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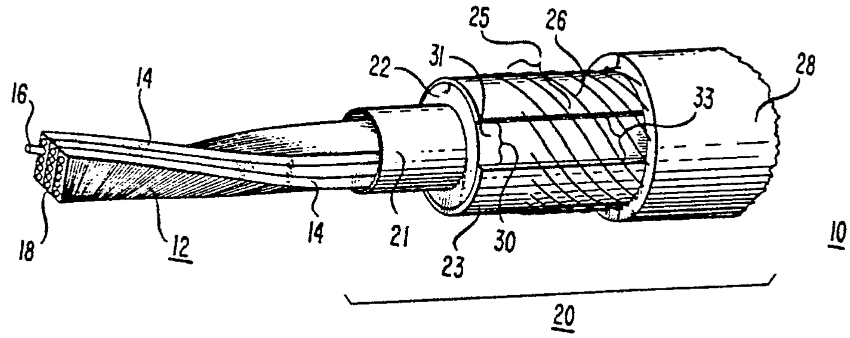

(57) Abstract

An improved optical cable (10) having increased bending flexibility along with increased tensile strength comprises means for controlling coupling between a cable jacket (28) and its reinforcing strength members (26). In one embodiment, a reinforcement bedding layer (23) is applied between a plastic-extruded inner jacket (22) and the outer cable jacket (28). Before extrusion of the outer jacket (28), the reinforcing strength members (26) are helically applied onto the bedding layer with predetermined strength member surfaces (27) making intimate surface contact with the bedding layer. Because the bedding layer is impervious to the plastic extrudant used to construct the outer jacket and is capable of rendering the predetermined strength member surfaces sufficiently inaccessible to the plastic extrudant, encapsulation of strength member lengths (25) containing the predetermined strength member surfaces (27) by the plastic extrudant is prevented. In another embodiment, the cable sheath (57) includes two separate layers (64, 70) of strength members, each layer having predetermined lays in opposite directions such that under a tensile load they produce equal but oppositely directed torques about the cable's longitudinal axis. The coupling between each layer of strength members and its surrounding jacket can also be controlled.

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OPTICAL COMMUNICATION CABLE

Technical Field

This invention relates to cables comprising light-transmitting optical fibers and more particularly, to optical communication cables having improved sheath structures.

Background of the Invention

While desired for their large bandwidth capabilities and small size, light-transmitting optical fibers are mechanically fragile, exhibiting low-strain fracture under tensile loading and degraded light transmission when bent. As a result, cable structures have been developed to mechanically protect the fibers, hence rendering fibers a realizable transmission medium.

A potential application for an optical cable is in ducts where space may be scarce. Such a cable must be capable of withstanding tensile loads applied when being pulled into a duct and bending stresses due to bends and turns in the ducts and manholes. One cable particularly suited for such an application is described in U.S. Patent No. 4,078,853.

In one embodiment, the known cable comprises a core of optical ribbons surrounded by a loose-fitting plastic-extruded inner tubular jacket; a thick, compliant insulative layer of polypropylene twine; and a plastic-extruded outer jacket reinforced with primary strength members. In the reference cable, the strength members are embedded and encapsulated in the outer jacket to achieve tight coupling with the outer jacket. During cable manufacture, the insulative layer of polypropylene twine, onto which the strength members are wrapped prior to outer-jacket extrusion, retreats from the strength members under the pressure of the outer-jacket plastic extrudant, thus allowing encapsulation of the strength members by the outer jacket.

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The reference cable has sufficient tensile strength to reliably protect the core of optical fibers under tensile loading and sufficient bending flexibility to ease cable handling prior to, during, and following duct installation. However, in certain situations, greater tensile loads are expected, especially where ducts are extremely congested, and/or when ducts have been found to have more bends than previously expected. In the known cable, bending flexibility decreases when more strength members are added to the outer jacket for increased tensile strength. However, greater bending flexibility is desired at the same time as higher tensile strength to ease cable handling and installation.

Therefore, there is a need to design an improved optical communication cable which is capable of greater bending flexibility and greater tensile strength at the same time.

Desirably, such a cable is also designed to perform reliably under sustained tensile loads.

Summary of the Invention

One objective of this invention is to develop an optical communication cable which has high tensile strength and which is relatively flexible. A second objective is that the bending flexibility can be varied substantially independent of the amount of tensile reinforcement added.

Pursuant to the above objectives, an optical communication cable has been developed in which the coupling between the strength members and the outer jacket is precisely controlled. In the illustrative embodiment, a reinforcement bedding layer of material, about which the strength members are helically wrapped, is added between the plastic-extruded inner and outer jackets to control the extent to which the strength members are encapsulated by the plastic extrudant of the outer jacket.

The bedding layer, which is substantially impervious to penetration by the plastic extrudant, interfaces with the strength members to define

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predetermined strength member surfaces inaccessible to the plastic extrudant during outer jacket extrusion. By preventing encapsulation of predetermined lengths of the strength members, the strength members are still tightly coupled to the outer jacket under a tensile load, but are capable of more readily sliding with respect to the outer jacket under local bending where no encapsulation occurs. Under tensile loading, the sliding is substantially eliminated because sufficient shear and frictional coupling exists between the outer jacket and the strength members.

In one of the illustrative embodiments, the inventive cable features two such reinforcement bedding layers and two separate layers of strength members. In accordance with another aspect of this invention, the two layers of strength members are helically wrapped with predetermined lays in opposite directions. Under a tensile load these two layers of strength members produce equal but oppositely directed torques about the longitudinal axis of the cable. This ensures the absence of torsional creep under sustained tensile loads.

The invention will be readily apparent from a reading of the description to follow of illustrative embodiments.

Brief Description of the Drawing

FIG. 1 is a fragmented perspective view of an optical communication cable constructed in accordance with this invention;

FIG. 2 depicts a partial cross section of the FIG. 1 cable sheath showing the effect the reinforcement bedding layer has on encapsulation of the reinforcing steel wires by the plastic-extruded outer jacket; and

FIG. 3 shows in fragmented perspective view another embodiment of the inventive optical communication cable featuring two layers of strength members and two reinforcement bedding layers.

Detailed Description of Illustrative Embodiments

Shown in FIG. 1 is a fragmented

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perspective view of one embodiment 10 of the optical communication cable constructed in accordance with this invention. The cable 10 comprises a core 12 of optical ribbons 14, with each ribbon 14 comprising a pluarlity of light-transmitting optical fibers 16 contained in a mechanically protective medium 18. Surrounding the core 12 is a cable sheath 20 which comprises a heat barrier layer 21 made of an insulative material such as a synthetic resin polymer tape, a plastic-extruded inner tubular jacket 22 which forms with the heat barrier layer 21 a loose tube for loosely containing the core 12, a reinforcement bedding layer 23, a layer or group of reinforcing strength members 26, and a plastic-extruded outer jacket 28.

In the cable 10 of FIG. 1, both jackets 22 and 28 are made of polyethylene though other plastics can be used, even a different plastic for each jacket. The strength members 26 are steel wires in the FIG. 1 cable. However, it is apparent that other materials, metallic and nonmetallic, can be used for the strength members.

In accordance with this invention, the bedding layer 23 controls coupling between the strength members 26 and the outer jacket 28. The bedding layer 23 intimately interfaces with the strength members 26 to render predetermined surfaces 27 (FIG. 2) of the strength members 26 sufficiently inaccessible for coupling with the plastic extrudant used to construct the outer jacket 28, hence preventing wire encapsulation for the strength member lengths 25 containing the predetermined surfaces 27.

During cable manufacture, the steel wires 26 are first helically wrapped onto the bedding layer 23 under tension so that the predetermined wire surfaces 27 make intimate surface contact with the bedding layer 23. Then, the outer jacket 28 is pressure extruded onto the bedding layer 23 and steel wires 26. The bedding layer

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23 is sufficiently stiff to sufficiently hinder the flow of the outer-jacket plastic extrudant to the predetermined wire surfaces 27 so that encapsulation of those lengths 25 of wires 26 is prevented. This reduces jacket-wire coupling sufficiently so that the wires 26 can more readily slide with respect to the outer jacket 28, where the bedding layer 23 is present, during local cable bending.

Preventing encapsulation has a minimum effect on the reinforcing tensile strength of the steel wires 26. When the plastic-extruded outer jacket 28 cools during cable manufacture, it forms a tight mechanical interference fit about the steel wires 26. Hence, during tensile loading of the cable, sufficient wire-jacket shear coupling exists to ensure tight longitudinal coupling between the steel wires 26 and jacket 28.

In the FIG. 1 cable, the bedding layer 23 is advantageously made of a thin layer, say 0.020-0.025 cm, of spunbonded polyester. The particular spunbonded polyester used is a standard product of E. I. DuPont de Nemours and Company. Spunbonded polyester is sufficiently compliant to develop trough-like recesses 24 (FIG. 2), which increase surface contact with the steel wires 26 having circular cross sections. In the illustrative embodiment, the wires 26 have a 0.043 cm diameter while the bedding layer 23 has a thickness of 0.023 cm. Advantageously, the trough-like recesses 24 also aid to maintain accurate registration of the steel wires 26 in prescribed regular intervals in the sheath 20. The relatively high-friction surface of the spunbonded polyester also promotes registration.

The spunbonded polyester 23 is sufficiently compliant and thick enough to enhance registration of the strength members, but sufficiently stiff and thin enough to utilize the rigidity of the inner jacket 22 to prevent the outer-jacket plastic extrudant from penetrating the predetermined wire surfaces to encapsulate the wires 26.

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The bedding layer 23 also supports the wires 26 sufficiently to minimize their inward radial movement, which movement can increase the tendency of a cable sheath to buckle. At the same time, it is sufficiently thin so as to not add significantly to the diameter of the cable or the radial compliance of the cable which can result in tensile creep.

It is apparent that the bedding layer 23 can be made of other materials having varying thicknesses and stiffnesses. A thicker and stiffer material can be used. Also, if the strength members are flat, a material with a high-friction surface, but with little compliance, can be used. The bedding layer can also be of multi-ply construction with an outer layer which is relatively compliant and/or surface-roughened to register the strength members and with a rigid and stiff bottom layer which helps to substantially prevent access to the predetermined wire surfaces 27 by the plastic extrudant. It is critical that the bedding layer be capable of preventing strength member encapsulation by the outer jacket 28.

It should also be pointed out that the strength members can be a material other than steel. For example, nonmetallic strength members, such as graphite or aramid* rods can be used. It is also apparent that the strength members can be composite structures comprising any of a number of high modulus materials.

In the FIG. 1 cable, the bedding layer 23 is longitudinally applied and does not completely wrap about inner jacket 22 to define a gap or a strength member encapsulating region 30, where encapsulation of the steel wires 26 does occur. Advantageously, the bedding layer 23 suspends the strength members 26 over the inner jacket 22 in the strength member encapsulating region 30 to promote effective encapsulation by the outer-jacket plastic extrudant. Also, during extrusion of the outer jacket, the

* aramid is a long chain of polyamid substance having aromatic rings (Definition of the Federal Trade Commission)

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heat and pressure of the outer-jacket plastic extrudant cause the inner-jacket plastic extrudant along the exposed surface 31 of the inner jacket 22 to melt. Hence, the inner jacket 22 integrally fuses with the outer jacket 28 to form one unitary structure to help ensure encapsulation of the strength members 26. In FIG. 2, an imaginary dotted line 32 denotes the fused interface between the inner and outer jackets 22 and 28.

By adjusting the bedding layer width, the size of the gap 30 can be varied to attain the desired strength member encapsulation and thus the desired bending flexibility.

Lengths 25 of the strength members 26 abutting the bedding layer 23 are not encapsulated while the lengths 33 of the strength members 26 in the gap 30 are encapsulated. Where the steel wires 26 are encapsulated by the outer-jacket plastic extrudant, the jacket 28 forms a shrink fit, like a closed ring, which substantially mitigates relative movement of the strength members 26 with respect to the jacket 28. Where the strength members 26 are seated onto the bedding layer, the outer jacket 28 forms a split-type ring, which more easily allows relative movement of the strength members 26 with respect to the outer jacket 28 under local bending.

It is apparent that the bedding layer 23 can be applied to form no gaps so that entire lengths of the steel wires 26 are not encapsulated, in which case the cable 10 will have its greatest bending flexibility.

FIG. 3 shows an alternative embodiment 50 of this invention. Similar to the FIG. 1 cable, the FIG. 3 cabel 50 comprises a core 52 of optical ribbons 54 containing optical fibers 56. However, the cable 50 comprises a cable sheath 57 with a layer of insulative material 58, a plastic-extruded inner tubular jacket 60, a first reinforcement bedding layer 62, a first layer 64 of strength members, a plastic-extruded first outer jacket 66, a second reinforcement bedding layer 68, a second layer 70

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of strength members, and a plastic-extruded second outer jacket 72.

In the FIG. 3 cable, the bedding layers 62 and 68 are helically applied in opposite directions to form candy-striped gaps or strength member encapsulating regions 63 and 69. In this embodiment, the lay length of the bedding layers, as well as their width, can be varied to obtain the desired amount of strength member encapsulating regions. It is apparent that either bedding layer 62 or 68 can be applied continuously to form a reinforcement bedding layer without a strength member encapsulating region.

Advantageously, the FIG. 3 cable is a torque-balanced cable. The two layers 64, 70 of strength members are helically wrapped in opposite lay directions with predetermined lays so that under a tensile load the two layers produce equal but oppositely directed torques about the longitudinal axis of the cable. This advantageously eliminates torsional creep or twisting that can otherwise occur when the cable is under sustained tensile loads. In the illustrative embodiment, each layer 64, 70 is also wrapped in a lay direction opposite to its bedding layer 62, 68 to ensure periodic encapsulation of each strength member.

Another torque-balanced cable can be constructed which is more similar to the FIG. 1 cable. In this further embodiment, a layer of second strength members is helically applied with an opposite lay direction directly onto a layer of first strength members (similar to members 26). Such a cable has a sheath identical to the FIG. 1 cable but for the second strength members, which are substantially encapsulated in the outer jacket.

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Claims

1. An optical communication cable comprising a core having at least one light-transmitting optical fiber, an inner jacket surrounding the core, a plurality of strength members, and an outer jacket constructed of plastic extrudant, wherein the outer jacket surrounds the inner jacket and is coupled with the strength members,

CHARACTERIZED IN THAT

controlling means (23) are provided between the outer jacket (28) and the strength members (26).

2. Optical cable in accordance with claim 1,

CHARACTERIZED IN THAT

the controlling means (23) comprise means for preventing encapsulation of the strength members (26) by a plastic extrudant used to construct the outer jacket (28).

3. Optical cable in accordance with claim 2,

CHARACTERIZED IN THAT

the encapsulation-preventing means comprises a bedding layer (23 interposed between the inner jacket (22) and the outer jacket (28), where the bedding layer is made of a material which is substantially impervious to plastic extrudant and which is capable of rendering predetermined surfaces (27) of the strength members (26) sufficiently inaccessible to the plastic extrudant.

4. Optical cable in accordance with claim 3,

CHARACTERIZED IN THAT

the strength members (26) are helically wrapped onto the bedding layer (23), form an intimate interface with the bedding layer and define the predetermined strength member surfaces (27).

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5. Optical cable in accordance with claim 4,

CHARACTERIZED IN THAT

the bedding layer (23) is made of a material which is sufficiently compliant to form trough-like recesses (24) to register and hold the strength members (26) in regular intervals around the cable.

6. Optical cable in accordance with claim 4,

CHARACTERIZED IN THAT

the bedding layer (23) is discontinuously applied over the inner jacket (22) and forms at least one gap (30) defining a strength-member encapsulating region (30).

7. Optical cable in accordance with any one of claims 1-6,

CHARACTERIZED IN THAT

each of the strength members (26) is periodically encapsulated by the plastic extrudant.

8. Optical cable in accordance with any of claims 3-7,

CHARACTERIZED IN THAT

the bedding layer (62) is applied in a candy-stripe fashion over the inner jacket (60).

9. Optical cable in accordance with claim 6,

CHARACTERIZED IN THAT

the bedding layer (23) is applied longitudinally over the inner jacket (22) and the gap (30) is longitudinally continuous.

10. Optical cable in accordance with claim 8,

CHARACTERIZED IN THAT

the strength members (64, 70) are helically wrapped onto the bedding layer (62, 68) in a lay direction opposite to the direction with which the

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bedding layer is applied.

11. Optical cable in accordance with claim 4,

CHARACTERIZED IN THAT

the bedding layer (23) is made of spunbonded polyester.

12. Optical cable in accordance with claim 11,

CHARACTERIZED IN THAT

the bedding layer (23) is sufficiently thin to utilize the rigidity of the inner jacket (22), to help hinder flow of the plastic extrudant to the predetermined strength member surfaces (27).

13. Optical cable in accordance with any of claims 1-12,

CHARACTERIZED IN THAT

the strength members (26) are rods.

14. Optical cable in accordance with any of claims 1-12,

CHARACTERIZED IN THAT

the strength members (26) are nonmetallic structures.

15. Optical cable in accordance with claim 13,

CHARACTERIZED IN THAT

the strength members (26) are metallic.

16. Optical cable in accordance with claim 7,

CHARACTERIZED IN THAT

the outer jacket (28) is made of pressure-extruded polyethylene.

17. An optical communication cable (50) having a longitudinal axis characterized in combination by:

a core (52) comprising at least one light-transmitting optical fiber (56);

an inner jacket (60) surrounding the

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core;

a first layer (64) of strength members;

a first outer jacket (66) surrounding the inner jacket;

a second layer (70) of strength members; and

a second outer jacket (72);

where the first and second layers of strength members are helically wrapped in opposite directions with predetermined lays such that under a tensile load each layer produces a substantially equal but oppositely directed torque with respect to the longitudinal axis of the cable.

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FIG. 1

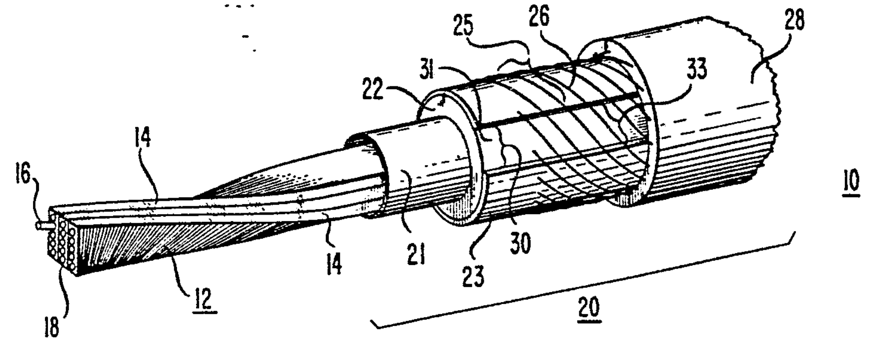


FIG. 2

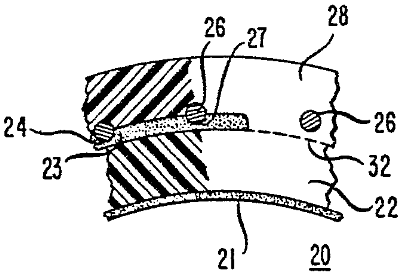
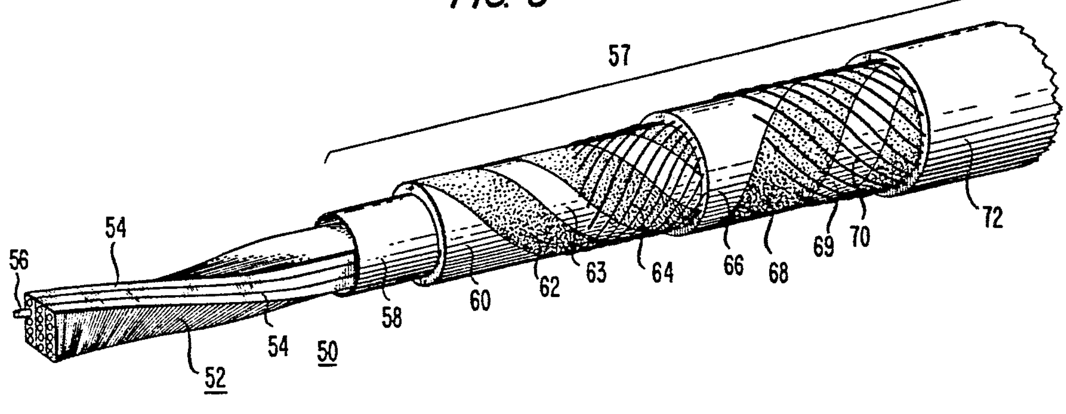


FIG. 3



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INTERNATIONAL SEARCH REPORT WO 80/01517

International Application No PCT/US79/01119

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

INT. CL.[3] G02B 5/16
U.S. CL. 350/96.23

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
U. S.	350/96.23, 174/70R

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
A	US, A, 4,076,382, PUBLISHED 28 FEBRUARY 1978, OESTREICH	10,17
X	US, A, 4,078,853, PUBLISHED 14 MARCH 1978, KEMPF ET AL, SEE COL. 4, LINES 40-52, AND COL. 5, LINES 18-27	1,17
X	US, A, 4,082,423, PUBLISHED 04 APRIL 1978, GLISTA ET AL, SEE COL. 3, LINE 62, TO COL. 4, LINE 18	1-17
A	US, A, 4,129,468, PUBLISHED 12 DECEMBER 1978, KNAB	1,17
X,P	US, A, 4,169,657, PUBLISHED 02 OCTOBER 1979, BEDARD, SEE COL. 2, LINE 48 TO COL. 3, LINE 18	1-5, 11-15,17
X	FR, A, 2,265,108, PUBLISHED 17 OCTOBER 1975, PIRELLI...	4-17
A	FR, A, 2,296,192 PUBLISHED 23 JULY 1976, COX	1,4
A	DE, A, 2,556,861 PUBLISHED 08 JULY 1976, GOELLET AL	1,4
A	DE, A, 2,513,722 PUBLISHED 30 SEPTEMBER 1976 OESTREICH	1
A	DE, B, 2,628,069, PUBLISHED 11 AUGUST 1977, OESTREICH	11
A	DE, B, 2,628,070 PUBLISHED 11 AUGUST 1977, OESTREICH	11

* Special categories of cited documents: [15]

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IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
13 FEBRUARY 1980	22 FEB 1980
International Searching Authority [1]	**Signature of Authorized Officer [20]**
ISA/US	JOHN D. LEE *John D. Lee*