About 75 Years of Synthetic Fiber Rope History

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Abstract

This paper is a survey review of the development of synthetic fiber ropes during the past approximately 75 years. It is partially based on discussions at a recent International Rope Technology Workshop and on the authors' recollections. It is also based on an extensive file and literature review.

Nylon was discovered in the late 1930's and was first introduced into fiber ropes during World War II. Since that time a number of other synthetic fiber materials have been discovered and used in ropes. These include polyester, polypropylene, aramid, high modulus polyethylene (HMPE), and liquid crystal aromatic polyester (LCAP). Improvements continue to be made to the properties of these rope-making synthetic fibers. But no other significant new rope fiber making material has been introduced in the last 25 years.

The first synthetic fiber ropes were small braided parachute cords and three-strand tow ropes for gliders, made of nylon during World War II. Many other useful rope structures have been developed since that time. These include 8-strain plaited, 12-strand braided, double braid, multi-strand laid (wire rope construction), parallel fiber and parallel subrope constructions.

The earliest ropes were made of natural fibers, before recorded history. With the development of steel wire ropes in the 18th century, the use of natural fiber ropes declined. But now synthetic fiber ropes have almost completely replaced natural fiber in all uses and have replaced wire ropes in many mooring applications. Without large, high-strength synthetic fiber ropes, it would be difficult or impossible to explore for and produce oil in very deep water.

The paper includes a timeline showing the evolution of synthetic fiber rope materials, rope structures, and rope developments and uses.

Each of the contributing authors has lived through these 75 years and has spent many of these years in careers related to the subject.

This paper will be of particular interest to users of synthetic fiber ropes and mooring systems.

Key Words – rope, fiber, fibre, nylon, polyester, polypropylene, aramid, HMPE, LCAP, buoy, mooring, towing, tether, net

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INTRODUCTION

Fiber rope was one of man's first inventions. Natural fibers were twisted into ropes long before recorded history. But, unlike bone, pottery and metal, natural fibers decay, and thus few examples of ancient fiber rope now exist.

Natural fiber ropes were for many purposes, including to moor ships and to rig sails, from pre-history. In the 19th century steel chain and wire rope replaced most natural fiber rope in the most demanding applications.

A number of synthetic fiber materials were discovered and introduced in the middle of the 20th century. Fiber ropes then regained position and are now used in many important uses, particularly marine uses.

The attached Table is a timeline of significantly events in synthetic fiber materials, rope designs, and rope uses over the past approximately 75 years. References are provided for many of these events. But even extensive archival research might not accurately date all of the events, and there may be errors and omissions.

The following narratives discuss materials, constructions and rope developments and uses separately. There may be some repetition among these narratives.

More details on synthetic fiber material and rope properties can be found in the *Handbook of Fibre Rope Technology*.[1]

Conventional Synthetic Fiber Rope Materials

The first "man-made" or "manufactured" fiber material was rayon, which was commercially developed in the early 20th century. But rayon is made from cellulose and is not a synthetic material. Rayon was widely used for tire cords, but it was not used significantly in rope making.

Nylon 6.6 was discovered by Wallace Carouthers at DuPont in 1935.[2] Nylon 6 was discovered by Paul Schlack at IG Farben in 1938. These are the two types of nylon used in ropes. The chemical name for nylon is polyamide (PA). It is known by a number of different trade names. Nylon fiber was first used to replace silk in women's stockings, in 1939. The first use a synthetic material in ropes was that of nylon in parachute cords and glider tow lines during World War II. After the war, nylon found its way into most rope applications.

Low-density polyethylene fiber was discovered before World War II, but it was low strength and of little use in ropes. High-density polyethylene (HDPE), with a different molecular form, was discovered in 1953. HDPE ropes generally have much less strength than nylon, but they float. Polyethylene is not commonly used in ropes today. (HMPE, high-modulus polyethylene is discussed later).

The polyester, polyethylene terephthalate (PET), was discovered by John Whinfield and James Dickson in 1941. It was developed as *Terylene* by Imperial Chemical Industries (ICI). DuPont acquired rights and in 1950 developed an improved PET fiber, marketed as *Dacron*. By 1953 PET polyester was in limited use in rope making, but It was not widely used for rope until later when it became more available and less expensive.

Isotatctic polypropylene material was discovered in 1954 and proved to be superior to polyethylene. Polypropylene fiber was commercialized in the late 1950s. Unlike other synthetic fibers, polypropylene fiber can be made in the rope factory. Because of the varying quality of the fiber, polypropylene rope strength is generally significantly lower than nylon and polyester rope. However, Because of its low cost and buoyancy, polypropylene is popular, especially for marine ropes.

Polyethylene and polypropylene are known as polyolefins. They are sometimes blended together or with polyester in making fiber. These blended fibers can have very good strength properties.

Another form of polyester known is known as PEN (polyethylene naphthalate). PEN polyester fiber is about twice as stiff as PET polyester but not as stiff as aramid and HMPE. PEN fiber has the same strength as PET fiber. Several companies have produced commercial PEN fiber in recent years. There is interest in it as an alternative for mooring systems which require a stiffer rope.[3] But so far PEN polyester has seldom been used in ropes because it is relatively expensive and availability is limited.

High Performance Fiber Rope Materials

The above fiber materials are referred to here as conventional materials. Beginning in the mid 1960s, a new class of fiber materials was developed, referred to here as high performance, but generally called high modulus fibers. Ropes made of these fiber materials can be as strong as steel wire rope of the same size but are much lighter and easier to handle.

Fully aromatic polyamide (poly(p-phenylene terephthamide, PPTA), known as aramid, was first discovered by Stephany Kwolek in 1965. It was developed by DuPont as *Fiber B* and later introduced as *Kevlar*.[4] Akzo developed a similar aramid fiber in 1973 which was introduced as a commercial product called *Twaron* in the mid 1980s. Aramid ropes can experience axial compression fatigue if not maintained under tension. *Technora*, a related para-armid copolymer fiber, with less tendency for axial compression, was introduced by Teijin in 1987.

High modulus polyethylene, HMPE, fiber is made by two producers. Allied Chemical, now part of Honeywell, introduced *Spectra* in 1985. DSM, then known as Dutch State Mines, introduced *Dyneema* in 1989. Honeywell later adopted the DSM fiber extrusion process because it was more environmentally friendly. HMPE fiber ropes are lighter than water and have very high strength. However, these ropes tend to continue to creep and may eventually fail under tension. DSM has now developed a grade of *Dyneema* which has greatly reduced creep.

LCAP (Liquid Crystal Aromatic Polyester) fiber was developed by Celanese and introduced as *Vectran* in 1989. LCAP has strength and stretch characteristics similar to aramid and HMPE but has much less tendency for axial compression fatigue and has minimal creep. However, it is more expensive.

PBO fiber was developed by the U.S. Air Force in the 1980s. Its full chemical name is poly(para-phenylene benzobisoxazole. It is now manufactured by Toyoba under the name *Zylon*. PBO fiber is very strong and very stiff, but very expensive. The use of PBO in personnel body armor was discontinued after discovery that its strength quickly deteriorated. PBO loses about 65% strength when exposed to sunlight for six months.[5] It has been difficult to make rope from PBO. Small jacketed PBO ropes have been used as rigging on high-performance sail boats, where they can be afforded and can be replaced after only a few races.

M5 fiber was developed by Doetze Sikkema of Akzo Nobel in 1993.[6] (The full chemical name is too long to include in this short article.) DuPont now owns rights to the M5 technology. Small quantities of M5 fiber have been produced, which exhibit outstanding properties. But efforts to scale the M5 fiber production process to commercial quantities have not been successful to date.

An ePTFE (expanded polytetrafluoroethylene) fiber was introduced by Gore in 2006.[7] This ePTFE fiber has very low friction characteristics, but does not have outstanding strength properties. It is now blended with other fibers to make ropes which have excellent bend-over-sheave service life.

There are possibilities for future advances in fibers for ropes.

Natural spider silk has about half the strength of aramid and HMPE fibers. But spider silk can absorb much more energy because it stretches much more before it breaks. There have been successful attempts to make spider silk proteins from genetically modifying micro-organisms or goat's milk.[8] But no company has demonstrated a way of spinning fibers with the fine fiber structure necessary to achieve the strength of natural spider silk.

Carbon fibers have strengths comparable to aramid and HMPE and are used extensively in composite materials because of their very high stiffness (modulus). However, they are too brittle for most rope uses. Carbon nanotubes are exceptionally strong, but they are inherently very short and difficult to convert into yarns. Converting graphene into yarns is another possible approach. The goal is to develop a practical process to produce a carbon fiber which can be made into very strong, very stiff rope. Someday it may happen.[9]

Rope Constructions

The first 3-strand ropes were made before recorded history. At first such rope was made by hand, but even the Egyptians used rope-walks and machinery. Large rope walks with rope making machines were common in sea ports in the late middle ages. In addition to many marine, agricultural, and similar uses, natural fiber ropes were used to drive machinery in water-powered mills and factories. The 8-strand plaited rope structure was developed as an improved driving means in steam-powered factories. But the introduction of electric motors made rope drives obsolete early in the 20th century.

The first large nylon 3-strand rope was produced by American Ropes in 1948.[10] In the mid 1950s, Hawkins and Tipson introduced 8-strand plaited nylon rope for ship mooring and towing hawsers.

Nylon 3-strand rope was used for climbing in the 1940s. The nylon kernmantle rope, comprising a core group of small, parallel, twisted ropes enclosed in a braided jacket, was introduced for climbing in 1953 by Edelrid of Germany. (Kernmantle means core and cover.) The kernmantle construction soon replaced natural fiber and nylon 3-strand climbing ropes because it is much more durable.

The double-braid rope construction was invented by Ken Fogden and Arthur Chance of Samson Cordage in 1960.[11] [12] It comprises a braided core surrounded by a braided cover. This is still a popular synthetic fiber rope design.

Hawkins and Tipson (H&T) (later Marlow) installed machinery capable of making 8-strand plaited rope as large as 200 mm dia. (24 in. circum., size 24) in about 1965.[13]

A unique 7-strand (6 around 1) rope structure named *Jetcore* was developed by Robert Stanton of American Manufacturing Co. in 1966.[14] The core strand was comprised of helically laid nylon fibers. The outer strands were comprised of a helically laid nylon center covered by helically laid yarns of polyester and black polypropylene yarns, giving the rope a black and white liquorice stick appearance. This rope was firmly laid such that it was durable and performed well on ships winches. It is still in use today.

The parallel-fiber rope structure, *Parafil*, was invented by Mike Parsey while at ICl in 1967.[15] It comprises many individual fiber yarns extending in parallel for the entire rope length which are enclosed in a tight extruded plastic jacket. *Parafil* ropes are made of polyester and aramid. The aramid parallel-fiber rope has very low stretch and is used as guy lines for antennas.

In 1978 Simion Whitehill set up a plant to manufacture aramid fiber rope using machinery acquired from the Roebling wire rope plant. In the basic form, this "wire-rope" construction comprises a center core strand surrounded by 6 outer strands laid in a helical pattern. A second layer of 12 helically wound strands makes up an 18-strand rope, and a third layer of 18 helically wound strands makes up a 36 strand rope. Such ropes are used for many purposes in the marine industry.

Mike Parsey, after joining H&T, and Aliedus Bosmen, of Bexco Ropes, conceived the parallel subrope structure (parallel strand), *Superline*, in 1979. It comprises many subropes which extend in parallel for the entire rope length and are enclosed by a tight braided jacket. Many other manufacturers now make similar parallel-strand ropes, with 3-strand, 4-strand and 12-strand subrope constructions. Most deepwater platform moorings now use the parallel subrope design.

Bridon installed machinery to make double braid rope as large as 240 mm (30 in. circ, size 30) in about 1981. Other than the parallel subrope construction ropes now used in deepwater moorings, this is probably the largest synthetic fiber rope ever made.

The 12-strand braided rope structure was introduced by Samson Cordage in 1982.[16] This construction has become very popular for marine mooring hawsers and other purposes.

A successful reduced-recoil-risk (RRR) 4-strand rope design was developed by Sim Whitehill in 1987. The principle is that after one strand fails, the remaining strands remain intact for sufficient time that rope tension can be reduced or that personnel can get out of the way.[17] The Cordage Institute has now developed a special test method for this category of rope.[18] Several other manufacturers now make similar reduced-recoil-risk rope.

Puget Sound introduced a 12 x 12 rope construction in 1997.[19] This construction is similar to the conventional 12-strand rope design, except each of the 12 strands is itself a 12-strand rope.

A braided rope design blending HMPE and LCAP (*Vectran*) yarns was invented in 2002 by Bob Knusdon of Celanese and Forest Sloan of Puget Sound Ropes.[20] Called "*BOB*", for Braid Optimized for Bending, this specialized rope gives very good performance in cyclic bend-over-sheave service.[21] It is an example of the synergy of using several synthetic fibers together.

An advantage of wire rope is that its deterioration can be monitored by electromagnetic non-destructive test methods. Elizabeth Huntley and others of Whitehill Manufacturing recently invented a method for incorporating a carbon-treated yarn within the rope structure which can be detected and monitored by an electromagnetic method. This new development may facilitate the use of synthetic fiber ropes in critical applications where visual rope inspection is not practical.

Rope Developments and Uses

This section attempts to describe the most significant developments in synthetic fiber rope use. There are many others that might merit mention.

Nylon was introduced before World War II, famously, to replace silk in women's stockings. During the war, it replaced silk in parachute cords and canopies. Nylon was also used in glider tow ropes, marine ropes and climbing ropes during the war.[22]

Large nylon shipboard hawsers were used as early as 1948. By the early 1950s nylon was commonly used for mooring lines. Nylon was much stronger than natural fiber rope and did not rot. Because of its high stretch, it was particularly favored for towing hawsers. Natural fiber ropes were initially replaced by smaller nylon ropes on an equivalent strength basis. But the smaller nylon rope was less resistant to external damage. And nylon rope stretched much more before it broke. When it broke, the stretched nylon rope recoiled and caused injuries and fatalities. Eventually, tables were complied to recommend the sizes of replacement nylon rope.

Polyester fiber was slowly adopted into rope making during the 1950s. It was initially more expensive than nylon and was not as strong when dry. But later it was recognized that nylon rope lost about 10% of its strength when wet and also that wet nylon rope rapidly lost strength due to internal abrasion.[23] Polyester then became popular for many marine applications.

The first single point mooring (SPM) was installed in 1959.[24] At an SPM, a tanker moors to a large buoy by one or a pair of very large synthetic fiber hawsers while transferring oil. SPM hawsers are typically 150 and 200 mm dia. (18 to 24 in. diameter, size 18 and 24).

Polypropylene fiber was quickly adopted into rope making after its development in 1960. Although It was not as strong as nylon or polyester, it was less expensive and it floated.

In 1966 the Gemini 11 manned space craft deployed a 30 m (100 ft) long synthetic fiber rope tether to stabilize the capsule and create a small amount of artificial gravity.[25] The tether was designed by Dr. Pete Scala of Cornell University and manufactured by Cortland Line Co. a predecessor of Cortland Cable Co.

A double-drum traction winch system was developed by Henry McKenna, then with Ocean Systems, Inc.[26] IT was installed on two dedicated tankers to offload oil from the Ekofisk SPM in the North Sea.[27] The mooring hawser was provided by Samson Cordage. This system enabled the tanker to pick up the end of the mooring line and self-moor without the assistance of a workboat. Similar systems have now been used on other SPMs.

Aramid fiber rope was first made by Philadelphia Resins in 1972. It was used in small mooring ropes and instrumentation cables for buoys.[28] Ropes made of the stiffer *Kevlar* 49 aramid supplanted steel wire for antenna guy wires because of its high strength to weight ratio.

In the late 1970s the U.S. Navy sought solutions from industry for ship-board accidents caused by recoil of broken hawsers. Several reduced recoil rope designs looked promising when tried on short laboratory test machines. But these early designs were not successful when long rope lengths were tested in the field.

In 1983, the Ocean Builder 1 construction barge was to be moored alongside Exxon's Lena tower in approximately 300 m (1000 ft) water depth in the Gulf of Mexico. Aramid rope was selected to moor the barge because of concern that wire mooring lines might damage the polymer coated steel cables which guyed the tower. However, when the moored barge applied tension to the pre-installed aramid ropes, they failed. Investigations revealed that the aramid ropes failed because of axial compression fatigue.[29] Axial compression fatigue is now better understood and can be prevented in aramid ropes by avoiding cycling to low tensions.[30]

The Oil Companies International Marine Forum, OCIMF, issued the first SPM Hawser Guidelines in 1987.[31] These were based on the findings of extensive research on the performance and used strength of SPM hawsers which began in 1979.[32] [33]

Tension Technology International, Nobel Denton and National Engineering Labs initialed the Fibre Tethers 2000 research Joint Industry Project in 1989.[34] The goal was to evaluate rope materials and constructions to moor oil exploration and production platforms in very deep water. Tests were performed on polyester, aramid, HMPE and LCAP yarns and on different rope designs made from these materials. The results of this JIP were then published in 2002 as *The Engineers Design Guide to Deepwater Moorings*.[35]

The first successful riser protection net was installed on the Shell Auger platform, in the Gulf of Mexico in 1993. The net was designed by Hank McKenna of Tension Technology International and manufactured by Southwest Ocean Services. The riser protection net extends between the legs of an offshore platform and prevents work boats from passing under the platform and damaging the drill stem or production riser. Today they are used regularly on offshore oil platforms.

Whitehill Manufacturing Co. developed the first successful reduced recoil risk rope in 1987. The U.S. Navy readily adopted these ropes to enhance deck crew safety.

Aramid and HMPE mooring lines were tried on tankers and other vessels during the 1980s. HMPE ropes installed to replace wire mooring lines on the Exxon Baytown (later SeaRiver Baytown) in 1990 lasted 8 years, about twice the expected life of the wires.[36] Although these high-performance fiber ropes were much more expensive, they and proved to be more economical because they lasted much longer and saved time when docking the tanker, and especially because they reduced crew injuries. High-performance mooring lines are now commonly used on vessels.

The first deepwater platform to utilize a synthetic fiber rope mooring line was the Petrobras P-IX, moored in 230 m (755 ft) water depth off the coast of Brazil in 1995. It tested a polyester rope in one mooring leg. Cesar Del Vecchio contributed much to Petrobras' pioneering efforts in the use of synthetic fiber ropes in offshore moorings.[37] Petrobras installed polyester mooring lines on 27 other platforms through the year 2008.[38]

Shortly after its introduction, LCAP *Vectran* was used in ropes and cables for special applications which require minimum creep. An example is halyards on competition sailing yachts. One of the most exotic applications of *Vectran* rope was to support a large acrylic water-filled hemisphere within a deep mine cavity in Sudbury, Ontario, which is used to detect neutrinos from outer space.[39]

ABS issued the first guidelines for the use of synthetic fiber ropes in deepwater mooring systems in 1999.[40] API issued similar guidelines in 2001.[41] These guidelines facilitated the design and approval of the use of synthetic fiber rope platform moorings in the Gulf of Mexico. Both of these have recently been completely revised and reissued.

Research sponsored by the Oil Companies International Marine Forum (OCIMF) in the early 1980s revealed that wet nylon rope quickly loses strength during cycling due to internal abrasion, but that the use of "marine grade" finishes can lessen this problem. The Yarn-on-Yarn (YoY) abrasion test method was then developed by John Flory, John Hearle and Mustafa Goksoy.[42] The YoY abrasion test method was finally adopted by OCIMF when the SPM Hawser Guideline was republished in 2000.[43] ASTM and the Cordage institute also published the YoY abrasion test method at that time.[44] [45]

The honor of the first synthetic rope deepwater platform mooring system in the Gulf of Mexico was virtually a tie between the BP Mad Dog and Kerr-McGee Red Hawk platforms, both installed in the spring of 2004. Mad Dog used Marlow polyester ropes in 1,348 m (4,420 ft) of water.[46] Red Hawk used Whitehill polyester rope in 1,615 m (5,300 ft) of water.[47] At this time, 16 synthetic fiber platform deepwater mooring systems have been installed in the Gulf of Mexico.

The weight of rope used to lower and lift objects is of particular concern in deepwater. The practical limit on the use of steel wire is about 2000 m (6,500 ft). Several deep-water winching systems were recently developed to employ synthetic fiber rope. The Deep Tek heave-compensated winch, using Cortland's 12X 12 rope, was used in 3,000 m (10,000) water depth in 2004.[48] The ODIM CTCU (Cable Traction Control Unit), using Cortland's "*BOB*" rope, was used in water depths over 2500 m (8000 ft) in 2006.[49]

One of the "blue-sky" applications for fiber rope is the space tether elevator. The concept was first published by Yuri Artsutanov, in Pravda in 1960. A very high strength rope would be deployed from a geosynchronous satellite down to the earth, and payloads could then be lifted into outer space using very little energy. A recently published feasibility study evaluates the use of carbon nanotube rope for this endeavor.[50] If this works, some day, some of you may be spending a vacation in outer space.

Conclusions

One of the tools of technology forecasting is to do technology hindcasting. At the beginning of our careers (in the case of the authors, about 1960), what would we have predicted of the future of rope technology, and would we have believed predictions of what actually happened by the year 2015?

Another way of looking at 75 years of synthetic rope history is the rate of introduction of new materials. In the fifty years beginning in 1940, seven new materials were introduced into rope making: nylon, polyethylene, polypropylene, polyester, aramid, HMPE and LCAP. That is one new rope making material about every seven years. In the 20 years since 1990, no new, practical rope making material has been introduced. Have we hit a barrier? Or is a new break-through material just ahead of us?

Rope constructions have continued to evolve. There are some "new" constructions which we haven't mentioned. And some "tweaks" in design details and quality control have been significant. The recent introduction of a practical NDT method for fiber ropes may be very significant in overcoming the objections that "they can't be inspected in-situ, like wires."

Synthetic fiber ropes are now used in applications which would have been very difficult or impossible with natural fiber ropes, wire ropes and chains. Examples are mooring systems in water depths of 10,000 m (3,300 ft) and tethers between satellites in outer space.

We have only mentioned some of the developments and uses of synthetic fiber ropes, with emphasis on the marine industry. The continued efforts of rope manufacturers and rope researchers to improve synthetic fiber rope technology will certainly "push" ropes into new uses. (Who said you can't push a piece of rope?)

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Table	Time Line of Synthetic Fiber Rope Materials, Constructions, Uses and Developments		
year	**Materials**	**Constructions**	**Developments and Uses**
ancient	**Natural Fibers**	**3-Strand & 4-Strand**,	
C1900	**Rayon** (not a synthetic material)	**8-Strand Plaited Rope**, used as belt drives	
1935	**Nylon 6.6** (Polyamide) discovered		
1936			
1937			
1938	**Nylon 6** (Polyamide) (Perlon) discovered		
1939	**Polyethylene** fiber produced		**Nylon** (6.6) used for nylon stockings
1940			
1941	**Polyester** (PET) **(*Terylene*)** discovered		
1942			
1943	**High-Tenacity Nylon**		**Parachute cords**, glider tow ropes, etc., World War II
1944			
1945			
1946			
1947			
1948		**Large 3-Strand Nylon rope** produced	**Nylon Shipboard Hawsers**
1949			
1950	***Dacron* Polyester** developed		**Nylon** widely used for rope
1951			
1952			
1953	**High-Density Polyethylene** discovered	**Kernmantle Rope** developed	**Polyester** used in ropes
1954	**Isotatic Polypropylene** discovered	**8-Strand Plaited Rope**, marine mooring lines	
1955			
1956			
1957			**Polyethylene** used in ropes
1958			
1959	**Polypropylene fiber** introduced		**Single Point Mooring Hawsers**
1960		**Double-Braid Rope** developed	**Polypropylene** used in ropes
1961			
1962		**7-strand Rope** (6 around 1) developed	
1963			
1964			
1965	**Aramid *Kevlar*** discovered	**H&T 24 in. 8-Strand Braiding Machine**	**Polyester** widely used in ropes
1966		**7-strand *Jetcore* Mixed Fiber Rope**	**Space Tether**, Gemini 11
1967		**Parallel Fiber Rope *Parafi*l**	

Table	Time Line of Synthetic Fiber Rope Materials, Constructions, Uses and Developments		
year	**Materials**	**Constructions**	**Developments and Uses**
		developed	
1968			
1969			
1970	**Aramid Kevlar** (Fiber B) introduced		
1971			**Double Drum Traction Winch**
1972			**Aramid** first used in ropes
1973	**Aramid** ***Twaron*** produced		**Aramid Rope Small-Buoy Moorings**
1974			
1975			
1976			
1977			
1978		**"Wire-Rope Construction" developed**	
1979			**Reduced-Recoil-Risk Rope** attempts
1980	**HMPE** ***Spectra*** fiber discovered	**Parallel Strand Rope** ***Superline*** developed	
1981	**HMPE** ***Dyneema*** fiber discovered	**Bridon 30 in. Double-Braid Machine**	
1982	**PBO** development		
1983			**Aramid Deepwater Mooring** (unsucessful)
1984			
1985	**HMPE** *Spectra* introduced		**Riser Protection Net** (unsucessful)
1986	**Copolymer Aramid** ***Technora*** discovered	**12-Strand Rope** developed	**HMPE** ***Spectra*** used in ropes
1987	**Copolymer Aramid** ***Technora*** introduced	**"Reduced Recoil Rope"** developed	**OCIMF Hawser Guidelines**
1988	**LCAP** ***Vectran*** discovered		**Aramid and HMPE Ship Mooring Lines**
1989	**HMPE** ***Dyneema*** fiber introduced		**Fibre Tethers 2000 JIP**
1990	**LCAP** ***Vectran*** fiber introduced		
1991			
1992			**Riser Protection Net**
1993	**M5 fiber** discovered		**Reduced-Recoil-Risk Rope**
1994			**LCAP** ***Vectran*** used in ropes
1995			**Polyester Deepwater Platform Mooring**, Petrobras
1996			
1997	**Polyester PEN fiber** introduced	**12 x 12 Rope** developed	
1998			
1999			
2000			**Yarn-on-Yarn Abrasion Method**, ASTM & CI

Table	Time Line of Synthetic Fiber Rope Materials, Constructions, Uses and Developments		
year	**Materials**	**Constructions**	**Developments and Uses**
2001			**ABS and API Deepwater Mooring Guidelines**
2002		***"BOB"*, HMPE/LCAP Hybrid Rope** developed	
2003			
2004			**Deepwater Platforms In Gulf of Mexico**
2005			**Heave-Compensated Winch Rope**
2006	***ePTFE* Fiber** introduced		
2007			
2008			
2009			
2010			
2011			
2012			
2013			
2014		**NDT Method for Fiber Rope**	
2015			
?	**Synthetic Spider Silk?** **Carbon Nanotubes** ?		**Space Tether Elevator** ?