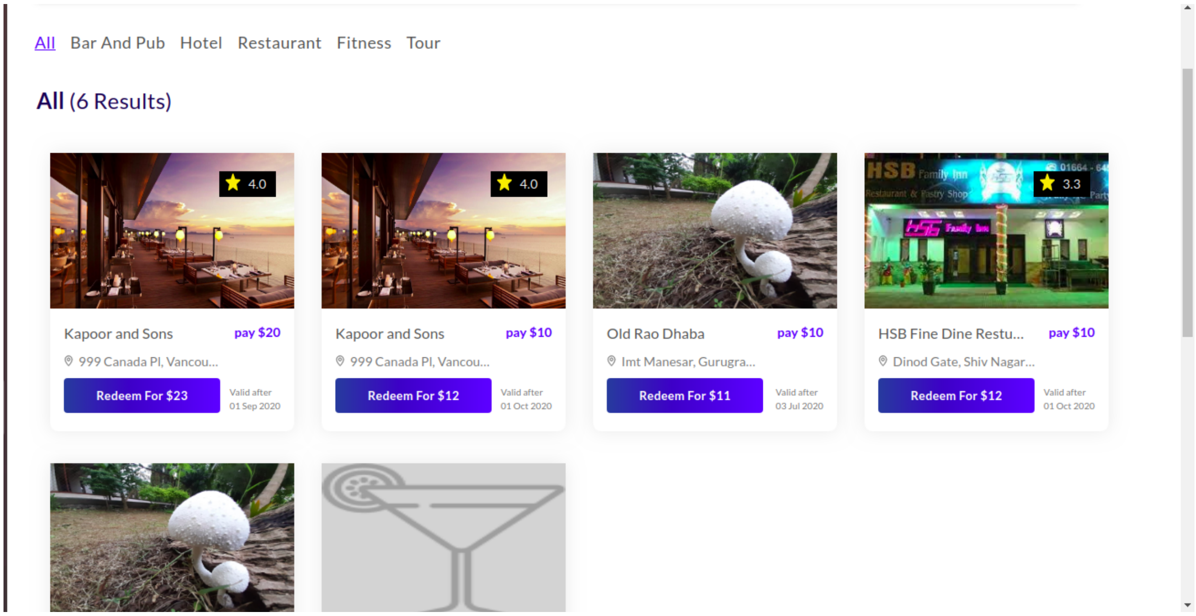
After Quarantine Plans

Looking for a place?

Pre-book your favorite spots now and avail added benefits later at a time that suits you: Start today with us

We are in this together – help local businesses sail through this pandemic by sponsoring today

Fig 3.10:- Customer Home Page



All (6 Results)

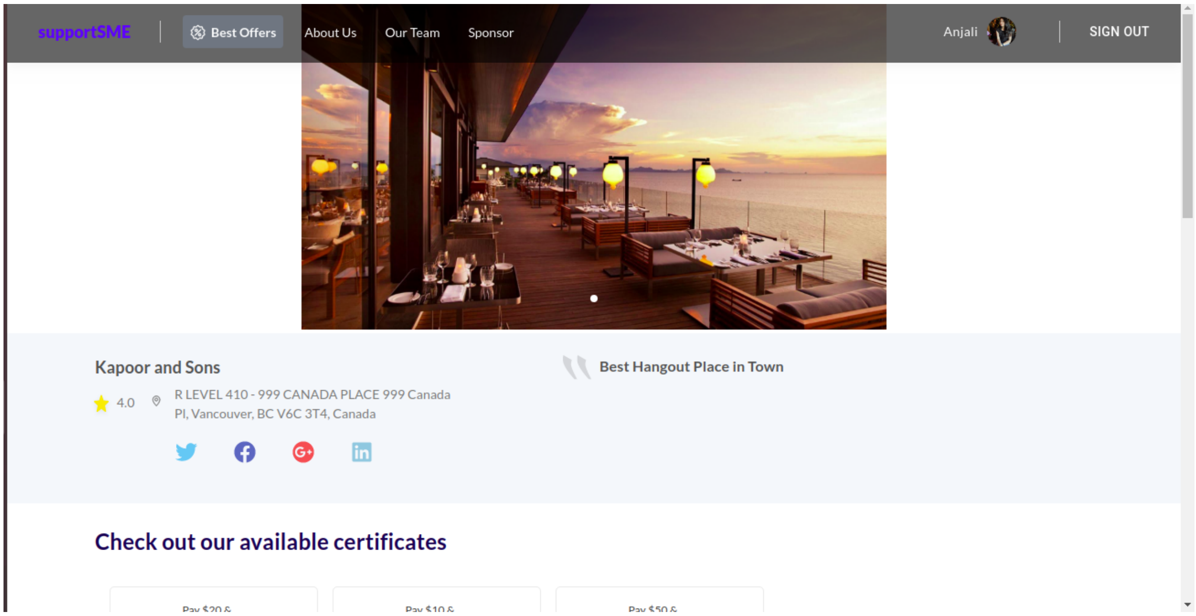
Kapoor and Sons 4.0 pay $20
999 Canada Pl, Vancou...
Redeem For $23 Valid after 01 Sep 2020

Kapoor and Sons 4.0 pay $10
999 Canada Pl, Vancou...
Redeem For $12 Valid after 01 Oct 2020

Old Rao Dhaba pay $10
Imt Manesar, Gurugra...
Redeem For $11 Valid after 03 Jul 2020

HSB Fine Dine Restu... 3.3 pay $10
Dinod Gate, Shiv Nagar...
Redeem For $12 Valid after 01 Oct 2020

Fig 3.11:- Displaying Available Certificates



Kapoor and Sons

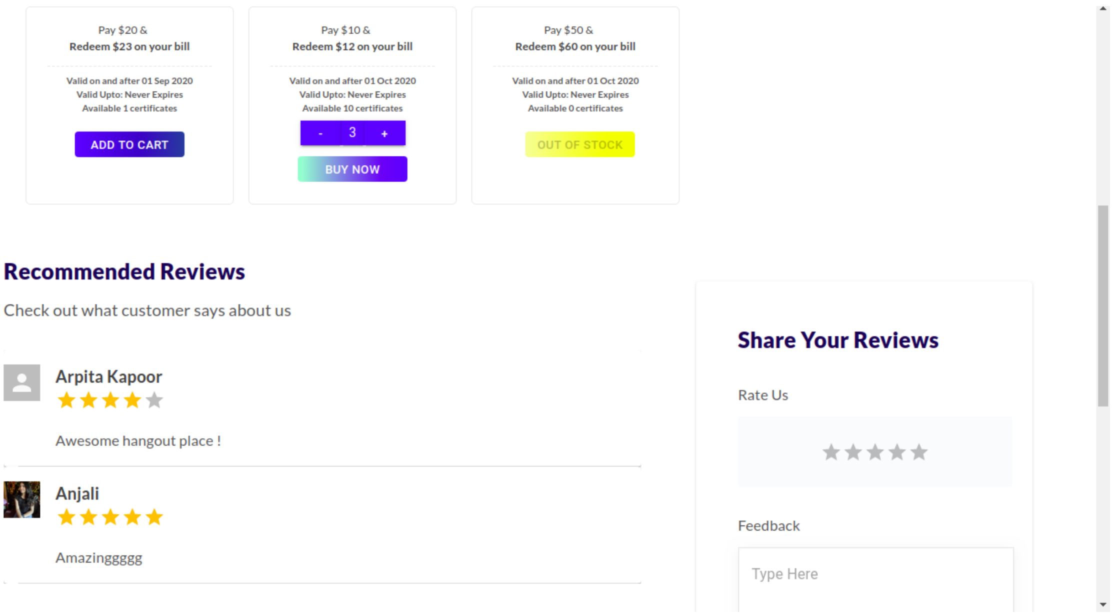
4.0 R LEVEL 410 - 999 CANADA PLACE 999 Canada Pl, Vancouver, BC V6C 3T4, Canada

Best Hangout Place in Town

Check out our available certificates

Pay $20 &
Pay $10 &
Pay $50 &

Fig 3.12:- Business Detail



Pay $20 &
Redeem $23 on your bill
Valid on and after 01 Sep 2020
Valid Upto: Never Expires
Available 1 certificates

Pay $10 &
Redeem $12 on your bill
Valid on and after 01 Oct 2020
Valid Upto: Never Expires
Available 10 certificates

Pay $50 &
Redeem $60 on your bill
Valid on and after 01 Oct 2020
Valid Upto: Never Expires
Available 0 certificates

Recommended Reviews

Check out what customer says about us

Arpita Kapoor

Awesome hangout place !

Anjali

Amazinggggg

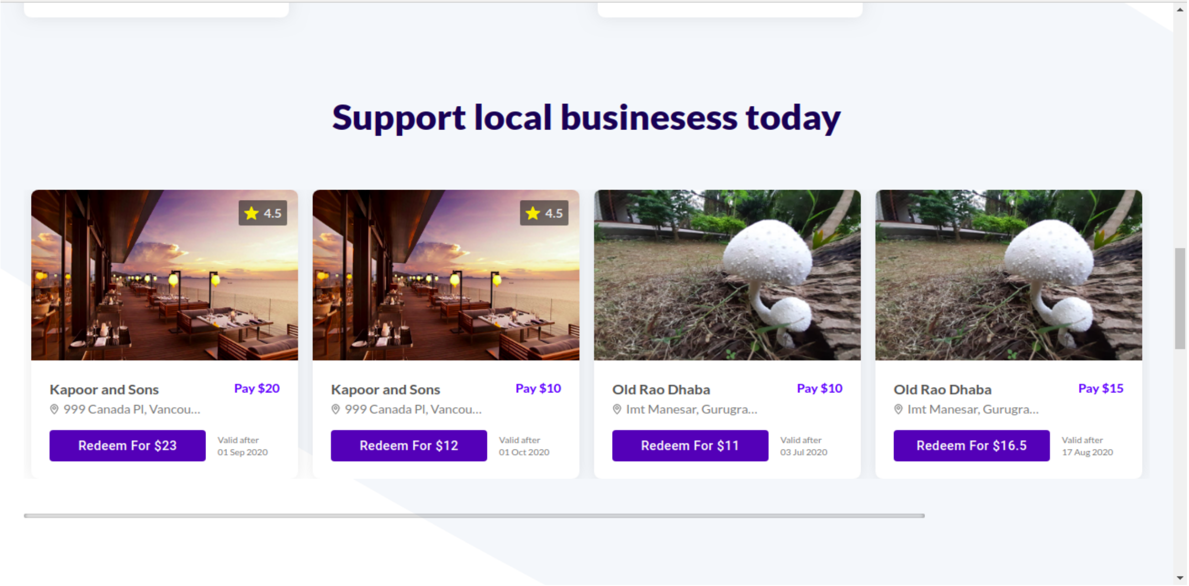
Share Your Reviews

Rate Us

Feedback

Type Here

Fig 3.13:- Purchasing Certificate



Support local businesess today

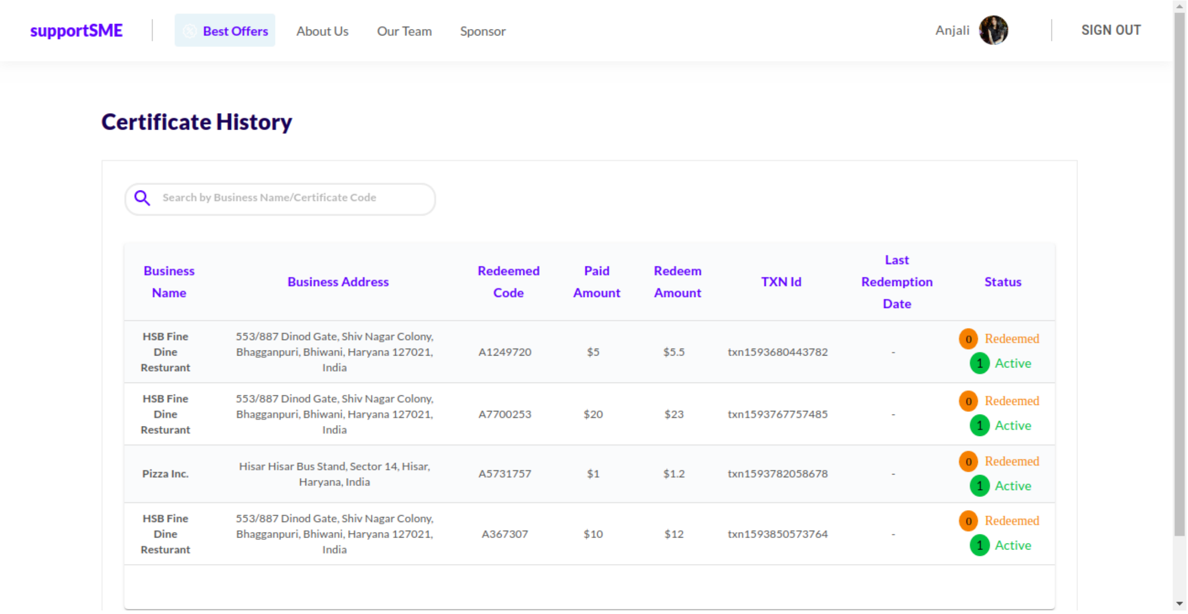
Kapoor and Sons
Pay $20
999 Canada Pl, Vancou...
Valid after
01 Sep 2020

Kapoor and Sons
Pay $10
999 Canada Pl, Vancou...
Valid after
01 Oct 2020

Old Rao Dhaba
Pay $10
Imt Manesar, Gurugra...
Valid after
03 Jul 2020

Old Rao Dhaba
Pay $15
Imt Manesar, Gurugra...
Valid after
17 Aug 2020

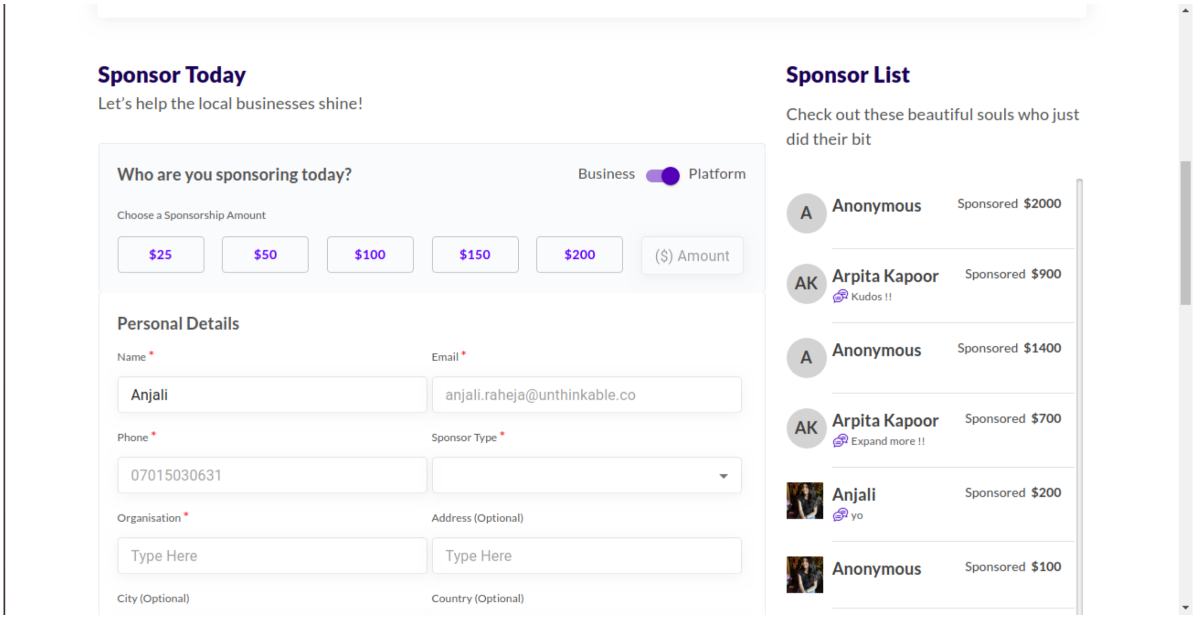
Fig 3.14:- Certificates on Home Screen



Certificate History

Business Name	Business Address	Redeemed Code	Paid Amount	Redeem Amount	TXN Id	Last Redemption Date	Status
HSB Fine Dine Resturant	553/887 Dinod Gate, Shiv Nagar Colony, Bhagganpuri, Bhiwani, Haryana 127021, India	A1249720	$5	$5.5	txn1593680443782	-	0 Redeemed 1 Active
HSB Fine Dine Resturant	553/887 Dinod Gate, Shiv Nagar Colony, Bhagganpuri, Bhiwani, Haryana 127021, India	A7700253	$20	$23	txn1593767757485	-	0 Redeemed 1 Active
Pizza Inc.	Hisar Hisar Bus Stand, Sector 14, Hisar, Haryana, India	A5731757	$1	$1.2	txn1593782058678	-	0 Redeemed 1 Active
HSB Fine Dine Resturant	553/887 Dinod Gate, Shiv Nagar Colony, Bhagganpuri, Bhiwani, Haryana 127021, India	A367307	$10	$12	txn1593850573764	-	0 Redeemed 1 Active

Fig 3.15:- Customer Purchase History



Sponsor Today

Let's help the local businesses shine!

Who are you sponsoring today?

Choose a Sponsorship Amount

Personal Details

Name * Anjali

Email * anjali.raheja@unthinkable.co

Phone * 07015030631

Sponsor Type *

Organisation * Type Here

Address (Optional) Type Here

City (Optional)

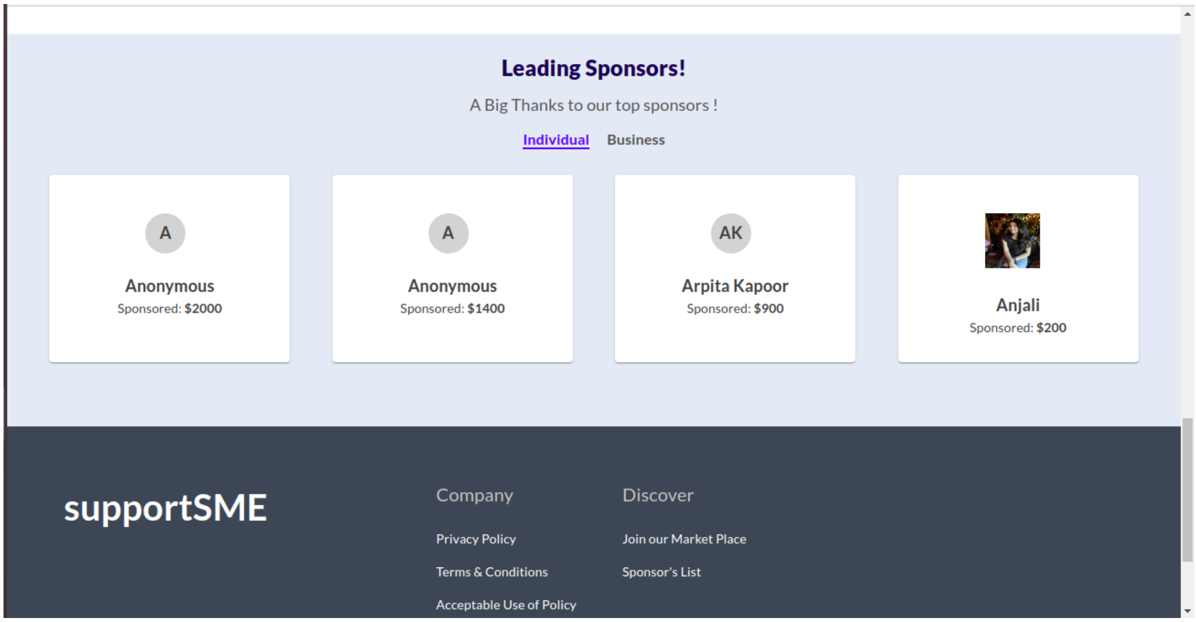
Country (Optional)

Sponsor List

Check out these beautiful souls who just did their bit

A	Anonymous	Sponsored $2000
AK	Arpita Kapoor Kudos !!	Sponsored $900
A	Anonymous	Sponsored $1400
AK	Arpita Kapoor Expand more !!	Sponsored $700
	Anjali yo	Sponsored $200
	Anonymous	Sponsored $100

Fig 3.16:- Donation Form and Donor List



Leading Sponsors!

A Big Thanks to our top sponsors !

Anonymous
Sponsored: $2000

Anonymous
Sponsored: $1400

Arpita Kapoor
Sponsored: $900

Anjali
Sponsored: $200

Fig 3.17:- Top Donors

Chapter- 4

CONCLUSION AND FUTURE SCOPE

4.1 Present Scope

In today's digital world almost every system is getting computerized and proceeds very fast execution. Using a fast way computerized system for manipulating the data related to the project saves time, papers and minimum power which will further help in providing better services to the society along with providing social distancing among people in this global pandemic and helping various businesses financially. This E-commerce system provides the better facilities that totally fulfill the needs of the end user. That user can operate easily and conveniently.

4.2 Future Scope:

The system development is so flexible that it can be extended to include other features and it easily extended. Without any problem which will be of great benefit. Every businessman can utilize this for extending his business. This can be converted into a totally different paradigm for online shopping by adding a little php and bootstrap code. This application can be easily implemented under various situations. We can add new features as and when we require. Reusability is possible as and when require in this application. There is flexibility in all the modules.

4.2.1 Software Scope

- **Extensibility:** This software is extendable in ways that its original developers may not expect. The following principles enhances extensibility like hide data structure, avoid traversing multiple links or methods, avoid case statements on object type and distinguish public and private operations.

- **Reusability:** Reusability is possible as and when require in this application. We can update it next version. Reusable software reduces design, coding and testing cost by amortizing effort over several designs. Reducing the amount of code also simplifies understanding, which increases the likelihood that the code is correct. We follow up both types of reusability: Sharing of newly written code within a project and reuse of previously written code on new projects.

- **Understandability**: A method is understandable if someone other than the creator of the method can understand the code (as well as the creator after a time lapse). We have used a method, which is small and coherent, to accomplish this.

- **Cost-effectiveness**: When the cost is within the budget and is completed within a given time period then the project is termed as most cost effective. It is desirable to aim for a system with a minimum cost subject to the condition that it must satisfy the entire requirement. Scope of this document is to put down the requirements, clearly identifying the information needed by the user, the source of the information and outputs expected from the system.

4.3 Conclusion:

From a proper analysis of positive points and constraints on the component, it can be safely concluded that the product is a highly efficient GUI based component. This application is working properly and meeting to all user requirements. This component can be easily plugged in many other systems. The SupportSME platform targets all small and medium businesses including restaurants, spas, beauty salons, clinics, fitness centers, shops, and arts and entertainment venues that are directly or indirectly dependent on free movement of buyers arriving in-person to physical business locations. The platform provides a “natural” community-based financing solution to help businesses meet their liquidity and operating expense requirements by channeling immediately available cash funds from buyers who are willing to support their favorite service providers now in lieu of the services delivered later. Supportsme’s marketplace platform allows local suppliers to list their businesses and offer services by issuing certificates. Customers will be able to purchase these certificates during the restrictions, making the funds immediately available for the businesses, and redeem them after the restrictions are lifted at the issuer-specified premium and we have successfully onboarded 15 businesses on our platform and waiting to see our platform getting enhanced.

REFERENCES

Websites:-

- https://developer.mozilla.org/en-US/docs/Web/JavaScript
- https://material-ui.com/
- https://reactjs.org/docs/getting-started.html
- https://redux.js.org/
- https://www.npmjs.com/