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LESSON 1

Introduction of Technical Textiles

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1.0 Aims and Objectives

This chapter gives a clear outline about Technical textiles and its application in Textile industry. It also defines the developments in fibers and its end uses in various fields of Technical textiles.

1.1 Introduction

Technical textiles are generally recognized to be one of the most dynamic and promising areas for the future of the textiles industry. Technical textiles are textile material and products manufactured primarily for their performance and functional properties rather than aesthetic or decorative purpose. Aesthetic properties are not much important for the Technical Textiles.

Although ‘technical’ textiles have attracted considerable attention, the use of fibres, yarns and fabrics for applications other than clothing and furnishing is not a new phenomenon. Nor is it exclusively linked to the emergence of modern artificial fibres and textiles. Natural fibres such as cotton, flax, jute and sisal have been used for centuries (and still are used) in applications ranging from tents and tarpaulins to ropes, sailcloth and sacking. There is evidence of woven fabrics and meshes being used in Roman times and before to stabilise marshy ground for road building – early examples of what would now be termed geotextiles and geogrids. What is relatively new is a growing recognition of the economic and strategic potential of such textiles to the fibre and fabric manufacturing and processing industries of industrial and industrialising countries alike. In some of the most developed markets, technical products (broadly defined) already account for as much as 50% of all textile manufacturing activity and output. The technical textiles supply chain is a long and complex one, stretching from the manufacturers of polymers for technical fibres, coating and speciality membranes through to the converters and fabricators who incorporate technical textiles into finished products or use them as an essential part of their industrial operations.
textiles extends far beyond the textile industry itself and has an impact upon just about every sphere of human economic and social activity.

And yet this dynamic sector of the textile industry has not proved entirely immune to the effects of economic recession, of product and market maturity, and of growing global competition which are all too well known in the more traditional sectors of clothing and furnishings. There are no easy paths to success and manufacturers and converters still face the challenge of making economic returns commensurate with the risks involved in operating in new and complex markets. If anything, the constant need to develop fresh products and applications, invest in new processes and equipment, and market to an increasingly diverse range of customers, is more demanding and costly than ever. Technical textiles have never been a single coherent industry sector and market segment. It is developing in many different directions with varying speeds and levels of success. There is continual erosion of the barriers between traditional definitions of textiles and other ‘flexible engineering’ materials such as paper and plastics, films and membranes, metals, glass and ceramics. What most participants have in common are many of the basic textile skills of manipulating fibres, fabrics and finishing techniques as well as an understanding of how all these interact and perform in different combinations and environments. Beyond that, much of the technology and expertise associated with the industry resides in an understanding of the needs and dynamics of many very different end-use and market sectors. It is here that the new dividing lines within the industry are emerging. An appreciation of the development and potential of technical textile markets therefore starts with some clarification of the evolving terminology and definitions of scope of the industry and its markets.

1.2 Technical or industrial textiles: what’s in a name?

For many years, the term ‘industrial textiles’ was widely used to encompass all textile products other than those intended for apparel, household and furnishing
end-uses. This usage has seemed increasingly inappropriate in the face of developing applications of textiles for medical, hygiene, sporting, transportation, construction, agricultural and many other clearly non-industrial purposes. Industrial textiles are now more often viewed as a subgroup of a wider category of technical textiles, referring specifically to those textile products used in the course of manufacturing operations (such as filters, machine clothing, conveyor belts, abrasive substrates etc.) or which are incorporated into other industrial products (such as electrical components and cables, flexible seals and diaphragms, or acoustic and thermal insulation for domestic and industrial appliances).

If this revised definition of industrial textiles is still far from satisfactory, then the problems of finding a coherent and universally acceptable description and classification of the scope of technical textiles are even greater. Several schemes have been proposed. For example, the leading international trade exhibition for technical textiles, Techtextil (organised biennially since the late 1980s by Messe Frankfurt in Germany and also in Osaka, Japan), defines 12 main application areas (of which textiles for industrial applications represent only one group):

- agrotech: agriculture, aquaculture, horticulture and forestry
- buildtech: building and construction
- clothtech: technical components of footwear and clothing
- geotech: geotextiles and civil engineering
- hometech: technical components of furniture, household textiles and floorcoverings
- indutech: filtration, conveying, cleaning and other industrial uses
- medtech: hygiene and medical
- mobiltech: automobiles, shipping, railways and aerospace
- oekotech: environmental protection
- packtech: packaging
- protech: personal and property protection
- sporttech: sport and leisure.
The search for an all embracing term to describe these textiles is not confined to the words ‘technical’ and ‘industrial’. Terms such as performance textiles, functional textiles, engineered textiles and high-tech textiles are also all used in various contexts, sometimes with a relatively specific meaning (performance textiles are frequently used to describe the fabrics used in activity clothing), but more often with little or no precise significance.

1.3 Classification of Technical Textiles

Technical textiles can be divided into many categories, depending on their end use. The classification developed by Techtextil, Messe Frankfurt is widely used. The classifications and its applications are shown in Fig -1

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<th>Buildtech</th>
<th>Clothtech</th>
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<td></td>
<td>Horticulture + landscape gardening, agriculture + forestry, animal keeping</td>
<td>Membrane, lightweight + massive construction, engineering + industrial building.</td>
<td>Garments, shoes</td>
<td>Road infrastructure, Railways, Irrigation and Hydraulic structures, Waste Landfills, Dams etc.</td>
<td>Furniture, upholstery + interior furnishing, rugs, floor coverings</td>
<td>Filtration, cleaning, mechanical engineering, chemical industry</td>
<td>Hygiene, medicine</td>
<td>Cars, ships, aircraft, trains, space travel</td>
<td>Environmental protection, recycling, waste disposal</td>
<td>Packaging, protective-cover systems, sacks, big bags, container systems</td>
<td>Person and property protection</td>
<td>Sport and leisure, active wear, outdoor, sport articles.</td>
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Fig -1 The classifications of Technical Textiles

1.3.1 Agrotech (Agro-textiles)

Textiles used in Agriculture are termed as agro textiles. They are used for crop protection, fertilisation, ... The essential properties required are strength,
elongation, stiffness, and bio-degradation, resistance to sunlight and resistance to toxic environment. All these properties help with the growth and harvesting of crops and other foodstuffs. There is a growing interest in using materials which gradually degrade (biodegradables).

1.3.2 Buildtech (Construction Textiles)

Textiles used in construction - concrete reinforcement, façade foundation systems, interior construction, insulations, proofing materials, air conditioning, noise prevention, visual protection, protection against the sun, building safety.

An interesting and aesthetic appealing application is the use of textile membranes for roof construction. This area is also referred to as textile architecture. PVC coated high tenacity PES, teflon coated glass fibre fabrics or silicone coated PES are used for their low creep properties. Splendid examples of such construction are found in football stadia, airports and hotels.

1.3.3 Clothtech (Clothing Textiles)

Technical textiles for clothing applications.

1.3.4 Geotech (Geo-textiles)

These are used in reinforcement of embankments or in constructional work. The fabrics in geo textiles are permeable fabrics and are used with soils having ability to separate, filter, protect or drain. The application areas include civil engineering, earth and road construction, dam engineering, soil sealing and in drainage systems. The fabric used in it must have good strength, durability, low moisture absorption and thickness. Mostly nonwoven and woven fabrics are used in it. Synthetic fibers like glass, polypropylene and acrylic fibers are used to prevent cracking of the concrete, plastic and other building materials. Polypropylene and polyester are used in geo textiles and dry/liquid filtration due to their compatibility.
1.3.5 Hometech (Domestic Textiles)

Textiles used in a domestic environment - interior decoration and furniture, carpeting, protection against the sun, cushion materials, fireproofing, floor and wall coverings, textile reinforced structures/fittings.

In the contract market such as for large area buildings, ships, caravans, busses, fire retardant materials are used. Fire retardant properties are obtained either through the use of inherent fire retardant fibres such as modacryl or through the application of a coating with fire retardant additives (bromide of phosphorus compounds).

1.3.6 Indutech (Industrial Textiles)

Textiles used for chemical and electrical applications and textiles related to mechanical engineering. Silk-screen printing, filtration, plasma screens, propulsion technology, lifting/conveying equipment, sound-proofing elements, melting processes, roller covers, grinding technology, insulations, seals, fuel cell.

1.3.7 Medtex (Medical textiles)

These are commonly used in bandages and sutures (stitching the wounds). Not all the textile fibers can be used here, because their performances depend upon interaction with the cells and different fluids produce by the body. Sutures and wound dressing uses fibers like silk and other synthetic fibers. Hollow synthetic fibers are used with nano or very small particles are used for the delivery of drugs to any specific part of the body to prevent over dosage. Cotton, silk polyester, polyamide are also used in medical applications.

Medical textiles also cover surgical gowns and drapes. There are two classes of materials: reusables and non-wovens. Reusable are either PES or PES-cotton woven materials or laminates. Also non-woven materials are used in the operating
theater. High performance non-wovens are usually laminated with a plastic foil in order to provide for sufficient barrier properties to reduce wound infection.

1.3.8. Mobiltech (Textiles used in transport)

These textiles are used in the construction of automobiles, railways, ships, aircraft and spacecraft. Examples are Truck covers (PVC coated PES fabrics), car trunk coverings (often needle felts), seat covers (knitted materials), seat belts, non-wovens for cabin air filtration (also covered in inutech), airbags, parachutes, boats (inflatable), air balloons.

1.3.9 Oekotech or Ecotech (Environmentally-friendly textiles)

New applications for textiles in environmental protection applications - floor sealing, erosion protection, air cleaning, prevention of water pollution, water cleaning, waste treatment/recycling, depositing area construction, product extraction, domestic water sewerage plants.

1.3.10 Packtech (Packaging textiles)

Packaging, silos, containers, bags, canvas covers, marquee tents.

1.3.11 Protech (Protective textiles)

Protection against heat and radiation for fire fighter clothing, against molten metals for welders, for bullet proof jackets etc, all these things are obtained by usage of technical textiles with high performance fibers. In bullet proof jackets, special fiber aramid are used which have high tenacity, high thermal resistance and low shrinkage. Glass fiber is also used in fire proof jackets due to its high strength, chemical and flame resistance. Protective clothing is also used by the astronauts when they go in space. It was used by the astronauts when they went on moon, their suits where covered with special chemicals including lead to protect them from suns heat, their suit not only made from special fibers but their airship was also lined with special fabric.
1.3.12 Sporttech (Sports textiles)

Shoes, sports equipment, flying and sailing sports, climbing, angling, cycling, winter and summer sports, indoor sports wear

1.4 Specific areas of application

1.4.1 Conveyor belts

For industrial applications and in power transmission, technical textiles are used in conveyor belts. Carcass is a fabric inside the conveyor belt, which is responsible for the strength and stretch properties of the belt. This carcass is made with layers of woven fabrics bonded together.

1.4.2 Electronics in textiles

It has been heard that soon textiles will be merged with electronics in all areas. In future wearable computers would be launched, these will not be like advance wrist watches etc, they will contain ICs in fabric to develop fabric keyboards and other wearable computer devices. These types of products are known as Interactive electronic textiles (IET). Research to support IET development is being conducted in many universities. Growing consumer interest in mobile, electronic devices will initiate the demand for IET products.

1.5 Summary

Technical textiles have never been a single coherent industry sector and market segment. It is developing in many different directions with varying speeds and levels of success. There is continual erosion of the barriers between traditional definitions of textiles and other ‘flexible engineering’ materials such as paper and plastics, films and membranes, metals, glass and ceramics. What most participants have in common are many of the basic textile skills of manipulating fibres, fabrics and finishing techniques as well as an understanding of how all these interact and perform in different combinations and environments. Beyond that, much of the
technology and expertise associated with the industry resides in an understanding of the needs and dynamics of many very different end-use and market sectors. It is here that the new dividing lines within the industry are emerging. An appreciation of the development and potential of technical textile markets therefore starts with some clarification of the evolving terminology and definitions of scope of the industry and its markets.

1.6 Lesson End Activities

A) Define Technical textiles
B) Classification and applications of Technical Textiles

1.7 References

1. Techtextil Frankfurt - Trade fair for Technical Textiles and Nonwovens consulted 21 August 2008
2. Resisto Protection Textil GmbH visited 21 August 2008
5. Resisto Protection Textil GmbH visited 21 August 2008
6. www.technicalfabrics.webs.com
Definition and Scope of Technical Textiles

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2.1 Definition and Scope of Technical Textiles
2.2 Scope of Technical Textiles
2.3 Technical Textiles has tremendous growth scope in India
2.4 Present Scenario of Technical Textiles
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2.1 Definition and Scope of Technical Textiles

Technical Textiles are defined as Textile material and products manufactured primarily for their Technical performance and functional properties rather than aesthetic and decorative characteristics.

The Definition of Technical Textiles adopted by the authoritative Textile Terms and Definitions, published by the Textile Institute. “Materials and products intended for end-uses other than non-protective clothing, household furnishing, and floor covering, where the fabric or fibrous component is selected principally but not exclusively for its performance and properties as opposed to its aesthetic or decorative characteristics" (Textile Terms and Definitions, TI, Manchester, 10theEd.)

Such a brief description clearly leaves considerable scope for interpretation, especially when an increasing number of textile products are combining both
performance and decorative properties and functions in equal measure. Examples are flame retardant furnishings and ‘breathable’ leisurewear. Indeed, no two published sources, industry bodies or statistical organisations ever seem to adopt precisely the same approach when it comes to describing and categorising specific products and applications as technical textiles.

It is perhaps not surprising that any attempt to define too closely and too rigidly the scope and content of technical textiles and their markets is doomed to failure. In what is one of the most dynamic and broad ranging areas of modern textiles, materials, processes, products and applications are all changing too rapidly to define and document. There are even important linguistic and cultural perceptions of what constitutes a technical textile from geographical region to region in what is now a global industry and marketplace.

2.2 Scope Of Technical Textiles

According to the recent reports, there has been a sharp increase in the global demand for Technical Textiles in various application areas namely Meditech, buildtech, Mobiletech, Protech, Indutech, Hometech, Clothtech, Sporttech, Packtech, Oekotech, Defence, Geotech. These applications have provided scope for making various products – from Car Upholstery to Parachutes, Shelter Fabric to Home furnishing, Infrastructure to Environmental and even to Hospitals. The WORLD TRADE in technical textiles is believed to be over USD 50 Billion per annum and it is growing at an accelerated pace. It is expected to increase to USD 127 Billion by 2010 and drivers of future growth of this industry is expected to be Asian countries like India and China. The new promise of technical and performance textiles is an emerging generation of products combining the latest developments in advanced flexible materials with advances in computing and communications technology, biomaterials, nanotechnology and novel process technologies such as plasma treatment. These will eventually have a direct impact upon all sorts of consumer textile markets, including both clothing and furnishings. The field of ‘wearable
electronics’ has already captured the imagination of many researchers and large corporations and, although most products on the market today are relatively unsophisticated ‘implants’ of conventional electronics and wiring, the prospect of truly ‘interactive textiles embodying sensors, actuators and logic circuits built into the structure of the fibres, yarns and fabrics themselves is not impossibly far-fetched.

The term “technical textiles” was coined in the 1980s to describe the growing variety of products and manufacturing techniques being developed primarily for their technical properties and performance rather than their appearance or other aesthetic characteristics. It largely superseded an earlier term “industrial textiles” (still widely used in the USA) which had become too restrictive in its meaning to describe the full complexity and richness of this fast growing area. A major international exhibition, Techtextil, was launched in 1985 to reflect the growth of technical textiles and soon developed a simple taxonomy that has been used ever since to describe the scope of this new industry and market sector.

- Agrotech - agriculture, horticulture, forestry and aquaculture textiles
- Buildtech - building and construction textiles
- Clothtech - technical components of shoes and clothing e.g. linings
- Geotech - geotexiles and civil engineering materials
- Hometech - components of furniture, household textiles & floorcoverings
- Indutech - textiles for industrial applications filtration, conveying, cleaning etc
- Medtech - hygiene and medical products
- Mobiltech- automobiles, shipping, railways and aerospace
- Oekotech - environmental protection
- Packtech - packaging materials
- Protech - personal and property protection
- Sporttech- sport and leisure
Within each of these headings are literally hundreds of products and applications for textiles, some traditional, some replacing other well-established materials and techniques, and some that have been newly created by the unique properties and capabilities of textile materials and structures. The automotive industry is not only one of the largest single markets for technical textiles but also one of the most diverse. Applications range from tyre cord, hose and drive belt reinforcements to thermal and sound insulation, safety belts and airbags, filters, cable harnesses and textile reinforced composites for body and suspension parts. Even the internal furnishings of a car—headliners, seating, carpets, parcel shelf and trunk liners—are all regarded as technical textiles because of the extremely demanding specifications to which they are made and tested. As just one other example, the medical and hygiene textiles market ranges from high volume disposable products for babies’ nappies, feminine hygiene and adult incontinence through to extremely specialised and high value textile products for use in blood filtration, surgical sutures, prostheses and, most recently, scaffolds for new tissue growth.

2.3 Technical Textiles has tremendous growth scope in India

As the importance of Technical Textile is rising day by day, market opportunities are increasing and thus the usage of the same is growing rapidly. Currently, approximately US $120 billion worth of Technical Textiles is consumed world over and in India it is just $6 billion. Though India has a significant presence in some segments of Technical Textiles such as Automotive and Industrial textiles, it is yet to make a presence in other segments of Technical Textiles.

Government has taken initiatives to promote Technical Textiles through fiscal support, research spending and inter-departmental co-ordination. This is expected to stimulate domestic consumption in the coming years.
Besides, going by the past trends as shown in the developed countries, one can anticipate higher per capita consumption of Technical Textiles as the Indian economy continues to grow despite current slowdown.

The other major segment that is expected to stimulate the demand will be medical textiles, as India is fast emerging as a centre for medical tourism.

Indian Government is rightly increasing the spending on infrastructure significantly and this is expected to result in the growth of geo-textiles applications in roads, airports, dams, sea erosion control and solid waste management systems.

Agrotech is another area which promises a huge growth for Technical Textiles. Indian agriculture practices are presently not sufficiently modern. But with increasing awareness of advantages such as productivity and quality improvement due of use of woven, coated and non-woven textiles in agriculture, high growth is anticipated in this segment.

2.4 Present Scenario of Technical Textiles

Global Scenario:- India is the world second largest producer of textile and garments. The textile industry in India contributes 14 % towards the GDP of USD 1.18 billion. This market itself being so big, there is tremendous potential for technical textiles as well. Currently the consumption of technical textiles in India forms only 3 % of the total world consumption; however, it is growing at a rate higher than most developed countries. The reasons for low penetration in this market are several, such as scattered production structure, inadequate research and development (R&D), lack of skilled personnel. Another major contributing factor is that there is lack of awareness about the benefits of using technical textile and therefore leading to low consumption. So, India still has to make its presence felt in the world technical textiles market, which earns that a highly unexploited market is waiting to be explored.
2.5 The economic importance of technical textiles

The new promise of technical and performance textiles is an emerging generation of products combining the latest developments in advanced flexible materials with advances in computing and communications technology, biomaterials, nanotechnology and novel process technologies such as plasma treatment. These will eventually have a direct impact upon all sorts of consumer textile markets, including both clothing and furnishings. The field of ‘wearable electronics’ has already captured the imagination of many researchers and large corporations and, although most products on the market today are relatively unsophisticated ‘implants’ of conventional electronics and wiring, the prospect of truly ‘interactive textiles embodying sensors, actuators and logic circuits built into the structure of the fibres, yarns and fabrics themselves is not impossibly far-fetched.

2.6 Market Size Of Indian Technical Textile Industry

India is emerging as a significant player in technical textiles. The fast-paced economic growth leading to infrastructure creation as well as higher disposable income has made India a key market for the technical textile products. Moreover, the country has developed a foothold in the production of technical textiles owing to its skilled and technical manpower as well as abundant availability of raw-material. More investments are underway in this sector; as per the Ministry of Textiles, as on September 2010, 26,163 applications for technical textile projects with a project cost of US$ 14.5 billion were disbursed under Technology Upgradation Fund Scheme (TUFS).

Indian Technical Textile industry is estimated at Rs 41,756 Crore (2007-08), with domestic consumption of Rs. 38,835 Crore. The Industry has witnessed a significant growth of 16% from 2001-02 to 2009-10 and, is expected to grow at a rate of 11% year-on-year and reach a market size of Rs. 70,151 Crore by the year (2012-13), with domestic consumption of Rs. 65,722 by the year 2012-13.
2.7 Summary

Textile contributes 14% towards GDP of US $ 1.18 billion. Technical Textile has also tremendous potential to the textile market. Currently the consumption of technical textile is 3% which is expected to be 11%. this will lead to several benefits, viz.:-

1. Manufacturers will become educated and they will invest in building their brands
2. Entry of large manufacturers will result in price decrease, and in providing consumers same products at cheaper rates same as mobile phone industry
3. Job opportunities will develop indirectly.
4. Increase in export will lead to increase in market value of India.

2.8 Lesson End Activities
Discuss in detail about scope of Technical Textiles.

2.9 References
2. Techtextil Frankfurt - Trade fair for Technical Textiles and Nonwovens consulted 21 August 2008
Developments In Technical Fibers

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3.0 Aims and Objectives

This chapter initially attempts to discuss fibres under this category highlighting their importance and the scope of their versatility. The discussion covers concisely an outline of fibre backgrounds, chemical compositions and their salient characteristics. It then introduces other fibres which have been specially developed to perform Technical fibres under extreme stress and/or temperature; ultrafine and novel fibres are also discussed. Finally, the chapter concludes by identifying areas of application and the roles that selected fibres play in fulfilling their intended purpose.

3.1 Introduction

A number of definitions have been used to describe the term ‘technical textiles’ with respect to their intended use, functional ability and their non-aesthetic or decorative requirements. However, none of these carefully chosen words include the fundamental fibre elements, technical or otherwise, which make up the technical textile structures. The omission of the word ‘fibre’ may indeed be deliberate as most
technical textile products are made from conventional fibres that are already well established. In fact over 90% of all fibres used in the technical sector are of the conventional type. Specially developed fibres for use in technical textiles are often expensive to produce and have limited applications.

Use of silk in semitechnical applications also goes back a long way to the lightweight warriors of the Mongolian armies, who did not only wear silk next to their skin for comfort but also to reduce penetration of incoming arrows and enable their subsequent removal with minimal injury. Use of silk in wound dressing and open cuts in web and fabric form also dates back to the early Chinese and Egyptians.

3.2 Developments in Technical fibers

3.2.1 Natural Fibers

Cotton accounts for half of the world’s consumption of fibres and is likely to remain so owing to many of its innate properties. The length of the chains determines the ultimate strength of the fibre. The unique physical and aesthetic properties of the fibre, combined with its natural generation and biodegradability, are reasons for its universal appeal and popularity. High moisture absorbency, high wet modulus and good handle are some of the more important properties of cotton fibre.

Wool, despite its limited availability and high cost, is the second most important natural fibre. It is made of protein: a mixture of chemically linked amino acids which are also the natural constituents of all living organisms. Keratin or the protein in the wool fibre has a helical rather than folded chain structure with strong inter- and intrachain hydrogen bonding which are believed to be responsible for many of its unique characteristics.

Flax, jute, hemp and ramie, to name but a few of the best fibres, have traditionally taken a secondary role in terms of consumption and functional
requirements. They are relatively coarse and durable, and flax has traditionally been used for linen making. Jute, ramie and to a lesser extent other fibres have received attention within the geotextile sector of the fibre markets which seeks to combine the need for temporary to short-term usage with biodegradability, taking into account the regional availability of the fibres.

**Silk** is another protein-based fibre produced naturally by the silkworm, *Bombyx Mori* or other varieties of moth. Silk is structurally similar to wool with a slightly different combination of amino acids which make up the protein or the fibroin, as it is more appropriately known. Silk is the only naturally and commercially produced continuous filament fibre which has high tenacity, high lustre and good dimensional stability.

### 3.2.2 Regenerated Fibers

Viscose rayon was the result of the human race’s first attempts to mimic nature in producing silk-like continuous fibres through an orifice. Thin sheets of cellulose are treated with sodium hydroxide and aged to allow molecular chain breakage. Further treatment with carbon disulphide, dissolution in dilute sodium hydroxide and ageing produces a viscous liquid, the viscose dope, which is then extruded into an acid bath. The continuous filaments that finally emerge are washed, dried and can be cut to staple lengths. The shorter cellulose molecules in viscose and their partial crystallisation accounts for its rather inferior physical properties relative to cotton.

Lyocell, is the latest addition to this series of fibres, commercially known as Tencel (Acordis), has all the conventional properties of viscose in addition to its much praised environmentally friendly production method. The solvent used is based on non-toxic *N*-methyl morpholine oxide used in a recyclable closed loop system, which unlike the viscose process avoids discharge of waste. Highly absorbent derivatives of Tencel, known as Hydrocell are establishing a foothold in wound dressing and other medical-related areas of textiles.
3.2.3 Synthetic Fibers

The first synthetic fibre that appeared on the world market in 1939 was nylon 6.6. It was produced by DuPont and gained rapid public approval. A series of nylons commonly referred to as polyamides now exists in which the amide linkage is the common factor. Nylon 6.6 and nylon 6 are most popular in fibre form. They are melt extruded in a variety of cross-sectiona shapes and drawn to achieve the desired tenacity. They are well known for their high extensibility, good recovery, dimensional stability and relatively low moisture absorbency. Nylon was later surpassed by the even more popular fibre known as polyester, first introduced as Dacron by DuPont in 1951. Polyester is today the second most used fibre after cotton and far ahead of other synthetics both in terms of production and consumption. Polyethylene terephthalate or polyester is made by condensation polymerisation of ethylene glycol and terephthalic acid followed by melt extrusion and drawing. It can be used in either continuous form or as short staple of varying lengths. The popularity of polyester largely stems from its easycare characteristics, durability and compatibility with cotton in blends. Its very low moisture absorbency, resilience and good dimensional stability are additional qualities. Wool-like properties are shown by polyacrylic fibres which are produced by the polymerisation of acrylonitrile using the addition route into polyacrylonitrile. They can then be spun into fibres by dry or wet spinning methods. Orlon 14 was produced by DuPont. It had a distinctive dumbbell shaped cross-section and was extruded by the dry process in which the solvent is evaporated off.

Polyolefin fibres include both polyethylene and polypropylene made by addition polymerisation of ethylene and propylene and subsequent melt extrusion, respectively. Polyethylene has moderate physical properties with a low melting temperature of about 110 °C for its low density form and about 140 °C for its high density form which severely restricts its application in low temperature applications.
Polypropylene has better mechanical properties and can withstand temperatures of up to 140 °C before melting at about 170°C.

3.2.4 High performance Inorganic fibres

Any fibre that consists of organic chemical units, where carbon is linked to hydrogen and possibly also to other elements, will decompose below about 500°C and cease to have long-term stability at considerably lower temperatures. For use at high temperatures it is therefore necessary to turn to inorganic fibres and fibres that consist essentially of carbon.

Glass, asbestos and more recently carbon are three well-known inorganic fibres that have been extensively used for many of their unique characteristics. Use of glass as a fibre apparently dates back to the ancient Syrian and Egyptian civilizations which used them for making clothes and dresses. Their good resistance to heat and very high melting points has also enabled them to be used as effective insulating materials.

3.2.5 Ultra-fine and novelty fibres

Ultra-fine or microfibres were developed partly because of improved precision in engineering techniques and better production controls, and partly because of the need for lightweight, soft waterproof fabrics that eliminate the more conventional coating or lamination processes. As yet there are no universal definitions of microfibres. *Textile Terms and Definitions* simply describes them as fibres or filaments with linear densities of approximately 1.0 dtex or less. Others have used such terms as fine, extra-fine and micro-fine corresponding to linear densities ranging from 3.0 dtex to less than 0.1 dtex. They are usually made from polyester and nylon polymers, but other polymers are now being made into microfibres. The Japanese first introduced microfibres in an attempt to reproduce silk-like properties with the addition of enhanced durability. They are produced by at least three established methods including island-in-sea, split process and melt
spinning techniques and appear under brand names such as Mitrelle, Setila, Micrell, Tactel and so on. Once in woven fabric form their fine diameter and tight weave allows up to 30000 filaments cm$^{-2}$, making them impermeable to water droplets whilst allowing air and moisture vapour circulation. They can be further processed to enhance other characteristics such as peach-skin and leather-like appearances. The split technique of production imparts sharp-angled edges within the fibre surface, which act as gentle abraders when made into wiping cloths that are used in the optical and precision microelectronic industries. Microfibres are also used to make bacteria barrier fabrics in the medical industries. Their combined effect of low diameter and compact packing also allows efficient and more economical dyeing and finishing.

Finally, constant pressure to achieve and develop even more novel applications of fibres has led to a number of other and, as yet, niche fibrous products. In principle, the new ideas usually strive to combine basic functional properties of a textile material with special needs or attractive effects.

3.5 Summary

Conventional fibres dominate the technical fibre market and are likely to do so for a long time to come. The rate of growth in consumption of fibres destined for technical applications, however, is now faster than those going to the traditional clothing and furnishing sectors. It was estimated that the world’s technical fibres share of the market would have reached the 40% mark by the year 2000. Much of this growth will depend on greater realisation of the technological and financial benefits that fibre-based structures could bring to the traditional and as yet unyielding sectors of engineering. Issues such as environment, recycling and biodegradability, which are increasingly subjects of concern for the public, will further encourage and benefit the growth and use of technical textiles.
3.6 References


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LESSON 4

Application of Technical Textiles

Contents

4.0 Aims and Objectives
4.1 Introduction
4.2 Innovative and technical textiles: A sector of niches with high added value
4.3 Application Function
4.4 Applications of Technical textiles
4.5 Summary
4.6 Lesson End Activity
4.7 References

4.0 Aims and Objectives

This chapter deals with applications of Technical textiles and its end uses at various fields.

4.1 Introduction

Textiles are everywhere in modern society; Worn as protection and self expression on the human body, used as decoration and comfort elements in homes, offices, hospitals, hotels or public buildings, as interior components in cars, buses, trains, ships and airplanes, or structural elements for tents, roofs, bridges, or as reinforcements for roads, and dikes but also as bags, nets or artificial turf in sports and outdoor activities. In spite of the fact that normally the textile industry is considered a traditional sector, today it has become one of the main test-beds regarding new business strategies. The new market standards, achievable with process innovations, which on one hand reduce costs, whereas on the other hand allows to distinguish oneself from the other competitors, have become a very
important competitive factor. Ever since the mid 80's, the market of textile products started to change radically, and it was divided between: Standard productions, identified with a low innovation and technology level, medium to low quality, weak customer service - complex productions identified with a high product innovation level, with the use of state-of-the-art process technologies and product research, a strong aesthetic element, as well as certain and high quality levels, quick timing addressing requirements, production flexibility and customer service. As well as the above, currently there is a new phase in the textile field in which new materials allow to make dynamic and interactive products, able to offer protection, comfort and performance. The textile materials are therefore becoming the basis for a completely new range of new applications.

4.2 Innovative and technical textiles: A sector of niches with high added value

Today it's needed to adopt a different approach to textiles; Fabrics have to be regarded not only just as a surface, to be interpreted graphically, but as a material to all intents and purposes, with its own intrinsic structure and performance. In the sector of technical textiles there are a large number of niches and products, often highly technological and where the end user requires specific requirements, and for which the cost is no longer the only parameter taken into consideration. Regarding innovative textiles the market is growing rapidly and many developments of new products and applications are underway. The technological evolution which transversally integrates human science, materials and information technology, does allow to foresee positive perspectives in the approach towards development of new products and applications. The general trend is therefore towards high tech, high performance fabrics designed not just to look attractive, but to offer a significant added value in terms of functionality.

Application field of technical textiles In the field of specialised applications, the technological assets are those that provide the highest performance and comfort
standards, and ensure a better quality of life. Already there are fabrics capable of reducing risks (e.g., antibacterial, mite-proof, insect proof, odourless, flame retardant, soil-resistant, anti-UV and anti-electromagnetic radiation, etc). Other fabrics function actively (e.g., heat-regulating, with new visual features, or providing cosmetic-medical effects, and so forth).

4.3 Application Functions

1. Mechanical functions
2. Exchange functions
3. Functionalities for living beings
4. Protective functions

1. Mechanical functions
   - Mechanical resistance
   - Reinforcement of materials
   - Elasticity
   - Tenacity

2. Exchange functions
   - Filtration
   - Insulation and conductivity
   - Drainage
   - Impermeability

3. Functionalities for living beings
   - Antibacteria
   - Antidustmites
   - Biocompatibility (hypoallergenic textiles)
   - Biodegradability / biore sorption
4. Protective functions
   - Thermal
   - Fire
   - Mechanical
   - Chemicals
   - Impermeable - Breathable
   - Antistatic
   - Particles antirelease
   - Electrical insulation,
   - IR and UV rays,
   - NBC (Nuclear, biological and chemical)
   - High visibility
   - Electromagnetic fields

4.4 Applications of Technical Textiles

4.4.1 Agrotech (Agro-textiles)

Agro-textiles, also known as Agrotex, that are used in agricultural applications related to growing and harvesting of crops and animals. Not only crop production, they are also used in forestry, horticulture, as well as animal and poultry rearing including animal clothing. Agro-textiles have to be strong, elongated, stiff, bio-degradable, resistant to sunlight and toxic environment. The essential properties required are strength, elongation, stiffness, and bio-degradation, resistance to sunlight and resistance to toxic environment. All these properties help with the growth and harvesting of crops and other foodstuffs. There is a growing interest in using materials which gradually degrade (biodegradables).

Applications for technical textiles in agriculture include all activities concerned with the growing and harvesting of crops and animals. The principal
function of most agricultural textiles relates to the protection of either food produce, animals or land. Enduses range from crop production, through forestry and horticulture, to animal and poultry rearing and fishing. The fishing segment is a large consumer of textile materials Fishing methods are becoming more industrialised, replacing older small net and line fishing techniques.

Some of the examples of agro textiles are preventing erosion and paving way for afforestation in greenhouse cover and fishing nets. For Layer separation in fields, in Nets for plants, rootless plants & protecting grassy areas As sun screens (since they have adjustable screening)and wind shields As packing material and in bags for storing grass (that has been mowed) Controlling stretch in knitted nets Shade for basins Anti-birds nets Fabrics for sifting and separation, for the phases of enlargement of the larvae Materials for ground and plant water management at the time of scarcity and abundance of water.

4.4.2 Buildtech

These are the Construction Textiles, also known as Buildtex, used in construction and architectural applications, such as for concrete reinforcement, facade foundation, interior construction, insulation, air conditioning, noise prevention, visual protection, protection against sun light, building safety etc. The field of textile architecture is also expanding as textile membranes are increasingly being used for roof construction. Such fabrics as PVC coated high tenacity PES, teflon coated glass fiber fabrics or silicone coated PES are used extensively in football stadia, airports and hotels.

4.4.4 Clothtech

These are the Clothing Textiles, also known as Clohttex, including all those textile products that represent functional, most often hidden components, of
clothing and footwear such as interlinings, sewing thread, insulating fibrefill and waddings. They are the 'high performance' garment fabrics whose demand is increasingly rising with the time.

The skin is the principal element that separates and protects the human body from the environment around it. It is also acts as a major exchange system of energy (eg, heat) and matter (fluids and gases such as water, oxygen etc) between body and environment. Clothing as an artificial second skin has always been used by humans to enhance the protective function of their own skin. However such additional protection often has a negative effect upon the exchange functionality of the human skin, in certain cases very severely like in the case of full body armour, fire-fighters, uniforms or diving suits. Functional and smart or intelligent clothing are the innovative response to such limitations. Functional clothing refers to products in which one or several specific functionalities are emphasised like strong insulation, water or fire resistance, breathability, wear resistance etc. Smart clothing takes (multi) functionality one step further as it refers to products that can offer their functions in a more adaptive way in response to stimuli from the environment or the wearer.

Smart garments can for instance:

- Adapt their insulation function according to temperature changes.
- Detect vital signals of the wearer's body.
- Change colour or emit light upon defined stimuli.
- Generate or accumulate electric energy to power medical and other electronic devices.

4.4.5 Geotech

These are the Geotextiles, also known as Geotex, which are woven, nonwoven and knit fabric used for many functions such as support, drainage and separation at or below ground level. Their application areas include civil and
coastal engineering, earth and road construction, dam engineering, soil sealing and in drainage systems. Geotech have good strength, durability, low moisture absorption and thickness. Synthetic fibers such as glass fiber, polypropylene and acrylic fibers are used to prevent cracking of the concrete, plastic and other building materials.

4.4.6 Hometech:

These are the Domestic Textiles, also known as Hometex, used in making of many home furnishing fabrics including carpet backings, curtains, wall coverings, etc. They are mostly fire retardant fabrics whose properties are derived either by using fire retardant fibers such as modacrylic fiber or by coating the fabrics with fire retardant additives such as bromide of phosphorus compounds.

Traditionally textiles have been an important part of the interior of human habitations, as well as human transportation systems such as cars, buses, passenger trains, cruise ships or airplanes. In that respect textile served three basic purposes:

a) Decoration (carpets, wall coverings, curtains & drapes, table cloths, etc).

b) Comfort (upholstery, seat covers, mattresses, bed sheets, blankets, carpets etc).

c) Safety (safety belts and nets, airbags).

Textile Structures for building Textiles have in the past been predominantly confined to the interior decoration; They are now increasingly becoming part of these constructions themselves. Thanks to better performance characteristics in terms of their strength-weight ratio, durability, flexibility, insulating and absorption properties, and fire and heat resistance, they are in a position to replace more traditional construction materials such as steel and
other metals, wood and plastics. Examples of such innovative uses of textiles include

- Lightweight textile roofing.
- Textile-reinforced concrete.
- Fibre and textile-based bridging cables and elements.
- Erosion and landslide protection systems.
- Textile reinforcement of dykes and other water management systems.
- Fibre-based light, flexible and durable piping and canalisation.

### 4.4.7 Indutech

These are the Industrial Textiles, also known as Indutex, used in different ways by many industries for activities such as separating and purifying industrial products, cleaning gases and effluents, transporting materials between processes and acting as substrates for abrasive sheets and other coated products. They range from lightweight nonwoven filters, knitted nets and brushes to heavyweight coated conveyor belts.

### 4.4.8 Medtech

These are the Medical Textiles, also known as Medtex. They include all the medical fabrics that are used in health and hygiene applications in both consumer and medical markets. They are generally used in bandages and sutures that are used for stitching the wounds. Sutures and wound dressing uses fibers like silk fibers and other synthetic fibers. Hollow synthetic fibers are used with nano particles (very small particles) for delivery of drugs to any specific part of the body. Cotton, silk, polyester, polyamide fabrics are also used in medical applications. Innovative textile products can both add significantly to effectiveness of medical treatments as well as patient comfort at the same time, new medical textiles, may contribute to cost containment. Such innovative products:
- Provide new treatment options (textile based implants instead of scarce donor organs; artificial tissues, joints and ligaments).
- Speed up recovery after medical treatment (innovative wound dressings; Light, breathable orthoses/protheses).
- Enhance quality of life of chronically ill people (functional clothing).

4.4.9 Mobiltech:

These textiles, also known as Mobiltex, are used in transport industry, such as in construction of automobiles, railways, ships etc. Truck covers and restraints are significant textile end-uses in the transportation sector. They can range from simple ropes and tarpaulins to highly engineered flexible curtain systems and webbing tie-downs. Other examples include seat covers, seat belts, non-wovens for cabin air filtration, airbags, parachutes, inflatable boats, air balloons etc.

4.4.10 Oekotech:

These are the Eco-friendly Textiles, also known as Oekotex or Ecotex. They are mostly used in environmental protection applications - floor sealing, erosion protection, air cleaning, prevention of water pollution, water cleaning, waste treatment/recycling, depositing area construction, product extraction, domestic water sewerage plants. They are even gaining unimaginable popularity in other sectors of textile industry. Clothing, home furnishings, fashion accessories etc. all now come in eco-friendly versions made of oekotech.

4.4.11 Packtech:

These are the Packaging Textiles, also known as Packtex. Textiles have been used for packaging since ages. It ranges from heavyweight woven fabrics used for bags, packaging sacks, Flexible Intermediate Bulk Carriers (FIBCs) and wrappings for textile bales and carpets to the lightweight nonwovens used as durable papers, tea bags and other food and industrial product wrappings.
4.4.12 Protech:

These are the Protective Textiles, also known as Protex, that are used in the manufacturing of protective clothing of different types. Protection against heat and radiation for fire fighter clothing, against molten metals for welders, for bullet proof jackets or for chemical protective clothing - all depend on the use of protech. The main target of the technical protective fabrics is to improve people safety in their workplaces. A technical protective fabric can save a worker's life, that's why, most of them are mainly used to manufacture PPE (personal protective equipment). The demand of these fabrics is growing around the world thanks to the sensibilization of the society, requiring more safety at work. The aim of a technical protective fabric isn't fashion, they are designed to have extra values in protection, against some hazards. The protective textiles are made with the help of specialty fibers such as aramid fiber used in making of bullet proof jackets, glass fibers used in fire proof jackets etc. Sometimes the protective textile is also coated with special chemicals, for example, when used in manufacturing astronauts’ suits. The main end use segments include:

- Chemical protection.
- Flame retardant.
- Cut resistant.
- Outdoor protection, hi-visibility.

Manufacturers of protective clothing are also realising the need to supply workers with comfortable garments. In fact although guaranteed high levels of performance will remain critical for protective garments, increased emphasis is being placed on wearer comfort, and design aesthetics.

4.4.13 Sporttech:

These are the Sports Textiles, also known as Sporttex, used mainly for making sports wear including sports shoes and other sports accessories. Increasing
interest in active sports and outdoor leisure activities such as flying and sailing sports, climbing, cycling, etc. has led to immense growth in the consumption of textile materials in manufacturing sporting and related goods and equipment. Synthetic fibers and coatings have largely replaced traditional cotton fabrics and other natural fibers in the making of sporttech.

4.5 Summary

Technical Textile provides opportunities to use textiles in new areas enhancing the market potential. They are playing an important role in the emerging fields like Roads, buildings, automobiles, and medical applications, and in industrial. Domestic consumption of Technical Textiles will grow rapidly due to higher market potential and developing country. India will have the advantage of manufacturing than other countries due to low cost of production. Technical textile has two distinctive characteristics; first, it is high tech business and second it has a niche market. Nevertheless, it owns it a specific place in the market.

4.6 Lesson End Activities

Explain the use of Technical Textile in the areas of Industrial products and components.

4.7 References


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LESSON 5

FINISHING OF TECHNICAL TEXTILES

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5.0 Aims and Objectives

This chapter gives a clear idea about finishing process both mechanically and chemically and also deals with the chemistry of coatings and their application to various coated technical textiles that are in use.

5.1 Introduction

The name textile finishing covers an extremely wide range of activities, which are performed on textiles before they reach the final customer. They may be temporary, for example the way bed sheets are pressed before packing, or they may be permanent, as in the case of a flame-retardant tenting fabric. However, all finishing processes are designed to increase the attractiveness or serviceability of the textile product. This could involve such techniques as putting a glaze on an upholstery fabric, which gives it a more attractive appearance, or the production of water repellent finishes, which improve the in-service performance of a tenting fabric. Thus a further aim of textile finishing may be described as improvement in customer satisfaction, which finishing can bring about. This improvement in the perceived value of a product to the consumer forms the basis of modern ideas on product marketing. Technical textiles are defined as those materials with non-clothing applications. Thus the fashion aspects of textiles will be ignored, although aesthetic aspects of say upholstery and drapes will be covered.

5.2 Finishing Process

The finishing processes that are available can be divided into four main groups, which are:

5.2.1. Mechanical processes

These involve the passage of the material through machines whose mechanical action achieves the desired effects. A heating process, the purpose of which is usually to enhance these desired effects, frequently accompanies this.
5.2.1.1 **Calendering:** compression of the fabric between two heavy rolls to give a flattened, smooth appearance to the surface of the fabric.

5.2.1.2 **Raising:** plucking the fibres from a woven or knitted fabric to give a nap effect on the surface.

5.2.1.3 **Cropping:** cutting the surface hairs from the fabric to give a smooth appearance, often used on woollen goods where the removal of surface hair by a singeing process is not possible.

5.2.1.4 **Compressive shrinkage:** the mechanical shrinking of the warp fibres in woven fabrics so that shrinkage on washing is reduced to the desired level.

5.2.2. **Heat setting**

This is a process for the stabilisation of synthetic fibres so that they do not shrink on heating.

5.2.3. **Chemical processes**

These may be described as those processes that involve the application of chemicals to the fabric. The chemicals may perform various functions such as water repellency or flame retardancy, or may be used to modify the handle of a fabric. Chemical finishes are normally applied in the form of an aqueous solution or emulsion and may be applied via a variety of techniques, the main one being the pad mangle, which is illustrated in Fig. 2.1.

After the padding or the application stage of the chemical finishing the fabric is usually dried to remove the water from the fabric and some form of fixation of the finish is then performed. This commonly takes the form of a baking process, where the fabric is subjected to a high temperature for a short period, which enables the applied chemicals to form a more durable finish on the fabric than would otherwise be achieved.
5.2.4. Surface coating

This is a most important part of the finishing of technical textiles.

5.2.1 Mechanical Finishes

5.2.1.1 Calendering

Calendering may be defined as the modification of the surface of a fabric by the action of heat and pressure. The finish is obtained by passing the fabric between heated rotating rollers (or bowls as they are frequently called), when both speed of rotation and pressure applied are variable. The surfaces of the rollers can be either smooth or engraved to provide the appropriate finish to the fabric, while the actual construction of the rollers may be varied from hardened chromium-plated steel to elastic thermoplastic rollers. (Fig -2.1)

![Fig- 2.1 Padding Mangle](image)

5.2.1.1.1 Effects which may be achieved by calendering

Calendering is done for many purposes but the main effects are:

- smoothing the surface of the fabric
- increasing the fabric lustre
- closing the threads of a woven fabric
- decreasing the air permeability
- increasing the fabric opacity
- improving the handle of a fabric, i.e. softening
• flattening slubs
• obtaining silk-like to high gloss finishes
• surface patterning by embossing
• consolidation of nonwovens.

### 5.2.1.1.2 Types of calenders

In general calenders usually have between two and seven rollers, with the most common being the three-bowl calender. Perhaps the most important factor in calender design is the composition of the rollers and the surface characteristics of these. Textile calenders are made up from alternate hard steel and elastic bowls. The elastic bowls are made from either compressed paper or compressed cotton, however, a lot of modern calenders are made with a thermoplastic thick covering, which is usually nylon. The latter have the advantage that they are less liable to damage from knots, seams and creases than cotton and paper bowls, damage that would then mark off onto the calendered fabric.

In two-bowl calenders (Fig. 2.2) it is normal to have the steel bowl on top so that the operator can see any finish. This type of arrangement is often used with the nylon bottom bowl mentioned previously, especially where the calender is used for glazing or the embossed type of finishes. The arrangement where two steel bowls are used together only occurs in exceptional circumstances, for example, in the compaction of nonwovens. Here both bowls are usually oil heated so that some form of permanent setting occurs. Finally, the arrangement with two elastic bowls is not common but is sometimes used on cotton knitgoods to obtain a soft handle.

The three-bowl calender (Fig 2.3) was developed from the two-bowl calendar and with this type of calender it is normal to use only the top nip, with the bowls arranged steel–elastic–steel. The bottom bowl is used to keep the central elastic bowl smooth and thus assist in the finishing. The same arrangement also
serves the same purpose on embossing calenders, where there is the possibility of permanent indentation from the top roller.

Pressure used in all of the above calenders can be varied between 10 and 40 tonnes, with running speeds up to 60mmin-1. However, these are very much average figures with figures as low as 6 tonnes for a 1m wide calender to as high as 120 tonnes for a 3m wide calender. In addition, running speeds of 20mmin-1 are used on an embossing calender, while on a glazing calender speeds of over 150mmin-1 have been quoted.

![Two-bowl calender.](image1)

![Three-bowl calendar](image2)

The temperatures which are used in calender rollers can, of course, vary from room temperature to 250°C. However, it must be stressed that temperature control is
of vital importance, with a tolerance of $\pm 2$ °C being commonly quoted. Some generalizations can be made as follows:

- Cold bowls give a soft handle without much lustre; warm bowls (40–80 °C) give a slight lustre.
- Hot bowls (150–250 °C) give greatly improved lustre, which can be further improved by the action of friction and waxes.

5.2.1.1.3 Types of finish

- **Swissing or normal gloss:** a cold calender produces a smooth flat fabric. However, if the steel bowl of the calender is heated then in addition to smoothness the calender produces a lustrous surface. If a seven-bowl multipurpose calendar is used then a smooth fabric with surface gloss on both sides is produced.

- **Chintz or glazing:** this gives the highly polished surface which is associated with glazed chintz. The effect is obtained by heating the top bowl on a three-bowl calender and rotating this at a greater speed than that of the fabric. The speed of this top bowl can vary between 0 and 300% of the speed of the fabric. In certain cases where a very high gloss is required, the fabric is often pre impregnated with a wax emulsion, which further enhances the polished effect. This type of calendering is often called friction calendering.

- **Embossing:** in this process the heated top bowl of a two-bowl calender is engraved with an appropriate pattern which is then transferred to the fabric passing through the bowls. The effect can be made permanent by the use of thermoplastic fibres or in the case of cellulosics by the use of an appropriate crosslinking resin.

- **Schreiner or silk finishing:** this is a silk-like finish on one side of the fabric. It is produced by embossing the surface of the fabric with a series of fine lines.
on the surface of the bowls.(Fig 2.4 ). These lines are usually at an angle of about 30° to the warp threads. The effect can be made permanent by the use of thermoplastic fabric or, in the case of cotton, by the use of a resin finish. This finish is particularly popular on curtains and drapes because of the silk-like appearance this type of finish gives to the product.

![Fig 2.4 Principle of Schreiner calender.](image)

- **Delustering:** this is commonly achieved by passing the fabric through the bottom two bowls of a three-bowl calender, where these are elastic. However, steel bowls with a special matt finish have been manufactured that are very effective for this purpose.

- **Chasing:** the fabric is threaded through the calender in such a way as to press the fabric against itself several times. It is common to use a five- or seven-bowl calender, the fabric passing through each nip of the calender in two or three layers.

- **Palmer finishing:** in this type of finish the damp fabric is carried on the inside of a felt blanket round a steam-heated cylinder, often called a Palmer drier. The face of the fabric, which is run on the surface of the heated cylinder, takes a light polish from the cylinder, while the back of the fabric, which is in contact with the felt blanket, takes a roughened effect from the cylinder. This finish is particularly popular for cotton drill fabric.
5.2.1.2 Raising

Raising is the technique whereby a surface effect is produced on the fabric that gives the fabric a brushed or napped appearance. The way this was done originally was to use the seedpod of the thistle, which was known as a teasel. These teasels were nailed to a wooden board and the fabric was drawn over them to produce a fabric with a hairy surface, which had improved insulating properties. This method has largely been superseded by the use of rotating wire brushes, although where a very gentle raising action is required, such as in the case of mohair shawls, teasels are still used.

5.2.1.2.1 Modern raising machines

All modern raising machines use a hooked or bent steel wire to tease the fibres from the surface of fabric. The most important factor in the raising operation is the relationship between the point and the relative speed of the cloth. The raising wires or ‘card’ wires are mounted on a flexible base, which is then wrapped around a series of rollers, which are themselves mounted on a large cylindrical frame.

The raising action is brought about by the fabric passing over the rotating rollers and the wire points teasing out the individual fibres in the yarn. Because there are a large number of points acting on the fabric at any one time, the individual fibres must be sufficiently free to be raised from the fibre surface. This is a combination of the intrafibre friction and the degree of twist in the raised yarns. Thus for ‘ideal’ raising, the yarns should be of low twist and be lubricated. One further point to note is that because the fabric runs in the warp direction over the machine, only the weft threads are at right angles to the rotating raising wires and therefore only the weft threads take part in the raising process.

5.2.1.2.2 Raising action

From Fig. 2.5 it can be seen that both the card wire rollers and the cylinder to which these are attached may be rotated; it is the relative speed of these in relation
to that of the fabric that produces the various raising effects that may be achieved. There are two basic actions in raising and these are governed by the direction in which the card wires point and the relative speed of rotation of these in relation to the fabric. These actions are called the pile and the counterpile actions. In the counterpile action, the working roller rotates in the opposite direction to that of the cylinder with the points of the wire moving in the direction of rotation. This action pulls the individual fibres free from the surface. In the pile action, the points of the wire are pointing away from the direction of movement of the fabric. This results in an action where the raised fibres are subject to a combing action which tends to tuck back the fibres into the body of the fabric.

The most common raising action uses a combination of both of these actions, producing an even raise over the whole of the fabric surface. Control of the raising action has been achieved by measurement of the surface roughness of the raised fabric. It is therefore possible to control the exact height of the nap on the surface of fabrics.

5.2.1.3 Shearing

This is a process by which the fibres which protrude from the surface of a fabric, are cut to an even height. The principle used in this technique is similar to a
lawn mower in that a spiral cutter rotates against a stationary blade and cuts off any material protruding from the fabric surface.

This principle is that the fabric passing over the cutting bed and the protruding hairs on the surface being caught between the rotating head of the spiral cutter and the ledger blade. By raising and lowering the height of the cutting bed, the depth of cut may be varied. Obviously the cutting action produces a great deal of cut pile and this must be removed by strong suction otherwise a large amount of fly rapidly accumulates. In order to achieve an even cut and a smooth surface, several passes through the machine are required or a single pass through a multiple head machine is required. Average speeds of about 15m/min-1 are commonly encountered.

One important use for this technique is the production of pile fabrics from a looped terry fabric. When this type of fabric is sheared the top of the loops of the terry fabric are cut off and a velvet like appearance is produced. When knitted loop pile fabrics are sheared, knitted velour is produced that has found a great deal of use in upholstery fabric.

5.2.1.4 Compressive shrinkage

The shrinkage of fabrics on washing is a well-known phenomenon. It is caused in part by the production and processing stresses on the fabric. Production stresses are introduced into the fabric by the yarn tension and also by the tension which is necessary for the satisfactory production of fabric. Processing stresses are introduced during the bleaching, dyeing and finishing of fabric when the fabric is pulled in the warp direction. This tends to remove the warp crimp from the fabric as illustrated in Fig. 2.5

![Fig- 2.5 a) Fabric under tension, (b) tension relaxed.](image-url)
In order to replace the warp crimp and thus minimise warp shrinkage, a process known as compressive shrinkage is carried out on the fabric to replace the crimp that has been pulled out in the preparation and finishing processes. This may be illustrated in the following way. A strip of fabric is placed on a convex rubber surface and gripped at each end of the rubber. As the rubber is allowed to straighten, the length of the fabric exceeds that of the rubber. However, if the fabric could be stuck to the surface of the rubber then the fabric would be subjected to compression and warp crimp would be introduced.

This principle then is applied to the compressive shrinking machine, where the cloth is fed in a plastic state onto a thick rubber belt at point A as shown in Fig. 2.6. While the belt is in the convex position for A to B the fabric merely lies on the surface, but at point B the belt starts to wrap its way round a large heated cylinder and thus changes from a convex to a concave shape. Thus the surface of the rubber belt contracts and the fabric, which is held onto the surface of the rubber, is subject to a warp compression over the region C to D. The actual degree of shrinkage which takes place is controlled by the amount of fabric fed onto the rubber belt and the pressure between the heated metal cylinder and the belt, which increases or decreases the concave shape of the rubber belt. The principles of compressive shrinkage have also been reviewed.
5.2.1.5 Heat setting

The main aim of the heat setting process is to ensure that fabrics do not alter their dimensions during use. This is particularly important for uses such as timing and driving belts, where stretching of the belt could cause serious problems. It is important to examine the causes of this loss in stability so that a full understanding can be obtained of the effects that heat and mechanical forces have on the stability of fabrics. All fabrics have constraints placed on them by their construction and method of manufacture, but it is the heat-setting mechanism that occurs within the fibre that will ultimately influence fabric dimensions.

5.2.1.5.1 Heat-setting mechanisms

The first attempt to describe the various mechanisms of heat setting synthetic fibres was that of Hearle. He describes the various techniques which have been used to set fabrics into a given configuration and leaving aside the chemical methods of stabilisation, these techniques may be described as influencing the following:

1. chain stiffness
2. strong dipole links
3. hydrogen bonds
4. crystallisation.

Hydrogen bonding is the most important of the factors which influence setting, and nylon has a strong hydrogen-bonded structure whereas polyester has not. Thus relaxation of nylon can occur in the presence of water at its boiling point. In fact one of the common tests for the nylon fabrics used in timing belts is a 5min boil in water.

5.2.1.5.2 Fibre structure

All fibre-forming molecules consist of long chains of molecules. In fact, a typical nylon molecule will have a length which is some 5000 times the molecule
diameter. X-ray diffraction techniques have confirmed that all synthetic fibres contain crystalline and non-crystalline regions. In nylon and polyester these crystalline regions occupy about 50% of the total space in the fibre.

5.2.1.5.3  Polymer orientation

During the processing of both polyester and nylon, the fibres are spun through fine holes and have a structure similar. However, to develop the strength in the fibre these fibres are then cold drawn to create an orientated structure. Once the chains have been orientated then the fibres show a much greater resistance to applied loads and a greater stiffness, hence the reason for cold drawing.

5.2.1.5.4  Transition temperatures

In the previous section the crystalline and amorphous regions of the polymer were discussed. These do have an effect on two important parameters:

- **Glass transition temperature**: this represents the temperature at which molecular movement starts in the amorphous regions of the polymer, and was given the name because it is the temperature at which the polymer changes from a glassy solid to a rubbery solid. This is the temperature at which segmental loosening takes place and hence dyeing can only take place above this temperature.

- **Melting point**: at this point the forces holding the molecules in the crystalline regions of the fibre are overcome by the thermal energy and the polymer melts. In both polyester and nylon these temperatures are separated by about 150°C.

5.2.1.5.5  Heat shrinkage

All textile fibres are subjected to a cold drawing process and hence when they are heated above the point at which molecular motion sets in, they will progressively shrink until they reach the point of thermodynamic equilibrium. In other words the cold drawing process is reversed by the application of heat.
5.2.1.5.6 Essentials of heat setting

From the previous discussion it can be seen that heat setting is a temperature dependent process and for practical purposes the heat setting temperatures vary for polyester between 190–200 °C and for nylon 6.6 between 210–220°C. The fibres must not be allowed to move during the heating process and the heating must be sufficiently long enough to allow crystallisation to take place, after which the fibre must be cooled down to well below the heat setting temperature before being released.

There is an important difference between the behaviour of the two common polyamides (nylon 6 and nylon 6.6) and polyester, because of their different behavior towards water. Polyester is non-absorbent, so the heat setting behaviour is not affected by water. However, nylon will absorb sufficient water to obtain a temporary set that is based on hydrogen bonding and is destroyed on boiling in water. The consequence of this is that to obtain a permanent set on nylon, the water has to be removed from the fibre so that crystallisation can take place. Therefore nylon tends to be heat set at a higher temperature than polyester.

In summary:

1. Heat the fabric to within about 20–40 °C of the fibre melting point.
2. Hold at this temperature under tension for approximately 20 s.

The time–temperature relationship will vary depending on the polymer, the fabric weight and construction. The simple way to determine these is to look at the shrinkage of the finished product, if the material has been correctly heat set then it should show a residual shrinkage of less than 1% on a 5 min immersion in boiling water.
5.3 Summary

The finishing processes are designed to increase the attractiveness or serviceability of the textile product. This could involve such techniques as putting a glaze on an upholstery fabric, which gives it a more attractive appearance, or the production of water repellent finishes, which improve the in-service performance of a tenting fabric. Thus a further aim of textile finishing may be described as improvement in customer satisfaction, which finishing can bring about. This improvement in the perceived value of a product to the consumer forms the basis of modern ideas on product marketing.

5.4 Lesson End Activities

Discuss about the mechanical process in detail.

5.5 References

2. Techtextil Frankfurt - Trade fair for Technical Textiles and Nonwovens consulted 21 August 2008
LESSON 6

Finishing - Chemical Process

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6.0 Aims and Objectives

This chapter deals about One of the most important properties of clothing and its resistance to small burning sources, thus flame resistance combined with easy cleaning is a most important consideration.

6.1 Introduction

It has been suggested that by the end of 2000 some 50% of all textile fibre consumption in industrialised countries will be in technical textiles. A large percentage of this will consist of safety equipment and protective clothing and in fact this comprises the most significant portion of the technical textiles market. Protective clothing must provide resistance to the elements in the workplace, whilst at the same time providing comfort during wear. The customers for these products demand strict compliance with the regulations designed to protect the wearer. One of the most important properties of this type of clothing is its resistance to small burning sources, thus flame resistance combined with easy cleaning is a most important consideration. The flame retardance must be maintained throughout the lifetime of the garment. The main regulation governing the use of flame-retardant technical textiles was the Furniture and Furnishing Fire Safety Regulations which were introduced into the UK in 1988.

6.2 Chemical processes

6.2.1 Durable flame-retardant treatments

Fire-retardant technical textiles have been developed from a variety of textile fibres, the choice of which is largely dependent on the cost of the fibre and its end-use. However, the main fibre in this area is cotton and thus treatments of this fibre will be discussed first. Two major flame-retardant treatments are popular. These are Proban (Rhodia, formerly Albright and Wilson) and Pyrovatex (Ciba).

The Proban process uses a phosphorus-containing material, which is based on tetrakis(hydroxymethyl)phosphonium chloride (THPC). This is reacted with urea.
and the reaction product is padded onto cotton fabric and dried. The fabric is then reacted with ammonia and finally oxidised with hydrogen peroxide.

The Proban process may be summarised as follows:

1. Pad the fabric with Proban CC.
2. Dry the fabric to a residual moisture content of 12%.
5. Wash off and dry the fabric.

The actual chemistry of the process is fairly straightforward and the Proban forms an insoluble polymer in fibre voids and the interstices of the cotton yarn. There is no actual bonding to the surface of the cellulose, but the insoluble Proban polymer is held by mechanical means in the cellulose fibres and yarns. Because of this the Proban treated fabric has a somewhat harsh handle and some softening is usually required before the fabric is fit for sale. The next method of forming a durable treatment for cellulose is by the use of Pyrovatex. This material is closely related to the crosslinked resins used in textile finishing and is in fact always applied with a crosslinked resin to form a chemical bond to the cellulose.

The Pyrovatex process may be summarised as follows:

1. Pad the Pyrovatex mixture.
2. Dry at 120°C.
3. Cure at 160 °C for 3 min.
4. Wash in dilute sodium carbonate.
5. Wash in water.
6. Dry and stenter to width.
As the reaction is with the cellulose, the flame-retardant substance is chemically bound to the fibre and is therefore durable. However, because the flame-retardant substance has to be applied with a crosslink resin, then the finished fabric has good dimensional stability and also excellent crease-recovery properties making this finish the one preferred for curtains. Unfortunately these desirable properties are not without disadvantages, the main one in the case of Pyrovatex being the loss in tear strength, which occurs with this and all cross linking systems.

6.2.2 Synthetic fibres with inherent flame-retardant properties

The Furniture and Furnishing (Fire) (Safety) Regulations12 made it mandatory that all upholstery materials should withstand the cigarette and match test as specified in BS 5852:1979: Pt1. This produced an enormous amount of work in the industry on possible routes which could be used to meet this legislation. These ranged from the use of materials that would not support combustion to chemical treatments and backcoating techniques. It is now clear, however, that backcoating is the main means by which these regulations are being met. Currently, some 5000 tonnes of backcoating formulations are being used in the UK for upholstery covers.

The majority of backcoating formulations are based on the well-known flame retardant effect of the combination of antimony(III) oxide and a halogen, which is usually bromine, although chlorine is also used to a lesser degree. The synergistic mixture for this is one part of antimony(III) oxide to two parts of bromine containing organic compound. In addition, foaming agents are used which enable the use of foam application techniques, so that a minimum amount of penetration of the backcoating compound onto the face of the fabric is achieved. The use of foam application also enables higher precision in the weights applied and shorter drying times to be achieved. Thus Proban, Pyrovatex and backcoating with antimony/bromine compounds represent the major flame-retardant treatments for cellulose.
6.2.3 Water-repellent finishes

The early water-repellent finishes were all based on the application of a mixture of waxes, which were pliable at normal temperatures, applied to tightly woven cotton fabrics. These were, of course, well suited to sail cloth and protective clothing, but problems were encountered when the garments were cleaned. Therefore, the search was on for water-repellent treatments that were simple to apply but would also allow the treated fabrics to be cleaned.

It was noted early on that the heavy metal soaps did have water-repellent properties and therefore the first attempt at the production of a durable treatment was to use the chromium salt of a fatty acid, which was applied to cotton and then baked. This gave a certain durability to the fabric thus treated and the mechanism.

6.2.4 Antistatic finishes

Static electricity is formed when two dissimilar materials are rubbed together. It cannot be formed if identical materials are rubbed together. Thus when dissimilar materials are rubbed together a separation of charges occurs and one of the materials becomes positively charged and the other negatively charged. The materials at the top of the table will derive a positive charge when rubbed with any of the materials below them.

Cotton is a fibre that has very good antistatic properties on its own and presents few problems. This is because the natural water content of cotton is high (moisture contents of around 8% are commonly quoted), which provides the fibre with sufficient conductivity to dissipate any charge that might accumulate.

Antistatic treatments, therefore, are based on the principle of making the fibre conductive so that high charge densities are dissipated before sparks can form. This is done by the application of both anionic and cationic agents to the fibre. Typical structures of these materials are similar to the softening agents used for
cotton, which contain a long chain hydrocarbon with an ionic group at the end. One of the most interesting advances in the field of antistatic treatments has been the development of the permanent antistatic finishes, one of which was the Permolose finish developed by ICI. These are actually a series of finishes that consist of block copolymers of ethylene oxide and a polyester. When polyester fibres are treated with Permolose, the polyester block of the copolymer is adsorbed by the polyester fibre but the polyethylene oxide portion is incompatible with the polyester fibre and thus remains on the surface, where it attracts water and forms a conductive surface on the polyester fibre.

6.2.5 Antimicrobial and antifungal finishes

Problems of hygiene are coming more and more to the fore in textile finishing and it is now generally realised that a microbiocidal finish is very valuable in certain textiles for two reasons: as a prophylactic measure to avoid reinfections and as a deodorant. Perhaps at this stage it might be useful to define some of these terms:

- **Bacteriostatic**: a chemical that inhibits the growth of bacteria. Fabric that has been impregnated with a bacteriostat will stop the growth of germs, which eventually die in time.

- **Fungistatic**: a chemical that inhibits the growth of fungi. *Bactericidal*, *fungicidal* and *microbicidal* all mean that the chemical will kill these three types of microorganism.

Here are just a few of the many microorganisms with the infections they cause:

- **Staphylococcus aureus**: found in mucus membranes, causes boils and abscesses
- *Pseudomonas pyocyanea*: causes spots and boils
- *Trichophyton mentagrophytes*: fungus, which causes dermatomycosis of the feet
- *Candida albicans*: yeast-like mould which is the main cause of thrush and foot rot.

### 6.2.5.1 Areas of use

Microbicidal finishes are mainly used in textiles that are being handled continuously by a large number of people. Locations where these are used include, hotels, hospitals, asylums and student hostels, where mattress ticking, blankets and pillows, carpets and upholstery all come into contact with a large number of different individuals.

Any one of the following methods can be applied

- exhaust
- pad batch
- continuous
- spray.

The normal add on depends on the efficiency of the particular product, but add-on weights of 1–4% are commonly quoted.

### 6.3 Summary

One of the most important properties of this type of clothing is its resistance to small burning sources, thus flame resistance combined with easy cleaning is a most important consideration. The flame retardance must be maintained throughout the lifetime of the garment.

### 6.4 Lesson End Activities

Discuss in detail about the chemical processes and its types.
6.5 References


2. Techtextil Frankfurt - Trade fair for Technical Textiles and Nonwovens consulted 21 August 2008


Coating and its Techniques used for Technical Textiles

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7.5 References
7.0 Aims and Objectives

This chapter will deal with the chemistry of coatings and their application to various coated technical textiles that are in use.

7.1 Coating of Technical Textiles – Introduction

Coatings used in the production of technical textiles are largely limited to those products that can be produced in the form of a viscous liquid, which can be spread on the surface of a substrate. This process is followed by a drying or curing process, which hardens the coating so that a non-blocking product is produced. Thus the coatings for these products are limited to linear polymers, which can be coated as a polymer melt or solution and on cooling form a solid film or form a solid film by evaporation of the solvent. There are some types of coatings that can be applied in the liquid form and then chemically crosslinked to form a solid film.

The coatings used in technical textiles are all thermoplastic polymers, which are long chain linear molecules, some of which have the ability to crosslink. The properties of these polymeric materials directly influence the durability and performance of the end product.

7.1.1 Polyvinyl chloride (PVC)

The polymer is a hard rigid solid, which if it is to be used as a coating material for technical textiles needs to be changed to a soft flexible film. This is possible because of a remarkable property of PVC, the ability of the powdered polymer to absorb large quantities of non-volatile organic liquids. These liquids are known as plasticisers and a typical plasticiser for PVC is cyclohexyliso-octylphthalate. The polymer can absorb its own weight of this plasticiser. However, when the powdered polymer and plasticiser are first mixed, a stable paste is formed which is easily spreadable onto a textile surface. The paste of PVC and plasticiser, known as a plastisol. When this mixture is heated to 120 °C complete solution of the plasticiser and polymer occurs, which on cooling gives a tough non-blocking
film. Plasticised PVC forms a clear film, which shows good abrasion resistance and low permeability. The film may be pigmented or filled with flame-retardant chemicals to produce coloured products of low flammability. The coatings are resistant to acids and alkalis but organic solvents can extract the plasticiser, making the coatings more rigid and prone to cracking.

One great advantage of a polymer with an asymmetric chlorine atom is its large dipole and high dielectric strength. This means that the coated product may be joined together by both radiofrequency and dielectric welding techniques.

### 7.1.2 Polyvinylidene chloride (PVDC)

PVDC is very similar to PVC. As in the case of PVC it is made by the emulsion polymerisation of vinylidene chloride. The resulting polymer forms a film of low gas permeability to gases, however, the polymer is more expensive than PVC and therefore only tends to be used where flame resistance is required. As may be seen from the formula, PVDC contains twice the amount of chlorine as PVC and this extra chlorine is used in flame-resistant coatings. When a flame heats these materials the polymer produces chlorine radicals which act as free radical traps, thus helping to snuff out the flame.

### 7.1.3 Polytetrafluoroethylene (PTFE)

PTFE is perhaps the most exotic of the polymers which occur in coated textiles. It is manufactured by the addition polymerisation of tetrafluoroethylene. Since its discovery by Du Pont in 1941, PTFE has found many uses in coating particularly in the protection of fabrics from the harmful effects of sunlight. One remarkable feature of the polymer is its very low surface energy, which means that the surface cannot be wetted by either water or oil. Textile surfaces treated with this polymer are both water repellent and oil repellent. Hence PTFE is found on diverse substrates which range from conveyor belts used in food manufacture to carpets
where stain resistance is required. In addition the polymer shows excellent thermal stability and may be used up to a temperature of 250°C.

In order to reduce the cost of fluoropolymers several less expensive compounds have been produced, such as polyvinyl fluoride (PVF) and polyvinylidene fluoride (PVDF), which are analogous to the corresponding PVC and PVDC. However, while these materials are similar to PTFE they are slightly inferior in terms of resistance to weathering.

### 7.1.4 Rubber

Natural rubber is a linear polymer of polyisoprene, found in the sap of many plants, although the main source is the tree *Hevea brasiliensis*. Rubber occurs as an emulsion, which may be used directly for coating, or the polymer may be coagulated and mixed at moderate temperatures with appropriate fillers.

### 7.1.5 Styrene–Butadiene Rubber (SBR)

SBR is made by the emulsion polymerisation of styrene and butadiene. The formula illustrated implies a regular copolymer but this is not the case and SBR is a random copolymer. The compounding and application techniques are very similar to those for natural rubber although the material is not as resilient as natural rubber and also has a greater heat build-up, which make SBR inferior to natural rubber in tyres.

### 7.1.6 Nitrile rubber

Nitrile rubbers are copolymers of acrylonitrile and butadiene. These materials are used primarily for their excellent oil resistance, which varies with the percentage acrylonitrile present in the copolymer and show good tensile strength and abrasion resistance after immersion in oil or petrol. They are not suitable for car tyres but are extensively used in the construction of flexible fuel tanks and fuel hose.
7.1.7 Butyl rubber

Butyl rubbers are copolymers of isobutylene with a small amount of isoprene to make the copolymer vulcanisable or crosslinked. Because of the low amount of isoprene in the structure, the vulcanised structure contains little unsaturation in the backbone and consequently the rate of oxidation or oxygen absorption is less than that of other elastomers except for the silicones and fluorocarbons. When an elastomer contains double bonds, oxidation leads to crosslinking and embrittlement, whereas in butyl rubbers oxidation occurs at the tertiary carbon atom which leads to chain scission and softening. Further, the close packing of the hydrocarbon chains leads to a structure which is impermeable to gases and its main use is in tyre tubes and inflatable boats.

7.1.8 Polychloroprene (neoprene)

Neoprene rubber was first developed in the United States as a substitute for natural rubber, which it can replace for most applications. It is made during the emulsion polymerisation of 2-chlorobutadiene. Neoprene rubbers can be vulcanised and show tensile properties similar to natural rubber, however, they are perhaps most widely used for their excellent oil resistance. Weathering and ozone resistance is good and the polymer finds its main end-uses in the production of belts and hoses. The neoprene latex can also be used in dipping and coating.

7.1.9 Silicone rubbers

Silicone rubbers are polymers which contain the siloxane link Si—O—Si and are formed by the condensation of the appropriate silanol which is formed from the halide or alkoxy intermediate; the final condensation then takes place by the elimination.

The groups R1 and R2 are normally inert groups such as methyl, but they may include a vinyl group and therefore are capable of crosslinking. It is also normal to fill these polymers with finely divided silica, which acts as a reinforcing
filler. These polymers show outstanding low temperature flexibility and can be used at temperatures as low as -80°C, while they retain their properties up to 250°C. They also show good resistance to weathering and oxidation. Unfortunately their price is high.

7.2 Coating Techniques - Introduction

The original methods of coating were largely based on various impregnating techniques based on an impregnating trough followed by a pair of squeeze rollers to ensure a constant pick-up. The material was then air dried at constant width, usually on a stenter, and rolled. However, when the coating was required on one side of the fabric then total immersion of the fabric in the coating liquor was not possible and other techniques had to be developed.

7.2.1 Lick roll

In this method the fabric was passed over the coating roll which was rotated in a trough of the coating liquor. There were several variations on this theme, which were developed to ensure a more even application of the coating by metering the coating onto the fabric. This was done by two main approaches, the first of which was to use a second roll on the primary coating roll, which picked up a fixed amount. The second was to use a doctor blade on the primary roll, so that again only a fixed amount of liquor was transferred to the fabric. The main disadvantage of these systems was that the amount of coating on the fabric was dependent on the surface tension and viscosity of the coating fluid and also the surface condition of the fabric. To overcome this problem knife coating was developed, which functions in basically the same way that butter is spread on toast. (Fig- 2.7)
7.2.2 Knife coating

In this method the coating fluid is applied directly to the textile fabric and spread in a uniform manner by means of a fixed knife. The thickness of the coating is controlled by the gap between the bottom of the knife and the top of the fabric. The way in which this gap is controlled determines the type of machinery used. The following are the main techniques used:

- knife on air
- knife over table
- knife over roller
- knife over rubber blanket.

In the first of these the spreading blade is placed in direct contact with the fabric under tension and the coating compound is thus forced into the fabric. The main advantage of this technique is that any irregularities in the fabric do not affect the running of the machine. However, this is not the case with the knife over table or knife over roll methods (Fig. 2.8), for although the coating thickness can be accurately controlled, any fabric faults or joints in the fabric are likely to jam under the blade causing fabric breakage.
The problem of metering an accurate amount of coating onto the substrate was finally solved by the use of a flexible rubber blanket, which gives a controlled gap for the coating compound and yet is sufficiently flexible to allow cloth imperfections or sewing to pass underneath the blade without getting trapped and causing breakouts. (Fig. 2.9)

![Diagram](image)

7.2.2.1 Knife geometry

The geometry of the coating knife and the angle of application also have an important role to play in the effectiveness and penetration of the coating. Obviously if uniform coatings are to be obtained over the width of the fabric then an accurately machined flat blade is mandatory. In addition the profile of the knife can have a marked influence on the coating weights and penetration of the coating. There are three main types of knife profile with many variations in between these three:
- **Pointed blade**: the sharper the blade the more of the coating compound is scraped off and consequently the lower the coating weight.
- **Round blade**: this gives a relatively higher coating weight than a sharp point.
- **Shoe blade**: this gives the highest coating of all the blade profiles; the longer the length of the shoe the higher the coating weight.

In general knife coating fills in any irregularities in the fabric surface giving a smooth finish to the coated surface. The machines which use knife coating are in general simple to operate and can be used for a wide variety of thicknesses from about 1mm up to 30mm.

### 7.2.2.2 Air knife coating

In discussing knife coating, mention must also be made of the air knife as a method of removal of the excess coating fluid. In this technique a blast of air is used to blow off the excess coating fluid. The viscosity of the fluid is much lower than in the case of conventional knife doctoring and the coating applied follows the profile of the substrate to which it is being applied. The technique is more frequently used in the paper industry, where it is used to coat photographic paper, rather than in the textile industry.

### 7.2.3 Gravure coating

The use of a gravure roller in coating was developed from the printing industry, where it was used to print designs. The technique involves the use of a solid roller, the surface of which has been engraved with a closely packed series of small hemispherical depressions. These act as metering devices for the coating fluid, which fills the hemispheres with coating fluid from reservoirs of the fluid. The excess fluid is scraped from the roll with a doctor blade, leaving the depressions with an exact amount of fluid in each. This is then transferred to the substrate to be coated. The quantity of fluid transferred depends on the volume of the engraved depressions and the packing on the surface of the roll.
The greatest drawback to this technique is that for a fixed depth of engraving a fixed coating weight is obtained. Thus if a different coating weight is required then a new engraved roll has to be produced. Further, unless the viscosity characteristics of the coating fluid are controlled, the pattern of the printed dot can be seen on the coated substrate. What is required is a printing fluid that will flow and form a flat surface in the drying process. This formation of a flat coating can be greatly improved by the use of offset gravure printing. Here the fluid is printed onto a rubber roller before being transferred onto the substrate.

7.2.4 Rotary screen coating

This technique is similar to the rotary screen printing process that is used to apply coloured patterns to fabric. The applicator is a cylindrical nickel screen, which has a large number of perforated holes. The coating compound is fed into the centre of the screen, from whence it is forced through the holes by either a doctor blade or a circular metal rod. The coating weight can be controlled by the number of holes per unit area and the coating weights are very precise. However, the coatings have a dot configuration and to obtain a continuous coating a wiper blade that spreads the dots into a continuous coat must be used.

7.2.5 Hot-melt coating

In this technique the coating materials must be thermoplastic, so that they melt when heated and in this condition are capable of being spread onto a textile substrate. Thus, in some respects they are similar to paste coating. However, the big difference from paste coating is that the thermoplastic coating has no solvents to evaporate and no water that has to be evaporated, giving the process both economic and ecological advantages. The molten polymer is usually calendered directly onto the textile or in some cases extruded directly from a slotted die. This is followed by contact with a polished chill roller, if a smooth surface is required on the coating or a patterned roll if a patterned effect is required. One further process, the use of
powdered polymers as a coating medium, needs to be mentioned in the area of hot-melt coating. In this technique the powdered polymer is sprinkled onto the substrate, followed by heating with radiant heaters to melt the thermoplastic. The coating is then compacted and rendered continuous by a compaction calender. The main materials used in this are polyethylenes and nylon and these are now being applied in the production of carpets for car interiors, where because of the mouldability of the thermoplastic, a complete car carpet may be pressed out in one operation.

7.2.6 Transfer coating

The final coating technique to be described in this section is transfer coating. In this the coating material is preformed into a continuous sheet which is laminated to the substrate either by the application of heat or by the use of an adhesive known as a tie coat. The great advantage of this technique over all the others is that the coating film may be made completely free of holes and defects before it is applied to the fabric. In general, transfer coating will give the softest coating of all coating techniques in terms of fabric handle and furthermore there is no possibility of the coating bleeding through onto the face of the coated fabric.

7.3 Summary

In the early 1950’s, a search began for the chemicals which could be coated onto the base fabric and fused by the action of heat and pressure alone, thus avoiding the use of flammable and toxic solvents. This led to development of various coatings discussed earlier order which melt when heated and then undergo cross-linking, thus producing a very stable bond.

The initial coatings produced were known as sinter or scatter coatings. New coating techniques were then developed and refined by more precise positioning of the adhesive dot, so that the handle of the end product could be more accurately controlled.
7.4 Lesson End Activities
A) Describe the importance of finishing in technical textiles.
B) Discuss in detail about the various finishing process used
C) Explain the speciality of polyvinyl chloride and Nitril rubber as a coating agent.
D) State the different kinds of Coating Techniques.

7.5 References


2. Techtextil Frankfurt - Trade fair for Technical Textiles and Nonwovens consulted
   21 August 2008


LESSON 8

Heat and Flame Protection

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8.0 Aims and Objectives

In this Unit, various factors affecting the flammability, development of new inherently heat-resistant fibres, and the flame-retardant finishes for both natural and man-made fibre fabrics along with the relevant test methods are described.

8.1 Heat and Flame Protection

8.1.1 Introduction

With industrialisation, the safety of human beings has become an important issue. A growing segment of the industrial textiles industry has therefore been involved in a number of new developments in fibres, fabrics, protective clothing. Major challenges to coatings and fabrication technology for production in the flame retardant textile industry have been to produce environmentally friendly, non-toxic flame-retardant systems that complement the comfort properties of textiles. The 1990s, therefore, saw some major innovations in the development of heat-resistant fibres and flame-protective clothing for firefighters, foundry workers, military, aviation and space personnel, and for other industrial workers who are exposed to hazardous conditions.

For heat and flame protection, requirements range from clothing for situations in which the wearer may be subjected to occasional exposure to a moderate level of radiant heat as part of his/her normal working day, to clothing for prolonged protection, where the wearer is subject to severe radiant and convective heat, to direct flame, for example the firefighter’s suit. In the process of accomplishing flame protection, however, the garment may be so thermally insulative and water vapour impermeable that the wearer may begin to suffer discomfort and heat stress. Body temperature may rise and the wearer may become wet with sweat.
8.1.2 What constitutes flammability?

Ease of ignition, rate of burning and heat release rate are the important properties of textile materials which determine the extent of fire hazard. The other factors that influence the thermal protection level include melting and shrinkage characteristics of synthetic fibre fabrics, and emission of smoke and toxic gases during burning. So, while selecting and designing flame protective clothing, the following points should be kept in mind:

- the thermal or burning behaviour of textile fibres
- the influence of fabric structure and garment shape on the burning behaviour
- selection of non-toxic, smoke-free flame-retardant additives or finishes
- design of the protective garment, depending on its usage, with comfort properties
- the intensity of the ignition source
- the oxygen supply.

8.1.3 Thermal behaviours of fibers

The effect of heat on a textile material can produce physical as well as chemical change. In thermoplastic fibres, the physical changes occur at the second order transition ($T_g$), and melting temperature ($T_m$), while the chemical changes take place at pyrolysis temperatures ($T_p$) at which thermal degradation occurs. Textile combustion is a complex process that involves heating, decomposition leading to gasification (fuel generation), ignition and flame propagation.

A self-sustaining flame requires a fuel source and a means of gasifying the fuel, after which it must be mixed with oxygen and heat.

When a textile is ignited, heat from an external source raises its temperature until it degrades. The rate of this initial rise in temperature depends on the specific heat of the fibre, its thermal conductivity and also the latent heat of fusion (for melting fibres) and the heat of pyrolysis.
In protective clothing, it is desirable to have low propensity for ignition from a flaming source or, if the item ignites, a slow fire spread with low heat output would be ideal. In general, thermoplastic-fibre fabrics such as nylon, polyester fibre, and polypropylene fibres fulfil these requirements because they shrink away from flame and, if they burn, they do so with a small slowly spreading flame and ablate. For protective clothing, however, there are additional requirements, such as protection against heat by providing insulation, as well as high dimensional stability of the fabrics, so that, upon exposure to the heat fluxes that are expected during the course of the wearer’s work, they will neither shrink nor melt, and if they then decompose, form char. The above mentioned requirements cannot be met by thermoplastic fibres and so recourse must be made to one of the so-called high-performance fibres such as aramid fibre (e.g. Nomex, DuPont), flame-retardant cotton or wool, partially oxidised acrylic fibres, and so on. It may also be noted that the aramid fibres, in spite of their high oxygen index and high thermal stability, have not been found suitable for preventing skin burns in molten-metal splashes because of their high thermal conductivity.

8.1.4 Selection of Fibers suitable for thermal and Flame Protection

Selection of fibres suitable for thermal and flame protection. The fibres could be classified into two categories:

- **Inherently flame-retardant fibres**, such as aramid, modacrylic, polybenzimidazole (PBI), Panox (oxidised acrylic) or semicarbon, phenolic, asbestos, ceramic etc.

- **Chemically modified fibres and fabrics**, for example, flame retardant cotton, wool, viscose and synthetic fibres.

8.1.5 Inherently flame-retardant fibres

For some 2000 years, there was only one type of naturally occurring mineral fibre, asbestos which could not be completely destroyed by fire. Asbestos has many
desirable properties and is cheap as well. However, the fibres are so fine that they can be breathed into the lungs and can promote fatal cancerous growth.

Glass fibres are also heat-resistant materials. In earlier times such fibres were used for printed circuit boards. Now developments in the texturing of glass fibres have provided a material that could substitute for the asbestos fibres to some extent. Unlike asbestos fibres, glass fibres with high diameter are non-respirable. They have an upper temperature resistance of about 450°C. They spin well, knit or braid easily and can be coated with rubber, polyacrylate or silicones. Glass fibres have also good electrical and insulation properties. However, they cause skin irritation, which limits their application in protective clothing. Silica-based fibres have high rates of thermal conductivity, a property that may be valuable in heat dissipation in some uses but in situations like hot metal splashes, where the heat is transmitted to the person by conduction, they will cause more burn injuries instead of protecting the skin. Thus, the selection of the fibre for making thermally protective clothing should be decided on the basis of the environment to which a worker is exposed, namely, whether the heat will be transmitted to the person by conduction, convection or radiation. Despite their high temperature resistance, ceramic fibres have poor aesthetic characteristics, high densities and are difficult to process.

8.1.5.1 Aramids

Aromatic polyamides such as poly(metaphenylene isophthalamide) char above 400 °C and may survive short exposures at temperatures up to 700°C. Nomex (DuPont), Conex (Teijin), Feniolon (Russian) and Apyeil (Unitika) meta-aramid fibres have been developed for protective clothing for fighter pilots, tank crews, astronauts and those working in certain industries. Para-aramid fibres like Kevlar (DuPont), Twaron (Akzo Nobel) and Technora (Teijin) are also being used for ballistic and flame protection. Nomex nonwovens are used for hot gas filtration and thermal insulation.
Aramids are resistant to high temperatures, for example at 250 °C for 1000 hours the breaking strength of Nomex is about 65% of that before exposure. They begin to char at about 400 °C with little or no melting. Generally, meta-aramids are used in heat protective clothing, however, in intense heat, Nomex III (a blend of Nomex and Kevlar 29 (95 : 5 by wt) is preferred, in order to provide a greater mechanical stability to the char. Teijin23 has introduced a new fabric, X-fire, a combination of Teijin Conex (meta-aramid) and Technora (para-aramid) fibres. This fabric is capable of resisting temperatures up to 1200 °C for 40–60 s.

Nomex can also be blended with FR fibres, for example FR wool and FR viscose. Karvin (DuPont) is a blend of 30% Nomex, 65% FR viscose and 5% Kevlar. Kevlar blends were formerly used by Firotex Co. UK (now defunct) with partially carbonized viscose in fabric form. This blend was developed as a fire blocking fabric for aircraft seats but found little favour because of the poor abrasion resistance of the carbonised viscose component.

Other examples of such blends include Fortafil and Fortamid needle felt NC580, which comprise aramid and FR viscose. This material is useful for gloves and mittens in which temperatures may reach up to 350°C. The outer working surface of the aramid fibre is needled through a reinforcing polyester fibre scrim over an inner layer of FR viscose.

Another aromatic copolyamide fibre developed by Lenzing AG is P84. This fibre does not melt but becomes carbonized at temperatures in excess of 500 °C and has an LOI value of 36–38%. The basic fibre is golden yellow in colour but Lenzing AG offers it as spun material dyed in limited colours. P84 fibres have irregular crosssection, which provides a higher cover factor at lower weights of fabrics made from it. Its extensibility is >30% with good knot and loop strength. The applications of high performance P84 include protective clothing, as a sealing or packing material, for hot gas filtration and in aviation and space including covers for aircraft seats.
8.1.5.2 Poly(amide-imide) fibres

Rhone-Poulenc produces polyamide–imide fibre called Kermel. This is available in two forms: 234 AGF and 235 AGF. Type 234 is a staple fibre for use in both cotton and worsted spinning systems, and is produced in five spun-dyed colours. Type 235 is intended for nonwovens applications. In France, Kermel is used by firefighters and military personnel where the risk of fire is higher than usual. Its LOI is 31–32%, and it resists up to 250 °C exposure for a long duration. At 250°C after 500 hours exposure, the loss of mechanical properties is only 33%. Kermel fibre does not melt but carbonises. During its carbonization it generates very little opacity. Blends of 25–50% Kermel with FR viscose offer resistance to ultraviolet (UV) radiation and price advantage also compared with 100% Kermal fabrics. Blending with 30–60% wool also produces more comfortable woven fabrics with enhanced drape. In the metal industry, the 50 : 50 blend gives very good results, but a 65 :35 Kermel/viscose blend is preferred for such applications. Kermel-based fabrics are now used both on-shore and off-shore by leading petrochemical groups. The army, navy and airforces are also using Kermel in woven and knitted forms.

8.1.5.3 Polybenzimidazole (PBI) fibres

Celanese developed PBI, a non-combustible organic fibre. Its LOI is 41% and it emits little smoke on exposure to flame. PBI can withstand temperatures as high as 600 °C for short-term (3–5 s) exposures and longer term exposure at temperatures up to 300–350°C. It provides the same protection as asbestos while weighing half as much. It also absorbs more moisture than cotton. The current area of interest in PBI is in the replacement of asbestos-reinforced rubbers used in rocket motors and boosters to control ignition. Its other applications include fire blocking fabrics in aircraft seats, firefighter suits and racing-car driver suits.

Ballyclare Special Products, UK has recently developed a fire-resistant garment assembly for firefighter’s safety. The outer fabric of the garment is made...
from Pbi Gold(R), a fire-resistant fabric from Hoechst Celanese. This fabric, which was originally developed for the US Apollo space programme, combines the comfort, thermal and chemical resistance of polybenzimidazole (PBI) with the strength of aramid fibre. Pbi Gold is stable even under simulated flash conditions at 950°C. The fabric is also resistant to puncturing, tearing and ripping.

8.1.5.4 Poly(phenylene sulphide) PPS fibres

Ryton (Sulfar) fibres (Tm 285 °C) produced by Amoco Fabrics and Fibres are nonflammable. They do not support combustion under normal atmospheric conditions, and the LOI is 34–35%. Chemical resistance and the ability to retain physical properties under extremely adverse conditions make the fibre valuable for protective clothing.

8.1.5.5 Polyacrylate (Inidex)

Polyacrylate is a crosslinked copolymer of acrylic acid and acrylamide. Its LOI is 43%, and when subjected to flame, it neither burns nor melts. It emits virtually no smoke or toxic gases. Because of its low strength and brittleness, it can be used in nonwovens although the durability of fabrics made from this fibre may not be adequate for some apparel uses.

8.1.5.6 Semicarbon/Panox fibres

These fibres are produced by thermal treatment (thermo-oxidative stabilization) of either viscose or acrylic fibres. Asgard and Firotex are produced from viscose while Panox, Pyromex, Fortasil, Sigratex and so on are made from acrylic precursors. The acrylic fibres can be oxidised in the fibre, filament or fabric form at 220–270 °C in air, but the viscose fibres are generally partially carbonized in the fabric form in a nitrogen atmosphere.

These semicarbon fibres have excellent heat resistance, do not burn in air, do not melt and have outstanding resistance to molten metal splashes. After exposure
to flame, there is no afterglow and fabrics remain flexible. In view of their outstanding properties, the Panotex fabrics (Universal Carbon Fibres) made from Panox (RK Textiles), for example, are ideal for use in protective clothing where protection against the naked flame is required. Currently, this range of fabrics is probably the most common and versatile of oxidised acrylic-based materials.

To prevent transfer of radiant heat, Panotex fabrics may be aluminized. An aluminized Panotex fabric is thus suitable for fire-proximity work but not for fire entry. It has been demonstrated that with a heat flux of 3Wcm-2, an aluminium coating will ignite, but a stainless steel coating can withstand such a situation for a prolonged period. Multiple layers of Panotex fabric tend to protect a polyvinyl chloride (PVC)-simulated skin against irradiance as high as 170Wcm-2 applied for 2 s.

Another advantage of Panotex outer fabric is the shedding of burning petrol, and it can even withstand several applications of napalm.

8.1.5.7 Phenolic or novoloid fibres

Kynol is a well-established novoloid heat-resistant fibre which is produced by spinning and postcuring of phenol formaldehyde resin precondensate. The fibre is soft and golden coloured with a moisture regain of 6%. When strongly heated, Kynol fabric is slowly carbonised with little or no evolution of toxic gases or smoke. However, its poor strength and abrasion properties preclude its application for making apparel. To upgrade its mechanical properties, Kynol fibres can be blended with Nomex or FR viscose to produce flame-protective clothing.

Another phenolic fibre, Philene has also been developed, for example Philene 206 (0.9 den) and Philene 244 (2.1 den). The moisture regain of the fibre is 7.3% and is said to be non-flammable and self-extinguishing, with an LOI of 39%. It does not show any change in tensile properties after being heated for 24 hours at
140°C (or for 6 hours at 200 °C). A charred Philene fabric is claimed to form a thermal insulating barrier that retains its initial form.

8.1.5.8 **Modacrylic**

Flame-retardant modacrylic under different brand names, such as Velicren FR (Montefibre, Italy) and SEF (Solutia Inc.) is a copolymer of acrylonitrile, vinyl chloride or vinylidene chloride in the ratio of 60 : 40 (w/w) along with a sulphonated vinyl monomer. It has an LOI in the range of 26–31%.

8.2 Flame retardation of conventional textile fibres

8.2.1 **FR viscose**

Inherently flame-retardant viscose fibres are produced by incorporating FR additives/ fillers in the spinning dope before extrusion. For example, Sandoflam 5060 (Sandoz), polysilicic acid or polysilicic acid and aluminium (Sater).

8.2.2 **Flame-retardant polyester**

There are three methods of rendering synthetic fibres flame retardant:

- use of FR comonomers during copolymerization,
- introduction of an FR additive during extrusion,
- application of flame retardant finishes or coatings.

The first two methods would give inherently flame-retardant polyester fibres. Trevira CS(R) and Trevira FR(R) produced by Hoechst are flame-retardant polyesters. Both are manufactured by copolymerizing a bifunctional organophosphorus compound based on phosphinic acid derivative.

8.2.3 **Flame-retardant nylon**

Nylons have a self-extinguishing property due to extensive shrinking and dripping during combustion. Problems arise in blends with natural fibres like
cellulosics which will char and form a supporting structure (the so-called scaffolding effect) which will then hold the molten polymer. Introduction of flame or combustion retarders into polyamide melts before spinning appears to be an economical and feasible process if they are stable.

8.2.4 Flame-retardant acrylic fibres

Like other synthetic fibres, acrylic fibres shrink when heated, which can decrease the possibility of accidental ignition. However, once ignited, they burn vigorously accompanied by black smoke. Thus, many efforts have been devoted to improve the flame resistance of acrylic fibres. Among these studies, halogen-based and particularly bromine derivatives or halogen- or phosphorus-containing comonomers, are the most effective flame retardants used in acrylic fibres.

8.2.5 Flame-retardant finishes for polyester

There has been some developments in flame retardant finishes for polyester fabric and its blends. Flame-retardant finishes for synthetic fibres should either promote char formation by reducing the thermoplasticity or enhance melt dripping so that the drops can be extinguished away from the igniting flame. For protective clothing, char forming finishes would be desirable.

8.2.6 Flame-retardant finish for wool

Wool is not as flammable as cotton, and wool fabric was the traditional material for thermal protection except for the more arduous conditions where asbestos was required. However, for thermal protective clothing a Zirpro(IWS) finish, based on hexafluorotitanates and hexafluorozirconates, has been developed, which is extremely stable in acid solutions and exhausts onto wool well below the boil. The Zirpro finish produces an intumescent char, which is beneficial for protective clothing, where thermal insulation is a required property of a burning textile.
8.2.7 Glass-fibre fabrics

In one finishing treatment, colloidal graphite was used, together with silicone oil, to provide protection at higher temperatures. Clothes treated in this way can be used at 400 °C or higher if exposure times are in minutes rather than days or in the absence of oxygen.

Another feature of glass fibre is that it melts at around 1000°C, so that in the untreated form, it is unsuitable for applications at higher temperatures. However, it can be treated to improve its resistance to such temperatures, by incorporating finely dispersed vermiculite and another involving aluminium salts. At high temperatures, the aluminium will react with the glass fibre to raise its melting point above 1500°C.

8.3 Summary

Most flame-retardant textiles are designed to reduce the ease of ignition and also reduce the flame propagation rates. Conventional textiles can be rendered flame retardant by chemical after-treatments as co-monomers in their structures or use of FR additives during extrusion. High performance fibres with inherently high levels of flame and heat resistance require the synthesis of all aromatic structures, but these are expensive and used only when performance requirements justify cost. In addition, while heat and flame-resistant textiles have been reviewed and compared, the mechanisms of char formation and the role of intumescents and plasma treatment have also been highlighted. The increasing need to use environmentally friendly FR finishes has been emphasized. Improved standards for fire and heat protective clothing including more realistic tests, such as instrumented manikins, have also been discussed.
8.4 Lesson End Activities
Discuss in detail about Heat proof fibres and its applications on Fabrics

8.5 References

2. Techtextil Frankfurt - Trade fair for Technical Textiles and Nonwovens consulted 21 August 2008


LESSON 9

Water Proof Fabrics

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9.0 Aims and Objectives

This chapter deals with the Waterproof fabric types and its applications.

9.1 Introduction

Waterproof breathable fabrics are designed for use in garments that provide protection from the weather, that is from wind, rain and loss of body heat. Clothing that provides protection from the weather has been used for thousands of years. The first material used for this purpose was probably leather but textile fabrics have also been used for a very long time. Waterproof fabric completely prevents the penetration and absorption of liquid water, in contrast to water-repellent (or, shower-resistant) fabric, which only delays the penetration of water. Traditionally, fabric was made waterproof by coating it with a continuous layer of impervious flexible material. The first coating materials used were animal fat, wax and hardened vegetable oils. Nowadays synthetic polymers such as polyvinylchloride (PVC) and polyurethane are used. Coated fabrics are considered to be more uncomfortable to wear than water-repellent fabric, as they are relatively stiff and do not allow the escape of perspiration vapour. Consequently they are now used for ‘emergency’ rainwear. Water-repellent fabric is more comfortable to wear but its water-resistant properties are short lived.

The term ‘breathable’ implies that the fabric is actively ventilated. This is not the case. Breathable fabrics passively allow water vapour to diffuse through them yet still prevent the penetration of liquid water. Production of water vapour by the skin is essential for maintenance of body temperature. The normal body core temperature is 37°C, and skin temperature is between 33 and 35°C, depending on conditions. If the core temperature goes beyond critical limits of about 24 °C and 45°C then death results. The narrower limits of 34 °C and 42 °C can cause adverse effects such as disorientation and convulsions. If the sufferer is engaged in a hazardous pastime or occupation then this could have disastrous consequences.
During physical activity the body provides cooling partly by producing insensible perspiration. If the water vapour cannot escape to the surrounding atmosphere the relative humidity of the microclimate inside the clothing increases causing a corresponding increased thermal conductivity of the insulating air, and the clothing becomes uncomfortable. In extreme cases hypothermia can result if the body loses heat more rapidly than it is able to produce it, for example when physical activity has stopped, causing a decrease in core temperature. If perspiration cannot evaporate and liquid sweat (sensible perspiration) is produced, the body is prevented from cooling at the same rate as heat is produced, for example during physical activity, and hyperthermia can result as the body core temperature increases.

If the body is to remain at the physiologically required temperature, clothing has to permit the passage of water vapour from perspiration at the rates under the activity conditions. The ability of fabric to allow water vapour to penetrate is commonly known as breathability. This property should more scientifically be referred to as water vapour permeability. Although perspiration rates and water vapour permeability are usually quoted in units of grams per day and grams per square metre per day, respectively, the maximum work rate can only be endured for a very short time.

During rest, most surplus body heat is lost by conduction and radiation, whereas during physical activity, the dominant means of losing excess body heat is by evaporation of perspiration.

Thus, waterproof breathable fabrics prevent the penetration of liquid water from outside to inside the clothing yet permit the penetration of water vapour from inside the clothing to the outside atmosphere.
9.2 Types of waterproof breathable fabric

There are several methods which can be used to obtain fabrics which are both breathable and waterproof. These can be divided into three groups:

- Densely woven fabrics
- Membranes
- Coatings.

9.2.1 Densely woven fabrics

Probably the first effective waterproof breathable fabric was developed in the 1940s for military purposes and is known as Ventile. The finest types of long staple cottons are selected so that there are very small spaces between the fibres. The cotton is processed into combed yarn, which is then plied. This improves regularity and ensures that the fibres are as parallel as possible to the yarn axis, and that there are no large pores where water can penetrate. The yarn is woven using an Oxford weave, which is a plain weave with two threads acting together in the warp. This gives minimum crimp in the weft, again ensuring that the fibres are as parallel as possible to the surface of the fabric.

When the fabric surface is wetted by water, the cotton fibres swell transversely reducing the size of the pores in the fabric and requiring very high pressure to cause penetration. The fabric is thus rendered waterproof without the need for any water-repellent finishing treatment. It was first made for military applications but the manufacturers are now producing a range of variants to widen the market appeal. The military variants use thread densities as high as 98 per cm. Fabric for other applications uses much lower thread densities, necessitating a water-repellent finish to achieve the waterproof properties.

Densely woven fabric can also be made from synthetic microfilament yarns. The individual filaments are less than 10mm in diameter, so that fibres with very
small pores can be engineered. Microfilaments are usually made from polyamide or polyester. The latter is particularly useful as it has inherent water-repellent properties. The water penetration resistance of the fabric is improved by application of silicone or fluorocarbon finish.

9.2.2 Membranes

Membranes are extremely thin films made from polymeric material and engineered in such a way that they have a very high resistance to liquid water penetration, yet allow the passage of water vapour. A typical membrane is only about 10mm thick and, therefore, is laminated to a conventional textile fabric to provide the necessary mechanical strength. They are of two types, microporous and hydrophilic.

9.2.2.1 Microporous membranes

The first and probably the best known microporous membrane, developed and introduced in 1976 by W Gore, is known as Gore-Tex. This is a thin film of expanded polytetrafluoroethylene (PTFE) polymer claimed to contain 1.4 billion tiny holes per square centimetre. These holes are much smaller than the smallest raindrops (2–3mm compared with 100mm), yet very much larger than a water vapour molecule (40 × 10⁻⁶mm). The hydrophobic nature of the polymer and small pore size requires very high pressure to cause water penetration. Contamination of the membrane by various materials including body oils, particulate dirt, pesticide residues, insect repellents, sun tan lotion, salt and residual detergent and surfactants used in cleaning have been suspected of reducing the waterproofing and permeability to water vapour of the membrane. For this reason microporous membranes usually have a layer of a hydrophilic polyurethane to reduce the effects of contamination. Figure 3.1 is a schematic diagram of a fabric incorporating a microporous membrane.
9.2.2.2 Hydrophilic membranes

Hydrophilic membranes are very thin films of chemically modified polyester or polyurethane containing no holes which, therefore, are sometimes referred to as non-poromeric. Water vapour from perspiration is able to diffuse through the membrane in relatively large quantities. The polyester or polyurethane polymer is modified by incorporating up to 40% by weight of poly(ethylene oxide). The poly(ethylene oxide) constitutes the hydrophilic part of the membrane by forming part of the amorphous regions of the polyurethane polymer system. It has a low energy affinity for water molecules which is essential for rapid diffusion of water vapour. These amorphous regions are described as acting like intermolecular ‘pores’ allowing water vapour molecules to pass through but preventing the penetration of liquid water owing to the solid nature of the membrane.
9.2.2.3 Methods of incorporation

Membranes have to be incorporated into textile products in such a way as to maximize the high-tech function without adversely affecting the classical textile properties of handle, drape and visual impression. There are four main methods of incorporating membranes into textile articles. The method employed depends on cost, required function and processing conditions:

1. **Laminate of membrane and outer fabric**– The membrane is laminated to the underside of the outer fabric to produce a two-layer system. This method has the disadvantage of producing a rustling, paper-like handle with reduced aesthetic appeal but has the advantage of having very effective protective properties of wind resistance and waterproofing. This method is mainly used for making protective clothing. (Fig – 3.2)

2. **Liner or insert processing** - The membrane is laminated to a light-weight knitted material or web. The pieces are cut to shape from this material, sewn together and the seams rendered waterproof with special sealing tape. This structure
is then loosely inserted between the outer fabric and the liner. The three materials (outer, laminate and lining) are joined together by concealed stitch seams. If high thermal insulation is required then the lightweight support for the membrane is replaced by a cotton, wool or wadding fabric. This method has the advantage of giving soft handle and good drape. The outer fabric can also be modified to suit fashion demands.

3. Laminate of membrane and lining fabric – The laminate is attached to the right side of the lining material. The functional layer is incorporated into the garment as a separate layer independent of the outer fabric. This method has the advantage that the fashion aspects can be maximised.

4. Laminate of outer fabric, membrane and lining – This produces a three-layer system, which gives a less attractive handle and drape than the other methods and, therefore, is not commonly used.

9.2.3 Coatings

These consist of a layer of polymeric material applied to one surface of the fabric. Polyurethane is used as the coating material. Like membranes, the coatings are of two types; microporous and hydrophilic. These coatings are much thicker than membranes.

9.2.3.1 Microporous coatings

Microporous coatings have a similar structure to the microporous membranes. The coating contains very fine interconnected channels, much smaller than the finest raindrop but much larger than a water vapour molecule. (Fig- 3.3)

- **Wet coagulation**: Polyurethane polymer is dissolved in the organic solvent dimethyl formamide to produce a solution insoluble in water. This is then coated on to the fabric. The coated fabric is passed through a conditioning chamber containing water vapour. As the organic solvent is miscible with
water, it is diluted and solid polyurethane precipitates. The fabric is then washed to remove the solvent, which leaves behind pores in the coating. Finally the coated fabric is mangled and dried. This method is not very popular as it requires high capital cost for machines and solvent recovery is expensive.

- **Thermocoagulation**: Polyurethane is dissolved in an organic solvent and the resulting solution mixed with water to produce an emulsion. The emulsion ‘paste’ is coated on to one side of the fabric. The coated fabric then goes through a two-stage drying process. The first stage employs a low temperature to remove the organic solvent, precipitating the polyurethane. The coating is now a mixture of solid polyurethane and water. The second stage employs a higher temperature to evaporate the water leaving behind pores in the coating.

- **Foam coating**: A mixture of polyurethane and polyurethane/polyacrylic acid esters are dispersed in water and then foamed. The foam is stabilised with the aid of additives. The foam is then coated on to one side of the fabric. The coated fabric is dried to form a microporous coating. It is important that the foam is open cell to allow penetration of water vapour but with small enough cells to prevent liquid water penetration. The fabric is finally calendered under low pressure to compress the coating. As the foam cells are relatively large, a fluorocarbon polymer water-repellent finish is applied to improve the water-resistant properties.

### 9.2.3.2 Hydrophilic coatings

Hydrophilic coatings use the same basic water vapour permeability mechanism as the hydrophilic membranes. The difference between microporous materials and hydrophilic materials is that with the former, water vapour passes through the permanent air-permeable structure whereas the latter transmit vapour by a molecular mechanism involving adsorption–diffusion and desorption. These
coatings are all based on polyurethane, which has been chemically modified by incorporating polyvinyl alcohols and polyethylene oxides. These have a chemical affinity for water vapour allowing the diffusion of water vapour through the amorphous regions of the polymer. The balance between hydrophilic and hydrophobic components of the polymer system has to be optimised to give acceptable vapour permeability, flexibility, durability and insolubility in water and dry cleaning solvents. Swelling of the membrane is encouraged to assist water vapour diffusion yet it also has to be restricted to prevent dissolution or breakdown in water or in the other solvents with which the polymer is likely to come into contact. Poly(ether–urethane) coatings and membranes have excellent integrity. This can be conferred in two ways:

1. by a high degree of hydrogen bonding, principally between polar groups in the hydrophobic segments of adjacent polymer chains
2. by forming covalent crosslinks between adjacent polymer chains. The effective length and density of the crosslinks are variables affecting polymer swelling and thus vapour permeability.

![Schematic diagram of a microporous coating.](image-url)
9.2.3.3 Methods of applying coatings

The conventional method of applying coatings to fabric is to use direct application using the knife over roller technique. The fabric is passed over a roller and liquid coating is poured over it. Excess liquid is held back by a ‘doctor blade’ set close to the surface of the fabric. The thickness of the coating is determined by the size of the gap between the blade and the surface of the fabric. The coated fabric is passed through a dryer to solidify the coating. Sometimes the coating is built up in several layers by a number of applications. In order to achieve thinner coatings and, therefore, more flexible fabric and to apply coating to warp knitted, nonwoven, open weave and elastic fabric, transfer coating is used. The liquid coating is first applied to a silicone release paper using the knife over roller technique. This is then passed through an oven to solidify the coating. A second coating is then applied and the textile fabric immediately applied to this. The second coating, therefore, acts as an adhesive. This assembly is passed through an oven to solidify the adhesive layer. The coated fabric is stripped from the release paper, which can be reused.

9.3 Applications of Water Proof fabrics:

Applications of waterproof breathable fabrics is shown in (Table 3.1)

(Table 3.1) Applications of waterproof breathable fabrics

<table>
<thead>
<tr>
<th>Leisure</th>
<th>Work</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy duty, foul weather clothing: Anoraks, cagoules, packs, over-trousers, hats, gloves, gaiters</td>
<td>Foul weather clothing: Survival suits, special military protective clothing, clean-room garments, surgical garments, hospital drapes, mattress and seat covers, specialised tarpaulins, packaging, wound dressings, filtration</td>
</tr>
<tr>
<td>Fashionable weather protection: Rainwear, skiwear, golf suits, walking boot linings, panels and inserts, sport footwear linings, panels and inserts</td>
<td>Domestic and transport: Non-allergic bedding, car covers, fire smoke curtains in ships, cargo wraps in aircraft</td>
</tr>
<tr>
<td>Tents</td>
<td></td>
</tr>
<tr>
<td>Sleeping bag covers</td>
<td></td>
</tr>
</tbody>
</table>
9.4 Summary

1. There was no significant overall difference between the various categories of breathable fabric.

2. The main parameter contributing to durability is the outer material to which the waterproof polymer is attached.

3. It makes no sense to design leisurewear that is used only occasionally to meet the same rigorous standards as professional clothing.

4. Polyurethane coatings have better resistance to mechanical damage than PTFE and PES laminates.

5. Almost all the samples had sufficient to good vapour transport properties but ventilation openings in garments are important because the vapour permeability capabilities of the fabrics are not sufficient for moderate physical activity.

6. Correct manufacture of the final product is as important as the properties of the fabric for water penetration resistance.

7. The question ‘which product performs the best’ cannot be answered. The conditions of application and corresponding requirements imposed on a product are quite different.

9.5 Lesson End Activity

Discuss about Water proof Fabrics a, its coatings and its applications.

9.6 References


LESSON 10

Geo Textiles

Contents

10.0 Aims and Objectives

10.1 Introduction

10.2 Important Characteristics Of Geotextiles

10.3 Selection of Fibre For Geotextiles

10.4 Types of Geotextiles

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10.8 References
10.0 Aims and Objectives

This Chapter deals with the importance of Geo Textiles and also some interesting commercial aspects related to geotextiles that are specific to the industry.

10.1 Introduction

Geotextiles were one of the first textile products in human history. Excavations of ancient Egyptian sites show the use of mats made of grass and linen. Geotextiles were used in roadway construction in the days of the Pharaohs to stabilise roadways and their edges. These early geotextiles were made of natural fibres, fabrics or vegetation mixed with soil to improve road quality, particularly when roads were made on unstable soil. Only recently have geotextiles been used and evaluated for modern road construction. Geotextiles today are highly developed products that must comply with numerous standards. To produce tailor-made industrial fabrics, appropriate machinery is needed.

Geotextiles have been used very successfully in road construction for over 30 years. Their primary function is to separate the sub base from the sub grade resulting in stronger road construction. The geotextile perform this function by providing a dense mass of fibres at the interface of the two layers.

Geotextiles have proven to be among the most versatile and cost-effective ground modification materials. Their use has expanded rapidly into nearly all areas of civil, geotechnical, environmental, coastal, and hydraulic engineering. They form the major component of the field of geosynthetics, the others being geogrids, geomembranes and geocomposites. The ASTM (1994) defines geotextiles as permeable textile materials used in contact with soil, rock, earth or any other geotechnical related material as an integral part of civil engineering project, structure, or system.
Geotextiles should fulfill certain requirements like it must permit material exchange between air and soil without which plant growth is impossible, it must be penetrable by roots etc. and it must allow rain water to penetrate the soil from outside and also excess water to drain out of the earth without erosion of the soil. To obtain all these properties in geotextiles, the proper choice of textile fibre is of paramount importance. The different synthetic fibres used in geotextiles are nylon, polyester, polypropylene while some natural fibres like ramie, jute etc. can also be used.

10.2 Important Characteristics Of Geotextiles

The characteristics of geotextiles are broadly classified as:

1. Physical properties:
   a) specific gravity
   b) weight
   c) thickness
   d) stiffness
   e) density.

2. Mechanical properties:
   a) tenacity
   b) tensile strength
   c) bursting strength
   d) drapability
   e) compatibility
   f) flexibility
   g) tearing strength
   h) frictional resistance
3. **Hydraulic properties:**

a) porosity  
b) permeability  
c) permittivity  
d) transitivity  
e) turbidity / soil retention  
f) filtration length etc.

4. **Degradation properties:**

a) biodegradation  
b) hydrolytic degradation  
c) photo degradation  
d) chemical degradation  
e) mechanical degradation  
f) other degradation occurring due to attack of rodent, termite etc.

5. **Endurance properties:**

a) elongation  
b) abrasion resistance  
c) clogging length and flow etc.

10.3 **Selection Of Fibre For Geotextiles**

Different fibres from both natural as well as synthetic category can be used as geotextiles for various applications.

**Natural fibres:** Natural fibers in the form of paper strips, jute nets, wood shavings or wool mulch are being used as geotextiles. In certain soil reinforcement applications, geotextiles have to serve for more than 100 years. But bio-degradable natural geotextiles are deliberately manufactured to have relatively short period of
life. They are generally used for prevention of soil erosion until vegetation can become properly established on the ground surface.

The commonly used natural fibres are –

**Ramie:** These are subtropical bast fibres, which are obtained from their plants 5 to 6 times a year. The fibres have silky luster and have white appearance even in the unbleached condition. They constitute of pure cellulose and possess highest tenacity among all plant fibres.

**Jute:** This is a versatile vegetable fibre which is biodegradable and has the ability to mix with the soil and serve as a nutrient for vegetation. Their quick biodegradability becomes weakness for their use as a geotextile. However, their life span can be extended even up to 20 years through different treatments and blendings. Thus, it is possible to manufacture designed biodegradable jute geotextile, having specific tenacity, porosity, permeability, transmissibility according to need and location specificity. Soil, soil composition, water, water quality, water flow, landscape etc. physical situation determines the application and choice of what kind of jute geotextiles should be used. In contrast to synthetic geotextiles, though jute geotextiles are less durable but they also have some advantages in certain area to be used particularly in agro-mulching and similar area to where quick consolidation are to take place. For erosion control and rural road considerations, soil protection from natural and seasonal degradation caused by rain, water, monsoon, wind and cold weather are very important parameters. Jute geotextiles, as separator, reinforcing and drainage activities, along with topsoil erosion in shoulder and cracking are used quite satisfactorily.

Furthermore, after degradation of jute geotextiles, lignomass is formed, which increases the soil organic content, fertility, texture and also enhance vegetative growth with further consolidation and stability of soil.
Synthetic Fibres: The four main synthetic polymers most widely used as the raw material for geotextiles are – polyester, polyamide, polyethylene and polypropylene, which was discovered in 1935. The next oldest of the four main polymer families relevant to geotextile manufacture is polyester, which was announced in 1941. The most recent polymer family relevant to geotextiles to be developed was polypropylene, which was discovered in 1954.

Polyamides (PA): There are two most important types of polyamides, namely Nylon 6 and Nylon 6,6 but they are used very little in geotextiles. The first one an aliphatic polyamide obtained by the polymerization of petroleum derivative ε-caprolactam. The second type is also an aliphatic polyamide obtained by the polymerization of a salt of adipic acid and hexamethylene diamine. These are manufactured in the form of threads which are cut into granules. They have more strength but less moduli than polypropylene and polyester. They are also readily prone to hydrolysis.

Polyesters (PET): Polyester is synthesised by polymerizing ethylene glycol with dimethyle terephthalate or with terephthalic acid. The fibre has high strength modulus, creep resistance and general chemical inertness due to which it is more suitable for geotextiles. It is attacked by polar solvent like benzyl alcohol, phenol, and meta-cresol. At pH range of 7 to 10, its life span is about 50 years. It possesses high resistance to ultraviolet radiations. However, the installation should be undertaken with care to avoid unnecessary exposure to light.

Polyethylene (PE): Polyethylene can be produced in a highly crystalline form, which is an extremely important characteristic in fiber forming polymer. Three main groups of polyethylene are – Low density polyethylene (LDPE, density 9.2-9.3 g/cc), Linear low density polyethylene (LLDPE, density 9.20-9.45 g/cc) and High density polyethylene (HDPE, density 9.40-9.6 g/cc).

Polypropylene (PP): Polypropylene is a crystalline thermoplastic produced by polymerizing propylene monomers in the presence of stereo-specific Zeigler- Natta
catalytic system. Homo polymers and copolymers are two types of polypropylene. Homo polymers are used for fibre and yarn applications whereas co-polymers are used for varied industrial applications. Propylene is mainly available in granular form. Both polyethylene and polypropylene fibres are creep prone due to their low glass transition temperature. These polymers are purely hydrocarbons and are chemically inert. They swell by organic solvent and have excellent resistance to diesel and lubricating oils. Soil burial studies have shown that except for low molecular weight component present, neither HDPE nor polyethylene is attacked by micro-organisms.

**Polyvinyl chloride (PVC):** Polyvinyl chloride is mainly used in geo membranes and as a thermo plastic coating materials. The basic raw materials utilized for production of PVC is vinyl chloride. PVC is available in free-flowing powder form.

### 10.4 Types Of Geotextiles

Geotextiles are a permeable synthetic material made of textile materials. They are usually made from polymers such as polyester or polypropylene. The geotextiles are further prepared in three different categories — woven fabrics, non-woven fabrics and knitted fabrics.

**Woven fabrics:** Large numbers of geosynthetics are of woven type, which can be sub-divided into several categories based upon their method of manufacture. These were the first to be developed from the synthetic fibers. As their name implies, they are manufactured by adopting techniques which are similar to weaving usual clothing textiles. This type has the characteristic appearance of two sets of parallel threads or yarns -- the yarn running along the length is called warp and the one perpendicular is called weft. The majority of low to medium strength woven geo synthetics are manufactured from polypropylene which can be in the form of extruded tape, silt film, monofilament or multifilament. Often a combination of yarn
types is used in the warp and weft directions to optimize the performance/cost. Higher permeability is obtained with monofilament and multifilament than with flat construction only.

**Non-woven:** Non woven geo-synthetics can be manufactured from either short staple fibre or continuous filament yarn. The fibers can be bonded together by adopting thermal, chemical or mechanical techniques or a combination of techniques. The type of fibre (staple or continuous) used has very little effect on the properties of the non-woven geo synthetics. Non-woven geotextiles are manufactured through a process of mechanical interlocking or chemical or thermal bonding of fibres/filaments. Thermally bonded non-wovens contain wide range of opening sizes and a typical thickness of about 0.5-1 mm while chemically bonded non-wovens are comparatively thick usually in the order of 3 mm. On the other hand mechanically bonded non-wovens have a typical thickness in the range of 2-5 mm and also tend to be comparatively heavy because a large quantity of polymer filament is required to provide sufficient number of entangled filament cross wires for adequate bonding.

**Knitted fabrics:** Knitted geosynthetics are manufactured using another process which is adopted from the clothing textiles industry, namely that of knitting. In this process interlocking a series of loops of yarn together is made. An example of a knitted fabric is illustrated in figure. Only a very few knitted types are produced. All of the knitted geosynthetics are formed by using the knitting technique in conjunction with some other method of geosynthetics manufacture, such as weaving.

Apart from these three main types of geotextiles, other geosynthetics used are geonets, geogrids, geo-cells, geo membranes, geo composites, etc. each having its own distinct features and used for special applications.

**10.5 Functions Of Geotextiles**

Every textile product applied under the soil is a geotextile. The products are used for reinforcement of streets, embankments, ponds, pipelines, and similar
applications (Figure 3.5). Depending on the required function, they are used in open-mesh versions, such as a woven or, rarely, warp-knitted structure, or with a closed fabric surface, such as a non-woven. The mode of operation of a geotextile in any application is defined by six discrete functions: separation, filtration, drainage, reinforcement, sealing and protection. Depending on the application the geotextile performs one or more of these functions simultaneously.

![Fig- 3.5 Functions of Geo Textiles](image)

The principle functions performed by geo-textiles are given below.

1. **Confinement/ Separation**: Confinement provides a media between the aggregate and the subsoil which absorbs the load in the form of tension and prevents change in alignment of the aggregate. Geo-textile economically helps the separation concept of keeping two dissimilar apart to maximize the physical attributes of each of those materials. (Fig 3.6)

![Fig-3.6) Concept of Separation function](image)
2. **Reinforcement:** The purpose of geo-textiles in the reinforcement function is to reinforce the weak subgrade or subsoil. It helps to strengthen the soil surface and to increase the soil's ability to stay put especially on the slopes. This function is important in wall embankments, foundations, and slopes. There is no problem of corrosion and there is minimum excavation behind the face of the wall when geo-textiles fabrics are laid.

3. **Filtration:** The purpose of geo-textiles with reference to drainage and filtration is simply to retain soil while allowing the passage of water. When geo-textiles are used as drains, the water flow is within the plane of the geo-textile itself i.e., they have lateral permeability. Adequate dimensional stability becomes an important factor to retain their thickness.

4. **Drainage:** Use of Geo-textiles in drainage has outstanding advantages. They eliminate the filter sand with the dual media backfill. In some cases, they eliminate the need for perforated pipes. They are used as a chimney drain or a drainage gallery in an earth dam as a drain behind wall or beneath railroad ballast, athletic fields, and for salt migration in arid areas.

5. **Protection:** Geo-textiles are used with geo-membranes to provide long term protection of geo-membranes used for applications such as landfills and waste containment from puncture or training by sharp stones or stress. Typical application areas are highway tunnels, landfills, water and sewage tunnels, railroads, and subway tunnels and reservoirs.

**10.6 Summary**

Most flame-retardant textiles are designed to reduce the ease of ignition and also reduce the flame propagation rates. Conventional textiles can be rendered flame retardant by chemical after-treatments as co-monomers in their structures or use of FR additives during extrusion. High performance fibres with inherently high
levels of flame and heat resistance require the synthesis of all aromatic structures, but these are expensive and used only when performance requirements justify cost.

Consumption of geo-textiles in roads & highways constitutes 85 percent of the total consumption. Then major players in India are Garware Wall Ropes for wovens Supreme Nonwovens for needle punch nonwovens. The market potential for geo-textiles is linked with the various infrastructure projects under implementation or likely to be taken up in future.

10. 7 Lesson End Activities
A) Explain in detail about functions and properties of Geo Textiles.

10.8 References

2. Techtextil Frankfurt - Trade fair for Technical Textiles and Nonwovens consulted 21 August 2008


4. “www.technicaltextiles.com”
LESSON 11

Medical textiles

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11.2 Fibres used

11.2.1 Commodity fibres

11.2.2 Speciality fibres

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11.0 Aims and Objectives

The aim of this chapter is to highlight the specific medical and surgical applications for which textile materials are currently used. A variety of products and their properties that make them suitable for these applications will be discussed.

11.1 Introduction

An important and growing part of the textile industry is the medical and related healthcare and hygiene sector. The extent of the growth is due to constant improvements and innovations in both textile technology and medical procedures. Combination of textile technology and medical sciences has resulted into a new field called medical textiles. New areas of application for medical textiles have been identified with the development of new fibers and manufacturing technologies for yarns and fabrics.

Textile materials and products that have been engineered to meet particular needs, are suitable for any medical and surgical application where a combination of strength, flexibility, and sometimes moisture and air permeability are required. Materials used include monofilament and multifilament yarns, woven, knitted, and nonwoven fabrics, and composite structures. The number of applications are huge and diverse, ranging from a single thread suture to the complex composite structures for bone replacement, and from the simple cleaning wipe to advanced barrier fabrics used in operating rooms. Although textile materials have been widely adopted in medical and surgical applications for many years, new uses are still being found. Research utilising new and existing fibres and fabric-forming techniques has led to the advancement of medical and surgical textiles. At the forefront of these developments are the fibre manufacturers who produce a variety of fibres whose properties govern the product and the ultimate application, whether the requirement is absorbency, tenacity flexibility, softness, or biodegradability.
Development in the field of textiles, either natural or manmade textiles, normally aimed at how they enhance the comfort to the users.

11.2 Fibres used

11.2.1 Commodity fibres

Fibres used in medicine and surgery may be classified depending on whether the materials from which they are made are natural or synthetic, biodegradable or nonbiodegradable. All fibres used in medical applications must be non-toxic, nonallergenic non-carcinogenic, and be able to be sterilised without imparting any change in the physical or chemical characteristics. Commonly used natural fibres are cotton and silk but also included are the regenerated cellulosic fibres (viscose rayon); these are widely used in nonimplantable materials and healthcare/hygiene products. A wide variety of products and specific applications utilise the unique characteristics that synthetic fibres exhibit. Commonly used synthetic materials include polyester, polyamide, polytetrafluoroethylene (PTFE), polypropylene, carbon, glass, and so on. The second classification relates to the extent of fibre biodegradability. Biodegradable fibres are those which are absorbed by the body within 2–3 months after implantation and include cotton, viscose rayon, polyamide, polyurethane, collagen, and alginate. Fibres that are slowly absorbed within the body and take more than 6 months to degrade are considered non biodegradable and include polyester (e.g. Dacron), polypropylene, PTFE and carbon.

11.2.2 Speciality fibres

A variety of natural polymers such as collagen, alginate, chitin, chitosan, and so on, have been found to be essential materials for modern wound dressings. Collagen, which is obtained from bovine skin, is a protein available either in fibre or hydrogel (gelatin) form. Collagen fibres, used as sutures, are as strong as silk and are biodegradable. The transparent hydrogel that is formed when collagen is
crosslinked in 5–10% aqueous solution, has a high oxygen permeability and can be processed into soft contact lenses. Calcium alginate fibres are produced from seaweed of the type Laminariae. The fibres possess healing properties, which have proved to be effective in the treatment of a wide variety of wounds, and dressings comprising calcium alginate are non-toxic, biodegradable and haemostatic. Chitin, a polysaccharide that is obtained from crab and shrimp shells, has excellent antithrombogenic characteristics, and can be absorbed by the body and promote healing. Chitin nonwoven fabrics used as artificial skin adhere to the body stimulating new skin formation which accelerates the healing rate and reduces pain. Treatment of chitin with alkali yields chitosan that can be spun into filaments of similar strength to viscose rayon. Chitosan is now being developed for slow drug-release membranes. Other fibres that have been developed include polycaprolactone (PCL) and polypropiolactone (PPL), which can be mixed with cellulosic fibres to produce highly flexible and inexpensive biodegradable nonwovens. Melt spun fibres made from lactic acid have similar strength and heat properties as nylon and are also biodegradable. Microbiocidal compositions that inhibit the growth of microorganisms can be applied on to natural fibres as coatings or incorporated directly into artificial fibres.

11.3 Materials Used For Medical Textiles

The textile materials especially for medical purpose can be termed as Bio materials. It can be defined as materials that are used in contact with tissue, blood, cells, protein and living substance. Bio materials include metals, ceramics, polymers, natural fibers. The following chart gives an overall idea of textile materials used for medical applications.
11.4 Characteristics of materials for medical use

The major requirements for biomedical polymers

- Non toxicity
- Nonallergenic response
- The ability to be sterilized
- Mechanical properties
- Strength
- Elasticity
- Durability
- Biocompatibility

As biomedical materials may be contaminated with bacteria, sterilization is important for biomedical polymers. The sterilization technique can be physical or chemical.

### 11.5 Textile Materials used in Medical applications

Textile Materials in the form of Fiber, yarn, Woven cloth, Knitted fabrics, Non wovens and composites are used in medical field according to their end uses. Hollow fibers are the latest developments in textile field for medical use.

![Fig 4.1 Constituent Element Of Medical Textile Product](image-url)
11.6 Classification Of Medical Textiles

These are the textile products for medical applications include materials as fibres, yarns, woven, knitted, nonwoven, PTFE felts and mesh etc. Depending upon the usage, they are classified as

a. Healthcare and Hygiene products
b. Extracorporeal devices
c. Implantable materials
d. Non-implantable materials

Medical textiles can be classified as follows:

11.7 End uses of Medical Textiles

The textile products according to the end uses in medical field may be classified in a broad manner as follows:
Medical textile Materials

- Surgical Textiles
- Non Implantable textiles
- Extra Corporeal Devices
- Health care & Hygiene
  - Sutures
  - Bandages
  - Artificial liver
  - Bedding
  - Vascular Grafts clothing
  - Wound Dressing
  - Artificial kidney
  - Protective
  - Fibrous Bone plates & Wipes
  - Plasters
  - Artificial Lung
  - Surgical Gowns

The Use of cloth in medical application is known since ages and the development of various man made fibers changed the scenario of application for medical purposes in various ways.

Fabrics

- Dressings
- Garments Woven / Knitted
- Cardio Vascular Grafts
- Other applications
  - Bandage Cloth
  - Stretch Terry Sheets
  - Musculo
  - Skeletal - Plasters, applications
  - Medical under Wear
  - Dental
  - Wound Dressings
  - Stretch Bandages

11.8 Fibres used for medical and healthcare application

Textiles materials that are used in medical applications include fibres, yarns, fabrics and composites. Depending upon the application, the major requirements of medical textiles are absorbency, tenacity, flexibility, softness and at times biostability or biodegradability. Fibres used in medical field may vary from natural
fibre such as cotton, silk, regenerated wood fluff (absorbent layer), to, manmade fibres like polyester, polyamide, polyethylene, glass etc. (Table 4.1)

**Table 4.1 The various applications of different fibre in medical field**

<table>
<thead>
<tr>
<th>Sr No.</th>
<th>Fibre</th>
<th>Application in medical field</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cotton</td>
<td>Surgical clothing gowns, Beddings, Sheets, Pillow cover, Uniforms, Surgical hosiery</td>
</tr>
<tr>
<td>2</td>
<td>Viscose</td>
<td>Caps, Masks, Wipes</td>
</tr>
<tr>
<td>3</td>
<td>Polyester</td>
<td>Gowns, Masks, Surgical cover drapes, Blankets, Coverstock</td>
</tr>
<tr>
<td>4</td>
<td>Polyamide</td>
<td>Surgical hosiery</td>
</tr>
<tr>
<td>5</td>
<td>Polypropylene</td>
<td>Protective clothing</td>
</tr>
<tr>
<td>6</td>
<td>Polyethylene</td>
<td>Surgical covers, Drapes</td>
</tr>
<tr>
<td>7</td>
<td>Glass</td>
<td>Caps mask</td>
</tr>
<tr>
<td>8</td>
<td>Elastomeric</td>
<td>Surgical hosiery</td>
</tr>
</tbody>
</table>

**11.9 Summary**

Materials used include monofilament and multifilament yarns, woven, knitted, and nonwoven fabrics, and composite structures. The number of applications is huge and diverse, ranging from a single thread suture to the complex composite structures for bone replacement, and from the simple cleaning wipe to advanced barrier fabrics used in operating rooms. These materials can be categorised into four separate and specialised areas of application.

**11.10 Lesson End Activities**

Discuss in detail about the Classification of Medical Textiles

**1.11 References**


2. Techtextil Frankfurt - Trade fair for Technical Textiles and Nonwovens consulted 21 August 2008


LESSON 12

Non-implantable materials

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12.0 Aims and objectives

This chapter deals with materials used for external applications.

12.1 Non-implantable materials - Introduction

These materials are used for external applications on the body and may or may not make contact with skin. They are made from co-polymer of two amino acids. They are employed as covering, absorbent, protective and supports for injured or diseased parts. Table 4.2 illustrates the range of textile materials employed within this category, the fibres used, and the principal method of manufacture.

12.2 Wound care

A number of wound dressing types are available for a variety of medical and surgical applications (Fig. 4.2). The functions of these materials are to provide protection against infection, absorb blood and exudate, promote healing and, in some instances, apply medication to the wound. Common wound dressings are composite materials consisting of an absorbent layer held between a wound contact layer and a flexible base material. The absorbent pad absorbs blood or liquids and provides a cushioning effect to protect the wound. The wound contact layer should prevent adherence of the dressing to the wound and be easily removed without disturbing new tissue growth. The base materials are normally coated with an acrylic adhesive to provide the means by which the dressing is applied to the wound.

Developments in coating technology have led to pressure sensitive adhesive coatings that contribute to wound dressing performance by becoming tacky at room temperature but remain dry and solvent free. The use of collagen, alginate, and chitin fibres has proved successful in many medical and surgical applications because they contribute significantly to the healing process. When alginate fibres are used for wound contact layers the interaction between the alginate and the exuding wound creates a sodium calcium alginate gel. The gel is hydrophilic,
permeable to oxygen, impermeable to bacteria, and contributes to the formation of new tissue. Other textile materials used for wound dressing applications include gauze, lint, and wadding.

Gauze is an open weave, absorbent fabric that when coated with paraffin wax is used for the treatment of burns and scalds. In surgical applications gauze serves as an absorbent material when used in pad form (swabs); yarns containing barium sulphate are incorporated so that the swab is X-ray detectable. Lint is a plain weave cotton fabric that is used as a protective dressing for first-aid and mild burn applications. Wadding is a highly absorbent material that is covered with a nonwoven fabric to prevent wound adhesion or fibre loss. It can be used as it is for absorbency or coated with paraffin wax for treatment to burns and scalds. Gauze with paraffin coating is easier to be removed from the wound after use.

12.3 Types.

12.3.1 PRIMARY WOUND DRESSINGS: Placed next to the wound surface. Nonwoven with a binder content of 60% and made from cellulose fabrics are being used.

12.3.2 ABSORBENT: Similar to wound pads used in surgery. Manufactured from well-bleached, carded and cleaned cotton fabrics

12.3.3 BANDAGES: These are narrow cotton or linen, plain weave cloth of low texture, either woven or knitted. Ex: Plaster of Paris Bandage, orthopaedic bandage, crepe Bandage.

12.3.4 PROTECTIVE EYE PAD: Scientifically shaped 2 ¾” x2 ¾ x to lit over the eye used in outpatient clinic and industrial medical department.

12.3.5 ADHESIVE TAPES: It is narrow, plain weave fabric having a coating of adhesive paste. It is used with other pads to conform them to the injury.
### Table 4.2 Non-implantable materials

<table>
<thead>
<tr>
<th>NON-IMPLANTABLE MEDICAL TEXTILES</th>
<th>Wound care absorbent pad</th>
<th>Wound contact layer base materials</th>
<th>Bandages simple inelastic/ Elastic light support Compression</th>
<th>Orthopedic</th>
<th>Plasters</th>
<th>Gauze’s</th>
<th>Lint</th>
<th>Wadding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cotton, viscose, silk, polyamide fiber viscoso, polyethylene fiber viscoso plastics film</td>
<td>Cotton, viscose polyamide fiber, Elastomeric-fiber yarns, cotton, viscose, electrometric fiber, electrometric fiber yarns</td>
<td>Woven, knitted, Non – woven Woven, knitted woven Knitted</td>
<td>Woven, non-woven</td>
<td>Knitted woven</td>
<td>Non woven</td>
<td>Woven, non-woven</td>
<td>Woven</td>
<td>Non-woven</td>
</tr>
</tbody>
</table>

**Fig 4.2** Wound dressings. (a) and (b) wound dressings, (c) wound dressing concept.
12.4 Bandages

Bandages are designed to perform a whole variety of specific functions depending upon the final medical requirement. They can be woven, knitted, or nonwoven and are either elastic or non-elastic. The most common application for bandages is to hold dressings in place over wounds. Such bandages include lightweight knitted or simple open weave fabrics made from cotton or viscose that are cut into strips then scoured, bleached, and sterilised. Elasticated yarns are incorporated into the fabric structure to impart support and conforming characteristics. Knitted bandages can be produced in tubular form in varying diameters on either warp or weft knitting machines. Woven light support bandages are used in the management of sprains or strains and the elasticated properties are obtained by weaving cotton crepe yarns that have a high twist content. Compression bandages are used for the treatment and prevention of deep vein thrombosis, leg ulceration, and varicose veins and are designed to exert a required amount of compression on the leg when applied at a constant tension. Compression bandages are classified by the amount of compression they can exert at the ankle and include extra-high, high, moderate, and light compression and can be either woven and contain cotton and elastomeric yarns or warp and weft knitted in both tubular or fully fashioned forms. (Fig 4.3)

Orthopaedic cushion bandages are used under plaster casts and compression bandages to provide padding and prevent discomfort. Nonwoven orthopaedic cushion bandages may be produced from either polyurethane foams, polyester, or polypropylene fibres and contain blends of natural or other synthetic fibres. Nonwoven bandages are lightly needle-punched to maintain bulk and loft.

Fig 4.3 Different types of bandages and their application. (a) Elasticated flat bandage, (b) tubular finger bandages, (c) tubular elasticated net garment, (d) tubular support bandages, (e) and (f) orthopaedic casting bandage, (g) pressure gloves, (h) pressure garment, (i) hip spica, (j) lumbar/abdominal support, (k) anti-embolism stockings.
Fig 4.3 Different types of bandages and their application.

(a) Elasticated flat bandage, (b) tubular finger bandages, (c) tubular elasticated net garment, (d) tubular support bandages, (e) and (f) orthopaedic casting bandage, (g) pressure gloves, (h) pressure garment, (i) hip spica, (j) lumbar/abdominal support, (k) anti-embolism stockings.
12.5 PRODUCTS USED FOR MEDICAL SURGICAL DRESSINGS

12.5.1. Wound care products:

A wound dressing is used for many purposes including protection against infection, absorption and exudation of blood and excess fluids, healing and application of medication ideally a wound dressing should be soft pliable pad the wound to protect it from further injury, be easily applied and removed, be sterile lint free and non – toxic. The wound dressing should not adhere to the wound allowing easy removal without disturbing new tissue growth. An absorbent cotton swab placed at the wound and tied with gauze forms the oldest form of wound dressing. However, this traditional method of wound covering is found to stick to the wound and does not provide a moist microclimate to the wound conducive to its faster healing.

The modern wound dressing is usually made of three layers-

(a) **Wound contact layer**: - It should not stick to the wound or cause maceration of the skin if the dressing is not changed. It can be woven, knitted or non-woven made from silk, viscose, polyamide or polyethylene.

(b) **Middle absorbing layer**: - If has to absorb blood or liquids while providing a cushioning effect to protect the wound. It is generally a non-woven composed of cotton or viscose.

(c) **Base Material**: It provides a means by which the dressing is applied to the wound. The material is coated with acrylic adhesive to hold the dressing in place, eliminates the need for bandage.

Because sterilization is a major concern for surgical dressings, nonwovens are considered. Nonwovens can be smooth and lint-free for the most part. This allows lesser chance for debris to be left at the wound. Nonwoven can be made softer and more absorbent by latex or thermal calendaring. For post–operative dressing, sophisticated nonwoven structures such as perforated films on absorbent base,
polymers/nonwoven welded laminate and metalised nonwoven are used. Polypropylene is promoted as most unwettable fibre, but it can also be quite wettable if converted to a fibrous web by melt blowing. In melt blowing a stream of molten polymer is subjected to blasts of air which form tiny fibrils that fall randomly as a web. This gives polypropylene a role of absorbable dressing’s material. Traditionally polypropylene is used in wound dressings in fibre or fabric form, coupled with absorbent material. Polysaccharide based dressings have increasingly become viable alternative to biologically incompatible and often problematic cotton and viscose gauzes used for wound dressings. Abundantly available alginates and their relatively ease of solubility in particular have been instrumental in developing these fibres and their applications as vehicles for drug delivering. The other polysaccharide is Branan ferulate that is gel spun. It is extracted from corn bran and has water soluble properties. This polysaccharide can infiltrate the biological activities in the body and hence accelerate wound healing.

12.5.2. Types of Bandages:

Bandages are designed to perform a whole variety of specific functions depending upon the final medical requirement. They can be woven, knitted, non–woven or composite in structure. They can be classified into various classes depending upon the function they serve as.

(a) Simple bandages – These are fixation bandages that can be elastic or inelastic in nature. Adhesive bandage, cohesive bandages and tubular bandages belong to this class. A simple non–elastic bandage is required to the dressing in proper place over the wound. One such bandage is simple, open weave cotton or viscose fabric cut into strips which have been scoured, bleached and sterilized. The problems of fraying in the plain woven bandage are overcome by use of non-fraying cotton leno bandage. The structure of bandage is more stable with crossing warp threads in the leno woven structures. These can be further coated with paraffin to prevent sticking
of the bandage to the wound. Further some ointment dressing can also be given along with paraffin to aid faster healing of the wound. Elasticated yarns are incorporated into bandages to form elastic bandage for providing support and comfort,

(b) **Light support bandages** – Woven light support bandages are used for sprains or strains. Elastic crepe bandages are used for sprained wrist or ankle support. The elasticated properties of these bandages are obtained by weaving cotton crepe yarns that have twist content. Similar properties can also be achieved by combination of two warp sets with normal and high tension. Stretch and recovery properties of these bandages apply sufficient tension to support the sprained limb.

(c) **Compression bandages** – Compression bandages are used to exert a certain compression for the treatment and prevention of deep vein thrombosis, leg ulceration and varicose veins. Depending upon the compression they provide, compression bandages are classified as light, moderate, high and extra – high compression bandages. They can be woven, warp or weft knitted from cotton and elastomeric yarns.

(d) **Orthopaedic bandages** – These bandages are used under plaster casts and compression bandages to provide padding and prevent discomfort. Non – woven orthopaedic cushion bandages are made from polyester or polypropylene and blends of natural and synthetic fibres. Polyurethane foam can also be used. Light needle punching gives bulk and left to the structure for greater cushioning effect.

**Two main types of fabrics are currently used for making pressure garments.**

- Firm elastic fabric containing elastane yarns is used for making pressure garments. This fabric is usually warp knitted.
- Tubigrip is a circular weft knitted cotton fabric with rubber yarn laid – in, tubular lengths of different diameters. Since these garments are to be continuously worn, the seams should be strong enough to resist strong
transverse forces. Also the seam should have high extensibility and recovery to allow for body movement. In the various suitable fabric structures and garment constructions, the following have been established:

- Fabrics with low coefficient of friction are more comfortable than those with high coefficient of friction and are less likely to cause maceration. Hence, powernet, sleeknit fabrics are found to be more suitable as compared to weft or warp knit fabrics. However, the deviation in the coefficient of friction was found to be quite high for almost all fabrics. The face side of all fabrics was rougher than the reverse side. Hence an optimum construction is to be arrived at for comfort and recovery of the patient.

12.5.3. Gauze

Gauze and paraffin coated gauzes are the most commonly used dressing. Most gauze is made up from cotton in the form of a loose plain weave. The typical yarn density per inch is 12 – 19 for warp and 8 –15 for the weft. 44sNe warp and 54sNe carded weft yarn is generally used. Gauze is mostly used as a direct dressing for wounds or may be used in internal pads and general swabbing applications. The burns and skin grafts have their dressings changed frequently and the difficulty with this gauze is that its fibres stick to the wound. The removal is not only painful, but also destroys the regenerating tissues. This leads to delay in healing process and also leaves scars behind. The problems associated with the traditional woven cotton gauze are as below:

- A possibility of loose fibres getting caught in the wound
- A large adherence surface
- Irritation or mechanical injuring of the wound when the dressing is changed.
- Prolonged time of wound healing
- Paraffin – coated gauze is usually multi – layered, is a little easier to remove, but it does not rapidly absorb the wound liquids. Also this being a petroleum based coating can liquefy at body temperature and introduced foreign matter into the wound. It is used to treat burns and scalds.
12.5.4. PLASTER:

Plasters are made up of three layers – 1) Plaster fabrics, 2) adhesive and 3) – wound pad. A simple plaster cast consists of gauze impregnated with plaster of Paris. The modern plaster fabric is made from spun bonded nonwovens of cotton, viscose, polyester or glass fibre. The adhesive used for plaster fabric is acrylic that doesn’t stick to the skin. The cushioning wound pad is made from knitted viscose fabric impregnated with an antiseptic. The highly absorbent wound pad helps in rapid absorption of secretion from the wound.

12.5.5. Others Dressings:

The other surgical dressings include wadding and lint. Wadding is an absorbent material to prevent adhesion to wound or fibre loss, it is covered with a non – woven fabric. Lint is a plain weave cotton fabric that is frequently used in treatment of mild burns.

12.6 Summary

Form the above depiction of the various available for medical purposes, it can be seen that there are a wide variety of fibres used for the purpose. The technology of manufacture also ranges from woven, knitted, non-woven and composites. The improvements in the non-implantable products have been directed towards faster healing of the wound and minimising discomfort to the patient. The uses of haemostatic fibres like polysaccharides help faster wound healing. The present day wound covering doesn’t stick to the wound and hence prevents its maceration.

12.7 References


2. Techtextil Frankfurt - Trade fair for Technical Textiles and Nonwovens consulted 21 August 2008


LESSON 13

Extracorporeal devices

Contents

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13.1 Introduction

13.2 Extracorporeal devices

   13.2.1 Artificial kidney
   13.2.2 Artificial liver
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   13.2.4 Mechanical lung

13.3 Function of device

13.4 Summary

13.5 Lesson End Activity

13.6 References
13.0 Aims and Objectives

This chapter deals with the function and performance of extracorporeal devices benefit from fibre and textile technology.

13.1 Introduction

Extracorporeal devices are mechanical organs that are used for blood purification and include the artificial kidney (dialyser), the artificial liver, and the mechanical lung. The function and performance of these devices benefit from fibre and textile technology. The function of the artificial kidney is achieved by circulating the blood through a membrane, which may be either a flat sheet or a bundle of hollow regenerated cellulose fibres in the form of cellophane that retain the unwanted waste materials. Multilayer filters composed of numerous layers of needlepunched fabrics with varying densities may also be used and are designed rapidly and efficiently to remove the waste materials. The artificial liver utilizes hollow fibres or membranes similar to those used for the artificial kidney to perform their function. The microporous membranes of the mechanical lung possess high permeability to gases but low permeability to liquids and functions in the same manner as the natural lung allowing oxygen to come into contact with the patient’s blood.

13.2 EXTRA CORPOREAL DEVICES:

Extra corporal devices are mechanical organs that are used for blood purification and include the artificial kidney, the artificial liver and the mechanical lung.

13.2.1. ARTIFICIAL KIDNEY:

- Tiny instrument, about the size of a two-cell flashlight.
- Made with hollow hair sized cellulose fibres or hollow polyester fibre slightly larger than capillary vessels.
- Fabric which is used to remove waste products from patient’s blood.
As the blood flows through the kidney it is cleaned by passing through thousands of tiny filters. The waste materials go through the ureter and are stored in the bladder as urine. Dialysis machine hollow viscose or hollow polyester fiber, to stimulate functions of the real kidney to remove the waste products from the patients blood (Fig 4.4 Artificial Kidney).

![Fig 4.4 Artificial Kidney]

**13.2.2. ARTIFICIAL LIVER:**

- Made with hollow viscose to separate and dispose patients plasma and supply fresh plasma. (Fig 4.5 Artificial Liver)

One of the liver’s most important functions is to break down food and convert it into energy. When energy is required in an emergency the liver rapidly converts its store of glycogen back into glucose ready for the body to use. The liver also helps the body to get rid of waste products. Waste products that are not excreted by the kidneys are removed from the blood by the liver. Artificial livers are made from hollow viscose, to filter patients’ blood and to help remove the waste products.
13.2.3 ARTIFICIAL HEART:

- An 8 – ounce plastic pump lined with dacom velour to reduce damage to blood and is a chambered apparatus about the size of a human heart. (Fig 4.6 Artificial Heart).

- Silastic backing makes the fabric imperious to emerging gas that is not desirable in the blood.

13.2.4 MECHANICAL LUNG:

- Made with hollow polypropylene fibre or a hollow silicone membrane
• Used to remove carbon-di-oxide from patient’s blood and supply fresh oxygen.

The human respiratory system carries oxygen to the lungs, where it enters the bloodstream to travel throughout the body. This system also carries the "used" air, which is mostly carbon dioxide, back to the lungs so that it can be breathed out. Hollow polypropylene fibre and hollow silicon membrane are used to make mechanical lungs. The functions the mechanical lung performs are to remove carbon dioxide from the patients’ blood and to supply fresh oxygen. (Fig 4.7 Mechanical Lung).

Fig 4.7 Mechanical Lung

13.3 Function of device

Table 4.3 illustrates the function of each device and the materials used in their manufacture

<table>
<thead>
<tr>
<th>Product application</th>
<th>Fibre type</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artificial kidney patients</td>
<td>Hollow viscose, hollow Polyester</td>
<td>Remove waste products from blood</td>
</tr>
<tr>
<td>Artificial liver plasma,</td>
<td>Hollow viscose</td>
<td>Separate and dispose patients and supply fresh plasma</td>
</tr>
<tr>
<td>Mechanical lung patients</td>
<td>Hollow polypropylene, hollow silicone, silicone membrane</td>
<td>Remove carbon dioxide from blood and supply fresh blood</td>
</tr>
</tbody>
</table>
13.4 Summary

Extracorporeal devices are mechanical organs that are used for blood purification and include the artificial kidney (dialyser), the artificial liver, and the mechanical lung (blood oxygenator). Blood purification is an effective therapy for incurables such as end-stage renal failure. It is used to correct the abnormality of blood quality and quantity in treating sickness. Use of an artificial organ is a life saving treatment which can restore the spring that does not function, and a dynamic balance can be obtained by organ transplantation to recover health again.

13.5 Lesson End Activities

Discuss in detail About the Extra corporeal Devices and its Advanced functions

13.6 References


2. Techtextil Frankfurt - Trade fair for Technical Textiles and Nonwovens consulted 21 August 2008


LESSON 14

Implantable Materials

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14.2 Sutures
14.3 Soft-tissue implants
14.4 Orthopaedic implants
14.5 Cardiovascular implants
14.6 Hernia repair
14.7 Hard tissue implants
14.8 Nerve guidance channel
14.9 Biomaterials in ophthalmology
14.10 Dental biomaterials
14.11 Tissue engineering
14.12 Healthcare & hygienic products
14.12.1 Operating theatre
14.13 Summary
14.14 Lesson End Activities
14.15 References
14.0 Aims and Objectives

This Chapter clearly gives the Types and important of implantable materials of Medical Textiles.

14.1 Implantable materials – Introduction

These materials are used in effecting repair to the body whether it be wound closure (sutures) or replacement surgery (vascular grafts, artificial ligaments, etc.). Table 4.4 illustrates the range of specific products employed within this category with the type of materials and methods of manufacture. Biocompatibility is of prime importance if the textile material is to be accepted by the body and four key factors will determine how the body reacts to the implant. These are as follows:

The most important factor is porosity which determines the rate at which human tissue will grow and encapsulate the implant.

1. Small circular fibres are better encapsulated with human tissue than larger fibres with irregular cross-sections.

2. Toxic substances must not be released by the fibre polymer, and the fibres should be free from surface contaminants such as lubricants and sizing agents.

3. The properties of the polymer will influence the success of the implantation in terms of its biodegradability. Polyamide is the most reactive material losing its overall strength after only two years as a result of biodegradation. PTFE is the least reactive with polypropylene and polyester in between.
Sutures for wound closure are either monofilament or multifilament threads that are categorised as either biodegradable or nonbiodegradable. Biodegradable sutures are used mainly for internal wound closures and nonbiodegradable sutures are used to close exposed wounds and are removed when the wound is sufficiently healed.

14.3 Soft-tissue implants

The strength and flexibility characteristics of textile materials make them particularly suitable for soft-tissue implants. A number of surgical applications utilise these characteristics for the replacement of tendons, ligaments, and cartilage in both reconstructive and corrective surgery. Artificial tendons are woven or braided porous meshes or tapes surrounded by a silicone sheath. During implantation the natural tendon can be looped through the artificial tendon and then sutured to itself in order to connect the muscle to the bone. Textile materials used to replace damaged knee ligaments (anterior cruciate ligaments) should not only possess biocompatibility properties but must also have the physical characteristics
needed for such a demanding application. There are two types of cartilage found within the body, each performing different tasks. Hyaline cartilage is hard and dense and found where rigidity is needed, in contrast, elastic cartilage is more flexible and provides protective cushioning.

14.4 Orthopaedic implants

Orthopaedic implants are those materials that are used for hard tissue applications to replace bones and joints. Also included in this category are fixation plates that are implanted to stabilise fractured bones. Fibre-reinforced composite materials may be designed with the required high structural strength and biocompatibility properties needed for these applications and are now replacing metal implants for artificial joints and bones. To promote tissue ingrowth around the implant a nonwoven mat made from graphite and PTFE (e.g. Teflon) is used, which acts as an interface between the implant and the adjacent hard and soft tissue.

14.5 Cardiovascular implants

Vascular grafts are used in surgery to replace damaged thick arteries or veins 6mm, 8mm, or 1 cm in diameter. Commercially available vascular grafts are produced from polyester (e.g. Dacron) or PTFE (e.g. Teflon) with either woven or knitted structures. Straight or branched grafts are possible by using either weft or warp knitting technology. Polyester vascular grafts can be heat set into a cramped configuration that improves the handling characteristics. During implantation the surgeon can bend and adjust the length of the graft, which, owing to the crimp, allows the graft to retain its circular cross-section. Knitted vascular grafts have a porous structure which allows the graft to become encapsulated with new tissue but the porosity can be disadvantageous since blood leakage (haemorrhage) can occur through the interstices directly after implantation. This effect can be reduced by using woven grafts but the lower porosity of these grafts hinders tissue in growth; in addition, woven grafts are also generally stiffer than the knitted equivalents.
The first artificial vascular graft was produced from polyamide fibre in 1956. Polytetrafluoroethylene (PTFE) fibre soon replaced polyamide and then polyester fibre was introduced. The implants are made from variety of synthetic materials. The main fibres include polyester, PTFE. Polypropylene, polyacrylonitrile. However polyester and PTFE are most common vascular prosthesis currently available.

The major requirements of a good vascular graft include

- Non-fraying
- Flexibility
- Durability
- Biocompatibility
- Stability to sterilization
- Resistance to bacteria/viruses

Knitted polyester vascular prosthesis has become the standard vascular graft for replacement of arterial vessels of 6mm and greater. However while this has many features required by a surgeon, such as ease of handling, saturability, and conformability, it has one major disadvantage; it is not blood-tight. The knitted structure, by its nature, is porous, which is what is required for rapid incorporation by tissue in growth from the host. At the time of surgery the surgeon has to percolate the grafted using some of the patients own blood, which is taken before heparinisation- a time consuming process which can be difficult to carry out satisfactorily. This prevents its use when patients are heparinised such as cardiopulmonary bypass and in emergency aneurismal surgery when percolating is not possible.

14.6 Hernia repair

Meshes find use in hernia repair and abdominal wall replacement, where mechanical strength and fixation are very important. Fibres can be woven or knitted
into a mesh with each side designed with a specific porosity and texture to optimize its long term function. Polypropylene mesh is an example of fabrics used in hernia repair. Polypropylene is resistant to infection and is anti allergenic. Gore-Tex soft issue patch, which is used in hernia repair, is made of expanded PTFE.

### 14.7 Hard tissue implants

Hard tissue compatible materials must have excellent mechanical properties compatible to hard tissue. Typical characteristics of polymers related to hard tissue replacements are good processability, chemical stability and bio compatibility. Applications include artificial bone, bone cement and artificial joints. Orthopedic implants are used to replace bones and joints, and fixation plates are used to stabilize fractured bones. Textile structural composites are replacing metal implants for this purpose. A non-woven fibrous mat made of graphite and Teflon is used around the implant to promote tissue growth.

### 14.8 Nerve guidance channel

A developing area of research is the development of nerve guidance channels that are used to bridge the damaged nerve endings and facilitate the passage of molecules secreted by the nerve and bar fibrous tissue from infiltrating the area thus preventing repair. An innovation is the use of electrically conducting polymers such as polypyrrole to promote nerve regeneration by allowing a locally applied electrical stimulus. It is a blossoming field of textile research, since the nerve guidance channel may be a single continuous hollow tube, or it may be a hollow tube comprised of fibres.

### 14.9 Biomaterials in ophthalmology

Natural and synthetic hydro gels physically resemble the eye tissue and hence have been used in ophthalmology as soft corneal lenses. Soft contact lenses are made of transparent hydro gel with high oxygen permeability. Hard contact lenses are made of poly (methyl methacrylate) and cellulose acetate butyrate. Flexible contact lenses are made from silicone rubber.
14.10 Dental biomaterials

Major requirements of dental polymers include translucence or transparency, stability, good resilience and abrasion resistance, insolubility in oral fluids, non-toxicity, relatively high softening point and easy fabrication and repair. The most widely used polymer for dental use is poly (methyl methacrylate) (PMMA) and its derivatives. Other materials for denture base polymers are polysulfone and polyether polysulfone.

14.11 Tissue engineering

Tissue engineering is one of the fastest growing research fields in modern medicine. Tissue engineering unites cell and molecular biologists, clinicians and surgeons, bioreactors and biomaterial specialists. The spectrum ranges from the multiplication of simple skin cells for burnt victims to the regeneration of entire tissues and organs from the patient’s own cells. Tissue engineering is the replacement of damaged tissues or organs with biologically based systems. Tissue engineering seeks to create functional substitutes for damaged tissues by combining engineering principles with those of life sciences.

A small number of healthy cells are taken from a patient and allowed to multiply in the laboratory culture. These are then combined with an absorbable polymer that may be shaped to mirror the target organ or tissue. This may be fabricated in a number of ways including a three dimensional arrangement of fibres into a scaffold. The scaffold material provides structural integrity and mechanical stability in the short term. The cells are added to the scaffold and allowed to adhere and grow on the plastic material. The cell/scaffold is implanted into the patient and as the cells develop and form tissue, the plastic breaks down and is removed from the body. Thus the fundamental application of a scaffold is to grow new tissues/organs by culturing isolated cells on templates. Textile structures form an important class of porous scaffolds.
Embroidery technology is being widely used for medical textiles and tissue engineering. Embroideries complement the field of technology and medical textiles in a unique way since they combine very high architectural variability with the freedom of adjusting the mechanical properties in a wide range and matching it with the mechanical properties of the host tissue.


An important area of textile is the healthcare and hygiene sector among other medical applications. The range of products available for healthcare and hygiene is vast, but they are typically used either in the operating theatre or in the hospital wards for hygienic, care and safety of the staff and patients. They could be washable or disposable.

14.12.1. Operating theatre

This includes surgeon’s gown, caps and mask, patient drapes and cover cloth of various sizes.

1. Surgical gown: -

   It is essential that environment of operating theatre is clean and strict control of infection is maintained. A possible source of infection to the patient is the pollutant particle shed by the nursing staff, which carries bacteria. Surgical gowns should act as barrier to prevent release of pollutant particles into air. Traditional surgical gowns are woven cotton goods that not only allow the release of particles from the surgeons but also a source of contamination generating high levels of dust (lint). Disposable non woven surgical gowns have adopted to prevent these sources of contamination to patients and are often composite materials of nonwoven and polyethylene films.

2. Surgical masks:- They should have higher filter capacity, high level of air permeability, lightweight and nonallergic.
3. **Surgical caps**: These are made from nonwoven materials based on cellulose.

4. **Surgical drapes and covercloths**: These are used to cover patients or to cover working areas around patients. It should be completely impermeable to bacterial and also absorbent to body perspiration and secretion from wound.

Table 4.5 illustrates the range of specific products employed within this category with the type of materials and methods of manufacture

**Table 4.5 Healthcare and hygiene products : Product application**

<table>
<thead>
<tr>
<th>Healthcare and hygiene products : Product application</th>
<th>Fibre type</th>
<th>Fabric type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surgical clothing gowns</td>
<td>Cotton, Polyester, Viscose rayon, Polypropylene</td>
<td>Nonwoven, Woven</td>
</tr>
<tr>
<td>Caps masks</td>
<td>Viscose rayon, Polyester, Viscose, Glass</td>
<td>Nonwoven</td>
</tr>
<tr>
<td>Surgical covers</td>
<td>Polyester, Polyethylene</td>
<td>Nonwoven or Woven</td>
</tr>
<tr>
<td>Drapes cloth</td>
<td>Polyester, Polyethylene</td>
<td>Nonwoven or Woven</td>
</tr>
<tr>
<td>Beddings, Blankets, Sheets</td>
<td>Cotton, Polyester</td>
<td>Woven, Knitted</td>
</tr>
<tr>
<td>Pillow covers</td>
<td>Cotton</td>
<td>Woven, Knitted</td>
</tr>
<tr>
<td>Clothing uniforms</td>
<td>Cotton, Polyester</td>
<td>Woven</td>
</tr>
<tr>
<td>Protective clothing</td>
<td>Polyester, Polypropylene</td>
<td>Nonwoven</td>
</tr>
<tr>
<td>Incontinence Diaper sheet</td>
<td>Polyester, Polypropylene</td>
<td>Nonwoven</td>
</tr>
<tr>
<td>Coverstock</td>
<td>Wood fluff</td>
<td>Nonwoven</td>
</tr>
<tr>
<td>Absorbent layer</td>
<td>Superabsorbents</td>
<td>Nonwoven</td>
</tr>
<tr>
<td>Outer layer</td>
<td>Polyethylene fibre</td>
<td>Nonwoven</td>
</tr>
<tr>
<td>Cloths/ Wipes</td>
<td>Viscose rayon</td>
<td>Nonwoven</td>
</tr>
<tr>
<td>Surgical hosiery</td>
<td>Polyamide, Polyester, Cotton, Elastomeric yarns</td>
<td>Nonwoven Knitted</td>
</tr>
</tbody>
</table>
14.13 Summary

Textiles are developing into interdisciplinary high tech products with interesting chances on the market. Owing to the greater co-ordination among textile technologists and medical researchers, textile products for surgical procedures are being developed indigenously. Textile structures in implantation are identified by structure, material composition, behavior of fibre surface and degradation. Developments of biologically friendly and predictable absorbable fibres will be of great interest, both as suture materials and as the basis of tissue engineering constructs. Improved absorbable fibres will be of great interest, both as suture materials and as the basis of tissue engineering constructs. Improved absorbable fibres will be necessary as new sterilization technologies are introduced to meet evolving environmental specifications. Advances in textile technology will clearly bring a new and improved group of biomedical textiles.

14.14 Lesson End Activities

Discuss in detail about Implantable Materials and its applications in medical field Discuss in detail about health Care and Hygienic Products

14.15 References


LESSON 15

Recent Developments in Medical Textiles

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15.0 Aims and Objectives

This Chapter deals with the recent Developments in Medical Textiles

15.1 Sutures and Ligaments

15.1.1. Surgical Sutures

Fibres are also used as sutures in surgery. Sutures are sterile filaments which are used to hold tissues together until they heal adequately or to join tissues implanted prosthetic devices. Sutures are either braided or monofilament and are mostly used to close wounds and approximate tissues. The textile materials have generated considerable interest in medical technology where materials in the form of monofilament, multifilament, woven and nonwoven structures are being used for bio and medical applications. The major requirement of the textile materials is the bioreceptivity and biocompatibility at the application site in human being. The medical textile group in the department of textile technology at IIT Delhi has been working on the development of antimicrobial biocompatible sutures and scaffolds for tissue engineering. Because of the lack of proper post-surgical care, the bacterial infection in stitched wounds is prevalent in many of the cases. The development of an antimicrobial suture based on nylon and polypropylene monofilaments is being pursued in the medical textile group. The surface functionalization of the suture is carried out in such a way that the inherent characteristics, such as mechanical and knot strength of the suture are not affected.
Both the high energy gamma radiation and the plasma irradiation are being used to activate the materials for the surface functionalization. An antimicrobial drug is immobilized on the suture surface which subsequently is released slowly into tissues surrounding the stitch and prevents the microbial invasion. The tissue compatibility of these sutures is excellent and no adverse reaction has been observed against these sutures.

15.1.2. Barbed sutures

Recently a bi-directional barbed suture has been developed which obviates the necessity to tie a knot. It has ability to put tension in the tissues with less suture slippage in the wound, as well as to more evenly distribute the holding forces thereby reducing tissue distortion. The barbed suture with a steeper cutangle and a median cut depth have a higher tissue holding capacity than those with a moderate cutangle and a nominal cut depth.
15.1.3. Gelatin coated sutures

Gelatin coated sutures are having a superior handling characteristics. The gelatin coating given to the suture material improves the surface smoothness and reduces the fraying characteristics. It can be obtained by means of treating the suture with that of aqueous solution of gelatin to coat the suture and it is made to have a contact with that of fixative agent to crosslink gelatin. This process includes the step of contacting the coated suture with that of buffer solution and heats it to 50\(^{\circ}\)C for a particular period of time interval. Usually heating can be carried out for about 1-20hrs. Sometimes plasticizers can be incorporated into the gelatin solution. The plasticisers used are triethyl citrate, glycerin or other polyhydric alcohols. The plasticiser used is mainly to enhance the benefits of the gelatin coating. The fixative solution used in the process is a cross linking agent. The preferred cross linking agent is preferably a dialdehyde such as glyoxal, which may be used alone or in conjunction with formaldehyde or other aldehyde.

15.1.4. Catgut Polymer Composite Suture

The catgut material is bio-adsorbed and it will cause fewer tissue reactions. This can be reduced by producing catgut polymer composite suture. The catgut has the ability to degrade in the living tissue through the enzyme action. To avoid this degradation the material can be coated with a protective polymer sheet. The polymer used should have the ability to shield the collagen core from the enzymatic activity and it should be degradable by hydrolysis. The polyester reinforced by urethane and urea links are used as the suitable polymers. The coating can be carried out by passing the catgut filament through the polymer solution and then allow for hardening.

15. 2. Dressing Materials

15. 2.1. Calcium Alginate Fibres

The raw material for the production of this fibre is alginic acid, a compound obtained from the marine brown algae. It posses a variety of properties, including
the ability to stabilize viscous suspension, to form film layers, and to turn into gels. When the dressing made of this fibre is applied to wound, the reverse ion exchange take place. This fibre is placed on the wound in dry state and begin to absorb the exudates. The calcium ions are then gradually exchange against sodium ions that are present in the blood and wound exudates.

The fibre absorbs large amounts of secretion, starts to swell and in the presence turns into a moist gel that fills and securely covers the wound. Both the extent and the rate of gel formation depend on the available amount of secretions. The more exudates present the more rapid gel formation occur. Addition of excess sodium ion causes further dissolution of the gel, so that calcium alginate fibres remaining in the wound can be resorbed. if necessary, but mayh also without problems be rinsed out with physiological saline solution.

15.2.2. Sorbalgon

It is a supple, non-woven dressing made from high quality calcium alginate fibre with excellent gel forming properties. The dressing offers number of practical therapeutic advantages for wound healing over any other commonly uses textiles.

![Sorbafon Wound dressing](image1.jpg)
A Sorbalgon dressing absorbs approximately 10ml exudates per gram dry weight and thus provides with an absorption capacity. They in addition differ from textile dressings with respect to applied mechanism of absorption. It takes wound secretion directly into the fibres i.e., using intra capillary forces. Germs and detritus are retained with in the gel structure as the fibre swell during subsequent gelatinization. The wound is thus effectively cleansed and a considerable reduction of micro organism can be attained.

Intra capillary absorption of exudates along with swelling and gelatinization however not affect the fundamental permeability of the dressing for moisture. The gel remains permeable to gas so that sorbalgon represents a dressing material that facilitates a permeable moist wound treatment, in contrast to an occlusive moist wound treatment with hydro colloids. This especially important in infected wounds where air penetration reduces the risk of dangerous infection with anaerobic bacteria.

It is not an woven, rather consist of supple, fibrous mat that has excellent shaping and packing capabilities. When the fibres swell during gelatinization and finally fill out the wound, a close contact to the wound is generated even in the almost in accessible areas, absorption of wounds exudates thus being ensured even at the deepest point of the wound. Despite it high absorption capacities it prevents the wound from drying out without difficulties. The gel like consistency of
sorbafgon acts as a moist dressing during the whole therapy and helps to regulate physiological secretion. This creates a favourable micro climate for wound healing promoting granulation and epithelialisation.

15.2.3. Thin film dressing

An improved thin film dressing with an absorbant border has been developed. The dressing as a superior ability to rapidly take up and absorb body fluid and to prevent dressing leakage and wound maceration, while retaining the conformability of a thin layer and a support layer. The support layer is adhered to the occlusive layer and a layer by any suitable bonding means such as adhesive heat or ultrasonics.

![Fig.2.3. Thin film dressing](image)

15.3. Super Absorbable Polymer

Super absorbents are swellable cross linked polymer, which have the ability to absorb and store 400-600 times their own weight of aqueous liquid by forming a gel. The liquid is then retained and not released, even under pressure. The absorption rate of the polymers differs according to their mechanism used for preparation. SAP cannot dissolve because of their 3-D polymeric network structure. Of the many different types of polymers, only a few can be made into useful fibers. This is because a polymer must meet certain requirements before it can be successfully and efficiently converted into a fibrous product. Some of the most important of these requirements are:
• Polymer chains should be linear, long, and flexible.
• Side groups should be simple, small, or polar.
• Polymers should be dissolvable or meltable for extrusion.
• Chains should be capable of being oriented and crystallized.

15.3.1 Water absorbent Polymer

Water absorbent polymers are known as hydro-gel, water crystal, super absorbent polymers etc., are simply a type of plastic that possesses some unique water absorbing qualities. This is due to the presence of sodium or potassium molecules that form bridges between the long hydro carbon chains. These bridges are known as cross linking, which enables the polymer to form into a huge single super molecule, including its ability to degrade in the environment and breakdown into simpler molecules, and hold significant amount of water. When water comes in contact with super absorbent an electrical repulsion takes with in the particles. When this happens, water is drawn into the particles resulting in swelling of each particle. At maximum absorption capacity each particle will expand to over 30 times its original volume. When water evaporates it shrinks, returning to unswollen state.

15.3.2 Sodium acrylate polymer

Most SAP currently used are sodium acrylate based polymers having 3-D network like molecular structure formed by joining millions of identical units of acrylic acid. Which has been substantially neutralized with sodium hydroxide and enables SAP to absorb water or water based solution into the spaces in the molecular network, forming a gel and locking up liquid.

15.3.3 Polyacrylate

PAC can function as both an antiscalant and a dispersant. Polymeric antiscalant are generally low molecular weight polymers, whereas polymeric dispersant consist of higher molecular weight. Dispersant do not stop the formation
of scale, but instead keeps the scale particles suspended in the buld fluid by imparting a negative charge to the particles. These negatively charged ones repel one another and aggregation into large particles of scale. PAC comprises about 5% of many laundry detergent formulations because of its dispersant properties. A cross linked form of sodium salt of polyacrylic acid is used as super absorbent material in diapers and other hygienic products. Cross linked PAC has a great affinity for swollen in a compatible solvent. Because of the presence of charged groups on the polymer chain the polymer will be highly expanded in aqueous solution.

15.4. Spider Silk

Modified goat milk will contain web protein. A goat that produces spider's web protein is about to revolutionist the materials industry. It is Stronger and more flexible than steel, spider silk offers a lightweight alternative to carbon fibre. Up to now it has been impossible to produce "spider fibre" on a commercial scale. Unlike silk worms, spiders are too anti-social to farm successfully. Now a Canadian company claims to be on the verge of producing unlimited quantities of spider silk - in goat's milk. Using techniques similar to those used to produce Dolly the sheep, scientists at Nexia Biotechnologies in Quebec have bred goats with spider genes. New kids on the block Called Webster and Pete, the worlds first "web kids" cannot dangle from the ceiling, nor do they have a taste for flies. In fact they look like any other goat. But when they mate, it is hoped they will sire nanny goats that produce milk that contains the spider silk protein. This "silk milk" will be used to produce a web-like material called Biosteel. Naturally occurring spider silk is widely recognized as the strongest, toughest fibre known to man.
Its tensile strength is greater than steel and it is 25 percent lighter than synthetic, petroleum-based polymers. These qualities will allow Biosteel to be used in applications where strength and lightness are essential, such as aircraft, racing vehicles and bullet-proof clothing. Kind to humans another advantage of spider silk is that it is compatible with the human body. That means Biosteel could be used for strong, tough artificial tendons, ligaments and limbs. The new material could also be used to help tissue repair, wound healing and to create super-thin, biodegradable sutures for eye-or neurosurgery.

15.5. Antimicrobial Textile

Antibacterial fibre is produced by entrapping the metal ion with a cation exchange fibre having a sulphonic or carboxyl group through an ion exchange reaction reaction. The antibacterial metal ion is silver or silver in combination with either copper or zinc. The great advantage of this material is that those are not to react with tissue. Flexible products such as sponges and textile wites, which have protracted antimicrobial effect. The wipes are impregnated with biocides by spraying, dipping or soaking for use in medical field.

15.5.1 ACTICOAT dressing

It provides broader and faster protection against fungal infection than conventional antimicrobial products. The dressings are layered with mono crystalline silver known to have antimicrobial and antifungal properties, creating a protective barrier as silver ions are consumed. Acticoat has the faster kill rate and was effective against more fungal species. The product can be applied to variety of wounds including graft and donor sites and surgical wounds.

15.5.2. Antimicrobial Wound Dressing

Kerlix AMD is pure cotton treated with anecia's polyhexamethylene biguanidine agent. These antimicrobial agents resist bacterial growth with in the dressing as well as reducing bacterial penetration through the product. Wound
covering, is made of a hydrophobic bacteria-adsorbing material which comprises the antimicrobial active component which is not released into wounds, it is preferably made of mixture of hydrophobic fibres and fibre comprising antimicrobial property.

15.6. Compression Bandages

The basic function of bandages is compression, retention and support. This is obtained by properties intrinsic to the component and further enhanced and re-enforced supportively by the process of weaving and finishing relevant to the required end use. The regulation of the blood flow and prevention of swelling is closely interlinked with this property and there by enhancing improved healing healing process. It provides necessary support to restrict movement and speed up the healing process.

15.7. TEXTILE PERFORMANCE PRINCIPLES

Textile materials for medical applications typically have specific performance requirements relating to strength, stiffness, abrasion resistance, and mechanical Patency

**Strength:** Among the many factors affecting a fabric's strength (fiber type, molecular orientation, crystallinity) is the variability in properties especially elongation of its constituent elements. Usually, the greater the variability in elongation at break, the lesser the strength. Products requiring high strength (e.g., artificial ligaments) must incorporate elements whose properties range within a narrow limit.

**Stiffness:** Bending stiffness which governs the handling, comfort, and conformability of a fabric is a critical parameter in a number of medical applications. A low value is usually desirable. For example, a suture with low bending stiffness requires fewer throws to tie a secure knot and has higher knot strength. The most important factors affecting bending stiffness are the shape of the
fiber and the modulus, linear density, and specific gravity of the material. Generally, the higher the denier or the modulus or the lower the specific gravity, the higher the bending stiffness. For example, polyester has a higher modulus than that of nylon, and will result in a stiffer material.

Polypropylene, with a lower density than nylon, should have a higher stiffness, assuming all other factors are equal. In addition, a trilobal or tubular structure produces a stiffer product than does a solid circular structure of the same area or linear density. Monofilament materials are much stiffer than multifilament. With all other factors constant, the bending stiffness of a monofilament product such as a suture of denier T will be roughly n times greater than a multifilament structure with n filaments of denier T/n each. The use of multifilament yarns and/or fine-denier fibers in the yarn produces a more flexible and supple end product. Knot efficiency—the ratio of the tensile strength of knotted to unknotted thread is affected by elongation at break and bending stiffness. Most often, the greater the elongation, or the lower the stiffness, the greater the knot efficiency.

**Abrasion Resistance:** Whenever fibers, yarns, or fabrics rub against themselves or other structures, abrasion resistance assumes an important role. A high value is usually desirable, especially in applications such as artificial ligaments or tendons. The abrasion resistance of a yarn is influenced by several factors:

- The denier of the fiber (the lower the denier, the lower the resistance).
- The amount of twist in the yarn that binds the fibers together (the lower the twist, the lower the resistance).
- The orientation of molecules in the fibers (the higher the orientation, usually the lower the resistance).
- The surface coefficient of friction (the higher the coefficient, the lower the resistance).
Therefore, one can conclude that micro denier fibers, low-twist yarns, rough surfaces, and highly oriented materials generally exhibit low abrasion resistance. However, coating a bundle of fibers with a low-friction polymer can enhance its resistance to abrasion.

**Mechanical Patency:** Implanted products that must bear loads over the long term and maintain their dimensional integrity require a high degree of mechanical Patency that is, the ability to resist permanent change in physical size, shape, structure, and properties. The factors that contribute to mechanical Patency include:

- The chemical, biological, and stress environment into which the implant is placed.
- The nonreactivity of the polymer with the environment.
- The size of the fibers.
- The structure of the fabric (consolidated structures made of highly interlocked woven material or warp knits provide an advantage).
- Perhaps most importantly, the viscoelastic properties of the material.

Thus, material selection is extremely critical for products such as ligament prostheses that must continue to bear loads. The material specified must be able to resist the elongation or growth that may occur as a result of stress relaxation during each cycle of operation in the body. If no such material is available, then biological tissues will need to be integrated into the assemblage to provide partial support of the load and contribute to the product's long-term Patency.

**15.8 Summary**

Thus the application of textile in high performance and specialized fields are increasing day by day. There will be an increasing role for medical textile in future. Thus the textile will be used in all extra corporal devices, external or implanted materials, healthcare and hygienic products. Textile materials continue to serve an important function in the development of a range of medical and surgical products.
The introduction of new materials, the improvement in production techniques and fiber properties, and the use of more accurate and comprehensive testing have all had significant influence on advancing fibers and fabrics for medical applications. As more is understood about medical textiles, there is every reason to believe that a host of valuable and innovative products will emerge.

15.9 Lesson End Activities

Discuss in detail about the Recent Advancements In Medical Textiles

15.10 References

1. www.textilelearner.com
2. www.technicaltextiles.com
LESSON 16

Textiles for Survival

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16.0 Aims and Objectives

This Chapter deals with textiles for protection at different situations and at different Climatic Conditions

16.1 Introduction

The main emphasis here is on the preservation of human life. The clothing itself provides the protection rather than an individual textile material, but textile fabric is the critical element in all protective clothing and other protective textile products. As the safety barrier between the wearer and the source of potential injury, it is the characteristics of the fabric that will determine the degree of injury suffered by the victim of an accident. There has been a large increase in the hazards to which humans are exposed as a result of developments in technology in the workplace and on the battlefield, for example. The need to protect against these agencies is paralleled by the desire to increase protection against natural forces and elements. The dangers are often so specialised that no single type of clothing will be adequate for work outside the normal routine.

16.2 The Types of Protective Garment

- Tents
- Helmets
- Gloves (for hand and arm protection)
- Sleeping bags
- Survival bags and suits
- Heat-resistant garments
- Turnout coats
- Ballistic-resistant vests

Biological and chemical protective clothing
- Blast-proof vests
- Molten metal protective clothing
- Flotation vests
- Life rafts
- Fire Protective Clothing

Military protective apparel including antihypothermia suits and ducted warm air garments
- Submarine survival suits
- Immersion suits and dive skins
16.3 The Types Of Occupation And Activities For Which Protective Garments And Other Products Are Made

<table>
<thead>
<tr>
<th>Police</th>
<th>• Firefighters</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Security guards</td>
<td>• Water sports</td>
</tr>
<tr>
<td>• Mountaineering</td>
<td>• Winter sports</td>
</tr>
<tr>
<td>• Caving</td>
<td>• Commercial fishing and diving</td>
</tr>
<tr>
<td>• Climbing</td>
<td>• Offshore oil and gas rig workers</td>
</tr>
<tr>
<td>• Skiing</td>
<td>• Healthcare</td>
</tr>
<tr>
<td>• Aircrew (both military and civil)</td>
<td>• Racing drivers</td>
</tr>
<tr>
<td>• Soldiers</td>
<td>• Astronauts</td>
</tr>
<tr>
<td>• Foundry and glass workers</td>
<td>• Coal Mining</td>
</tr>
</tbody>
</table>

16.4 Types of Hazards

All clothing and other textile products provides some protection. It is a matter of timescale which decides the degree and type of protection required. Hazards to be survived can be divided into two main categories:

- **Short Term Survival**: Accidents - these involve short term exposure to extreme conditions.

- **Long Term Survival**: Exposure to hazardous environments- this involves long term exposure to milder conditions than those normally associated with accidents or disasters.

16.4.1 Short Term protection includes protection from

<table>
<thead>
<tr>
<th>Fire</th>
<th>Hypothermia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explosions including smoke and toxic fumes</td>
<td>• Molten metal</td>
</tr>
<tr>
<td>Attack by weapons of various types, e.g. ballistic projectiles, nuclear, chemical, and biological</td>
<td>• Chemical reagents</td>
</tr>
<tr>
<td></td>
<td>• Toxic Vapours</td>
</tr>
<tr>
<td></td>
<td>• drowning</td>
</tr>
</tbody>
</table>
16.4.2 Long term protection includes protection from

- Foul weather
- Extreme cold
- Rain
- Wind
- Chemical reagents
- Nuclear reagents
- High temperatures
- Molten metal splashes
- Microbes and dust.

16.5 Classification of Protective Textiles

Textiles for Survival (Personal protective textiles) can be classified as

1. Fire Protection
2. Heat and Cold Protection
3. Mechanical Impact Protection
4. Biological Protection
5. Electrical Protection
6. Radiation Protection

16.5.1 Fire Protection

It would have been impossible for humans to survive the primitive age without the use of fire.

However, fire could be dangerous. Fire disasters occur frequently resulting in nonfatal and fatal casualties. In most of the fire accidents most frequently ignited materials were the textiles, especially upholstery and furnishings. It should however, be noted that the main cause of death in a fire accident is not direct burning but suffocation due to the smoke and toxic gases released during burning.
Human tissue (skin) is very sensitive to heat. It is reported that, at 45°C, the sensation of pain is experienced, and at 72°C, the skin is completely burnt. The purpose of fire protective clothing is to reduce the rate of heating of human skin in order to provide the wearer enough time to react and escape. The time that a wearer stays in flammable circumstances and the amount of heat flux produced are important factors for designing the protective stratagem.

Protective clothing designed for flame protection must have two functions, i.e., be flame resistant and form a heat barrier. The latter is a very important factor if the wearer needs to stay near flames for a fairly long time. In fact, the danger of burning lies with the parts of body not covered by clothing. Using inherently flame retardant materials such as Kevlar, nomex, applying a flame retardant finish, or a combination of these methods are commonly used to make clothing and textiles flame retardant.

16.5.2 Heat and Cold Protection

Basic metabolisms occurring inside our body generate heat that can be life-saving or fatal depending on the atmosphere and circumstances that we are in.

Normally, human bodies are comfortable to heat in a very narrow temperature range of 28-30°C.

In summer, we need the heat from our metabolic activity to be transferred outside as soon as possible, while in winter especially in extremely cold conditions, we must find ways to prevent the loss of heat from our body. Heat stress, defined as the situation where the body cannot dissipate its excess heat to the environment is a serious problem especially during physical working.

Basically, heat is transferred either as conductive, convective, radiant heat or a combination of these modes depending on the source of heat, the atmosphere.
re the heat-absorbing material is in and the protection available against heat. Any heat transfer will have at least one of these modes and heat protection is the method to decrease or increase the rate of heat transfer. For protection from conductive heat, the fabric thickness and density are the major considerations, since air trapped between fibres has the lowest thermal conductivity of all materials. For protection from convective heat, the flame retardant properties of the fabric are important. As for radiant heat protection, metallized fabrics such as allumized fabrics are preferred, since metallized fabrics have high surface reflection and also electrical conductivity. Ideal clothing for protection from heat transfer are fabrics with thermoregulating or temperature adaptable properties. Phase change materials (PCM) are one such example that can absorb heat and change to a high energy phase in a hot environment, but can reverse the process to release heat in cold situations.

Nowadays, a heat resistant woven fabric with an optional aluminized backing is disclosed. The fabric is particularly suited for heat resistant garments intended to resist radiant heat and heavy molten metal splashes in the temperature range of 2700°F to 3000°F. The preferred fabric has corespun yarns with a flame and high heat resistant filament core covered by a layer of flame retardant fibres consisting of at least 35% melamine.

Specifically designed protective clothing is necessary to survive and operate in temperatures below 30°C. Such low temperature conditions are aggravated in the presence of wind, rain or snow leading to cold stress that may be fatal.

Clothing designed to protect from cold is usually multi-layered, consisting of a non-absorbent inner layer, a middle insulating layer capable of trapping air but transferring moisture, and an outer layer that is impermeable to wind and water.
16.5.3 Mechanical Impact Protection:

Ballistic protection is generally required for soldiers, policemen and general security personnel. Ballistic protection involves protection of body and eyes against projectiles of various shapes, sizes and impact velocities. Historically, ballistic protection devices were made from metals and were too heavy to wear. Textile materials provide the same level of ballistic protection as metals but have relatively lower weight and are therefore comfortable to wear.

Highperformance clothing designed for ballistic protection dissipates the energy of the fragment/shrapnel by stretching and breaking the yarns and transferring the energy from the impact at the crossover points of yarns. The ballistic protection of a material depends on its ability to absorb energy locally and on the efficiency and speed of transferring the absorbed energy. Fibres like Kevlar, Ultra high modulus polyethylene are used for ballistic protection.

An Advanced design bomb suit and helmet that offers highest ballistic protection in the world. The suit is constructed from Kevlar with an outer antistatic cover of 50/50 Nomex/Kevlar and comprises of a jacket, crotchless trousers, groin cup and rigid ballistic panels. The suit itself is light weight in comparison with other suits, with frond protection plates and this maneuverability reduces operator fatigue and increases operator effectiveness.

16.5.4 Biological Protection:

Most natural textile fibres such as wool, silk and cellulosics are subject to biological degradation by bacteria, dermatophytic fungi, etc. Textiles designed for biological protection have two functions: first, protecting the wearer from being attacked by bacteria, yeast, dermatophytic fungi, and other related microorganisms which cause aesthetic, hygienic or medical problems.
Secondly, protecting the textile itself from biodeterioration caused by mold, mildew and rot-producing fungi and from being digested by insects and other pests.

Fabrics designed for microbial protection should act as barriers to bacteria and other microorganisms that are believed to be transferred from one location to another by carriers such as dust or liquids. Films generally have high barrier properties against microbes and chemicals. However, films when used with fabrics to provide antimicrobial properties make fabrics impermeable to airflow leading to heat stress and other physiological problems that may be fatal. New membrane structures called ‘permSelect’ or breathable membranes have been developed that can prevent airflow through the fabric layer but have high water vapour permeability. Using these membranes with fabrics provides effective protection from hazardous material or microbes without causing heat stress.

16.5.5 Electrical Protection

16.5.5.1 Electromagnetic Protection

Protection from electromagnetic sources is required because people who work close to power lines and electrical equipment have the possibility of being exposed to electric shocks and acute flammability hazards. Generally, rubber gloves, zdielectric hard hats and boots, sleeve protectors, conductive Faraday cage garments, rubber blankets and non-conductive sticks are used for electromagnetic protection.

16.5.5.2 Electrostatic Protection:

Electrostatic charges accumulate easily on ordinary textile materials, especially in dry conditions. Charges once accumulated are difficult to dissipate. The dissipation of an electrostatic charge occurs through shocks and sparks which
can be hazardous in a flammable atmosphere. Therefore, the presence of a static charge in textiles can be a major hazard in explosives, papers, printing, electronics, plastics, and the photographic industry. The basic principle of making an antistatic garment is to decrease the electrical resistivity or the chance of electrostatic accumulation in a fabric.

### 16.5.6 Radiation Protection

#### 16.5.6.1 Nuclear Radiation Protection

Special clothing to prevent exposure to radiation is needed for people working in radioactive environments. Goggles, respiratory masks, gloves, and lightweight protective clothing may be adequate for protection from some weak alpha, beta rays. Woven cotton, polyester/cotton or nylon/polyester fabrics with a twill or sateen weave are the major types of fabric forms used for nuclear protective clothing.

#### 16.5.6.2 UV Radiation Protection

An appropriate amount of sunbath promotes the circulation of blood, invigorates the metabolism and improves resistance to various pathogens. 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. Many people love sunbathing, thereby extending the long term risk to their health. Persons working in the open atmosphere are also prone to keratose, the precursor of skin cancer. Australia has high levels of solar UV radiation, mainly because of its geographical position; New Zealand, USA, Switzerland, Norway, Scotland, Britain and Scandinavian countries also have high melanoma rates.
16.6 Summary

Textiles are more and more developing into interdisciplinary high-tech products with interesting changes in the market. Medical Textile Competence Centers are being established to make the most of knowledge, expertise and existing collaboration with medical researchers, microbiologists, physiologists and textile scientists. Each country has its own regulations and standards for medical textiles. As medical procedures continue to develop, the demand for textile materials is bound to grow. As society becomes more safety conscious and has to survive in more arduous conditions in order to provide raw materials, energy and to push the frontiers of knowledge further, there is a need to provide a safe working environment. The modern textile industry plays a part in providing this environment by developing and supplying sophisticated clothing and other products. The degree of sophistication and specialisation is increasing and many products are very highly specified requiring a complex combination of properties. Nonwoven fabric is now used extensively in survival products by combining the appropriate fibre content and appropriate method of production with other materials, such as chemical finishes, laminates and coatings.

16.7 Lesson end Activities

Discuss about Textiles for Survival

16.8 References

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LESSON 17

Smart textiles and Intelligent Textiles

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17.0 Aims and Objectives

The aim of this chapter is to describe the analysis on how ‘Smart’, ‘intelligent’ or ‘active’ materials and textiles are being incorporated in the healthcare sector to aid diagnostics, recording and transmitting of bio-physiological signals or ambulatory tele-monitoring of the body vitals, by encompassing the core concepts of smart materials under the light of the recent developments and projects.

17.1 Introduction

Humans are close to textiles more than anything, and certainly we carry it most, other than anything. The last few decades have shown enormous growth in the development of wireless communication technologies, nanoengineering, information technologies, and miniaturization of electronic devices. These developments draw the attention of researchers to envisage the significant characteristics of these advancements to the belongings with whom we are most close to. Researchers are now evaluating the new ideas and possibilities to functionalize this ‘natural necessity feature of human beings’ with emerging technologies into different arrays of human life especially in the Medical and Healthcare management - as mobile monitoring of health care, protection from life risk factors, life style management, rehabilitation and into other facilitation of our lives, by Hybridizing the Smart or Intelligent Technology in Textiles.

Intelligent textiles represent the next generation of fibres, fabrics and articles produced from them. They can be described as textile materials that think for themselves, for example through the incorporation of electronic devices or smart materials. Many intelligent textiles already feature in advanced types of clothing, principally for protection and safety and for added fashion or convenience.

One of the main reasons for the rapid development of intelligent textiles is the important investment made by the military industry. This is because they are used in different projects such as extreme winter condition jackets or uniforms that change colour so as to improve camouflage effects. Nowadays, the military industry
has become aware of the advantage of sharing knowledge with the various industrial sectors, because with joint collaboration far better results can be obtained through teamwork.

Intelligent textiles provide ample evidence of the potential and enormous wealth of opportunities still to be realised in the textile industry in the fashion and clothing sector, as well as in the technical textiles sector. Moreover, these developments will be the result of active collaboration between people from a whole variety of backgrounds and disciplines: engineering, science, design, process development, and business and marketing. Our very day-to-day lives will, within the next few years, be significantly regulated by intelligent devices and many of these devices will be in textiles and clothing.

17.2 Smart Textiles and Intelligent Textiles

17.2.1 What are smart textiles?

Smart textiles are defined as textiles that can sense and react to environmental conditions or stimuli from mechanical, thermal, chemical, electrical or magnetic sources. According to functional activity smart textiles can be classified in three categories:

Smart textiles are materials that are developed and/or designed for a special need or application where a very high performance is required. Smart textiles may combine fabrics with glass, ceramics, metal, or carbon to produce lightweight hybrids with incredible properties. Sophisticated finishes, such as silicone coatings and holographic laminates, transform color, texture, and even form.

Smart Textiles Materials should have the following

- Optimized moisture management
- Better heat flow control
- Improved thermal insulation
♦ Breathability
♦ High performance in hazard protection
♦ Environmental friendly
♦ Increased abrasion resistance
♦ Health control and healing aid
♦ Body control
♦ Easy care
♦ High aesthetic appeal
♦ Enhanced handle
♦ High/low visibility

Fig- 5.1 Properties of Smart Textiles

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Fig- 5. 2 Action of Smart textiles
17.2.2 Classification of Smart Textiles

♣ **Passive smart materials**, which can only sense the environmental condition or stimuli,

♣ **Active smart materials**, which sense and react to the condition or stimuli,

♣ **Very smart materials**, which can sense, react and adapt themselves accordingly, and

♣ **Intelligent materials**, which are those capable of responding or activated to perform a function in a manual or pre-programmed manner

17.2.2.1 **Passive Smart materials**: The first generations of smart textiles, which can only sense the environmental conditions or stimulus, are called Passive Smart Textiles.

17.2.2.2 **Active Smart materials**: The second generation has both actuators and sensors. The actuators act upon the detected signal either directly or from a central control unit. Active smart textiles are shape memory, chameleonic, water-resistant and vapour permeable (hydrophilic/non porous), heat storage, thermo regulated, vapour absorbing, heat evolving fabric and electrically heated suits.

17.2.2.3 **Very Smart materials**: Very smart textiles are the third generation of smart textiles, which can sense, react and adopt themselves to environmental conditions or stimuli. A very smart or intelligent textile essentially consists of a unit, which works like the brain, with cognition, reasoning and activating capacities. The production of very smart textiles is now a reality after a successful marriage of traditional textiles and clothing technology with other branches of science like material science, structural mechanics, sensor and actuator technology, advance processing technology, communication, artificial intelligence, biology, etc.
17.2.2.4 Intelligent materials: New fibre and textile materials, and miniaturised electronic components make the preparation of smart textiles possible, in order to create truly usable smart clothes. These intelligent clothes are worn like ordinary clothing, providing help in various situations according to the designed applications.

17.3 Application of Smart and Intelligent Textiles

17.3.1 Shape Memory Materials

These are the materials which are stable at two or more states of temperature. In these different temperature states, they have the potential to assume different shapes, when their transformation temperatures have been reached. There are another type of shape memory materials which are basically composed of electro active polymers (EAPs), which can change shape in response to electrical stimuli. Shape changing fibers, yarns and fabrics are also produced with the help of suitably designed stimuli sensitive copolymers that respond quickly and reversibly to small changes in temperature and pH. These materials are capable of providing sensing functions. EAPs can provide a range of basic actuator mechanisms, force and displacement levels. Also yarns made from Shape Memory Polymers are widely used to make fabrics which possess different properties below and above the temperature at which it is activated. (Fig 5.3.a,b,c).

17.3.1.1 Principle of shape memory materials

There are two types of Shape Memory Materials.

1. The first classes are materials stable at two or more temperature states. In these different temperature states, they have the potential to assume different shapes, when their transformation temperatures have been reached. This technology has been pioneered by the UK Defence Clothing and Textiles Agency.

2. The other types of shape memory materials are the electroactive polymers, which can change shape in response to electrical stimuli. In the last decade there have been significant developments in electroactive polymers (EAPs) to produce
substantial change in size or shape and force generation for actuation mechanisms in a wide range of applications. In contrast to many conventional actuation systems, many types of EAPs are also capable of providing sensing functions. EAPs can provide a range of basic actuator mechanisms, force and displacement levels.

17.3.2 Chromic Materials
Other types of intelligent textiles are those, which change their colour reversibly according to external environmental conditions, for this reason they are also called chameleon fibres. Chromic materials are the general term referring to materials which radiate the colour, erase the colour or just change it because its induction caused by the external stimulus, as "Chromic" is a suffix that means colour. Therefore we can classify chromic materials depending on the stimulus affecting them.

*Photochromic*: external stimulus is light.
*Thermochromic*: external stimulus is heat.
*Electrochromic*: external stimulus is electricity.
*Piezorochromic*: external stimulus is pressure.
*Solvatechromic*: external stimulus is liquid or gas.

17.3.2.1 Materials and applications in Smart Textiles
Photocromic materials are generally reversible unstable organic molecules that change of molecular configuration with the influence of a special
radiation. The molecular arrangement also perturbs the absorption spectra of the molecule and in consequence its colour. The applications in textile are intended to the fashion area and only a few for the solar protection.

Thermochromic materials are those whose colour changes as a result of reaction to heat, especially through the application of thermochromic dyes whose colours change at particular temperatures. Two types of thermochromic systems that have been used successfully in textiles are: the liquid crystal type and the molecular rearrangement type. In both cases, the dyes are entrapped in microcapsules and applied to garment fabric like a pigment in a resin binder.

The most important types of liquid crystal for thermochromic systems are the so-called cholesteric types, where adjacent molecules are arranged so that they form helices. Thermochromism results from the selective reflection of light by the liquid crystal. The wavelength of the light reflected is governed by the refractive index of the liquid crystal and by the pitch of the helical arrangement of its molecules. Since the length of the pitch varies with temperature, the wavelength of the reflected light is also altered, and colour changes occur. An alternative means of inducing thermochromism is by means of a rearrangement of the molecular structure of a dye, as a result of a change in temperature.

The most common types of dye, which exhibit thermochromism through molecular rearrangement, are the spirolactones, although other types have also been identified. A colourless dye precursor and a colour developer are both dissolved in an organic solvent. The solution is then microencapsulated and is solid at lower temperatures. Upon heating, the system becomes coloured or loses colour at the melting point of the mixture. The reverse change occurs at this temperature if the mixture is then cooled. However, although thermochromism through molecular rearrangement in dyes has aroused a degree of commercial interest, the overall mechanism underlying the changes in colour is far from clear-cut and is still very much open to speculation.
17.3.3 The Sensory Baby Vest

The sensory baby vest is equipped with sensors that enable the constant monitoring of vital functions such as heart, lungs, skin and body temperature which can be used in the early detection and monitoring of heart and circulatory illness. It is hoped to use this vest to prevent cot death and other life-threatening situations in babies. The sensors are attached in a way that they do not pinch or disturb the baby when it is sleeping.

17.3.4 Reflective Technology

A technology has been created to convert proprietary materials into miniature reflectors that, when imbedded into fabric by the millions, reflect oncoming light, such as automobile headlights, in a way that illuminates the full silhouette of a person, bicycle or any other object. The reflectors are smaller than a grain of sand and finer than a human hair. They can be imbedded into the weave of almost any fabric. The end result is a fabric that remains soft to the touch and retains its function and fashion. During the day, the treated fabrics are indistinguishable from untreated fabrics.

17.3.5 Thermal Performance Enhancing Fabric

Hydroweave® provides extraordinary protection against heat, actively cooling the wearer through evaporation, and helping to maintain the core body temperature in high-heat environments. It is a three-layer design that combines special hydrophilic and hydrophobic fibers into a fibrous batting core. The batting is sandwiched between a breathable outer shell fabric and a thermally conductive, inner lining.

17.3.6 Flash Dried Fabrics

3XDRY® finishing technology was developed to provide a treatment that retains water resistance on the face of a fabric and increases wicking on the
back. The two functions are truly separated within the fabric, which remains highly breathable.

3XDRY® uses a special process to apply a hydrophilic finish on the back that wicks perspiration away from the body, spreading it over the fabric, and evaporating it quickly on the face. It also has a hydrophobic finish that repels water and dirt.

The fabric dries six to eight times faster than untreated fabric. 3XDRY® also incorporates a hygienic treatment to control odor.

17.3.7 Protective Flex

The new “smart response” fiber is proving to enhance passenger safety because of its unique energy-management properties. Securus™ is the first in a new category of polyester copolymer fibers being developed for managed-load applications. It combines polyethylene terephthalate (PET), which provides restraining properties, and polycaprolactone (PCL), which provides flexibility and cushioning. During a collision, Securus fiber seat belts protect the passenger in a three-step process: holding the passenger securely in place; elongating and cushioning the body as it absorbs the energy of its forward motion; and restraining and limiting that motion.

17.3.8 Thermal Sensitivity

SmartSkin™ hydrogel is a new technology involving a hydrophilic / hydrophobic copolymer, which is embedded in an open-cell foam layer bonded to the inside of a closed-cell neoprene layer in a composite wet suit fabric with nylon or nylon/Lycra® outer and inner layers. SmartSkin absorbs cold water that has flushed into the suit and expands to close openings at the hands, feet and neck, preventing more water from entering. Water trapped inside the suit heats up upon body contact. If the water warms up past a transition temperature determined by the
proportion of hydrophilic to hydrophobic components, the hydrogel releases water and contracts, allowing more water to flush through the suit. This passive system constantly regulates the internal temperature — no batteries or mechanical action are needed.

17.3.9 Phase Change Materials

Outlast® temperature-regulating technology effectively recycles body heat, keeping the wearer’s skin temperature within a comfortable range. Outlast was first developed for use in astronaut uniforms and as a protection for instruments against the severe temperature changes in outer space. The technology is now used in apparel, footwear, equipment and linens. Outlast is a paraffin wax compound that is micro-encapsulated into thousands of miniscule, impenetrable, hard shells. It recycles body heat by absorbing, storing, distributing and releasing heat on a continuous basis, keeping the wearer’s skin temperature within a comfortable range.

17.3.10 Wearable Technology

Clothing is currently supposed to have more functions than just certain climatic protection and good look. These functions can be referred to wearing and durability properties. A revolutionary new property of clothing is to exchange information. Clothing is now capable of recording, analyzing, storing, sending and displaying data, which is a new dimension if intelligent systems. Clothing can extend the user’s senses, augment the view of reality and provide useful information anytime and anywhere the user goes.

Application fields are:

- Working: displaying helpful data, connecting to the internet or to other people
- Medicine: monitoring health parameters
- Security: detecting danger, calling for help
17.3.11 Bio-mimics

Fibers have been developed that can quickly change their color, hue, depth of shade or optical transparency by application of an electrical or magnetic field could have applications in coatings, additives or stand alone fibers. Varying the electrical or magnetic field changes the optical properties of certain oligomeric and molecular moieties by altering their absorption coefficients in the visible spectrum as a result of changes in their molecular structure.

The change in color is due to the absence of specific wavelengths of light; it varies due to structural changes with the application of an electromagnetic field.

17.3.12 Tissue Engineering

Tissue engineering uses living cells and their extracellular components with textile-based biomaterial scaffolds to develop biological tissues for human body repair. The scaffolds provide support for cellular attachment and subsequent controlled proliferation into predefined tissue shapes. Such an engineering approach would solve the severe shortage problem associated with organ transplants. Textile-based scaffolds have been used for such tissue engineering purposes. The most frequently used textile-based scaffolds are non-woven structures, preferably of biodegradable materials, because then there is no permanent foreign-body tissue reaction toward the scaffolds and, over time, there is more volume space into which the engineered tissue can grow.
17.3.13 Detection of Vital Signals

Sensatex is developing a SmartShirt™ System specifically for the protection of public safety personnel, namely firefighters, police officers, and rescue teams. Used in conjunction with a wireless-enabled radio system, the SmartShirt™ can monitor the health and safety of public safety personnel/victims trapped in a building or underneath rubble with the ability to detect the exact location of victims through positioning capability. In addition to monitoring vital signs, the system can detect the extent of falls, and the presence of hazardous gases; it also offers two-way voice communication.

17.3.14 Global Positioning System (GPS)

Textiles integrated with sensory devices driven by a GPS can detect a user’s exact location anytime and in any weather. Interactive electronic textiles with integrated GPS enhance safety by quickly locating the wearer and allowing the suit to be heated. GPS can provide added safety for firefighters and emergency personnel by facilitating offsite monitoring of vitals. It is a Wireless, hands-free communication. Fabric area networks (FANs) enable electronic devices to exchange digital information, power, and control signals within the user’s personal space and remote locations. FANs use wireless RF communication links using currents measuring one nanoamp; these currents can transmit data at speed equivalent to a 2400-baud modem. (Fig-5.5).

Fig 5.5 Global Positioning System (GPS)
17.3.15 Cooling – Warming System

A new high-tech vest has been developed to help keep soldiers, firefighters, etc. alive in the searing temperatures of deserts, mines and major fires. The vest uses a personal cooling system (PCS), which is based on heat pipe technology which works by collecting body heat (fig 5.6) through vapor filled cavities in a vest worn on the body. The heat is then transferred via a flexible heat pipe to the atmosphere with the help of an evaporative cooling heat exchanger. The heat exchanger is similar in principle to a bush fridge where a cold cloth is put over a container and the temperature drop caused by evaporation keeps the food cool. It is designed to be worn by personnel underneath NBC (nuclear, biological and chemical) clothing, body armor and other protective clothing.

17.3.16 Warning Signaling

A combination of sensors and small flexible light emitting displays (FLED) can receive and respond to stimuli from the body, enabling a warning signal to be displayed or sent. The sensors can monitor EKG, heart rate, respiration, temperature, and pulse oximetry readings. If vital signals were below critical values, a FLED would automatically display, for example, a flashing red light, and a wireless communication system could send a distress signal to a remote location.

17.3.17 Self Cleaning Fabrics

Far from being a dream, nanotechnology has proved successful in many of the emerging businesses during this time including textiles and fashion industries. Out of some of the most exciting area of challenges and opportunities in this field such as development of carbon nano tube based "super carbon fiber", solar cells to store energy for
electro textiles, Quantum dots to create the shades which are not achievable by normal techniques etc., self cleaning fabric is of a major interest for garment and fashion related industries

Nano size particles of Titanium Dioxide, Zinc Oxide etc, possess photo catalytic and oxidizing ability which is exploited in making self cleaning fabrics. The fabric is coated with a thin layer of titanium dioxide particles that measure only 20 nanometers in diameter. When this semi-conductive layer is exposed to light photons with energy equal to or greater than the band gap of the titanium dioxide excite electrons up to the conduction band. The excited electrons within the crystal structure react with oxygen atoms in the air, creating free-radical oxygen. These oxygen atoms are powerful oxidizing agents, which can break down most carbon-based compounds through oxidation-reduction reactions. In these reactions, the organic compounds (i.e. dirt, pollutants, and micro organisms) are broken down into substances such as carbon dioxide and water. Since the titanium dioxide only acts as a catalyst to the reactions, it is never used up. This allows the coating to continue breaking down stains over and over.

7.3.18 Electrical conductive fabrics

Electrical conductive fabrics are manufactured by using metals and polymers. However, the same materials can be used for the both conductivity (thermal and electric). Fabrics are manufactured by direct use of conductive yarns (Fig: 5.8a, 8b, 8c) in order to provide a versatile combination of physical and electrical properties for a variety of demanding applications. The yarn could constitute metal such as silver, copper, etc... or conductive polymer such as
polythiophene, polyaniline, and their derivatives. These conductive fabrics satisfy very well all the important properties that a garment should have. They are lightweight, durable, flexible (Fig: 8d) and cost competitive and they are able to be crimped and soldered and subjected to textile processing without any problems.

17.3.19 Smart Bra

One of the best examples of conductive polymer coated fabric for improving comfort properties of women is the Smart Bra (Fig- 5.9), an Australian invention. Wallace et. al at the University of Wollongong, have developed a bra that will change its properties in response to breast movement. This bra will provide better support to active women when they are in action. The smart bra will tighten and loosen its straps, or stiffen and relax its cups to restrict breast motion, preventing breast pain and sag. The fabrics can alter their elasticity in response to information about how much strain they are under. The smart bra will be capable of instantly tightening and loosening its straps or stiffening cups when it detects excessive movement. These conductive fabrics have also found wide application in the field of making sports garments. Also, these conductive textile materials can be used as heated clothes for extreme winter conditions or heated diving suits to resist very cold water. Another main applications of conductive textile materials are their uses for the power supply of electronic devices used in the garments called “SMART SHIRT” which is manufactured for use in combat conditions, for fire-fighters where the sensor that monitors oxygen or hazardous gas levels and other sensors monitor respiration rate and body temperature, etc.

17.3.20 Smart textiles from Electronics

Today, the interaction of human individuals with electronic devices demands specific user skills. In this context, the concept of smart clothes promises greater user-friendliness and more efficient services cost level of important microelectronic functions is sufficiently low 5 and enabling key technologies are
mature enough to exploit this vision. An interconnect and packaging technology is demonstrated using a polyester narrow fabric with several warp threads replaced by copper wires which are coated with silver and polyester. Six of those parallel conductive warp threads form one lead. For the electrical connections, the coating of the wires and the surrounding textile material is removed by laser treatment forming holes.

17.4 Summary

♦ The range and variety of high performance textiles that have been developed to meet present and future requirements are now considerable

♦ Textile materials are now combined, modified and tailored in ways far beyond the performance limit of fibers drawn from the silkworm cocoon, grown in the fields, or spun from the fleece of animals

♦ And the future promises even more!

♦ What new capacities should we expect as a result of future developments in smart/interactive textiles?

♦ They should include tera and nano scale magnitudes, complexity, cognition and holism

♦ The new capability of tera scale takes us three orders of magnitude beyond the present general-purpose and generally accessible computing capabilities. The technology of nano scale takes us three orders of magnitude below the size of most of today’s human-made devices
♦ It allows to arrange molecules inexpensively in most of the ways permitted by physical laws

♦ It lets make supercomputers that fit on the head of a fiber, and fleets of medical nano-robots smaller than a human cell to eliminate cancers, infections, clogged arteries

♦ Fibers are relentlessly replacing traditional materials in many more applications. From super-absorbent diapers, to artificial organs, to construction materials for moon-based space stations

♦ Clothing with its own senses and brain are integrated with Global Positioning Systems (GPS) and mobile phone technology to provide the position of the wearer and directions

♦ Biological tissues and organs, like ears and noses, are grown from textile scaffolds made from bio-degradable fibers

♦ Integrated with nano-materials, textiles are imparted with very high energy absorption capacity and other functions such as stain proofing, abrasion resistance, light emission, etc.

A few years ago, smart textiles were presented as imaginary products and as a non-competitive market. After scientific efforts and development phases, nowadays SFIT are an implanted customer interest and are presented as the future of the textile industry. A lot of commercial products are available and, as it was presented during this document, many scientists are developing new solutions, ideas and concrete products. Some approximations reveal a market size of 1 billion dollars by 2010, which certainly explains the current passion for these new developments.
17.5 Lesson end Activities

A) What are Smart Textiles?

B) Classification Of smart Textiles

C) Discuss about the Recent Trends used in Smart and Intelligent Textiles

D) Mention the Applications of Smart and Intelligent Textiles.

17.6 References


3. “www.technicaltextiles.com".