Chapter 3

Recent trends in fishing gear materials

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Introduction

Netting yarns for the fabrication of fishing gear are either of textile or non-textile origin. Textile materials compose of netting, twine and rope while non-textile origin materials,constitute floats, sinkers, hooks etc. Different kinds of fibres originating from plant and animal body parts have been used for production of textiles and other products are termed as natural fibres. Raw material for fish netting consists of fibres which can be distinguished into two groups: natural fibres and man-made fibres. Traditional fishing gears used earlier were mainly with natural fibres such as cotton, manila, sisal, juteand coir were the materials exclusively used in earlier days for fishing gear fabrication.

Later, the invention of polymers resulted in synthetic fibres which revolutionalized the fishing industry. In recent decades advances have taken place in fiber technology, along with the introduction of other modern materials. With the introduction of man-made synthetic fibers in India in the late 1950s, natural fibers used for the fishing gears have been substituted by these synthetic materials due to their high breaking strength, high resistance to weathering, low maintenance cost, long service life and better uniformity in characteristics. Most important synthetic fibres used in fisheries are polyamide (PA), polyester (PES),polyethylene (PE) and polypropylene (PP). Other synthetic fibres, which are less widely used and generally restricted to Japanese fisheries, are polyvinyl alcohol (PVA), polyvinyl chloride (PVC) and polyvinylidene chloride (PVD). Earlier, netting used to be fabricated manually, which is laborious and time consuming while the introduction of synthetic fibres paved way for machine made nettings which are almost exclusively used in fishing net fabrication.

Fishing Gear materials

Natural Fibres

Fibres of plant origin such as that of cotton, manila, sisal, hemp, linen, ramie, coir etc. and of animal origin such as silk, hair etc are termed as natrural fibres. Animal fibres are either too expensive or are not suitable for the fabrication of fishing gear. As far as the fishing industry is concerned, the plant/vegetable fibres are very important. Based on the source of origin, vegetable fibres come as seed fibre, fruit fibre, leaf fibre and bast fibre. Seed fibre is available from cotton (*Gossipium* sp.) while coir (*Cocosnucifera*) is a source of fruit fibre. Sisal (*Agavesisalana*), Abaca/Manila (*Musatextiles*) and pineapple leaf (*Ananascomosus*) are sources of leaf fibre.Examples of bast fires are true hemp (*Cannabissativa*), Indian hemp (*Crotalariajuncea*) and jute (*Corchoruscapsularis*).

Natural fibres have the advantage of ecofriendliness and reasonable weather resistance. But being cellulose in origin, vegetable fibres are subjected to biodeterioration by cellulose digesting bacteria/fungi when exposed to water. Thus vegetable fibres have the major disadvantage of a very short useful life time. To increase their service life, various preservative treatments and protective measures are required. This is a major drawback to the fishermen for effective utilization of fishing seasons. More ever, preservation does not offer the best solution. Natural fibres on wetting absorb water and increase in weight. This results in difficulty of handling by fishers and also limit the size of the gear that can be handled from a boat.

Man- made fibres

Natural polymers and synthetic polymers constitute man-made fibres. Natural polymers are manufactured by the alteration of natural polymers like cellulose and protein while synthetic polymers obtained by synthesis or chemical process. Man-made fibres derived from cellulose eg: rayon, are susceptible to microbial deterioration while synthetic fibres are very resistant to micro-organisms. For fishing gears, synthetic fibres only is suitable.

Synthetic fibres

Compared to vegetable fibres, synthetic fibres have better uniformity, continuity, higher breaking strength and are more resistant to rotting. These materials have greatly extended the endurance of fishing gears, and together with the mechanized vessels, have increased the size and complexity of nets. Developments of new synthetic materials and fabrication techniques played an important role in improving fishing gear efficiency. It is stated that synthetic fibres brought to one of man's oldest occupations, the miracle of science and in doing so provide easier living for the fishers.

The development of synthetic fibre was based on the discovery that all fibre materials consist of long chain molecules in which a great number of equal simple units are linked together. This structure gives the fibre the properties required for a textile fibre. Synthetic fibres are produced entirely by chemical process or synthesis from simple basic substances such as phenol, benzene, acetylene etc.The chemical process involves the production of macromolecular compounds by polycondensation or polymerization of simple molecules of a monomer. The raw materials are petroleum, coal, coke and hydrocarbon. Depending on the type of polymer, synthetics are classified into different groups and are known by different names in different countries. Altogether seven groups are developed; Aramid fibres, Ultra high molecular weight polyethylene andliquid crystal polymer are later additions to this group.

Polyamide (PA): Polyamide, a synthetic polymer, popularly known as nylon, is invented in 1935. Nylon refers to a family of polymers called linear polyamides. Nylon consists of repeating units of amide with peptide linkages between them. There are two common methods of making nylon for fibre applications. In one method, molecules with an acid (COOH) group are reacted with molecules containing amine (NH_2) groups. Thus nylon 66 widely used for fibres is made from adipic acid and hexamethylene diamine. In the second method, a compound containing an amine at one end and an acid at the other is polymerized to form a chain with repeating units of (-NH-[CH2]n-CO-)x. This type called nylon 6 is built with caprolactam. The number usually following the PA part refers to the number of C-H units between the reactive ends of the monomer. With regard to the fisheries, there is no difference between PA 66 and PA 6. In India, PA 6 is used for netting materials. The softness, lightness, elastic recovery, stretchability and high abrasion and temperature resistance are superior properties inherent to nylon. However, high moisture absorption along with dimension instability and requirement of UV stabilization are its disadvantages. On wetting, nylon loses up to 30% of elastic tensile strength and 50% of tensile modulus.

Polyolefines:PP and PE are often collectively called "polyolefines". Polyolefin fibres are long-chain polymers composed (at least 85% by weight) of ethylene, propylene or other olefin units. Polyolefin fibres are made by melt spinning. They do not absorb moisture and have a high resistance to UV degradation.

Polyethylene (PE):PE fibre is defined as: “fibres composed of linear macromolecules made up of saturated aliphatic hydrocarbons”.PE fibres, used for fishing gear, are produced by a method developed by Ziegler, in the early 1950s.The monomer ethylene, the basic substance of polyethylene, is normally obtained by cracking petroleum. PE has a very simple structure, a molecule of PE is a long chain of carbon atoms, with two hydrogen atoms attached to each carbon atom. Linear polyethylene or high density polyethylene has high crystallinity, melting temperature, hardness and tensile strength.

Polypropylene (PP):PP fibre is defined as: “fibres composed of linear macromolecules made up of saturated aliphatic carbon units in which one carbon atom in two carries a methyl side group”. Natta, developed the process for the synthesis of polypropylene in 1954. This is an additive polymer of propylene. PP was commercialized in 1956 by polymerizing propylene using catalysis.

Polyester (PES): The principal PES fibres are made from polymerization of terepthalic acid and ethylene alcohol. It was first synthesized by Whinfield and Dickson of Great Britain in 1940-41 and named the fibre "Terylene”.

Basic terms in netting

Fibre: It is the basic material of netting. Its length should be at least 100 times its diameter.

Netting yarn is the standardized universal term for all textile material which is suitable for the manufacture of netting for fishing gears and which can be knitted into netting by machine or by hand without having to undergo further process. Yarn is made into a netting by twisting or braiding. Monofilaments are used directly for making into netting without further process.

Netting twine: or folded yarn is a netting yarn which is made of two or more single yarns or monofilaments by only one twisting operation.

Cabled netting twine: Combines two or more netting twines by one or two further twisting operations. Fibres are combined to form single yarns. Several single yarns are twisted together to form a netting twine. Several of these folded yarns or netting twines are twisted together by a secondary twisting operation to form a cabled netting twine.

Braided netting yarns: These are produced by interlacing a number of strands in such a way that they cross each other in diagonal direction. These braids are usually in the form of tubes. The braided netting yarns are available with or without core. Core is the term used for single yarn, twisted yarn or monofilaments which do not belong to the braided tube but fills the space inside the tube.

Netting: Nettingis defined by ISO as a meshed structure of indefinite shape & size, composed of one yarn or one or more systems of yarns inter laced or joined or obtained by other means for example by stamping or cutting from sheet material or by extrusion

Basic yarn types

Fibre is the basic material used for the fabrication of netting yarns. By twisting, braiding or plating, yarns are made into twine. For twine construction, there are two steps, first is the twisting together of two or more single yarns to form a strand/ply and the second step involves the twisting together of two or more strands to form a twine. The basic forms in which most synthetic fibres are produced are continuous filaments (multifilaments), staple fibres, monofilaments and split fibres. Continuous filaments are fibres of indefinite length. A quantity of continuous filaments is gathered up, with or without twist to form a filament yarn termed as multifilament. Staple fibres are discontinuous fibres, prepared by cutting filaments into short lengths usually 40-120 mm suitable for the yarn spinning fibres. Staple fibres are twisted to form a spun yarn. These have a rough surface due to the numerous loose ends of fibres sticking out from the twine. Monofilament is a single yarn strong enough to function alone as a yarn without having to undergo further processing. Unlike fine continuous filaments and staple fibres, this can be directly used as individual fibres for netting. Split fibres, developed from oriented plastic tapes (flat tape) which are stretched during manufacture at a very high draw ratio resulting in the tapes splitting longitudinally when twisted under tension.

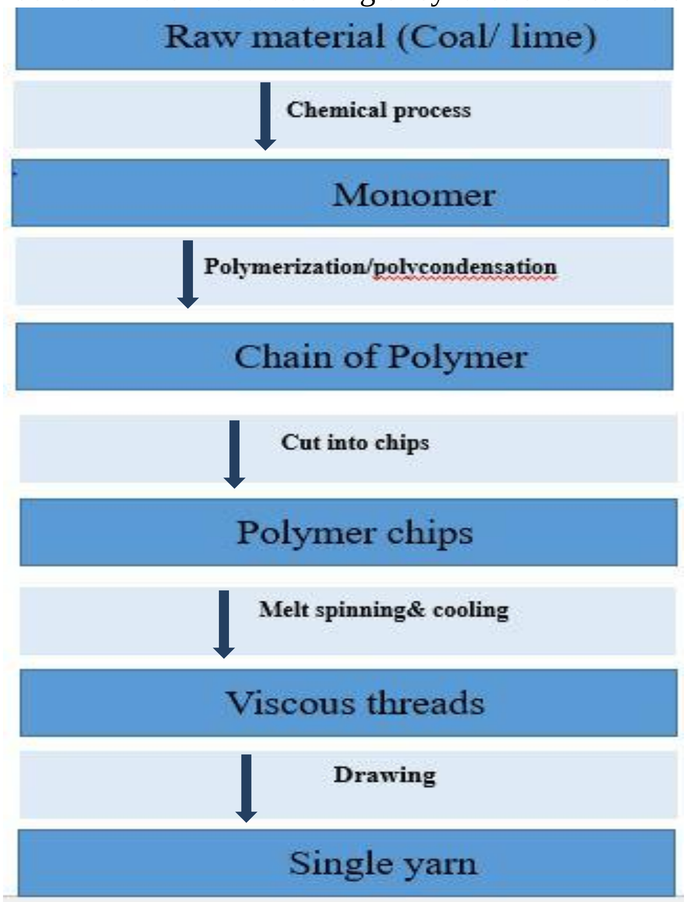
Probable Yarn types in each polymer group

All fibre types are not available/suitable as netting yarns from all the chemical groups. PA is available as multifilaments, staple and monofilaments yarn. PE is available as monofilaments (twisted) but not as staple fibres or as multifilaments while split fibres are not common. In the case of PP, fibres as multifilaments, split fibres and monofilaments for ropes are available. PES only as multifilament fibres and not as split fibres.

Synthetic netting yarns used in Indian fishing sector are polyamide, polyethylene and polypropylene. PA and PE are the most commonly used fibres for netting while PP and PE are used for ropes. Of these, PA is mostly used in the gill net line and purse seine sector while PE is used in the trawl net sector and deep-sea gill net sector.

Manufacturing process:

The basic steps involved in the manufacturing of synthetic fibres are depicted in Fig. 1.



Designation of yarn

In the case of monofilament yarn, diameter is used for designation. In the case of twisted twines, runnage (length of twine against a standard weight) or stating (i) the yarn size, (ii) the number of yarns in the strand, and (iii) the number of strands in the twine are used for designation.

Example: 200x4x6; indicates that the yarn size is 200 denier, there are 4 yarns in one strand and 6 such strands are twisted together to form the twine.

Identification

Identification of synthetic fibres by appearance alone is not possible. Different physical and chemical test methods are employed to identify groups of synthetic fibres.

Specific gravity

PA :1.14; PE: 0.96; PP: 0.91; PES: 1.38

Burning test:

In the burning test, the nature of burning and smoke in the flame as well after leaving the flame are considered as detailed in Table 1.

Table 1. Identification of different polymers by burning test

Material	PA	PE	PP	PES
In flame	Melts, burns with light flame, white smoke, melting drops fall down.	Shrinks, curls, melts and burns with light flame, drops of melting fall down.	Shrinks, melts and burns with light flame melting drops fall down.	Melts, burns with light flame, sooty black smoke, melting drops fall down.
After leaving the flame	Stops burning, melting drops can be stretched into fine thread	Continues to burn rapidly hot melting substance cannot be stretched.	Continues to burn slowly hot melting substance can be stretched.	Stops burning, melting bead may be stretched into fine thread

Solubility test:

Solubility test is used to identify different synthetic fibres. PA is soluble in 37% Hydrochloric acid in 30 min at room temperature.PA and PES are soluble in sulphuric acid 97-98% in 30 min at room temperature.PE and PP are soluble in Xylene on boiling for 5 min (Inflammable).

Yarn numbering system

For designation of the size of the yarn, a `yarn numbering system' is developed. The size of the yarn is given by yarn numbering system. This is based on the length-weight relationship of the yarn. There are two types of yarn numbering systemsviz., direct and indirect systems.

1. **Direct System:**In this system, the weight of the yarn against a standard length is taken. For example the length of yarn is kept constant and the weight changes.

i. Denier

9000 m of yarn weighing 1 g is 1 denier
9000 m of yarn weighing 210 g is 210 denier

ii. Tex: This is the internationally accepted system of numbering for all textile yarns.

1000 m of yarn weighing 1 g is 1 tex.
1000 m of yarn weighing 20 g is 20 tex

2. ***Indirect system:*** Here the length of yarn for a standard weight gives the yarn number or the weight is kept constant and the length varies.

i. British Count (Ne)

840 yards weighing 1lb is 1 Ne
20x840 yards weighing 1 lb is 20 Ne

This is commonly used for cotton and synthetic staple yarns.

ii. Metric Count (Nm)

1000 m of yarn weighing 1 kg is 1 Nm
20x1000 m of yarn weighing 1 kg is 20 Nm.

In the direct system of numbering the more the yarn number, the thicker the yarn would be and in the indirect system the more the yarn number, the finer the yarn would be.

For conversion from one system to another, the following conversion formula is used.

Tex = 590.5 = 1000 = 100000 = 496055 = 0.11 denier

Ne Nm m/kg yds/lb

Properties

Synthetic netting materials generally are resistant to biodeterioration i.e., they are resistant against destruction by mildew in air and bacteria in water. This is the major advantage of synthetics over natural fibres and it is the prime requisite for a fibre for consideration as a fishing gear material. Besides, synthetic fibres have high breaking strength, better uniformity in characteristics, long service life and low maintenance cost. However, unlike natural fibres, they are prone to degradation under sunlight at a much faster rate. As far as the fishing gear purpose is concerned, properties which are of importance are linear density, diameter, specific gravity, knot stability, breaking load, elongation, weathering resistance and abrasion resistance.

Diameter: The diameter of netting material is an important factor influencing the fishing gear performance. The ratio of diameter of twine to mesh bar is an important criterion to be considered while designing gill nets. Thicker twines are more visible and are easily detectable by the lateral line sense organs of the fish. Thickness and rigidity of the material influences the resistance of fishing gear to water flow and hence the power required or the speed obtained in towing gears are depended on it. Thinner twines offer less resistance. Diameter of a material is dependent on the type of polymer, type of yarn, size of yarn, specification and construction. Diameter is expressed in mm and is measured using a travelling microscope or a micrometer.

Linear density: It is the mass per unit length of the material. The mass in g of 1000 m length of a material is expressed as R tex and mass of 9000 m of the material as R denier. While comparing different types of yarns, the Rtex values serve as a relative measure for the mass of netting. For the same kind of material, lower Rtex means thinner material and generally costs less while buying on a mass basis.

Specific Gravity*:* Specific gravity of most of the synthetic fibres is less than the natural fibres. Specific gravity influences the fishing gear as fibres with lesser specific gravity allows a greater length of netting for a given weight of yarn and helps in savings in handling and power. However, for a gear such as purse seine, material with very low specific gravity is not the suitable one as quick sinking of the net is a prime requisite to capture a shoal of fish.

Twist: The number of turns or twists imparted to a twine per unit length is important as it influences many properties especially the breaking strength, diameter, linear density, resistance to abrasion and general wear and tear of the twine. As the amount of twist increases the breaking strength also increases upto a critical degree of twist beyond which it would weaken the twine. The stability of a twine depends on the correct amount of twists per unit length. The twine has an inner/strand/primary twist and outer/ secondary/ twine twist. Balance between these two twists ie primary twist for making strands from yarns and secondary twist to make twine from strands is important. Twines with a well balanced twist do not have a tendency to snarl.

The relation between inner twist and outer twist is:

Inner twist = outer twist x √No. of yarns

The amount of twist decides the softness or hardness of the twine. Based on the amount of twist, the twine is termed as soft, medium, hard and extra hard types. The number of strands in a twine can vary from 2 to 4 but generally 3 strand twines are used for fishing purposes as they possess stability, are free from distortion and round in appearance. The twist can be in two directions, viz., left hand (S twist) or right hand (Z twist). In S twist, the slope of the twisted product follows the direction of the central portion of the letter `S'. Similarly in Z twist, it follows the central portion of `Z'. Generally, the yarns and strands are twisted in the opposite directions for stability. In a double twisted twine, the direction of twist can be SZS or ZSZ for yarn, strand and twine respectively.

Twist coefficient is the measure of twist hardness and is determined by the formula

$$K = (t/m) \times (\sqrt{tex}/1000)$$

where K is the twist coefficient, t/m is the twist per meter and tex is the count in the direct system of numbering.

A coefficient of twist of 110-140, 150-160 and 200 denote degrees of soft, medium and hard twist respectively in PA multifilament netting twine.

Breaking load and elongation: The breaking strength/load of a material denotes the ability of a material to withstand the strain. It depends on the type of polymer, type of yarn, degree of twist and thickness of the material. Tenacity is the breaking load in terms of yarn denier while tensile strength is the force in terms of unit area of cross section. The strength of fibre changes in the wet condition; in natural fibres the wet strength is higher while the reverse is true of synthetic fibres. Knoting also causes reduction in the breaking strength. This is dependent on the type of polymer, type of yarn and knot, twine construction and also on the degree of stretching. Breaking load is expressed in Newton (N).

Elongation is the increase in the length of a specimen during a tensile test and is expressed mostly in percentage of the nominal gauge length. Extensibility is the ability of a netting material to change its dimension under a tensile force. It involves a reversible and an irreversible elongation. Irreversible or permanent elongation is the part of the total increase in length which remains after the removal of the stress. Reversible or elastic elongation is the part of the total increase in length which is canceled again, either immediately or after a long period of removal of stress.

Weathering Resistance: Even though all fibres, irrespective of natural or synthetic are prone to degradation on exposure to weathering, the problem is severe with synthetic fibres. The main factor responsible for weathering is the sunlight, i.e. the ultra violet part of the sun's radiation. Different synthetic fibres show variation in their susceptibility to and rate of deterioration by sunlight. It depends on the type of polymer and type of fibre. The rate of deterioration is generally assessed by the loss in breaking strength. The effect of weathering depends on the thickness of yarn, as thicker twines show better resistance. This is because the layers below are protected by the degraded outer layers and generally UV rays do not penetrate more than 1mm. By dyeing the weathering resistance can be improved.

PVC has very high resistance against weathering, while PES has high and PA and PE, have medium resistance against weathering. Among different types of fibres, monofilament form is more resistant than multifilament and staple yarn.

Abrasion Resistance: The resistance of netting materials to abrasion, ie, abrasion with hard substances such as boat hull, sea bottom and net haulers, or abrasion between yarns/twines is important in determining the life of a net. The resistance to abrasion depends on the type of fibre, thickness and construction of the material. Polyamide has the maximum abrasion resistance, followed by PP, PES and PVC. The better abrasion resistance of PA is due to the inherent toughness, natural pliability, and its ability to undergo a high degree of flexing without breakdown. Among different types of materials, monofilament is better than multifilament, and between staple and multifilament, the latter is better. Abrasion can cause rupture of the material as also reduction of mesh size due to the internal abrasion caused by the friction of the fibres against each other.

Table 2. Properties of important synthetic materials used for fishing gear.

Properties	PA	PE	PP	PVC	PES
Specific gravity	1.14	0.96	0.91	1.35-1.38	1.38
Melting point C	240-250	125-140	160-175	180-190	250-266
Weight g/m	104.5	157	81.2	-	97.8

Breaking strength	Very high	High	Very high	Low	High
Extensibility	Medium	Medium	Low	High	Low
Resistance against weathering	Medium	Medium	Low	Very high	High

Suitability of yarn types to different fishing gear

Even though different types of synthetic fibres are available, an ideal material satisfying all the requirements of different fishing gears does not exist. The various types of synthetics having different qualities provide a range of choice for selecting the best suited material for each type of gear. The choice of material depends not only on the technical properties but also on the local availability and price. For each type of gear, a particular property of the material may be important; for example, sinking speed for purse seine, transparency and softness for gill nets, high breaking strength and abrasion resistance for bottom trawls etc.

Fishing gears are classified into three main groups based on the strain the net material has to undergo. The classes are: Group 1-Low strain (Fine gill nets); Group 2-Medium strain (Fishing line, traps, scoop nets, dragged nets including small bottom trawls); and Group 3- High strain (Large bottom trawls, gape nets in fast flowing rivers). The material indicated as suitable for each group by Japan Chemical Fibre Association is given in Table 3.

Table 3. Synthetic fibres suitable for different fishing gears

Material	Groups	Fishing Gear
PA	Group 1,2	Gill nets, purse seines (sardin
PE	Group 2,3	Trawls
PP	Group 1	Entangling nets
PVC	Group 2	Set nets, Lift nets
PVA	Group 2	Purse seines (Tuna, horse mackerel)

Gill Nets: The material should be fine, strong, flexible and be invisible in water.

Trawl nets: Material should be strong, and cheap to buy.

Purse seines: Should possess good sinking speed and should be strong.

Nylon multifilament nettings are available as knotless and knotted while nylon monofilament nettings are available as knotted only. Nylon multifilament nettings are commonly used for the fabrication of various types of gill nets, ring seine, purse seine, cast net, chinese nets, drift nets etc. Common specifications of nylon multifilament twine for fishing ranges from 210x1x2 to 210x12x3. The mesh size commonly required ranges from 8 mm to 450 mm for different fishing gear. It is more effective for fishing than polyester because of the better sinking speed and extensibility. Nylon monofilament is better for long lining and various types of gill netting. The twine range for fishing purpose is from 0.10 to 0.50 m dia and for long line fishing 1.5 to 3 mm. The mesh size normally starts from 16 to 450 mm dia. Thinner monofilament nets are more effective for fishing but are less durable and not repairable.

HDPE twine is of two types; braided and twisted. Twisted twine is available normally in the range of 0.25 to 3.00 mm dia while braided twine is available in the range of 1.0 to 3.0 mm dia. HDPE netting is mainly used for the fabrication of trawl nets.

Recent advances in synthetic fibres

Introduction of synthetic materials with high tensile strength properties has made it possible to bring out changes in the design and size of fishing nets. As the fishing industry became highly energy intensive, the search and research for new generation materials which give better strenght for less thickness resulted in invention of new materials. Besides, the non-biodegradable nature of synthetic fibres leads to environmental and biodiversity threat to the aquatic bodies and ecosystem. Fishing related plastic debris in water bodies, ghost fishing etc are few such threats from the fishing sector. Aramid fibres, Kevlar, UHMWPE, biodegradable plastic etc are recent introductions to the fishing gear material sector. These materials have many advantages especially less drag which results in fuel efficiency. The performance of UHMWPE webbing and rope in the Indian context is being studied by ICAR-CIFT.

Aramid fibres:

Aramid fibres are fibres in which the base material is a long-chain synthetic polyamide in which at least 85% of the amide linkages are attached directly to two aromatic rings. Two types of aramid fibres are produced by the DuPont Company: Kevlar (para-aramid) and Nomex (meta-aramid), which differ primarily in the substitution positions on the aromatic ring. Generally, aramid fibres have medium to very high tensile strength, medium to low elongation-to-break, and moderate to very high modulus.

KEVLAR® is one of the most important man-made organic fibres ever developed in the early 1970s. It is a polymer containing aromatic and amide molecular groups. Because of its unique combination of properties, KEVLAR® is now used in a wide variety of industrial applications including in the fishing sector as netting and fishing line. Fibres of KEVLAR® consist of long molecular chains produced from poly (p-phenyleneterephthalamide). The chains are highly oriented with strong interchain bonding, which result in a unique combination of properties. It is produced as continuous filament yarn, staple fibre (38-100 mm in length), short fibre (6-12 mm in length) or pulp (2-4 mm in length), all with a nominal diameter of 12-15 μm. The strength to weight ratio of Kevlar is high; on a weight basis, it is five times as strong as steel and ten times as strong as aluminum. It has high tensile strength at low weight, low elongation to break, high toughness (work-to-break), and excellent dimensional stability. In sea water, ropes with KEVLAR® are upto 95% lighter than steel ropes of comparable strength.

Ultra high molecular weight polyethylene

UHMWPE is a type of polyolefinsynthesized from monomer of ethylene processed by different methods such as compression molding, ram extrusion, gel spinning, and sintering. The fiber made by gel spinning have a high degree of molecular orientation resulting in very high tensile strength. The fibre is made up of extremely long chains of polyethylene, which attain a parallel orientation greater than 95% and a level of crystallinity of up to 85%. The extremely long chains have molecular weight usually between 3.1 and 5.67 million while HDPE molecule has only 700 to 1,800 monomer units per molecule.

Ultra high molecular weight polyethylene (UHMWPE), also known as high modulus polyethylene (HMPE) or high performance polyethylene (HPPE) is a thermoplastic. It has extremely long chains, with molecular weight numbering in millions. The high molecular weight results from a very good packing of the chains into the crystal structure. This results in a very tough material, with the highest impact strength of any thermoplastic presently made. It has extremely low moisture absorption, very low coefficient of friction, is self lubricating and is highly resistant to abrasion (10 times more resistant to abrasion than carbon steel). To make fibres, they are dissolved and drawn into fibres and as the solvent evaporates, cause the polymer chains to orient in the direction of the fibre.

This is available as Dyneema and Spectra produced by two different companies. Polyethylene with an ultra high molecular weight (UHMWPE) is used as the starting material. In normal polyethylene, the molecules are not orientated and are easily torn apart. In the gel spinning process, the molecules are dissolved in a solvent and spun through a spinneret. In the solution, the molecules that form clusters in the solid state become disentangled and remain in that state after the solution is cooled to give filaments. As the fibre is drawn, a very high level of macromolecular orientation is attained resulting in a fibre with a very high tenacity and modulus. Dyneema fibres are produced in commercial grades, Dyneema SK 60, SK 62, Sk75 and SK 78 which are the multi-purpose grades. SK 60 and SK 75 are specially designed for ropes, cordage, fisheries and textile applications. It can be made into microfilament braided twine of fine diameter. Netting of simple knot, double knot and knotless are available. A comarison of properties of UHMWPE to other synthetic fibres is given in Table 4.

Table 4. Comparative properties of synthetic fibres

Chemical/physical characteristics	Fibre					
	PA 6	PA 6,6	PES	PP	PE	Dyneema SK75
Tenacity (g/den)	9	9	9	7	5	40
Elongation at break (%)	23	20	14	18	20	3.5
UV rays resistance	medium	weak	mediu m	medium	medium	good
Specific weight	1.14	1.14	1.38	0.91	0.97	0.97
Resistance to alkalis	good	good	weak	good	good	good
Acid resistance	weak	weak	good	good	good	good
Moisture absorption% (65%-20°C)	3.5-4.5	3.4-4.5	0.2-0.5	0	0	0

(Source: Badinotti, 2011)

Dyneema is 15 times stronger than steel and up to 40% stronger than Kevlar. Netting uses include trawl nets, purse seine nets and aquaculture nets. The low diameter of these twines and their favourable weight/strength ratio produce up to 40-percent less drag than conventional fibre structures as the net is pulled through the water or set against tide/currents. This allows fishing vessels to increase their catch — potentially by as much as 80 percent — by trawling faster or using larger nets, or to reduce fuel consumption. Dyneema trawl nets result a fuel saving upto 40%.The resistance of Dyneema nets to UV light, and abrasion is high, guaranteeing that nets last longer. With low elongation - as little as <5% - and no shrinkage in water, the mesh size remains stable during normal use of the netting allowing better filtering resulting in reduced bycatch. Besides, less deck space is required due to lower bulk volume of the net. Purse seines made of dyneema would facilitate 40% increase in sinking speed due to better filtering and reduced drag. Larger net for the same weight can be made. The net has better durability with negligible wear & tear.

Ropes made from UHMWPE have a higher breaking strength than that of steel wire ropes of the same thickness, but have only one-tenth the weight. Fishing uses for these high-strength polyethylene ropes include warp lines, bridles and headlines.UHMWPE ropes can be used in trawling to substitute wire ropes which helps in weight reduction and drag reduction resulting in fuel saving. By using UHMWPE ropes, the frequent oiling & greasing required for wire ropes can be avoided which would facilitate a clean and safe deck and free the crew from greasing the rope frequently. It also helps in a clean catch devoid of oil and grease contamination. From the safety point of view, while using UHMWPE rope, if it breaks there won't be any backlash unlike in steel wire rope in which the backlash on snapping can be fatal.

UHMWPE also finds good application in the aquaculture sector as a cage netting material due to the low diameter, favourable weight/strength ratio, low elongation and nil shrinkage in water which helps the mesh size to remain stable during normal use of the netting.

Liquid Crystal Polymer Fibre

Vectran® — a high-performance thermoplastic multifilament yarn spun from Vectra® liquid crystal polymer (LCP) — is the only commercially available melt-spun LCP Fibre in the world. Vectran fibre is five times stronger than steel and 10 times stronger than aluminum. The unique properties that characterize Vectran fibre include: high strength and modulus; high abrasion resistance; minimal moisture absorption; and high impact resistance. Although Vectran is lacking UV resistance, this limitation can be overcome by using polyester as a protective covering.

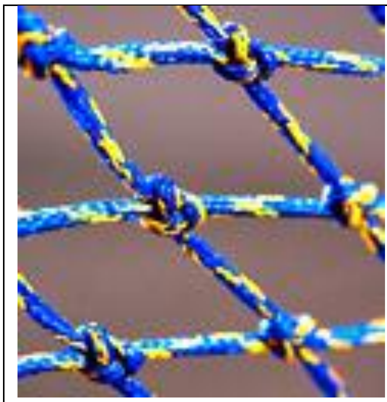
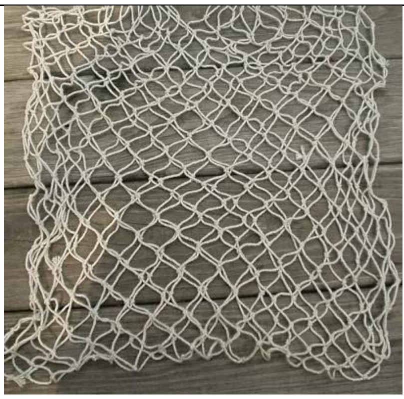
Fluorocarbon fibre

Fluorocarbon fibre is a new material that can be used in angling and high speed jigging lines. It has very high knot strength, almost invisible in water, has high breaking strength and abrasion resistance.

Sapphire

Sapphire PE netting manufactured from specialized polymers available in twisted and braided form is suitable for tawl nets and for cage culture. It has the highest knot breaking strength, knot stability and dimensional uniformity. Braided twine having compact construction restricts mud penetration and provides lesser drag.Sapphire is used on a limited scale for fabrication of large mesh gillnets targeting large pelagics in Maharastra region of India.

Sapphire ultracore is a knotless HDPE star netting with an outerlayer of heavier sapphire ultracore which features strands of marine grade stainless steel as an integral part of the netting twine. The stiffness and cut resistance enable it to be used as a predator protection net cum cage bag net where the predation problem is not very high.

		
Sapphire Ultracore	Kevlar	UHMWPE

Biodegradable polymers

As synthetic fibres are non biodegradable, the environmental threats it causes due to ghost fishing is an important problem. Environment friendly fishing line made of biodegradable polymer is a solution to this problem. Biodegradable polymers made from poly butylene succinate (PBS) are recent developments in this area. `Bioline'is a commercial fibre made from poly(butylene succinate) or PBS.This material retain its strength and durability for few months of use and then completely degrade in water (salt or fresh water) through the enzymatic reactions of naturally occurring microorganisms in the water.It does not deteriorate when kept clean and dry, but when exposed to bacterial activity underwater or underground, it deteriorates viz., it retains its strength and durability for the first 10-12 months of use and then completely degrade in water or on land within five years.

FIELDMATE™ is another example for biodegradble polymer. If exposed for three months in salt or fresh water, it decomposes through the enzymatic reactions of naturally occurring microorganisms, before eventually being reduced to water and carbon dioxide.

Conclusion

Among the new fibre types, only Sapphire and UHMWPE are used on a commercial basis for fishing gear viz., trawls and purse seines in Australia and Alaskan waters. Sapphire is also used on a limited scale as large mesh gillnets targeting large pelagics in Maharastra region of India.The introduction of synthetic fibres has revolutionized the fishing industry and it can be considered as the major single factor which led to the development of today's efficient fishing gears. Research and development in this industry is a continuing process and better materials suitable for the diverse fish harvesting implements can be expected in the future

Further reading

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