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(54) **ROPES HAVING IMPROVED CYCLIC BEND OVER SHEAVE PERFORMANCE**

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(57) **ABSTRACT**

An improved rope is formed from a blend of fluoropolymer fibers and high tenacity polyolefin fibers. The fibers and/or the rope are coated with a composition comprising an amino functional silicone resin and a neutralized low molecular weight polyethylene. The ropes are useful in marine applications, such as in deep sea lifting, and have improved cyclic bend over sheave fatigue resistance.

ROPES HAVING IMPROVED CYCLIC BEND OVER SHEAVE PERFORMANCE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation-in-part of application Ser. No. 11/361,180, filed Feb. 24, 2006.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] This invention relates to improvements in ropes, and in particular to high tenacity synthetic ropes suitable for use in marine applications.

[0004] 2. Description of the Related Art

[0005] Synthetic fiber ropes have been used in a variety of applications, including various marine applications. One type of rope that has excellent properties is rope made from high modulus polyolefin fibers and/or yarns. High tenacity polyolefin fibers are also known as extended chain or high molecular weight fibers. These fibers and yams are available, for example, as SPECTRA® extended chain polyethylene fibers and yams from Honeywell International Inc.

[0006] Ropes formed from extended chain polyethylene fibers have been suggested for use in marine applications. See, for example, U.S. Pat. Nos. 5,901,632 and 5,931,076 both to Ryan, the disclosures of which are expressly incorporated herein by reference to the extent not incompatible herewith.

[0007] In some marine applications, extended chain polyethylene ropes are repeatedly bent over sheaves, pulleys or posts as they are being used. Some synthetic ropes experience premature wear when they are subjected to repeated bending over sheaves, and particularly synthetic ropes used in marine industrial applications have experienced this problem.

[0008] Synthetic ropes continue to replace steel wire in many marine applications. As synthetic ropes progress to replace steel wire in many cyclic bend-over sheave (CBOS) applications, the need exists to improve the fatigue life of high performance synthetic ropes. In particular, the need exists to improve the performance of ropes made from high performance polyolefin fibers and yarns.

[0009] A proposed solution to provide a rope with improved properties is disclosed in U.S. Pat. No. 6,945,153 to Knudsen et al., the disclosure of which is expressly incorporated herein by reference to the extent not incompatible herewith. This patent discloses a large diameter rope that is formed from a blend of extended chain polyethylene fibers and liquid crystal polymer fibers. This particular rope requires the use of two fiber materials which adds to the expense of the product and its manufacture.

[0010] It would be desirable to provide a high tenacity polyolefin fiber rope which had improved wear resistance to repeated bending over sheaves and the like, especially in wet applications, while maintaining its otherwise excellent properties. It would also be desirable to provide a rope that is suitable for use in heavy lifting applications, e.g., to and from the seabed.

SUMMARY OF THE INVENTION

[0011] In accordance with this invention, there is provided a rope having improved CBOS fatigue resistance, the rope comprising a blend of fluoropolymer fibers and high tenacity polyolefin fibers, the rope and/or the fibers being coated with a composition comprising an amino functional silicone resin and a neutralized low molecular weight polyethylene.

[0012] Further in accordance with this invention, there is provided a method of improving the CBOS fatigue life of a rope, the method comprising forming the rope from a blend of fluoropolymer fibers and high tenacity polyolefin fibers, and coating the rope and/or the fibers forming such rope with a composition comprising an amino functional silicone resin and a neutralized low molecular weight polyethylene.

[0013] Also in accordance with this invention, there is provided in a method of lifting and placing heavy objects from and onto a seabed using a synthetic fiber rope, the improvement comprising utilizing as such rope a rope comprising a blend of fluoropolymer fibers and high tenacity polyolefin fibers, the rope and/or the fibers being coated with a composition comprising an amino functional silicone resin and a neutralized low molecular weight polyethylene.

[0014] It has been discovered that when fluoropolymer fibers are blended with high tenacity polyolefin fibers, such as polyethylene fibers, and the blended fibers are coated with a composition comprising an amino functional silicone resin and a neutralized low molecular weight polyethylene and formed into a rope, or if a rope formed from such blended fibers is coated with the composition, the cyclic bend over sheave resistance of such rope is unexpectedly improved.

DETAILED DESCRIPTION OF THE INVENTION

[0015] As mentioned above, ropes comprising high modulus polyolefin fibers, such as extended chain polyethylene fibers, and yarns made therefrom have been suggested for use in marine applications. One such use of the ropes is for heavy lifting and mooring of objects onto the seabed. Other applications include offshore oil and gas exploration, oceanographic, seismic and other industrial applications. The most preferred applications for ropes of this invention include deep sea lifting and placement.

[0016] One type of fiber used in the rope construction of this invention is high tenacity fibers. As used herein, the term "high tenacity fibers" means fibers which have tenacities equal to or greater than about 7 g/d. Preferably, these fibers have initial tensile moduli of at least about 150 g/d and energies-to-break of at least about 8 J/g as measured by ASTM D2256. As used herein, the terms "initial tensile modulus", "tensile modulus" and "modulus" mean the modulus of elasticity as measured by ASTM 2256 for a yarn.

[0017] Preferably, the high tenacity fibers have tenacities equal to or greater than about 10 g/d, more preferably equal to or greater than about 16 g/d, even more preferably equal to or greater than about 22 g/d, and most preferably equal to or greater than about 28 g/d.

[0018] The fibers utilized in the rope construction comprise extended chain (also known as high molecular weight or high modulus) polyolefin fibers, particularly high modulus polyethylene fibers and polypropylene fibers.

[0019] U.S. Pat. No. 4,457,985 generally discusses such high molecular weight polyethylene and polypropylene fibers, and the disclosure of this patent is hereby incorporated by reference to the extent that it is not inconsistent herewith. In the case of polyethylene, suitable fibers are those of weight average molecular weight of at least about 150,000, preferably at least about one million and more preferably between about two million and about five million.

Such high molecular weight polyethylene fibers may be spun in solution (see U.S. Pat. No. 4,137,394 and U.S. Pat. No. 4,356,138), or a filament spun from a solution to form a gel structure (see U.S. Pat. No. 4,413,110, German Off. No. 3,004, 699 and GB Patent No. 2051667), or the polyethylene fibers may be produced by a rolling and drawing process (see U.S. Pat. No. 5,702,657). As used herein, the term polyethylene means a predominantly linear polyethylene material that may contain minor amounts of chain branching or comonomers not exceeding 5 modifying units per 100 main chain carbon atoms, and that may also contain admixed therewith not more than about 50 wt % of one or more polymeric additives such as alkene-1-polymers, in particular low density polyethylene, polypropylene or polybutylene, copolymers containing mono-olefins as primary monomers, oxidized polyolefins, graft polyolefin copolymers and polyoxymethylenes, or low molecular weight additives such as antioxidants, lubricants, ultraviolet screening agents, colorants and the like which are commonly incorporated.

[0020] High tenacity polyethylene fibers are preferred, and these are available, for example, under the trademark SPECTRA® fibers and yarns from Honeywell International Inc. of Morristown, New Jersey, U.S.A

[0021] Depending upon the formation technique, the draw ratio and temperatures, and other conditions, a variety of properties can be imparted to these fibers. The tenacity of the polyethylene fibers are at least about 7 g/d, preferably at least about 15 g/d, more preferably at least about 20 g/d, still more preferably at least about 25 g/d and most preferably at least about 30 g/d. Similarly, the initial tensile modulus of the fibers, as measured by an Instron tensile testing machine, is preferably at least about 300 g/d, more preferably at least about 500 g/d , still more preferably at least about 1,000 g/d and most preferably at least about 1,200 g/d. These highest values for initial tensile modulus and tenacity are generally obtainable only by employing solution grown or gel spinning processes. Many of the filaments have melting points higher than the melting point of the polymer from which they were formed. Thus, for example, high molecular weight polyethylene of about 150,000, about one million and about two million molecular weight generally have melting points in the bulk of 138° C. The highly oriented polyethylene filaments made of these materials have melting points of from about 7° C. to about 13° C. higher. Thus, a slight increase in melting point reflects the crystalline perfection and higher crystalline orientation of the filaments as compared to the bulk polymer.

[0022] Preferably the polyethylene employed is a polyethylene having fewer than about one methyl group per thousand carbon atoms, more preferably fewer than 0.5 methyl groups per thousand carbon atoms, and less than about 1 wt. % of other constituents.

[0023] Similarly, highly oriented high molecular weight polypropylene fibers of weight average molecular weight at least about 200,000, preferably at least about one million and more preferably at least about two million may be used. Such extended chain polypropylene may be formed into reasonably well oriented filaments by the techniques prescribed in the various references referred to above, and especially by the technique of U.S. Pat. No. 4,413,110. Since polypropylene is a much less crystalline material than polyethylene and contains pendant methyl groups, tenacity values achievable with polypropylene are generally substantially lower than the corresponding values for polyethylene. Accordingly, a suitable tenacity is preferably at least about 8 g/d, more preferably at least about 11 g/d. The initial tensile modulus for polypropylene is preferably at least about 160 g/d, more preferably at least about 200 g/d. The melting point of the polypropylene is generally raised several degrees by the orientation process, such that the polypropylene filament preferably has a main melting point of at least 168° C., more preferably at least 170° C. The particularly preferred ranges for the above described parameters can advantageously provide improved performance in the final article. Employing fibers having a weight average molecular weight of at least about 200,000 coupled with the preferred ranges for the above-described parameters (modulus and tenacity) can provide advantageously improved performance in the final article.

[0024] In the case of extended chain polyethylene fibers, preparation and drawing of gel-spun polyethylene fibers are described in various publications, including U.S. Pat. Nos. 4,413,110; 4,430,383; 4,436,689; 4,536,536; 4,545,950; 4,551,296; 4,612,148; 4,617,233; 4,663,101; 5,032,338; 5,246,657; 5,286,435; 5,342,567; 5,578,374; 5,736,244; 5,741,451; 5,958,582; 5,972,498; 6,448,359; 6,969,553 and U.S. patent application publication 2005/0093200, the disclosures of which are expressly incorporated herein by reference to the extent not incompatible herewith.

[0025] For the purposes of the present invention, a fiber is an elongate body the length dimension of which is much greater that the transverse dimensions of width and thickness. Accordingly, the term "fiber" includes monofilament, multifilament, ribbon, strip, staple and other forms of chopped, cut or discontinuous fiber and the like having regular or irregular cross-section. Fibers may also be in the form of ribbon, strip or split film or tape. The term "fiber" includes a plurality of any of the foregoing or a combination thereof. A yarn is a continuous strand comprised of many fibers or filaments.

[0026] Another type of fiber that is present in the rope construction of this invention together with the high tenacity fibers is fibers formed from fluoropolymers. Such fluoropolymer fibers include fibers formed, for example, from polytetrafluoroethylene (preferably expanded polytetrafluoroethylene), polychorotrifluoroethylene (both homopolymers and copolymers (including terpolymers)), polyvinyl fluoride, polyvinylidene fluoride, ethylene-tetrafluoroethylene copolymers, ethylene-chlorotrifluorethylene copolymers, fluorinated ethylene-propylene copolymers, perfluoroalkoxy polymer, and the like, as well as blends of two or more of the foregoing. Especially preferred fluoropolymer fibers are those formed from polytetrafluoroethylene, and in particular expanded polytetrafluoroethylene fibers. Such fibers are available, for example, from Lenzing Plastics GmbH & Co. KG and WL Gore & Associates.

[0027] The cross-sections of fibers useful herein may vary widely. They may be circular, flat or oblong in cross-section. They may also be of irregular or regular multi-lobal cross-section having one or more regular or irregular lobes projecting from the linear or longitudinal axis of the fibers. It is preferred that the fibers be of substantially circular, flat or oblong cross-section, most preferably circular.

[0028] The portion of the fluoropolymer fibers that are blended with the high tenacity polyolefin fibers may vary widely, depending on the type of fluoropolymer and the end use application. For example, the amount of fluoropolymer

fibers in the blend may range from about 1 to about 40 percent by weight, more preferably from about 5 to about 25 percent by weight, and most preferably from about 10 to about 20 percent by weight, based on the total weight of the blended fibers. Correspondingly, the amount of the high tenacity polyolefin fibers may range from about 60 to about 99 percent by weight, more preferably from about 75 to about 95 percent by weight, and most preferably from about 80 to about 90 percent by weight, based on the total weight of the blended fibers.

[0029] A particularly preferred embodiment of this invention are ropes formed from expanded polytetrafluoroethylene fibers and extended chain polyethylene fibers. In such embodiment, the expanded polytetrafluoroethylene fibers may comprise from about 1 to about 40 percent by weight, more preferably from about 5 to about 25 percent by weight, and most preferably from about 10 to about 20 percent by weight, based on the total weight of the blended fibers, and correspondingly from about 60 to about 99 percent by weight, more preferably from about 75 to about 95 percent by weight, and most preferably from about 80 to about 90 percent by weight, of the extended chain polyethylene fibers.

[0030] The fluoropolymer fibers and high tenacity polyolefin fibers may be blended in any suitable manner. For example, strands of fluoropolymer fibers may be twisted with strands of high tenacity fibers to form a combined strand that is then braided into a rope. Alternatively, the fibers can be combined as a bicomponent fiber, having a sheath and a core, such as a core of high tenacity polyolefin fibers and a sheath of fluoropolymer fibers. Other constructions may also be employed. The fluoropolymer fibers may be present at any desired location in the rope.

[0031] The ropes of this invention comprise blends of the fluoropolymer fibers and the high tenacity polyolefin fibers, or consist essentially of blends of the fluoropolymer fibers and the high tenacity polyolefin fibers, or consists of blends of the fluoropolymer fibers and the high tenacity polyolefin fibers. These ropes may be of any suitable construction, such as braided ropes, twisted ropes, wire-lay ropes, parallel core ropes, and the like. Most preferably, the rope is a braided rope. The ropes may be of any suitable diameter and may be formed in any suitable manner from the desired fibers and/or yarns. For example, in forming a braided rope a conventional braiding machine may be employed which has a plurality of yarn bobbins. As is known in the art, as the bobbins move about, the yarns are woven over and under each other and are eventually collected on a take-up reel. Details of braiding machines and the formation of ropes therefrom are known in the art and are therefore not disclosed in detail herein.

[0032] The yarns that form the rope may be of any suitable denier, and the yarns of the fluoropolymer fiber may be of the same or different denier than the yarns of the high tenacity polyolefin fibers. For example, the high tenacity polyolefin yarns may have a denier of from about 50 to about 5000, and more preferably, from about 650 to about 3000, and the fluoropolymer yarns may have a denier of from about 50 to about 2500, and more preferably from about 400 to about 1600.

[0033] In accordance with this invention, a certain coating composition is applied to the rope construction. Either the individual fibers or yarns, or blends of the fibers or yarns, are coated with the coating composition and then a rope is formed from the coated fibers or yarns, or the rope is first formed and then is coated with the coating composition. The coating composition comprises an amino functional silicone resin and a neutralized low molecular weight polyethylene. The two components may be admixed in any desired ratio, such as from about 1 to about 99 percent by weight of the neutralized low molecular weight polyethylene and a corresponding amount of the amino functional silicone resin. All percents are by weight of the total weight of the composition, unless otherwise indicated. Preferably, the neutralized low molecular weight polyethylene is present in an amount of from about 30 to about 90 percent by weight, with the amino functional silicone resin correspondingly being present in an amount of from about 10 to about 70 percent by weight. More preferably, the neutralized low molecular weight polyethylene is the major component of the coating, such as from about 55 to about 85 percent by weight of coating composition, with the amino functional silicone resin being present in an amount of from about 15 to about 45 percent by weight. The composition may contain a variety of other additives, depending on the desired end properties.

[0034] Since the high modulus polyolefin fibers usually have a spin finish applied when formed, in the present invention the coating composition used herein is sometimes referred to as an overfinish composition.

[0035] The amino functional silicone is preferably in the form of an emulsion. Preferably, the emulsion comprises from about 20 to about 40 percent by weight of the silicone resin, and has a pH in the range of about 4.5 to about 6.5. The emulsion preferably includes a non-ionic emulsifier.

[0036] Likewise, the neutralized low molecular weight polyethylene is in the form of an emulsion. Preferably, the polyethylene is fully neutralized. The low molecular weight polyethylenes are also known as polyethylene waxes and are sometimes called wax dispersions. As is known in the art, these polyethylene waxes, also called resins, generally have a molecular weight of less than about 6000 Dalton, more preferably less than about 5000 Dalton, even more preferably below about 3500 Dalton, and most preferably between about 300 and about 3000 Dalton.

[0037] The coating components may be mixed in any suitable manner. For example, the amino functional silicone emulsion may be added to the neutralized low molecular weight polyethylene in a stainless steel or other inert vessel The vessel is preferably equipped with an agitator for appropriate mixing under low shear conditions (laminar flow). By adding the amino functional silicone emulsion to the neutralized low molecular weight polyethylene permits the pH of the system to remain on the basic side. Alternatively, the low molecular weight polyethylene may be added to the amino functional silicone emulsion. The mixing may be conducted at any suitable temperature, preferably between about 15 and about 45° C., more preferably between about 20 to about 30° C. It is preferred that the coating composition has a relatively high solids content, such as on the order of at least about 25% by weight and more preferably at least about 30% by weight. Most preferably, the solids content of the coating composition is from about 33 to about 35% by weight. It has been found that the use of high solids content coating emulsions permits higher pick up of the coating composition on the fiber/yarn or rope.

[0038] If the composition is coated directly on the fiber or yarn, any suitable coating device may be employed. Examples of such coating apparatus include lube rolls, kiss

rolls, dip baths and finish applicators. A constant temperature is desired to provide uniform application and superior performance as the viscosity of the system is impacted by temperature differences. If the composition is applied to the rope, the rope may be dipped into a bath containing the coating composition, with excess composition squeezed out followed by air drying, or the rope may be coated and then passed through a heating device to accelerate drying followed by air drying.

[0039] It is desired to have a relatively high final pick up of the coating solids on the fiber/yarn or rope. Preferably, the final pick up is at least about 0.5 percent by weight, more preferably at least about 5 percent by weight, and most preferably from about 10 to about 30% by weight .

[0040] The following non-limiting examples are presented to provide a more complete understanding of the invention. The specific techniques, conditions, materials, proportions and reported data set forth to illustrate the principles of the invention are exemplary and should not be construed as limiting the scope of the invention.

EXAMPLES

Example 1

[0041] A braided rope was formed from extended chain polyethylene yarns. The yarn employed was SPECTRAL® 1000 yarn from Honeywell International Inc., having a denier of 1300, a tenacity of 35 g/d and a modulus of 1150 g/d. The yarns were coated with an overfinish composition.

[0042] The overfinish composition was prepared from an amino functional silicone resin and a neutralized low molecular weight polyethylene. The amino functional silicone resin was an emulsion having a silicone content of 35 weight percent, a pH of 4.5-6.5 and included a non-ionic emulsifier, available from Dow Corning (2-8818 emulsion). The neutralized low molecular weight polyethylene was a neutralized non-ionic polyethylene wax emulsion (Fluftone® 1566 from Apollo Chemical), having a solids content between 29% and 31%, and pH in the range of between 9.0 and 11.

[0043] The coating composition was prepared by blending the neutralized low molecular weight polyethylene into the amino functional silicone resin emulsion, with the resulting composition comprising 70% by weight of the neutralized low molecular weight polyethylene. The yarn was coated by dipping the fiber in the overfinish composition at room temperature. The amount of pick up of the coating on the yarn was approximately 15 percent.

[0044] The coated yarn was braided into a 12-strand, ⅛ inch (0.32 cm) diameter rope. The yarn was braided into a rope by first twisting three coated yarns together into a cord at 0.5 turns per inch. Cords were twisted in the "S" direction and the "Z" direction. Twelve cords were then loaded onto a 12-strand braider in an alternating fashion (S, Z, S, Z, etc.). Three cords were then braided together resulting in a 12-strand braided rope of approximately ⅛ inch (0.32 cm) diameter.

[0045] The rope was tested for its cyclic bend over sheave (CBOS) resistance. In this test the ropes are bent approximately 180 degrees over a free rolling sheave or pulley. The ropes are placed under load and cycled over the sheave until the rope reaches failure. The test was run with a D:d ratio of 10 over a 1.3 inch (3.3 cm) pulley at 75 cycles per minute, with a 100 kg load on the sheave (50 kg of tension on each side of the rope). The number of cycles was determined based on an average of 5 positions before there was failure of the rope. The results are shown in Table 1, below.

Example 2

Comparative

[0046] As a control for Example 1, a braided rope was formed in the same manner but the extended chain polyethylene yarn was not coated with the overfinish composition. This rope was also tested for its CBOS resistance, and the results are shown in Table 1, below.

TABLE 1

Example	Coating	Cycles to Failure
1	Yes	190,938
2*	No	31,154

*comparative

[0047] The data in Table 1 demonstrates that the ropes coated with the coating composition of the invention have significantly higher CBOS fatigue resistance. In particular, the ropes of the invention achieved more than a 6-fold increase in cycles to failure compared with the uncoated control rope.

Examples 3-5

[0048] Example 1 was repeated, except that various ropes were formed from uncoated polyethylene yarns. The ropes were then coated with the same composition as in Example 1 with varying amounts of the overfinish composition. The ropes were coated with a kiss (or lube) roll in order to apply the overfinish. The amount of coating pick up on the ropes is shown in Table 2, below. The ropes were tested for their CBOS fatigue resistance as in Example 1, and the results are shown in Table 2, below.

TABLE 2

Example	Overfinish Coating (%)	Cycles to Failure
3	1.6	39,964
4	2.2	47,341
5	2.7	57,111

[0049] It can be seen from a comparison of Examples 2 and 3 that even with a minimal amount of the coating composition of the invention, the CBOS fatigue resistance of the ropes is increased by about 30%. Increasing the pick up of the coating composition solids further increases the CBOS fatigue resistance.

Example 6

[0050] Example 1 was repeated, except that the rope was formed from a blend of extended chain polyethylene yams and expanded polytetrafluoroethylene yams. The polyethylene yams were the same as used in Example 1, but were not coated with the overfinish. The expanded polytetrafluoroethylene yams were Profilen FG04 from Lenzing, which are

identified from the manufacturer as having a denier of 400, a breaking force of 7.5 N (1.68 pounds) and an elongation of 4%.

[0051] Two ends of the extended chain polyethylene yarns were twisted with one end of the expanded polytetrafluoroethylene yams to form a twisted yam. The twisted yam was braided into a 12-strand, ⅛ inch (0.32 cm) diameter rope. The yam was braided into a rope by first twisting three yarns together into a cord at 0.5 turns per inch. Cords were twisted in the "S" direction and the "Z" direction. Twelve cords were then loaded onto a 12-strand braider in an alternating fashion (S, Z, S, Z, etc.). Three cords were then braided together resulting in a 12-strand braided rope of approximately ⅛ inch (0.32 cm) diameter.

[0052] The rope comprised 13 percent by weight of the expanded polytetrafluoroethylene yarns and 87 percent of the extended chain polyethylene yarns.

[0053] The rope was then coated with the same composition as in Example 1. The ropes were coated with by dipping them into the overfinish composition and allowing them to air dry. The amount of coating pick up on the rope was 25 percent by weight.

[0054] The rope was tested for its CBOS fatigue resistance as in Example 1, and the results are shown in Table 3, below.

Example 7

[0055] Example 6 was repeated, except that the rope was formed only from the extended chain polyethylene yarns. The polyethylene yarns were the same as used in Example 1, but were not coated with the overfinish.

[0056] The amount of coating pick up on the rope was 24 percent by weight.

[0057] The rope was tested for its CBOS fatigue resistance as in Example 1, and the results are shown in Table 3, below.

Example 8

[0058] Example 6 was repeated, except that the polytetrafluoroethylene yams were Profilen FG08 from Lenzing, which are identified from the manufacturer as having a denier of 800, a breaking force of 14 N (6.35 pounds) and an elongation of 6%.

[0059] The rope comprised 24 percent by weight of the expanded polytetrafluoroethylene yarns and 76 percent of the extended chain polyethylene yams.

[0060] The amount of coating pick up on the rope was 23 percent by weight.

[0061] The rope was tested for its CBOS fatigue resistance as in Example 1, and the results are shown in Table 3, below.

Examples 9-11

Comparative

[0062] Examples 6-8 were repeated, except that the ropes were not coated with the composition of the invention. The ropes were tested for their CBOS resistance and the results are shown in Table 3, below.

TABLE 3

Example	PTFE content (%)	Cycles to Failure
6	13	228,127
7	0	206,795
8	24	229,650
9*	13	81,866
10*	0	72,780
11*	24	83,830

*comparative

[0063] It can be seen from a comparison of Examples 6 and 7 that the presence of the fluoropolymer yams significantly increases the CBOS fatigue resistance of the ropes. It can also be seen by comparing Examples 6 and 8 that increasing the fluoropolymer yarn content by almost two times does not greatly increase the CBOS resistance. Thus, a smaller amount of the expanded polytetrafluoroethylene yarns can be included in a rope and still provide the desirable increased CBOS resistance.

[0064] It can also be seen by comparing Examples 6 and 9 that the presence of the coating composition greatly increases the CBOS resistance of the ropes, even with the presence of expanded polytetrafluoroethylene yarns in the ropes. Similar results are noted when comparing Examples 8 and 11. A comparison of Examples 7 and 10 demonstrates that the CBOS resistance of the ropes is greatly improved by use of the coating composition of this invention.

[0065] It can be seen that the present invention provides ropes which have significantly improved CBOS fatigue resistance. As a result, these ropes can be employed in many demanding applications, including such marine applications as lifting and lowering heavy objects from the seabed.

[0066] Having thus described the invention in rather full detail, it will be understood that such detail need not be strictly adhered to but that further changes and modifications may suggest themselves to one skilled in the art, all falling within the scope of the invention as defined by the subjoined claims.

What is claimed is:

1. A rope having improved cyclic bend over sheave (CBOS) fatigue resistance, said rope comprising a blend of fluoropolymer fibers and high tenacity polyolefin fibers, said rope and/or said fibers being coated with a composition comprising an amino functional silicone resin and a neutralized low molecular weight polyethylene.

2. The rope of claim **1** wherein said high tenacity polyolefin fibers comprise extended chain polyethylene fibers.

3. The rope of claim **3** wherein said extended chain polyethylene fibers have a tenacity of at least about 15 g/d.

4. The rope of claim **3** wherein said extended chain polyethylene fibers have a tenacity of at least about 30 g/d.

5. The rope of claim **1** wherein said rope is formed from said blended fibers which are coated with said composition prior to forming said rope.

6. The rope of claim **1** wherein said rope is formed from said blended fibers and is thereafter coated with said composition.

7. The rope of claim **1** wherein said composition is present on said rope in an amount of at least about 5 weight percent based on the weight of said rope.

8. The rope of claim **1** wherein said low molecular weight polyethylene is the major component of said composition.

9. The rope of claim **1** wherein said low molecular weight polyethylene is present in an amount of from about 55 percent to about 85 percent by weight based on the total weight of said composition.

10. The rope of claim **9** wherein said low molecular weight polyethylene is fully neutralized.

11. The rope of claim **1** wherein said blended fibers are twisted together.

12. The rope of claim **1** wherein said rope comprises from about 1 to about 40 percent by weight, based on the total weight of the fibers, of said fluoropolymer fibers and correspondingly from about 60 to about 99 percent by weight, based on the total weight of the fibers, of said high tenacity polyolefin fibers.

13. The rope of claim **1** wherein said rope comprises a blend of polytetrafluoroethylene fibers and extended chain polyethylene fibers.

14. The rope of claim **13** wherein said polytetrafluoroethylene fibers comprise expanded polytetrafluoroethylene fibers.

15. The rope of claim **14** wherein said rope comprises from about 1 to about 40 percent by weight, based on the total weight of the fibers, of said expanded polytetrafluoroethylene fibers and correspondingly from about 60 to about 99 percent by weight, based on the total weight of the fibers, of said extended chain polyethylene fibers.

16. The rope of claim **15** wherein said rope is a braided rope.

17. The rope of claim **15** wherein said expanded polytetrafluoroethylene fibers are present in the form of yarns having a denier of from about 50 to about 1600, and said extended chain polyethylene fibers are present in the form of yarns having a denier of from about 50 to about 5000.

18. The rope of claim **1** wherein said blend consists essentially of a blend of polytetrafluoroethylene fibers and extended chain polyethylene fibers.

19. The rope of claim **1** wherein said fluoropolymer fibers are selected from the group consisting of polytetrafluoroethylene, polychorotrifluoroethylene, polyvinyl fluoride, polyvinylidene fluoride, ethylene-tetrafluoroethylene copolymers, ethylene-chlorotrifluorethylene copolymers, fluorinated ethylene-propylene copolymers, perfluoroalkoxy polymer, and blends thereof

20. A method of improving the cyclic bend over sheave (CBOS) fatigue life of a rope, said method comprising forming said rope from a blend comprising fluoropolymer fibers and high tenacity polyolefin fibers, and coating said rope and/or said fibers forming said rope with a composition comprising an amino functional silicone resin and a neutralized low molecular weight polyethylene.

21. The method of claim **20** wherein high tenacity polyolefin fibers comprises extended chain polyethylene fibers.

22. The method of claim **21** wherein said fluoropolymer fibers comprise polytetrafluoroethylene fibers.

23. The method of claim **22** wherein said rope comprises from about 1 to about 40 percent by weight, based on the total weight of the fibers, of expanded polytetrafluoroethylene fibers and correspondingly from about 60 to about 99 percent by weight, based on the total weight of the fibers, of extended chain polyethylene fibers.

24. The method of claim **23** wherein said expanded polytetrafluoroethylene fibers and said extended chain polyethylene fibers are twisted together.

25. The method of claim **20** wherein said low molecular weight polyethylene is present in said composition in an amount of from about 55 percent to about 85 percent by weight based on the total weight of said composition.

26. The method of claim **25** wherein said composition has a solids content of at least about 25% by weight.

27. The method of claim **26** wherein said amino functional silicone resin is in the form of an emulsion having a pH of from about 9 to about 11.

28. The method of claim **27** wherein said low molecular weight polyethylene in said composition has a molecular weight of from about 300 to about 3000 Dalton, and is in the form of an emulsion.

29. In a method of lifting and placing heavy objects from and onto a seabed using a synthetic fiber rope, the improvement comprising utilizing as said rope a rope comprising a blend of fluoropolymer fibers and high tenacity polyolefin fibers, said rope and/or said fibers being coated with a composition comprising an amino functional silicone resin and a neutralized low molecular weight polyethylene.

30. The method of claim **29** wherein said high tenacity polyolefin fibers comprise extended chain polyethylene fibers.

31. The method of claim **30** wherein said fluoropolymer fibers comprise polytetrafluoroethylene fibers.

32. The method of claim **31** including coating said composition onto said rope and/or said fibers to provide said composition on said rope in an amount of from about 10 to about 30 weight percent based on the weight of said rope.

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