



(11)

EP 4 545 703 A1

(12)

EUROPEAN PATENT APPLICATION
published in accordance with Art. 153(4) EPC

(43) Date of publication:
30.04.2025 Bulletin 2025/18

(51) International Patent Classification (IPC):
D07B 1/02 (2006.01)

(21) Application number: **23827305.6**

(52) Cooperative Patent Classification (CPC):
D07B 1/02

(22) Date of filing: **26.06.2023**

(86) International application number:
PCT/JP2023/023581

(87) International publication number:
WO 2023/249125 (28.12.2023 Gazette 2023/52)

(84) Designated Contracting States:
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL
NO PL PT RO RS SE SI SK SM TR**
Designated Extension States:
BA
Designated Validation States:
KH MA MD TN

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(30) Priority: **24.06.2022 JP 2022101743**

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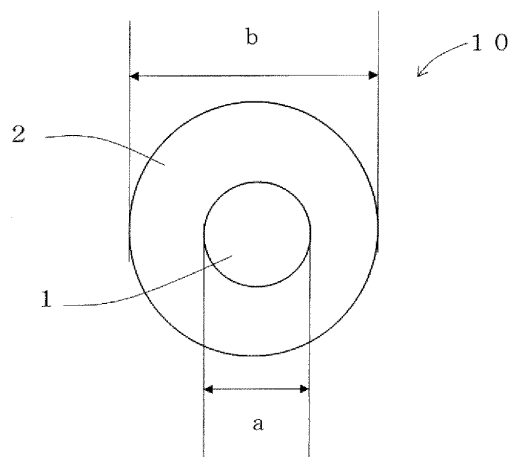
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(54) **DOUBLE-ROPE STRUCTURE**

(57) Provided is a double rope structure which comprises an inner core and an outer cover. In the double rope structure, the inner core includes high strength and high modulus fibers with a yarn tenacity of 20 cN/dtex or more and yarn elastic modulus of 400 cN/dtex or more, and an inner-and-outer-layer suitability represented by the following formula (1) is 0.70 to 1.20. Formula (1): $(a^2 /$

$b^2) / V_f \times 100$. In the formula (1), a represents the diameter of the outer periphery of the inner core, b represents the diameter of the outer periphery of the outer cover, and V_f represents the volume ratio (%) of the volume of the inner core to the total volume of the inner core and the outer cover.

Fig. 1



Description

CROSS REFERENCE TO THE RELATED APPLICATION

- 5 **[0001]** This application is based on and claims Convention priority to Japanese patent application No. 2022-101743, filed June 24, 2022, the entire disclosure of which is herein incorporated by reference as a part of this application.

FIELD OF THE INVENTION

- 10 **[0002]** The present invention relates to a double rope structure which comprises an inner core (inner layer) and an outer cover (outer layer).

BACKGROUND OF THE INVENTION

- 15 **[0003]** Ropes are produced from a plurality of strands by twisting or braiding them to obtain structures of cords or strings, and used for applications in water such as mooring ropes for vessels and bolt ropes for fishing nets, and applications on land such as traction ropes and load ropes. A strand comprises a plurality of yarns, and a yarn comprises a plurality of single fibers as raw fibers.

- 20 **[0004]** The rope structures include rope structures with a double structure, in addition to rope structures with a single structure. The double rope structure is formed from an inner core and an outer cover, in which the inner core and the outer cover are each formed from strands, either twisted or braided. For example, Patent document 1 (Japanese Utility Model Gazette No. 3199266) discloses a fiber rope having a double structure which comprises a core material and an outer cover rope covering the outside of the core material, wherein the core material is made of high strength and high modulus fibers, and the outer cover rope is a braided rope formed from mixed yarns of high strength and high modulus fibers and general-purpose fibers, in which the proportion of the high strength and high modulus fibers is higher than that of the general-purpose fibers.

RELATED ART DOCUMENT

- 30 **PATENT DOCUMENT**

[0005] [Patent Document 1] Japanese Utility Model Gazette No. 3199266

SUMMARY OF THE INVENTION

- 35 **[0006]** Patent Document 1 proposes that the general-purpose fibers and the high strength and high modulus fibers are used at a specific ratio for the outer cover to cope with "friction", and describes that the core material and the outer cover fit well with each other so that the entire rope hardly loses its shape. However, Patent Document 1 also describes that a rope having the core material which is not twisted adequately and which is too soft is vulnerable to bending or torsion.

- 40 **[0007]** Therefore, an object of the present invention is to provide a double rope structure excellent in bending durability and strength per cross-sectional area.

- [0008]** As a result of intensive studies conducted by the inventors of the present invention in an attempt to solve the problem of the conventional technology, it has been found that use of high strength and high modulus fibers as an inner core in a double rope structure can improve the strength of the rope structure thanks to the tenacity property of the high strength and high modulus fibers. On the other hand, the inventors have also found that the bendability of the rope structure can still be improved. As a result of the further investigation, the inventors have found that, when a suitable gap exists between the inner core and an outer cover, unexpectedly, the bendability of the entire rope structure can be improved and, moreover, the strength per cross-sectional area of the rope structure can be improved, and thus the inventors finally completed the invention.

- 50 **[0009]** That is, the present invention may include the following aspects.

Aspect 1

- 55 **[0010]** A double rope structure comprising an inner core and an outer cover, wherein the inner core comprises high strength and high modulus fibers with a yarn tenacity of 20 cN/dtex or more and a yarn elastic modulus of 400 cN/dtex or more, and an inner-and-outer-layer suitability represented by the following formula (1) is 0.70 to 1.20 (preferably 0.80 to 1.15, and more preferably 0.85 to 1.10).

$$(a^2 / b^2) / V_f \times 100 \quad (1)$$

In the formula (1), a represents a diameter of an outer periphery of the inner core, b represents a diameter of an outer periphery of the outer cover, and V_f represents a volume ratio (%) of a volume of the inner core to a total volume of the inner core and the outer cover.

Aspect 2

[0011] The double rope structure according to aspect 1, wherein the volume ratio V_f of the volume of the inner core to the total volume of the inner core and the outer cover is 10% or larger (preferably 15% or larger, more preferably 20% or larger, and further preferably 25% or larger, and for example, 75% or less, preferably 70% or less, more preferably 65% or less, and further preferably 60% or less).

Aspect 3

[0012] The double rope structure according to aspect 1, wherein the double rope structure has a ratio of yarn length/rope length of 1.005 to 1.400 (preferably 1.005 to 1.200, more preferably 1.006 to 1.180, and further preferably 1.007 to 1.150), the rope length being determined as a length of a cut section of the double rope structure cut to a certain length, the yarn length being determined as an average value of lengths of yarns constituting the inner core of the cut section.

Aspect 4

[0013] The double rope structure according to any one of aspects 1 to 3, wherein a tensile strength per cross-sectional area of the double rope structure is 180 N/mm² or more (preferably 200 N/mm² or more, and more preferably 220 N/mm² or more), the tensile strength being measured in accordance with JIS L 1013:2021.

Aspect 5

[0014] The double rope structure according to any one of aspects 1 to 4, wherein the high strength and high modulus fibers have a yarn elongation of 1 to 6% (preferably 2 to 5.5%).

Aspect 6

[0015] The double rope structure according to any one of aspects 1 to 5, wherein the high strength and high modulus fibers are at least one selected from the group consisting of liquid crystal polyester fibers, ultra-high molecular weight polyethylene fibers, aramid fibers, and poly(para-phenylene benzobisoxazole) fibers.

Aspect 7

[0016] The double rope structure according to any one of aspects 1 to 6, wherein a ratio of a tenacity of fibers used for the outer cover to a tenacity of fibers used for the inner core is 0.10 to 0.40 (preferably 0.12 to 0.35).

Aspect 8

[0017] The double rope structure according to any one of aspects 1 to 7, wherein the outer cover substantially comprises non-high strength and non-high modulus fibers.

Aspect 9

[0018] The double rope structure according to any one of aspects 1 to 8, wherein the outer cover includes multifilaments.

Aspect 10

[0019] The double rope structure according to any one of aspects 1 to 9, wherein a ratio of a tensile strength of the double rope structure after a bending test to a tensile strength of the double rope structure before the bending test is 90% or more, in which the bending test, the double rope structure is subjected to repeated bending of 10,000 times under a load of 1% of a tensile break strength of the double rope structure at a bending angle of 240° with a bending R of 7.5 mm.

[0020] Singular forms used with the articles "a", "an", and "the" in the present specification are intended to encompass plural forms including "at least one", unless the content clearly indicates otherwise. The terms "and/or", "at least one", and "one or more" used in the present specification encompass any and all of combinations of the relevant items having been listed.

[0021] The present invention encompasses any combination of at least two features disclosed in the claims and/or the specification and/or the drawings. In particular, any combination of two or more of the appended claims should be equally construed as included within the scope of the present invention.

[0022] According to the present invention, since the double rope structure comprises an inner core comprising yarns of high strength and high modulus fibers, and an outer cover formed such that a suitable gap exists between the inner core and the outer cover, both improved bending durability and improved strength per cross-sectional area can be achieved in the rope structure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] In any event, the present invention will become more clearly understood from the following description of preferred embodiments thereof, when taken in conjunction with the accompanying drawings. However, the embodiments and the drawings are given only for the purpose of illustration and explanation, and are not to be taken as limiting the scope of the present invention in any way whatsoever, which scope is to be determined by the appended claims.

Fig. 1 is a conceptual cross-sectional view for explaining a double rope structure according to one embodiment of the present invention;

Fig. 2 is an exploded schematic side view of the double rope structure according to one embodiment of the present invention;

Fig. 3 is an enlarged schematic perspective view of a part of a strand which forms an inner core of the double rope structure in Fig. 2;

Fig. 4 is a schematic perspective view for explaining the relationship between the length of a cut section of the double rope structure and the length of one yarn which is one of a plurality of yarns constituting a strand in the cut section; and

Fig. 5 is an exploded schematic side view of a double rope structure according to another embodiment of the present invention.

DESCRIPTION OF EMBODIMENTS

Double Rope Structure

[0024] A double rope structure comprises an inner core and an outer cover, and the inner core comprises yarns of high strength and high modulus fibers. As for the double rope structure, since a suitable gap exists between the outer cover and the inner core comprising the yarns of the high strength and high modulus fibers, the entire rope structure is flexible, and not only the bending durability but also the strength per cross-sectional area of the rope structure can be improved.

[0025] As for the double rope structure, an inner-and-outer-layer suitability represented by the following formula (1) is controlled to be in a predetermined range.

$$(a^2 / b^2) / V_f \times 100 \quad (1)$$

[0026] In the formula (1), a represents a diameter (mm) of an outer periphery of the inner core, b represents a diameter (mm) of an outer periphery of the outer cover, and V_f represents a volume ratio (%) of a volume of the inner core to a total volume of the inner core and the outer cover.

[0027] The diameter b of the outer periphery of the outer cover is a value measured by placing a double rope structure 10 between external measurement jaws of an electronic slide caliper.

[0028] The diameter a of the outer periphery of the inner core is a value measured by placing the inner core, which is obtained by removing the outer cover from the double rope structure, between the external measurement jaws of the electronic slide caliper.

[0029] Specifically, these diameters are measured according to the method described in Examples below.

[0030] The inner-and-outer-layer suitability is 0.70 to 1.20. In the case where the inner-and-outer-layer suitability is less than 0.70, the inner core rope cannot be tightened by the outer cover, so that a larger gap is produced between the inner core and the outer cover. In the case where there is a larger gap, the outer cover collapses due to hollow parts generated inside the rope and the strength of the outer cover cannot be maintained, so that the strength of the entire rope is reduced.

[0031] On the other hand, in the case where the inner-and-outer-layer suitability exceeds 1.20, the inner core is

excessively tightened by the outer cover, so that the entire rope becomes very stiff and poor in flexibility. Such a rope undergoes severe wear which is generated between fibers every time the rope is deformed, and thus is poor in bending durability.

[0032] The inner-and-outer-layer suitability may be preferably 0.80 to 1.15, and more preferably 0.85 to 1.10. When a twisted-covering body or a braided body is formed such that the inner-and-outer-layer suitability is in the range, a suitable gap exists between the inner core and the outer cover, and thus the entire rope structure is flexible and bending durability can be improved.

[0033] The volume ratio V_f of the volume of the inner core to the total volume of the inner core and the outer cover is the ratio (%) of the total sum of the volumes occupied by fibers of the inner core to the total sum of the volumes occupied by fibers of the double rope structure, determined by using a sample of the double rope structure cut to a predetermined length (1.000 m).

[0034] In the determination of the volume ratio V_f :

- (i) after measuring the weight of the sample, the sample is separated into the outer cover and the inner core, and the weights (g) of fiber groups constituting each of the outer cover and the inner core are measured for each kind of fiber;
- (ii) the volume of each fiber group is calculated by dividing the weight of that fiber group by the density (g/cm^3) peculiar to that kind of fiber;
- (iii) the total sum of the volumes of the fiber groups constituting the outer cover is calculated as a volume V_o , and the total sum of the volumes of the fiber groups constituting the inner core is calculated as a volume V_i ; and
- (iv) the volume ratio V_f can be obtained according to the following formula.

$$V_f = (V_i) / (V_i + V_o) \times 100$$

[0035] In the case where the outer cover is made of a single kind of fiber, the weight obtained by subtracting the weight (W_i) of the fiber groups constituting the inner core from the weight ($W_o + W_i$) of the sample may be regarded as the weight (W_o) of the fiber group constituting the outer cover.

[0036] The volume ratio V_f of the volume of the inner core to the total volume of the inner core and the outer cover may be, for example, 10% or larger, preferably 15% or larger, more preferably 20% or larger, and further more preferably 25% or larger. In the case where the volume ratio of the inner core is large, the strength of the double rope structure can be improved by the yarns of the high strength and high modulus fibers. The upper limit of the volume ratio V_f of the inner core is not particularly limited, and from the viewpoint of enhancing covering performance by the outer cover, the upper limit of the volume ratio V_f of the inner core may be, for example, 75% or less, preferably 70% or less, more preferably 65% or less, and further more preferably 60% or less.

[0037] The double rope structure is excellent in bending durability. Thus, when a bending test is carried out in which the double rope structure is subjected to repeated bending of 10,000 times under a load of 1% of the tensile break strength of the double rope structure at a bending angle of 240° with a bending R of 7.5 mm, a ratio of a tensile strength of the double rope structure after the bending test to a tensile strength of the double rope structure before the bending test, that is, a bendability retention (%), may be 90% or more, preferably 93% or more, and more preferably 95% or more. The bendability retention is a value measured according to the method described in the Examples below. The upper limit of the bendability retention is usually 100%.

[0038] Since the double rope structure can improve the strength per cross-sectional area of the rope structure, the tensile strength per cross-sectional area of the double rope structure, measured in accordance with JIS L 1013:2021, may be 180 N/mm^2 or more, preferably 200 N/mm^2 or more, and more preferably 220 N/mm^2 or more. The upper limit is not particularly limited, and for example, may be 2000 N/mm^2 .

[0039] Hereinafter, the present invention will be described in detail based on exemplification. Fig. 1 is a conceptual cross-sectional view for explaining the double rope structure.

[0040] As shown in Fig. 1, a double rope structure 10 comprises an inner core 1 having an outer periphery with the diameter a , and an outer cover 2 having an outer periphery with the diameter b and braided so as to cover the inner core 1. A gap that exists between the inner core 1 and the outer cover 2 is omitted in the drawings, and the diameter b of the outer periphery of the outer cover is also the diameter of the double rope structure 10.

[0041] As for the double rope structure, the outer cover 2 is braided such that the inner-and-outer-layer suitability is in a predetermined range by controlling the yarn fineness, the number of strands, and a pitch for the outer cover 2 according to the diameter, the weight, and the density of the targeted inner core 1, or the like, whereby bending durability and strength per cross-sectional area can be improved.

[0042] Fig. 2 is an exploded schematic side view of the double rope structure according to one embodiment of the present invention, and Fig. 3 is an enlarged schematic perspective view of a part of a strand 3 which forms the inner core of the double rope structure in Fig. 2. As shown in Fig. 2, the double rope structure 10 comprises the inner core 1 and the outer

cover 2 covering the inner core, and the outer cover 2 is a braided body and is unified with the inner core 1 to constitute the double rope structure. In Fig. 2, a part of the outer cover 2 is not shown in order to show the state of the inner core 1.

[0043] The inner core 1 and the outer cover 2 have structures in which a plurality of strands are twisted and/or braided. Each strand comprises a plurality of yarns, and each yarn comprises a plurality of single fibers which are twisted in a specific range. Each single fiber may be a monofilament or a multifilament.

[0044] For example, a strand 3 constituting the inner core 1 of the double rope structure 10 in Fig. 2 comprises a plurality of yarns 4 as shown in Fig. 3, and each yarn 4 is a twisted body in which a plurality of raw fibers (preferably monofilaments or multifilaments, and particularly preferably multifilaments) are twisted together.

[0045] Fig. 2 shows a cut section 1A which has a predetermined length V in the inner core 1. The cut section 1A represents an inner core portion of the double rope structure 10 which is cut to the predetermined length V. The cut section 1A can be disassembled into a plurality of strands which constitute the cut section 1A. In Fig. 2, one strand 3A of the plurality of strands is shown with dots. The strand 3A comprises a plurality of yarns (not shown).

[0046] Fig. 4 is a schematic perspective view for explaining the relationship between the length V of the cut section 1A and the length W of one yarn 4A which is one of the plurality of yarns constituting the strand 3A in the cut section 1A. The double rope structure 10 is cut to the predetermined length V to obtain the cut section 1A which contains the strand 3A. Then, the strand 3A is disassembled into yarns 4A to measure the length W of the yarn 4A.

[0047] As for the double rope structure of the present invention, the strand 3A in the cut section 1A comprises the yarns 4A having the length W, and a ratio of yarn length/rope length (W/V) may be, for example, within a range of 1.005 or more and 1.400 or less.

[0048] For example, as shown in Fig. 2, the strand 3A constituting the inner core crosses a longitudinal direction Z passing through the center of the double rope structure (hereafter, simply referred to as the rope longitudinal direction Z) at a crossing angle θ ($0^\circ < \theta < 90^\circ$) relative to the rope longitudinal direction Z. The crossing angle θ can be measured using a photo image of the side surface of the fibers in a state where the outer cover 2 is removed to expose the inner core 1. For example, in Fig. 2, the strand 3A which crosses the rope longitudinal direction Z of the double rope structure 10 is randomly selected, and the angle θ formed by the rope longitudinal direction Z and an outline of the strand 3A which is close to the rope longitudinal direction Z is regarded as the crossing angle.

[0049] Fig. 5 is an exploded schematic side view of the double rope structure according to another embodiment of the present invention. A double rope structure 20 comprises an inner core 6 and an outer cover 2 covering the inner core. The outer cover 2 is a braided body and is unified with the inner core 6 to constitute the double rope structure. The same constituting elements as those in Fig. 2 are denoted with the same reference signs, and the description thereof will be omitted.

[0050] Also, as for this double rope structure, the outer cover 2 is braided such that the inner-and-outer-layer suitability, represented by the above-described formula (1), for the inner core 6 and the outer cover 2 is in a predetermined range, whereby bending durability and strength per cross-sectional area can be improved in the double rope structure.

[0051] The inner core 6 has a twisted structure in which a plurality of strands 7 are twisted together. Each strand comprises a plurality of yarns, and each yarn comprises a plurality of single fibers. For example, a strand 7 constituting the inner core 6 of the double rope structure 20 in Fig. 5 comprises a plurality of yarns 4 as with the strand 3 shown in Fig. 3, and each yarn 4 is a twisted body of two or more raw fibers (preferably monofilaments or multifilaments, and particularly preferably multifilaments).

[0052] Fig. 5 shows a cut section 6A which has a predetermined length V in the inner core 6. The cut section 6A represents an inner core portion of the double rope structure 20 which is cut to the predetermined length V. The cut section 6A can be disassembled into a plurality of strands which constitute the cut section 6A. In Fig. 5, one strand 7A of the plurality of strands is shown with dots. The strand 7A comprises a plurality of yarns (not shown). The ratio of the length W of the yarns constituting the strand 7A relative to the length V of the cut section 6A, expressed as the ratio of yarn length/rope length (W/V), may be, for example, within a range of 1.005 or more and 1.400 or less.

[0053] As shown in Fig. 5, the strand 7A constituting the inner core crosses a rope longitudinal direction Z at a crossing angle θ ($0^\circ < \theta < 90^\circ$). For example, in Fig. 5, the strand 7A which crosses the rope longitudinal direction Z passing through the center of the double rope structure 20 is randomly selected, and the angle θ formed by the rope longitudinal direction Z and an outline of the strand 7A which is close to the rope longitudinal direction Z is regarded as the crossing angle.

[0054] As shown in Fig. 2 and Fig. 5, the outer cover 2 is formed by the braided body of the strands. As shown in Fig. 3, each strand comprises a plurality of yarns. Each yarn is a twisted body in which a plurality of raw fibers (preferably monofilaments or multifilaments, and particularly preferably multifilaments) are twisted together.

[0055] Hereinafter, a desirable embodiment of the double rope structure is described.

Inner Core

[0056] The diameter of the inner core can be suitably determined depending on the intended use, and may be, for example, 0.5 to 100 mm, preferably 1.0 to 80 mm, and more preferably 1.5 to 60 mm. The diameter of the inner core is a

value measured according to the method described in the Examples below.

[0057] As for the double rope structure, with respect to a plurality of yarns which constitute strands of the inner core, the number of twists of each yarn may be, for example, 150 to 0.1 T/m, preferably 100 to 2 T/m, more preferably 80 to 3 T/m, further preferably 70 to 5 T/m, and particularly preferably 60 to 6 T/m. Although a smaller number of twists can enhance the strength of a rope, untwisted yarns may deteriorate handleability for forming a strand. As for a plurality of strands constituting the inner core, the strands may be twisted if necessary. For example, only as a guide to select the number of twists of the strand, the strands may be twisted as appropriate in a range that the yarn length/rope length of the inner core is satisfied. Further, a plurality of strands may be twisted together if necessary.

[0058] The fineness of the yarn can be suitably determined depending on the desirable fineness of the double rope structure, or the like. For example, the yarn may have a fineness of 30 to 5000 dtex, preferably 200 to 4000 dtex, more preferably 400 to 2500 dtex, and further preferably 1000 to 2000 dtex. The fineness of the yarn within the above range is preferable in terms of handleability such as convergence of the strands.

[0059] In the inner core of the double rope structure of the present invention, from the viewpoint of improving the tensile strength of the double rope structure, the ratio of yarn length/rope length (W/V), which is calculated as the ratio of the average yarn length of the yarns constituting the inner core of the cut section to the rope length of the cut section cut to 1 m (correctly 1.000 m) in length, may be in a range of 1.005 to 1.400, preferably 1.005 to 1.200, more preferably 1.006 to 1.180, and further preferably 1.007 to 1.150. Here, the yarn length and the rope length are values measured according to the method described in the Examples below.

[0060] The inner core of the double rope structure of the present invention may be a twisted body or a braided body. A twisted body may usually have 3 strands or 4 strands, while a braided body may have 4 strands, 6 strands, 8 strands, 12 strands, 16 strands, 32 strands, 64 strands, or others. Among them, the inner core may be preferably a braided body. Particularly preferably, the inner core may be a braided body having 4 strands, 6 strands, 8 strands, 12 strands, 16 strands, or 32 strands.

[0061] In twisting or braiding, the pitch (counts/inch) may be, for example, adjusted to be 2.5 to 25, preferably 2.5 to 20, more preferably 3 to 18, and further preferably 3.3 to 15. The pitch denotes the number of yarns per inch along the longitudinal direction in a rope. For example, the pitch can be determined by measurement using a digital microscope VHX-2000 available from KEYENCE CORPORATION.

[0062] The crossing angle θ at which the strand crosses the rope longitudinal direction may be, for example, 50° or less, preferably 40° or less, more preferably 35° or less, further preferably 33° or less, still more preferably 30° or less, and particularly preferably 27° or less. The lower limit of the crossing angle may be, for example, 2° or more, preferably 3° or more, more preferably 6° or more, and further preferably 10° or more. When the crossing angle of the strand is the upper limit or less, it is preferable in terms of strength, and when the crossing angle of the strand is the lower limit or more, it is preferable in terms of bending durability.

[0063] The high strength and high modulus fibers which constitute the inner core may be any fibers which can achieve a yarn tenacity of 20 cN/dtex or more and a yarn elastic modulus of 400 cN/dtex or more. Such high strength and high modulus fibers may be exemplified as: liquid crystal polyester fibers such as Vectran (trademark), Siveras (trademark), Zxion (trademark), etc.; ultra-high molecular weight polyethylene fibers such as Isanas (trademark), Dyneema (trademark), etc.; aramid fibers such as Kevlar (trademark), Twaron (trademark), Technora (trademark), etc.; poly(paraphenylene benzobisoxazole) fibers such as Zylon (trademark), etc.; and other fibers with high strength and high modulus.

[0064] The high strength and high modulus fiber has a yarn tenacity of 20 cN/dtex or more, and may have a yarn tenacity of preferably 22 cN/dtex or more. The upper limit is not particularly limited, and may be, for example, 40 cN/dtex.

[0065] The high strength and high modulus fiber has a yarn elastic modulus of 400 cN/dtex or more, and may have a yarn elastic modulus of preferably 450 cN/dtex or more. The upper limit is not particularly limited, and may be, for example, 600 cN/dtex.

[0066] The high strength and high modulus fiber may have a yarn elongation of, for example, 1 to 6%, and preferably 2 to 5.5%.

[0067] The yarn tenacity, the yarn elastic modulus, and the yarn elongation are values measured according to the method described in the Examples below.

[0068] The use of such high strength and high modulus fibers allows the double rope structure to achieve a high strength per cross-sectional area.

[0069] As these high strength and high modulus fibers, the liquid crystal polyester fibers, the ultra-high molecular weight polyethylene fibers, and the aramid fibers are preferable.

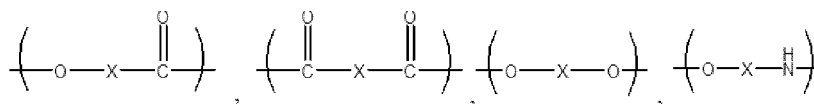
[0070] Liquid crystal polyester fibers can be produced, for example, by melt-spinning a liquid crystal polyester to obtain as-spun fibers, and subjecting the as-spun fibers to solid phase polymerization. A liquid crystal polyester multifilament includes two or more liquid crystal polyester monofilaments.

[0071] Liquid crystal polyester is a polyester capable of forming an optically anisotropic melt phase (liquid crystallinity), and can be recognized, for example, by placing a sample on a hot stage to heat under a nitrogen atmosphere and observing penetration light through the sample using a polarization microscope. The liquid crystal polyester comprises

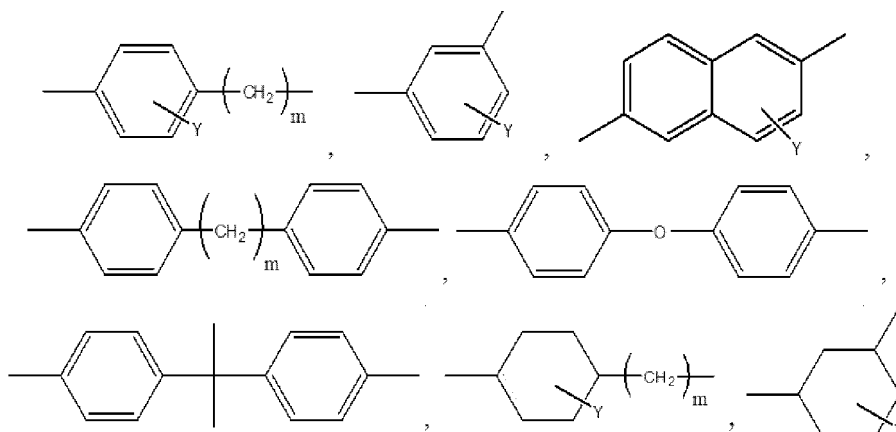
repeating structural units originating from, for example, aromatic diols, aromatic dicarboxylic acids, aromatic hydroxycarboxylic acids, etc. As long as the effect of the present invention is not impaired, the repeating structural unit is not limited to a specific chemical composition. The liquid crystal polyester may include the structural units originating from aromatic diamines, aromatic hydroxy amines, or aromatic aminocarboxylic acids in the range which does not impair the effect of the present invention.

[0072] For example, the preferable structural units may include units shown in Table 1.

Table 1



In the formula, X is selected from the following structures.



m is an integer from 0 to 2, Y is a substituent selected from hydrogen atom, halogen atoms, alkyl groups, aryl groups, aralkyl groups, alkoxy groups, aryloxy groups, aralkyloxy groups.

[0073] Y may represent one substituent or any number of substituents up to the maximum number of substitutable positions in the aromatic ring, and each substituent of Y can be independently selected from the group consisting of a hydrogen atom, a halogen atom (for example, fluorine atom, chlorine atom, bromine atom, iodine atom, etc.), an alkyl group (for example, an alkyl group having 1 to 4 carbon atoms such as methyl group, ethyl group, isopropyl group, t-butyl group, etc.), an alkoxy group (for example, methoxy group, ethoxy group, isopropoxy group, n-butoxy group, etc.), an aryl group (for example, phenyl group, naphthyl group, etc.), an aralkyl group [benzyl group (phenylmethyl group), phenethyl group (phenylethyl group), etc.], an aryloxy group (for example, phenoxy group, etc.), an aralkyloxy group (for example, benzyloxy group, etc.), and others.

[0074] As more preferable structural units, there may be structural units as described in Examples (1) to (18) shown in the following Tables 2, 3, and 4. It should be noted that where the structural unit in the formula is a structural unit which can show a plurality of structures, combination of two or more units may be used as structural units for a polymer.

Table 2

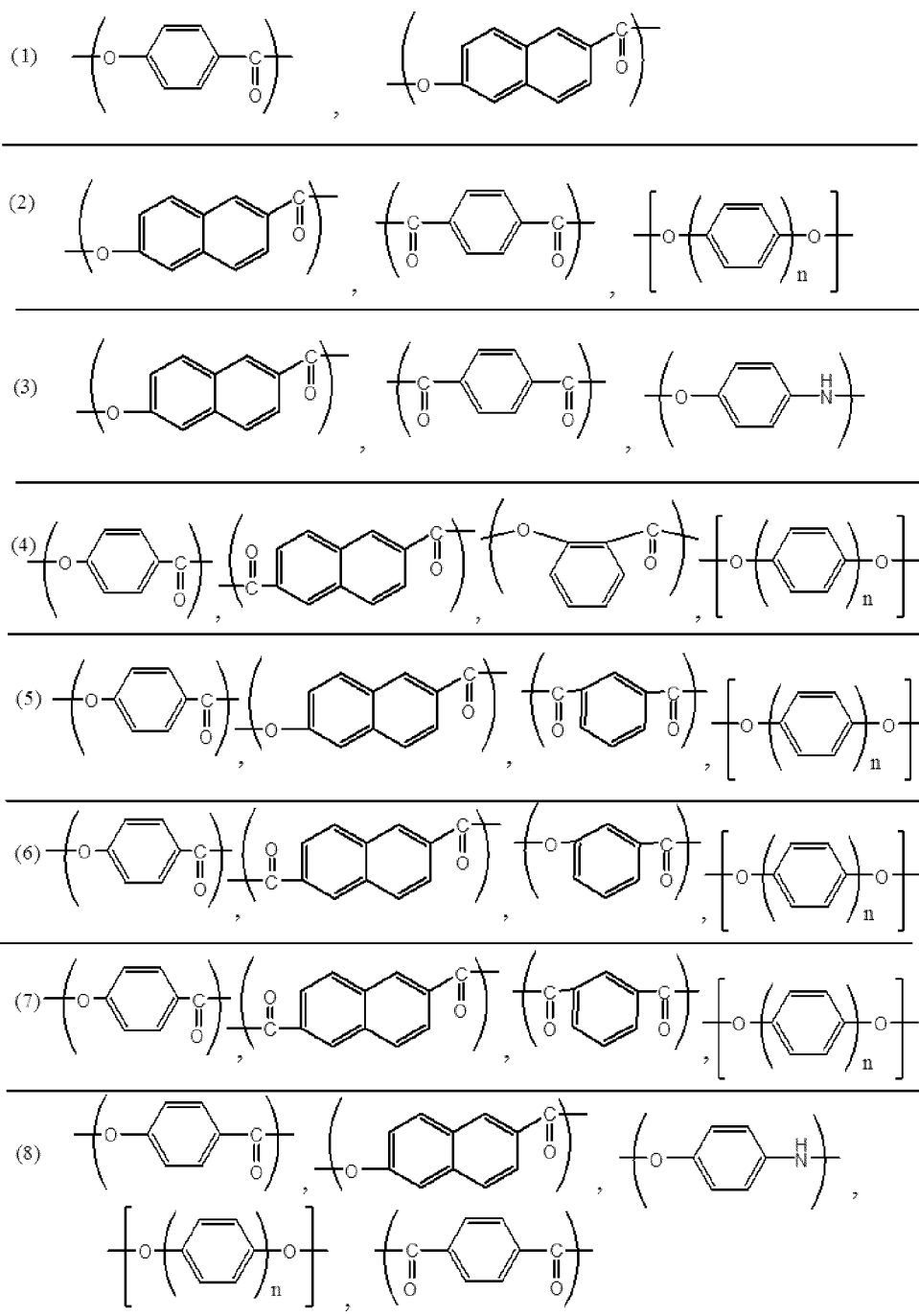


Table 3

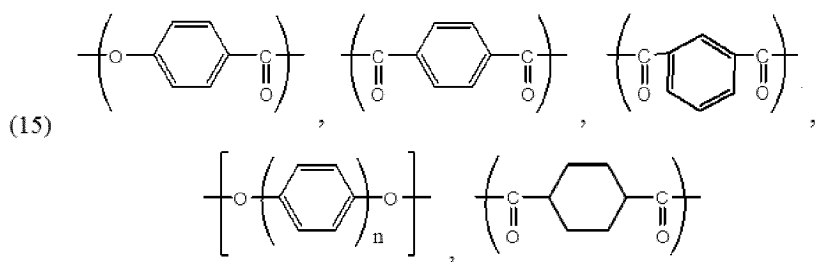
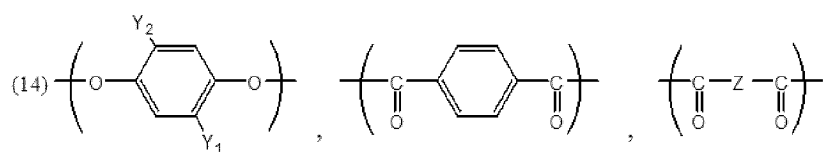
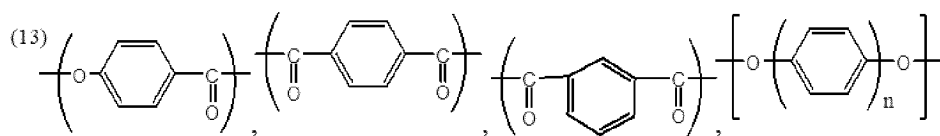
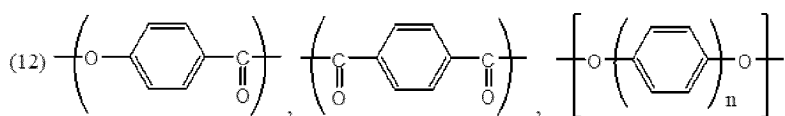
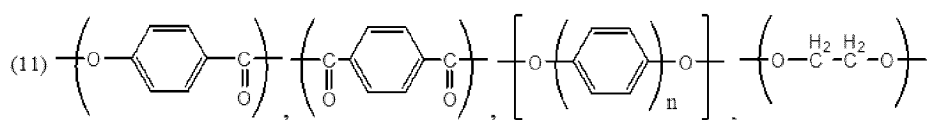
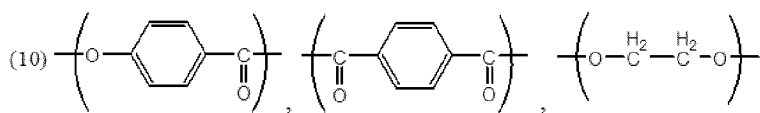
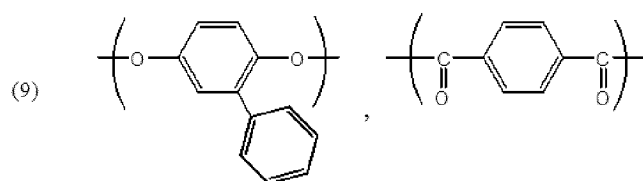
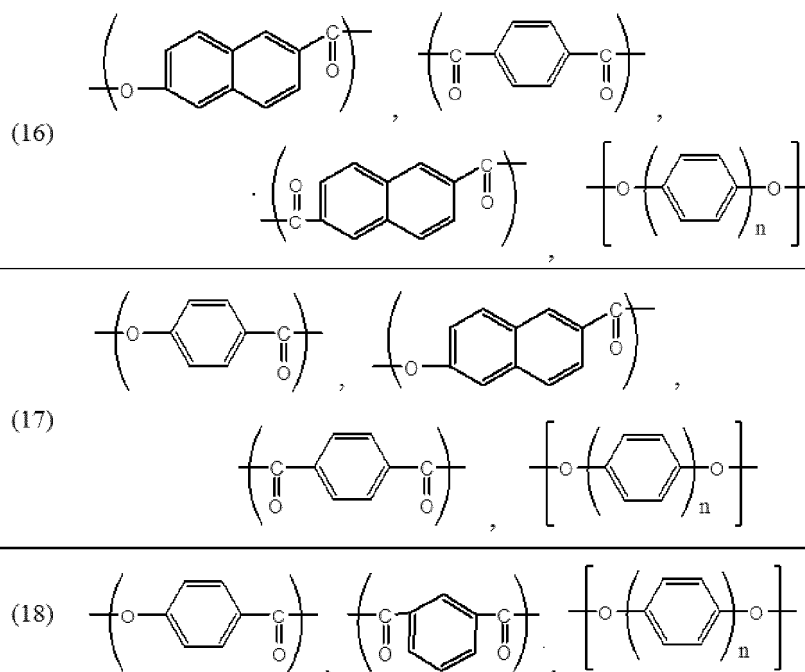


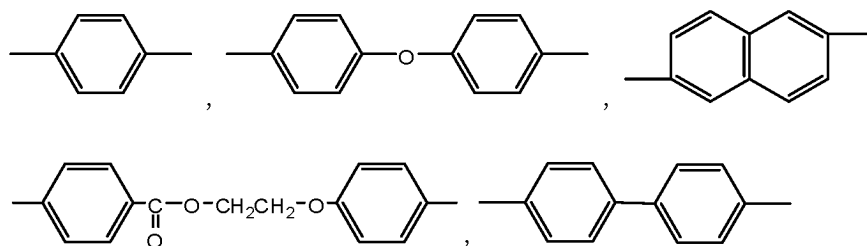
Table 4



[0075] In the structural units shown in Tables 2, 3, and 4, n is an integer of 1 or 2; in each of the structural units, n may be one of or a combination of $n = 1$ and $n = 2$; and each of the Y_1 and Y_2 may independently represent a hydrogen atom, a halogen atom (for example, fluorine atom, chlorine atom, bromine atom, iodine atom, etc.), an alkyl group (for example, an alkyl group having 1 to 4 carbon atoms such as methyl group, ethyl group, isopropyl group, and *t*-butyl group, etc.), an alkoxy group (for example, methoxy group, ethoxy group, isopropoxy group, *n*-butoxy group, etc.), an aryl group (for example, phenyl group, naphthyl group, etc.), an aralkyl group [benzyl group (phenylmethyl group), phenethyl group (phenylethyl group), etc.], an aryloxy group (for example, phenoxy group, etc.), an aralkyloxy group (for example, benzyloxy group, etc.), and others. Among these, the preferable Y_1 and Y_2 may include a hydrogen atom, a chlorine atom, a bromine atom, and a methyl group.

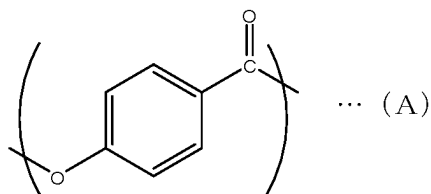
[0076] Z may include substituents denoted by the following formulae.

Chem. 1

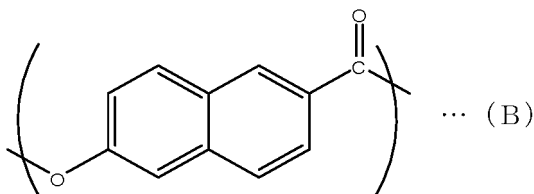


[0077] A preferable liquid crystal polyester may comprise a combination of two or more structural units having a naphthalene skeleton. Especially preferably, the liquid crystal polyester may include both a structural unit (A) derived from hydroxybenzoic acid and a structural unit (B) derived from hydroxy naphthoic acid. For example, the structural unit (A) may have the following formula (A), and the structural unit (B) may have the following formula (B). From the viewpoint of ease of enhancing melt-formability, the ratio of the structural unit (A) and the structural unit (B) may be in a range of former/latter of preferably 9/1 to 1/1, more preferably 7/1 to 1/1, and still more preferably 5/1 to 1/1.

Chem. 2



Chem. 3



[0078] The total proportion of the structural units of (A) and (B) may be, based on all the structural units, for example, 65 mol% or more, more preferably 70 mol% or more, and still more preferably 80 mol% or more. Especially preferably, the liquid crystal polyester has the structural unit (B) at a proportion of from 4 to 45 mol% in the polymer.

[0079] The liquid crystal polyester suitably used in the present invention preferably has a melting point in the range from 250 to 360°C, and more preferably from 260 to 320°C. The melting point here means a temperature at which a main endothermic peak is observed in measurement in accordance with JIS K7121: 2012 test method using a differential scanning calorimeter (DSC: "TA3000" produced by Mettler). More concretely, 10 to 20 mg of a sample is encapsulated in an aluminum pan and taken into the above-mentioned DSC. Then, the sample is heated at a heating rate of 20°C/minute with nitrogen as a carrier gas introduced at a flow rate of 100 cc/minute to measure a position of an endothermic peak. Depending on the type of polymer, where a clear peak does not appear in the 1st run in the DSC measurement, the sample is heated to a temperature higher by 50°C than the expected flow temperature at a heating rate of 50°C/minute and is kept at the temperature for 3 minutes to be completely molten, and then the sample is cooled to 50°C at a cooling rate of -80°C/minute. Subsequently, the sample is reheated at a heating rate of 20°C/minute to measure the position of the endothermic peak.

[0080] The liquid crystal polyester may be used with a thermoplastic polymer such as a polyethylene terephthalate, a modified polyethylene terephthalate, a polyolefin, a polycarbonate, a polyamide, a polyphenylene sulfide, a polyether ether ketone, and a fluoro-resin, and others to the extent that the effect of the present invention is not impaired. In addition, various additives may also be added, including an inorganic material such as titanium oxide, kaolin, silica, and barium oxide; a colorant such as a carbon black, a dye, and a pigment; an antioxidant; a UV absorber; and a light stabilizer.

Outer Cover

[0081] As for the double rope structure of the present invention, the outer cover comprises a twisted-covering body comprising strands to cover the inner core or a braided body comprising strands to cover the inner core. The yarns constituting the strand may be monofilaments or multifilaments, and are preferably multifilaments.

[0082] The twisted-covering body can be formed by twisting strands helically around the inner core. The braided body can be formed by braiding strands to cover the inner core as a core with 8 strands, 12 strands, 16 strands, 24 strands, 32 strands, 40 strands, 48 strands, 64 strands, or others. Among them, the braided body preferably has 12 strands, 16 strands, 24 strands, 32 strands, 40 strands, or 48 strands, and the braided body more preferably has 12 strands, 16 strands, 24 strands, 32 strands, or 40 strands.

[0083] The strands constituting the outer cover may be formed from the high strength and high modulus fibers, or non-high strength and non-high modulus fibers. The non-high strength and non-high modulus fiber may, for example, have a yarn tenacity of less than 20 cN/dtex, and usually about 1 cN/dtex to 15 cN/dtex. The non-high strength and non-high modulus fiber may have a yarn elastic modulus of less than 400 cN/dtex, and usually about 10 cN/dtex to 200 cN/dtex. The non-high strength and non-high modulus fiber may have a yarn elongation of, for example, 3 to 20%, and preferably 7 to 20%.

[0084] From the viewpoint of achieving the necessary strength of the inner core, the non-high strength and non-high modulus fibers may be such fibers that have a ratio of the tenacity of fibers used for the outer cover to the tenacity of fibers

used for the inner core, for example, in a range of 0.10 to 0.40 and preferably 0.12 to 0.35.

[0085] Specific examples of the non-high strength and non-high modulus fibers include general-purpose synthetic fibers, such as general-purpose polyester fibers (e.g., polyethylene terephthalate fibers), polyolefin fibers (e.g., polyethylene fibers, polypropylene fibers), polyamide fibers (e.g., nylon 6 fibers, nylon 6,6 fibers), polyvinyl alcohol fibers (e.g.,

vinylon (trademark) fibers), and others.

[0086] Since the strength of the rope structure can be achieved by the inner core in the double rope structure, the outer cover may substantially comprise non-high strength and non-high modulus fibers. Here, the term "substantially" means that a proportion of the non-high strength and non-high modulus fibers in the outer cover is 80 wt% or more. The proportion of the non-high strength and non-high modulus fibers in the outer cover may preferably be 90 wt% or more (90 to 100 wt%).

[0087] The fineness of the yarn constituting the strand of the outer cover can be suitably determined depending on the desired diameter of the double rope structure, or the like. The fineness of yarn may be, for example, 50 to 100000 dtex, preferably 100 to 50000 dtex, more preferably 200 to 40000 dtex, further preferably 200 to 10000 dtex, and still more preferably 200 to 1000 dtex. When the fineness of the yarn constituting the strand of the outer cover is in the above range, the inner-and-outer-layer suitability can be easily adjusted.

[0088] The diameter of the double rope structure, that is, the diameter b of the outer periphery of the outer cover, can be suitably determined depending on the intended use, and may be, for example, 1.0 to 250 mm, preferably 1.5 to 200 mm, and more preferably 1.8 to 100 mm. Here, the diameter b is the diameter of the outer periphery of the outer cover 2, and is the value measured by placing the double rope structure 10 between external measurement jaws of an electronic slide caliper.

EXAMPLES

[0089] Hereinafter, the present invention will be demonstrated by way of some examples that are presented only for the sake of illustration, and which are not to be construed as limiting the scope of the present invention. It should be noted that in the following Examples and Comparative Examples, various properties were evaluated in the following manners.

Diameter and Cross-sectional Area

[0090] The diameter of each of the double rope structure and the inner core was measured at seven random points by placing each of the double rope structure and the inner core between external measurement jaws of an electronic slide caliper, and then an average value was calculated from the obtained five values by excluding the maximum value and the minimum value.

[0091] Here, the diameter of the double rope structure was used as the diameter of the outer periphery of the outer cover.

[0092] When the diameter of the inner core was measured, the outer cover was carefully removed starting from the surface layer while the inner core was held in a taut state so as not to affect the structure of the inner core of the double rope structure, and measurement was performed by placing only the inner core portion between the external measurement jaws of the electronic slide caliper.

[0093] In addition, the cross-sectional area of the double rope structure was calculated using the diameter of the double rope structure according to the formula, $(\text{diameter} / 2)^2 \times 3.14$.

Volume Ratio

[0094] From the double rope structure, a randomly selected section was cut to a length of 1.000 m, and the weight of the section (weight of the double rope structure: $W_i + W_o$) was measured by using an electronic precision balance. After the measurement, the outer cover was carefully removed while the inner core was held in a taut state, and the weight of the outer cover (outer cover weight: W_o) and the weight of the inner core (inner core weight: W_i) were measured by using the electronic precision balance.

[0095] Then, the volume ratio V_f (%) of the volume of the inner core to the total volume of the inner core and the outer cover was calculated according to the following formula:

$$V_f = (W_i / \rho_i) / (W_i / \rho_i + W_o / \rho_o) \times 100$$

wherein W_i represents the weight (g) of the inner core, ρ_i represents the density (g/cm^3) of the inner core, W_o represents the weight (g) of the outer cover, and ρ_o represents the density (g/cm^3) of the outer cover.

[0096] In the above formula, the densities of polymers forming yarns constituting each of the inner core and the outer cover were used as the densities of the inner core and the outer cover.

Rope Length and Yarn Length in Inner Core

[0097] From the double rope structure (hereafter, may be simply referred to as a rope structure), a randomly selected section was cut to a length of 1.000 m to be regarded as a rope length. The strands in the cut section were disassembled to take out the inner core. From the inner core, one strand was randomly selected and disassembled into yarns constituting the inner core, then lengths of all of the obtained yarns from the inner core were measured in a taut state in accordance with JIS L 1013:2021, and the average of the lengths was regarded as a yarn length.

Yarn Fineness (dtex)

[0098] Strands constituting the inner core and strands constituting the outer cover in the rope structure were disassembled into yarns. The yarn fineness values of thus-obtained yarns from the inner core and the outer cover were measured in accordance with JIS L 1013:2021.

[0099] Yarn Strength (N), Yarn Tenacity (cN/dtex), Yarn Elongation (%), and Yarn Elastic Modulus (cN/dtex)

Strands constituting the inner core of the rope structure were disassembled into yarns, and the tensile strength as the yarn strength (N) of thus-obtained yarn was measured in accordance with JIS L 1013:2021. In addition, the yarn elongation and the yarn elastic modulus were also measured. The yarn tenacity (cN/dtex) was calculated by dividing the yarn strength (cN) by the yarn fineness (dtex).

Pitch (counts/inch)

[0100] The number of yarns which existed in 1 inch in the rope was counted using a digital microscope VHX-2000 available from KEYENCE CORPORATION to obtain a pitch.

Crossing Angle

[0101] Using a digital microscope VHX-2000 available from KEYENCE CORPORATION, a crossing angle of the strand in the inner core of the double rope structure was measured relative to the longitudinal direction of the rope.

Tensile Strength per Cross-sectional Area (N/mm²) of Rope

[0102] Using a swirl type jig for rope evaluation (available from Chubu Machine Co., Ltd.) as a grip jig of a universal tester, the double rope structure was wound into a groove of the swirl part so that the rope was fixed by surface frictional resistance, and the tensile strength of the double rope structure was measured in accordance with JIS L 1013:2021. In addition, the diameter of the double rope structure was measured to calculate the cross-sectional area. The value obtained by dividing the obtained tensile strength by the cross-sectional area was regarded as the tensile strength per cross-sectional area of the rope.

[0103] Bending Durability: Strength Retention (%) After Bending Test Using a bending test machine (TC111L / available from YUASA SYSTEM Co., Ltd.) employing a tension-free bending test jig (DX-TFB / available from YUASA SYSTEM Co., Ltd.), a bending test was carried out in which the double rope structure was subjected to repeated bending of 10,000 times under a load of 1% of the tensile break strength of the double rope structure at a bending angle of 240° with a bending R of 7.5 mm so as to measure the tensile strength of the double rope structure before and after the bending test. The ratio of the tensile strength of the double rope structure after the bending test relative to the tensile strength of the double rope structure before the bending test was calculated as the strength retention after the bending test and was expressed as a percentage.

Example 1

[0104] Liquid crystal polyester multifilaments ("Vectran" produced by KURARAY CO., LTD., fineness: 1670 dtex) as high strength and high modulus fibers were braided using an EL-type 6-strand braider (manufactured by KOKUBUN LTD.), by adjusting the number of rotations and the taken-up speed of the braider, so as to obtain an inner core rope having a pitch of 8.6 counts/inch.

[0105] The obtained inner core rope was used as a core material, and polyethylene terephthalate multifilaments (fineness: 280 dtex, yarn tenacity: 7.2 cN/dtex, yarn elastic modulus: 88 cN/dtex, yarn elongation: 15.1%, available from Toray Industries, Inc.) were braided using a middle-type 32-strand braider (manufactured by KOKUBUN LTD.), by adjusting the number of rotations and the taken-up speed of the braider, so as to obtain a double rope structure with an outer cover rope a pitch of 50 counts/inch.

Example 2

[0106] A double rope structure was produced in the same manner as Example 1 except that the number of strands and a pitch for the inner core and fineness and a pitch for the outer cover in the double rope structure were changed as shown in Table 5. The results are shown in Table 5.

Example 3

[0107] A double rope structure was produced in the same manner as Example 1 except that ultra-high-molecular-weight-polyethylene multifilaments ("Isanas" produced by Toyobo Co., Ltd., fineness: 1760 dtex) were used as high strength and high modulus fibers for the inner core of the double rope structure, and a pitch for the inner core was changed to 8.5 and a pitch for the outer cover was changed to 49. The results are shown in Table 5.

Example 4

[0108] A double rope structure was produced in the same manner as Example 3 except that the number of strands and a pitch for the inner core and fineness, the number of strands, and a pitch for the outer cover of the double rope structure were changed as shown in Table 5. The results are shown in Table 5.

Example 5

[0109] By using a winding machine, 38 liquid crystal polyester multifilaments ("Vectran" produced by KURARAY CO., LTD., fineness: 1670 dtex) as high strength and high modulus fibers are wound onto a bobbin under a certain tension to produce a bundled yarn, and 38 bundled yarns are produced. The bundled yarns are further wound onto a bobbin by using the winding machine under a certain tension to obtain a strand for braiding (fineness: 2,411,480 dtex). Then, the obtained strands for braiding using a 6-strand braider, by adjusting the number of rotations and the taken-up speed of the braider, so as to obtain an inner core rope having a pitch of 0.45 counts/inch.

[0110] By using a winding machine, 20 polyethylene terephthalate multifilaments (fineness: 1100 dtex, yarn tenacity: 6.8 cN/dtex, yarn elastic modulus: 88 cN/dtex, yarn elongation: 14%, available from Toray Industries, Inc.) are wound onto a bobbin under a certain tension to produce a bundled yarn, and 20 bundled yarns are produced. The bundled yarns are wound onto a bobbin while the bundled yarns are being twisted 10 turns/meter in a Z direction by using a yarn twister under a certain tension to obtain a twisted strand for braiding (fineness: 456,000 dtex). Then, a double rope structure (diameter a of outer periphery of inner core: 48 mm, and diameter b of outer periphery of outer cover: 76 mm) with the inner-and-outer-layer suitability of 1.00 can be produced using the inner core rope as a core material by using a 32-strand braider, by adjusting the number of rotations and the taken-up speed of the braider, so as to have a pitch of 3.1 counts/inch.

Comparative Example 1

[0111] A double rope structure was produced in the same manner as Example 1 except that the number of strands and a pitch for the inner core and a pitch for the outer cover of the double rope structure were changed as shown in Table 5. The results are shown in Table 5.

Comparative Example 2

[0112] A double rope structure was produced in the same manner as Example 2 except that a pitch for the inner core and fineness and the number of strands for the outer cover of the double rope structure were changed as shown in Table 5. The results are shown in Table 5.

Comparative Example 3

[0113] A double rope structure was produced in the same manner as Example 3 except that the number of strands and a pitch for the inner core and fineness and a pitch for the outer cover of the double rope structure were changed as shown in Table 5. The results are shown in Table 5.

Comparative Example 4

[0114] A double rope structure was produced in the same manner as Example 4 except that a pitch for the inner core and fineness and the number of strands for the outer cover of the double rope structure were changed as shown in Table 5. The results are shown in Table 5.

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results are shown in Table 5.

Comparative Example 5

[0115] A double rope structure was produced in the same manner as Example 1 except that fibers for the inner core of the double rope structure were changed to polyethylene terephthalate multifilaments (fineness: 1670 dtex, yarn tenacity: 8.0 cN/dtex, yarn elastic modulus: 143 cN/dtex, yarn elongation: 12.6%, available from Toray Industries, Inc.), a pitch for the inner core was changed to 9.6, the number of strands for the inner core was changed to 12, and a pitch for the outer cover was changed to 55. The results are shown in Table 5.

Table 5

		Ex. 1	Ex. 2	Ex. 3	Ex. 4	Comp. Ex. 1	Comp. Ex. 2	Comp. Ex. 3	Comp. Ex. 4	Comp. Ex. 5
Inner core	Fiber	Vectran	Vectran	Isanas	Isanas	Vectran	Vectran	Isanas	Isanas	PET
	Density	1.40	1.40	0.98	0.98	1.40	1.40	0.98	0.98	1.39
	Yarn fineness (dtex)	1670	1670	1760	1760	1670	1670	1760	1760	1670
	Yarn strength (N)	430	430	415	415	430	430	415	415	133
	Yarn tenacity (cN/dtex)	25.7	25.7	23.6	23.6	25.7	25.7	23.6	23.6	8.0
	Yarn elastic modulus (cN/dtex)	465	465	496	496	465	465	496	496	143
	Yarn elongation (%)	4.4	4.4	5.0	5.0	4.4	4.4	5.0	5.0	12.6
	Number of strands	6	4	6	4	12	4	4	4	12
	Pitch (count-s/inch)	8.6	8.0	8.5	8.2	9.1	8.2	8.1	8.1	9.6
	Diameter (mm)	1.5	1.3	1.7	1.4	2.0	1.2	1.5	1.4	1.6
	Yarn length/rope length	1.08	1.10	1.09	1.10	1.04	1.09	1.09	1.07	1.06
	Crossing angle (°)	17	18	19	24	19	19	25	24	20
Outer cover	Fiber	PET	PET	PET	PET	PET	PET	PET	PET	PET
	Yarn fineness (dtex)	280	440	280	560	280	560	440	1670	220
	Number of strands	32	32	32	16	32	16	32	32	32
	Pitch (count-s/inch)	50	25	49	25	47	25	26	25	55
	Density	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39

(continued)

			Ex. 1	Ex. 2	Ex. 3	Ex. 4	Comp. Ex. 1	Comp. Ex. 2	Comp. Ex. 3	Comp. Ex. 4	Comp. Ex. 5
5	Double rope struc- ture	Volume ratio (vol%)	50.8	32.8	59.6	51.7	65.8	41.8	42.2	13.6	50.0
		Diameter (mm)	2.1	2.3	2.2	1.9	2.2	1.6	3.1	4.8	2.2
10		Inner-and- outer-layer suitability	1.00	0.97	1.00	1.05	1.26	1.34	0.55	0.62	1.06
15	Physical properties	Tensile strength per cross-sec- tional area (N/mm ²)	974.9	240.8	500.1	352.9	921.2	497.6	159.1	138.2	210.6
20		Strength re- tention (%) after bending test	97	100	97	99	81	83	103	101	95

25 **[0116]** As shown in Table 5, in any of Examples 1 to 4, the inner-and-outer-layer suitability of the double rope structure is in a range of 0.70 to 1.20, the strength retention (%) after the bending test is 90% or more, and the tensile strength per cross-sectional area is 180 N/mm² or more in the double rope structure.

30 **[0117]** On the other hand, in Comparative Examples 1 and 2, the inner-and-outer-layer suitability of the double rope structure exceeds 1.20 and the strength retention after the bending test is poor compared to those of Examples. In addition, in Comparative Examples 3 and 4, the inner-and-outer-layer suitability of the double rope structure is less than 0.70, and the tensile strength per cross-sectional area is poor compared to those of Examples. Since fibers constituting the inner core are non-high strength and non-high modulus fibers in Comparative Example 5, the strength of the entire rope structure is halved compared to the rope structure of Example 1 having almost the same diameter.

INDUSTRIAL APPLICABILITY

35 **[0118]** The double rope structure according to the present invention can be advantageously used in the field such as: applications in water for mooring ropes for vessels, bolt ropes for fishing nets, ropes for mooring floating waterborne facilities on the surface of water, and marine ropes for mooring floating marine structures used for exploration of marine resources to the ocean floor; applications in water such as traction ropes and load ropes, as well as ropes for wind power station and transforming equipment; applications on land such as traction ropes and load ropes; and further applications for sports and leisure, and others.

40 **[0119]** Although the present invention has been described above in connection with the preferred embodiments thereof with reference to the accompanying drawings, those skilled in the art can make numerous additions, changes, or deletions without departing from the gist of the present invention upon the reading of the specification herein presented of the present invention. Therefore, such additions, changes, and deletions are also construed as included within the scope of the present invention.

Claims

50 1. A double rope structure comprising an inner core and an outer cover, wherein the inner core comprises high strength and high modulus fibers with a yarn tenacity of 20 cN/dtex or more and a yarn elastic modulus of 400 cN/dtex or more, and

55 an inner-and-outer-layer suitability represented by the following formula (1) is 0.70 to 1.20,

$$(a^2 / b^2) / Vf \times 100 \quad (1)$$

wherein a represents a diameter of an outer periphery of the inner core, b represents a diameter of an outer periphery of the outer cover, and Vf represents a volume ratio (%) of a volume of the inner core to a total volume of the inner core and the outer cover.

- 5 **2.** The double rope structure according to claim 1, wherein the volume ratio Vf of the volume of the inner core to the total volume of the inner core and the outer cover is 10% or larger.
- 10 **3.** The double rope structure according to claim 1, wherein the double rope structure has a ratio of yarn length/rope length of 1.005 or more and 1.400 or less, the rope length being determined as a length of a cut section of the double rope structure cut to a certain length, the yarn length being determined as an average value of lengths of yarns constituting the inner core of the cut section.
- 15 **4.** The double rope structure according to any one of claims 1 to 3, wherein a tensile strength per cross-sectional area of the double rope structure is 180 N/mm² or more, the tensile strength being measured in accordance with JIS L 1013:2021.
- 20 **5.** The double rope structure according to any one of claims 1 to 4, wherein the high strength and high modulus fibers have a yarn elongation of 1 to 6%.
- 25 **6.** The double rope structure according to any one of claims 1 to 5, wherein the high strength and high modulus fibers are at least one selected from the group consisting of liquid crystal polyester fibers, ultra-high molecular weight polyethylene fibers, aramid fibers, and poly(para-phenylene benzobisoxazole) fibers.
- 30 **7.** The double rope structure according to any one of claims 1 to 6, wherein a ratio of a tenacity of fibers used for the outer cover to a tenacity of fibers used for the inner core is 0.10 to 0.40.
- 35 **8.** The double rope structure according to any one of claims 1 to 7, wherein the outer cover substantially comprises non-high strength and non-high modulus fibers.
- 40 **9.** The double rope structure according to any one of claims 1 to 8, wherein the outer cover comprises multifilaments.
- 45 **10.** The double rope structure according to any one of claims 1 to 9, wherein a ratio of a tensile strength of the double rope structure after a bending test to a tensile strength of the double rope structure before the bending test is 90% or more, in which the bending test, the double rope structure is subjected to repeated bending of 10,000 times under a load of 1% of a tensile break strength of the double rope structure at a bending angle of 240° with a bending R of 7.5 mm.
- 50
- 55

Fig. 1

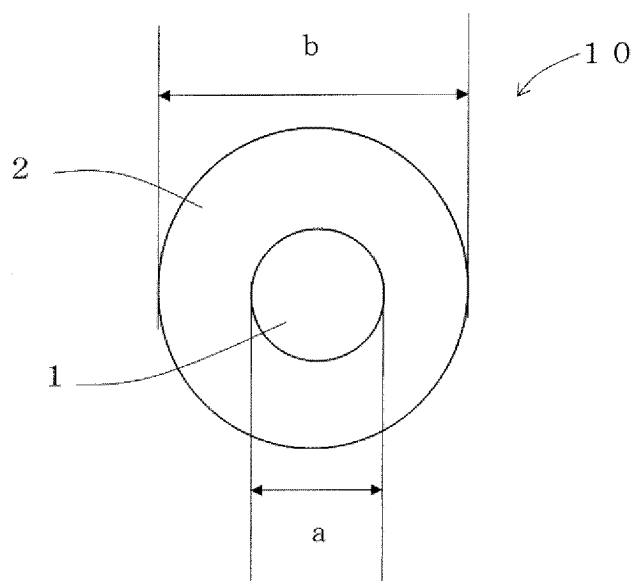


Fig. 2

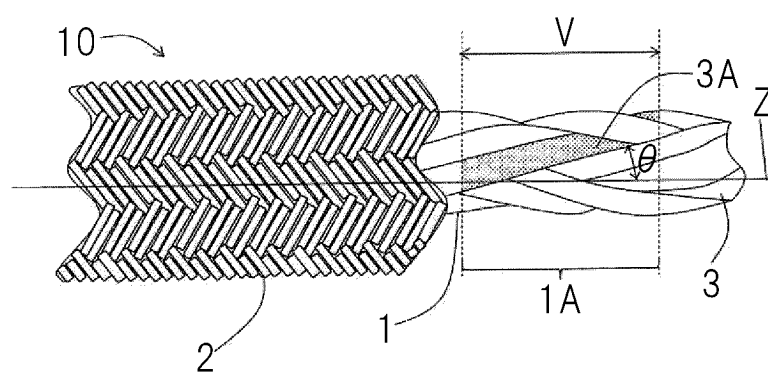


Fig. 3

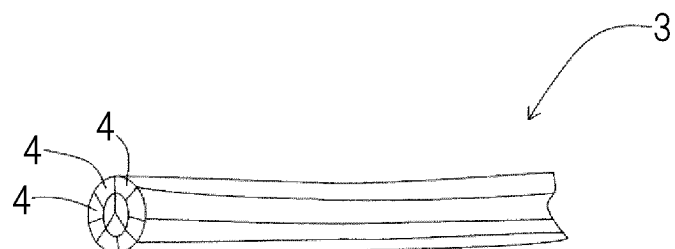


Fig. 4

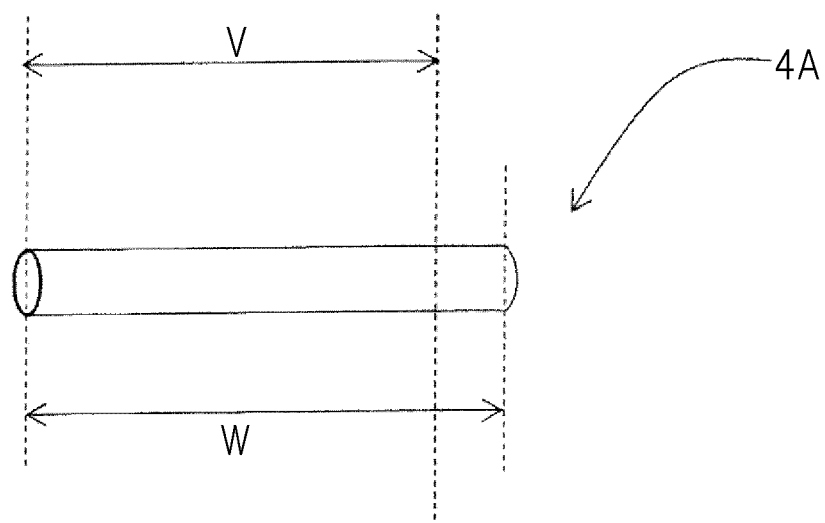
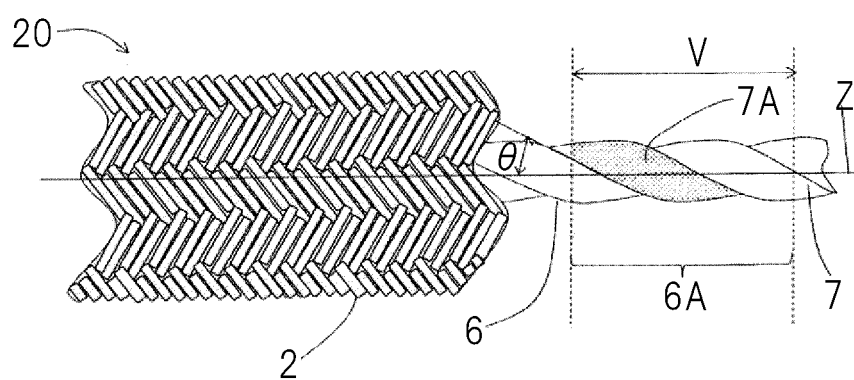


Fig. 5



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2023/023581

A. CLASSIFICATION OF SUBJECT MATTER**D07B 1/02**(2006.01)i

FI: D07B1/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

D07B1/00-9/00; D04C1/00-7/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996
 Published unexamined utility model applications of Japan 1971-2023
 Registered utility model specifications of Japan 1996-2023
 Published registered utility model applications of Japan 1994-2023

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 7-165164 A (TOYO BOSEKI) 27 June 1995 (1995-06-27) paragraphs [0004], [0014], [0025]-[0042], examples 1, 3-6, tables 1-5, fig. 1	1-10
A	JP 2011-111692 A (SEIWA CO LTD) 09 June 2011 (2011-06-09) claims, paragraphs [0031]-[0041], examples, tables 1-2, fig. 1-2	1-10
A	JP 2002-105878 A (KURISANSEMAMU KK) 10 April 2002 (2002-04-10) claims	1-10

☐ Further documents are listed in the continuation of Box C.
 ☒ See patent family annex.

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Date of the actual completion of the international search

09 August 2023

Date of mailing of the international search report

29 August 2023

Name and mailing address of the ISA/JP

Japan Patent Office (ISA/JP)
 3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915
 Japan

Authorized officer

Telephone No.

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2023/023581

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Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
JP	7-165164	A	27 June 1995	(Family: none)	
JP	2011-111692	A	09 June 2011	(Family: none)	
JP	2002-105878	A	10 April 2002	(Family: none)	

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2022101743 A [0001]
- JP 3199266 U [0004] [0005]