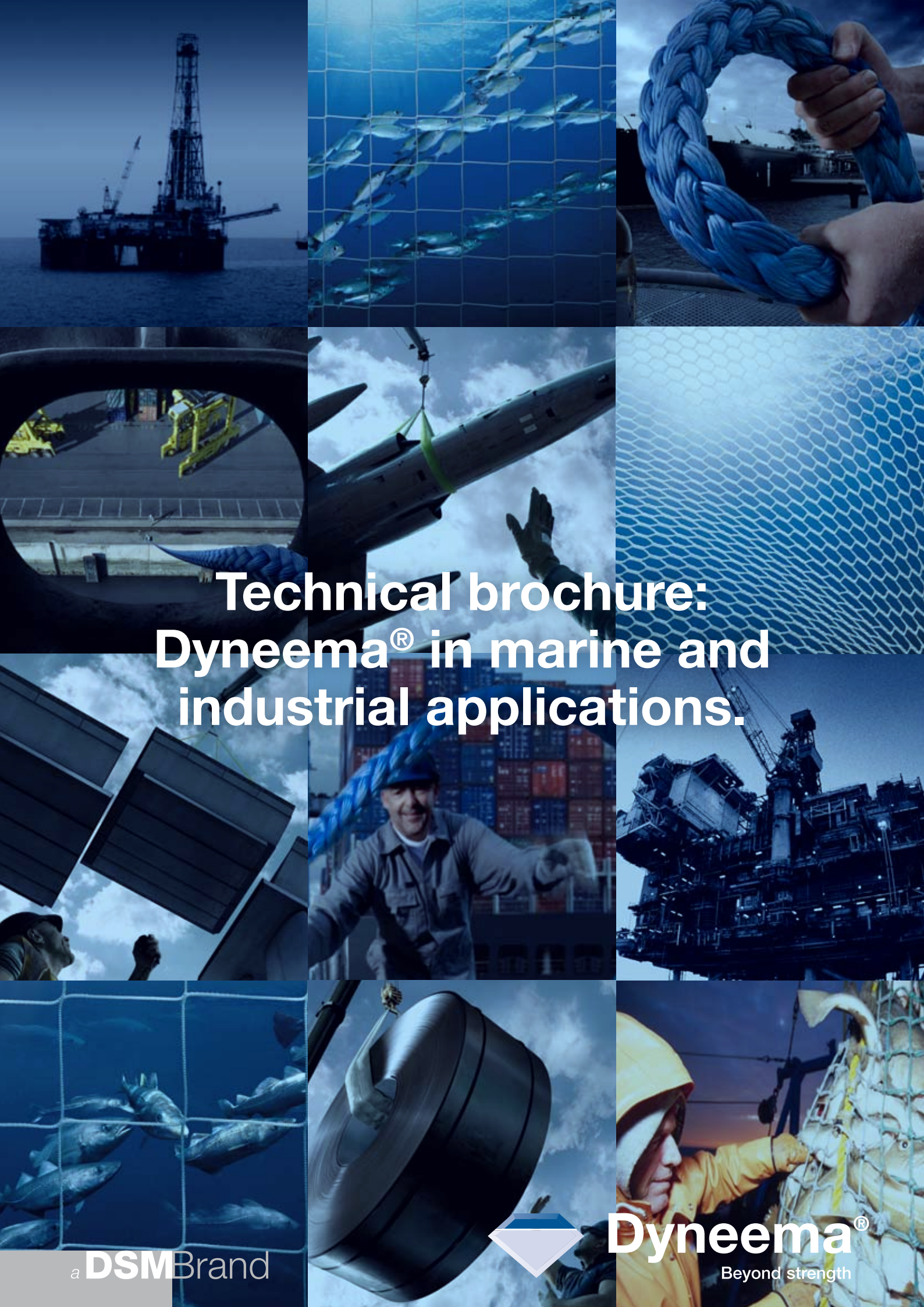


Technical brochure: Dyneema® in marine and industrial applications.

a DSMBrand

Dyneema®
Beyond strength

Dyneema® fiber and

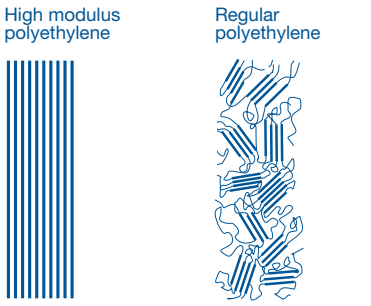
Dyneema® fiber: proven valuable.

Invented and manufactured by DSM Dyneema, Dyneema®, the world's strongest fiber™ is a versatile, low-weight, high-strength High Modulus Polyethylene fiber. Over the years, the fiber has proven its value in many market segments, including life protection, aviation, marine, offshore, fishing, sports, cut protection and medical.

Dyneema® fiber: high-performance characteristics.

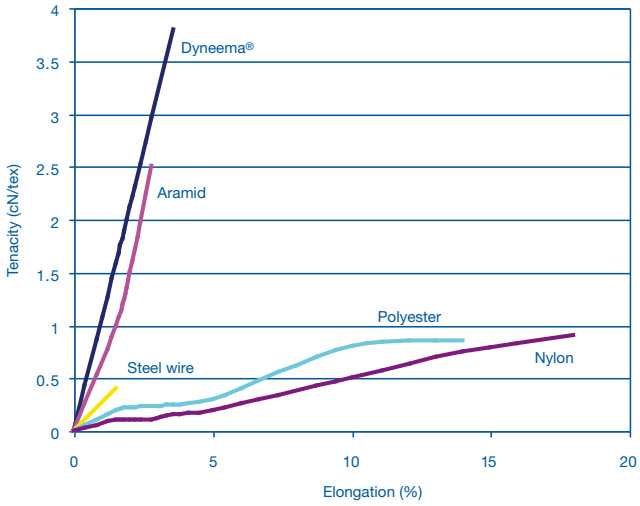
Molecular structure.
The Dyneema® fiber originates from an Ultra High Molecular Weight Polyethylene solvent spinning process. Stretching the fiber introduces molecular alignment and a high level of crystallinity.

Figure: Macromolecular orientation of HMPE and regular PE.



Having a density of less than one provides the basis for the fiber's light weight and high strength, as well as for its low elongation. Diameter for diameter, the strength and elongation of products made with Dyneema® are comparable to that of steel, with only 15% of the weight. In marine and industrial applications, Dyneema® is the fiber with the highest strength-to-weight ratio. Also, the low-friction properties of the fiber protect it from internal abrasion, resulting in long service lives in rope tensile- and bending fatigue testing.

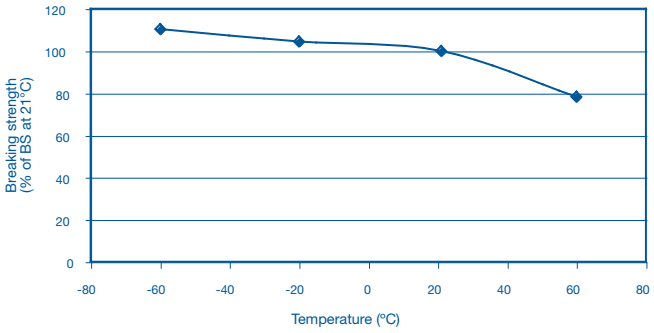
Figure: Tenacity elongation curves for various fibers.



Operating window.

Temperature.
Dyneema® fiber has a melting point between 144°C and 152°C. The tenacity and modulus decrease at higher temperatures but increase at sub-zero temperatures. There is no brittle point found as low as -150°C, so the fiber can be used between this temperature and 70°C. Brief exposure to higher temperatures will not cause any serious loss of properties.

Figure: Influence of temperature on Dyneema® fiber breaking strength.



Static load.
With increasing static load and temperature the Dyneema® fiber elongates irreversibly. This is called creep. Among the commercial available HMPE fibers, Dyneema® shows the lowest creep with the longest creep life. DSM Dyneema has developed a widely accepted model for accurate creep calculations. These calculations support the search for applicability of the Dyneema® fiber in most applications.

its many applications.

Dyneema® fibers for marine and industrial applications.

Dyneema® SK75 is the multi-purpose grade. This versatile grade is used in most marine applications like ropes, lines, nets and lifting gear.

Table: Dyneema® SK75 dtex1760.

Property	Typical value		
Yarn count	1760 dtex	1600 den	
Breaking force	610 N		
Tenacity	35.1 cN/dtex	39.8 g/den	3.4 GPa
Modulus	1160 cN/dtex	1314 g/den	113 GPa
Elongation	3.5 %		

Dyneema® SK62 is an intermediate grade. It has a lower tenacity and is used in netting applications and in rope covers for increased abrasion resistance.

Dyneema® SK78 offshore grade is specially designed for improved service life in applications that are subjected to long-term static loads. Dyneema® SK78 is the only HMPE fiber that is type approved by Bureau Veritas and American Bureau of Shipping for Mobile Drilling Unit (MODU) mooring systems.

Marine and industrial markets: an environment that demands strong, lightweight solutions.

The high strength and light weigth of the Dyneema® fiber combined that it floats and is better resistant to salt water UV rays and most chemicals makes it ideal for products in tough marine and industrial markets. At the moment, several market segments are served. Ropes, lines, nets and other products made with Dyneema® are used for heavy marine (tugging, salvage and mooring), industrial, offshore and fishing (in both wild catch and aquaculture) markets.

Table: Water and chemicals.

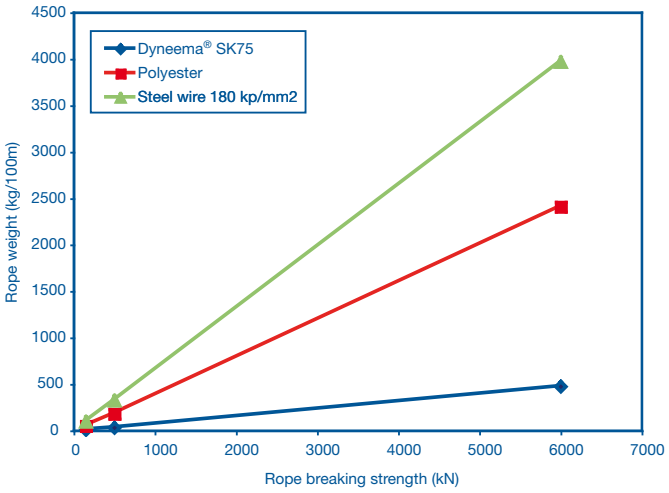
	Dyneema®
Water take-up when soaked	None
Boiling water shrinkage	< 1%
Resistance to (salt) water	Excellent
Resistance to acids	Excellent
Resistance to alkali	Excellent
Resistance to most chemicals	Excellent

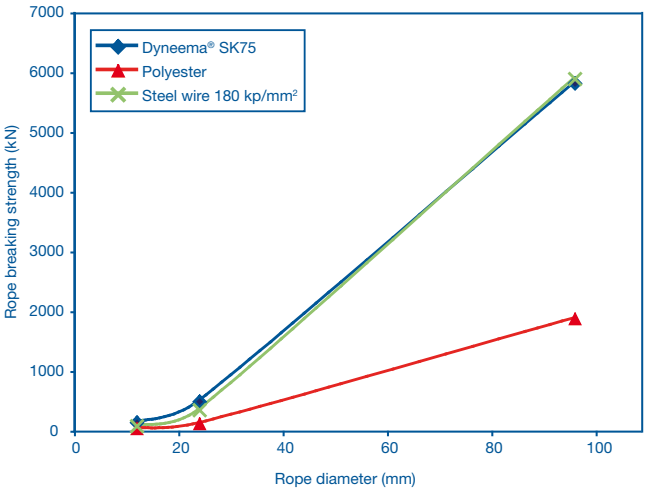
Heavy Marine: Faster Ropes.

Mooring.
The trend towards larger ships like LNG carriers, oil tankers, bulk carriers and container carriers, has resulted in mooring lines being specified with a higher breaking load. Traditionally, steel-wire mooring lines have been used. But with the larger, heavier ships, these lines have become too heavy and difficult to handle. Conventional synthetic mooring lines made of nylon and polyester are also too bulky and heavy.

Mooring lines made with Dyneema® have proven to be a very workable solution. They are much lighter and easier to handle than other types. They are as strong as steel-wire lines of the same diameter, yet they are less than one-seventh the weight. Furthermore, they are about 60% of the diameter and 30% of the weight of equally strong polyester or nylon lines.

Table: Typical weight and strength of various ropes.



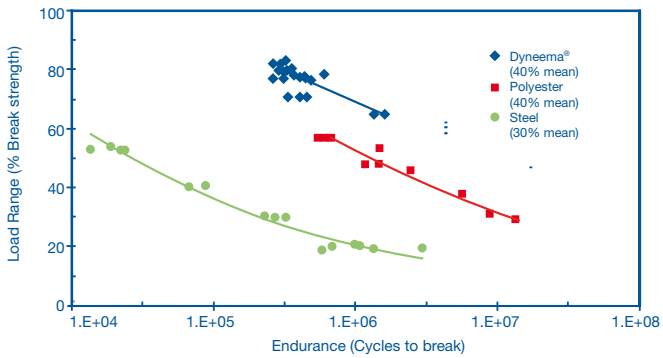


Dyneema®
Beyond strength

In addition, mooring lines made with Dyneema® have an elongation of less than 2.5% at break, almost the same as those made with steel wire. The lines can be used with similar deck equipment like winches and fairleads, thus eliminating the need for additional equipment. Although Dyneema® fiber has an excellent abrasion resistance compared to other synthetic fibers, care should to be taken that contact points of deck equipment are well maintained and sharp edges are avoided.
Tension fatigue properties of lines made with Dyneema® are excellent, outperforming other rope materials. They are also maintenance free, easy to respool, can be spliced on board and are resistant to most chemicals.

Mooring lines made with Dyneema® have shown lifetimes of over 10 years on frequently moored vessels, thus demonstrating the great possibilities of using Dyneema® fiber in this application.

Figure: Tension fatigue life of various ropes.



Last, but not least: mooring lines made with Dyneema® are safe. Hand, back and shoulder injuries are minimized due to the low weight and easy handling. In case of a failure, lines made with Dyneema® have a minimal risk of dangerous snap-back.

Tugging and salvage.
Everything that makes lines with Dyneema® a successful application in the mooring of ships, applies to the tugging or salvage industry, as well. Given the increasing size of ships, it follows that tugboats will become larger and more powerful.

Modern tugboats have substantially increased pulling power, which puts more tension on the tugging lines. So they need to be stronger, while remaining lightweight, easy and safe to handle, and durable. Tugging lines made with Dyneema® provide an ideal solution.

Industrial: right for many jobs.

Slings or ropes with Dyneema® are very strong and durable, yet lightweight and easy and safe to handle. They are of similar diameter as slings or ropes from steel wire, yet are a fraction of the weight. In addition, a rope or sling made with Dyneema® is 40% less bulky and about one third the weight of an equally strong polyester rope or sling.

Table: Abrasion and cutting protection of rope and sling covers with different fibers.

		Dyneema®	Aramid	Polyester
External abrasion resistance	Dry	++	+	0
	Wet	++	0	0
Cutting resistance	Dry	++	0	0

Legend to table: Performance levels.

Rope protection performance of covers	0	+	++
	Reference	Good	Excellent
Increase in cycles to failure	1 x	5 x	>10 x

Lifting slings.
Lightweight slings with Dyneema® are ideal for repetitive lifting operations. They can be easily handled and quickly placed around the load, enabling faster, more productive lifting. Adding a cover made with Dyneema® to the sling provides good cut- and abrasion-resistance, thereby minimizing the need for time-consuming placement of protection pads.

The slings are also soft, thus reduce the chance of damaging your load. The lower weight, even compared to polyester or aramids, enables easier handling and presents less danger to the crew handling them. There are fewer back injuries, for example. And in contrast to steel wire, which can fray and leave sharp edges, slings with Dyneema® have a very smooth surface.

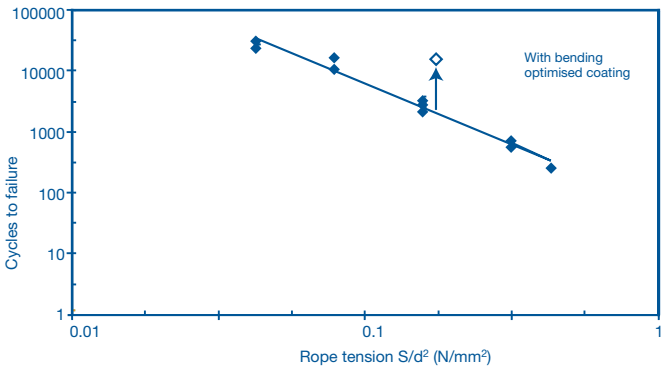
Industrial applications.
Many kinds of wire rope have already been replaced by those made with Dyneema®. This gives end-users the benefit of a much lower weight, and all the speed and handling benefits resulting from that. Lines with Dyneema® are used in a wide variety of applications, including electricity cable pulling and forestry.

Offshore: going deeper.

Seismic.
Over a decade ago, the seismic industry discovered reliable ropes made with Dyneema®, which are now an established part of towing arrays. The high-strength, low-diameter ropes reduce drag, while the low elongation gives a high degree of accurate positioning of the sensors. At the same time, due to the floating character of the ropes they do not form a catenary, adding even more accuracy to the system compared to other type of ropes. Finally, the high degree of tension and bending fatigue resistance offers extended service lives.

Deep sea installation/Pipe-laying A&R.
In the continuing quest to work in deeper waters, ropes made with Dyneema® offer many solutions. Capable of replacing steel wire size for size, a rope made with Dyneema® fiber is only 15% of the weight, and is weightless when submerged. For ultra-deep operations, the full capacity of the winch is available for lifting at every water depth. Specially designed ropes for bending applications are available to be used in heave compensation systems.

Figure: Bending fatigue life of ropes with Dyneema®



Mobile drilling unit (MODU) mooring.
Mooring system installation companies will benefit in many ways by using rope with Dyneema® SK78. Compared to polyester mooring ropes, these ropes have a much smaller

Dyneema®
Beyond strength

diameter that offers 3 times as much length on the installation winch. The low weight results in easy handling, thus reducing the installation time of a full pre-set mooring system by up to 40%. The hook-up time of the rig is also reduced by half.

The rope's low elongation improves the station-keeping performance. Due to more strict regulations, ropes made with Dyneema® are used in a steel catenary mooring system in the case of crossing sub-sea constructions. Finally, in case of line failure, the structure will not be damaged as it would by falling steel wire.

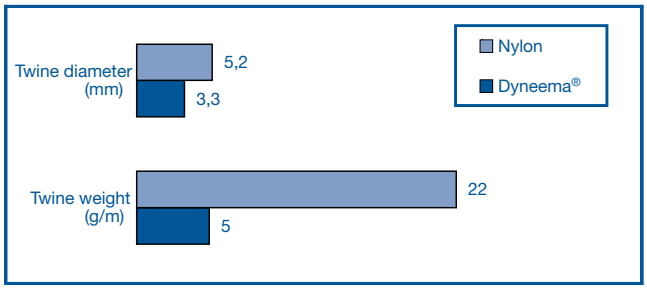
With extended creep life and excellent tension fatigue properties Dyneema® SK78 is the only fiber that has been type approved by Bureau Veritas and American Bureau of Shipping (ABS) to be used for MODU mooring systems.

Working ropes.
The lightweight and compact ropes made with Dyneema® fiber offer flexible tension members that can be easily handled on board, by divers or by ROVs. Many offshore engineers have discovered the benefits of replacing steel wire by ropes made with Dyneema®. Technical data on rope performance are available, and enables the offshore engineer to optimize the rope design for best performance. Turret pull-in ropes, stinger ropes, anchor retrieval lines and riser tensioning ropes are some of the examples where rope with Dyneema® has proven itself successful.

Fishing: better for fish and the fishermen.

Fishing can be divided in two categories: wild catch and aquaculture. In each one, Dyneema® fiber is highly valuable, with many enabling properties for several applications.

Figure: Twines with knot strength of 2.5 kN.



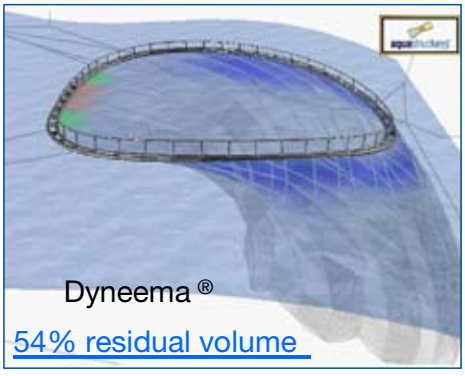
Wild catch.
Fishermen active in wild catch have many worries. Fishing quotas, high fuel- and labor costs are a struggle for economic survival. Fishing gear that contributes to increased reliability and reduction of costs is therefore a necessity. Over the years more and more parts of the nets that are normally made out of nylon are being replaced by netting made with Dyneema® fiber. The diameter of netting twines made with Dyneema® fiber is reduced by up to a factor of two, resulting in a huge drop in drag resistance. A boat equipped with nets made with Dyneema® can sail faster, uses less fuel or has a bigger net.

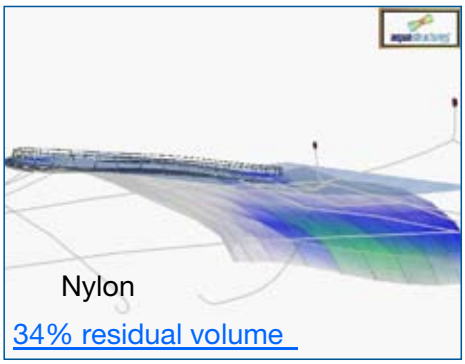
In addition to the nets, ropes made with Dyneema® are extensively used as bridles, gilson- and rib lines. Most recently, warp lines made with Dyneema® have also been developed and are being used for trawling. The lightweight ropes replacing steel wire reduce drag and enable near surface fishing. The low elongation enables better control of the net, improving overall flexibility for the captain.

In general, the low weight and high strength of nets and ropes made with Dyneema® result in easier handling. The abrasion resistance and resistance to (sea) water enhances the lifetime compared to other materials. This superior resistance to abrasion can be further improved by applying proper coatings.

Aquaculture.
The high demand for fish puts a lot of pressure on the aquaculture industry to increase capacity. Innovations in the field lead to improve efficiency and enabling technologies. Products made with Dyneema® play a prominent role. Nets made with Dyneema® fibers are up to a third of the weight compared to traditional nylon, and have smaller twine diameters. This results in a reduced drag from current and waves, thereby improving net stability and improving the environment for the fish inside. The well-being of the fish is further enhanced by the improved fresh water flow.

Figure: Net shape at 0,7 m/s current





Maintance costs are reduced since the thinner nets need less antifoulant and repairs to the net are reduced considerably.

One special feature, which is very important when farming fishbiting species such as sea-bream or cod, is the high bite-resistance of netting made with Dyneema® fiber. This extends the lifetime of the nets and significantly reduces the number of escapes and necessary repairs.

Of course, in addition to the challenge of keeping the fish in the nets, there's also the threat from outside of keeping predators away from the nets. Its high knot-strength, together with the high bite-, cut- and abrasion resistance make Dyneema® fiber the preferred material for the job.

Table: Fiber properties.

	Dyneema® SK75	Nylon	
Break strength (dry)	35	6 – 8	cN/dtex
Break strength (wet)	35	5 – 7	cN/dtex
Elongation at break (dry)	3,5 %	16 – 25 %	
Elongation at break (wet)	3,5 %	20 – 30 %	
Moisture regain 22 °C and 65 % RH	None	± 4.5 %	
Water take-up soaked	None	± 10 %	
Yarn-on-yarn abrasion (dry) at 5,5N	5927	3835	Cycles
Yarn-on-yarn abrasion (wet) at 5,5N	15636	130	Cycles

Also consider the challenge of moving large offshore cages to more remote areas. The forces on the nets increase and daily inspections may not be possible. Netting made with Dyneema® is outperforming all other fiber based nets in this respect.

New markets.

The use of products made with Dyneema® seems to be unlimited. New products and new markets are continually being explored and developed. The high technical demands for these products are translated in application development projects taking place in our well-equipped technical lab to improve our products or develop new products. DSM Dyneema application engineers are putting a lot of effort in improving our current products and solving the challenges of the markets.

DSM Dyneema marine and industrial standard product portfolio.

	Linear density in dtex		
	440	1760	2640
Dyneema® SK75*	x	x	x
Dyneema® SK78		x	x
Dyneema® SK62	x	x	x

* Also available in twisted yarn.

Dyneema®
Beyond strength

Dyneema®, the world's strongest fiber™.
DSM Dyneema is the inventor and manufacturer of Dyneema®, the world's strongest fiber™. Dyneema® is a super strong polyethylene fiber that offers maximum strength combined with minimum weight. On a weight-for-weight basis, it is up to 15 times stronger than steel and up to 40% stronger than aramid fibers. Dyneema® floats on water and is extremely durable and resistant to moisture, UV light and chemicals. Its applications, therefore, are more or less unlimited. Dyneema® fiber is an important component in not only body armor, but also ropes, cables and nets in the fishing, shipping and offshore industries. It is also used in safety gloves for the metalworking industry and as fine yarns for applications in sporting goods and the medical sector.

DSM – the Life Sciences and Materials Sciences Company.
DSM creates innovative products and services in Life Sciences and Materials Sciences that contribute to the quality of life. DSM's products and services are used globally in a wide range of markets and applications, supporting a healthier, more sustainable and more enjoyable way of life. End markets include human and animal nutrition and health, personal care, pharmaceuticals, automotive, coatings and paint, electrics and electronics, life protection and housing. DSM has annual sales of almost EUR 8.8 billion and employs some 23,000 people worldwide. The company is headquartered in the Netherlands, with locations on five continents. DSM is listed on Euronext Amsterdam.

Dyneema® is produced in Greenville, North Carolina (USA) and Heerlen (The Netherlands).

a DSM Brand

DSM Dyneema B.V., Mauritslaan 49, 6129 EL Urmond,
The Netherlands. Tel. +31 (46)4 76 79 99

DSM Dyneema LLC, 1101 Highway 27 South,
Stanley, NC 28164, USA. Tel. (800)8 83 74 04

DSM Dyneema, 11F The Headquarters Building,
168 Middle Xi Zang Road, Shanghai 200001, China.
Tel. +86 (21)61 41 80 51

www.dyneema.com

Dyneema®
Beyond strength