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Iwaguchi et al.

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(54) **OPTICAL FIBER RIBBON**

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(58) **Field of Classification Search**
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USPC 385/114
See application file for complete search history.

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(57) **ABSTRACT**

An optical fiber ribbon includes a plurality of optical fibers arranged in parallel in a direction orthogonal to a longitudinal direction of the optical fibers, and a collective coating covering outer peripheries of the plurality of optical fibers. The collective coating includes a connected portion at which the optical fibers adjacent to each other are connected in at least a part of the plurality of optical fibers. An outer diameter of each of the plurality of optical fibers is 215 μm or less, and a dynamic friction force of the collective coating is 0.3 N or less.

5 Claims, 11 Drawing Sheets

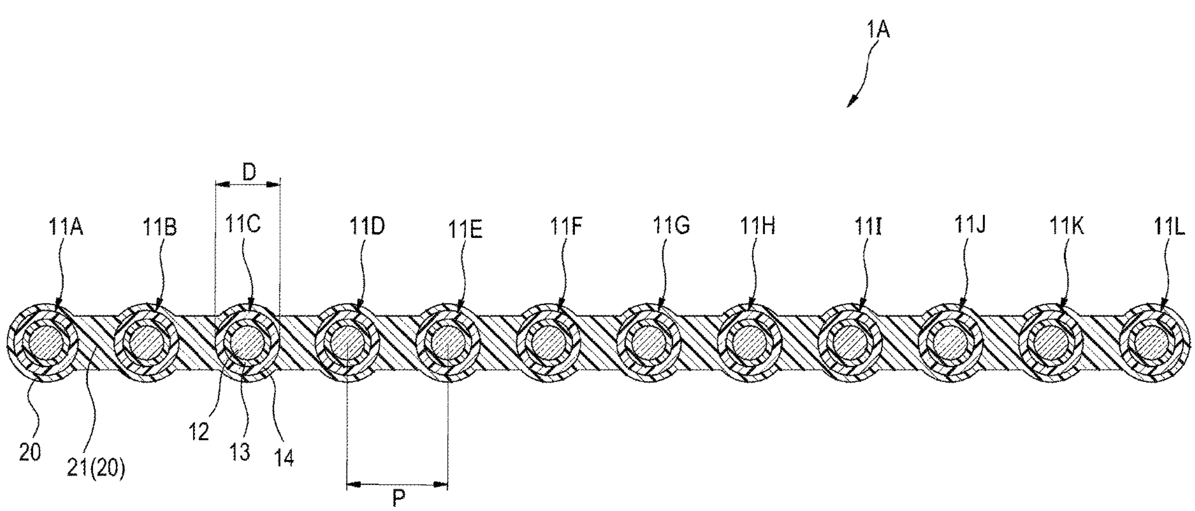

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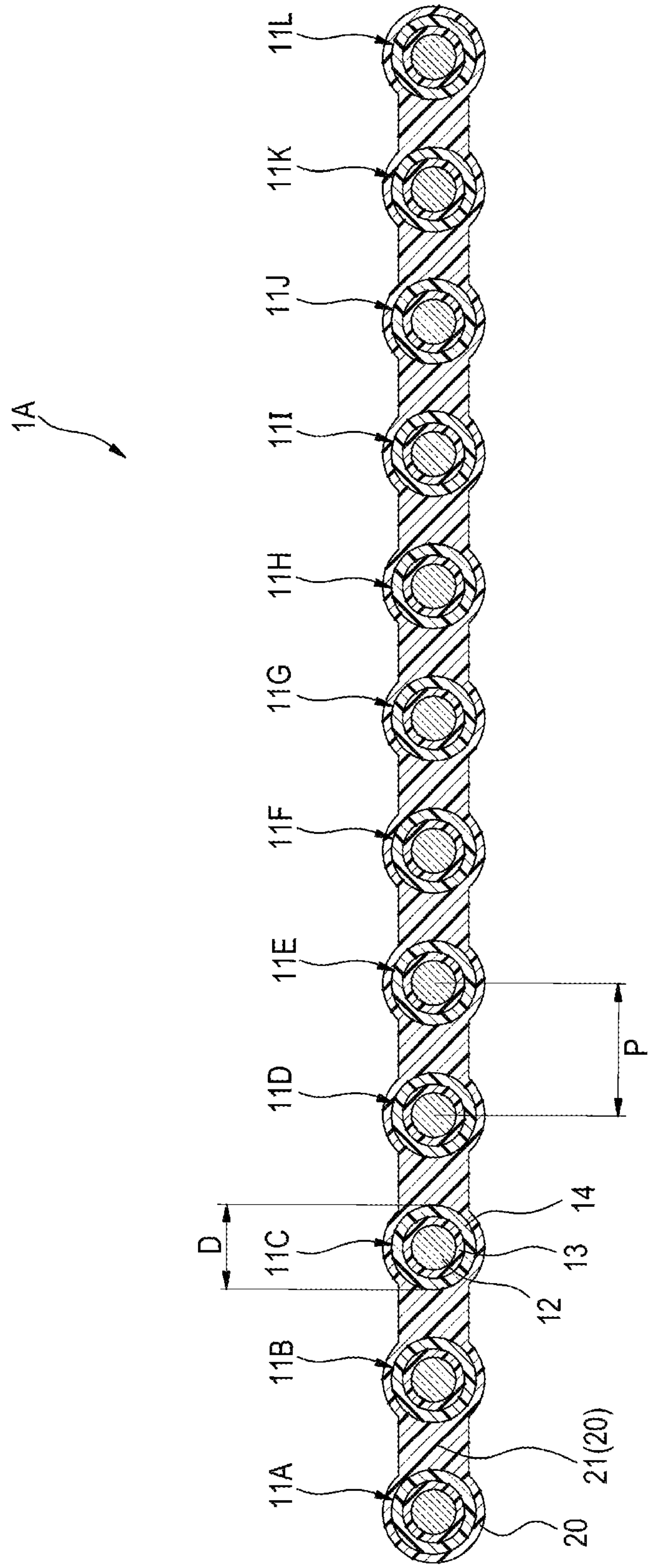
FIG.1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11B
11C
11D
11E
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11I
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11L
12
13
14
20
21(20)
D
P

FIG.2

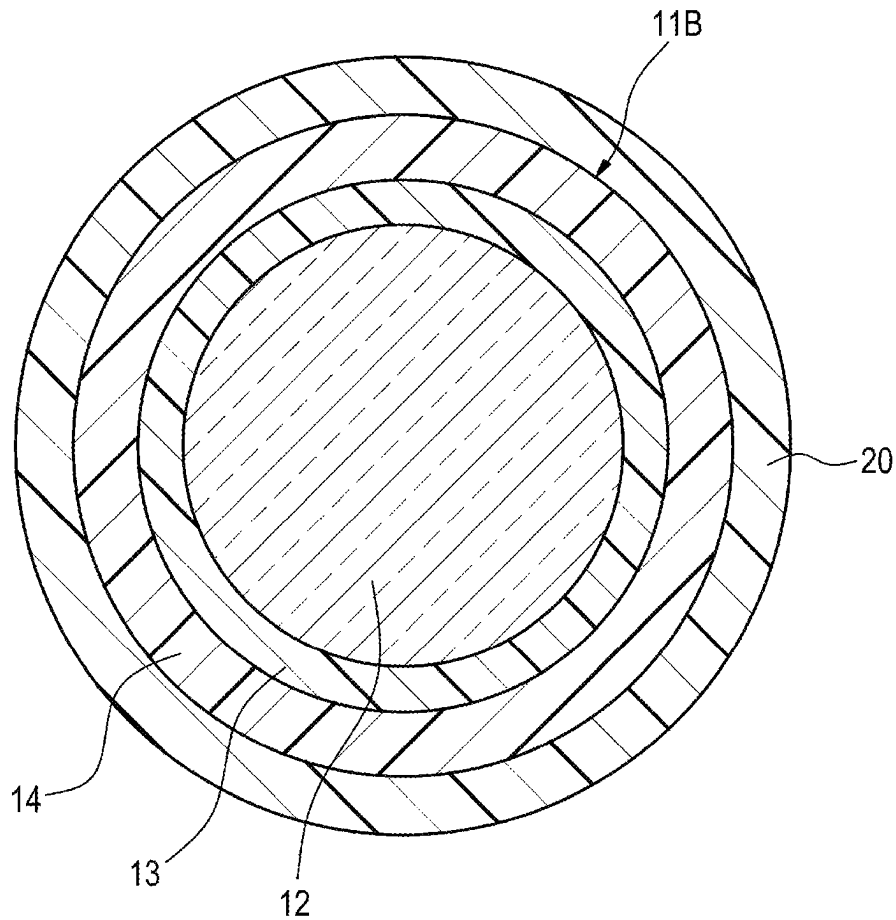
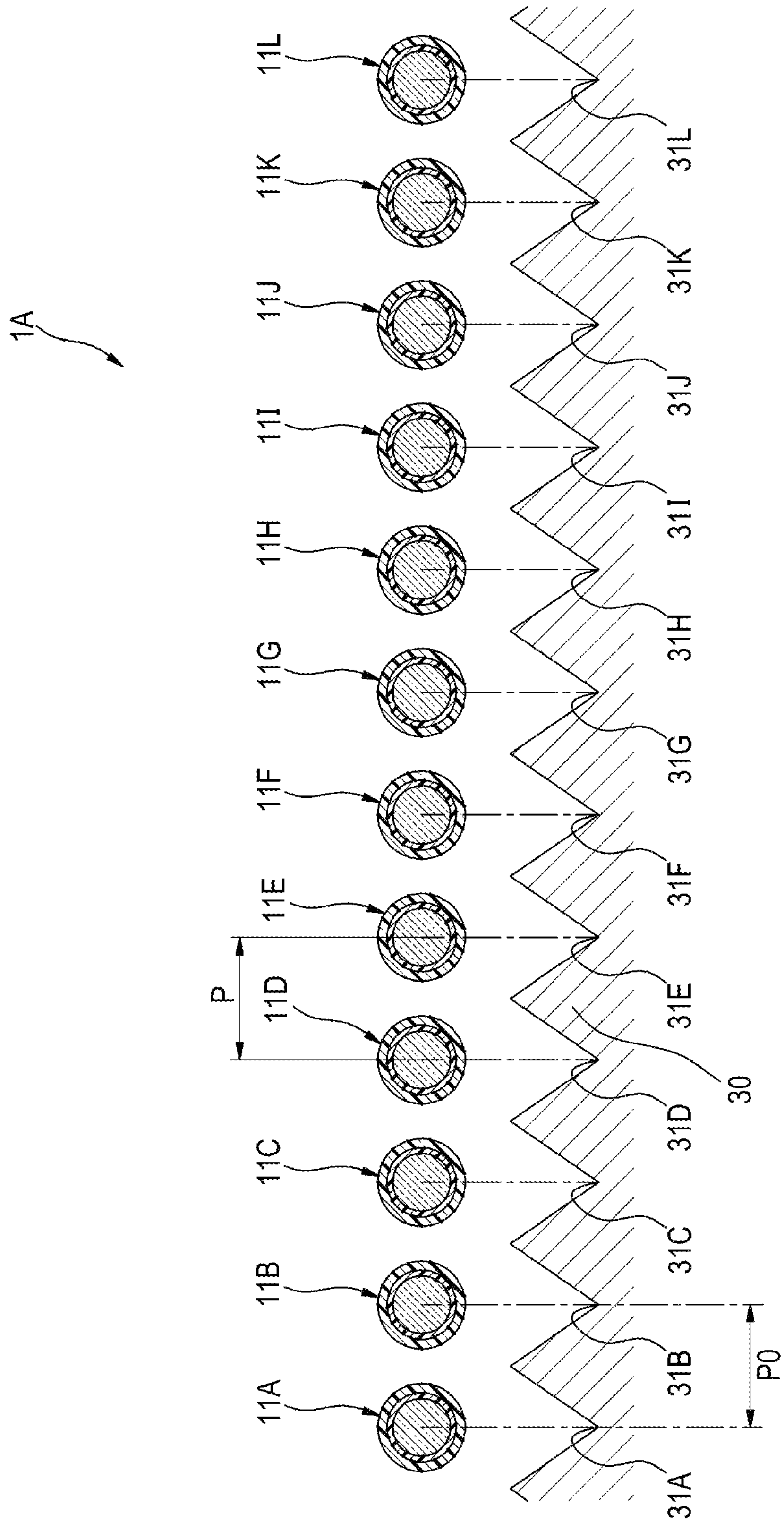


FIG.3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11L
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31J
31K
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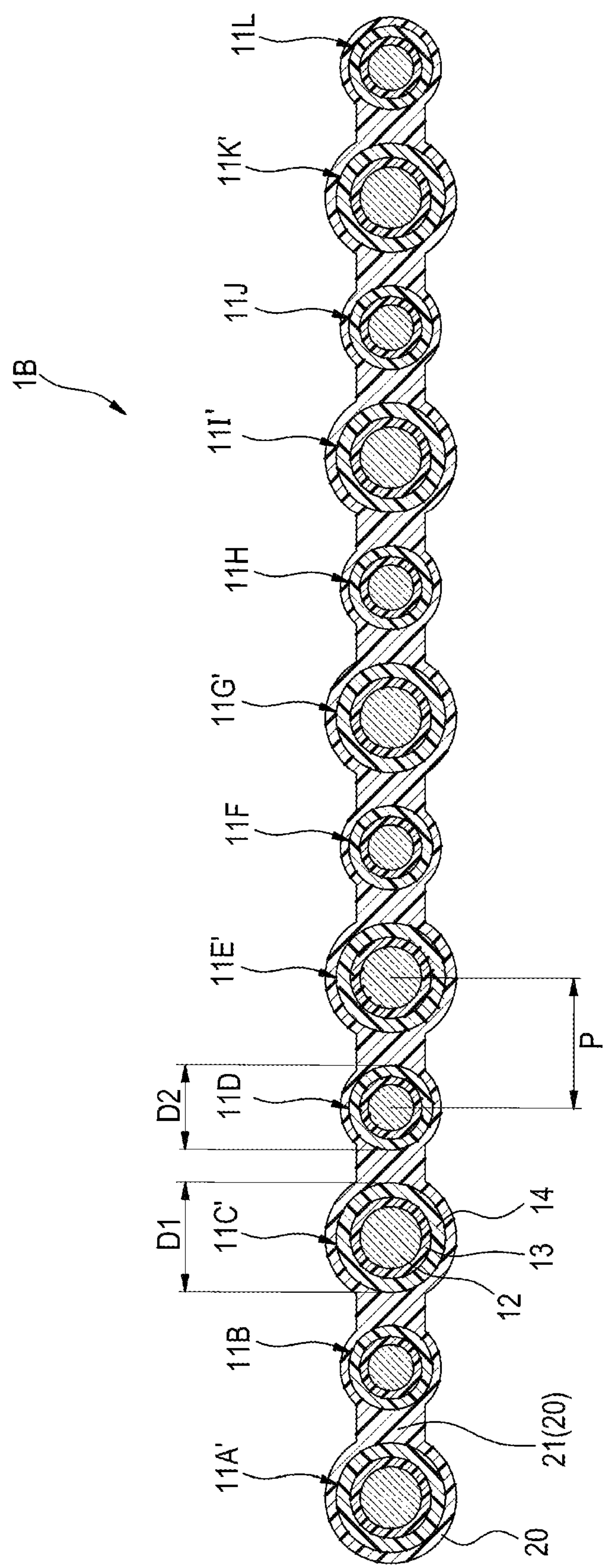
FIG.4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D2
D1
14
13
12
21(20)
20

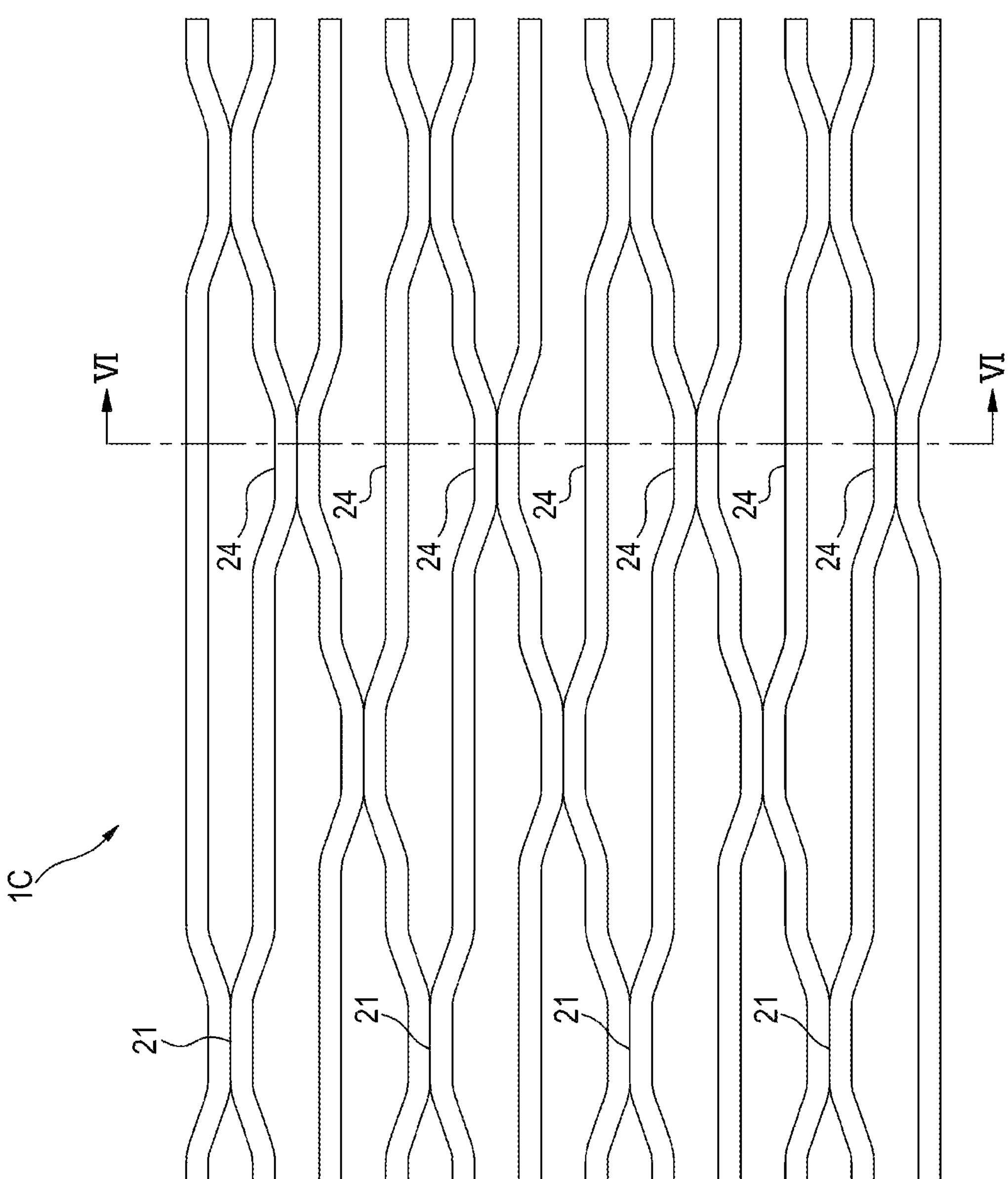
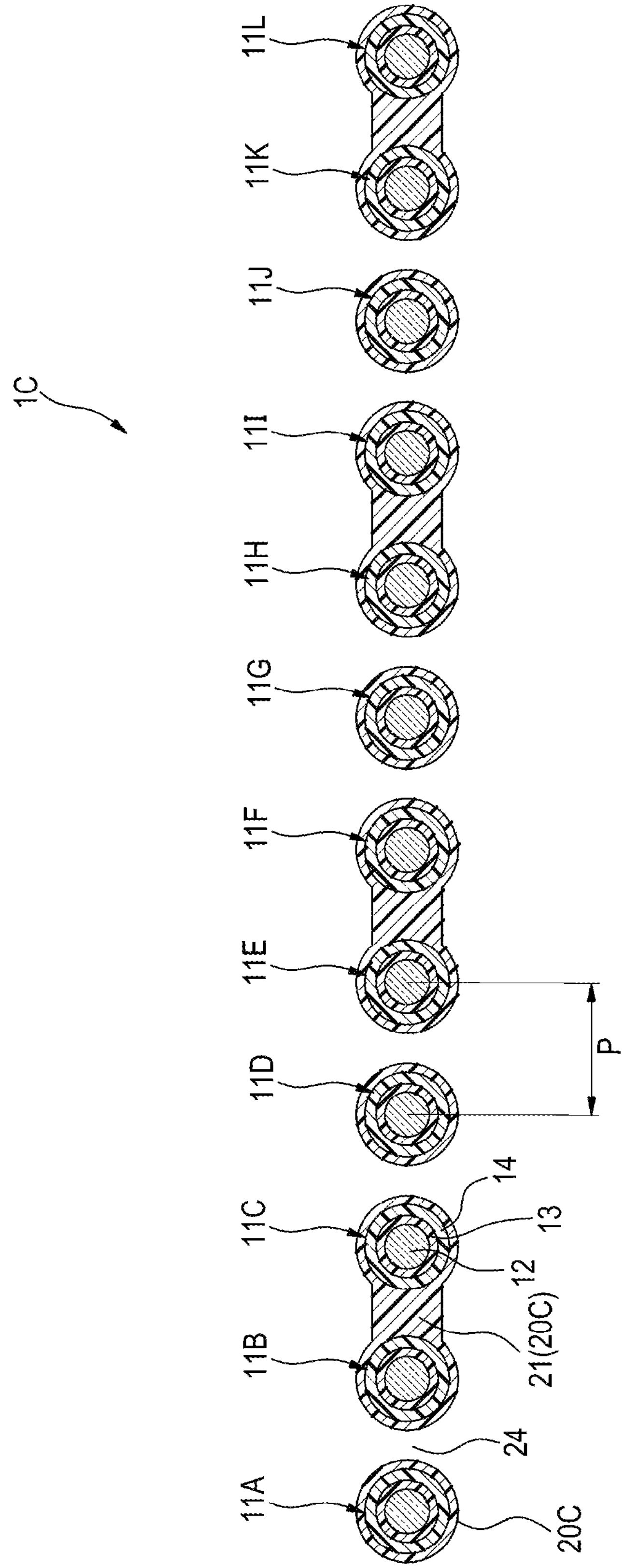
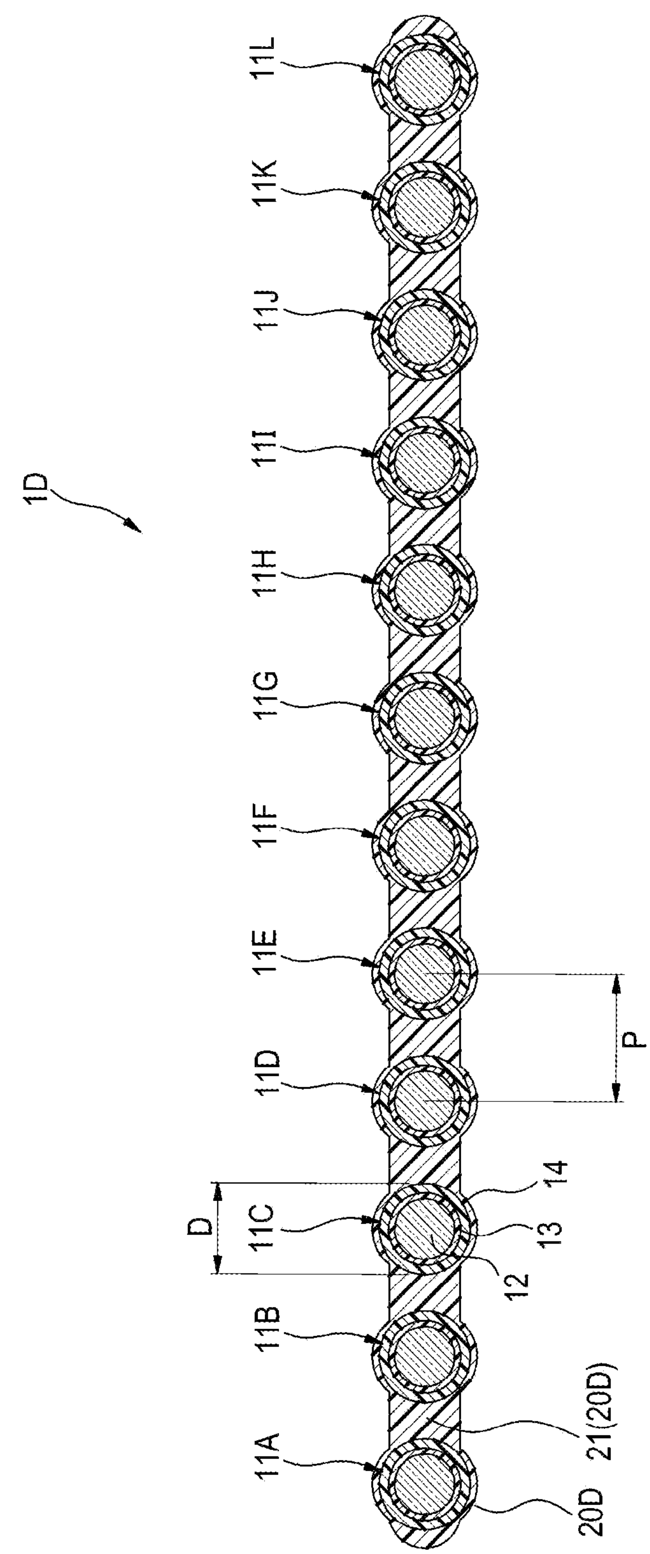


FIG.5

FIG.6



1C
11A
11B
11C
11D
11E
11F
11G
11H
11I
11J
11K
11L
12
13
14
21(20C)
24
20C
P



1D
11A
11B
11C
11D
11E
11F
11G
11H
11I
11J
11K
11L
D
P
12
13
14
21(20D)
20D

FIG.7

FIG.8

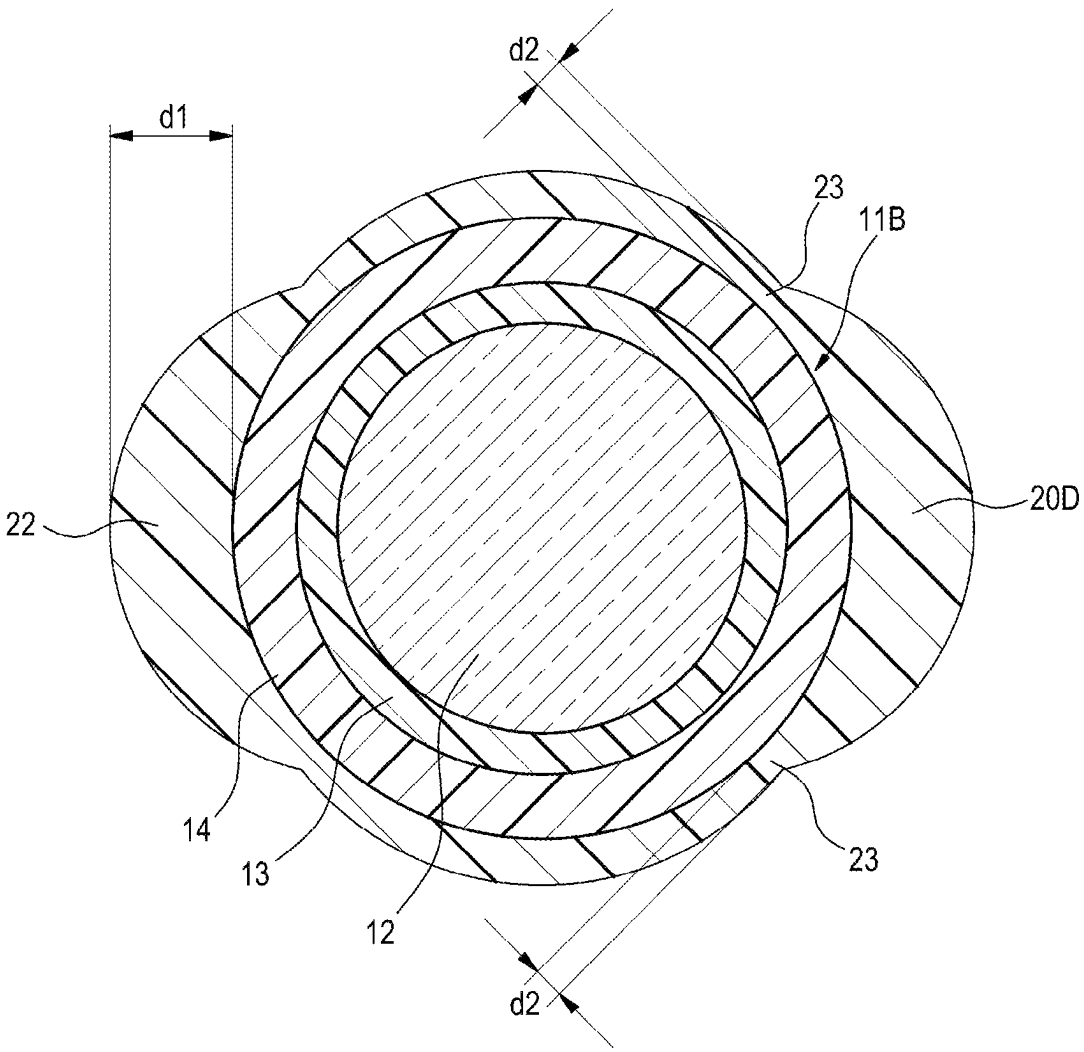


FIG.9

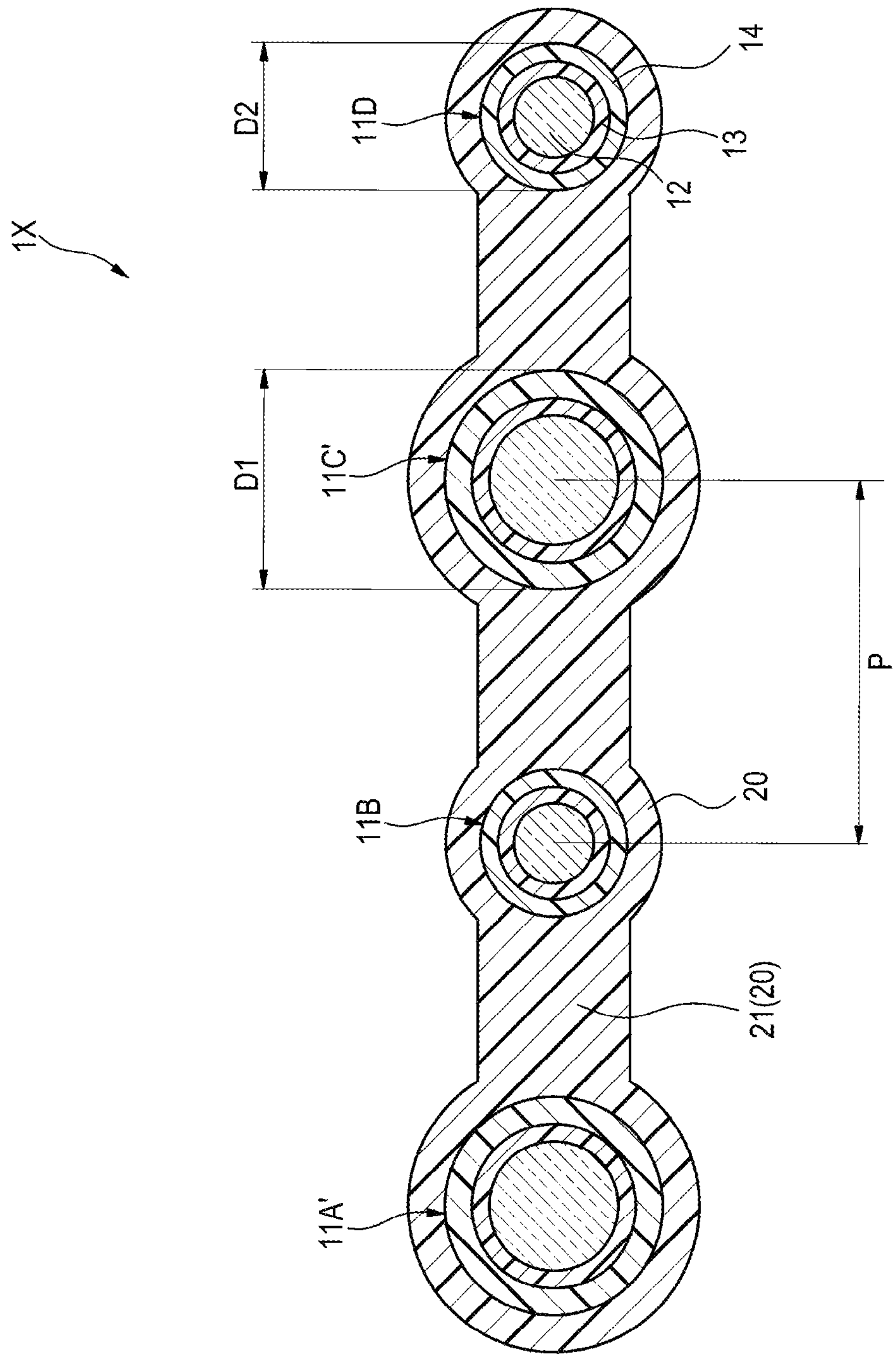


FIG.10

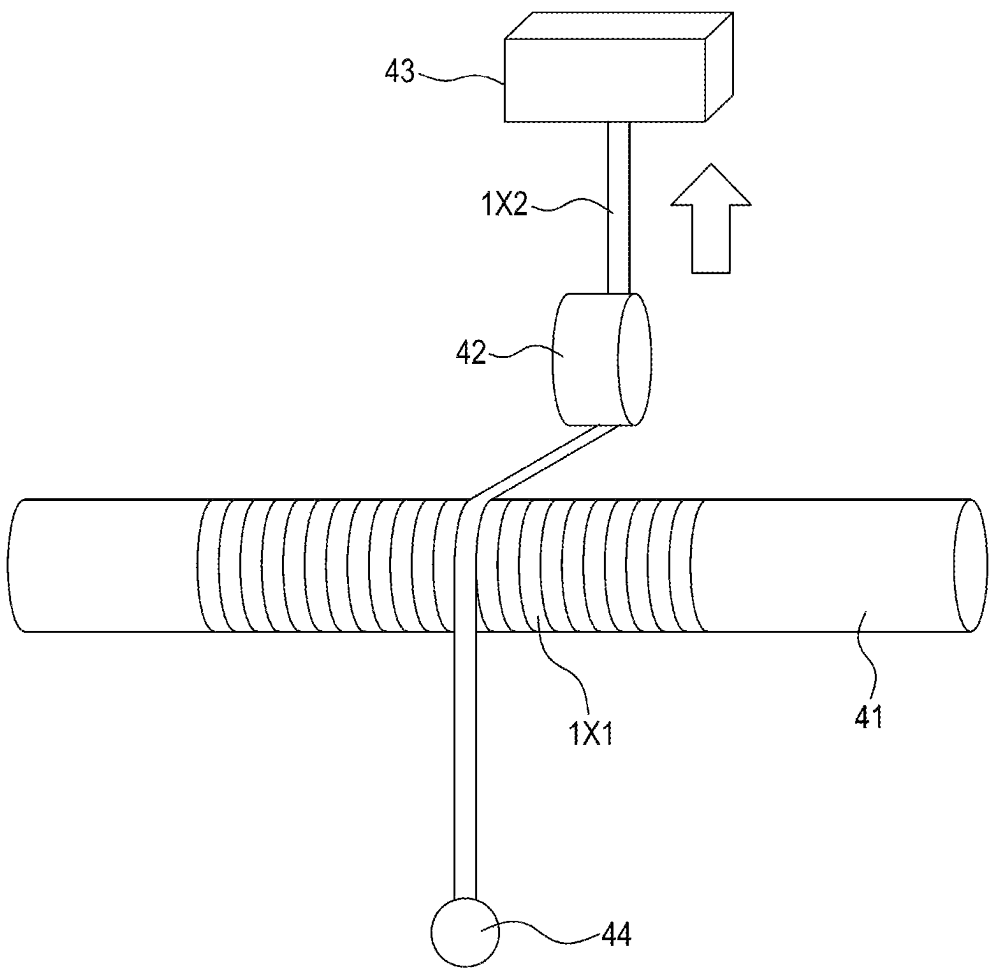
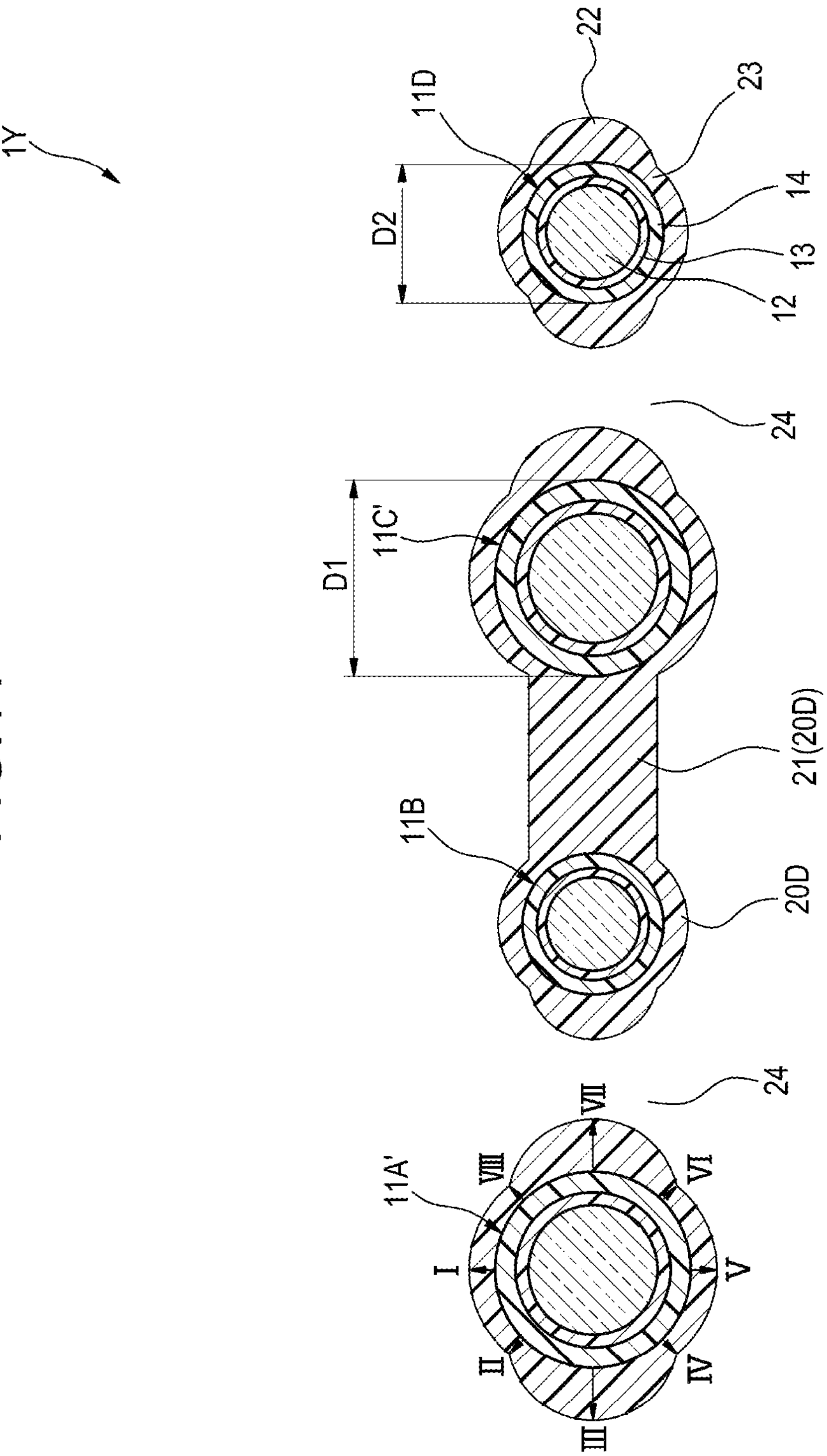


FIG.11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D1
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21(20D)
11B
20D
24
VII
VIII
VI
11A'
I
V
II
IV
III

OPTICAL FIBER RIBBON

TECHNICAL FIELD

The present disclosure relates to an optical fiber ribbon. The present application claims the benefit of priority of Japanese Patent Application No. 2020-175368, filed on Oct. 19, 2020, the content of which is incorporated herein by reference.

BACKGROUND ART

In recent years, there is an increasing demand to increase a density of an optical fiber cable. As an example of increasing the density, it is known to reduce an outer diameter of an optical fiber to be mounted in the optical fiber cable or to use a plurality of optical fibers having different outer diameters. Further, in order to improve workability and identifiability at the time of splicing, there is known an optical fiber ribbon in which a plurality of optical fibers are arranged in parallel and integrally coated (Patent Literature 1).

CITATION LIST

Patent Literature

Patent Literature 1: JP2014-238480A

SUMMARY OF INVENTION

An optical fiber ribbon according to the present disclosure includes:

a plurality of optical fibers arranged in parallel in a direction orthogonal to a longitudinal direction of the optical fibers; and

a collective coating covering outer peripheries of the plurality of optical fibers,

the collective coating includes a connected portion at which the optical fibers adjacent to each other are connected in at least a part of the plurality of optical fibers,

an outer diameter of each of the plurality of optical fibers is 215 μm or less, and

a dynamic friction force of the collective coating is 0.3 N or less.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a cross-sectional view of an optical fiber ribbon according to a first embodiment of the present disclosure.

FIG. **2** is a cross-sectional view of an optical fiber of the optical fiber ribbon shown in FIG. **1**.

FIG. **3** is a schematic view showing a relationship between a pitch of the optical fiber ribbon according to the first embodiment and V-grooves of a fusion machine in a fusion step.

FIG. **4** is a cross-sectional view of an optical fiber ribbon according to a first modification.

FIG. **5** is a view showing a part of an optical fiber ribbon according to a second modification in a longitudinal direction of the optical fiber ribbon.

FIG. **6** is a cross-sectional view of the optical fiber ribbon shown in FIG. **5**.

FIG. **7** is a cross-sectional view of an optical fiber ribbon according to a third modification.

FIG. **8** is a cross-sectional view of an optical fiber of the optical fiber ribbon shown in FIG. **7**.

FIG. **9** is a cross-sectional view of an optical fiber ribbon used in an evaluation experiment.

FIG. **10** is a schematic diagram of an experiment for measuring a dynamic friction force used in the evaluation experiment.

FIG. **11** is a cross-sectional view of an optical fiber ribbon used in an evaluation experiment.

DESCRIPTION OF EMBODIMENTS

Technical Problem

In a case where the optical fiber ribbons are mounted in the optical fiber cable at a high density, since the optical fibers tend to be in contact with each other, friction may occur between the optical fibers. When the friction occurs non-uniformly in a longitudinal direction of the cable, the cable tends to meander. Further, transmission characteristics of the cable at a low temperature tend to deteriorate. In particular, in a case where outer diameters of the plurality of optical fibers are different, the cable is more likely to meander, and the transmission characteristics are more likely to deteriorate.

The present disclosure is to provide an optical fiber ribbon that enables high-density mounting of optical fibers in an optical fiber cable and prevents occurrence of cable meandering.

(Description of Aspect of Present Disclosure)

First, an embodiment of the present disclosure will be listed and described.

(1) An optical fiber ribbon according to an aspect of the present disclosure includes:

a plurality of optical fibers arranged in parallel in a direction orthogonal to a longitudinal direction of the optical fibers; and

a collective coating covering outer peripheries of the plurality of optical fibers,

the collective coating includes a connected portion at which the optical fibers adjacent to each other are connected in at least a part of the plurality of optical fibers,

an outer diameter of each of the plurality of optical fibers is 215 μm or less, and

a dynamic friction force of the collective coating is 0.3 N or less.

According to the present disclosure, since the dynamic friction force of the collective coating of the optical fiber ribbon is 0.3 N or less, friction generated between the optical fiber ribbons adjacent to each other can be reduced. Accordingly, even when the optical fiber ribbons are mounted in the cable at a high density, cable meandering can be prevented. Further, transmission characteristics of the cable at a low temperature can be ensured.

Since the outer diameter of each optical fiber of the optical fiber ribbon of the present disclosure is 215 μm or less, the optical fiber ribbons can be mounted in a cable at a high density.

(2) A surface hardness of the collective coating may be 1.2 GPa or more and 3 GPa or less.

According to the present disclosure, since the surface hardness of the collective coating is 1.2 GPa or more and 3 GPa or less, meandering generated between the optical fiber ribbons adjacent to each other can be reduced. Accordingly, even when the optical fiber ribbons are mounted in the cable at a high density, the cable meandering can be prevented. Further, the transmission characteristics of the cable at a low temperature can be ensured.

(3) A distance between centers of the optical fibers adjacent to each other may be 220 μm or more and 280 μm or less.

According to the present disclosure, since the distance between the centers of the optical fibers adjacent to each other is 220 μm or more and 280 μm or less, a general splicing device can be used. Even if each of the optical fibers is small in diameter, it is not necessary to prepare a dedicated splicing device for small-diameter optical fibers, so that a versatile optical fiber ribbon can be provided.

(4) The collective coating may include a non-connected portion at which the optical fibers adjacent to each other are not connected in at least a part of the plurality of optical fibers.

The connected portion may be formed intermittently in the longitudinal direction. According to the present disclosure, since the non-connected portion is provided intermittently in the longitudinal direction, the optical fiber ribbon is easily deformed in a cross section perpendicular to the longitudinal direction. Accordingly, the optical fibers can be mounted in the optical fiber cable at a high density.

(5) In a cross-sectional view of each of the optical fibers, the collective coating may include a thick portion and at least two thin portions in each of which a thickness of the collective coating is smaller than the thickness of the collective coating in the thick portion.

A difference between the thickness of the collective coating in the thick portion and the thickness of the collective coating in each of the thin portions may be 5 μm or more and 19 μm or less.

In the optical fiber ribbon of the present disclosure, the collective coating includes the thick portion and at least two thin portions, and the thickness of the collective coating is non-uniform. In particular, since the difference between the thickness of the collective coating in the thick portion and the thickness of the collective coating in each of the thin portions is as relatively large as 5 μm or more and 19 μm or less, a contact area between the optical fiber ribbons can be reduced. Therefore, friction is unlikely to occur between the optical fiber ribbons adjacent to each other, and even when the optical fiber ribbons are mounted in a cable at a high density, the cable meandering can be further prevented.

(6) The plurality of optical fibers may include a first optical fiber having a first outer diameter and a second optical fiber having a second outer diameter.

According to the present disclosure, since the plurality of optical fibers include the first optical fiber having the first outer diameter and the second optical fiber having the second outer diameter, the optical fibers can be mounted in the optical fiber cable at a high density while reducing the cable meandering.

Advantageous Effects of Invention

According to the present disclosure, an optical fiber ribbon that enables high-density mounting of the optical fibers in the optical fiber cable and prevents occurrence of cable meandering can be provided.

(Details of First Embodiment of Present Disclosure)

Specific examples of an optical fiber ribbon according to a first embodiment of the present disclosure will be described with reference to the drawings.

The present disclosure is not limited to these examples and is defined by the scope of the claims, and is intended to include all modifications within the scope and meaning equivalent to the scope of the claims.

FIG. **1** is a cross-sectional view perpendicular to a longitudinal direction of an optical fiber ribbon **1**A according to an embodiment of the present disclosure. As shown in FIG. **1**, the optical fiber ribbon **1**A includes a plurality of optical fibers **11** and a collective coating **20** that covers the plurality of optical fibers **11**. In this example, 12 optical fibers **11**A to **11**L are arranged in parallel in a direction orthogonal to the longitudinal direction of the optical fiber ribbon **1**A. The plurality of optical fibers **11** are arranged at regular intervals. Outer peripheries of the plurality of optical fibers **11** are covered with the collective coating **20**, and the entire optical fibers **11** are connected by the collective coating **20**.

An outer diameter D of each of the plurality of optical fibers **11** is 215 μm or less. In this example, the outer diameter D of each optical fiber is 200 μm. Each optical fiber **11** includes, for example, a glass fiber **12** including a core and a cladding, a primary resin layer **13** covering an outer periphery of the glass fiber **12**, and a secondary resin layer **14** covering an outer periphery of the primary resin layer **13**. The glass fiber **12** may include pure silica glass, silica glass doped with germanium, or silica glass doped with fluorine. The primary resin layer **13** may include a soft material having a relatively low Young's modulus, as a buffer layer. The secondary resin layer **14** may include a hard material having a relatively high Young's modulus, as a protective layer.

The Young's modulus of the primary resin layer **13** at 23° C. is preferably 0.04 MPa or more and 0.8 MPa or less, more preferably 0.05 MPa or more and 0.7 MPa or less, and still more preferably 0.05 MPa or more and 0.6 MPa or less. Since the Young's modulus of the primary resin layer **13** is 0.04 MPa or more and 0.8 MPa or less, voids are less likely to be generated in the optical fiber. The Young's modulus of the secondary resin layer **14** at 23° C. is preferably 900 MPa or more, more preferably 1000 MPa or more, and still more preferably 1200 MPa or more. The Young's modulus of the secondary resin layer **14** at 23° C. may be 3000 MPa or less, 2500 MPa or less, 2000 MPa or less, or 1800 MPa or less. Since the Young's modulus of the secondary resin layer **14** is 900 MPa or more, lateral pressure resistance is likely to be improved. When the Young's modulus of the secondary resin layer **14** is 3000 MPa or less, the secondary resin layer **14** has appropriate elongation at break, so that stripping is easily performed.

The collective coating **20** includes connected portions **21** at each of which adjacent optical fibers are connected in at least a part of the plurality of optical fibers **11**. In this example, the connected portion **21** is disposed between all adjacent optical fibers. The connected portions **21** are arranged such that a distance P between centers of adjacent optical fibers is 220 μm or more and 280 μm or less.

The collective coating **20** may contain, for example, an ultraviolet curable resin. A dynamic friction force of the collective coating **20** is 0.3 N or less. Further, a surface hardness of the collective coating **20** is 1.2 GPa or more and 3 GPa or less. A Young's modulus of the collective coating **20** at 23° C. is preferably 50 MPa or more and 900 MPa or less, and more preferably 100 MPa or more and 800 MPa or less, from the viewpoint of lateral pressure resistance and flexibility of the optical fiber ribbon.

FIG. **2** is a cross-sectional view of one optical fiber **11**B among the plurality of optical fibers **11** included in the optical fiber ribbon **1**A shown in FIG. **1**. Since configurations of other optical fibers **11**A and **11**C to **11**L are the same as the configuration of the optical fiber **11**B shown in FIG. **2**, repeated description will be omitted.

As shown in FIG. **2**, in the cross-sectional view of the optical fiber **11**B, the collective coating **20** covers the entire outer periphery of the optical fiber **11**B, so that there is no location where the optical fiber **11**B is exposed from the collective coating **20**. In other words, the thickness of the collective coating **20** is uniform on the outer periphery of the optical fiber cable **11**B. The thickness of the collective coating **20** is, for example, 20 μm or less. In this example, the thickness of the collective coating between the optical fiber **11**B and the optical fiber **11**A or **11**C refers to a thickness excluding the connected portion **21**.

Next, fusion splicing of the optical fiber ribbon **1**A will be described. In general, in a case of splicing an optical fiber ribbon and another optical fiber ribbon, a plurality of optical fibers can be wholly fusion-spliced by using optical fiber fusion splicer (not shown). FIG. **3** is a schematic view showing a relationship between a pitch of the optical fiber ribbon **1**A (a distance P between centers of adjacent optical fibers) and a V-groove base **30** of a fusion machine. As shown in FIG. **3**, the fusion splicer includes the V-groove base **30** including a plurality of V-grooves **31** in which the plurality of optical fibers **11** are arranged. In this example, the 12 optical fibers **11**A to **11**L are respectively arranged in 12 V-grooves **31**A to **31**L. A pitch P**0** of the V-grooves **31**A to **31**L is 250 μm according to an international standard of an outer diameter of the optical fiber.

At the time of fusion-splicing, the optical fibers **11**A to **11**L in a state where the collective coating **20** is stripped are arranged above the V-groove base **30**. The optical fibers **11**A to **11**L are arranged such that, for example, center positions of the V grooves **31**A to **31**L in a parallel arrangement direction and center positions of the optical fibers **11**A to **11**L in a parallel arrangement direction are aligned. In this state, a clamp cover (not shown) of the fusion splicer is closed, and the optical fibers **11**A to **11**L are pushed down from above by the clamp cover.

If there is no connected portion in the optical fiber ribbon and a distance between adjacent optical fibers among the optical fibers is zero, the distance between the centers is smaller than the pitch P**0** of the V-grooves **31**A to **31**L. In this case, the plurality of optical fibers are arranged to be gathered toward a center position of the V-groove base **30**, and are not arranged to face the V-grooves **31**A to **31**L. Accordingly, the plurality of optical fibers are not necessarily accommodated in the V-grooves **31**A to **31**L, respectively, and for example, a case where the optical fibers are not accommodated in the V-grooves **31**A and **31**L occurs. This may also occur in a case where the distance P between the centers of adjacent optical fibers is less than 220 μm.

On the other hand, in the optical fiber ribbon **1**A in this example, since the connected portions **21** are arranged such that the distance P between the centers of adjacent optical fibers is 220 μm or more and 280 μm or less, the optical fibers **11**A to **11**L are arranged to face the V-grooves **31**A to **31**L respectively. Therefore, when the optical fibers **11**A to **11**L are pushed down substantially vertically, the optical fibers **11**A to **11**L are accommodated in the V-grooves **31**A to **31**L respectively.

FIG. **3** shows that the optical fibers **11**A to **11**L in a state where the collective coating **20** is stripped are to be accommodated in the V-grooves **31**A to **31**L respectively, but for example, the primary resin layer **13** and the secondary resin layer **14** may be further stripped in addition to the collective coating **20**, and only the glass fiber **12** may be accommodated in each of the V-grooves **31**A to **31**L.

As described above, in the optical fiber ribbon **1**A according to this example, since the dynamic friction force of the collective coating **20** is 0.3 N or less, friction between adjacent optical fiber ribbons can be reduced. Even when a plurality of optical fiber ribbons **1**A are mounted in an optical fiber cable at a high density, friction between adjacent optical fiber ribbons **1**A is reduced, so that cable meandering can be prevented, and cable laying work can be improved.

In the optical fiber ribbon **1**A of this example, the collective coating **20** covers the outer peripheries of the plurality of optical fibers. If the outer periphery of any optical fiber **11** is not completely covered with the collective coating **20** and there is a portion exposed from the collective coating **20**, the collective coating **20** may be peeled off from the optical fiber **11** starting from the exposed portion, and as a result, the optical fiber **11** may be single core-separated from the optical fiber ribbon. However, in this example, since the outer peripheries of the plurality of optical fibers are covered with the collective coating **20**, the single core-separation does not occur.

Since the outer diameter of each optical fiber **11** of the optical fiber ribbon **1**A of this example is 215 μm or less, a cross-sectional area of the optical fiber **11** is small, and the optical fiber ribbons **1**A can be mounted in an optical fiber cable at a high density.

In the optical fiber ribbon **1**A of this example, since the surface hardness of the collective coating **20** is 1.2 GPa or more and 3 GPa or less, friction generated between adjacent optical fibers can be reduced. Accordingly, even when the optical fiber ribbons are mounted in the cable at a high density, the cable meandering can be prevented, and the cable laying work can be improved. Further, transmission characteristics of the cable at a low temperature can be ensured.

In this example, since the distance between the centers of adjacent optical fibers is 220 μm or more and 280 μm or less, the optical fiber ribbon can be used in a general multi-core fusion machine or splicing device. Even if each of the optical fibers **11** is small in diameter, it is not necessary to prepare a multi-core fusion machine dedicated to small diameter fiber, such as a multi-core fusion machine in which V-grooves are formed at a narrow pitch, so that the versatility of the optical fiber ribbon **1**A is high and the manufacturing cost can be reduced.

(First Modification)

In the optical fiber ribbon **1**A according to the first embodiment, the outer diameters of the optical fibers **11** are all the same, but the outer diameters of the optical fibers **11** may not be the same. FIG. **4** is a cross-sectional view perpendicular to a longitudinal direction of an optical fiber ribbon **1**B according to a first modification. In the description of FIG. **4**, elements substantially the same as or corresponding to those in the configuration shown in FIG. **1** are denoted by the same reference numerals, and repeated description thereof will be omitted.

As shown in FIG. **4**, the plurality of optical fibers **11** of the optical fiber ribbon **1**B include first optical fibers each having an outer diameter D**1** (an example of a first outer diameter), and second optical fibers each having an outer diameter D**2** (an example of a second outer diameter). In this example, the outer diameter D**1** of the first optical fibers **11**A', **11**C', **11**E', **11**G', **11**I', and **11**K' is different from the outer diameter D**2** of the second optical fibers **11**B, **11**D, **11**F, **11**H, **11**J, and **11**L, and the first optical fibers each having the outer diameter D**1** and the second optical fibers each having the outer diameter D**2** are alternately arranged. The outer diameter D**1** of the first optical fiber and the outer diameter D**2** of the second optical fiber are both 215 μm or less. In this example, the outer diameter D**1** is 200 μm, and the outer diameter D**2** is 180 μm. Each of the first optical fibers **11**A', **11**C', **11**E', **11**G', **11**I', and **11**K' includes the glass fiber **12**, the primary resin layer **13**, and the secondary resin layer **14**. Further, when the outer diameters D**1** and D**2** are different from each other, the connected portions **21** of the collective coating **20** are also arranged such that the distance P between the centers of adjacent optical fibers is 220 μm or more and 280 μm or less.

When the optical fiber ribbon **1**B according to the first modification is mounted in an optical fiber cable, the second optical fibers **11**B, **11**D, **11**F, **11**H, **11**J, and **11**L each having the small outer diameter D**2** are disposed in gaps between the first optical fibers **11**A', **11**C', **11**E', **11**G', **11**I', and **11**K' each having the large outer diameter D**1**. Accordingly, as compared with a case where the plurality of optical fibers **11** have the same outer diameter, a mounting density of the optical fibers **11** with respect to the optical fiber cable is higher in a case where the plurality of optical fibers **11** have the outer diameters D**1** and D**2** different from each other.

As described above, since the optical fiber ribbon **1**B according to the first modification includes the plurality of optical fibers **11** including the first optical fibers each having the outer diameter D**1**, and the second optical fibers each having the outer diameter D**2**, the optical fibers **11** can be mounted in the optical fiber cable at a higher density.

(Second Modification)

The connected portions **21** of the optical fiber ribbon **1**A according to the first embodiment connect all adjacent optical fibers, but the arrangement of the connected portions is not limited thereto. FIG. **5** is a view showing a part of an optical fiber ribbon **1**C according to a second modification in a longitudinal direction of the optical fiber ribbon **1**C. FIG. **6** is a cross-sectional view of the optical fiber ribbon **1**C. In the description of FIG. **6**, elements substantially the same as or corresponding to those in the configuration shown in FIG. **1** are denoted by the same reference numerals, and repeated description thereof will be omitted.

As shown in FIGS. **5** and **6**, a collective coating **20**C of the optical fiber ribbon **1**C includes non-connected portions **24** at each of which adjacent optical fibers are not connected in at least a part of the plurality of optical fibers **11**. In other words, FIGS. **5** and **6** show the optical fiber ribbon **1**C including the non-connected portions **24**. In the second modification, the non-connected portions **24** are formed between the optical fibers **11**A and **11**B, between the optical fibers **11**C and **11**D, between the optical fibers **11**D and **11**E, between the optical fibers **11**F and **11**G, between the optical fibers **11**G and **11**H, between the optical fibers **11**I and **11**J, and between the optical fibers **11**J and **11**K. The arrangement positions of the non-connected portions **24** shown in FIG. **6** is an example, and is not limited thereto. The non-connected portions **24** are intermittently formed in the longitudinal direction of the optical fiber ribbon **1**C. Further, when the non-connected portions **24** are formed, the optical fibers **11**A to **11**L are also arranged such that the distance P between the centers of adjacent optical fibers is 220 μm or more and 280 μm or less.

As described above, according to the optical fiber ribbon **1**C of the second modification, since the non-connected portions **24** are intermittently formed in the longitudinal direction of the optical fiber ribbon **1**C, deformability of the optical fiber ribbon **1**C is enhanced in the cross section perpendicular to the longitudinal direction. Since the optical fiber ribbon **1**C is easily deformed, a plurality of optical fiber ribbons **1**C can be mounted in the optical fiber cable at a high density.

Although the outer diameters of the optical fibers **11** of the optical fiber ribbon **1**C according to the second modification are all the same, the optical fibers **11** of the optical fiber ribbon **1**C may have different outer diameters D**1** and D**2** as shown in the first modification.

(Third Modification)

In the optical fiber ribbon **1**A according to the first embodiment, a thickness of the collective coating **20** is uniform on the outer periphery of each of the optical fibers **11**, but the thickness of the collective coating **20** may not be uniform. FIG. **7** is a cross-sectional view perpendicular to a longitudinal direction of an optical fiber ribbon **1**D according to a third modification. FIG. **8** is a cross-sectional view of one optical fiber **11**B among the plurality of optical fibers **11** included in the optical fiber ribbon **1**D shown in FIG. **7**. In the description of FIGS. **7** and **8**, elements substantially the same as or corresponding to those in the configurations shown in FIGS. **1** and **2** are denoted by the same reference numerals, and repeated description thereof will be omitted.

As shown in FIGS. **7** and **8**, in the cross-sectional view of the optical fiber **11**B, a collective coating **20**D includes a thick portion **22** and at least two thin portions **23**. In other words, a thickness of the collective coating **20**D in the third modification is non-uniform on the outer periphery of the optical fiber **11**B. Here, the thickness of the collective coating **20**D on the outer periphery of the optical fiber **11**B is measured at a total of five locations except for the connected portion **21**. Among the five locations, a portion around a location where the thickness of the collective coating **20**D is largest is defined as the thick portion **22**, and a portion around a location where the thickness of the collective coating **20**D is thinner than the thick portion **22** by 5 μm or more is defined as the thin portion **23**. Positions of the thick portion **22** and the thin portion **23** on the outer periphery of the optical fiber **11**B shown in FIG. **8** are merely examples, and the present disclosure is not limited thereto. Further, since the collective coating **20**D covers the entire outer periphery of the optical fiber **11**B, there is no location where the optical fiber **11**B is exposed from the collective coating **20**D.

A thickness d**2** of the collective coating **20**D in the thin portion **23** is smaller than a thickness d**1** of the collective coating **20**D in the thick portion **22**. Specifically, a difference between the thickness d**1** of the collective coating **20**D in the thick portion **22** and the thickness d**2** of the collective coating **20**D in the thin portion **23** is 5 μm or more and 19 μm or less. The thickness d**1** of the collective coating **20**D in the thick portion **22** is, for example, 20 μm or less. The thickness d**2** of the collective coating **20**D in the thin portion **23** is, for example, 11 μm or more and 15 μm or less. The thickness of the collective coating between the optical fiber **11**B and the optical fiber **11**A or **11**C refers to a thickness from a middle point of the connected portion **21** to the optical fiber **11**B.

As described above, in the optical fiber ribbon **1**D according to the third modification, the collective coating **20**D includes the thick portion **22** and at least two thin portions **23**, and the thickness of the collective coating **20**D is non-uniform. In particular, since the difference between the thickness d**1** of the collective coating **20**D in the thick portion **22** and the thickness d**2** of the collective coating **20**D in the thin portion **23** is as relatively large as 5 μm or more and 19 μm or less, even when a plurality of optical fiber ribbons **1**D are mounted in an optical fiber cable at a high density, a contact area between the optical fibers in adjacent optical fiber ribbons **1**D and a contact area between the optical fiber ribbons can be reduced. Accordingly, friction is less likely to occur between adjacent optical fiber ribbons, cable meandering can be prevented, and cable laying work can be improved.

Further, when the optical fiber ribbon **1**D is mounted in an optical fiber cable, the thick portion **22** of each optical fiber may be disposed at a position facing the thin portion **23** of another optical fiber. Accordingly, as compared with a case where the collective coating has a uniform thickness, a mounting density of the optical fiber **11** with respect to the optical fiber cable is higher in a case where the thick portion **22** and the thin portion **23** are provided.

(First Evaluation Experiment)

The dynamic friction force and the surface hardness of the optical fiber ribbon of the present disclosure were evaluated. FIG. **9** is a cross-sectional view perpendicular to a longitudinal direction of an optical fiber ribbon **1**X used in a first evaluation experiment. In the description of FIG. **9**, elements substantially the same as or corresponding to those in the configuration shown in FIG. **4** are denoted by the same reference numerals, and repeated description thereof will be omitted.

As shown in FIG. **9**, the optical fiber ribbon **1**X used in the first evaluation experiment includes four optical fibers **11**A', **11**B, **11**C', and **11**D. Each of the optical fibers includes the glass fiber **12**, the primary resin layer **13**, and the secondary resin layer **14**. The outer diameter D**1** of each of the optical fibers **11**A' and **11**C' is 200 μm. The outer diameter D**2** of each of the optical fibers **11**B and **11**C is 180 μm. In other words, the optical fiber having the outer diameter D**1** of 200 μm and the optical fiber having the outer diameter D**2** of 180 μm are alternately arranged along a direction orthogonal to the longitudinal direction of the optical fiber ribbon **1**X. A distance between centers of adjacent optical fibers **11** is 255 μm.

In a manufacturing process of the optical fiber ribbon **1**X, outer peripheries of the four optical fibers **11**A' to **11**D arranged in parallel are coated with an ultraviolet curable resin. Thereafter, the ultraviolet curable resin is cured by being irradiated with ultraviolet rays, and the collective coating **20** is formed. At this time, the outer peripheries of the optical fibers **11**A' to **11**D are covered with the collective coating **20**. The dynamic friction force and the surface hardness of the collective coating **20** vary depending on a composition of the applied ultraviolet curable resin. The ultraviolet curable resin is cured, and the connected portions **21** are formed between all adjacent optical fibers. In the optical fiber ribbon **1**X, the thickness of the collective coating **20** is from 5 μm to 20 μm.

In the first evaluation experiment, samples No. 1 to No. 5 for the optical fiber ribbon **1**X having various dynamic friction forces or surface hardnesses were prepared by adjusting the composition of the applied ultraviolet curable resin. Further, samples No. 6 to No. 7 were prepared as comparative examples. In the first evaluation experiment, the dynamic friction force, the surface hardness, and low-temperature characteristics of the optical fiber ribbon **1**X were evaluated.

FIG. **10** is a schematic diagram of an experiment for measuring the dynamic friction force used in the first evaluation experiment. As shown in FIG. **10**, first, an optical fiber ribbon **1X1** to be measured is wound around an outer periphery of a mandrel **41** having an outer diameter of 10 mm. Further, another optical fiber ribbon **1X2** to be measured is arranged to be brought into contact with the optical fiber ribbon **1X1**, which is wound around the mandrel **41**, from above the mandrel **41** via a roller **42**. A pulling machine **43** is disposed at one end (upper side in FIG. **10**) of the optical fiber ribbon **1X2**, and a weight **44** is disposed at the other end (lower side in FIG. **10**) of the optical fiber ribbon **1X2**. The optical fiber ribbon **1X2** extending from the roller **42** to the mandrel **41** is bent at 90 degrees with respect to the optical fiber ribbon **1X2** extending from the pulling machine **43** to the roller **42**. The optical fiber ribbon **1X2** extending from the mandrel **41** to the weight **44** is bent at 90 degrees with respect to the optical fiber ribbon **1X2** extending from the roller **42** to the mandrel **41**. A detector provided inside the pulling machine **43** measured tension of the optical fiber ribbon **1X2** and defined the measured tension as the dynamic friction force. A measurement temperature was 23° C. A dynamic friction coefficient μ can be determined by a method described in JPH06-265737A.

In the first evaluation experiment, a weight of the weight **44** is 10 g. In this state, the pulling machine **43** pulls the optical fiber ribbon **1X2** in a certain direction (upward in FIG. **10**) at a speed of 500 mm/min, and the detector provided inside the pulling machine **43** measures tension as a dynamic friction force of the optical fiber ribbon **1X2**.

Further, in the measurement of the optical fiber ribbon **1**X, a composite modulus in a depth direction was determined by a test method based on ISO14577 using HYSITRON TI950 Tribolndenter manufactured by BRUKER. In the first evaluation experiment, the composite modulus refers to the surface hardness. An indentation depth was set to 100 nm, and the measurement was performed using a Berkovich indenter. Further, in the first evaluation experiment, the low-temperature characteristics of the optical fiber ribbon **1**X were evaluated. Here, the low-temperature characteristics were evaluated by measuring an attenuation amount per unit distance in a case where light having a wavelength of 1.55 μm was incident on the optical fiber **11**A' inside the cable under an environment of 23° C. and an environment of −30° C., and evaluating a difference between measured values under the two temperature environments. Evaluation results are shown in Table 1.

TABLE 1

	Sample						
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7
Dynamic friction force (N)	0.3	0.3	0.1	0.03	0.1	0.5	1
Surface hardness (GPa)	1.2	2.3	1.2	1.2	3	1.2	1
Low-temperature characteristics	Exceed 0.1 dB/km and 0.3 dB/km or less	0.1 dB/km or less	Exceed 0.1 dB/km and 0.3 dB/km or less	0.1 dB/km or less	0.1 dB/km or less	Exceed 0.3 dB/km	Exceed 0.3 dB/km

As shown in Table 1, the low-temperature characteristics of the samples No. 1 to No. 5 were all 0.3 dB/km or less, and it was confirmed that a cable attenuation was small. On the other hand, the low-temperature characteristics of the samples No. 6 and No. 7 both exceeded 0.3 dB/km. In particular, although the surface hardness of the sample No. 1 and the surface hardness of the sample No. 6 are 1.2 GPa, the sample No. 1 has better low-temperature characteristics than the sample No. 6. From the above, it was confirmed that the optical fiber ribbon **1**X having low cable attenuation characteristics can be implemented when the dynamic friction force is 0.3 N or less. Further, since the low-temperature characteristics of the samples No. 1 to No. 5 are all relatively excellent, it was confirmed that the optical fiber ribbon **1**X having low cable attenuation characteristics can be implemented when the surface hardness is 1.2 GPa or more and 3 GPa or less.

(Second Evaluation Experiment)

The low-temperature characteristics and the presence or absence of single core-separation of the optical fiber ribbon of the present disclosure were evaluated. FIG. **11** is a cross-sectional view perpendicular to a longitudinal direction of an optical fiber ribbon **1**Y used in a second evaluation experiment. In the description of FIG. **11**, elements substantially the same as or corresponding to those in the configuration shown in FIG. **9** are denoted by the same reference numerals, and repeated description thereof will be omitted.

As shown in FIG. **11**, the optical fiber ribbon **1**Y used in the second evaluation experiment includes the non-connected portions **24**. In a manufacturing process of the optical fiber ribbon **1**Y, outer peripheries of the four optical fibers **11**A' to **11**D arranged in parallel are coated with an ultraviolet curable resin. Thereafter, the ultraviolet curable resin is cured by being irradiated with ultraviolet rays, and the collective coating **20**D is formed. At this time, the outer peripheries of the optical fibers **11**A' to **11**D are covered with the collective coating **20**D. The thick portion **22** and the thin portion **23** are formed by adjusting a thickness of the applied ultraviolet curable resin by a shape of a die or the like. Further, after the ultraviolet curable resin is cured and the connected portions **21** are formed between all the adjacent optical fibers, the non-connected portions **24** are formed by inserting a cleaving blade such as a cutter between the adjacent optical fibers **11**A' and **11**B and between the adjacent optical fibers **11**C' and **11**D intermittently in the longitudinal direction of the optical fiber ribbon **1**Y. The connected portion **21** remains between the optical fibers **11**B and **11**C' where no cleaving blade is inserted.

In the second evaluation experiment, samples No. 1 to No. 3 for the optical fiber ribbon **1**Y having various thicknesses of the collective coating **20**D were prepared by adjusting a thickness of the applied ultraviolet curable resin. Further, a sample No. 4 was prepared as a comparative example. In the second evaluation experiment, the optical fiber **11**A' was selected as any optical fiber of each sample, and the thickness of the collective coating **20**D was measured at any eight measurement positions I to VIII in the optical fiber **11**A'. Further, the optical fiber ribbon **1**Y was mounted in an optical fiber cable, and cable attenuation characteristics were evaluated as low-temperature characteristics of the optical fiber ribbon **1**Y. An evaluation method for the cable attenuation characteristics is the same as the evaluation method in the first evaluation experiment. Further, the optical fiber ribbon **1**Y was taken out from the optical fiber cable, and the presence or absence of single core-separation of the optical fiber was examined. Evaluation results are shown in Table 2.

TABLE 2

		Sample			
		No. 1	No. 2	No. 3	No. 4
Thickness of collective coating (μm)	I	20	20	20	20
	II	15	1	1	0
	III	20	20	20	20
	IV	15	1	1	0
	V	20	20	20	20
	VI	20	20	1	20
	VII	20	20	20	20
	VIII	20	20	20	20
Low-temperature characteristics		0.3 dB/km	0.27 dB/km	0.25 dB/km	0.25 dB/km
Presence or absence of optical fiber-separation		NO	NO	NO	YES

As shown in Table 2, in the samples No. 1 to No. 3, the optical fiber separation of the optical fiber ribbon **1**Y was not found. On the other hand, in the sample No. 4 as the comparative example, the optical fiber separation of the optical fiber ribbon **1**Y was found. The sample No. 4 has two portions where the thickness of the collective coating **20**D is zero at the measurement positions II and IV. Portions at which the optical fiber **11**A' is not covered with the collective coating **20**D and is exposed from the collective coating **20**D are at the measurement positions II and IV. It was confirmed that the collective coating **20**D was peeled off from the optical fiber **11**A' starting from the exposed portion, and as a result, the optical fiber **11**A' was separated from the optical fiber ribbon **1**Y. From the above, it was confirmed that when the outer peripheries of the plurality of optical fibers **11** were covered with the collective coating **20**D, there was no fiber-separation.

In the sample No. 2, the measurement positions I, III, and V to VIII correspond to the thick portion **22**, and the thickness of the collective coating **20**D at each measurement position is 20 μm. In the sample No. 4, the measurement positions II and IV correspond to the thin portion **23**, and the thickness of the collective coating **20**D at each measurement position is 1 μm. It was confirmed that the cable attenuation in the sample No. 2 is 0.27 dB/km. Further, in the sample No. 3, the measurement positions I, III, V, VII, and VIII correspond to the thick portion **22**, and the thickness of the collective coating **20**D at each measurement position is 20 μm. In the sample No. 3, the measurement positions II, IV and VI correspond to the thin portion **23**, and the thickness of collective coating **20**D at each measurement position is 1 μm. It was confirmed that the cable attenuation in the sample No. 3 is 0.25 dB/km. From the above, it was confirmed that the optical fiber ribbon **1**Y having low cable attenuation can be implemented when the difference between the thickness of the collective coating **20**D in the thick portion **22** and the thickness of the collective coating **20**D in the thin portion **23** is 19 μm or less.

As shown in Table 2, it was confirmed that the cable attenuation in the sample No. 1 was 0.3 dB/km. In the sample No. 1, the measurement positions I, III, and V to VIII correspond to the thick portion **22**, and the measurement position II and IV correspond to the thin portion **23**. In the sample No. 1, the thickness of the collective coating **20**D in the thick portion **22** is 20 μm, and the thickness of the collective coating **20**D in the thin portion **23** is 15 μm. From the above, it was confirmed that the optical fiber ribbon **1**Y having low cable attenuation can be implemented when the difference between the thickness of the collective coating

20D in the thick portion 22 and the thickness of the collective coating 20D in the thin portion 23 is 5 μm or more.

As shown in the sample Nos. 1 to 3 in Table 2, it was confirmed that the smaller the thickness of the collective coating 20D in the thin portion 23 is and the larger the number of thin portions 23 is, the better the low-temperature characteristics are. This is considered to be because the number of contact points between the optical fiber ribbons is reduced when the thin portions 23 are formed.

Although the present disclosure has been described in detail with reference to specific embodiments, it will be apparent to those skilled in the art that various changes and modifications can be made without departing from the spirit and scope of the present disclosure. The numbers, positions, shapes or the like of components described above are not limited to the above embodiment, and can be changed to suitable numbers, positions, shapes or the like during carrying out the present disclosure.

REFERENCE SIGNS LIST

1A, **1**B, **1**C, **1**X, **1X1**, **1X2**, **1**Y: optical fiber ribbon
11, **11**A to **11**L: optical fiber
12: glass fiber
13: primary resin layer
14: secondary resin layer
20D: collective coating
21: connected portion
22: thick portion
23: thin portion
24: non-connected portion
30 V-groove base
31, **31**A to **31**L: V-groove
41: mandrel
42: roller
43: pulling machine
44: weight
D, D**1**, D**2**: outer diameter of optical fiber
P: distance between centers of adjacent optical fibers
P**0**: V-groove pitch
d**1**: thickness of collective coating in thick portion
d**2**: thickness of collective coating in thin portion

What is claimed is:

1. An optical fiber ribbon comprising:
a plurality of optical fibers arranged in parallel in a direction orthogonal to a longitudinal direction of the optical fibers; and
a collective coating covering outer peripheries of the plurality of optical fibers, wherein
the collective coating includes a connected portion at which the optical fibers adjacent to each other are connected in at least a part of the plurality of optical fibers,
an outer diameter of each of the plurality of optical fibers is 215 μm or less, and
a dynamic friction force of the collective coating is 0.3 N or less, wherein
a surface hardness of the collective coating is 1.2 GPa or more and 3 GPa or less.

2. The optical fiber ribbon according to claim **1**, wherein
a distance between centers of the optical fibers adjacent to each other is 220 μm or more and 280 μm or less.

3. The optical fiber ribbon according to claim **1**, wherein
the collective coating includes a non-connected portion at which the optical fibers adjacent to each other are not connected in at least a part of the plurality of optical fibers, and
the connected portion is intermittently formed in the longitudinal direction.

4. The optical fiber ribbon according to claim **1**, wherein
in a cross-sectional view of each of the optical fibers, the collective coating includes a thick portion and at least two thin portions in each of which a thickness of the collective coating is smaller than the thickness of the collective coating in the thick portion, and
a difference between the thickness of the collective coating in the thick portion and the thickness of the collective coating in each of the thin portions is 5 μm or more and 19 μm or less.

5. The optical fiber ribbon according to claim **1**, wherein
the plurality of optical fibers include a first optical fiber having a first outer diameter and a second optical fiber having a second outer diameter.

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