

MOORING LINE

The present invention relates to a mooring line comprising synthetic fibers, said mooring line having a length of at least 800 meters and being suitable to
5 secure in place a water floating system.

Such a mooring line comprising synthetic fibers and having a length of at least 800 meters is already used for heavy-duty marine purposes such as to secure in a place water floating systems, because said mooring line presents the advantages of high strengths and high stiffness. Further important advantages to be
10 mentioned are a reduced weight and a corrosion-free character.

The problem with the present mooring lines comprising synthetic fibers and having a length of at least 800 meters lies with the continuing increase in size and tonnage of water floating systems. Therefore, the requirements in terms of design, size and mechanical properties of today's mooring lines have become even
15 more exacting. Securing large water floating systems into place becomes increasingly difficult with increasing the distance between a fixed anchoring point and the water floating system. External elements such as winds, water waves or water currents, strongly influence the motions of the water floating systems. This while in many instances it is very important to secure the floating systems exactly in place, for
20 example in case of systems used for oil or natural gas production.

Materials that are generally used in producing the synthetic fibers comprising said mooring line are polyester, nylon, polypropylene, aramid, polyethylene and the like, each material having advantages and disadvantages.

An example of a known mooring line used to secure in place oilrigs
25 and the like is a mooring line comprising polyester fibers, such mooring line presenting good strength and stiffness and low creep. However, mooring lines comprising polyester fibers and having a length of at least 800 meters, are extremely heavy, having a diameter of more than 250 mm and being extremely difficult to handle. Another drawback is that because of the relatively low stiffness of the polyester fibers,
30 the water floating system when subjected to external factors such as wind currents or water waves exhibits a larger displacement from the original position.

Mooring lines having a length of at least 800 meters are also made of steel wire, however, supplementary to being extremely heavy, such mooring lines also have the drawback that they cannot be used in locations where the water depth
35 exceeds 2000 meters. For water depths exceeding 2000 meters, the steel wire mooring

lines present strongly the risk of breaking under their own weight due to their increased length. Furthermore, such steel wire mooring lines often need extra buoyancy and in case of failure under load, such a heavy weight steel wire mooring line presents an increased risk of damaging the hardware that may come in contact with.

5 High stiffness polyethylene fibers are also used in fabricating said mooring lines. A mooring line comprising polyethylene fibers has a higher strength than for example a mooring line having the same diameter and comprising polyester fibers. It also has the advantage of lightweight and better handling properties. The disadvantage of a mooring line having a length of at least 800 meters and use to
10 secure in place a water floating system, is that because of the higher stiffness of polyethylene fibers, the up and down movements of the water floating system due to water currents or waves, may induce high tensions and also high peak loads that can lead to the failure of said mooring line.

 The above-enumerated drawbacks make the known mooring lines
15 having a length of at least 800 meters less suitable for permanent mooring of water floating systems, when great distances between the fixed anchoring point and the water floating system are involved.

 The object of the present invention is to provide a mooring line having a length of at least 800 meters suitable to secure in place a water floating system, said
20 mooring line comprising synthetic fibers and having an improved balance in size and mechanical properties.

 Surprisingly, the aim is achieved according to the invention in that the mooring line comprises at least a first and a second module, wherein at least the first and the second module have different compositions of synthetic fibers.

25 Surprisingly, it has been found that the mooring line according to the invention, said mooring line for convenience hereinafter being referred to as modular mooring line is able to hold more precisely the water floating system in its original position. A further advantage is, because the modular mooring line comprises modules with different compositions and therefore, with different mechanical properties, a better
30 dampening of the high peak loads occurring in said modular mooring line due to waves, winds or water currents is achieved. The modular design of the mooring line allows an easier tunability of the mooring line to specific applications where a correct balance between the fixation of the water floating system and the dampening of the high peak loads is necessary. Yet a further advantage is, because of its special modular design,
35 said modular mooring line is subjected to a reduced tension. Yet further advantages of

said modular mooring line are achieved, as it will become clear from the description of the present invention, by adjusting the compositions of said modules to obtain a correct balance of strength and size of the modular mooring line.

By line are understood rope, cord, twine, cable, string, and similar structures comprising fibers or fibers and staple fibers. By mooring line is herein understood a line that is used to anchor a water floating system to a fixed anchoring point.

By module is understood a segment of a mooring line having a characteristic composition of fibers, said composition of fibers being different from the composition of fibers characteristic to the segment(s) or module(s) adjoining said segment or module.

Preferably, said module is provided at both ends with connectors, said connectors being used in joining an end of a module with an end of another module to form said modular line. Furthermore, the connectors may also be used to connect said modular mooring line to the fixed anchoring point as well as to the water floating system. Said connectors may be for example different types of shackles, loops, etc. For example, using said connectors to join an end of a module with an end of another module a series of two modules is obtained. A bundle of modules may be obtained for example when connecting an end of a module with an end of two or more other modules. According to specific applications, a person skilled in the art would choose a suitable combination to produce a modular mooring line having improved balance in size and mechanical properties.

By water floating system is understood a system being anchored to an anchoring point via mooring lines. Said water floating systems may be a system floating on water or a system buoyant in water at a certain water depth, suitable examples including floating production storage and offloading vessels, spar buoys, semi-submersible or other hydrocarbon storage and/or processing and the like.

In the modular mooring line according to the invention, the synthetic fibers comprising the modules may be fibers from all kind of materials suitable for producing synthetic fibers, for example propylene, polyester, copolymers of polypropylene or polyesters, nylon, aramid, polyolefins and the like, and combinations thereof.

The synthetic fibers comprising the modules are being obtained by twisting together synthetic filaments. Preferably said synthetic fibers consist of at least 100 synthetic filaments, more preferably at least 200 synthetic filaments, even more

preferably at least 300 synthetic filaments. The synthetic filaments may have a linear density or titre varying in a wide range, preferably the titre of the synthetic filaments being between 0.2 and 50 dtex per fiber, more preferably between 0.3 and 20 dtex, and most preferably between 0.4 and 10 dtex.

5 Further, the synthetic fibers are preferably being twisted to form a yarn, said yarn preferably consisting of at least 10 synthetic fibers, more preferably at least 20 synthetic fibers, even more preferably at least 50 synthetic fibers. The yarns are further preferably twisted to form strands, each strand preferably consisting of at least 10 yarns, more preferably at least 20 yarns, most preferably at least 50 yarns.

10 The modules may be obtained by laying, plaiting or braiding or combinations thereof of said strands. The skilled man in the art can choose the type of construction in relation to the desired final construction and size of the module, based on his knowledge or with help of some calculations or experimentation. Suitable examples include hollow braided or laid modules, solid braided or solid laid modules, twisted braided modules, 15 plain braided or plain laid modules, and the like. It is to be understood that the module construction is not limited only to the above-mentioned module configurations, any other module configuration may be successfully used according to the invention.

The fibers comprising said modules and/or said modules may be further coated with lubricant coatings applied thereon, to reduce abrasion and inner 20 friction, to prevent galling and fretting, to increase the life time of the module, to prevent unwanted substances to enter inside the module, etc. The modules may further contain a particle filter used as a barrier to prevent ingress of abrasion particles and at the same time to allow the environment, i.e., air or water to circulate inside the module.

Hereinafter, examples of preferred embodiments of the modular 25 mooring line according to the invention are given, substantiating the advantages gained by using said modules. It is to be understood that the preferred embodiments are not limited only to those presented hereinafter, and a person skilled in the art will easily find additional embodiments and advantages according to the present invention that will be apparent from the following detailed description when read in conjunction with the 30 appended claims.

In a preferred embodiment, the modular mooring line according to the invention is suitable for use to secure in place a water floating system, said modules having a length of at least 100 meters, more preferably at least 200 meters, even more preferably at least 300 meters, yet even more preferably at least 500 meters, most 35 preferably at least 700 meters.

Preferably all modules of the modular mooring line according to the invention comprise synthetic fibers, more preferably all modules consist of synthetic fibers.

In a further preferred embodiment, the modular mooring line
5 according to the invention comprises at least a first and a second module, wherein said first module comprises polyester fibers.

Yet in a further preferred embodiment the modular mooring line according to the invention comprises at least a first and a second module, wherein said second module comprises high performance polyolefin fibers as second fibers.

10 Yet in another further preferred embodiment the modular mooring line according to the invention comprises at least a first and a second module, wherein said first module comprises at least 51% by weight first fibers and said second module comprises at least 51% by weight high performance polyolefin fibers as second fibers.

The first fibers in the first module may be fibers from all kind of
15 materials suitable for producing fibers, for example propylene, polyester, copolymers of polypropylene or polyesters, nylon, and the like, and combinations thereof. Preferably, the first module comprises at least 60% by weight first fibers, more preferably at least 75% by weight first fibers, most preferably at least 95% by weight first fibers. Next to the first fibers, the first module may also comprise high performance polyolefin fibers

20 The second fibers in the second module according to the invention are high performance polyolefin fibers. Preferably, the second module comprises at least 60% by weight high performance polyolefin fibers as second fibers, more preferably at least 75% by weight high performance polyolefin fibers as second fibers, most preferably at least 95% by weight high performance polyolefin fibers as second
25 fibers. Next to the high performance polyolefin fibers, the second module may also comprise other kinds of fibers.

Preferably, the free end of the second module comprising high performance polyolefin fibers is connected to the anchor that will provide the anchoring point on the seabed. Accordingly, the free end of the module comprising first fibers is
30 preferably provided with connectors suitable to anchor the modular mooring line to the water floating system. The connection of the free ends of the modular mooring line according to the invention to the water floating system and to the anchor that will provide the anchoring point on the seabed is preferably made using a steel wire rope or a steel chain having a length preferably of at most 100 meters. Once installed, the steel
35 wire rope or the chain are used to prevent the direct contact of the modular mooring

line according to the invention with the water floating system or the anchoring point on the seabed in order to prevent eventual damages that may be induced to the modules by friction, mishandling, etc.

Yet a further more preferred embodiment is a modular mooring line
5 according to the invention comprising at least a first and a second module wherein said first module comprises at least 51% by weight polyester fibers and said second module comprises at least 51% by weight high performance polyolefin fibers as second fibers.

Suitable polyolefins that may be used to produce said high
performance polyolefin fibers include, for example polyethylene homopolymer,
10 polypropylene homopolymer, a polyethylene copolymer, and a polypropylene copolymer and the like and combinations thereof. The most preferred high performance polyolefin fibers are preferably ultrahigh molecular weight polyethylene (UHMWPE) fibers.

This embodiment of the modular mooring line according to the
15 invention, combines the durability and low creep specific to polyester fibers with lightweight and high strength specific to UHMWPE polyethylene fibers, reducing greatly the total weight and volume and improving the handling properties of said modular mooring line. It was found that the weight and the volume of the modular mooring line according to the invention were strongly reduced when compared to existent polyester
20 mooring lines. A further advantage is that the breaking length in water of said modular mooring line is greatly increased. Because of its lightweight, said modular mooring line has improved handling properties and therefore, increased safety for the personnel involved in the installation and maintenance of said modular mooring line, as well as reduced risk of damaging the hardware that may come in contact with said modular
25 mooring line. It was also remarkably found that said modular mooring line according to the invention, exhibits enhanced tension, torsion and bending fatigues.

The presence of the module comprising polyester fibers, said
polyester fibers having lower stiffness than the UHMWPE fibers, has the advantage
that the effect of the heave characteristic to oilrigs and the like is more efficiently
30 detuned. Therefore the presence of the module comprising polyester fibers, provides the modular mooring line with good dampening properties helping in reducing the peak loads occurring in the modular line.

Moreover, said modular mooring line presents a better combination of
stiffness, elongation to break and energy absorption. A further advantage is that the
35 presence of the module comprising UHMWPE fibers helps to hold more precisely the

water floating system in its original position, also after a long service life.

Therefore, a better fixation, a better control over the movements of the water floating system and a minimization of the total tension in the modular mooring line is achieved, when said modular mooring line is used according to the invention.

5 Said modular mooring line is specially suitable to be used in securing in place water floating systems in locations where the occurrence of storms is high or in locations where the water currents are extremely strong. Such locations can be found for example in the Gulf of Mexico where due to the constant occurrence of hurricanes, strong winds and strong water currents, a good fixation of oilrigs and the like is of great
10 importance.

The preferred polyesters that may be used to produce said polyester fibers are linear terephthalate polyesters, i.e. polyesters of a glycol containing from 2 to 20 carbon atoms and a residual dicarboxylic acid component containing preferably at least 75 percent, more preferably 90 percent terephthalic acid. The residual
15 dicarboxylic may be any suitable dicarboxylic acid such as sebacic acid, adipic acid, isophthalic acid, sulfonyl-4,4'dibenzoic acid, 2,8-dibenzofuran-dicarboxylic acid, or 2,6-naphthalene dicarboxylic acid. The glycols may contain more than two carbon atoms in the chain, e.g., diethylene glycol butylenes glycol, decamethylene glycol, and bis-(1,4-hydroxymethyl)cyclohexane. The most preferred linear terephthalate polyester is
20 poly(ethylene terephthalate).

The polyester fibers preferably have a tensile strength of at least 0.6 GPa, more preferably at least 0.7 GPa and most preferably at least 0.8 GPa. The elongation to break of said polyester fibers preferably is at least 3%, more preferably at least 10% and most preferably at least 16%. The titer of said polyester fibers preferably
25 is at most 50 dtex, more preferably at most 110 dtex and most preferably at most 220 dtex.

The UHMWPE fibers are preferably manufactured according to a gel spinning process. Gel spinning of UHMWPE is well known to the person skilled in the art; and described in numerous publications, including EP 0205960 A, EP 0213208 A1,
30 US 4413110, GB 2042414 A, EP 0200547 B1, EP 0472114 B1, WO 01/73173 A1, and Advanced Fiber Spinning Technology, Ed. T. Nakajima, Woodhead Publ. Ltd (1994), ISBN 1-855-73182-7, and references cited therein. Gel spinning is understood to include at least the steps of spinning at least one fiber from a solution of ultra-high molecular weight polyethylene in a spin solvent; cooling the fiber obtained to form a gel
35 fiber; removing at least partly the spin solvent from the gel fiber; and drawing the fiber

in at least one drawing step before, during or after removing spin solvent. Suitable spin solvents include for example paraffins, mineral oil, kerosene or decalin. Spin solvent can be removed by evaporation, extraction, or by a combination of evaporation and extraction routes. The shape of the cross – section of the fibers may be selected here through selection of the shape of the spinning aperture.

Within the context of the present invention, ultrahigh molar mass polyethylene (UHMWPE) is understood to be polyethylene with an intrinsic viscosity (IV) of at least 5 dl/g. IV was determined according to method PTC-179 (Hercules Inc. Rev. Apr. 29, 1982) at a temperature of 135°C and using decalin as a solvent for UHMWPE, with a dissolution time of 16 hours, with an anti-oxidant DBPC in an amount of 2 g/l solution, and extrapolating the viscosities at different concentrations to zero concentration. Particularly suitable, is UHMWPE with an IV of preferably between 8 and 40 dl/g, more preferably between 10 and 30 dl/g, even more preferably between 12 and 28 dl/g, and most preferably between 15 and 25 dl/g.

Preferably, the UHMWPE is a linear polyethylene with less than one branch or side chain per 100 carbon atoms, and preferably less than one side chain per 300 carbon atoms, a branch usually containing at least 10 carbon atoms. The linear polyethylene may further contain up to 5 mol% of one or more comonomers, such as alkenes like propylene, butene, pentene, 4-methylpentene or octene.

In a preferred embodiment, the UHMWPE contains a small amount of relatively small groups as side chains, preferably a C1-C4 alkyl group. It was found that a fiber from UHMWPE with a certain amount of such groups show reduced creep behaviour. If the side chains are too long, or if the amount of the side chains is too high, their presence will negatively affect the processing and especially the drawing behaviour of the UHMWPE fibers. For this reason, the UHMWPE preferably contains methyl or ethyl groups or combinations thereof as side chains, more preferably the UHMWPE contains only methyl groups as side chains. The amount of side chains is preferably at least 0.3 per 1000 carbon atoms, more preferably at least 0.5 per 1000 carbon atoms, most preferably at least 1 per 1000 carbon atoms. The amount of side chains is preferably at most 20 per 1000 carbon atoms, more preferably at most 10 per 1000 carbon atoms.

The UHMWPE can be a single polymer grade, but also a mixture of at least two different UHMWPE grades. By UHMWPE grade is understood UHMWPE with a specific IV or molar mass distribution, and a specific number of side chains, said side chains having a specific configuration.

The UHMWPE polymer may further contain usual amounts, generally less than 5% by weight of customary additives, such as anti-oxidants, thermal stabilizers, colorants, nucleating agents, flow promoters, catalyst residues and the like, and may also contain other polymers, preferably polyolefinic polymers, like other polyethylenes, polypropylenes, or their copolymers, including rubbery copolymers like EPDM, EPR, and the like.

The UHMWPE fibers may have a filament linear density or titer varying between wide ranges. Preferably the titer of the UHMWPE filaments is between 0.2 and 20 dtex per fiber, more preferably between 0.3 and 10 dtex, and most preferably between 0.4 and 5 dtex.

Preferably, the tensile strength of UHMWPE fibers is at least 1.5 GPa, more preferably at least 2.0 GPa and most preferably at least 3.0 GPa. Tensile strength, is determined on multi-fiber yarns as specified in ASTM D885M, using a nominal gauge length of the fibre of 500 mm, a crosshead speed of 50%/min and Instron 2714 clamps, type Fibre Grip D5618C.

Preferably the stiffness of UHMWPE fibers is at least 35 GPa, more preferably at least 50 GPa, even more preferably at least 70 GPa, yet even more preferably at least 100 GPa and most preferably at least 140 GPa. In a preferred embodiment, the stiffness of UHMWPE fibers is between 110 GPa and 135 GPa.

The length of the first module comprising polyester fibers is preferably at most 2000 meters, more preferably at most 1500 meters, even more preferably at most 1000 meters, yet even more preferably at most 500 meters, yet even more preferably at most 350 meters, most preferably 200 meters. The ratio between the length of the module comprising polyester fibers and the length of the module comprising UHMWPE fibers is preferably at most 90%, more preferably at most 60%, and most preferably at most 30%.

The advantage of adjusting said ratio is that depending on the locations where the modular mooring line is used, the module comprising UHMWPE fibers is located at a water depth where the water temperature is preferably below 15 degrees. This ensures that the module comprising UHMWPE fibers is used at water depths where the water temperature helps preserving the mechanical properties of the UHMWPE fibers.

CLAIMS

1. A mooring line comprising synthetic fibers, said mooring line having a length of at least 800 meters and being suitable to secure in place a water floating system, characterized in that the mooring line comprises at least a first and a second module, wherein at least the first and the second module have different compositions of synthetic fibers.
2. The mooring line of claim 1, characterized in that said modules having a length of at least 100 meters.
3. The mooring line of any one of claims 1 and 2, characterized in that said first module comprises polyester fibers.
4. The mooring line of any one of claims 1 and 2, characterized in that said second module comprises high performance polyolefin fibers as second fibers.
5. The mooring line of any one of claims 1 – 3, characterized in that said first module comprises at least 51% by weight first fibers and said second module comprises at least 51% by weight high performance polyolefin fibers as second fibers.
6. The mooring line of claim 5 characterized in that said first module comprises at least 60% by weight first fibers.
7. The mooring line of claim 5 characterized in that said first module comprises at least 95% by weight first fibers.
8. The mooring line of claim 5 characterized in that said second module comprises at least 60% by weight high performance polyolefin fibers as second fibers.
9. The mooring line of claim 5 characterized in that said second module comprises at least 95% by weight high performance polyolefin fibers as second fibers.
10. The mooring line of any one of claims 1 – 4, characterized in that said first module comprises at least 51% by weight polyester fibers and said second module comprises at least 51% by weight high performance polyolefin fibers as second fibers.
11. The mooring line of claim 10, characterized in that the high performance polyolefin fibers are ultrahigh molecular weight polyethylene (UHMWPE) fibers.
12. The mooring line of claims 3 and 10, characterized in that the polyester fibers

have a tensile strength of at least 0.6 GPa and an elongation to break of at least 3%.

13. The mooring line of any one of claims 11 – 12, characterized in that the UHMWPE fibers have a tensile strength of at least 1.5 GPa and a stiffness of at least 35 GPa.
14. The mooring line of any one of claims 4 and 11 – 13, characterized in the length of the first module comprising polyester fibers is at most 2000 meters.
15. The mooring line of any one of claims 11 – 14 characterized in that the ratio between the length of the module comprising polyester fibers and the length of the module comprising UHMWPE fibers is at most 90%.
16. The mooring line of any one of claims 4 – 16 characterized in that the free end of the module comprising high performance polyolefin fibers is connected to the anchor that will provide the anchoring point on the seabed.