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MODERN COMPOSITES FOR ENGINEERING APPLICATIONS

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Abstract: *This paper reviews the literature on technical textiles and new composite fibres. Technical textile is a term given to textile product used for industrial purpose. It gives the benefits of durability light weight cost effectiveness versatility and high strength in comparison of conventional material and high strength in comparison of conventional material. It is becoming an important part of our day-to-day activities. This paper also includes new composite fibres like Kevlar, Carbon, Basalt, Coir which are also used on large scale for production process and these fibres does not create any kind of complexity during production or after production. Therefore, production of technical textile is carried out on large scale in the world and it is also a growing sector in India. It has taken textile industries to higher level and it has become essential for economic growth, employment generation and increasing export. Depending on product characteristics, functional requirement and end user applications, these have been grouped into 12 segments i.e. Agrotech, Meditech, Buildtech, Mobitech, Clothtech, Oekotech, Geotech, Packtech, Hometech, Protech, Indutech and Expotech.*

Keywords: Oekotech, Kevlar, Carbon fibre, Basalt fibre, Coir fibre.

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INTRODUCTION

A technical textile is a textile product manufactured for non-aesthetic purposes, where function is the primary criterion. Terms such as industrial textiles, performance textiles, functional textiles, engineered textiles and high tech textiles are also used in various contexts instead of technical textiles. An exceptional feature of technical textiles is the use of innumerable varieties of raw materials, processes, products and applications for their production. 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. Technical textiles are reported to be the fastest growing sector of the textile industrial sector. It gives benefits of durability, lightweight, cost effectiveness, versatility and high strength in comparison of conventional material. It is becoming an important part of our day- to-day activities. It has become very significant in world economy as well as Indian economy.

Fibers used for modern composites

This paper comprehends new fibres like Synthetic fibre**: Kevlar,** Mineral fibre**: Basalt,** Metal fibre**: Carbon,** Natural fibre**: Coir.** These fibres are rapidly emerging in the field of textiles and are also aiding in the economic and technical growth of industries. The demand for these materials is increasing day by day. These fibres or materials are cost effective and are very profitable for technical textile industries. Most of these above mentioned fibres are not only used in single segment but also they are trying to make their roots firm in all 12 segments.

HISTORY

1. KEVLAR

Kevlar is the registered trademark for para-aramid synthetic fibre, related to other aramid such as Nomex and Technora . Developed by Stephanie Kwolek at DuPont in 1965, this high-strength material was first commercially used in the early 1970s as a replacement for steel in racing tires. By 1971, modern Kevlar was introduced. Typically it is spun into ropes or fabric sheets that can be used as such or as an ingredient in composite material components Aramid fibers are widely used for reinforcing composite materials, often in combination with carbon fibre and glass fibre. It is synthesized in solution from the monomers. 1, 4- phenylene diamine (para-phenylenediamine) and terephthaloyl chloride in a condensation reaction yielding hydrochloric acid as a byproduct. The result has liquid crystalline behavior and mechanical drawing orients the polymer chain in the fibres direction. Hexamethylphosphoramide (HMPA) was the solvent initially used for the polymerization, for safety reasons, DuPont replaced it by a solution of Nmethylpyrrolidone and calcium chloride. As this process had been patented by Akzo in the production of Twaron.

2. BASALT FIBRE

The first attempts to produced basalt fibre were made in United States in 1923 by Paul Dhe who was granted United State patent. This were further developed after world war 2 by researchers in USA, Europe and sovient union specially foe military and aerospace applications. since declassification in 1995. Basalt fibre has been used in a wider range of civilian applications. Kamenny Vek, located in Dubna, Russia, is a global leader for the production of high-quality basalt fibre and has been producing continuous basalt fibre since 2002.

3. CARBON FIBRE

The history of carbon fibre dates back to late 1800s. Renowned inventor, Thomas Edison, used carbon fibres as filaments for early light bulbs. It wasn't until the late 1950s that high tensile strength carbon fibres were discovered. In the beginning of 1970's, commercial production of PAN-based and isotropic pitch-based carbon fibers was started on a large scale in Japan. In the latter half of 1980's, anisotropic pitch-based carbon fiber manufacturers broke into the market.

4. COIR FIBRE

The first recorded history of coconut in the country dates back to Ramayana period. Coconut and coir fibre has been in record from since 3rd century BC. Generally it is believed that the coconut was introduced in India during the post- Vedic period. Ropes and cordage, made out of coconut fibre have been used from ancient times. Indian navigators, who sailed to seas to Malaya, Java, China and to the Gulf of Arabia centuries ago, had been using coir as their ship's cables. In India, Kerela is the largest producer of Coir. The history of coir and its associates with the state of kerala dates back to the 19th century.

COMPOSITES AND COMPOSITE FIBRES

Def:-A composite is a material made up of two or more different materials that are combined in a way that allows the materials to stay distinct and identifiable. Composites are composed of separate parts or compound. The purpose of composites is to allow the new material to have strengths from both materials. Composites are produced by reinforcing a resin matrix (thermoplastic/thermoset) with fibres like glass fibre, aramid, carbon fibre and/or natural fibres. Composites are created by combining two or more materials to produce a new material that retains important properties from the original elements. A common example of a composite is concrete. It consists of a binder as cement and reinforcement as gravel. The reinforcement is used to strengthen the composite. The individual materials that make up composites are called constituents. Most composites have two constituents, a matrix and reinforcement.

Why to use composite?

The biggest advantage of modern composite materials is that they are light as well as strong. By choosing an appropriate combination of matrix and reinforcement material, a new material can be made that exactly meets the requirements of a particular application. Composite also provides designed flexibility because many of them can be molded into complex shapes. The downside is often the cost. Although the resulting product is more efficient, the raw materials are often expensive.

1. Kevlar

Manufacturing of Kevlar

Kevlar is made from a condensation reaction of para-phenylene diamine and terephthaloyl (PPD-T) chloride. The resultant aromatic polyamide contains aromatic and amide groups which makes them rigid rod like polymers. The rigid rod like the chemical composition of Kevlar is poly para-phenyleneterephthalamide (PPD-T) and it is more properly known as a para-aramid. It is oriented para-substituted aromatic units. Aramids belong to the family of nylons. Common nylons, such as nylon 6,6 do not have very good structural properties, so the para-aramid distinction is important.

Aramid fibers like Nomex or Kevlar, however, are ring compounds based on the structure of benzene as opposed to linear compounds used to make nylon. The aramid ring gives Kevlar thermal stability, while the para structure gives it high strength and modulus. Like nylons, Kevlar filaments are made by extruding the precursor through a spinneret. The rod form of the para-aramid molecules and the extrusion process make Kevlar fibers anisotropic they are stronger and stiffer in the axial direction than in the transverse direction. In comparison, graphite fibers are also anisotropic, but glass fibers are isotropic.

Crystallinity is obtained by a manufacturing process known as spinning, which involves extruding the molten polymer solution through small holes. When PPD-T solutions are extruded through a spinneret and drawn through an air gap during fiber manufacture, the liquid crystalline domains can orient and align in the flow direction. Kevlar can acquire a high degree of alignment of long, straight polymer chains parallel to the fiber axis. The structure exhibits anisotropic properties and this structure results in poor shear and compression properties for aramid composites.

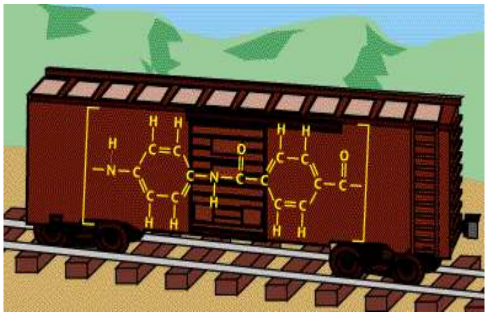


Figure1: Chemical composition of Kevlar

Figure 2: Kevlar fibre

COMPOSITION OF HYBRID KEVLAR FIBRE:

In the process of produce hybrid kevlar fibre three types of fibres are used which includes glass, carbon and kevlar. These three types of fibres are used in fabrication of the specimen. A plain woven Hexcel aramid (polyparaphynylene terephthalmide) is constructed by using Kevlar as the composite. This fabric is a high performance fabric- style 706 (Kevlar KM- 2,600 denier) with a real density of 180gm per meter square . This sample is then cured at room temperature by using epoxy resins and hardeners (Polyamide- Domide) at the ratio of 50:50 and it is again cured after at 20C.

PROPERTIES:

When Kevlar is spun, the resulting fiber has a tensile strength of about 3,620 MPa and a relative density of 1.44 and it has high abrasion resistance. It withstands high temperature upto 450C and as low as -196C.At higher temperatures the tensile strength is immediately reduced by about 10–20%, and after some hours the strength progressively reduces further. Strength to weight ratio of Kevlar fibre is more. It is self extinguishable. It has resistance to almost all types of chemicals.

APPLICATIONS:

Kevlar has much application in the areas like industry, sports, military, sports, personal safety equipment. Kevlar is used to make hoses, belts, reinforcement materials. It is used to make parts of air-craft, ship hulls and reinforced tires. It is also used to make bullet proof vest, helmets, reinforcement for military vehicles and in making other lightweight equipment. Kevlar is used in making kanoe hulls, race car parts and body, sport shoe, snow boards, skate board, surf board, gloves racquets, motor sport helmets. Kevlar is used to making various personal protection equipment such as riding shoe, helmet industrial gloves, fire fighting apparel vests body armors body parts.

New Types of Kevlar Fibre:

Kevlar® AP, Kevlar® 29 (K29), Kevlar® 49 (K49), Kevlar® 100, Kevlar® 119, Kevlar® 129, Kevlar® KM2, Kevlar® KM2 Plus.

Kevlar ®K-29

Kevlar ®K-29 with one very important difference—it has up to a 15% higher tenacity than K-29. And, as shown in Figure 1, DuPont™ Kevlar®K-29 AP has more than double the tenacity of other materials commonly used in similar commercial and industrial applications. This significant improvement in strength performance gives you greater design flexibility. With DuPont™ Kevlar®K-29 AP, you can use less yarn to achieve the same level of performance, resulting in cost savings, or you can continue to use the same amount of yarn and design higher performing products. You now have the flexibility to choose which option best meets your needs. DuPont™ .These yarns are used in ballistic applications, ropes and cables, protective apparel such as cut-resistant gloves, in life protection uses such as helmets, vehicular armoring, and plates, and as rubber reinforcement in tires and automotive hoses.

Kevlar® 49 (K49)

High-modulus type used primarily in fiber optic cable, textile processing, plastic reinforcement, ropes, cables, and composites for marine sporting goods and aerospace applications.

Kevlar® 100

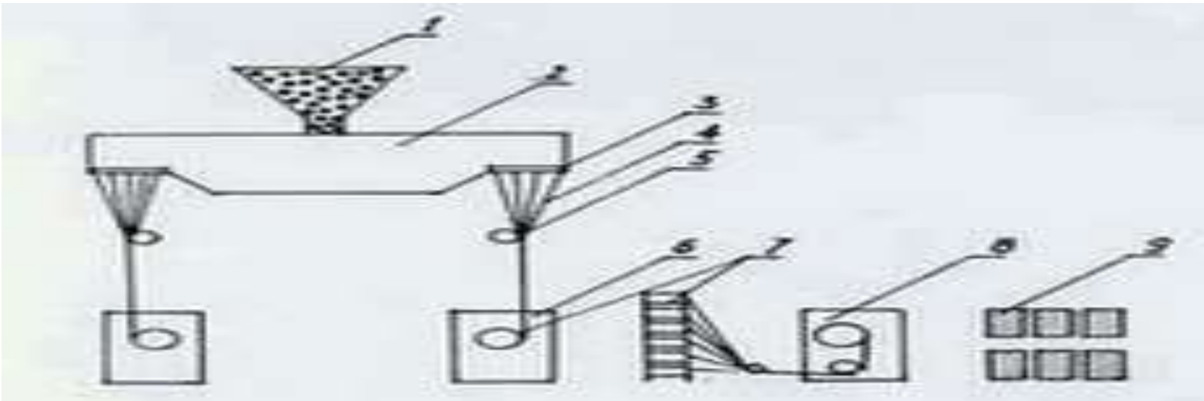
Producer-colored Kevlar® yarns, used in ropes and cables, tapes and strappings, gloves and other protective apparel, and sporting goods.

2. BASALT FIBRE

Basalt fibre or fiber is a material made from extremely fine fibres of basalt, which is composed of mineral plagioclase, pyroxene and olivine. It has similar properties to carbon fibre and fiberglass. It is used as a fireproof textile in aerospace and automotive Industry and can also be used a fireproof textile in aerospace and automotive industries and can also be used as a composite to produce product such as tripods. Features of reinforced basalt fibres are high strength, corrosion resistance, high temperature resistance, easy to handle.

MANUFACTURING OF BASALT FIBRE:

The basalt raw material is reduced to fractures 5 ~ 20 mm in dimension→ the basalt fractions are fed by the charging conveyer (1) to the melting furnace (2)→ the charged basalt is melting at a temperature of 1400 ~1600 °C → the melted basalt passes through the die holes of the bushing (3) → from the bushing, the basalt continuous fibers 9 ~ 15 mm in diameter (4) are fed to the unit (5) for applying lubricant → the winding unit (6) performs the operation of winding the continuous basalt fibers on the spools (7) → the basalt continuous fibers from the spools are rewound into the bundles (9) of basalt fiber roving.



1. **Melting Furnace, 2. Charged basalt, 3. Bushing, 4.Continuos fibre, 5. Lubrication unit 6. Winding unit 7. Spools, 8. Roving 9. Roving can**

Figure 2: Basalt manufacturing process

COMPOSITION OF BASALT REBER GLASS FIBRE:

In the composition of basalt reber glass fibre continuous fibre is used and it is then chopped to 1cubic cm to produce (BCF chopped fiber). Two types of equipment are taken for chopping of single roving and more productive installation for chopping of bundles. The actual production process begins with three types of the process equipment for production of basalt-plastic rebar. In the first stage bobbin carrier is set for basalt fiber roving and in the second satge a section for installing the bobbin carriers for feeding basalt fiber roving is incorporated. Later, basalt fibre roving is then taken to the pultrusion process line. After the pultrusion process is completed. These newly produced composite is then drawn and inspected at the same time. Basalt Rebar (fibre) is an alternative to steel and fiberglass for reinforcing concrete. It is made from volcanic rock basalt rebar is tough, stronger than steel and has a higher tensile strength. Much lighter than steel, 89% percent in fact. Basalt rebar is naturally resistant to alkali, rust and acids. Moisture penetration from concrete does not spall. Basalt rebar has the same thermal coefficient expansion as concrete.

Figure4: Basalt Reber Fibre (Pipe)

PROPERTIES:

Basalt fiber is a relative newcomer to fiber reinforced polymers (FRPs) and structural composites. Basalt fibre has tensile strength up to 4.84 GPa, it has high elastic modulas up to 89 GPa, elongation at break is 3.15% and density is 2.7gm per cubic centimeter. It has good insulating properties so they are incorporated into printed circuit boards. It has a similar chemical composition as glass fiber but has better strength characteristics, and unlike most glass fibers is highly resistant to alkaline, acidic and salt attack making it a good candidate for concrete, bridge and shoreline structures.

APPLICATIONS:

Basalt has many applications like heat protection, friction materials, and it is also used as high pressure vessels for tanks and gas cylinders. Beside these uses it has other applications like load bearing profiles, windmill blades, lamp posts, ship hulls, car bodies, sports equipment, Basalt fibre has also been emerged in the sector of building and constructions. It is used as a concrete reinforcement for bridges and buildings, speaker cones, cavity wall ties. Basalt fibres can be used as composite material. It is also used as a tripod. Basalt micro fibres are used as water proof and fire proof fabrics. These micro fibres are used to make fabrics for windy season as well as cold season.

Figure 5: Formation of basalt fibre

TYPES OF BASALT FIBRE

1. BASALT SUPER THIN FIBRE

Subtypes of basalt fibre are continuous fibers and discrete fibers.

A) Continuous Fibers

At thickness 7-15 microns, it is used as reinforcing filler in production of composite materials (basalt-plastic) and products on their basis with polymer and inorganic matrix. As initial material, it is used in production of fabrics of various purposes (for filters, fire-proof clothes, anti-fire felting etc.), covering bags (pipe reinforcing, cable protection, etc.). At thickness 15-24 microns, it is used as reinforcing filler of composite materials with organic and mineral binder (concrete, asphalt, gypsum, etc.).

B) Discrete Fibers

Thickness of elementary fiber is 3-9 microns, length 40-60 mm. It is used for production of energy-efficient heat-sound-insulating materials,cryogenic equipment, hydroponics,as filler of 3-D reinforced basalt composite materials,in ship-, aircraft-, motor building, engineering, acoustic technique,and for increasing fire-resistance and fire prevention of various objects.

3. CARBON FIBRES

The benefits of these high strength fibres were clear. It had much greater tensile strength than steel. Carbon fibres are fibres about 5-10 micrometer in diameter and composed mostly of carbon atoms. To produce a carbon fibre, the carbon atoms are more or less aligned parallel to the long axis of the fibre. This gives high strength to the fibre. It has high stiffness/ tensile strength, low weight, high chemical resistance, high temperature, tolerance etc.

COMPOSITION AND MANUFACTURING:

Various types of carbon manufacturing process-

A) PAN-based carbon fibers

B) Pitch-based carbon fibers

C) Mesophase pitch-based carbon fibers

D) Isotropic pitch-based carbon fibers

E) Rayon-based carbon fibers

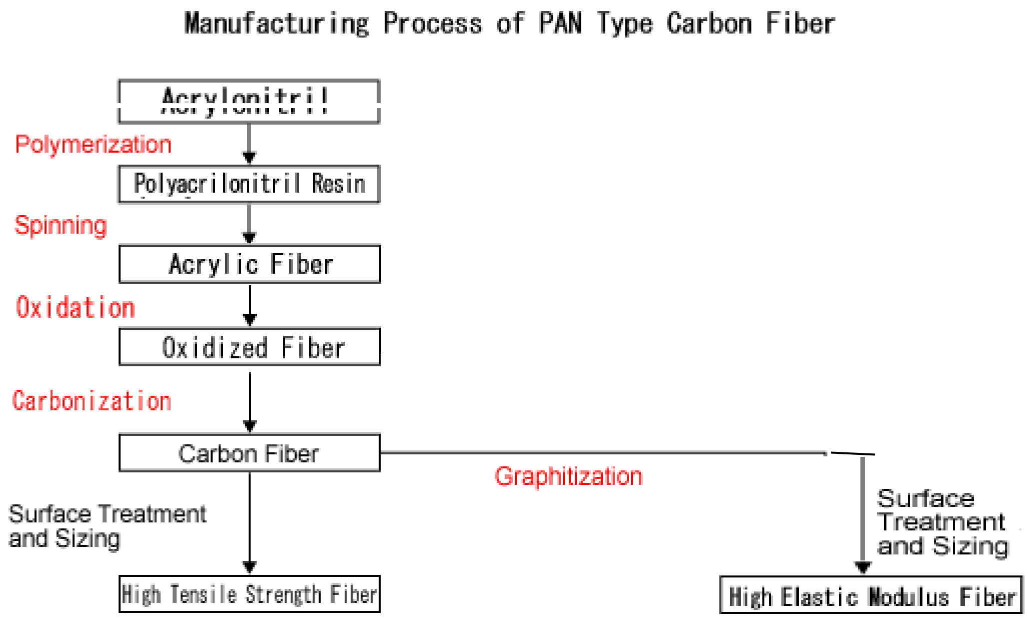
F) Gas-phase-grown carbon fibers

A) PAN-based carbon fibers

The raw material used to make carbon fiber is called the precursor. About 90% of the carbon fibers produced are made from polyacrylonitrile (PAN). Process begins with the use of acrylonitrile and then polymerization process is carried out in this process copolymerization of acrylonitrile with a small quantity of an appropriate co-monomer. Thereafter polyacrylonitrile(PAN) resin is the compound which participates in the chemical reaction and then generation of acrylic fibre takes place.

This process containing PAN precursor is then wound upon a bobbin continuously pass through a high temperature furnace (Oxidation furnace) under an air atmosphere at 200-300c. The oxidized fibre is then heated at 1000-1500C in carbonization furnace under an inert gas atmosphere and under longitudinal tension. Final process which is known as graphitization is carried out to produce carbon fibre threads.

The carbon fibre thread is being heat treated at 2000-3000C in graphitization furnace under an inert gas atmosphere and under longitudinal tension. Carbon fibre can further be sized to increase its strength.



PROPERTIES:

Carbon Fiber's reputation as a material has taken on mystical proportions! Not only does it have a reputation for being the best and the strongest, but it's also become cool to have something made of carbon fiber. Carbon fibre has high strength to weight ratio. Carbon fibre has good rigidity, corrosion resistance, good electrical conductivity, fatigue resistance, good tensile strength but brittle. Carbon fibre has other applications like fire resistance i.e., it is non flammable, high thermal conductivity, low coefficient of thermal expansion, non poisonous. It is biologically inert, self lubricate, having excellent EMI(electromagnetic Interferance) shielding property. It is relatively expansion and it requires specialized experience and equipment to use.

APPLICATIONS:

Due to its low weight and high conductivity, carbon is used in aerospace and space. It is used in sporting goods where high performance and accuracy is needed. It is used in the production of large yachts. In sports it is used for making carbon fibre bicycle, bikes and shoes. It is used to make wind turbine blade. Carbon fibre and other composite materials are being used in the development of musical instruments. Carbon fibre also has several applications in science. One of the main uses is carbon fibre electrodes.

4. COIR FIBRE

The English word 'coir' comes from Malyalam word 'kayar'. It is a natural fibre extracted from the husk of coconut and used in brushes, mattresses, etc. Coir comes between the hard, internal shell of the coat of coconut. Other uses of brown coir are in upholstery padding, sacking and horticulture. White coir harvested from unripe coconut is used for making finer brushes, string, rope and fishing nets. Fibres are mechanically extracted from dry mature coconut husk after soaking. Coir fibre comes under the category of seed fibre and coir is from "Palm Family".

MANUFACTURING OF COIR FIBRE:

De-husking of coconut (Brown husk/ Green husk)

↓

Retting or Softening of husk

↓

Segregation (machine)

↓

De-fibreing (machine)

↓

Combing

↓

Drawing

↓

Yarn or Rope preparation

↓

Hand spinning or Mechanical spinning

DE-HUSKING

It is a process of removal of husk from coconut shell. The raw material for the extraction of coir fiber can be broadly classified into two groups, Green husk and Dry husk.

RETTING

Retting or soaking of husk is most important operation in the preparation of coir. Retting can be described as immersing the husks in brackish water for periods varying from 6 to 10 months.

CHEMICAL RETTING

Formulation of chemical recipe for retting as well as softening of coconut fiber to make it more pliable for finer yarn spinning has been achieved.

SEGREGATION

The segregator will assort the coconut fibres into different grades, which can be used for development of high value products. It works on the principle of air drag and gravity for quality based segregation of fibres.

DE-FIBRING

A process of de-fibreing of coconut husk comprises of crushing the coconut husk in a crusher to ensure maximum exposure of the husk to the microbial action without damaging the husk.

COMBING

Combing of coir takes place on disintegrator machine. In combine green husk are gently crushed and punctured avoiding much fiber breakage.

DRAWING

In this process the fibres are straightened to get more uniform quality yarn.

SPINNING

Commercially coir yarn is produced either by hand spinning or 'ratt' spinning. Hand spun yarn is soft twist, whereas the wooden, motorized or automated ratt spinning machines is used for spinning yarns of hard and soft twist.

COMPOSITION OF COIR-POLYESTER COMPOSITES

Coir dust is very similar to peat in appearance. It is light to dark brown in colour and consists of primarily of particles size range 0.2 to 2.0mm. Coir fibers are typically 10–30cm long, and consequently have a high length/diameter ratio. In addition, helical arrangements of microfibrils at 45° mean that the coir fibers can be stretched to more than their elastic limit, without rupturing.

Attempts have been made to incorporate retted coir fibre into general purpose polyster resin to prepare laminates and some consumer articles by hand layup. As coir fibres are readily available so at first polyester resin is manufactured thereafter coir fibres are embedded in polyester resin. Polyester resin is manufactured by reacting a dialkyl terephthalate with a polyhydric alcohol in the presence of an interesterification catalyst and then reacting this reaction with unsaturated dicarboxylic acid or optionally a saturated dicarboxylic acid to produce an unsaturated alkyd resin and later this unsaturated alkyd resin is dissolved in a vinyl monomer and further the polyester is being manufactured by using hydroquinone and phosphate. After embedding coir fibres in polyester resin and is treated with hot air or at normal at room temperature strong bonding is 1achieved and composition of coir- polyester composite is completed.

Figure6: Coir fibre

PROPERTIES:

Coir is hard and tough fibre. Coir fibre has good absorbency. It is longest and more durable product than any other textile product. Coir offers vast scope of utilization on account of its strength, dampness and roughness, natural resiliency and durability. This fibres are electrical resistive. It has good blending characteristics. The density of fibre is about 1150 kg/m. The fibre is hygroscopic and the moisture content is 10-12% at 65% relative humidity (RH), while it is 22-25% at 95% RH. Coir has strong resilience to saltwater.

APPLICATIONS:

Coir finds its applications in geotextile, meditech, hometech, ecotech, agrotech, etc. Coir fibre has good strength, roughness and hardness so it is used to make yarns, ropes, ships cables, rigging, and cordages. Due to hairiness of fibres coarse cloths and bristles for brushes, mattings, carpets, and rugs are manufactured. Mattreses fibre, decorticated and bristle fibre or mixture of this are twisted into ropes to produce curled fibre which is used in manufacture of rubberized coir. This coir pads are used for spring mattresses, upholstery, sound and heat insulating material in industries. Coir fibre is also used to make door mats and floor furnishing.

CONCLUSION:

As a result of characteristics and properties, of all fiber (Kevlar, basalt, carbon and coir) mentioned in this paper can be really considered as the material of our future for a green and sustainable development. These fibers are now being a popular choice for the material scientists and research fellows for the development of 12 segments of technical textiles viz; Meditech, buildtech, Mobiletech, Protech, Indutech, Hometech, Clothtech, Sporttech, Packtech, Oekotech, Defence, Geotech due to their properties like durability, high strength, good electrical conductivity, high rigidity, low elongation at break etc. Their high performance value makes them as a useful reinforcement material in the present and also for the future era to come.

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