Chapter 1
Introduction

Yasir Nawab and Sheraz Ahmad

Abstract Technical Textile is a dynamic and fastest growing sector, which is primarily known for performance and functional properties. In this chapter, the definition of technical textile, Scope, market share, and categories of technical textiles have been explored. The current volume market worldwide for technical textile is 193.9 billion in US dollars, and it's projected to reach $220.37 billion by 2022 at CAGR 5.89%. In terms of volume, this market is projected to reach 42.20 million metric tons by the end of 2020. The Broad areas of technical textile and their application areas, including Protech, Sportstech, Aggrotech, Clothtech, Geotech, Hometech, Indutech, MedTech, Mobiltech, Oekotech, and Packtech, are also discussed. Moreover, in this chapter, conventional fibers and high-performance fibers used in technical textiles are systematically introduced. The main principle involved in the selection of raw materials and the importance of material selection are also explored. Along with it, the Global manufacturers of technical textile products and technical textile fibers and major countries producing these fibers have also been examined. At the end, major tests for technical textile fibers, yarns, and fabric and test standards according to ASTM, AATCC, and ISO have been evaluated.

1.1 Introduction

1.1.1 Technical Textiles

Technical textiles are the textile materials and products used primarily for their technical performance and functional properties. The conventional textiles are used for the aesthetic and furnishing purpose. The main reason for usage of technical textile

Y. Nawab (✉) · S. Ahmad
Faculty of Engineering and Technology, National Textile University, Faisalabad, Pakistan
e-mail: yasir.nawab@yahoo.com

S. Ahmad
e-mail: itsadeelnaz@hotmail.com

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is their specific functional and physical properties. The technical textile represents various fields and has numerous applications [1].

The technical textiles gain considerable attention, the technical fibers, yarns, and fabric are being used for various technical applications apart from clothing. Various kinds of natural fibers such as flax, cotton, sisal, jute have been used since many years in the applications like tents, tarpaulins, sacking, ropes, and sailcloth. In roman times the woven fabrics and meshes were used for stabilizing marshy ground for the road building. Nowadays these are named as Geo textiles and Geo grids.

The technical textile field is very vast and diverse, hence somehow difficult to define. Generally, it comprises of the largest segment of conventional and domestic textile industry's output. Now a day almost 45% of woven, knitted, and nonwoven fabric are used in technical textile products. The biggest market of technical textiles is automotive, healthcare and construction, agriculture sector, and military applications [2].

Depending upon their endues technical textiles are categorized into 12 broad areas [3].

S. no	Category of technical textiles	Applications areas
1	Protect	Protech are the protective textiles that are used in protection against various threats such as heat and radiation for fire fighter clothing, molten metals for welders, bulletproof jackets for army and police officers, and chemical materials for labors working in petrochemical. They also provide protection against bacterial and blood pollution in hospitals. The protective textiles are made with the help of specialty fibers such as high tenacity Polyethylene terephthalate (PET) or polypropylene (PP), Aramids, Ultra-High Molecular Weight Polyethylene (UHMWPE)
2	Sportstech	Sportech are the sports textiles used mainly for making sportswear, including sports shoes and other sports accessories. Increasing interest in active sports and outdoor leisure activities such as flying and sailing sports, climbing, and cycling has led to immense growth in the consumption of textile materials related to sport goods and equipment
3	Packtech	Packtech are the packaging textiles used for bags, packaging sacks, Flexible Intermediate Bulk Carriers (FIBC) and wrappings for textile bales and carpets, durable papers, tea bags, and other food and industrial product wrappings
4	Oekotech	Oekotech are the environmental textiles used in environmental protection applications, such as floor sealing, erosion protection, air cleaning, prevention of water pollution, water cleaning, waste treatment/recycling, depositing area construction, product extraction, and domestic water sewerage plants

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S. no	Category of technical textiles	Applications areas
5	Mobiltech	Mobiltech is used in the transportation industry for the construction of vehicles such as automobiles, railways, and ships. Examples of Mobiltech include seat covers, seat belts, nonwovens for cabin air filtration, airbags, parachutes, inflatable boats, air balloons, truck covers, and restraints which are significant textile end uses in the transportation sector
6	Medtech	Medtech includes all textile structures that are designed and manufactured for a medical application. They are used in health care and hygiene applications in both consumer and medical markets. They are generally used in bandages and sutures that are used for stitching the wounds
7	Indutech	Indutech are the industrial textiles used in different industries for functions such as separation and filtration, transportation of materials, and serving as substrates for abrasive sheets and other coated products. They range from lightweight nonwoven filters, to knitted nets and brushes, to heavyweight coated conveyor belts
8	Hometech	Hometech is used in manufacturing for many home furnishing fabrics including carpet backings, curtains, and wall coverings. Much of Hometech consists of fire-retardant fabrics
9	Geotech	Geotech are textile fabrics which can be woven, nonwoven, or knitted fabric used for a variety of purposes such as support, drainage and separation at/or below ground level, coastal engineering, earth and road construction, dam engineering, soil sealing, and drainage systems. Geotech must be thick and have good strength and durability, and low moisture absorption
10	Clothtech	Clothtech includes functional textile products that are most often invisible components in clothing and footwear products e.g., interlinings, sewing thread, insulating fiberfill, and waddings
11	Buildtech	Buildtech is used in construction and architectural applications, such as for concrete reinforcement, facade foundation, interior construction, insulation, noise prevention, visual protection, protection against sun light, and building safety. The field of textile architecture is also expanding as textile membranes are increasingly being used for roof construction. Main fabrics used are high tenacity Polyester coated with PVC
12	Agrotech	Agro-textiles, also known as Agrotech, are used in agricultural applications related to growing and harvesting of crops and animals. They are also used in forestry, horticulture, and animal and poultry rearing, including animal clothing. Agro-textiles must be strong, elongated, stiff, bio-degradable, resistant to sunlight, and nontoxic

1.1.1.1 Scope

The textile institute defined technical textiles as "The textile products and materials manufactured primarily for their functional and performance properties instead of decorative or aesthetic properties." Such a concise definition clearly leaves the considerable scope for the understanding, specifically when the increasing number of textile products are mixed for both performance and aesthetic look and provide functionality in equal measure. Such as, breathable wear application, flame retardant cloths. Though, no two published sources such as industry bodies and statistical organizations are ever seemed to adopt concisely the same method when it comes to classifying and explaining the products and applications as technical textiles [4].

The scope as well as content of functional textiles are difficult to fully define because of technological advancement, new processing and innovation and rapidly expanding market. "If the adjective 'technical or functional' is difficult to define with any precision and concisely, then so too is the scope of the term textiles" [5].

The Fig. 1.1 shows all types of products, materials as well as the process which falls within the functional textile scope. But there are certain grey regions as well as manufacturing and development of metallic wires into different products like cable-meshes, reinforcement, and screens are not considered to fall in the scope of functional textiles.

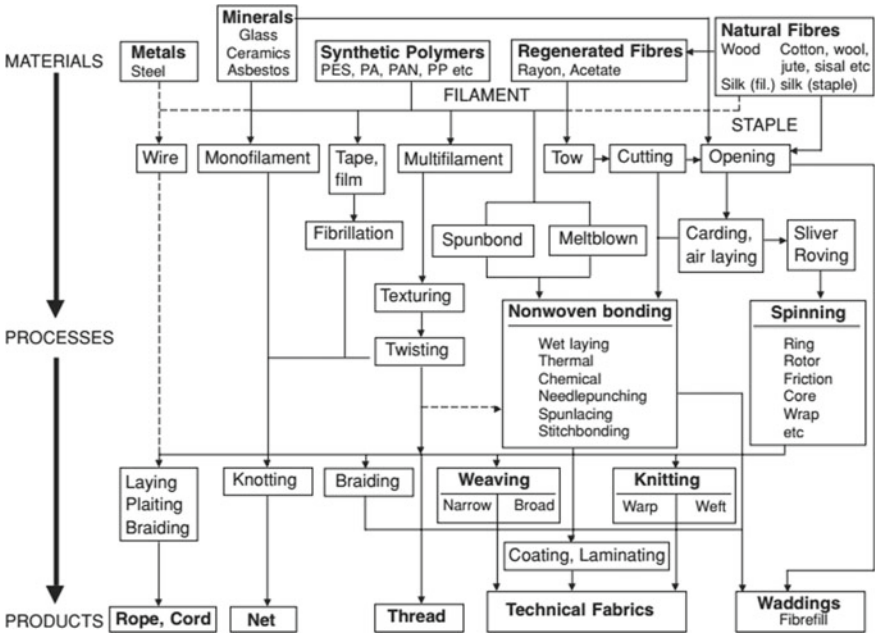


Fig. 1.1 Technical textile material, process, and product [4]

In the composite industry, the woven, knitted, nonwoven, braided reinforcements manufactured from different fibers such as glass fiber, carbon, organic polymers (aramid) fall within the premises and scope of functional textile products. Various products like loosely pulped fiber, as well as milled glass, chopped matt are not considered as a functional textile [4].

1.1.1.2 Market

The technical textile market is projected to reach US$ 193.9 billion by 2020 and US$ 220.37 billion by 2022, at a CAGR of 5.89%. In terms of volume, this market is projected to reach 42.20 Million Metric Tons by 2020 (Fig. 1.2). This illustrates that the market of technical textile is increasing significantly. This can be attributed to the increasing demand for functional products in different end-use areas such as personal safety, light weight replacement materials for metals, medical and health care, and industrial applications. The demand of technical textile worldwide is changing constantly due to technological advancement, new innovations, and superior performance. Factors such as increasing awareness on health and safety and increasing end-use applications are expected to drive the technical textile market in the future. Increasing demand from end-use industries such as healthcare, construction, clothing, packaging, sportswear and sports equipment, automotive, environmental protection, and other areas is expected to drive the overall technical textile market growth. However, the high cost of finished products affects the pricing structure of the intermediate industry, thereby restraining the growth of the market.

The forecasted share of the global technical textile market is estimated to be one fourth the global textile market sectors by 2020 as shown in Fig. 1.3.

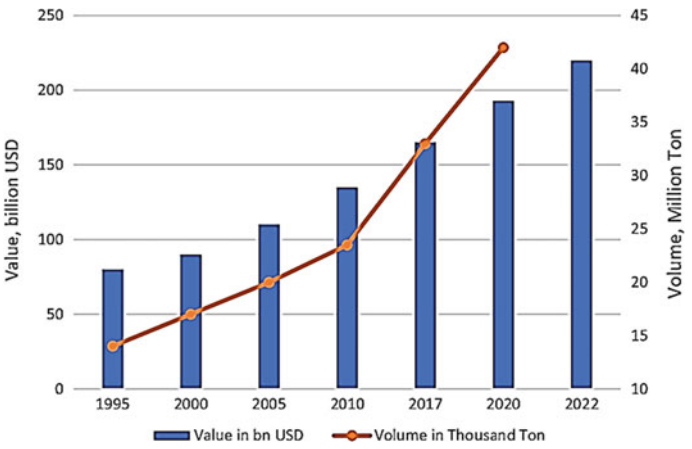


Fig. 1.2 Technical textile materials, process, and product [6]

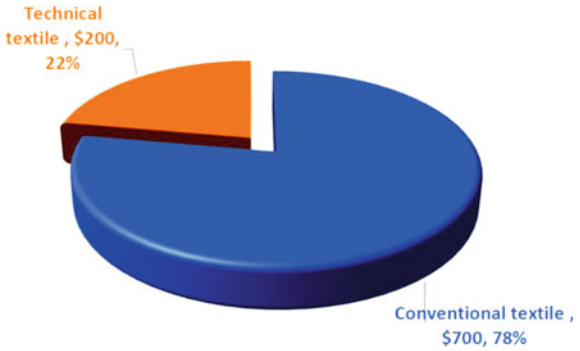


Fig. 1.3 Technical textile market share [7]

Moreover, the growth of new industries and end user requirement also lead to grow in demand of functional textiles market. Huge demands for functional textiles come from various type of industries such as sports tech, automotive, environmental protection, sports equipment and sportswear, packing industries, agriculture sector, and clothing sector [5].

There has been an increasing and smooth growth in terms of production as well as consumption of technical textile product. The technical textiles are utilized in various forms like fibers, unspun fibers, yarns, fabric, and the final product. The functional textiles are utilized in the form of unspun fibers form, yarn, and fabric, with a large part of end use of technical textiles being consumed in the form of fabric [8] (Fig. 1.4).

Among all sectors of technical textiles, the three largest contributors are Packtech, Aggrotech, and Clothtech. These three sectors have the largest market share in the global textiles market. Based on investment potential key contributors are, Nonwoven, Meditech, Composites, and fibers, which accounts for almost 75% of total investment in this sector. Moreover, the increasing demand of the automobile

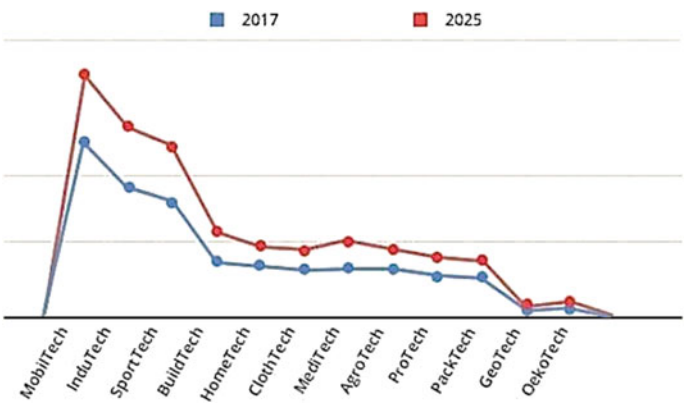


Fig. 1.4 Technical textile market volume and growth rate [9]

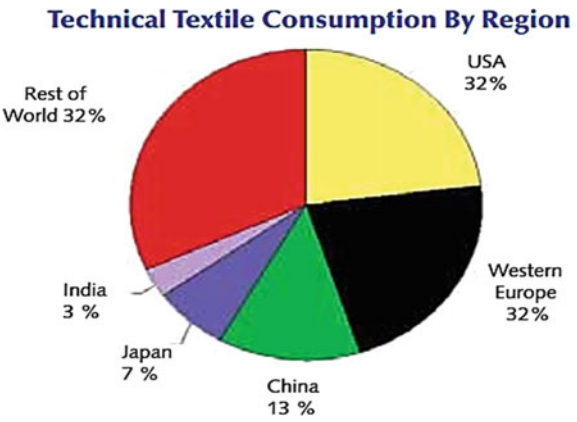


Fig. 1.5 Technical textile consumption by region [12]

industry and Geo textile is predicted to drive the Growth of Geotech and Mobiltech industry.

The developed countries like the US and EU are the global key players in the technical textile market while China and India are considered as emerging countries in this field [10]. USA is considered as a largest global market for the consumption of technical textiles products which is 23%, Europe 22%, China 13%, Japan 7%, respectively. All other countries including India, Vietnam, etc., contribute 35% of consumption of technical textiles. The Asia Pacific and Latin America is currently growing rapidly in technical textile sector. Other countries like China, Brazil, and India are expected to lead their respective regional markets and expected to grow in this sector rapidly. The growth of these countries is due to sound and effective policies, Government initiatives, and interest, spending on infrastructure play a key role in shaping and emerging the countries [11] (Fig. 1.5).

USA is the leading exporter of technical textile products, especially in Taiwan, Brazil, Korea, India. These countries are also working to enhance the market share by innovation and research development. It is predicted that in a near future these emerging countries will be competitor to the United States.

Technical textile market is growing rapidly parallel to the conventional textile sector. In technical textile the products, processes, and technologies are changing day by day, hence the market is becoming competitive as well. This innovation and demand led to expand the current market and enable to generate new ones for the technical textile sector. Many countries which are only producing conventional textiles and currently they are meeting their demands by importing from other countries are trying to shift toward technical textiles.

1.1.2 Fibers for Technical Textiles

Until the twentieth century very limited number of textile fibers were available for functions and industrial use such as cotton, flax, Sisal, and Jute. These fibers were utilized for manufacturing canvas, ropes, twines, and heavy products. These products were characterized by a heavy weight, attacked by microorganism, fungal and very low resistance to water and showed very low flame retardancy [8] (Fig. 1.6).

With the passage of time, new technical textile manufacturing units were established, for example, Dundee located in Scotland, which is the flax growing area as well as a whaling port. At that time bast fiber such as jute was used widely for sacking and packing, carpet, furniture, roofing felts, twine and other applications purpose.

Around 1900, jute industry was at a peak, but it starts to decline due to competition from other materials and cheaper, cost effective, economical import. The industries like Dundee and other industries became a central industry for the development of UK Polypropylene industry in 1960. After 1960 new polymer were developed which were superior than the conventional fibers and proved to be most suitable for technical and functional applications. Sisal was utilized and converted into the ropes, net twine. Wool and silk are versatile fibers having different industrial applications. Conventional silk is used mostly in Asia and Japan for technical and functional applications. Wool provides outstanding insulating property hence used for protective clothing and higher temperatures [14].

1.1.2.1 Conventional Fibers

The conventional fibers are modified and used for technical applications. Among various conventional fibers Viscose, PET, PP, and Polyamide can be classified as conventional fibers for technical textile application [15].

- **Viscose rayon**

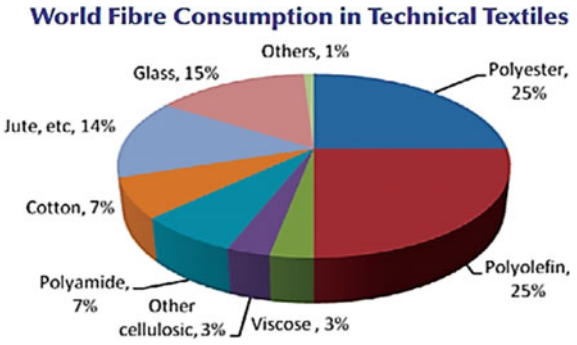


Fig. 1.6 World fiber's consumption in Technical textiles [13]

Viscose rayon was developed in 1910 and it is considered as first commercial synthetic fiber. After 1920 it was made as a reinforcement material for tires and then found its application in conveyor belts, rubber goods, drive belts, and hoses. Superior properties such as high uniformity, high modulus and tenacity and good temperature resistance enable its usage in new emerging automotive industry. Some other properties of viscose fiber are good absorbency property and easy processing of fiber by paper industry type, with wet laying techniques for its use of nonwoven products such as disposable hygiene end uses.

- **Polyamide**

Nylon or polyamide fiber was first manufactured in 1939, give high strength property as well as better abrasion resistance, good elasticity property, uniformity, and superior moisture resistance. It is widely used in climbing ropes, parachute fabrics, spinnakers sail owing to invaluable properties such as energy absorbency. Moreover, polyamide reinforced tires are being used in various countries where the quality of the road surface has been ruined and poor, as well as it is an emerging market for off road vehicles worldwide.

- **Polyester**

Polyester has superior performance properties and good in price. Its outstanding mechanical properties, heat resistance properties, resistance to light degradation, and fastness to light are outstanding. For the dyeing of polyester disperse dyes are used.

The world production of polyester has increased since 1950. Initially, it was only used for household application and with the advent of time, polyester being cost effective, finds its application as a technical textile fiber. The usage of polyester in staple and filament form is increasing rapidly for various applications. PET fiber is most widely used in fiber for technical textiles. For Airbag, tire cord, car seat applications, sail cloth, Geo textiles, fishing nets purpose, and no-woven are examples of its application product.

- **Polyolefin**

Polyolefin developed in 1960s revolutionized the technical textile sector. Polypropylene and polyethylene are mostly polyolefins used in technical applications. Major properties of polyolefin include good abrasion resistance, low density, low cost and easy processability, superior moisture resistant properties. Owing to these properties they are being used for various applications such as carpet backing purpose, for sacks, packaging purpose and in bags, furniture linings, ropes applications, and netting.

Characteristics of Polyolefins

The poor temperature resistant and hydrophobic properties have been turned into advantages in nonwoven. Firstly, used with viscose for thermal bonding purpose, polypropylene is used in hygiene due to its important role in wicking such as the

cover of diaper, nappies. Polyethylene has good physical properties with normal melting temperature of 112 °C for a low density form of fiber and for high density form melting temperature reaches up to 140 °C, hence it is preferred for mostly low temperature applications.

The polypropylene fiber has superior mechanical properties than polyethylene and it can withstand temperature up to 170 °C. These polymers have lower density than water due to which they float as a net, rope on water and used in similar applications. The greatest demand of polypropylene in Geo textile is due to bulk availability, outstanding resistance to acids and environmental, and low cost [16] (Table 1.1).

Properties

Heat Resistant Fibers

There are various type of heat resistant fibers which are used as per requirement. These fibers include silica, alumina, basalt, glass fiber, PBO, tungsten fiber, carbon fiber, and P-aramid have also superior heat resistant properties. The fiber having high LOI (Limiting Oxygen Index) value shows outstanding heat resistant properties. The Table 1.2 compares the heat resistant properties of different fibers.

Table 1.1 Comparison of properties of PET, PA, and PP with Para-aramid fiber as (standard type)

Fiber material	The specific gravity	Melting point (°C)	Tg (°C)	Tensile strength (MPa)	Elongation at break (%)	LOI value (%)	Tensile modulus (GPa)
PET	1.3.7	255	71	510–691	15–41	18–22	6–11
Nylon66	1.15	250	37	350–551	18–37	20–22	3–6.5
Nylon6	1.14	221	22	450–701	20–33	20–22	2.5–3.4
PP	0.95	1162	16	411	25–61	18–21	6.4
p-Aramid	1.15	–	304	2761	3.4	30	58

Table 1.2 Properties of high heat resistance fibers

Fiber material	Melting point (°C)	Tenacity (CN/dTex)	Degradation temperature (°C)	LOI (%)
M-aramid	350	5.5	425	30
Polyamide-imide	220	2.7	450	32
Polyimide	232	3.8	470	38
Melamine	345	2.0	550	32
PPs	285	5.0	510	34
PEEK	335	7.2	480	33
PTFE	–	1.6	400	95

High-Performance Fibers

The conventional fibers discussed above account for almost 95% of all types of organic fibers used in technical textiles except glass fiber, mineral-based fiber, and metal fiber. Most of these fibers need to be converted and modified for high-tech applications by changing, tenacity, length of fiber. This includes surface modification, applying finishes or combining both types of fiber and converting into hybrid and biocomponent products. However, the high-performance start emerging after the 1980s, which have upgraded the technical textiles and increased the demand and expand market share [17].

Aramids Fiber

Firstly, aramid fibers were developed which include meta aramid and para aramid. Meta aramids are mostly used in protective clothing and similar applications while para aramid find its applications in bullet proof vest, ropes, composites, and reinforcement. Meta aramids are high-temperature resistant and para aramid are high strength and high modulus fibers.

The commercial production of p-aramid was started in 1970 and it reached almost 40,000 t per annum in 2000 at the same time meta aramid consumption was 17–18,000 t. The aramid fiber has revolutionized the technical textile industry and enhanced its market share.

Carbon Fiber

Carbon fiber is highly pure and pyrolyzed acrylic based. When the impurities are removed the carbon content increases and prevent the process of nucleation and reduce graphite crystal growth, which are responsible for the decrement of strength in these fibers. From mesophase pitch different types of carbon structures are made. In PAN fiber the graphite planes arranged themselves along the axis of the fiber instead of perpendicular as is the case with pitch base carbon fibers. Low extensibility along with high strength and modulus led to be used with epoxy resin as composites.

Carbon fiber is not only important for aerospace market, but also find its application in sports equipment and goods, industrial applications like generators, turbine blades and used as reinforcement for fuel tanks. The advancement in technology and manufacturing method reduced the cost, hence application of carbon fiber also increases.

Other High-Performance Fibers

New high-performance fibers were introduced late 1980s, which were used for technical and high-performance applications after aramids. These fibers include several types ranging from flame and heat resistant material for protective textiles like PBI, phenolic fibers, PBI, polyheterocyclic fiber, PTFE and have highest LOI values than aramid. It resists heat and chemical agents cannot attack it easily but remains rather expensive. Lenzing initially produces p. 84 and now it is produced by Inspect fibers. USA developed Polyimide that possesses high chemical and fire-resistant properties. Another fiber named as acrylic copolymer-based fiber was produced by Acordis

called Index, unlike aramid fibers, it has very high resistance to ultraviolet radiations and has higher LOI value at the expense of reduced tenacity.

HMPE (need to elaborate all abbreviations) is ultra-strong high modulus polyethylene mainly used for ballistic protection and rope manufacturing. PTFE polytetrafluoroethylene is one of chemically stable, high-performance polymer fiber. PPS polyphenylene sulphide and PEEK polyethyl ether ketone are used in filtration application due to high mechanical stability and preferred for aggressive environments.

Dyneema Fiber

Dyneema is also known as ultra-high molecular weight polyethylene is strongest known fiber today with a tensile modulus of 70 GNm^2. This fiber is almost 15 time stronger as compared to steel and two times stronger than aromatic polyamides like Kevlar. Major properties include chemical inertness, low density, and high abrasion resistant. It is mostly used in low temperature application due to the low melting temperature of 150 °C and it degrades thermally at 350 °C.

Inorganic Fibers (Glass and Ceramic)

Glass fiber used for technical application for a long time. For many years it has been used as a cost-effective insulating material and reinforcement. Glass is considered as a sophisticated material having superior heat and fire resistance properties. For low performance plastic glass is used as reinforcement material and roofing material in the USA.

Now a days it is being used for different high-tech applications such as rubber reinforcement, filtration purpose, composite applications, packaging and protective clothing. The glass fiber is widely used in the automotive industry and it has replaced metal body parts, hence the market of glass reinforcement body parts is merging in the market. Ceramic fiber is used for very high-tech application, but they are restricted to limited area due to the high cost of fiber.

1.1.3 Importance of Materials Selection

The selection of right fiber depends on the end use of the product. Selection of right fiber is necessary for the performance and functionality of textiles. Generally, the performance of textile depends upon three factors:

1. Material of fiber
2. Configuration of fiber
3. The assembly structure of fiber

Furthermore, the selection of right fiber is based on cost effectiveness, reliability, desired end used properties and the ease of processability. These three structural elements should be kept in mind while choosing any fiber for certain application. Various types of fibers are used in different application for technical purpose [18].

1.1.3.1 Cost

The cost of raw material such as fiber and fabric are directly associated with the cost of the product and profitability. Hence the cost of the material is directly associated with the economy textile industry. High cost of raw material used in the fabric processing increase the total cost of product and reduce profit of the industry. In textile industry overall 70% of total cost depends on the raw material and 30% is included in processing and services. From start to final product various steps are included the developers by the product and each step add cost to the product.

The technique to use for development of technical textiles includes spinning and twisting. For technical textile various types of raw material used are fiber, natural threads, chemical fibers, dyes, etc. The high cost of raw materials is impacting the overall production cost of textile industry and affect the growth of the market. For example, according to an international manufacturer (Samruk Kazyna) in November 2016, the cost of Polypropylene was USD 1028 per t and USD 1.028 per kg. According to vendor in 2018, the cost of Polypropylene reached USD 1.2–3.5 per kg. Hence, by controlling the cost of raw materials and processing, the growth and profitability can be increased [19].

1.1.3.2 Properties

Since technical textiles are mainly focused on functionality, the requirement of functional properties such as mechanical performance, fire resistance, stab resistance, ageing, filtration, antimicrobial, antistatic, etc., is common. In addition to these functional properties, the properties are conventional textiles such as esthetics, drape, comfort, etc. are also a requirement.

These properties are mainly governed by:

i. Fiber properties
ii. Textile structure
iii. Finishing/Coating, etc.

Fiber properties mainly depend on their material, chemical structure, and microstructure of fibers. Textile structure such as spinning technique, blending of materials/fibers, fabric structure (nonwoven, woven, braiding, knitting, etc.) is a major factor to define the textile's properties. For example, a woven structure is more stable mechanically than other textile structures hence preferred for applications with requirement of good mechanical properties such as tarpaulin, stab resistance, and geotextiles, etc., however, due to its porous structure, it is not preferred for very fine filters.

Several properties of technical textiles are obtained by applying finishes and coating during textile processing. Hydrophobicity, antimicrobial activity, and fire retardancy, etc., are obtained by applying chemical finishes to textiles.

1.1.3.3 End User Requirement

Mainly technical textiles are different than conventional textiles due to end user requirement. The focus here is the performance or functionality. Due to nature and end use of these textiles, the requirements of user are diverse and more as compared to conventional textiles. Keeping in view the application, sometimes the requirement of functionality is very precise and very high quality is required. For example, in life saving application such as airbag, fire fighter suits and bullet proof shield and vest, etc., the end user requirements are very precise and strict compliance is mandatory.

1.1.4 Selection of Right Fibers

1.1.4.1 International Manufacturers

Global countries producing technical textile products are Germany, U.K, Japan, USA, Korea, France, Turkey, India, and China. Top companies producing technical products are Dupont, Ahlstrom-Munksjo, Freudenberg Performance Materials, Lenzing Plastics, Low & Bonar, Koninklijke, DeRoyal industries, SRF Limited, and Swift Textile Metalizing LLC [20].

Some of the known international fiber manufactures are given in the Table 1.3 along with fiber names, brand names, major properties of fibers, and country of origin of these manufactures.

1.1.4.2 Testing

In technical textiles, the requirements of user are mainly the functionality and the testing required for a given textiles is more as compared to conventional textiles. No dedicated test methods exist for technical textiles. Keeping in view the functionality required the test methods available in ISO, ASTM, AATC, DIN, etc., are used.

The materials used in technical textile products may be in the form of fiber, yarn, fabric, or in the form of composite. The assessment of both raw materials as well as the final product is necessary for meeting the quality standards. Testing is carried out to evaluate the functionality, performance of required products. Common testing of fiber, yarn, and fabric are listed below.

Table 1.3 Some global manufactures of technical fibers

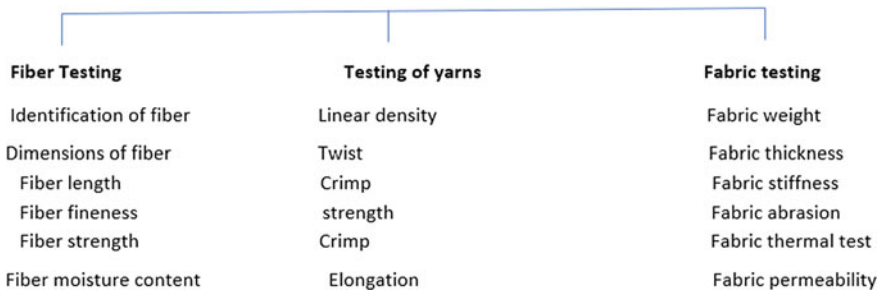
Manufacture	Fibers	Brand name	Property	Country
DMS	UHMWPE fiber	Dyneema	Cut, bullet, stab resistance	USA
Honeywell	UHMWPE fiber	Spectra	Cut, bullet, stab resistance	USA
Dupont	Aramid fiber	Kevlar	Fire, cut, bullet, stab resistance	USA
Yantai	Aramid fiber	Taparan	Fire, cut, bullet, Stab resistance	China
Hexcel	Carbon fiber	Hextow	Super mechanical properties	USA
Cytec	Carbon fiber	–	Super mechanical properties	USA
DOW AKSA	Carbon fiber	–	Super mechanical properties	Turkey
SGL group	Carbon fiber	–	Super mechanical properties	Germany
Toray	Carbon fiber	–	Super mechanical properties	Japan
Teijin	Carbon fiber	–	Super mechanical properties	Japan
Mitsubishi Rayon	Carbon fiber	–	Super mechanical properties	Japan
Owen corning	Glass fiber	NYSE	Hardness, transparency, stability, and inertness	USA
Jushi group	Glass fiber	–	Hardness, transparency, stability, and inertness	China
PPG	Glass fiber	–	Hardness, transparency, stability, and inertness	USA
Taishan	Glass fiber	Sinoma	Hardness, transparency, stability, and inertness	China
CPIC	Glass fiber	–	Hardness, transparency, stability, and inertness	Canada
Nittobo Boseki	Glass fiber	Nittobo	Hardness, transparency, stability, and inertness	Japan
Advanced glass fiber yarns	Glass fiber	–	Hardness, transparency, stability, and inertness	USA
Binani-3B	Glass fiber	–	Hardness, transparency, stability, and inertness	India
Sichuan Weibo	Glass fiber	Innofiber	Hardness, transparency, stability, and inertness	China
Jiangsu Jiuding	Glass fiber	–	Hardness, transparency, stability, and inertness	China
Lenzing	Polyester	–	Resist wrinkling, abrasion	Austria

(continued)

Table 1.3 (continued)

Manufacture	Fibers	Brand name	Property	Country
KOLON	Polyamide	–	Low creep, high tensile strength	South Korea
AKSA	PAN	–	Thermal stability, high modulus	Turkey
Dralon	PAN	–	Thermal stability, high modulus	China
Taconi	PTFE	–	High chemical resistance	China
Dow chemical company	Saran	–	Resistance to chemical such as salt, acid, alkalis etc.	USA
International fiber group	PP	–	Resist bacteria and microorganism	Sweden
Rath	Ceramic fiber	–	High-temperature resistance, good thermal stability, low thermal conductivity	Austria
Ibiden	Ceramic fiber	–	High-temperature resistance, good thermal stability, low thermal conductivity	Japan
Morgan thermal ceramics	Ceramic fiber	–	High-temperature resistance, good thermal stability, low thermal conductivity	United Kingdom
Shandong Luyang share	Ceramic fiber	–	High-temperature resistance, good thermal stability, low thermal conductivity	China

1.1.4.3 Common Tests for Technical Textile



Medical Textile Testing

Implantable Textiles

Implantable includes the replacement of damaged blood vessel and segments of the large arteries. These implantable materials are used to repair the affected part of the body. They can be used as a wound suture or used in replacement surgery. The tests should be carried out for sutures include Diameter, tensile strength, bending stiffness, surface roughness, and knot pull. Most of the implantable products are tested for Biocompatibility test [12].

Non implantable Textiles

Non implantable materials are used on the body; most of the time they have direct contact with the human skin. The test methods for the assessment of the characteristic of bandage product are yarn count, thread/10 cm surface active substances, water soluble substances, foreign matters, microorganism prior to sterility, pH, and absorbency. Surgical dressings are one of the main types of non implantable medical textile product. Health care and hygiene products are also included in the medical textile.

Geo Textile Testing's

Various types of tests carried out on Geo textile are wide width tensile test, tension creep behavior, coefficient of friction between soil and Geo textile, and cross water Permeability testing.

Protective Textile Testing's

Protective textile can be divided into following category according to end use, thermal protective clothing, chemical protective clothing, mechanical protective clothing, antimicrobial protective clothing, UV protective clothing, high visibility suits, radiation protective clothing, protective clothing for defense, etc. Various kinds of tests are carried out on technical textiles. Some of these are listed below (Table 1.4).

Table 1.4 Major tests and test standard required for testing of technical textiles

S. no	Property	Test standard	Equipment used
1	Static charge test	BS EN 1149-1	Conductivity tester
2	Limiting oxygen index test	IS0 4589-1, ASTM D 2863	LOI tester
3	Hydrophobicity	ASTM F22	Contact angle tester
4	Flame retardancy	ISO 6940, ASTM D 6413	Flammability tester
5	Stab resistance	NIJ standard 0115.00, ISO 13,997	Stab resistance tester
6	Cut resistance	EN388, ISO 13997	Cut resistance tester
7	Bullet resistance	NIJ. Standard 0101.06	–
8	Filtration	ISO 16890	HPLC
9	Weather resistance	M025A	Weathering tester
10	Antimicrobial activity	AATCC 100, AATCC 147	Agar diffusion
11	Impact testing	EN388	Impact tester
12	Fatigue testing	ASTM F963	Fatigue tester
13	Stretch and recovery	ASTM D3107	extensometer
14	UV/Sun protection factor test	AATCC 183	UV protection tester
15	UV resistance	ASTMD 4355	Xenon arc apparatus
16	Water resistance of fabric	ISO 811, AATCC 127	Hydrostatic head tester
17	Water repellency test (Spray method)	AATCC 22	Spray tester
18	Protective clothing for cold protection	EN342	Thermal manikin
19	Chemicals protection	EN 465,466	–
20	Electric hazard	EN 1149	Electric hazard testing machine
21	High visibility material	EN 471	–
22	Mechanical impact testing	EN 510	Impact tester
23	Radioactive contamination	EN 1073	Nuclear shield radiation
24	Thermal hazard	TS 50354	Thermal tester
25	Protective glove against mechanical risk	EN 388	CUT test machine, tensile machine
26	Protective gloves against cold	EN 511	Cold contact tester

(continued)

Table 1.4 (continued)

S. no	Property	Test standard	Equipment used
27	Body protection for sports	EN 13227	High pressure test manifold
28	Bursting strength	ISO 13938	Bursting strength tester
29	Puncture resistance testing	ASTMD 4833	Compression testing machine
30	Friction resistance	ASTMD 5321	Pendulum skid resistance tester
31	Trapezoidal tear	ASTMD 4533	Trapezoid tear tester

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