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(54) [Title of Invention] FIBER OPTIC CABLE

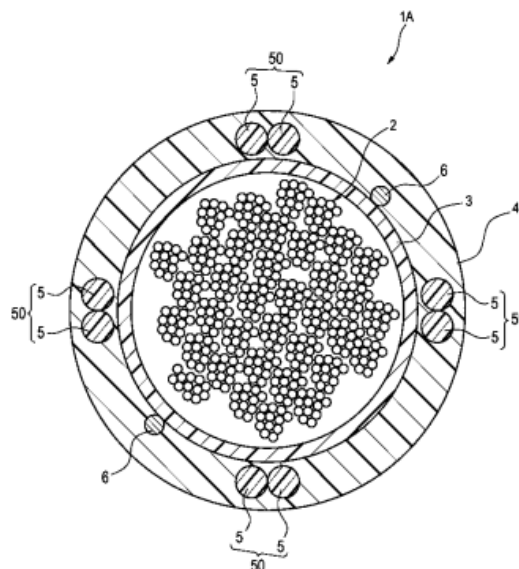
(57) [Abstract]

[Problem] To provide a fiber optic cable having favorable pneumatic feeding characteristics.

[Resolution Means] A fiber optic cable 1A, provided with a plurality of fiber optic cores or a plurality of fiber optic tape cores 2, a cable outer cover 4 containing the plurality of fiber optic cores or the plurality of fiber optic tape cores 2, and eight or more tensile strength bodies 5 provided so as to be embedded within the cable outer cover 4, being pairs of two, wherein each pair of two of the tensile strength bodies 5 is provided at opposing position across the center of the fiber optic cable 1A in a sectional view, the eight or more tensile strength bodies 5 are disposed to include a straight line connecting each pair of two at positions orthogonal in a sectional view, and a cable outer diameter is 6 mm or more and 16 mm or less.

[Selected Drawing] FIG. 1

FIG. 1



[Scope of Patent Claims]

[Claim 1]

A fiber optic cable, comprising:

a plurality of fiber optic cores or a plurality of fiber optic tape cores;

a cable outer cover containing the plurality of fiber optic cores or the plurality of fiber optic tape cores; and
eight or more tensile strength bodies provided so as to be embedded within the cable outer cover, being pairs of two,
wherein:

each pair of two of the tensile strength bodies is provided at opposing position across the center of the fiber optic cable
in a sectional view;

the eight or more tensile strength bodies are disposed to include a straight line connecting each pair of two at positions
orthogonal in a sectional view; and

a cable outer diameter is 6 mm or more and 16 mm or less.

[Claim 2]

The fiber optic cable according to claim 1, wherein

a bending rigidity of the fiber optic cable in the radial direction is $0.35 \text{ N}\cdot\text{m}^2$ or more and $1.3 \text{ N}\cdot\text{m}^2$ or less in the full
circumferential direction.

[Claim 3]

The fiber optic cable according to claim 1 or claim 2, wherein

the tensile strength body is an aramid FRP.

[Claim 4]

The fiber optic cable according to claim 1 or 2, wherein the tensile strength body is a liquid crystal polymer.

[Claim 5]

The fiber optic cable according to any one of claims 1 to 4, wherein the cable outer cover includes a silicon-based
lubricant.

[Claim 6]

The fiber optic cable according to claim 5, wherein the silicon-based lubricant contained in the cable outer cover is
3% by mass or more.

[Claim 7]

The fiber optic cable according to any one of claims 1 to 6, wherein the cable outer cover has protrusions protruding
in a radial direction of the fiber optic cable in an outer peripheral portion.

[Claim 8]

The fiber optic cable according to claim 7, wherein the protrusion is formed in a helical shape in a longitudinal
direction of the fiber optic cable.

[Claim 9]

The fiber optic cable according to any one of claims 1 to 8, wherein the cable outer cover includes flame retardant
PVC or flame retardant polyethylene having an oxygen index of 50 or more.

[Claim 10]

The fiber optic cable according to any one of claims 1 to 9, wherein the fiber optic core or the fiber optic tape core has
a glass fiber and a coating covering an outer periphery of the glass fiber, the coating includes two layers, the outer coating
layer is a cured resin composition containing a base resin having a urethane acrylate oligomer or urethane methacrylate
oligomer, a monomer having a phenoxy group, a photoinitiator, and a silane coupling agent, and hydrophobic inorganic
oxide particles, and the content of the inorganic oxide particles is from 1% to 45% by mass based on the total amount of
the resin composition.

[Claim 11]

The fiber optic cable according to any one of claims 1 to 10, wherein the fiber optic core or the fiber optic tape core
constituting the fiber optic tape core has a bending loss of 1550 nm in a wavelength of 0.5 dB or less for a bending diameter
of $\phi 15 \text{ mm} \times 1 \text{ turn}$ and 0.1 dB or less for a bending diameter of $\phi 20 \text{ mm} \times 1 \text{ turn}$.

[Detailed Description of Invention]

[Technical Field]

[0001]

The present disclosure relates to a fiber optic cable.

[Background Art]

[0002]

Patent document 1 teaches a fiber optic cable having an intermittently connected fiber optic tape core within a pipe.

Patent document 2 teaches a fiber optic cable in which is mounted a unit formed by winding an identification thread

around the periphery of a fiber optic bundle formed by assembling a plurality of single-core coated fiber optics constituting an intermittently connected fiber optic tape core.

Patent document 3 teaches a slot rod type fiber optic cable.

[Prior Art Documents]

[Patent Documents]

[0003]

[Patent Document 1] JP 2015-517679 A (Translation of PCT Application)

[Patent Document 2] JP 2010-8923 A

[Patent Document 3] JP 2014-71441 A

[Summary of Invention]

[Problem to Be Solved by Invention]

[0004]

When the fiber optic cable has a structure having tensile bodies on both sides of the outer covering, it tends to bend easily in the direction of 90 degrees with respect to the line connecting the tensile bodies in the cross-sectional view, and the bending rigidity in that direction tends to be low. Conversely, it is difficult to bend in the direction in which the tensile strength body is located, and the bending rigidity tends to be large in that direction. In other words, fiber optic cables of the above structure have anisotropic bending.

When the fiber optic cable for pneumatic feeding is made into the above structure, due to having anisotropic bending, bending in a direction with low bending rigidity is easy when feeding pneumatically or pushing in the duct, and there is a risk of buckling in the middle of the duct. Thus, it is difficult to obtain favorable pneumatic feeding characteristics for fiber optic cables for pneumatic feeding having a structure such as the foregoing.

[0005]

In addition, in order to reduce the diameter and weight of the fiber optic cable for pneumatic feeding, the cable outer cover of the cable is thinned and a hard cable outer cover is often used, in which case only a slight tensile force is put into the cable outer cover, and it is difficult to reduce stiffness and suppress linear expansion of the cable outer cover. On the other hand, when the structure is arranged around a large diameter tensile strength body or a plurality of tensile strength bodies bundled together, such as a fiber optic cable of the loose tube type or a slot rod type, the inner space is reduced by the volume of the tensile strength body, and thus it is difficult to increase the core density of the fiber optic cable.

[0006]

The present disclosure is intended to provide a fiber optic cable having favorable pneumatic feeding characteristics.

[Means For Solving Problem]

[0007]

The fiber optic cable according to one aspect of the present disclosure is provided with:

a plurality of fiber optic cores or a plurality of fiber optic tape cores;

a cable outer cover containing the plurality of fiber optic cores or the plurality of fiber optic tape cores; and

eight or more tensile strength bodies provided so as to be embedded within the cable outer cover, being pairs of two, wherein:

each pair of two of the tensile strength bodies is provided at opposing position across the center of the fiber optic cable in a sectional view;

the eight or more tensile strength bodies are disposed to include a straight line connecting each pair of two at positions orthogonal in a sectional view; and

a cable outer diameter is 6 mm or more and 16 mm or less.

[Effect of Invention]

[0008]

According to the present disclosure, it is possible to provide a fiber optic cable having favorable pneumatic feeding characteristics.

[Brief Description of Drawings]

[0009]

[FIG. 1] A sectional view illustrating a configuration of the fiber optic cable according to a first embodiment.

[FIG. 2] A plan view illustrating one example of a fiber optic tape core housed in a fiber optic cable.

[FIG. 3] A sectional view illustrating a configuration of the fiber optic cable according to a second embodiment.

[FIG. 4] A side view of the fiber optic cable illustrated in FIG. 3.

[FIG. 5] A schematic diagram illustrating a cable pneumatic feeding evaluation device.

[Embodiments of Invention]

[0010]

(Description of Embodiments of Present Disclosure)

First, embodiments of the present disclosure will be described in a list.

The fiber optic cable according to one aspect of the present disclosure is

(1) provided with:

a plurality of fiber optic cores or a plurality of fiber optic tape cores;

a cable outer cover containing the plurality of fiber optic cores or the plurality of fiber optic tape cores; and
eight or more tensile strength bodies provided so as to be embedded within the cable outer cover, being pairs of two,
wherein:

each pair of two of the tensile strength bodies is provided at opposing position across the center of the fiber optic cable
in a sectional view;

the eight or more tensile strength bodies are disposed to include a straight line connecting each pair of two at positions
orthogonal in a sectional view; and

a cable outer diameter is 6 mm or more and 16 mm or less.

According to the fiber optic cable of the above configuration, there are eight or more tensile strength bodies in which
two or more of them are paired in a balanced manner, and thus anisotropic bending of the fiber optic cable (bias in the
direction of bending ease) can be suppressed. Therefore, it is possible to suppress buckling within the duct, for example,
when the fiber optic cable is pneumatically fed or pushed in the duct. Therefore, the fiber optic cable of the above
configuration can obtain favorable pneumatic feeding characteristics. Moreover, the outer diameter of the cable is 16 mm
or less, and thus such can be housed in a general microduct of an inner diameter of 20 mm or less. When the outer diameter
of the cable is less than 6 mm, the occurrence of buckling during pneumatic feeding is more likely when the microduct is
laid while bent at a small diameter, but the fiber optic cable of the above configuration has an outer diameter of 6 mm or
more, and thus the occurrence of buckling during pneumatic feeding can be suppressed.

[0011]

(2) A bending rigidity of the fiber optic cable in the radial direction is may be $0.35 \text{ N}\cdot\text{m}^2$ or more and $1.3 \text{ N}\cdot\text{m}^2$ or less
in the full circumferential direction.

According to the fiber optic cable of the above configuration, a moderate bending rigidity suitable for pneumatic
feeding can be obtained due to being within the above bending rigidity range. In addition, because the bending rigidity in
the radial direction is $0.35 \text{ N}\cdot\text{m}^2$ or more in the full circumferential direction, buckling when the fiber optic cable is fed
pneumatically can be suppressed, and because the bending rigidity in the radial direction is $1.3 \text{ N}\cdot\text{m}^2$ or less in the full
circumferential direction, the retractability when storing the excess length of the fiber optic cable is favorable.

[0012]

(3) The above tensile strength body may be a aramid FRP.

(4) The above tensile strength body may be a liquid crystal polymer.

Aramid FRPs and liquid crystal polymers have relatively high elastic modulus, and thus the cable stiffness can be
reasonably high. Furthermore, aramid FRPs and liquid crystal polymers have relatively low coefficients of linear
expansion, which can reduce the shrinkage of fiber optic cables under low temperature conditions. In addition, aramid
FRPs and liquid crystal polymers are non-inductive, and thus there is no need to provide grounding for lightning protection.

[0013]

(5) The cable outer cover may contain a silicon-based lubricant.

According to the fiber optic cable of the above configuration, the cable outer cover contains a silicon-based lubricant,
and thus the coefficient of friction of the cable outer cover can be lowered. As a result, friction between the cable outer
cover and the duct is reduced when the fiber optic cable is pneumatically fed in the duct, and the pneumatic feeding distance
can be increased.

[0014]

(6) The silicon-based lubricant contained in the cable outer cover may be 3% by mass or more.

According to the fiber optic cable of the above configuration, the cable outer cover contains 3% by mass or more of
the silicon-based lubricant, and thus the coefficient of friction of the cable outer cover can be lowered more reliably.

[0015]

(7) The cable outer cover may have protrusions protruding in a radial direction of the fiber optic cable at the outer
peripheral portion.

According to the fiber optic cable of the above configuration, there are protrusions protruding in the radial direction
of the fiber optic cable on the outer peripheral portion of the cable outer cover, and thus the contact area between the cable
outer cover and the duct can be reduced when the fiber optic cable is fed pneumatically in the duct. This reduces the friction
between the cable outer cover and the duct and increases the pneumatic feeding distance.

[0016]

(8) The protrusion may be formed in a helical shape in a longitudinal direction of the fiber optic cable.

According to the fiber optic cable of the above configuration, the above protrusion is formed in a helical shape in the

longitudinal direction of the fiber optic cable, and thus the contact resistance can be further reduced because the inner wall of the duct and the fiber optic cable are in point contact.

[0017]

(9) The cable outer cover may include flame retardant PVC or flame retardant polyethylene having an oxygen index of 50 or more.

Although it is difficult to improve the flame retardancy of the fiber optic cable for pneumatic feeding because the cable outer cover has a thin structure, the flame retardancy can be improved by using flame retardant PVC or flame retardant polyethylene having an oxygen index of 50 or more for the cable outer cover according to the fiber optic cable of the above configuration.

[0018]

(10) The fiber optic core or the fiber optic tape core may have a glass fiber and a coating covering an outer periphery of the glass fiber, the coating including two layers, the outer coating layer being a cured resin composition containing a base resin having a urethane acrylate oligomer or urethane methacrylate oligomer, a monomer having a phenoxy group, a photoinitiator, and a silane coupling agent, and hydrophobic inorganic oxide particles, and the content of the inorganic oxide particles being from 1% to 45% by mass based on the total amount of the resin composition.

According to the fiber optic cable of the above configuration, the lateral pressure resistance of the fiber optic core becomes stronger due to using the above resin composition as the outer coating layer constituting the coating in the fiber optic core. This reduces increase in transmission loss of fiber optic cables.

[0019]

(11) The fiber optic core or the fiber optic tape core constituting the fiber optic tape core may have a bending loss of 1550 nm in a wavelength of 0.5 dB or less for a bending diameter of $\phi 15$ mm $\times$ 1 turn and 0.1 dB or less for a bending diameter of $\phi 20$ mm $\times$ 1 turn.

According to the fiber optic cable of the above configuration, the side pressure characteristic can be improved and the low temperature loss characteristic improved.

[0020]

(Details of Embodiments of Present Disclosure)

Specific example of the fiber optic cable according to embodiment of the present disclosure will be described below with reference to the drawings.

Note that the present invention is not limited to these examples, but is indicated by the Scope of Patent Claims and is intended to include all modifications within the meanings and scope equivalent to the Scope of Patent Claims.

[0021]

(First Embodiment)

A fiber optic cable 1A according to a first embodiment will be described with reference to FIG. 1 and FIG. 2.

FIG. 1 is a sectional view perpendicular to the length direction of the fiber optic cable 1A. As illustrated in FIG. 1, the fiber optic cable 1A is provided with a plurality of fiber optic tape cores 2, a water absorption tape 3 covering the circumference of the fiber optic tape cores 2, an cable outer cover 4 containing the fiber optic tape cores 2 covered by the water absorption tape 3, and a tensile strength body 5 and a tear string 6 provided inside the cable outer cover 4.

[0022]

The water absorption tape 3 is wound around the entirety of the plurality of fiber optic tape cores 2, for example, vertically or horizontally. The water absorption tape 3 is subjected to water absorbing treatment by adhering water absorbing powder to a base fabric made of, for example, polyester or the like.

[0023]

The cable outer cover 4 is provided to cover around the water absorption tape 3. The cable outer cover 4 is formed from, for example, a resin such as polyvinyl chloride (PVC) or polyethylene (PE). The resin of the cable outer cover 4 preferably has a Young's modulus of 500 Pa or more. Also, a silicon-based lubricant is preferably contained in the cable outer cover 4. The silicon-based lubricant content is, for example, 2 wt% or more, preferably 3 wt% or more to 5 wt% or less.

[0024]

Furthermore, the cable outer cover 4 is preferably formed from a resin having high flame retardancy. The cable outer cover 4 is formed from, for example, flame retardant PVC, flame retardant polyethylene, or the like having an oxygen index of 50 or more. As a result, the fiber optic cable 1A conforms to the UL 1666 riser grade of the NEC (National Electronic Code) standard in North America, and to the Cca class of the CPR (Construction Products Regulation) standard in Europe. The cable outer cover 4 is, for example, a thermoplastic resin and is formed by extrusion molding a resin on the plurality of fiber optic tape cores 2 having the water absorption tape 3 wound thereon.

[0025]

The tensile strength body 5 is provided so as to be embedded inside the cable outer cover 4. The tensile strength body

5 is formed from, for example, a fiber reinforced plastic (FRP) such as an aramid FRP, a glass FRP, or a carbon FRP. In addition, the tensile strength body 5 may be formed from a liquid crystal polymer. It is preferable that the tensile strength body 5 is non-inductive.

[0026]

The tensile strength body 5 is formed in a circular shape in a cross-sectional view. Eight or more tensile strength bodies 5 (eight in this example) are provided. The eight tensile strength bodies 5 in this example are provided in pairs of two each. The two paired tensile strength bodies 5 are provided, for example, close to each other or in contact with at least a part of each other. Each tension in body 5 is provided in the cable outer cover 4 in the longitudinal direction of the fiber optic cable 1A. In the following description, the two paired tensile strength bodies 5 are collectively referred to as a tensile strength body unit 50.

[0027]

In this example, four tensile strength body units 50 are provided. The four tensile strength body units 50 are provided as two pairs of two tensile strength body units 50 at opposing positions across the center of the fiber optic cable 1A in a cross-sectional view of the fiber optic cable 1A. The positions of the four tensile strength body units 50 in the cross-sectional view are such that two straight lines connecting each of the two paired tensile strength body units 50 are orthogonal.

[0028]

Note that, for example, when the number of tensile strength bodies 5 is more than 8 and the number of tensile strength body units 50 is more than 4, each tensile strength body unit 50 is provided in the cable outer cover 4 so that the spacing between adjacent tensile strength body units 50 is equal.

[0029]

The tear string 6 is for tearing the cable outer cover 4 and is embedded in the cable outer cover 4 in the longitudinal direction of the fiber optic cable 1A. In the present example, two tear strings 6 are provided. The two tearing strings 6 are provided to face each other at approximately the center position of adjacent tensile strength body units 50. By pulling out the tear string 6, the cable outer cover 4 can be torn in the longitudinal direction and the fiber optic tape core 2 pulled out. The tear string 6 is formed from, for example, a plastic material (for example, polyester) strong against pulling.

[0030]

FIG. 2 illustrates one example of the fiber optic tape core 2 housed in the fiber optic cable 1A. As illustrated in FIG. 2, the fiber optic tape core 2 is an intermittently connected fiber optic tape core having a connected part 12 connected between adjacent fiber optic cores and a unconnected part 13 not connected between adjacent fiber optic cores in the longitudinal direction, a plurality of fiber optic cores 11A to 11L being disposed in parallel.

[0031]

The fiber optic tape core 2 of the present example has 12 fiber optic cores 11A to 11L disposed in parallel. FIG. 2 illustrates a plan view of the intermittently connected fiber optic tape core 2 with the fiber optic cores 11A to 11L open in the array direction and a cross-sectional view of the fiber optic core 11A. Where the connecting portion 12 and the disjoint portion 13 are intermittently provided may be between some fiber optic cores (intermittent per two cores) as shown in FIG. 2, or between all fiber optic cores (intermittent per one core). In the example illustrated in FIG. 2, there is no unconnected part 13 between the fiber optic cores 11A and 11B, 11C and 11D, 11E and 11F, 11G and 11H, 11I and 11J, 11K and 11L.

[0032]

The connected part 12 in the fiber optic tape core 2 is formed by applying a connecting resin 14 composed of, for example, ultraviolet curing resin or thermosetting resin between the fiber optic cores. By applying the connecting resin 14 between the predetermined fiber optic cores, the connected part 12 and the unconnected part 13 are intermittently provided, and each of the fiber optic cores 11A to 11L is integrated in a parallel state. The connecting resin 14 may be applied to only one side of the parallel faces formed by parallel fiber optic cores 11A to 11L or may be applied to both sides. In addition, the fiber optic tape core 2 may be fabricated so that, for example, a tape resin is applied to one side or to the entirety of both sides of the parallel fiber optic cores 11A to 11L, and all fiber optic cores 11A to 11L are connected together, and then a portion is cut using a rotary blade or the like to form the unconnected part 13.

[0033]

The fiber optic cores 11A to 11L have a glass fiber 15 configured from, for example, a core and a cladding, and two coating layers 16 and 17 covering the periphery of the glass fiber 15. The inner coating layer 16 among the two layers is formed from a primary resin. Also, the outer coating layer 17 of the two layers is formed from a secondary resin. The fiber optic cores 11A to 11L are so-called small diameter cores, and an outer diameter A thereof is, for example, 165 μm or more and 220 μm or less.

[0034]

For the primary resin constituting the inner coating layer 16 in contact with the glass fiber 15, a flexible resin having a relatively low Young's modulus is used as a buffer layer. Also, for the secondary resin comprising the outer coating layer

17, a hard resin having a relatively high Young's modulus is used as a protection layer. The secondary resin has, for example, a Young's modulus of 900 MPa or more at 23°C, preferably 1,000 MPa or more, and more preferably 1,500 MPa or more.

[0035]

The secondary resin that will constitute the coating layer 17 is preferably a resin composition including: a base resin containing a urethane acrylate oligomer or a urethane methacrylate oligomer, a monomer having a phenoxy group, a photoinitiator, and a silane coupling agent; and hydrophobic inorganic oxide particles. The content of inorganic oxide particles in the resin composition is 1% by mass or more to 45% by mass or less based on the total amount of the resin composition.

[0036]

Hereinafter, acrylates or their corresponding methacrylates are referred to as (meth)acrylates.

[0037]

Oligomers obtained by reacting polyol compounds, polyisocyanate compounds, and hydroxyl-containing (meth)acrylate compounds may be used as the urethane (meth)acrylate oligomer. This oligomer is obtained, for example, by reacting polypropylene glycol having a molecular weight of 4000, isophorone diisocyanate, hydroxyethyl acrylate, and methanol.

[0038]

(Meth)acrylate compounds having phenoxy groups can be used as monomers having phenoxy groups. For example, the monomer having phenoxy groups is nonylphenol EO modified acrylate (trade name "Aronix M-113" from Toagosei Co., Ltd.) or the like.

[0039]

The photoinitiator can be used by suitably selecting from publicly known radical photoinitiators, for example, 2,4,6-trimethylbenzoyldiphenylphosphine oxide.

[0040]

The silane coupling agent is not particularly limited unless it interferes with the curing of the resin composition. For example, the silane coupling agent is 3-mercaptopropyltrimethoxysilane or the like.

[0041]

Hydrophobic inorganic oxide particles have hydrophobic groups introduced on the surface of inorganic oxide particles. The inorganic oxide particles are, for example, silica particles. The hydrophobic group may be a reactive group such as a (meth)acryloyl group or a vinyl group, or a non-reactive group such as a hydrocarbon group (for example, an alkyl group) or an aryl group (for example, a phenyl group).

[0042]

Lateral pressure characteristics of the fiber optic cores 11A to 11L are improved by blending inorganic oxide particles with the secondary resin that will constitute the coating layer 17. The primary resin constituting the coating layer 16 and the secondary resin are formed from, for example, ultraviolet curing resin, thermosetting resin, or the like.

[0043]

The fiber optic tape cores 2 are rounded and aggregated when they are housed within the fiber optic cable 1A. Alternatively, the plurality of fiber optic tape cores 2 may be twisted together to form a unit, and a plurality of units may be housed in an aggregated state. Note that the plurality of fiber optic tape cores 2 in the aggregated state may be bundled via a bundling material or the like, or may be bundled via a bundling material or the like by unit.

[0044]

In the fiber optic cable 1A having the above configuration, it is preferable that the ratio of the total cross-sectional area of the eight tensile strength bodies 5 (four tensile strength body units 50) to the cross-sectional area of the cable outer cover 4 is 5.4% or more. The outer diameter of the fiber optic cable 1A is 6 mm or more and 16 mm or less; for example, when the outer diameter of the fiber optic cable 1A is 10 mm, the thickness of the cable outer cover 4 is 1.0 mm, and eight tensile bodies 5 of the outer diameter 0.5 mm are provided in the cable outer cover 4, the ratio of the total cross-sectional area is 5.6%. In addition, it is desirable that the bending rigidity in the radial direction in the fiber optic cable 1A is 0.35 N·m² or more and 1.3 N·m² or less in the full circumferential direction.

[0045]

In addition, it is preferable that a core density obtained by dividing the total number of fiber optic cores constituting the plurality of fiber optic tape cores 2 by the cable cross-sectional area of the fiber optic cable 1A be 5.0 cores/mm² or more. For example, when an outer diameter A of the fiber optic cable 1A is 10 mm, the thickness of the cable outer cover 4 is 1.0 mm, and the outer diameter of the fiber optic core is 200 μm, when the number of the 12-core fiber optic tape cores 2 housed within the cable outer cover 4 of the fiber optic cable 1A is 36, the total number of fiber optic cores at that time is 432, making for a core density of 5.5 cores/mm². Note that, considering that this will be fed pneumatically, it is desirable that the unit weight of the fiber optic cable 1A is 100 kg/km or less.

[0046]

Note that although a 12-core fiber optic tape core 2 is used in this example, for example, a fiber optic tape core such as 16-core or 24-core may be used. In addition, although the fiber optic tape cores are housed within the fiber optic cable 1A in the present example, such may be housed as-is as a fiber optic core without a taped form. Furthermore, it is preferable that the fiber optic cores 11A to 11L have a bending loss equivalent to ITU-TG.657A2, wherein the bending loss of the wavelength 1550 nm is 0.5 dB or less for a bending diameter $\phi 15$ mm x 1 turn and 0.1 dB or less for a bending diameter $\phi 20$ mm x 1 turn. By using such fiber optic cores, the lateral pressure characteristic can be improved and the low temperature loss characteristic improved.

[0047]

As described above, according to the fiber optic cable 1A according to the first embodiment, the tensile tension body units 50, each of which is configured from two pairs of tensile strength bodies 5, are disposed in a balanced manner inside the cable outer cover 4, and thus anisotropic bending of the fiber optic cable 1A (deviation in the direction of easy bending) can be suppressed.

Thus, it is possible to suppress buckling within the duct, for example, when the fiber optic cable 1A is pneumatically fed or pushed in the duct. Therefore, the fiber optic cable 1A can be provided with favorable pneumatic feeding characteristics.

[0048]

In addition, the outer diameter of the fiber optic cable 1A is 16 mm or less, and thus the fiber optic cable 1A can be pneumatically fed into a microduct having an inner diameter of 20 mm or less and can be housed in the microduct.

[0049]

When the outer diameter of the fiber optic cable is less than 6 mm, once the duct is bent to a small diameter and laid, it is likely that buckling will occur in the fiber optic cable during pneumatic feeding. In contrast, the fiber optic cable 1A has an outer diameter of 6 mm or more, and thus the occurrence of buckling during pneumatic feeding can be suppressed.

[0050]

Furthermore, the fiber optic cable 1A can be provided with a moderate bending rigidity suitable for pneumatic feeding by setting the bending rigidity of the diameter thereof to a range of $0.35 \text{ N}\cdot\text{m}^2$ or more and $1.3 \text{ N}\cdot\text{m}^2$ or less in the full circumferential direction. For example, the bending rigidity in the radial direction is $0.35 \text{ N}\cdot\text{m}^2$ or more in the full circumferential direction, and thus the occurrence of buckling when the fiber optic cable 1A is fed pneumatically can be suppressed. Moreover, the bending rigidity in the radial direction is $1.3 \text{ N}\cdot\text{m}^2$ or less in the full circumferential direction, and thus it is possible to bundle the fiber optic cable 1A to a reasonable size, for example, when storing the extra length of the fiber optic cable 1A in a hand hole, and storability is favorable.

[0051]

In addition, it is preferable that the tensile strength bodies 5 of the fiber optic cable 1A are formed from, for example, aramid FRP or liquid crystal polymer. According to this configuration, aramid FRPs, liquid crystal polymers, and the like have relatively high elastic modulus, and thus the rigidity of the fiber optic cable 1A can be reasonably high. Furthermore, aramid FRPs, liquid crystal polymers, and the like have relatively low coefficients of linear expansion, and thus it is possible to suppress shrinkage of the fiber optic cable 1A due to shrinkage of the cable outer cover 4 under low temperature conditions. In addition, aramid FRPs, liquid crystal polymers, and the like are non-inductive, and thus there is no need to provide grounding for lightning protection.

[0052]

Also, the fiber optic cable 1A preferably contains a silicon-based lubricant in the resin of the cable outer cover 4. According to this configuration, the coefficient of friction of the cable outer cover 4 can be lowered. Also, by setting the silicon-based lubricant contained in the cable outer cover 4 to 3% by mass or more, it is possible to more reliably lower the coefficient of friction of the cable outer cover 4. As a result, friction between the cable outer cover 4 and the duct inner wall can be reduced when the fiber optic cable 1A is pneumatically fed in the duct, and the pneumatic feeding distance can be increased.

[0053]

By way of mention, it is difficult to improve the flame retardancy of fiber optic cables for pneumatic feeding because the cable outer cover is thin. In contrast, the flame retardancy of the fiber optic cable 1A can be increased by forming the cable outer cover 4 from flame retardant PVC or flame retardant polyethylene having an oxygen index of 50 or more.

[0054]

In addition, according to the fiber optic cable 1A, the lateral pressure resistance of the fiber optic cores 11A to 11L can be strengthened by using the curing material of the above resin composition as the outer coating layer 17 constituting the coating of the fiber optic cores 11A to 11L. Therefore, when the fiber optic tape core 2 is configured using such fiber optic cores 11A to 11L, increase in transmission loss when housed in the fiber optic cable 1A can be suppressed.

[0055]

(Second Embodiment)

A fiber optic cable 1B according to a second embodiment will be described with reference to FIG. 3 and FIG. 4. Note that configurations similar to those of the fiber optic cable 1A according to the first embodiment are labelled using the same reference numerals and that the description thereof is omitted.

[0056]

FIG. 3 is a sectional view perpendicular to the longitudinal direction of the fiber optic cable 1B. FIG. 4 is a side view of the fiber optic cable 1B illustrated in FIG. 3.

As illustrated in FIG. 3, the fiber optic cable 1B is provided with a plurality of intermittently connected fiber optic tape cores 2, a water absorption tape 3 covering the circumference of the fiber optic tape cores 2, a cable outer cover 4 containing the fiber optic tape cores 2 covered by the water absorption tape 3, and a tensile strength body 5 and a tear string 6 provided inside the cable outer cover 4. Furthermore, the fiber optic cable 1B has protrusions 7 on the outer peripheral portion of the cable outer cover 4.

[0057]

A plurality of protrusions 7 (eight in this example) are provided. As illustrated in FIG. 4, the eight protrusions 7 are provided in a spiral shape in the longitudinal direction of the fiber optic cable 1B. Each protrusion 7 may be provided continuously in the longitudinal direction or may be provided intermittently. In addition, the eight protrusions 7 are provided in the circumferential direction of the outer peripheral portion of the cable outer cover 4 at approximately equal intervals in a cross-sectional view. The protrusions 7 are formed protruding in the diametric direction of the fiber optic cable 1B on the outer peripheral portion of the cable outer cover 4. The protrusions 7 are formed such that end surfaces 7a in the protruding direction are composed of a curved surface, and the radius of curvature of the curved surface is 2.5 mm or more. The protrusions 7 are formed integrally with the cable outer cover 4 by extrusion. Note that although the eight protrusions 7 are provided in a spiral shape in this example, they may be provided in a linear shape in the longitudinal direction of the fiber optic cable 1B, for example.

[0058]

According to the fiber optic cable 1B of the second embodiment, the plurality of protrusions 7 protruding in the diametric direction of the fiber optic cable 1B are provided in the outer peripheral portion of the cable outer cover 4. Therefore, when the fiber optic cable 1B is fed pneumatically in the duct, the protrusion 7 comes into contact with the inner wall of the duct, and thus the contact area between the cable outer cover 4 and the duct can be reduced. This reduces the friction between the cable outer cover 4 and the duct and increases the pneumatic feeding distance.

[0059]

Also, according to the fiber optic cable 1B, the protrusions 7 of the cable outer cover 4 are formed in a helical shape in the longitudinal direction of the fiber optic cable 1B. As a result, the inner wall of the duct and the cable outer cover 4 of the fiber optic cable 1B are close to point contact when pneumatically feeding in the duct. Therefore, friction between the two can be further reduced and the pneumatic feeding distance can be increased.

[0060]

(Examples)

In the fiber optic cables 1A and 1B of the embodiments of the present disclosure, the pneumatic feeding distance was evaluated for samples of the fiber optic cables of each example in which the type, number, and structure of the cable outer cover 4 of the tensile strength body 5 are different, and for samples of the fiber optic cables of each comparative example of conventional structures. The evaluation results are shown in Table 1.

[0061]

[Table 1]

Table 1

Sample No.	Tensioning Body Configuration	Bending Rigidity (N·m ²)	Outer Cover Structure	Coefficient of Dynamic Friction	Pneumatic Feeding Distance (m) (Evaluation)
1	Outer diameter 0.5 mm glass FRP 2 strands	Max 1.0, min 0.1	HDPE No protrusions	0.3	600 m (C)
2	Outer diameter 0.5 mm glass FRP 4 strands	Max 1.0, min 0.8	HDPE No protrusions	0.3	1,100 m (B)
3	Outer diameter 0.5 mm aramid FRP 4 strands	Max 0.8, min 0.3	HDPE No protrusions	0.3	1,000 m (B)
4	Outer diameter 0.5 mm glass FRP 8 strands	Max 2.5, min 1.2	HDPE No protrusions	0.3	1,500 m (A)
5	Outer diameter 0.5 mm aramid FRP 8 strands	Max 1.2, min 0.4	HDPE No protrusions	0.3	1,300 m (A)
6	Outer diameter 0.5 mm aramid FRP 8 strands	Max 1.2, min 0.4	HDPE 2 wt% silicon added No protrusions	0.15	1,500 m (A)
7	Outer diameter 0.5 mm aramid FRP 8 strands	Max 1.2, min 0.4	HDPE 3 wt% silicon added No protrusions	0.12	1,800 m (S)
8	Outer diameter 0.5 mm aramid FRP 8 strands	Max 1.0, min 0.35	HDPE 5 wt% silicon added No protrusions	0.11	1,850 m (S)
9	Outer diameter 0.5 mm aramid FRP 8 strands	Max 1.2, min 0.4	HDPE 3 wt% silicon added Linear protrusions	0.11	1,900 m (S)
10	Outer diameter 0.5 mm aramid FRP 8 strands	Max 1.2, min 0.4	HDPE 3 wt% silicon added Spiral protrusions	0.1	2,000 m (S)
11	Outer diameter 0.5 mm liquid crystal polymer 8 strands	Max 1.3, min 0.5	HDPE 5 wt% silicon added No protrusions	0.11	1,930 m (S)

[0062]

In Table 1, samples No. 1 to 3 are comparative examples. Sample No. 1 is a fiber optic cable having a structure in which two tensile strength bodies are embedded in the cable outer cover, and samples No. 2 and 3 are fiber optic cables having a structure in which four tensile strength bodies are embedded in the cable outer cover. Samples No. 4 to 8 and 11 have eight tension bodies embedded in the cable outer cover, each two forming pairs, which corresponds to the first embodiment. Samples No. 9 and 10 have eight tensile strength bodies embedded in the cable outer cover in such a way that two of each are paired, and protrusions are provided on the outer peripheral portion of the cable outer cover, which corresponds to the second embodiment. Note that in sample No. 9, the protrusions 7 is formed in a straight line in the longitudinal direction of the fiber optic cable 1B. In sample No. 10, the protrusions 7 are formed in a spiral in the longitudinal direction of the fiber optic cable 1B as illustrated in FIG. 4.

In addition, the tensile strength bodies of samples No. 1, 2, and 4 is a glass FRP having an outer diameter of 0.5 mm. The tensile strength bodies of samples No. 3 and 5 to 10 are a glass FRP having an outer diameter of 0.5 mm. The tensile strength bodies of sample No. 11 are a liquid crystal polymer having an outer diameter of 0.5 mm.

In addition, sample No. 6 was made by adding 2 wt% silicon-based lubricant to the cable outer cover, samples No. 7, 9, and 10 were made by adding 3 wt%, and samples No. 8 and 11 were made by adding 5 wt%.

In addition, the cable outer diameter of each sample is 10 mm.

[0063]

Maximum and minimum bending rigidity indicates the bending rigidity value in the direction of maximum bending rigidity when bending each fiber optic cable in the radial direction and the bending rigidity value in the direction of minimum bending rigidity. The method for measuring bending rigidity is in accordance with IEC60794 Stiffness (MethodE17A). Note that the bending rigidity is the maximum value when bent in the direction of the tensile strength body 5, for example, for the structure of FIG. 1, and the minimum value when bent in a direction shifted by 45 degrees from the direction of the tensile strength bodies 5.

The coefficient of dynamic friction indicates the coefficient of friction between a fiber optic cable pneumatically fed through the duct and the inner wall of the duct.

For the pneumatic feeding distance, a pneumatic feeding test in compliance with IEC was performed using the pneumatic feeding device illustrated in FIG. 5. A pipe 20 is 1,000 m long and is folded back every 100 m. Bending (R) of the pipe 20 is 40 times the outer diameter of the pipe, and the inner diameter of the pipe 20 is 14 mm. An opening 21 is an entry feed port for air and a fiber optic cable, and an opening 22 is an exit feed port for air and a fiber optic cable. The pneumatic pressure was 1.3 MPa to 1.5 MPa.

[0064]

For evaluation of the pneumatic feeding distance, those for which the pneumatic feeding distance was 1,800 m or more were set to an evaluation S, those for which the pneumatic feeding distance was 1,300 m or more and less than 1,800 m were set to an evaluation A, those for which the pneumatic feeding distance was 800 m or more and less than 1,300 m were set to an evaluation B, and those for which the pneumatic feeding distance was less than 800 m were set to an evaluation C.

[0065]

According to the evaluation results of Table 1, samples having a pneumatic feeding distance of 1,800 m or more (samples evaluated as S) were No. 7 to 11, and samples having a pneumatic feeding distance of 1,300 m or more but less than 1,800 m (samples evaluated as A) were No. 4 to 6. Conversely, samples having a pneumatic feeding distance of 800 m or more and less than 1,300 m (samples evaluated as B) were No. 2 and 3, and the samples having a pneumatic feeding distance of less than 800 m (samples evaluated as C) was No. 1. It was found that the pneumatic feeding distance can be increased to more than 1,300 m in fiber optic cables by embedding a total of eight tensile bodies in the cable outer cover, each two forming a pair.

[0066]

Also, the samples having a pneumatic feeding distance of 1,800 m or more (samples evaluated as S) were No. 7 to 11, and thus it was found that the dynamic friction coefficient can be reduced to about 1/3 when 3 wt% or more of a silicon-based lubricant is added to the cable outer cover compared to when a silicon-based lubricant is not added, and the pneumatic feeding distance can be greatly extended. However, it was found that when 5 wt% of the silicon-based lubricant was added, the cable outer cover became slightly softer, resulting in a smaller bending rigidity and there was a slower rate of extension of the pneumatic feeding distance than when 3 wt% of the silicon-based lubricant was added. Furthermore, when a silicon-based lubricant is added in excess of 5 wt%, the fiber optic cable collapses and handling worsens. This showed that the ratio of addition of silicon-based lubricants is preferably 3 wt% or more and 5 wt% or less.

[0067]

It was also found that the pneumatic feeding distance can be made 1,900 m or more by providing protrusions on the cable outer cover, as in samples No. 9 and 10. Furthermore, it was found that the pneumatic feeding distance could even be extended to 2,000 m by making the protrusions spiral in the longitudinal direction of the fiber optic cable.

[0068]

Moreover, in order to further improve the characteristics of the fiber optic cable, secondary resins of the fiber optic cores 11A to 11L were examined. As a result, it was found that by combining inorganic oxide particles in the secondary resin, the lateral pressure characteristics of the fiber optic tape core could be improved, and the core density could be increased by about 1.0 to 1.5 cores/mm².

[0069]

So far, the present invention has been described in detail with reference to specific embodiments, but it is clear to a person skilled in the art that various changes and modifications can be made without departing from the spirit and scope of the present invention. Furthermore, the number, position, shape, and the like of the constituent members described above are not limited to the embodiments described above, and the number, position, shape, and the like can be changed as appropriate in implementing the present invention.

[Description of Reference Numerals]

[0070]

1A, 1B: Fiber optic cable

2: Fiber optic tape core

3: Water absorption tape

4: Cable outer cover

5: Tensile strength body

6: Tear string

7: Protrusion

7a: End surface

11A to 11L: Fiber optic core

12: Connected part

13: Unconnected part

14: Connection resin

15: Glass fiber

16: Inner coating layer

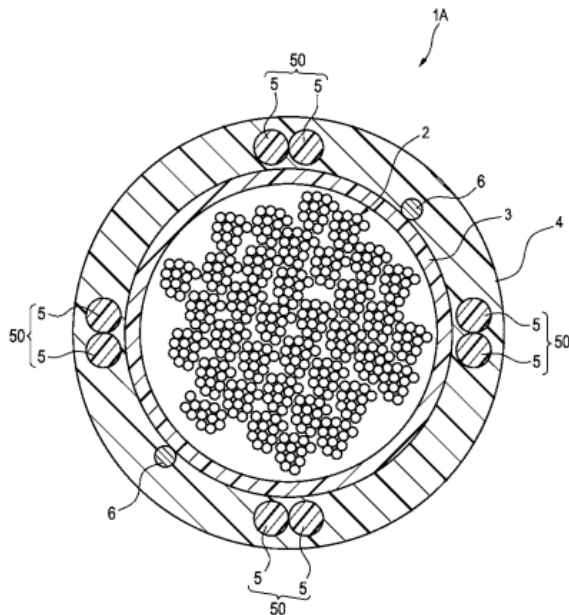
17: Outer coating layer

20: Pipe

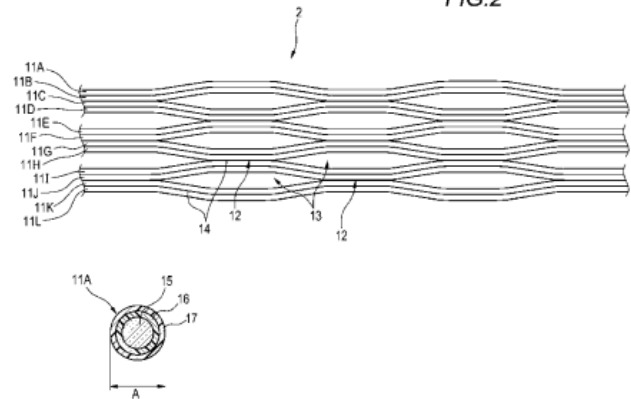
21, 22: Opening

50: Tensile strength body unit

[FIG. 1]

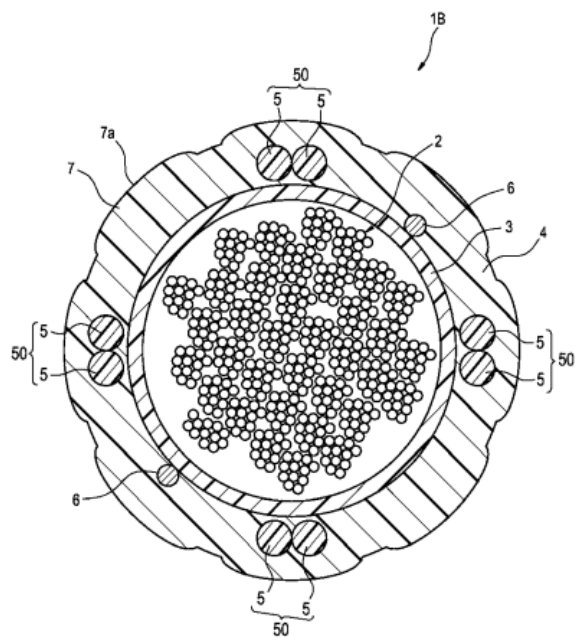
FIG.1

[FIG. 2]

FIG.2

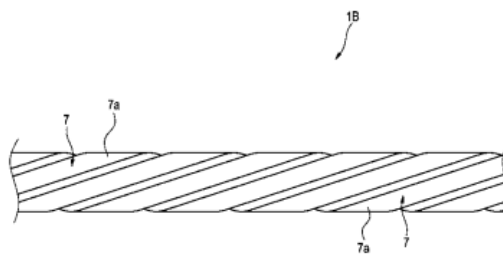
[FIG. 3]

FIG.3



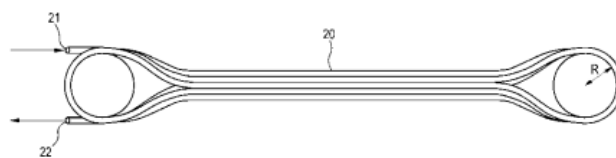
[FIG. 4]

FIG.4



[FIG. 5]

FIG.5



Continued from front page

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 BD20
 2H250 BA32 BB07 BB17 BB19 BB32 BB33 BC02 BD12 BD14 BD17
 BD20

CERTIFICATE OF TRANSLATION

I, Eric Vance, hereby certify that the document identified below, translated from Japanese into English, is true and accurate to the best of my knowledge and belief.

Reference: JP 2020-204752 A 2020.12.24

I declare under penalty of perjury under the laws of the United States of America that the foregoing is true and correct. I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

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Signature

Eric Vance

Printed Name

Sworn to before me this

31 day of October, 2024

Becky Watson

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Stamp, Notary Public