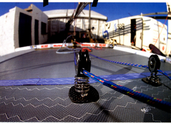
Rope yarns



Barely 50 years ago sailors still relied on hemp and tar for their ropes and rigging. Now technology advances mean that the string on your boat can be stronger than steel. **Des Pawson** uncovers the inner workings of modern materials.

When the world's largest single-masted sailing yacht, 'Mirabella V', recently ran aground her crew searched for the strongest rope they could find to pull her off. They chose a 12-strand Dyneema rope, made especially for the 100m yacht, with a breaking load of over 120 tonnes. However, the strain of pulling her off the rocks simply crushed the bollards around which the rope had been made fast. Something had to give. In the past it tended to be the rope, today's materials are so strong, some ropes may have a higher breaking strain than the hardware they are working with.

Early readers of Yachts and Yachting magazine, back in the late 1940s, would have been feeling glad to get afloat again after the Second World War. If they were lucky their boats could have been re-rigged using their hemp and manila rope from before the war – that is, if they had washed and dried it out after they had last used it and the mice had not eaten it.

If they went shopping for new rope to rig their boat they would have found only sisal and probably would have complained that it was nothing like the hemp or manila from before the war. A few bright souls might have looked in government surplus stores to find Nylon parachute cord. The polyamide (PA) known as Nylon was discovered in 1935 and was rapidly developed for military purposes. It was much stronger that anything else used to make rope, but was extremely stretchy and when it finally broke had a terrible whiplash.

Slowly the post war cordage market got back on its feet and people could once again buy lightly-tarred Italian hemp for their bolt ropes, tarred hemp for their standing rigging and untarred [white] hemp for running rigging. Nylon improved, with reduced stretch and was offered for mooring ropes. One company, Stephens Belting of Birmingham, wrote to Yachts and Yachting in January 1960 explaining that they had developed a combination rope of Nylon and leather. This never took off.

Above The power and heat generated by modern materials can be enormous and have even been known to melt some winch drums. This bollard on 'Mirabella' was tested to 60 tonnes, but the tow rope used withstood a greater load.

Man-made fibres

The early '50s saw an attempt at man-made rope using Polyethylene (PE), often sold under the name Courlene. This did not take off in the sailing world, as it was very stiff and slippery, although it was used by fishermen and, much later by water ski enthusiasts.

Another new man-made or synthetic fibre used for rigging was Polyester (PES), under the trade name Terylene, or Dacron in the USA. Polyester was first discovered in 1940-1941. British Ropes brought this rope to the market in the mid 1950s. Polyester was expensive compared to natural fibres, even the finest quality Italian yacht hemps being half its price. However, the weight saving, resistance to chafing and reduction in windage (due to the fact that smaller ropes were needed), made it popular with racing boats. By 1960, under the name 'Marlow brand synthetic Yacht Ropes', Hawkins and Timpson were advertising their product with the claim that winning sailors 'owed their success to Marlow Terylene rope'. Whilst not having anywhere near the stretch of Nylon, Polyester ropes still had a degree of stretch, but it was soon discovered that it was possible to heat set and pre-stretch the rope during the manufacturing process. Although this made a slightly stiffer rope, it was a great improvement for those stretch sensitive areas of the rig.

The death knell for even the cheapest of natural fibres, sisal, was the development of Polypropylene (PP). First discovered in 1954, it was cheap to produce and went on to squeeze out even the cheaper sisal from almost all applications. Although it did not rot as such, the early Polypropylenes broke down with exposure to UV light, and wore very easily. This is not such a great problem today, but still something to be borne in mind if you are using ropes made of this fibre. Polypropylene comes in a number of forms: split film, monofilament (large yarns) multifilament (fine yarns almost like Nylon or polyester) and staple-spun – where the extruded yarn is chopped up and then spun into a yarn that is rough but gives more grip. In all its variations it is a very lightweight fibre, which means it floats. This can be a benefit, or a cause of frustration if it wraps round your propeller, rudder or keel.

Because Nylon was the first man-made rope material for many years, even to this day people will call any synthetic rope Nylon, but the properties of each synthetic is different and it's important to realise this. As far as yachting was concerned, the natural ropes had soon had their day and polyester was king. Nylon continued to be used for mooring warps and polypropylene for the cheaper end of the market and where weight was the most significant factor, such as in dinghy spinnaker sheets. Nylon ropes are still be used today, but manufacturers are gradually reducing their range, especially of three-strand ropes, as Nylon tends to stiffen up with the age. Although Nylon is marginally stronger than polyester it does absorb water and loses some of its strength when wet.

In a twist

The other major break through in modern cordage was in construction. Up until the late '50s almost all rope consisted of three or four twisted strands. Traditionally ropes were made of fibres twisted ▶



Left (from left to right) Traditional three strand construction was followed by the evelopment of multiplait (12-plait is illustrated) and today's familiar braid on braid covered rope. The braid on braid construction allows load bearing fibres to be used for the core, and hard wearing materials for the cover.

Photos: [illegible]

into yarns, yarns twisted together into strands, then three or four of the strands were twisted into the rope. At each stage the twist would be opposite to the twist in the previous stage, and it was these conflicting twists that kept the whole rope together.

Between 1957 and 1962 the Dutch and Swedes developed a heavy plaited rope using eight strands giving a 'square' plait, sometimes know as an 'anchor plait', 'eight plait' or 'multi plait rope', which proved very good for mooring ropes as it did not kink when stowed. Much used by large commercial vessels, it is still very popular with yachts as anchor rope where it can be spliced onto chain and as mooring lines.

Although ropes of plaited yarns had been around for many years, usually in small sizes, it was almost impossible to splice, so always had to be knotted. The big breakthrough came with the braiding of an eight or 16-strand hollow plait, over a core of another hollow braid. Known as a 'braid on braid' rope, it was the developed between 1957 and 1960 by Samson (USA) ropes. This development was led by engineer Ken Fogden, who also developed an eye splice for this rope in 1959. Yacht ropes would never be the same again, as a good splice was so much stronger than a knotted loop. Soon there were other variations, such as hollow braided covers with a twisted core or continuous fibre parallel core. All of these constructions gave ropes that tended to kink and stretch less than the usual three or four-strand rope. It was these developments that paved the way to the ropes of today.

Material world

Since then other fibres have been discovered that can be used in rope construction, usually as the core because, although they may be stronger fibres, there is frequently either a problem with UV or with chafe, so a polyester cover can protect the more vulnerable core.

The first material that made a big difference

Right The combination of the construction of a rope and the materials used affect how much the rope extends under load. For halyards, minimising stretch is important, while it is good to have some give in mooring ropes to ease the sudden loads applied when the boat moves.

was an aramid known as Kevlar, and subsequently also by the trade names 'Twaron' and 'Technora'. This yellow coloured material has low stretch, low weight and a high breaking strain, but is less happy bending as it goes over the sheaves in blocks, so blocks were built with bigger sheaves to reduce flexing of the rope. For a while Kevlar was used to replace standing rigging and for halyards.

The late '70s saw another material, a high modulus polyethylene (HMPE), sold under the trade names of Dynema and Spectra. This material is incredibly light and strong, in fact it is 14 times as strong as steel weight for weight. It has found its way into many of the specialist ropes that are used today, on everything from dinghies to round the world maxis.

Research continued, developing materials that were stronger, lighter, and more resistant to friction and flexing. The most recent developments to have found their way into yacht and dinghy ropes are Vectran, a liquid crystal Polyester (LCP), and the very pricey PBO – short for its chemical name and sold under the trade name Zylon – which has been in production since 1998. These materials were first developed during the America's Cup as many ropemakers working closely with a particular team, and the developments from the big boats gradually found their way down to the smaller craft. None of them are low cost, in fact they are often a great deal more expensive than polyester, but can give that slight performance improvement.

Left tapering sheets means weight can be reduced, while the rope's harder-wearing cover can be retained for areas of high chafe and ease handling.

> "Sheets with a standard polyester cover had to be replaced after every America's Cup race"

Under cover

All of these materials tend to be used in combination with a cover using polyester, or sometimes polypropylene for lightness. In some constructions, an intermediate layer of matt polyester is used to help hold core and cover together. As most of the strength of the rope is in the exotic core the old-style braid on braid splice cannot be used; each manufacturer will have its own recommended method, related to the old way but giving a core-to-core splice.

There were times when, in the search for weight and windage reduction, crew would strip away the cover. It wasn't long before many of the rope manufactures offered the core on its own, normally in the form of a hollow 12-plait that could easily be spliced. Apart from running and standing rigging this basic material, in its smaller sizes, is also increasingly being used to replace shackles, by the use of sophisticated lashings.

Dynema, Spectra and Vectran are all subject to abrasion, fibre against fibre as well as ordinary chafe, and so are coated with a polyurethane coating to increase resistance. This has additional benefits of increased UV resistance, cutting down water absorption, holding the very fine fibres together, making splicing easier, and can be dyed for colour coding of lines.

Stripping the cover off a sheet, but leaving the exotic core, reduces weight and resistance but the thinness of the remaining core makes it almost impossible to handle. So, for the rope to work in jammers, or round winches, the cover would be left on at one end, making a tapered rope. Today some rope manufacturers will supply tapered sheets to order.

Nowadays as much thought goes into the cover of the rope as the fibre inside. Manufacturers like Gottifredi Manflioli of Italy have worked with America's Cup teams Alinghi and Luna Rossa, developing covers that use a variety of mixed fibres, mainly aramids and specially formulated polyesters. They focussed their tests for the very top end of the racing market, developing a number of variations of cover construction. Gottifredi Maffioli was the first to develop pre-stretched heat-treated Dynema, increasing the strength by 10-15 per cent and improving its grip. A choice of six covers can be used over a core made of Dynema, Vectran or PBO.

Gottifredi Maffioli was the first to put PBO on the outside of a rope and, whilst this made for a phenomenally expensive rope, it was a logical solution to the requirements of racing at an

Below By varying the materials used in the cover of a braid on braid rope it can be designed specifically for its application. Primary winches, for example, where only one or two initial turns are used, require the use of materials in the cover to allow more grip ▶

Above **A knot of any sort immediately reduces the breaking strain of a rope. Some materials, such as Kevlar do not react well to sharp angles, as their fibres are very brittle.**

Below **The diameter of a rope is not always an indication of its breaking load. The chart below (courtesy of information supplied by Marlow) is a rough guide to diameter selection for monohull yachts based on standard polyester ropes, stronger materials would allow you to reduce diameters, but you need to ensure your hardwear is designed to accommodate smaller diameters.**

America's Cup level. PBO is very vulnerable to break down with exposure to UV, but as a set of sheets with a standard polyester cover had to be replaced after every race, anything that lasted longer would be in the running. In fact Gottifredi Manfioli's PBO covered sheets could last for two round robin series, still not long enough for UV to be a factor and so making an overall cost saving. Most of the last America's Cup Challengers used their GM Zylon covered ropes.

Pushing boundaries

Where one rope maker has gone others soon follow, developing their own variations. For example Marlow created their MGP Nomex and MPG Aramid. It was found that the heat generated when easing a rope round a winch could cause the polyester cover to melt. By adding Kevlar to the cover there is a greater heat resistance and greater grip, so for a quick change only a couple of turns round the winch is required. If better control is needed then a cover with another aramid, Nomex, is used in the cover, so that there can be more turns round the winch drum, allowing more control when easing without the cover melting. But if the winches are not up to it, this can cause scouring of carbon drums. So, the winch manufacturers go on to develop even better winches, and the rope makers are pushed still further.

Liros developed their own special coatings with the Xtreme range of ropes. Cousin Trestec of France developed their Cable King Rope, with a compacting film to give a very compact and stiff rope for replacing steel ropes for backstays or similar. Manufactures such as Marlow, Liros and Holt are also now working very closely with the top dinghy sailors and developing special ranges for performance skiff or dinghy sailors.

Things keep on developing. Whilst pre-stretching and heat setting was first developed for smaller lines, Gleistein has built a major plant capable of pre-stretching larger diameter ropes. This recently produced a special 34mm diameter rope called Dyna One HS, to fit the winches on 'Mirabella V'. This rope was 12-strand construction in Dynema SK75, heavily coated in a special polyurethane, and pre-stretched and heat set with a breaking load in excess of 120 tonnes. But, as the crew of 'Mirabella V' discovered when she ran aground, whilst the rope could take the strain, the deckware couldn't.

One thing is certain, whilst hardware makers improve the strength of their fittings and the way they can handle the new ropes, the ropemakers will continue to develop new and innovative materials and methods of making this most essential material. ■

Yacht Length	Approximate Sail Area			Sheet Size				Halyard Size		
	Main	Genoa/Jib	Spinnaker	Main	Genoa/Jib	Spinnaker	Spinnaker/Guy	Main/Jib	Genoa	Spinnaker
6-8 20-26	**13** 140	**20** 215	**30** 323	8	8	8	8	10	10	8
8-9 26-30	**15** 161	**28** 301	**40** 431	10	10	8	8	10	10	8
9-10 30-33	**17** 183	**32** 344	**55** 592	10	10	8	10	12	12	10
10-11 33-36	**20** 215	**45** 484	**80** 861	10	12	10	10	12	12	10
11-12 36-40	**24** 258	**55** 592	**110** 1184	12	12	10	12	14	14	12
12-14 40-46	**32** 344	**75** 807	**170** 1830	12	14	12	14	14	14	12
14-16 46-53	**50** 538	**110** 1184	**240** 2583	14	16	14	16	18	18	14
16-18 53-59	**70** 753	**150** 1615	**340** 3660	16	18	16	18	20	20	16
Metres feet	**sq m** sq feet			mm				mm		