

Lecture 58: Polymer applications in different fields: Polymer in textile

Hello friends. Welcome to the next segment of the application of polymers. Here, we are going to discuss polymer application in different fields, specifically in polymers in textiles, under the aegis of polymer process engineering. So, let us have a look at what we are going to discuss in this particular table in this particular lecture. We are going to have an introduction to the polymers that are used in the textile industry. We will discuss the brief history of manmade fibers. Apart from this, we will discuss the various terminologies and definitions being used in such contexts. We will have a brief outlet about fiber manufacturing. Then, how do we characterize and attest to the pattern of the textile fibers we are going to discuss? Then we will discuss the manmade fibers specifically used in the textile industries, and apart from this, we will have a brief outlook on the high-performance fibers.

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Let's delve into the discussion of manmade fibers, particularly the use of polymeric materials in the manufacture of synthetic fibers for textile applications.

Polymeric fabrics, whether derived from natural or synthetic sources, serve as the foundation of textile fabrics. The versatility of polymer materials allows them to be shaped into fibers of varying geometries and sizes, imparting unique properties to textiles. The final characteristics of textile fabrics are often determined by the method of fiber preparation, the construction process into fabric, and the finishing techniques applied.

Historically, natural fibers like cotton have been utilized for clothing, home furnishings, and building materials for thousands of years. Various civilizations employed agricultural fibers, such as straw mixed with clay by the Egyptians to construct walls and buildings. The Chinese cultivated hemp as early as 2800 BC and, like the Greeks, utilized wool to create nonwoven felted materials.

Despite their historical significance, natural fibers had limitations. Cotton and linen, for instance, were known to wrinkle after wearing and washing, while wool exhibited shrinkage and could be irritating to the touch.

In this lecture, the focus shifts to manmade fibers, also known as manufactured fibers. Specifically, we will explore the use of polymeric materials in the production of synthetic fibers tailored for textile applications. This marks a significant advancement, addressing some of the shortcomings associated with natural fibers and paving the way for innovations in the textile industry. The realm of technical textiles encompasses diverse applications, spanning medical, military, transportation, construction, modern apparel, and consumer goods. In this segment, we will delve into the modern applications and the potential of developing polymeric materials to meet the demanding and challenging textile needs of the future.

The history of manmade fibers with a polymer base began taking shape in the early 19th century. In the 1800s, a French chemist named Chardonnet embarked on a series of trials aiming to produce artificial silk from dissolved nitrocellulose. Chardonnet presented his artificial silk fabric at the Paris Exhibition in 1889 and later successfully established the first commercial-scale production plant for Rayon in France. In the United States, the commercial production of artificial silk began in 1910 when the American Viscose Company opened a Rayon plant.

Before making its mark in the textile fiber market, cellulose acetate, a type of Rayon, was used as dope for airplanes in England. The year 1920 also marked a significant recognition by Herman Staudinger, who identified the macromolecular nature of polymer structures for the first time. Staudinger's groundbreaking discovery, rewarded with the Nobel Prize in Chemistry in 1952, paved the way for the establishment and rapid growth of the polymer and synthetic fiber industries.

Brief history of manmade fibers

- Before conquering the textile fiber market, **cellulose acetate (CA)** was made as **dope for airplane wings** in England
- **The 1920s** also witnessed the recognition, for the first time, **by Hermann Staudinger**, of the **macromolecular nature of the polymer structure**.
- This discovery, rewarded by **the Nobel Prize in Chemistry in 1952**, paved the way for **the eventual establishment** and fast growth of **the polymer and synthetic fiber industries**.
- **Carothers** synthesized **polyamide 66**, known as **nylon 66**, which revolutionized **the synthetic fiber industry**.

This historical journey highlights the pivotal role of polymers in the development of manmade fibers, setting the stage for innovations in the textile industry and anticipating future advancements. Carothers' synthesis of polyamide 6-6, known as nylon 6-6, marked a revolutionary moment in the synthetic fiber industry.

Now, let's delve into the terminologies and definitions related to fibers. Fibers, whether natural (like cotton or wool) or synthetic (such as polyester or polypropylene), serve as the foundational elements of any textile product. Fibers are characterized by a large length-to-diameter ratio before being woven or knitted into fabric. Textile fibers can exist in various forms.

It's essential to distinguish between certain textile terms:

- 1. Filament:** A single fiber of continuous length, sometimes referred to as monofilament.
- 2. Filament Yarn:** A collection of continuous filaments held together by twisting or other methods.
- 3. Filament Tow:** A large bundle of filaments held together without twisting.
- 4. Staple Fiber:** Short-cut fibers with a specific length made from filament tow, often packaged in bales before textile processing.
- 5. Spun Yarn:** Staple fibers are sometimes spun for ease of processing on cards and other textile machinery.



6. Textured Filament Yarn: Filament yarn that undergoes twisting and manipulation to impart texture and bulk before being incorporated into a textile fabric.

7. Nonwovens: Engineered fabric structures created directly from fibers to form a web, constituting the fabric itself. The Textile Institute defines nonwovens as textile structures made directly from fibers rather than yarn. Fibers are typically produced from continuous filament or fiber webs and then bonded using various techniques, including adhesive bonding, mechanical interlocking by needling, fluid jet entanglement, thermal bonding, and stitch bonding.

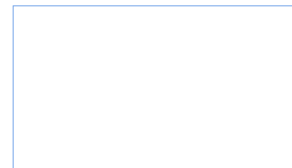
Understanding these terms provides insights into the diverse methods and structures employed in the textile industry, contributing to the wide array of textile products available. Each term represents a specific aspect of textile production, offering various options for creating fabrics with distinct characteristics and applications.

Let us talk about the fibre manufacturing. The conversion process of polymers into the fibre depends on the polymer type and chemical structure. And there are four type of fibre spinning processes commonly used for fibre industry name the melt spinning, the dry spinning, the wet spinning and the gel spinning. More recently electro spinning is gained more and more impetus as a way of to make the fibre in nanoscale.

1. Melt Spinning:

Fiber manufacturing: Melt spinning

- **Melt spinning** is the most common process used to make **textile-type polymer fibers**.
- Almost any **thermoplastic polymer** (thermoplastics are polymers that are able to flow upon heating and are readily shaped into various forms as the polymer melt is cooled down) is made into **fiber form** via melt spinning, with **varying degrees of difficulty**.
- **The melt spinning** of polymers into **continuous filament yarn** consists of four steps :



Melt spinning is the most common process used to produce textile-type polymer fibers. It is applicable to almost any thermoplastic polymer, which can flow upon heating and be easily shaped into various forms as the polymer melt cools down.

Process Steps:

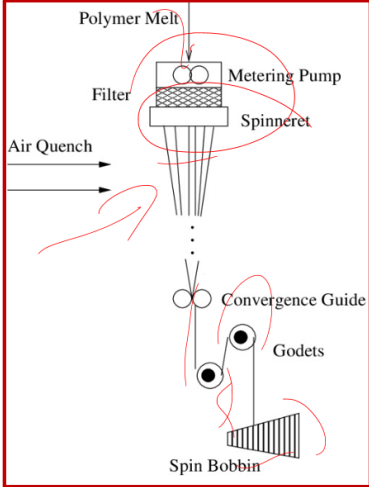
1. Melting of Polymer Pellets:

- The thermoplastic polymer is melted in an extruder.


2. Extrusion through Spinneret:


- The molten polymer is pushed through a spinneret, which contains tiny holes evenly distributed across its surface.

Fiber manufacturing: Melt spinning



- **Melting the polymer pellets** in an extruder and pushing it through a spinneret that consists of **tiny holes** evenly distributed through the surface.
- **A spinneret** pack with **polymeric filaments**.
- **Solidifying the filaments** exiting the spinneret using **cool air** and **collecting them in a bundle on a rotating roll**.

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3. Quenching with Cool Air:

- The extruded polymer filaments are subjected to cool air, solidifying them.

4. Collection on Rotating Roll:

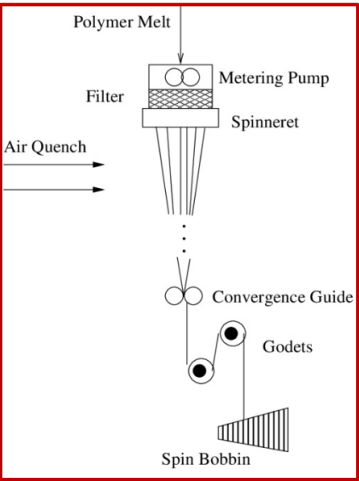
- The solidified filaments are collected in a bundle on a rotating roll.

5. Drawing Between Rolls:

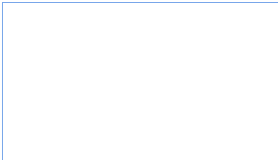
- Filaments are drawn between two rolls moving at different speeds.

- This process orients the polymer molecules and increases filament strength.

Fiber manufacturing: Melt spinning



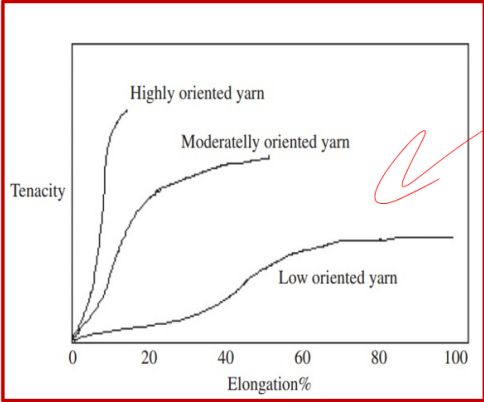
- **Drawing the filaments** between two rolls of different speeds in order to **orient the molecules and increase the filament strength**.
- **Heat setting the filaments** and collecting them on bobbins on a wind-up roll for further textile processing.



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This comprehensive process transforms thermoplastic polymers into continuous filaments suitable for textile applications. The melt spinning technique is widely used due to its versatility and effectiveness in producing various types of fibers.

Fiber manufacturing: Melt spinning



- Fig. shows the **significant effect of orientation** on the **tenacity and elongation** of polypropylene filament yarn.
- **Highly oriented yarn** becomes **extremely strong (high tenacity)** while having a **high modulus** and a **low elongation to break (E_b)**.

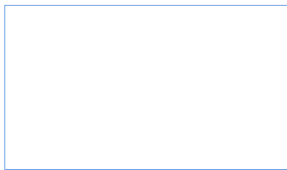


Fig: Effect of **orientation** on polypropylene fiber tenacity

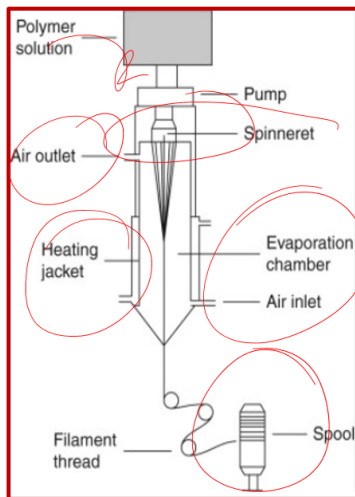
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The figure shows the significant effect of orientation on the tenacity and elongation of polypropylene filament yarn. Highly oriented yarn becomes extremely strong (high tenacity) while having a high modulus and a low elongation to break (E_b).

2. Dry Spinning:

Dry spinning is employed when polymers cannot be melted in a melt spinning process. In this method, a suitable solvent is chosen to dissolve the polymer. The solution is extruded through a spinneret, and as the fibers exit the spinneret, the solvent evaporates.

Fiber manufacturing: Dry spinning



- When polymers **cannot be melted** in a melt spinning process, an **adequate solvent** is chosen to **dissolve the polymer**.
- The solution is then **extruded through a spinneret**; as the fibers exit the spinneret, the **solvent is evaporated** by hot air and the dry filaments collected on a bobbin.
- **Dry spinning** has relatively **lower** spinning speeds than those of **melt spinning**.
- **Eg: acetate and acrylics.**

- Process Steps:

1. Dissolving Polymer in Solvent:

- The polymer is dissolved in a solvent.

2. Extrusion through Spinneret:

- The polymer solution is extruded through a spinneret.

3. Evaporation of Solvent:

- As the fibers exit the spinneret, the solvent evaporates.

4. Collection on a Woven:

- The dry filament is collected on a spool.

5. Low Spinning Speed:

- Dry spinning typically involves lower spinning speeds compared to melt spinning.

6. Examples:

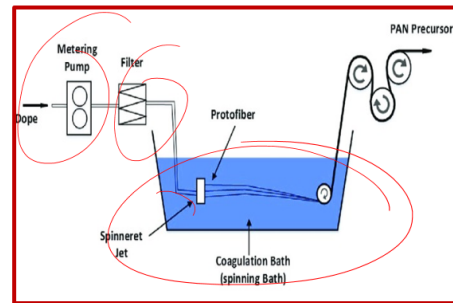
- Examples of fibers produced using dry spinning include acetate and acrylics.

3. Wet Spinning:

- Description: In wet spinning, the polymer is dissolved in a solvent, but instead of being extruded into hot air, it is extruded into a liquid coagulation bath.

Fiber manufacturing: Wet spinning

- **In wet spinning**, the polymer is dissolved in a solvent, but instead of being extruded into hot air, it is extruded into **a liquid bath**.
- The solvent is then **removed chemically in the bath** as opposed to being evaporated as in **dry spinning**.
- The speeds used are **low in wet spinning** and **the filaments are oriented** after the bath in order to impart strength on them.
- **Aramid, spandex, and modacrylic fibers** are made by wet spinning.



- Process Steps:

1. Dissolving Polymer in Solvent:

- The polymer is dissolved in a solvent.

2. Extrusion into Liquid Bath:

- The polymer solution is extruded into a liquid coagulation bath.

3. Chemical Removal of Solvent:

- The solvent is chemically removed in the bath instead of being evaporated.

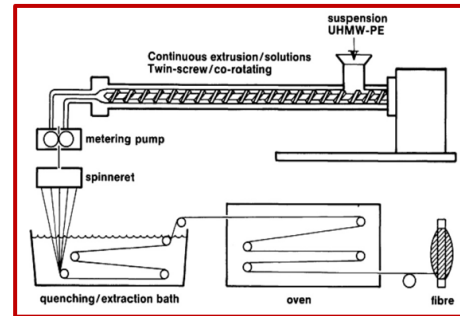
Both dry and wet spinning processes contribute to the production of synthetic fibers, each offering specific advantages depending on the polymer and desired properties of the final fiber.

4. Gel Spinning:

The gel spinning process consists of extruding a heated gel such as ultra-high molecular grade polyethylene through a spinneret drawing through air and cooling it down in a water bath. The key in the gel spinning is to separate the molecular chains in the solvent to minimize the entanglement and give the chain a chance to achieve a high degree of orientation.

Fiber manufacturing: Gel spinning

- The gel spinning process consists of extruding a **heated gel such as ultrahigh molecular weight polyethylene** (UHMWPE) through a spinneret, drawing it through air, and **cooling it down in a water bath**.
- The key in gel spinning is to **separate the molecular chains** in the solvent to **minimize entanglement** and give the chains a chance to **achieve a high degree of orientation**.



Characterization and testing of textile fibre

The polymeric fibres are characterized for the purpose of identification, quality control and fabric design using the standard test method. The most tests are common into all textile fibre while other to specific and the certain polymer types. Some common tests and fibre properties that are important to understand before the detailed discussion of a specific type of fibers and their characterization will take place.

1. Denier:

- Definition: Denier is a measure of the linear density of the fiber, expressed as the weight in grams of 9,000 meters of the fiber.

- Total Denier: For the same fiber type, a larger diameter results in a higher denier. Total denier is often used, referring to the denier of the entire yarn.

- Denier per Filament: Denier per filament is the denier of a single filament, calculated as the total denier divided by the number of filaments in the yarn.

2. Mechanical Properties:

- Tenacity: Tenacity is the stress at which the fiber breaks, expressed in grams per denier. It measures the strength of fiber.

- Elongation at Break (EB): EB is a measure of the fiber's extensibility and its ability to stretch before breaking. It depends on the stretching, withdrawing, and heat setting during the fiber-making process.

- Importance: These mechanical properties are crucial for understanding how fibers withstand stress, stretchability, and their performance during textile processing.

3. Fiber Structure and Morphology:

- Definition: Fiber morphology refers to the structure of fibers, including the arrangement of crystalline and amorphous regions along the fiber length.

- Significance: Morphology plays a significant role in determining a fiber's ultimate strength, elasticity, dyeability, and penetration by pigments.

- Factors Influencing Morphology: Polymer chemical structure, spinning conditions (speed, cooling type, cooling rate), and drawing conditions (draw ratio, heat setting, temperature relaxation) contribute to the fiber's morphology.

In the case of the melt spinning of semi-crystalline thermoplastics (such as polyester or nylon), the final morphology of the fiber is dictated by:

a) **Polymer chemical structure**

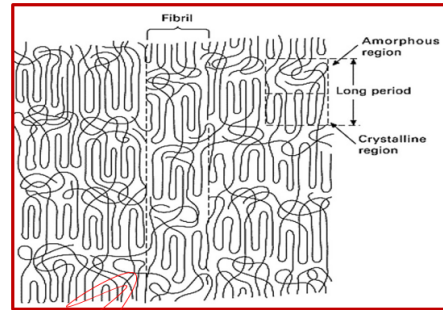
b) **Melt spinning conditions** (spinning speed, cooling type, cooling rate, etc.)

c) **Drawing conditions** (draw ratio, heat setting temperature, relaxation, etc.)

The relative amounts of amorphous and crystalline regions as well as the type of crystals and their arrangement along the fiber length will determine the mechanical behavior. High draw ratios are necessary to obtain highly crystalline, strong fibers. The figure illustrates the morphology of polyester fiber, showing the distribution of crystalline and amorphous regions and the orientation of crystals along the fiber length.

Fiber structure and morphology

- The relative amounts of **amorphous and crystalline regions** as well as **the type of crystals and their arrangement** along the fiber length will **determine the mechanical behavior**.
- **High draw ratios** are necessary to obtain highly crystalline, strong fibers.
- Fig. shows **the morphology** of polyester fiber and a typical distribution of **crystalline and amorphous regions** and **the orientation** of crystals along the fiber length



Fiber Identification Methods:

1. Microscopic Examination:

Optical microscopy is a valuable tool for examining and identifying textile fibers. It is often easier to identify natural fibers than synthetic ones due to similarities among synthetic fibers. Characteristics such as shape and cross-section are common features examined under the microscope.

2. Chemical Tests:

Highly effective in identifying fibers based on their chemical resistance to solvents. The polymer's chemical structure influences its solubility. Polyolefin fibers, with excellent chemical resistance, float in water. Techniques like Fourier Transform Infrared Spectroscopy (FTIR) help identify specific chemical groups in fibers.

3. Density Test:

Fiber density serves as an indicator of the fiber type. Polyolefin fibers, being less dense, will float in water.

4. Stain test:

This test is based on **the affinity of various fibers** toward **different dyes**.

- A series of dyes that have **known affinities for specific fibers** are prepared and **the fiber is immersed** to check its dye pick-up.

- **The morphology of the fiber** and its chemical structure determine its dyeability and hydrophilicity.

5. Burn Test:

When brought in contact with an open flame, different fibers may exhibit distinct flame colors, ash formations, and odors.

Observations:

- Flame Color: The color of the flame produced during burning.
- Ash Formation: The residue or ash left behind after burning.
- Smell: The odor emitted during burning.

Purpose:

- The burn test helps in identifying fibers based on their unique burning characteristics.

Caution:

- This test involves burning fibers, and proper safety precautions should be taken.

These identification methods play a crucial role in distinguishing between different fibers, whether natural or synthetic, based on their unique characteristics and responses to various tests. Polyester fibers have gained significant popularity and application in various industries.

Polymer in textile: Manmade fibers

According to a report by Grand View Research Inc., the global synthetic fiber market is expected to reach USD88.5 billion by the year 2025. The industry is expected to grow at an annual rate of 6.3%, largely driven by the growth in polyester. For each fiber type, the base polymer(s), the unique characteristics, and the main uses and applications are discussed in upcoming section.

Polyester Fiber

1. Chemistry of Polyester Fiber:

- Polyester fibers are defined as manufactured fibers, with the fiber-forming substance being a long-chain synthetic polymer.
- The polymer is composed of at least 85 percent by weight of an ester of a dihydric alcohol and terephthalic acid.

- The most common polyester fiber is made from polyethylene terephthalate (PET).

Polymer in textile: Polyester

- 1. Chemistry:** Polyester fiber is defined, according to **the Federal Trade Commission (USA)**, as a “manufactured fiber in which the fiber forming substance is any long chain synthetic polymer composed of at least 85% by weight of an ester of a di-alcohol and terephthalic acid”.
 - The most common **polyester fiber is made from polyethylene terephthalate (PET)**.
 - PET is a polymer made through **the condensation polymerization** of ethylene glycol and terephthalic acid

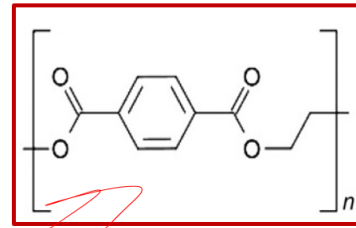
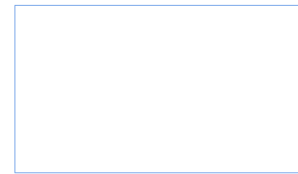


Fig: Chemical structure of PET



2. Properties of Polyester Fiber:

- Smooth Surface: Polyester fibers have a smooth and uniform round surface.
- Strength and Stretch Resistance: They exhibit good strength and resistance to stretching and shrinking.
- Abrasion Resistance: Polyester fibers show good resistance to abrasion.
- Chemical Resistance: They have resistance to various chemicals.
- Wrinkle Resistance: Excellent wrinkle resistance is a characteristic feature.
- Quick Drying: Polyester fibers dry quickly.
- Moderate Resilience: Moderate resilience is observed in both dry and wet conditions.

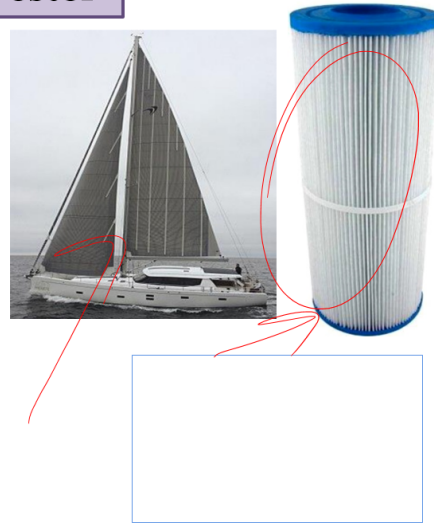
3. Uses and Applications of Polyester:

- Clothing and Textiles: Polyester is widely used in the textile industry for clothing, home textiles, and various fabric applications.
- Blended Fabrics: Often blended with cotton to balance properties, though this may affect cotton's breathability and heat resistance.
- Industrial Applications: Polyester fibers find applications in ropes, conveyor belts, tire reinforcements, and other industrial uses.

- Non-Woven Fabrics: Used in the production of non-woven fabrics for applications like filters, wipes, and geotextiles.

Polymer in textile: Polyester

- Polyester fabric is an excellent choice for **sail cloth** due to its **durability, high modulus,** and low cost.
- Figure 1 shows an example of a sail cloth made from high tenacity PET. In building and construction, **PET SB nonwovens** represent a material of choice for **roofing and geotextile applications**.
- PET nonwovens are also used as **liquid filtration media for pool and spa filter** cartridges such as the filter shown in Fig.



- Automotive Industry: Polyester fibers are used in car interiors, seat belts, and other automotive components.

- Packaging Materials: PET is widely used in the production of bottles and other packaging materials.

- Home Furnishings: Commonly used in carpets, curtains, and upholstery.

4. Historical Context:

- DuPont first manufactured polyester fibers in 1953.

Polyester's versatility, durability, and various desirable properties make it a ubiquitous material in everyday products across different industries. Since then, the demand for polyester fiber has steadily increased. Polyester is widely used in technical textiles, especially in fully oriented fibers with high tenacity. In transportation, polyester filaments are well-established as reinforcements in rubber, particularly in tires. Additionally, polyester is a popular choice in home furnishings, including blankets, bedsheets, and cushions, owing to its durability. Polyester tire cords are known for their durability and heat resistance.

Polybutylene terephthalate (PBT), another type of polyester fiber, finds application in V-belts and other automotive belts. Polyester fabrics are an excellent choice for sailcloth due to their durability, high modulus, and cost-effectiveness. The figure illustrates

sailcloth made from high tenacity polyester. In building and construction, PET (polyethylene terephthalate) non-wovens serve as a material of choice for roofing and geotextile applications. PET non-wovens are also used as liquid filtration media for pool and spa filter cartridges, as depicted in the figure.

Nylon Fibers

Now, let's shift our focus to nylon. According to the Federal Trade Commission, nylon is a manufactured fiber with the fiber-forming substance being any long-chain synthetic polyamide with recurring amide groups as an integral part of the polyester polymer chain. Nylon 6,6 and nylon 6 are the most common types of nylon fibers. The represented figure illustrates nylon 6,6. Nylon 6,6 is made via polycondensation of hexamethylenediamine and adipic acid, while nylon 6 is produced through ring-opening polymerization of caprolactam. Nylon fibers possess unique properties attributed to their polyamide structure, including strength, flexibility, and resistance to wear and tear.

Polymer in textile: Nylon

1. Chemistry: Nylon, according to the federal trade commission, is a “manufactured fiber in which the fiber forming substance is any long chain synthetic polyamide having recurring amide groups as an integral part of the polymer chain”.

- **Nylon 66 and nylon 6** are the most common types of nylon fibers.
- Nylon 66 is made via the **polycondensation of hexamethylene diamine and adipic acid** (Fig).
- Nylon 6, on the other hand, is made via **the ring opening polymerization of caprolactam**

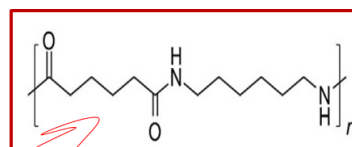
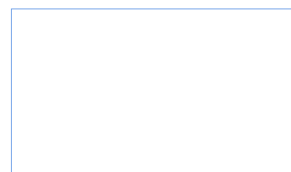


Fig: Nylon 66 chemical structure.



Nylon fibers exhibit an excellent combination of strength and elasticity, remarkable resiliency, good abrasion resistance, excellent wrinkle resistance, and good flame resistance. However, nylon fibers are known to have poor resistance to sunlight, making them susceptible to UV and thermal degradation. Nylon 6,6, in particular, owes its high tenacity to hydrogen bonding, which increases the percentage of crystallinity in the polymer chain.

Widely utilized in various applications, nylon fibers find their place in carpets, upholstery, hosiery, raincoats, and sewing threads. Despite being more expensive than polyester, nylon remains the preferred fiber for numerous technical textile applications.

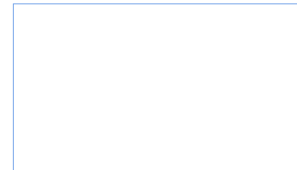
Polymer in textile: Nylon

3. Uses: Nylon fiber is widely used in carpets, upholstery, hosiery, raincoats, and sewing thread.

- It is **more expensive than polyester** so several textile applications have switched to **polyester fiber use**.
- Nylon, however, remains a **fiber of choice** for various **technical textile** applications.
- In automobiles, nylon fiber is used as **fabric for airbags and seat belts** and it is also used as **tire cord for rubber reinforcement** (Fig).
- In civil and military applications, nylon fiber is widely used in **tents, ropes, parachute canopies, and harnesses**



Fig: Automobile airbag made from nylon fabric



In the automotive industry, nylon fibers are employed in airbags, seat belts, and tire cords for rubber reinforcement. Civil and military applications make extensive use of nylon fibers in tents, ropes, parachute canopies, and harnesses.

High-performance fibers constitute a class of polymeric fibers with exceptional temperature resistance and superior mechanical properties that surpass those of conventional fibers. Common examples include aramid fibers like Nomex and Kevlar, along with fibers such as polyphenylene sulfide (PPS) and polyether ketones (P). These high-performance fibers play a crucial role in applications requiring advanced mechanical performance characteristics.

High-performance fibers, particularly aramids, are the preferred materials for demanding military and security applications, both in marine and terrestrial environments. Aramids, aromatic polyamides, have a fiber-forming substance with a polyamide structure where the polymer chain's amide groups have two adjacent aromatic rings on both sides.

Aramids, exemplified by Nomex and Kevlar, showcase unique properties. Nomex, in its metaform, is renowned for high-temperature resistance, making it widely used in protective clothing. On the other hand, Kevlar, in its paraform, is recognized for high strength and modulus, finding extensive application in bulletproof vests.

High performance fibers: Aramids (Nomex and Kevlar)

1. Chemistry: Aramids are simply **aromatic polyamides** (nylons). The fiber forming substance is a polyamide where the amide groups on the polymer chain have two aromatic rings adjacently attached on both sides (Fig.).

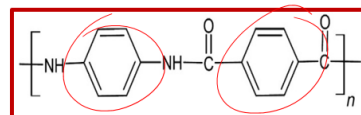
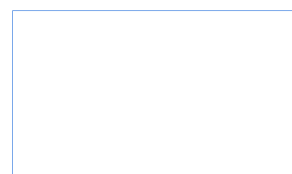


Fig: Aramid chemical structure

- **The meta** form of aramid, **Nomex**, is known for its **high temperature resistance** and is widely used in **protective clothing**.
- **The para** form of aramid, **Kevlar**, is known for its **high strength and modulus** and is widely used in bullet proof vests.



Key properties of aramid fibers include high-temperature resistance, exceptional strength and stiffness, excellent dimensional stability, low flammability, outstanding heat resistance, good chemical resistance, and effectiveness in bulletproofing and cut resistance. Nomex is a preferred fiber for firefighter suits, owing to its excellent heat resistance, and it is also utilized in space suits, heat-resistant gloves, and filters. Kevlar is employed in bulletproof vests, gloves, and serves as reinforcement for hoses, tires, belts, ropes, and advanced composites.

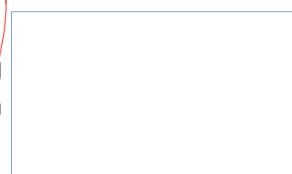
High performance fibers: Aramids (Nomex and Kevlar)

3. Uses: Aramid fibers such as **Kevlar and Nomex** are used in high temperature and mechanically demanding applications.



- **Nomex** is the fiber of choice for **fire fighter suits** due to its **excellent heat resistance**. It is also used in **space suits, heat resistant gloves, and filters** (Fig.).

- **Kevlar** is used in **bullet proof vests**, **cutresistant gloves**, reinforcement for hoses, tires, belts, ropes, and advanced composites (Fig.)



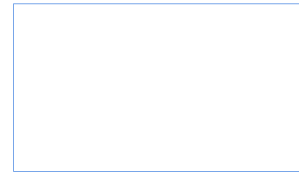
Carbon fibers stand out as one of the strongest manmade fibers available, boasting unmatched performance in terms of strength-to-weight ratio and exceptional rigidity. These fibers are crafted from precursors, specifically polyacrylonitrile (PAN) or rayon. PAN is spun into filaments that are collected into a flat tow, which undergoes pyrolysis in the absence of oxygen, eliminating non-carbon atoms. During this process, silicon-based finishes are often applied to lubricate and prevent filament sticking.

High performance fibers: Carbon fiber

- 1. Chemistry:** Carbon fibers are among the **strongest manmade fibers** available. Their performance is unmatched in terms of **strength-to-weight ratio** while they have **excellent rigidity**.
- **Carbon fibers** are made from what is known as a **precursor**, which is either **PAN or rayon**.
- PAN is **spun into filaments**, which are collected in a flat tow that is heated in the absence of oxygen in a **pyrolysis step** that removes all non-carbon atoms.
- **Silicone-based** finishes are usually used to lubricate the filaments and prevent them from sticking to each other **during processing**.



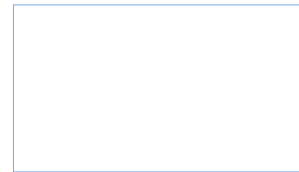
Fig: Carbon fiber on a bobbin



Carbon fibers are renowned for their superior strength and stiffness at a low weight, exhibiting excellent fatigue resistance, corrosion resistance, and chemical inertness. They can be woven into bi-directional sheets, later impregnated with epoxy resin and cured to create carbon fiber-reinforced plastics. These plastics find applications in various molded parts, serving as frames and panels in wide-body airplanes, space rockets, military vehicles, and racing vehicles. Additionally, they are utilized in sporting equipment like bicycles, fishing rods, tennis racquets, and hockey sticks.

High performance fibers: Carbon fiber

- **Carbon fiber** composites are used as frames and panels in **wide body airplanes and space rockets**. Other uses include **various parts in military and racing vehicles** (Fig.).
- CFRPs are also used in **sporting equipment** such as **bicycles, fishing rods, tennis rackets, and hockey sticks** (Fig.).



Polyolefin fibers, such as polyethylene and polypropylene, offer a distinct cost advantage over other synthetic fibers while possessing unique properties. Polypropylene is more prevalent than polyethylene in textile applications, although both exhibit relatively low melt points compared to other synthetic fibers. According to the official definition from the United States Federal Trade Commission, an olefinic fiber is a manufactured fiber where the fiber-forming substance is a long-chain synthetic polymer consisting of at least 85 percent by weight of ethylene, propylene, and other olefinic units.

High performance fibers: Polyolefins

1. Chemistry: According to the United States Federal Trade Commission's official definition, an olefin fiber is "A manufactured fiber in which the fiber forming substance is any long chain synthetic polymer composed of at least 85% by weight of ethylene, propylene or other olefin units".

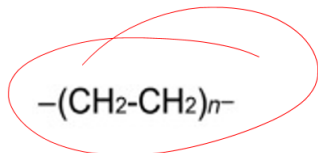


Fig: Polyethylene chemical structure

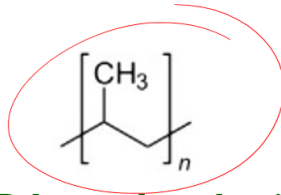
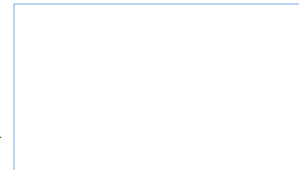


Fig: Polypropylene chemical structure



Polyolefinic fibers, be it polyethylene or polypropylene, are recognized for their good tensile strength, toughness, abrasion resistance, and chemical resistance. However, they present a drawback in that they are challenging to dye. In general textile use, polypropylene fibers may have a tendency of 40.5 to 50 deniers per decitex, while high tenacity yarns used in ropes and nets can achieve tenacity levels of up to 81. Polyethylene, with high density, softens at 130 degrees Celsius and melts around 140 degrees Celsius. In comparison, polypropylene softens at 150 degrees Celsius and melts around 160 degrees Celsius.

Some key properties and characteristics of polyolefin include their lightweight nature, with the lowest specific gravity among synthetic and natural fibers.

Polyolefin fibers, encompassing polyethylene and polypropylene, offer several notable characteristics. They provide good bulk, resulting in excellent cover properties, have low moisture regain, quick drying ability due to minimal moisture absorption, exhibit high thermal bonding, and possess commendable weakening characteristics. These fibers find extensive applications in diverse fields such as carpeting, ropes, geotextiles, hygiene products, nonwovens, construction, and technical textiles, delivering cost benefits across various uses.

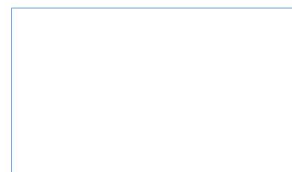
Polypropylene slit films and non-filament variants serve roles in ropes, agricultural nets, flexible intermediates, bulk containers, furniture coverings, and even artificial turf. In the realm of nonwovens, polypropylene contributes to automotive fabrics, geotextiles, disposable hospital clothing, industrial wipes, filtration media, face masks for virus protection, and battery separators. The global consumption of polypropylene in nonwovens exceeds 2.5 million tonnes, as reported by the Chemical Market Resource.

High performance fibers: Polyolefins

- Some of the main uses of **polypropylene in nonwovens** are in **filtration media, face masks** to protect from viruses and air pollutants (Fig.) and battery separators.
- The world consumes in **excess of 2.5 million tons of polypropylene** in nonwovens today, according to a report by **Chemicals Market Resources Inc.**



Fig: Face mask made from melt blown polypropylene nonwoven fabric



The advancements in shaping polymers into fibers of varied shapes and sizes have revolutionized textile manufacturing and design. The selection of the polymer is crucial to meeting specific fabric requirements. Polyester remains the most popular synthetic fiber, appreciated for its unique properties such as strength, abrasion resistance, and favorable economics. In applications demanding exceptional performance, such as military and aerospace, high-performance fibers become indispensable to meet stringent challenges.

Aramid and carbon fibers stand out as some of the most popular fibers with exceptional mechanical properties. In this segment, we delved into the application of polymers in textiles, exploring various fibers, their uses, and fundamental chemistry. References have been provided for your convenience. Thank you for joining us in this discussion on polymer applications in textiles.