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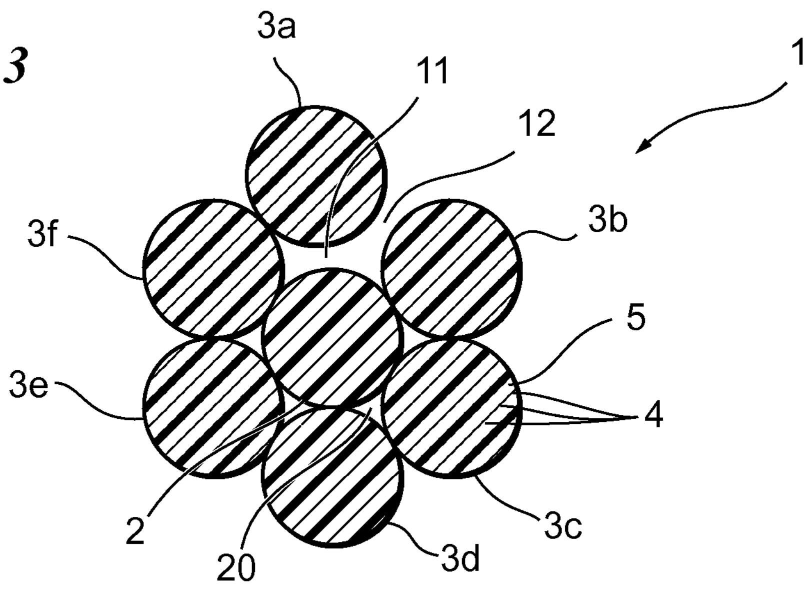
(54) SYNTHETIC FIBER CABLE

(57) A carbon fiber cable (1) includes a core member (2) having multiple thermosetting-resin-impregnated carbon fibers (2) bundled together, and multiple side members (3) each having multiple thermosetting-resin-impregnated synthetic fibers (4) bundled together in each side member. The thermosetting resin (5) is in a cured state and each of the multiple side members (3) has been shaped utilizing curability of the resin. The shaped multiple side members (3) are each in such a state that they are twisted together around the core member (2).

Fig. 3



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Description

Technical Field

[0001] This invention relates to a synthetic fiber cable.

Background Art

[0002] Patent Document 1 describes the insertion of a rod-shaped body, which is made of carbon fiber or aramid fiber, into a concrete structure with the aim of enhancing strength.

Prior-Art Documents:

Patent Documents:

[0003] Patent Document 1: Japanese Patent Application Laid-Open No. 2000-110365

[0004] An oblong hole is drilled into a reinforced-concrete pillar, and a rod-shaped body made of carbon fiber is driven into the oblong hole. A gap remaining in the oblong hole is subsequently filled with a fluidized curable resin, thereby fixing the rod-shaped body made of carbon fiber within the concrete. The rod-shaped body made of carbon fiber is merely fixed within the concrete by the fluidized curable resin that contacts the surface of the rod.

Disclosure of the Invention

[0005] An object of the present invention is to provide a synthetic fiber cable in which concrete or the like is allowed to penetrate the interior of a cable to thereby enlarge the area of contact with the concrete or the like, thereby making it possible to raise the efficiency of fixation.

[0006] A further object of the present invention is to provide a synthetic fiber cable that is excellent in terms of handling, the cable flexing suitably when bent.

[0007] The synthetic fiber cable according to the present invention is characterized by comprising: a core member having multiple resin-impregnated synthetic fibers, the fibers being bundled together; and multiple side members each having multiple resin-impregnated synthetic fibers, the fibers being bundled together in each side member; wherein the resin is in a cured state and each of the multiple side members has been shaped utilizing curability of the resin; each of the shaped multiple side members being in such a state that they are twisted together around the core member.

[0008] By curing the resin, the core member and side members formed by the multiple resin-impregnated synthetic fibers maintain the shape that prevails when the resin has cured. The resin will be cured by heating if it is a thermosetting resin and by cooling if it is a thermoplastic resin. If the resin is cured in a state in which a prescribed shape has been imparted, the core and side members will be capable of retaining this shape continuously thereafter.

[0009] The synthetic fibers that construct the core member and side members (not natural fibers such as of cotton or silk but fibers made from chemically synthesized polymer) include carbon fiber, glass fiber, boron fiber, aramid fiber, polyethylene fiber and PBO (polyp-phenylenebenzobisoxazole) fiber, as well as other fibers. These fibers are extremely slender and can be impregnated with resin by bundling a number of these synthetic fibers.

[0010] The synthetic fiber cable is constructed by placing each of the multiple side members, which have been shaped beforehand by utilizing the curability of the above-mentioned resin, in a state in which they are twisted together around the core member. In accordance with the present invention, owing to the pre-shaping of the side members utilizing the curability of the resin, suitable spaces or gaps can be assured in the interior of the synthetic fiber cable, specifically between the core member and its surrounding side members as well as between mutually adjacent side members, without impairing the substantially twisted state of the side members.

[0011] Owing to the fact that the core member and surrounding side members constituting the synthetic fiber cable are in such a state that the resin has cured on each member, slipping (shift in position) is allowed between the core member and surrounding side members as well as between mutually adjacent side members. As a result, there is provided a synthetic fiber cable which readily undergoes suitable flexing when bending is applied, and which excels in handling ease. For example, a synthetic fiber cable of great length can be put into compact form by being wound upon a small-diameter reel, thereby making handling easy at the workplace. The synthetic fiber cable according to the present invention is suitable for use as, for example, an electrical transmission cable (power transmission line), optical fiber cable, submarine cable and other comparatively long members, and as reinforcement for equipment.

[0012] In an embodiment, with regard to the core member and each of the multiple side members, they have, along the longitudinal direction thereof (there exist along the longitudinal direction), both contact portions where the side member is in contact with the core member and non-contact portions where the side member is not in contact with the core member. That is, the multiple side members surrounding the core member are not in continuous contact with the core member along their full length in the longitudinal direction but rather have portions which are not in contact the core member (portions where the side member is spaced away from the core member). The synthetic fiber cable is prevented from losing its shape owing to the contact portions. Because the non-contact portions define spaces between the core member and the side members, they contribute to improved bending ease (pliability) of the cable and are useful in facilitating the penetration of concrete, mortar or other coagulants or setting agents. For example, when the synthetic fiber cable is embedded in concrete, the concrete will penetrate into the interior of the synthetic fiber cable and the cable will be fixed firmly inside the concrete. The synthetic fiber cable according to the present invention is suitable for use as reinforcement for concrete structures, by way of example.

[0013] In another embodiment, with regard to each of the multiple side members, each has, along the longitudinal direction thereof, both contact portions in contact with mutually adjacent side members and non-contact portions not in contact with the mutually adjacent side members. That is, the multiple side members surrounding the core member are not in continuous contact with adjacent side members along their full length in the longitudinal direction but rather have portions which do not contact the adjacent side members (there are gaps between the side members). The synthetic fiber cable is prevented from losing its shape owing to the contact portions. The non-contact portions contribute to improved bending ease (pliability) of the cable and are useful in facilitating the penetration of concrete, mortar or other coagulants or setting agents.

[0014] With regard to the contact portions and non-contact portions between the core member and the side members as well as the contact portions and non-contact portions between mutually adjacent side members, it is preferred that the contact portions and non-contact portions be present repeatedly along the longitudinal direction. Thus is provided a synthetic fiber cable that is readily pliable along its full length. In a case where this synthetic fiber cable is used in a concrete structure, internal spaces that allow the penetration of concrete can be assured in dispersed fashion along the longitudinal direction of the synthetic fiber cable, and entrances that allow the penetration of concrete from the exterior to the interior can be assured in dispersed fashion.

Brief Description of the Drawings

[0015]

- Fig. 1 is a front view of a carbon fiber cable;
- Fig. 2 is an exploded perspective view of the carbon fiber cable;
- Fig. 3 is an enlarged sectional view taken along line III-III of Fig. 1;
- Fig. 4 is an enlarged sectional view taken along line IV-IV of Fig. 1;
- Fig. 5 is an enlarged sectional view taken along line V-V of Fig. 1; and
- Fig. 6 is a graph illustrating results of a concrete pull-out test.

Best Mode for Carrying Out the Invention

[0016] Fig. 1 illustrates the external appearance of a carbon fiber cable. Fig. 2 is an exploded perspective view of the carbon fiber cable. Figs. 3 to 5 are enlarged sectional views of the carbon fiber cable taken along lines III-III, IV-IV and V-V, respectively, of Fig. 1.

[0017] A carbon fiber cable 1 is constituted by a single core member 2 as well as six side members 3 (3a to 3f) (a 1x7 structure) placed in such a state that the side members are twisted together around the core member. When viewed in cross section, the carbon fiber cable 1, core member 2 and side members 3 all have a substantially circular shape. Further, when viewed in cross section, the carbon fiber cable 1 is such that the core member 2 is placed at the center thereof while the six side members 3 are situated so as to surround the core member 2. The carbon fiber cable 1 has a diameter of 5 to 20 mm, by way of example.

[0018] The core member 2 and side members 3 each comprise a large number, e.g., tens of thousands, of long carbon fibers 4 impregnated with a thermosetting resin (epoxy resin, for example) 5 and bundled into a shape having a circular cross section. The overall carbon fiber cable 1 includes on the order of several hundred thousand of the carbon fibers 4. Each of the carbon fibers 4 is very slender and has a diameter of 5 to 7 μm, by way of example. The core member 2 and side members 3 may each be formed by bundling together the large number of carbon fibers 4 impregnated with the thermosetting resin 5 and twisting together a plurality of these bundles of carbon fiber. The core member 2 and side members 3 can also be referred to carbon fiber reinforced plastics (CFRP).

[0019] In this embodiment, the core member 2 and side members 3 employed have the same thickness (cross-sectional area). The side members 3 used may of course be thinner or thicker than the core member 2. The thickness of the core member 2 and of each of the side members 3 can be adjusted at will depending upon the number of carbon fibers 4.

[0020] The core member 2 and side members 3 constituting the carbon fiber cable 1 are all used in a state in which the thermosetting resin 5 has been heated and cured in advance. Specifically, the carbon fiber cable 1 is produced by placing the side members 3, hardened by utilizing the thermal curability of the thermosetting resin 5, in such a state that they are disposed and twisted together around the core member 2 which, similarly, has been hardened by utilizing the thermal curability of the thermosetting resin 5. Since the thermosetting resin 5 of the core member 2 and of each of the side members 3 has cured, suitable slippage is allowed between the core member 2 and surrounding side members 3 and between the side members 3 that are adjacent each other.

[0021] With reference to Fig. 2, the six side members 3 that will be placed in a state in which they are twisted together around the core member 2 are all shaped into a helical configuration beforehand; the core member 2, on the other hand, does not undergo helical shaping. It goes without saying that the side members 3 are shaped into the helical configuration before the thermosetting resin 5 is thermally cured. The pitch of the helix of each of the helically shaped side members is substantially the same, and the inner diameter of the helix of each of the side members 3 is substantially equal to the diameter of the core member 2.

[0022] Each of the side members 3 partially has portions (referred to as "bulged portions" below) shaped so as to bulge slightly outward. Bulged portions 3A to 3D at four locations are illustrated in somewhat emphasized form on the carbon fiber cable 1 shown in Fig. 1.

[0023] Referring now to Fig. 3, when the portion having the bulged portion 3A is viewed in cross section, it will be seen that one side member (side member 3a) among the six side members 3a to 3f around the core member 2 is not in contact with the core member 2 but is positionally displaced outwardly away from the core member 2. The pre-shaping of the side member 3a is carried out so as to give rise to this positional displacement. Owing to the fact that the side member 3a is spaced away from the core member 2, an internal space (non-contact portion) 11 is assured between the core member 2 and side member 3a.

[0024] Since the core member 2 and side members 3 all have a circular cross section, portions of non-contact inevitably exist between the core member 2 and side members 3. [For example, in Fig. 3, an approximately triangular space (indicated at reference numeral 20), when viewed in cross section, is formed by the core member 2, the side member 3c and the side member 3d]. However, the internal space 11 referred to in this specification does not mean the space 20 having the approximately triangular cross section but rather signifies the space between the core member 2 and each of the core members 3, this internal space being assured by the pre-shaping of the core members 3. By assuring the internal space 11, the two spaces 20 having the approximately triangular cross section are connected.

[0025] In Fig. 3, the side member 3a situated between the two side members 3b, 3f on either side is in contact with the one side member 3f but is not in contact with the other side member 3b and is positionally displaced away from the side member 3b (shaping of the side member 3a being performed in advance so as to give rise to this positional displacement). A gap 12 is assured between the side member 3a and the side member 3b owing to the fact that the side member 3a is spaced away from the side member 3b.

[0026] Referring now to Fig. 4, when a portion having the other bulged portion 3B is viewed in cross section, it will be seen that two side members (side members 3e, 3f) among the six side members 3a to 3f around the core member 2 are not in contact with the core member 2. Instead, internal spaces 11 are assured between the core member 2 and the side members 3e, 3f. Since the side members 3e, 3f are adjacent each other, the two internal spaces 11 are connected, resulting in the formation of a large internal space. Further, although the other side member 3c is in contact with the core member 2, it is situated spaced away from both of the two side members 3b, 3d situated on either side of the side member 3c. Thus the gaps 12 are assured on both sides of the side member 3c.

[0027] In Fig. 4, the internal spaces 11 are illustrated as closed spaces. However, the internal spaces 11 are not spaces completely cut off from the outside but rather are open spaces in communication with the outside. Specifically, the internal spaces 11 assured between the core member 2 and side members 3 are connected to the above-mentioned gaps 12 that are assured by the fact that two mutually adjacent side members are spaced away at other locations along the longitudinal direction of the carbon fiber cable 1. The internal spaces 11 are in communication with the outside through the gaps 12.

[0028] Referring now to Fig. 5, when the portion having the bulged portions 3C, 3D is viewed in cross section, it will be seen that four side members (side members 3b, 3c, 3e, 3f) among the six side members 3a to 3f around the core member 2 are not in contact with the core member 2, thereby assuring internal spaces 11. Further, gaps 12 are assured between side members 3a and 3b, between side members 3c and 3d, between side members 3e and 3f, and between side members 3f and 3a.

[0029] Thus, the carbon fiber cable 1 is such that the locations and numbers of internal spaces 11 and gaps 12 differ depending upon the location where the cross section is taken. Naturally, depending upon where the cross section is taken, there will be instances where the internal spaces 11 and gaps 12 do not appear at all and, conversely, there can be instances where the six side members 3 will not be in contact with the core member 2 over its entire circumference. Further, as illustrated in Figs. 3 to 5, the sizes of the internal spaces 11 and gaps 12 (the distances between the core member 2 and side members 3 and the distances between mutually adjacent side members 3) that appear in a cross section will vary. This means that the extent of the multiple bulged portions 3A to 3D varies. It should be noted that extremely large bulged portions (internal spaces 11 and gaps 12) do not exist in the carbon fiber cable 1 and, hence, the essentially twisted state is not impaired.

[0030] The bulged portions mentioned above are formed repeatedly along the longitudinal direction of the carbon fiber cable 1. That is, with regard to the core member 2 and each of the multiple side members 3, contact portions where the side members 3 are in contact with the core member 2 (portions where the internal spaces 11 do not exist) and non-contact portions where the side members 3 are not in contact with the core member 2 (portions where the internal spaces 11 do exist) appear repeatedly along the longitudinal direction. Similarly, with regard to side members 3 that are adjacent each other, contact portions (portions where the gaps 12 do not exist) and non-contact portions (portions where the gaps 12 do exist) appear repeatedly along the longitudinal direction.

[0031] The bulged portion may be provided at prescribed intervals, or provided randomly, on each side member along the longitudinal direction thereof. Although the bulged portion may be provided at identical intervals on all of the side members 3 along the longitudinal direction thereof, the intervals of the bulged portions along the longitudinal direction may be made different for every side member 3. The bulged portions thus are provided on the carbon fiber cable 1 in dispersed fashion and the internal spaces 11 and gaps 12 along the longitudinal direction of the carbon fiber cable 1 are present in dispersed fashion.

[0032] As set forth above, since the carbon fiber cable 1 is such that the thermosetting resin 5 on the core member 2 and on each of the side members 3 has cured, slippage is allowed between the core member 2 and side members 3 and between side members 3 that are adjacent each other. Furthermore, since the cable has the internal spaces 11 and gaps 12, it undergoes suitable flexing when bent and excels in handling ease. The cable can be put into compact form by being wound upon a small-diameter reel, thereby making handling easy at the workplace. For example, the carbon fiber cable 1 is suitable for use as the core material of a long object such as a power transmission line.

[0033] Further, the carbon fiber cable 1 can be used as reinforcement for concrete structures, by way of example. When the carbon fiber cable 1 is embedded in concrete before the concrete sets (fresh concrete), the concrete penetrates into interior of the carbon fiber cable 1 with the gaps 12 between mutually adjacent side members 3 serving as entrances. Concrete that has entered into the interior of the carbon fiber cable 1 from the gaps 12 enters the internal spaces 11 assured between the core member 2 and side members 3, resulting in greater area of contact between the carbon fiber cable 1 and the concrete. Naturally, depending upon such factors as the viscosity of the fresh concrete and the sizes of the internal spaces 11 and gaps 12, the concrete may not fill the internal spaces 11 completely. However, in addition to the fact that the concrete comes into contact with the outer periphery (surface) of the carbon fiber cable 1, contact with the concrete also occurs in the interior of the carbon fiber cable 1 as well. Hence an increase in the area of contact between the concrete and the carbon fiber cable 1 is achieved. As a consequence, adhesion stress can be improved greatly in comparison with iron reinforcing bars and the carbon fiber cable 1 can be fixed inside the concrete with a high degree of fixing efficiency. Concrete structures include bridge beams, piers, bridge rails, protective barriers and the like.

[0034] Fig. 6 is a graph illustrating results of a concrete pull-out test in which the horizontal axis is a plot of slip displacement (mm) and the vertical axis a plot of adhesion stress (N/mm^2). The solid line in the graph indicates the result of testing the above-described carbon fiber cable 1, and the broken line indicates the result of testing a carbon fiber cable that does not have the internal spaces 11 and gaps 12. The diameters of the core members, side members, number and structure thereof, as well as the length embedded (the length fixed) in concrete were measured under identical conditions.

[0035] The concrete pull-out test was conducted in line with the "Method of Testing Adhesion Strength between Continuous Fiber Reinforcing Material and Concrete by Pull-out Test" of the Japan Society of Civil Engineers. According to this test, a concrete block in which the intermediate portion of a carbon fiber cable has been embedded with both ends of the cable exposed to the outside is fabricated. By using a tensile testing machine, a tensile load is applied at a prescribed loading rate to the carbon fiber cable projecting to the outside from one end of the concrete block, and a displacement gauge is used to measure the amount of displacement (slip displacement) of the carbon fiber cable projecting to the outside from the other end of the concrete block.

[0036] Adhesion stress τ(N/mm^2) was calculated using the following equation:

$$\text{Adhesion stress } \tau = P/u \cdot L$$

where P represents tensile load (kN), u the nominal circumference (mm) of the carbon fiber cable and L the adhesion length (mm) with respect to the concrete block.

[0037] As a result of the concrete pull-out test, it was confirmed that, in comparison with the adhesion stress (the broken line) of the carbon fiber cable devoid of the internal spaces 11 and gaps 12, the adhesion stress (the solid line) of the above-described carbon fiber cable 1 is greatly improved and exhibits a high concrete fixation efficiency.

[0038] The degree of shaping of the side members 3 (the degree of constraint due to the side members 3) in the carbon fiber cable 1 can be expressed by $D/(\sigma_1+2\sigma_2) \times 100(\%)$ (referred to as "shaping ratio" below) using diameter D of the cable 1 and diameters σ_1 and σ_2 of the core member 2 and side members 3, respectively, that constitute the cable 1. If the shaping ratio is on the order of 100.1 to 105(%), the carbon fiber cable 1 will undergo suitable flexing when bent, and the concrete adhesion efficiency will rise as well. In cases where the emphasis is placed on concrete adhesion efficiency and the concrete adhesion efficiency is to be raised, the multiple side members 3 may be shaped so as to take on a shaping ratio on the order to 110%, by way of example.

[0039] In the embodiment set forth above, an example is described in which bundles of the multiple carbon fibers 4 are impregnated with the thermosetting resin 5 and the carbon fiber cable 1 is constructed from the core member 2 and side members 3 hardened by applying heat to the thermosetting resin 5. However, a thermoplastic resin (polyamide, for example) may used instead of the thermosetting resin 5. Further, instead of carbon fiber, glass fiber, boron fiber, aramid fiber, polyethylene fiber and PBO (polyp-phenylenebenzobisoxazole) fiber, as well as other synthetic fibers, can be used.

[Description of Symbols]

[0040]

1: carbon fiber cable
2: core member
3, 3a, 3b, 3c, 3d, 3e, 3f: side members
3A, 3B, 3C, 3D: bulged portion
4: carbon fiber
5: thermosetting resin
11: internal space
12: gap

Claims

1. A synthetic fiber cable comprising:

a core member having multiple resin-impregnated synthetic fibers, the fibers being bundled together; and
multiple side members each having multiple resin-impregnated synthetic fibers, the fibers being bundled together in each side member;
wherein the resin is in a cured state and each of the multiple side members has been shaped utilizing curability of the resin;
each of said shaped multiple side members being in such a state that they are twisted together around said core member.

2. A synthetic fiber cable according to claim 1, wherein with regard to said core member and each of said multiple side members, they have, along the longitudinal direction thereof, both contact portions where said side member is in contact with said core member and non-contact portions where said side member is not in contact with said core member.

3. A synthetic fiber cable according to claim 1 or 2, wherein each of said multiple side members has, along the longitudinal direction thereof, both contact portions in contact with mutually adjacent side members and non-contact portions not in contact with the mutually adjacent side members.

4. A synthetic fiber cable according to claim 2 or 3, wherein the contact portion and non-contact portion are present repeatedly along the longitudinal direction thereof.

5. A concrete structure in which the synthetic fiber cable set forth in any one of claims 1 to 4 has been embedded in concrete.

6. An elongated object in which the synthetic fiber cable set forth in any one of claims 1 to 4 is used as reinforcement.

Fig. 1

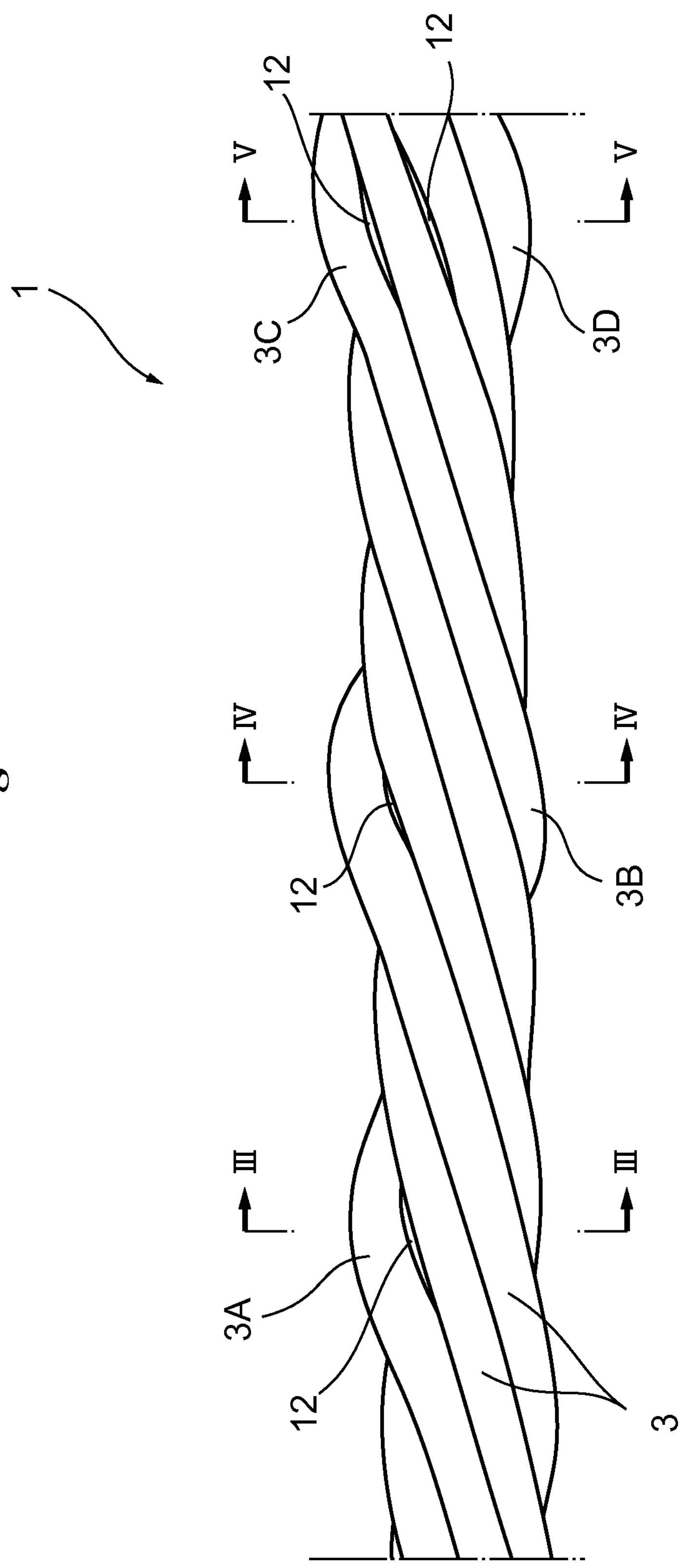


Fig. 2

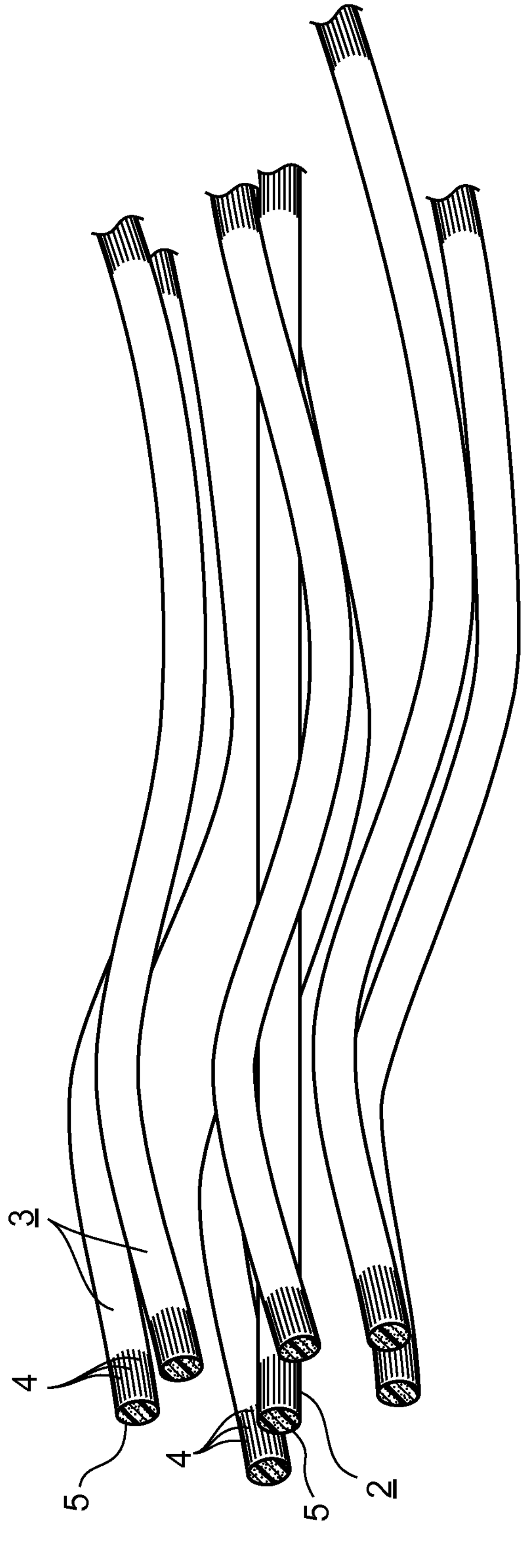


Fig. 3

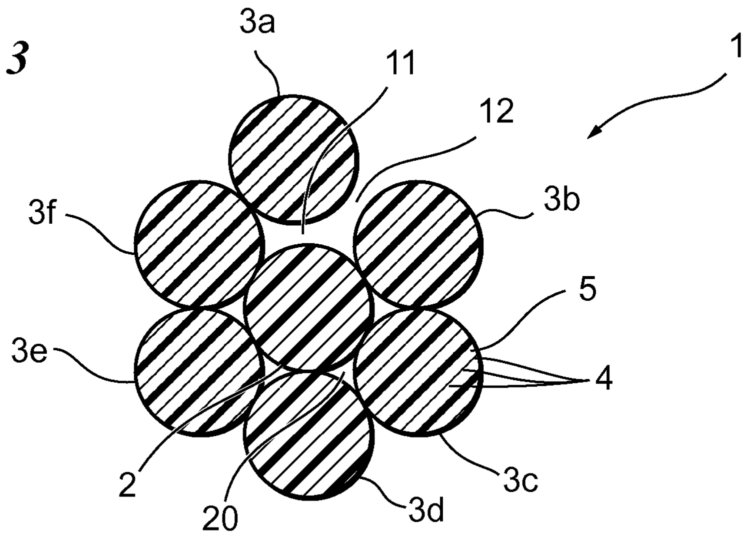


Fig. 4

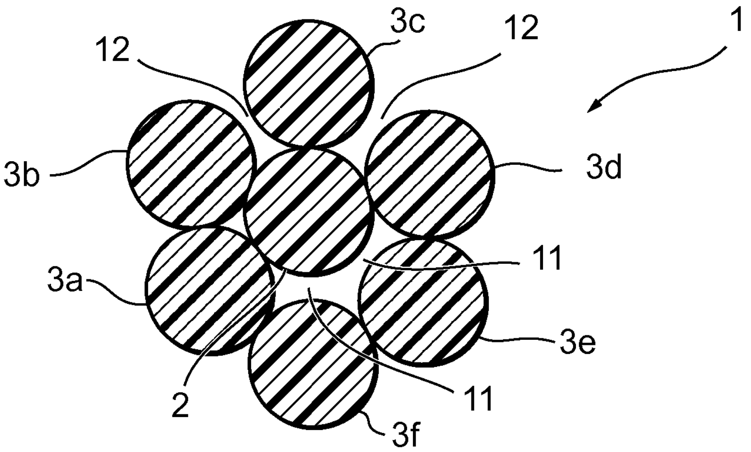


Fig. 5

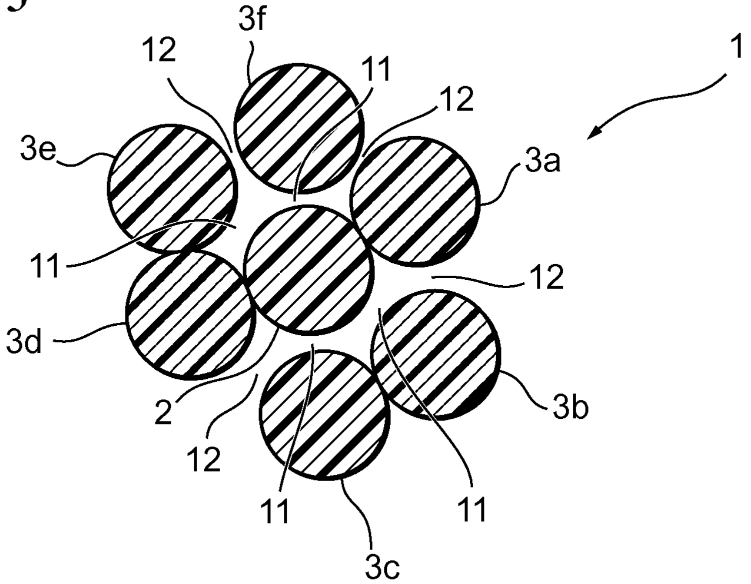
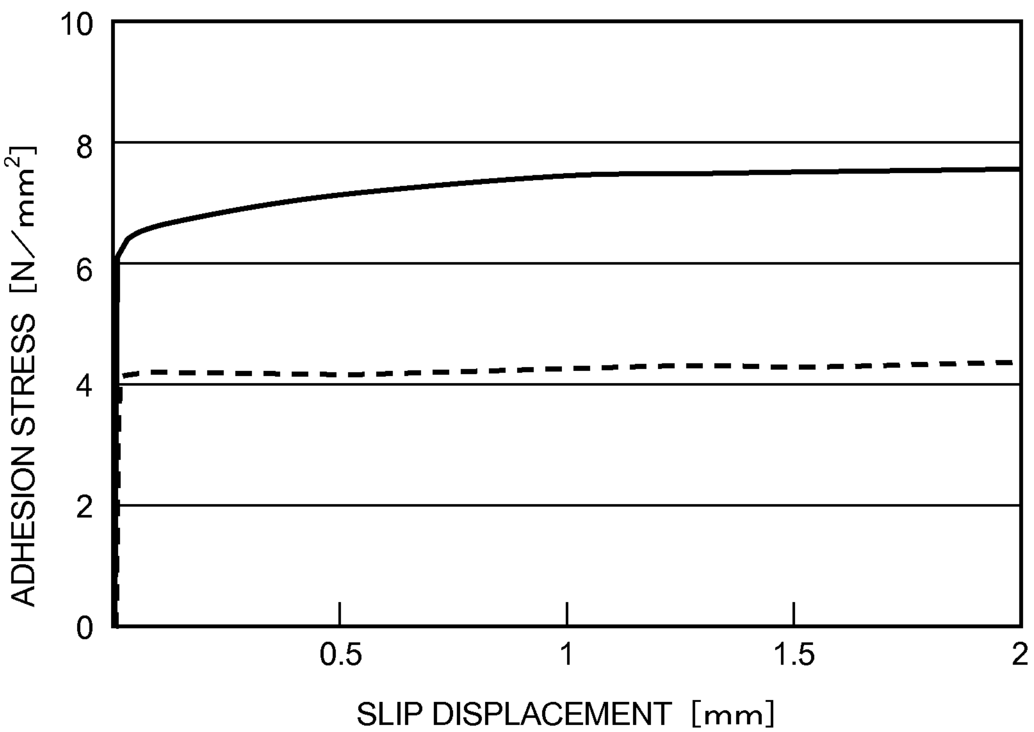


Fig. 6



INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2016/069283

A. CLASSIFICATION OF SUBJECT MATTER
D07B1/16(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
D07B1/16

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2016
Kokai Jitsuyo Shinan Koho	1971-2016	Toroku Jitsuyo Shinan Koho	1994-2016

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 3158927 U (Tokyo Rope Mfg. Co., Ltd.), 22 April 2010 (22.04.2010), claims; paragraphs [0016] to [0018], [0030], [0040]; examples (Family: none)	1-6
Y	JP 9-111679 A (Tokyo Rope Mfg. Co., Ltd.), 28 April 1997 (28.04.1997), claims; examples; drawings (Family: none)	1-6

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

* Special categories of cited documents:
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Date of the actual completion of the international search	Date of mailing of the international search report
05 September 2016 (05.09.16)	13 September 2016 (13.09.16)

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3,Kasumigaseki,Chiyoda-ku, Tokyo 100-8915,Japan	Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2000110365 A **[0003]**