MOORING LINE SOLUTIONS FOR STATE-OF-THE-ART CONTAINER VESSELS WITH DYNEEMA®

Euroneema® ropes, with Dyneema® and manufactured by Lankhorst Ropes, as excellent alternative for polyamide and polypropylene based mooring lines

Steven Wardenier, Lankhorst Ropes, The Netherlands
Marc Eijssen and **Edwin Grootendorst**, DSM Dyneema B.V., The Netherlands

SUMMARY

The shipping industry is rapidly growing worldwide; new-build activity is high and the trend is towards larger vessels. At the same time, operational costs need to be trimmed. Harbour turnaround needs to be faster. On top of that, labour regulations are becoming tighter and safety awareness is growing.
To face these challenges, an increasing number of ship operators have chosen mooring lines with Dyneema®, a High Modulus PolyEthylene (HMPE) fiber. Mooring lines with Dyneema®, like the 12-strand braided Euroneema® rope manufactured by Lankhorst Ropes, have a proven track record, providing secure and safe mooring for LNG, VLCC and container ships. Ropes providing benefits to ship designers, operators and end users.

NOMENCLATURE

GDP	Gross Domestic Product
HMPE	High Modulus PolyEthylene
LNG	Liquefied Natural Gas
NEL	National Engineering Laboratory
PA	Polyamide
PES	Polyester
PP	Polypropylene
TEU	Twenty-foot Equivalent Unit
UV	Ultra Violet
VLCC	Very Large Crude Carrier

1. INTRODUCTION

In this paper we will demonstrate the benefits of these next generation mooring lines to ship designers and end users, illustrated by case studies.

Since the introduction of modern container shipping, this industry is rapidly growing worldwide and has become one of the most dynamic economic sectors of the last years. Trends on the demand as well as the supply side have triggered this tremendous expansion. Since 1990 the growth rate has averaged just under 10% p.a.. New-build activity is high and the trend is towards larger (container) vessels. Currently, container vessels with a capacity of 10,000 TEU and even larger plus are being designed and ordered. Initial designs have already been published for container vessels carrying over 20,000 TEU. At the same time, operational costs need to be trimmed. Harbour turnaround needs to be faster since some harbours are already almost chronically overloaded. On top of that, labour regulations are becoming tighter and safety awareness is growing.
To face these challenges, an increasing number of ship operators have chosen mooring lines with Dyneema®, a High Modulus PolyEthylene (HMPE) fiber. Mooring lines with Dyneema®, like the 12-strand braided Euroneema® rope manufactured by Lankhorst Ropes, have a

proven track record, providing secure and safe mooring for LNG, VLCC and container carriers.

Nowadays container ships are mostly equipped with PA (polyamide, Atlas) and PP mooring lines. Comparing equal breaking strength, HMPE mooring lines will have 50 – 60% of the diameter and 30% of the weight of polyamide mooring lines. This could mean smaller winches can be designed.

The features of ropes with HMPE create valuable perspectives for the design and operation of today's and tomorrow's container shipping.

2. CONTAINERIZATION OF OCEAN SHIPPING

2.1 CONTAINER SHIPPING MARKET EXPANSION

Since the introduction in 1956, modern container shipping has brought about breath taking changes into the world economy. It transformed ocean shipping into a highly capital-intensive business and has become one of the most dynamic economic sectors of the last few years [1,5]. At the same time it has become the comber stone of global commercial integration [2].

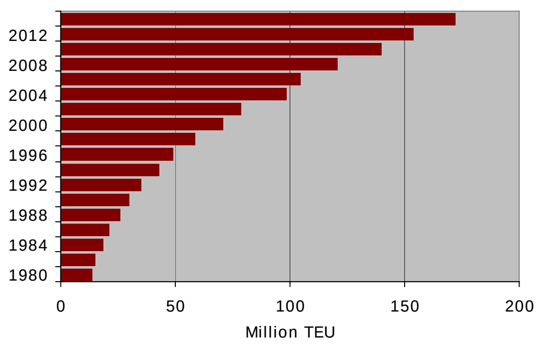

Figure 1. Global container vol. (1980-2015)

With an average increase of just under 10% 9% p.a. since 1990, container shipping has greatly surpassed seaborne trade overall. The annual growth is expected to continue for the next 10 years, with an only slightly reduced impetus (see figure 1) [1,5,6].

Major reasons on both the demand as well as the supply side have triggered the growth of modern container shipping.
The growth, on the demand side, has predominantly been caused by:

- High GDP growth in the last few years;
- The international division of labour in the course of liberalisation and the resulting trade movement;
- Decentralisation of production processes resulting in production at the component level occurring globally where it makes most sense to continue cost reductions;
- The shift from transport of raw materials to transport of (finished and part-finished) goods suited to transport by container as well as general cargo [2,4,5,6].

Trends on the supply side have as well significantly contributed, like:

- The considerable expansion of the container ship fleets (see figure 2);
- The development and building of larger (up to 10,000 TEU plus) and faster container ships;
- Increase flexibility through the combination of different (finished and part-finished) goods;
- Faster loading and unloading of container ships allowing shorter turnaround time [1,3,5,6].

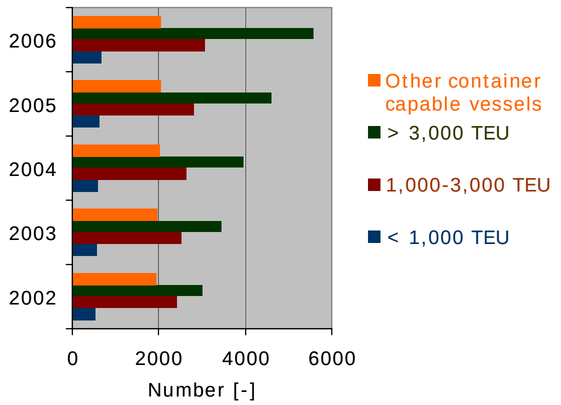

Figure 2. Increasing global container fleet

In this dynamic sector Asia is a key driving force, keeping into consideration China is dominating [3,5]. Of the 25 largest container ports in the world, 16 are in Asia and 7 of those are in China [5].

2.1 CHALLENGES OF AN EXPANDING CONTAINER SHIPPING MARKET

Despite the increasing demand for container transport freight rates are under considerable pressure. At the same time fuel rates are increasing. In view hereof improvements of productivity are of key importance. Shorter loading and unloading times, increasing size of the container fleet in terms of TEU (potentially by alliances/merges) as well as larger and faster ships contribute to the required improvement of operational excellence in which container ships and container handling form the capital-intensive parts [1,3,5,6].

The increasing demand for larger vessels induces infrastructural constraints. Congestions in and outside the ports are no rarity due to temporary capacity overloading, and canal sizes reduce flexibility and redundancy. This results in higher demands for the capacity and performance of infrastructure and superstructures to keep up with larger and faster ships [1,2,5,6,7,8]. Container terminals are moved to more exposed areas in order to provide easy access and new superstructures, like to the construction of new locks in the Panama Canal, are being build.

As a result stronger mooring and tugging ropes are required to minimize loading and unloading times and control and secure the container vessels.
Greater loads are placed on mooring lines in case terminals are exposed to currents and weather. Additional tugs may be needed for berthing container vessels at these terminals, and these tugs will also face greater marine exposure.

To provide the required strength to handle larger ships and harsher environments, traditional steel wire and conventional synthetic ropes must be made thicker in diameter – and this leads to a whole host of problems. First, these thicker ropes are heavier and more massive – and therefore more difficult to lift and manoeuvre. They put greater stress on handlers, mooring equipment and tugboats, and require more workers. The longer distances and increased exposures associated with offshore terminals, together with greater rope weight and mass, mean that the larger and heavier mooring lines can only be deployed one at a time. This slows down the mooring process and can add hours to turnaround times.

Safety is an ongoing concern for ships. More massive ropes have the potential to increase safety risks, such as injuries from backlash following a rope break, hand cuts from wire “fishhooks”, and back strain from lifting and carrying the heavy ropes.
Similarly, the container shipping sector seeks to comply with environmental regulations. Not only by increasing fuel efficiency but also by eliminating the negative impact on water quality and sea

life caused by grease applied to prevent corrosion of wire ropes.

As a result, container shipping companies seek mooring rope materials that can provide improved performance while directly addressing these challenges. Many are upgrading to specialized fibers from the conventional materials that have long dominated the shipping and towing industries.

3. NEW FIBER ROPE TECHNOLOGY SURPASSES TRADITIONAL ROPE MATERIALS

In the beginning, mooring lines were made of organic materials such as sisal and manila. Today, many vessels and tugs use lines made of common synthetics and steel wire. Especially on large vessels, the use of steel wire rope is the norm. Each of these materials offers advantages and disadvantages.

3.1 COMMON SYNTHETICS

PA, PES and PP have been used for many years, including for 11-meter stretching tail connected to steel wire mooring ropes. Although these are attractive for their lower cost, they have significant drawbacks. First, high elasticity means they will stretch under stress. This raises the safety risk of dangerous backlash if the rope breaks, and makes it difficult to position the ship at the quay. Failure to secure the vessel during rough weather can lead to shutdown of loading or offloading. For adequate mooring strength, synthetics require a large-diameter rope that takes up a large amount of space. In addition, these materials (except polypropylene) have a higher specific gravity than water, causing lines to sink and possibly become entangled in the propulsion screws of the tugs or the mooring boats. Nylon also absorbs water, lowering its breaking strength and making the ropes even heavier.

3.2 STEEL WIRE

Like traditional synthetics, steel wire ropes are also relatively inexpensive. An advantage over traditional synthetics is their low elongation, resulting in less ship movement when moored. Steel wire ropes have different disadvantages than synthetics. Steel corrodes in a marine environment, limiting the useful life of the rope and requiring lubrication with grease that can cause pollution both on the ship as well as in the environment. Compared to common synthetics of equal strength, steel wire is up to twice as heavy, posing lifting and carrying risks for workers. The rough surface of the rope can also damage workers' hands as well as fairleads, chocks and other ship components.

3.3 HIGH-PERFORMANCE FIBERS

To solve the performance issues of these materials, chemical companies have developed high-performance materials for rope fiber. Dyneema®, a leading HMPE material invented and manufactured by DSM, has been in production since the 1990s. Mooring ropes with Dyneema® made their entry into the shipping industry around 2002, and have been in use since 1994.

4. DESIRABLE PROPERTIES OF HMPE FIBER FOR MOORING AND TOWING ROPES

High modulus polyethylene offers many advantages over steel wire and conventional synthetics for mooring and towing ropes.

4.1 EXCEPTIONAL STRENGTH WITH MINIMAL WEIGHT

HMPE solves the problem of delivering enough strength to moor and tow larger container vessels without increasing the weight and mass of the ropes to a too high level. In fact, a mooring line made of HMPE fiber that is as strong as steel wire rope weighs only one-seventh as much as the wire. Compared to an HMPE fiber rope of equal strength, a PES and PA rope would have to be nearly twice as thick and would weigh four times as much.

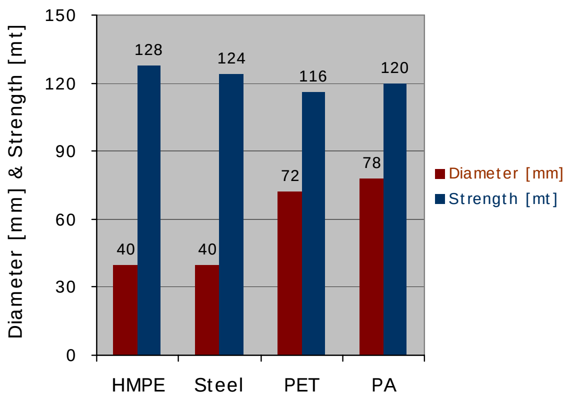

Figure 3. The diameter of ropes with equal breaking strength made of various materials

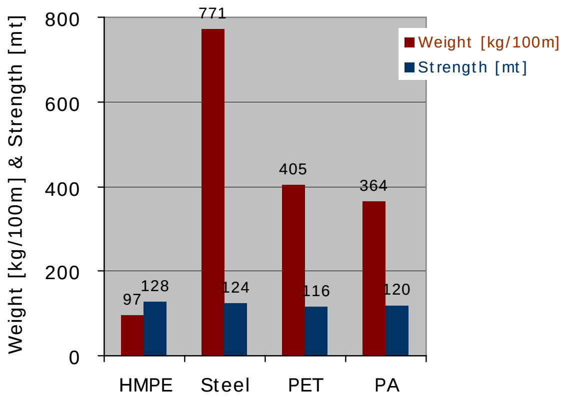

Figure 4. The weight of ropes with equal breaking strength made of various materials

Lankhorst Ropes, a manufacturer of Euroneema® ropes, with Dyneema® fiber, is seeing a major movement to replace steel wire rope, based on superior performance of the HMPE synthetic. “Low weight, high performance, and low elasticity are keys to producing rope for our markets,” said Steven Wardenier, Commercial Director of Maritime Business with Lankhorst Ropes. “Dyneema® is the fiber to do this. We are now replacing both steel wire rope and chain. This is huge for us. Dyneema® allows us to do this at one-seventh (if not less) the weight of heavier materials. We partner with our end users (ship operators, tugboat companies, etc.) then tailor our product to meet their needs using Dyneema® fiber.”

4.2 LOW ELONGATION

There can be a multitude of forces imposed on a container ship from wind and currents, speed and direction of waves, surge effects from passing vessels, tidal changes, and vessel draft changes due to loading or discharge of product. A mooring or towing rope, already subjected to stress from the weight of the ship alone, can build up dangerous energies under these additional forces. If the rope fails, the sudden release of energy - backlash - can lead to severe injury or death.

Dyneema® fiber provides a very low elongation of less than 2.5% at break. This low elongation results in a low energy storage level in the rope, so that there is hardly any backlash of the rope in case of failure. PA and PES both have higher elongation at break and are known to give a strong backlash when a rope breaks. Breaking steel wire ropes are known to have an unpredictable trajectory, leading to injuries, fatalities and material damage due to their high weight.

In actual mooring systems, steel wire ropes are often used in combination with an 11-meter mooring tail made from PET or PA. This is done to add some elasticity to the mooring system. A similar practice can be followed when using mooring ropes with Dyneema®.

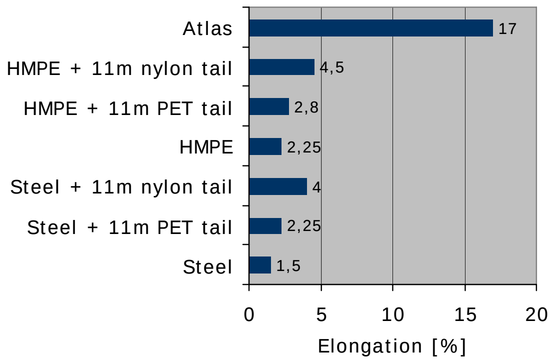

Figure 5. The elongation of mooring systems

Various components can be attached to the main mooring line to give the system some elasticity; this is done by attaching an 11-meter tail. The main mooring line is steel or HMPE. PET or PA is used as a tail to the main mooring line. The elongation of the mooring system at each load can be easily read from the graph.

4.3 DURABILITY

The work life of a rope can be affected by many environmental and usage factors, including degradation from exposure to sunlight and chemicals, corrosion from sea water, abrasion, bending fatigue and tension fatigue. Of course, for economic reasons, it is desirable to choose a rope that can offer the longest useful life.
Ropes made with HMPE exhibit excellent resistance to these wear factors. The material is resistant to most chemicals, salt and to UV light. It has superior tension fatigue performance, surpassing nylon and steel wire rope by several orders of magnitude. This superior tension fatigue performance plays an even more important role when mooring in offshore locations that are exposed to rough seas.

All these performance advantages add up to improved lifespan. It is for that reason that even though the initial investment in HMPE ropes is higher, the total cost over the lifespan of the product is lower due to exceptional durability and other factors.

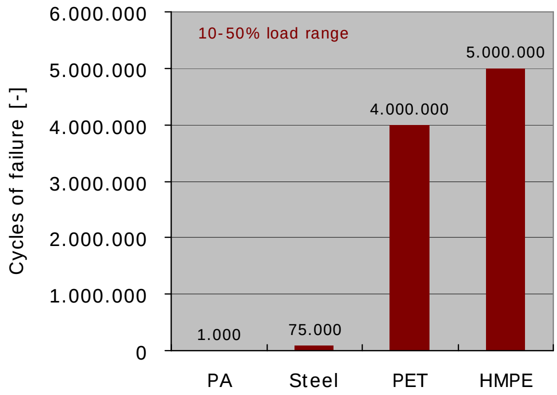

Figure 6. Tension-tension fatigue data

Each material is cycle loaded between 10% and 50% of minimum breaking strength of the ropes. Experiments have been performed at NEL in Scotland. As shown here, HMPE clearly outperforms steel wire with respect to tension-tension fatigue.

4.4 LOW MAINTANCE

As a synthetic with a smooth texture, HMPE fiber does not require lubrication to prevent corrosion or damage to ship surfaces. This saves the cost and labor of greasing steel wire ropes and repairing ship damage periodically. In fact, ropes made with HMPE fiber do not require any maintenance; however, some shippers wash them with fresh water after several moorings as a standard procedure.

5. BENEFITS OF UPGRADING TO HMPE MOORING AND TOWING ROPES

The safe, reliable and efficient mooring of container ships is more important today than ever. Ropes incorporating HMPE fiber can enhance the safety, reliability and speed of ship mooring and towing processes, while delivering excellent overall value.

5.1 IMPROVED SAFETY

Safety is not only related to the wellness of the people, it is also a matter of the image of the ship owner and operator; especially when sensitive cargo is carried. Together with environmental protection, safety is getting more and more important. Professional operations more and more want their partners to comply to environmental and safety policies.

There are a number of safety issues related to mooring a ship. For example, the risk of injury to crews is greatly increased during the mooring of a vessel when the first lines to be connected are under highest loads. This situation is exacerbated in bad weather. Workers in close proximity to mooring lines under tension face the risk of injury or even death from backlash if a rope fails.
On a less-dramatic scale, workers can be injured over time while trying to haul, lift and carry bulky, heavy ropes simply because of the sheer weight of the ropes. Broken wires in a steel wire rope can poke out and form “fishhooks” that can slice through workers’ hands.

Unlike traditional rope materials, HMPE fiber addresses these safety concerns. The handling time of the ropes during mooring is shorter due to the lower weight involved, thus resulting in less exposure time to the workers. The backlash is minimal due to the low elongation of the HMPE ropes resulting in a minimal ‘danger-zone’. Again, the workers are much less exposed to danger.

HMPE rope enables container ship operators to eliminate a number of safety risks associated with traditional mooring systems and to demonstrate their commitment to the highest safety standards.

5.2 SCALABILITY

One way of segmentation of container vessels is by the number of containers that can be loaded. For instance:

A) < 1,000 TEU;
B) 1,000 TEU – 10,000 TEU;
C) > 10,000 TEU;

The smallest segment refers to Coasters and River Ships. The size of the ropes is not so much the issue with these vessels, but the handling is. These ships have a tendency of very frequent mooring in combination with a minimal number of sailors on board. In numerous cases Captain/Owner are man and wife, with maybe one or two sailors on board. The HMPE ropes are easy to handle and thus quickly applied, they are comfortable in the hands as offer greater safety to all of them.

River Ships can be a combination of two or three vessels locked into each other the moment they set off on the river. Traditionally the connections were made with steel wire ropes. Lankhorst has developed a special Euroneema®, with Dyneema®, as an alternative for these applications. A six months trial period has been conducted with m/v Norma, sailing on the river Rhine and the results are excellent. Where several sailors were working with the steel wire ropes while making the connection, now only one sailor can make the connection in less time. Four different lines are put around the boulders in a specific sequence, on four individual winches these are pulled tight and the connection is made. These handlings can be done several times a day while operating in a port, the time saving in men hours is enormous.

In the middle segment of 1,000 up to 10,000 TEU, today's interest for HMPE is relatively small. By tradition these vessels sail with PA or PP ropes and the crews and line boats are familiar handling these. A few customers though did make the change to HMPE ropes and once accustomed to this, there is no turning back. A container ship carrying 8,000 TEU can be safely moored with a Euroneema® 40 mm in diameter, weighing 89 kg per 100 meters. A PP rope with the same breaking strength would measure 110 mm in diameter and weight 560 kg per 100 meter (figure 7 and 8).

The segment of super large vessels is still in the future but will have challenges of its own. Extrapolating the mooring lines of a container ship carrying 8,000 TEU to those carrying 22,000 TEU, each line with PP would measure 160 mm and weight 1160 kg per 100 meter. The same breaking strength in a Euroneema® mooring line with Dyneema®, would measure 60 mm and weight 202 kg per 100 meter (figure 7 and 8).

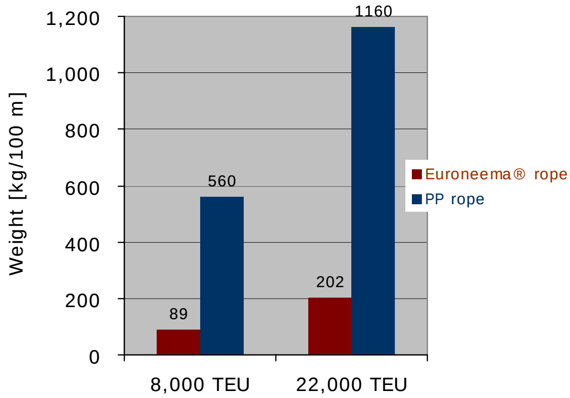

Figure 7. Weight of mooring systems with equal strength for 2 types of container ships

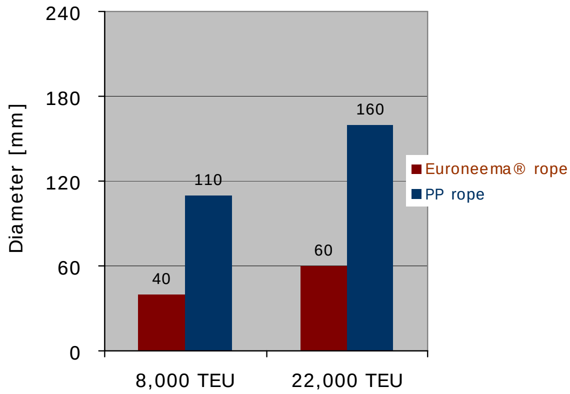

Figure 8. Diameter of mooring systems with equal strength for 2 types of container ships

In a new design, where the Naval Architects will calculate with the HMPE ropes, vast saving can be made on the sizes of the winches as well as the space that these winches require to operate. Less space means a higher payload. This may seem insignificant, but if due to smaller winches on a vessel 1 TEU could be added, over the life span of the vessel additional revenue up to one million US dollars could be achieved.

Tug boats that are handling all these container vessels when they come into port, more and more apply HMPE ropes in their towing system. The cargo vessels becoming bigger and bigger consequently have higher bows with the fairleads inside it. The connection has to be made by handing the rope from the tug boat up to the cargo vessel and the weight of the connecting line has to be transported across.
With the tug boat sailing very close to the vessel when making the connection, she cannot be seen by any of the people on the bridge, it is not a position the captain wants to stay long. Especially in case of high winds and high swell.

When the vessels are being disconnected, the HMPE ropes can simply be dropped from the main vessel and the rope will not damage the tug boat. Or in the event the lines drop in the water, they stay afloat and can easily be hauled inside.

Even though the operational costing of the HMPE ropes is higher than those of steel wire ropes, the ease of handling, the time involved and the safety of the people make the HMPE ropes a preferred proposition with tug boats. With less crew on board vessels, safety is becoming more and more important, let alone the down time of a vessel following an investigation after an accident would have occurred.

6. CONCLUSIONS

Naval Architects induce a quite rapidly changing maritime environment, implying newly designed vessels, challenging dimensions and new applications. An increasing number of ship operators have chosen mooring lines with Dyneema®, a High Modulus PolyEthylene (HMPE) fiber, to face these challenges. The 12-strand braided Euroneema® rope, with Dyneema® and manufactured by Lankhorst Ropes, has a proven track record, providing secure and safe mooring for LNG, VLCC and container ships.

Considering the container shipping market segmented into size of vessels and its applications, the stage of the product life cycle of HMPE ropes in these segments differ. Where handling is priority one, HMPE ropes has grown to the 'majority' stage. With container vessels carrying 1,000-10,000 TEU, the HMPE ropes are still at the stage of 'early adopters'.

Although the turning point to switch to HMPE ropes and the evolutions that will follow differs, sooner or later the strength-to-weight ratio of HMPE ropes will become an issue in each of the segments in order to face the challenges and create the benefits.

7. ACKNOWLEDGEMENTS

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9. AUTHORS' BIOGRAPHIES

Steven Wardenier holds the current of position Commercial Director for Maritime Business at Lankhorst Ropes in The Netherlands. He is responsible for the world wide sales and marketing of the Lankhorst branded products.

Marc Eijssen, PhD, holds the current position of Application Manager EMEA within the Commercial Marine Group of DSM Dyneema B.V. in The Netherlands. He is responsible for application development and technical service of Dyneema® fiber for mooring and towing ropes as well as other industrial and offshore applications.

Edwin Grootendorst, PhD, holds the current position of Market Segment Manager Heavy Marine within the Commercial Marine Group of DSM Dyneema B.V. in The Netherlands. He is responsible for global marketing of Dyneema® fiber in mooring and towing ropes.