# Chapter 2

# Fishing gear materials: properties & identification

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## Introduction

Netting materials for fabrication of fishing gear are either of textile or non-textile origin. The raw material for fish netting consists of fibres which can be distinguished into two groups: natural fibres and man-made fibres. 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. Traditional fishing gears used earlier, till 1950s were mainly with natural fibres such as cotton, manila, sisal, jute and coir. 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 are 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 biodeterioration. In the late 1950s, with the introduction of man-made synthetic fibres, natural fibres used for the fishing gears have been substituted by these synthetic materials. This transition was mainly due to the highly positive properties of these fibres such as highly non-biodegradable nature, high breaking strength, better uniformity in characteristics, high abrasion resistance, low maintenance cost and long service life.

## Synthetic fibres

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, synthetic fibres are classified into different groups and are known by different names in different countries. Altogether seven groups of polymers are developed; most important polymer/synthetic fibres used in fishing gears 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). Aramid fibres, ultra high molecular weight polyethylene (UHMWPE) and liquid crystal polymer are later additions to this group.

***Polyamide (PA)*****:** Polyamide, a synthetic polymer, popularly known as nylon, invented in 1935 refers to a family of polymers called linear polyamides. Nylon consists of repeating units of amide with peptide linkages between them. Depending on the raw material and method of making two types of nylon viz., PA 6 and PA 66 are available for fibre applications. PA 66, widely used for fibres is made from adipic acid and hexamethylene diamine while PA 6 is built with caprolactam. With regard to the fisheries, there is no difference between PA 66 and PA 6, while in India, for fishing purposes PA 6 is used. The softness, lightness, elastic recovery, stretchability and high abrasion and temperature resistance are superior properties inherent to nylon. However, high moisture absorption along with dimensional instability and requirement of UV stabilization are its disadvantages. On wetting, nylon loses up to 30% of tensile strength and 50% of tensile modulus.

***Polyolefins:*** Polypropylene (PP) and Polyethylene (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. Linear polyethylene or high-density polyethylene has high crystallinity, melting temperature, hardness and tensile strength. In India, PE is used for manufacture of netting and ropes.

***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”. This is an additive polymer of propylene. PP was commercialized in 1956 by polymerizing propylene using catalysis. Though PP netting and ropes are available, in India, PP is mainly used for ropes.

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

**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 competitive, the search and research for new generation materials which give better strength for less thickness resulted in invention of new materials. Aramid fibres, Kevlar, UHMWPE, biodegradable plastic, etc. are recent introductions to the fishing gear material sector. These materials have 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. 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 in large mesh gillnets targeting large pelagic in Maharashtra region of India.

**Ultrahigh molecular weight polyethylene (UHMWPE):** UHMWPE is a type of polyolefin synthesized from monomer of ethylene processed by different methods such as compression molding, ram extrusion, gel spinning, and sintering. Polyethylene with an ultrahigh molecular weight (UHMWPE) is used as the starting material. In normal polyethylene, the molecules are not orientated and are easily torn apart. The fibres made by gel spinning have a high degree of molecular orientation with very high tensile strength. The fibre is made up of extremely long chains of polyethylene, which attains a parallel orientation > 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.

UHMWPE, also known as high modulus polyethylene (HMPE) or high-performance polyethylene (HPPE) is a thermoplastic. 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). This is available as Dyneema and Spectra produced by two different companies. Commercial grades of dyneema fibres SK 60 and SK 75 are specially designed for ropes, cordage, fisheries and textile applications.

UHMWPE is 15 times stronger than steel and up to 40% stronger than Kevlar. UHMWPE netting is 3 times stronger than nylon with the same dimension, and increases the net's strength while the abrasion resistance increases the net's life. Netting can be used for trawl nets, purse seine nets and aquaculture nets. Nylon purse seines last for about 2-3 years while UHMWPE netting ensures 2-3 times more life for the net. The netting twines made with dyneema fibre can be reduced by upto a factor of 2 on thickness (diameter basis) and on weight basis by a factor of 4. This allows fishing vessels to increase their catch potentially by as much as 80% by trawling faster or using larger nets, or to reduce fuel consumption. 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. 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.

**Sapphire:** Sapphire PE netting manufactured from specialized polymers available in twisted and braided form is suitable for trawl 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 Maharashtra region of India. Sapphire ultracore is a knotless HDPE star netting with an outer layer 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 very high.

**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® polyphenylene terephthalamide (PPTA):*** A polymer containing aromatic and amide molecular groups is one of the most important man-made organic fibres ever developed. Because of its unique combination of properties, KEVLAR® is used in the fishing sector as netting, fishing rod and fishing line. Fibres of KEVLAR® consist of long molecular chains produced from poly (p-phenylene terephthalamide). The chains are highly oriented with strong interchain bonding, which result in a unique combination of properties. 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 up to 95% lighter than steel ropes of comparable strength.

**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. Vectran fibre is 4 times stronger than polyethylene fibre or nylon fibre. 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. It is very suitable for trawl nets and ropes.

**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.

**Properties**

Synthetic netting materials are generally resistant to biodeterioration. 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. For quality evaluation and selection of appropriate material for different gears, knowledge on various properties of netting yarn are required. The numerical values of these properties are determined through standard test procedures. As far as the fishing gear purpose is concerned, properties which are of importance are as follows.

***Diameter***

The diameter of netting material is an important factor influencing the fishing gear performance. 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. Diameter of a material is dependent on the type of polymer, type of yarn, size of yarn, specification and construction. Diameter is usually determined as the distance between the two edges of the yarn/twine measured on a travelling microscope and expressed in mm.

***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. For the same kind of material, lower Rtex means thinner material and generally costs less while buying on a mass basis.

***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. 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.

***Breaking load***

The breaking 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. Knotting 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. A length of yarn is extended until it reaches the load at rupture by a suitable apparatus, The Universal Testing Machine, that records the applied force. Breaking load is expressed in Newton (N).

***Elongation***

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. 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. Elongation is also tested in UTM and sample preparation procedure is similar as above described in breaking load.

***Abrasion Resistance:*** The resistance of netting materials to abrasion, i.e., 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. For testing the abrasion resistance, the principle is to apply a certain number of frictions or abrasion cycles and measuring the remaining breaking load of abraded material expressed as the percentage of initial breaking load.

***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 depending on the type of polymer and fibre. The rate of deterioration is generally assessed by the loss in breaking strength. Weathering resistance is measured by exposing the material to natural sunlight. Weathering resistance can also be studied in controlled conditions in the laboratory by using Weather O meters with artificial light sources such as fluorescent arc, UV arc, Carbon arc, Mercury arc and Xenon arc. Xenon arc is a good substitute as it approximates solar radiation and gives very steady illumination. Weathering studies in Xenotest take only one-seventh to one tenth of the time than the samples exposed to natural conditions.

**Tests for identification of synthetic fibres**

Different groups of synthetic fibres can be identified by various methods.

*Water test*

Identification of synthetic fibres can be started with this test. In a short piece of netting yarn, tie a simple overhand knot and put the piece into a vessel filled with water. Air bubbles in the material must be squeezed out by hand underwater. Based on water test, netting materials can be classified into two groups; (1) synthetic fibres which float in water (PE & PP) (2) fibres which sink (all other synthetic fibres).

*Burning test*

In the burning test, the nature of burning and smoke in the flame as well as after leaving the flame are observed. The netting material can be brought near to the flame and after removal from the flame, observe the smell of smoke and the residue. Synthetic fibres shrink and melt in the flame, the melting substance drips from the flame mostly forming a bead or a hard irregular residue. The changes in different synthetic fibres during burning test is given in table 1

*Solubility test*

Solubility test is a relatively simple chemical test. Fibres of the sample to be tested should be in a loose form. The netting yarn must be untwisted and the fibres can be cut into small pieces of 1cm length. Coarse material like split fibres and especially monofilaments should be cut to very small pieces. Take 10-15ml of the solvent into the test tube and put the sample pieces into it. The results of the reactions are shown in table 2.

**Table 1. Burning characteristics of synthetic fibres**

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

(Source: Klust, 1982)

**Table 2. Identification of synthetic fibres by solubility test**

| Reagent | Type of fibre | | | |
|---|---|---|---|---|
| | PA 6 | PES | PE | PP |
| Hydrochloric acid/HCL (37%) 30 minutes at room temperature | + | 0 | 0 | 0 |
| Sulphuric acid/$H_2SO_4$ (97-98%) 30 minutes at room temperature | + | + | 0 | 0 |
| (1) Dimethylformamide/HCON $(CH_3)_2$ 5 minutes boiling | + | + | 0 (2) | 0 (2) |
| Formic acid/HCOOH (96-100%) 30 minutes at room temperature | + | 0 | 0 | 0 |
| Glacial acetic acid/$CH_3$-COOH 5 minutes boiling | + | 0 | 0 | 0 |
| Xylene/$C_6H_4$ $(CH_3)_2$ 5 minutes boiling (inflammable) | 0 | 0 | + | + |
| Pyridine 30 minutes at room temperature | 0 | 0 | 0 | 0 |

(Source: Klust, 1982)

+ = soluble, 0 = not soluble, (1) = Dimethylformamide is decomposed by exposure
to light even when stored in a brown bottle, needs to be stored
away from light preferably in a cool place, (2) Destroyed but not soluble

**Further readings**


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