Abstract Title: Connector for cable or pipe made of composite thermoplastic material

A connector or terminator 40, 54 for a cable 16 or pipe (70, figures 15, 16) formed of thermoplastic composite material comprises a mandrel 54 and a collar member 40. At least one of the mandrel 54 and collar 40 have a non-cylindrical surface 48 facing the cable or pipe, and at least the other of the members 56 is deformable towards the cable or pipe. The end of the pipe or cable is arranged around the mandrel and within the collar, and is then heated until it is soft and tacky. The deformable member 56 is then deformed towards the pipe or cable so that the pipe or cable is deformed between the mandrel and the collar. This arrangement allows a termination or connection to be formed without damaging the reinforcing fibres.
Elongate members such as cables and tubes, and methods of termination thereof

DESCRIPTION

A first aspect of the present invention relates to elongate members of thermoplastic composite material, and in particular to a method of terminating such members.

Examples of such materials are thermoplastics such as polyetheretherketone, polyphenylene sulphide, polyamide, polyether sulphide, and polyether imide, that are reinforced by filaments of reinforcing material such as carbon fibres, glass fibres or aramid fibres. Examples of such members are tension cables that might, for example, be used in the rigging of a marine vessel, or pipes that might be used for conveying a fluid.

There is a need to be able to terminate such elongate members, for example so that a rigging cable can be securely attached to a mast, or so that a pipe can be coupled to another pipe or to some other apparatus. Simple variations of conventional swaging, crimping, friction and compression fittings are unsuitable for the termination of thermoplastic composite members. Thermoplastics are notoriously difficult to bond to, so variations of glued, potted and adhesive joints should be avoided. Also, any termination method that might sever or significantly weaken the reinforcing fibre should be avoided.

In accordance with the first aspect of the invention, there is provided a method of terminating an end of an elongate member formed of thermoplastic composite material, the end of the elongate member having a portion or portions arranged around an axis of the end of the elongate member. The method comprises the steps of forming an assembly of the end of a elongate member with a collar member and a mandrel member, and then working the assembly so as to secure the members to the end of the elongate member; the assembling step comprising arranging the portion or portions of the end of the elongate member around the mandrel member and inside the collar member, at least one of the mandrel and collar members having a surface facing the portion or portions that is non-cylindrical and at least the other of the mandrel and collar members being deformable towards the portion or portions; and the working step comprising the steps of heating the assembly so that the portion or portions of the end of the elongate member become soft and tacky, then deforming said other member so that the portion or portions are compressed between the mandrel and collar members, and then allowing the
assembly to cool so that the portion or portions become bonded to the mandrel and collar members.

The compression of the end portion or portions while soft and tacky causes it/them to deform so as to conform to the non-cylindricity of said one member so that the end of the elongate member, once cool, cannot subsequently be removed from the assembly without further deformation. Furthermore, the compression of the end portion or portions while soft and tacky between the mandrel and collar members causes the thermoplastics, once cool, to bond to the mandrel and collar members so that the end of the elongate member cannot subsequently be removed from the assembly without breaking the bond.

In the case where the elongate member is a cable formed by a bundle of strands of the thermoplastic composite material with the end of each strand forming such a portion, the assembling step preferably includes splaying out the ends of the strands around the mandrel member. The ends of the strands are then compressed together during the deforming step to form a homogeneous mass between the mandrel and collar members, in addition to bonding the homogeneous mass to the mandrel and collar members. In this case, the mandrel member preferably tapers in the direction away from the end of the cable and more preferably tapers to a point. This avoids the formation of sharp kinks in the reinforcing fibres during the deforming step.

In addition to being applicable in the case of a stranded cable, the method of the first aspect of the invention can also be used to terminate an elongate member that is tubular, such as a pipe.

The mandrel member may be deformable and hollow, in which case the deforming step may comprise applying pressure inside the mandrel member to expand the mandrel member radially. Additionally or alternatively, the collar member may be deformable, and the deforming step may comprise contracting the collar member, for example with a mechanical swaging or crimping action, but preferably with an electromagnetic action.

The assembling step preferably includes disposing filler material between the end portion or portions of the elongate member and one or both of the mandrel and collar members.

According to a second aspect of the invention, there is provided an elongate member of thermoplastic composite material terminated by a method of the first aspect of the invention.
According to a third aspect of the invention, there is provided a machine for use in performing a method of the first aspect of the invention, the machine comprising means for supporting either or both of the mandrel and collar members, means for so heating the assembly and means for so deforming said other member.

A fourth aspect of this invention relates to tension cables. It is well known to form a tension cable from a plurality of separate flexible strands that are twisted helically along the length of the cable. The twisting serves to hold the strands together and also makes the cable more flexible and able to be coiled. Many configurations are possible, such as three strands that are mutually twisted (as shown in Figure 1 of the accompanying drawings) and six strands that are wound around a central strand (as shown in Figure 2 of the accompanying drawings). Typically each strand has a circular cross-section. As a result, there can be many interstices within the cable between the strands, the overall cross-sectional area of the cable can be significantly greater than the total cross-sectional area of the strands, and the cable may have a cross-sectional outline that is significantly non-circular. Accordingly, the cable has a higher wind drag coefficient, a greater bulk and the ability to absorb more water than a single circular strand having the same cross-sectional area of strand material.

In accordance with the third aspect of the present invention, there is provided a tension cable comprising a bundle of elongate strands of flexible material each wound helically along the length of the cable each for bearing a proportion of a tensile load applied to the cable, wherein each strand is a ribbon having an elongate cross-section having a width extending in the radial direction of the cable and a length extending around the centre of the cable, the ribbons as viewed cross-sectionally of the cable being wound in a spiral series. As will be demonstrated below, with various shapes, sizes and arrangements of the ribbons, the strands can be tightly packed with an insignificant amount of interstitial space and with a relatively smooth cross-sectional outline.

In one arrangement, in cross-section, the ribbons are four-sided having a pair of opposed shorter sides and a pair of opposed longer sides, and, for a majority of the ribbons, the shorter sides of the ribbon abut the shorter sides of the ribbons before and after that ribbon in the spiral series. It is therefore possible that at least the bulk of the cable can be formed from 'off-the-shelf' ribbon stock.

In other arrangements, the ribbons may be specially shaped. For example, in cross section, the ribbons may be three-sided having a longer side and two shorter sides, and, for a majority of the ribbons, the longer side of the ribbon may in part overlap one of the shorter
sides of the ribbon after that ribbon in the spiral series and may in part overlap the previous turn of the spiral.

The ribbons are preferably arranged as at least one group of a multiplicity of the ribbons, with the ribbons of the or each group being made from stock having an, or a respective, identical cross-sectional shape and size. This reduces the variety of ribbon stock that needs to be available in order to construct the cable. Nevertheless, at least the ribbon at the end of the spiral series nearer and/or further from the centre of the cable is preferably made from stock having a different cross-sectional shape and size to the stock from which the majority of the ribbons are made.

The cable may have a further, generally-central, strand, for example of generally circular cross-section, around which the spiral series of ribbons is wound.

The cable lends itself to the use of strands that are of thermoplastic composite material, and may be terminated by the method of the first aspect of the invention.

Specific embodiments of the present invention will now be described, purely by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a cross-sectional view of a conventional three-stranded cable;

Figure 2 is a cross-sectional view of a conventional seven-stranded cable;

Figure 3 is a cross-sectional view of a tension cable of a first embodiment of the invention;

Figures 4-6 are end views of three different shapes of strand that are used in the cable of Figure 3;

Figure 7 is an isometric view of the cable of Figure 3;

Figure 8 is an end view of a tension cable of a second embodiment of the invention;

Figures 9-12 are end views of three different shapes of strand that are used in the cable of Figure 8;

Figures 13A-E are longitudinal sectional views showing steps in a first example of a method of terminating an end of a cable;
Figures 14A-E are longitudinal sectional views showing steps in a second example of a method of terminating an end of a cable;

Figures 15A-D are longitudinal sectional views showing steps in a third example of a method of terminating an end of a pipe; and

Figure 16 is a longitudinal sectional view of two pipes terminated by the third method and coupled together.

Referring to Figures 3 to 7, the first embodiment of tension cable 16 comprises a single central strand 18, two triangular-section ribbons 20 and fifteen rectangular-section ribbons 22. The strand 18 and ribbons 20,22 are each of flexible thermoplastics material such as polyetheretherketone, polyphenylene sulphide, polyamide, polyether sulphide, and polyetherimide, that is reinforced by filaments of reinforcing material such as glass, carbon or aramid, with each filament extending partly or completely along the strand 18 or ribbon 20,22. The strand 18 is of circular cross-section. Each rectangular-section ribbon 22 has a width W that is, say, 1½ times the diameter D of the strand 18, and a thickness T that is substantially less than its width W, for example 10 or 15% of its width W. Each triangular-section ribbon 20 has a shortest side length that is about equal to the thickness T of the ribbons 22 and longer side lengths that are both about equal to the width W of the ribbons 22.

Each ribbon 20,22 is wound helically along the cable 16, as can be seen in Figure 7. An innermost one of the triangular ribbons 20 is curved as it is wound onto the central strand 18 with one of its longer sides against the central strand 18. An innermost one of the rectangular ribbons 22 is curved as it is wound onto the central strand 18/innermost triangular ribbon 20 with one of its faces against the central strand 18/innermost triangular ribbon 20 and with one of its edges against the shorter side of the innermost triangular ribbon 20. The remaining rectangular ribbons 22 are curved as they wound in a similar fashion so that they form a spiral series, each with its two edges against the edges of the preceding and succeeding ribbons 22 in the spiral. The remaining triangular ribbon 20 finishes the outermost end of the spiral with its shorter side against the outermost edge of the last rectangular ribbon 22 in the spiral.

The cable 16 may be manufactured using a cable-winding machine having a stand for a supply reel of the central strand 18, two stands for two supply reels of the triangular ribbons 20, fifteen stands for fifteen supply reels of the rectangular ribbons, and a winding head and take-up reel that rotate as the strand 18 and ribbons 20,22 are drawn off their reels so as to provide the helical twist to the ribbons 20,22. The strand 18 and ribbons 20,22 may be wound at room
temperature. However, the ribbons 20,22 (and the central strand 18) are preferably heated to a
temperature at which the thermoplastics material softens so that the ribbons 20,22 can more
easily take on their curved shapes. However, the ribbons 20,22 are not heated to such an extent
that the thermoplastics material becomes tacky and the ribbons 20,22 tend to bond together. If
desired, a lubricating and anti-bonding agent may be applied to the ribbons 20,22 before they
are wound, and pressure may be applied to the ribbons 20,22 by a die or rollers in order to pack
the ribbons tight.

As can be seen from Figures 3 and 7, there may be interstices between the shorter
sides/edges of the ribbons 20,22, but they are relatively small compared to the interstices of a
cable wound from eighteen circular-section strands. Furthermore, as can be seen from Figures 3
and 7, the outline of the cable 16 is relatively smooth, far smoother than the outline of a cable
wound from circular-section strands. It should also be noted that the construction shown in
Figures 3 to 7 provides a cable manufacturer with far more flexibility as to the load bearing
capacity of the cables they make. The cable 16 can be made stronger by including more
rectangular-section ribbons 22 in the spiral, or can be made smaller, lighter and less expensive
by including less rectangular-section ribbons 22.

The second embodiment of cable 16 will now be described with reference to Figures 8
to 12. The cable 16 of Figures 8 to 12 is similar to the cable 16 of Figures 3 to 7 except in the
following respects. The innermost ribbon 20a (Figure 11) has a cross-section that is spiral
shaped and has a thickness that increases from a point at its innermost end 24 to a maximum at
a position 26 more than half way around the spiral and then decreases to a point at its outermost
end 28. The outermost ribbon 20b (Figure 12) has a cross-section that is crescent shaped but
with a kink 30 in its outer edge. The remaining ribbons 22 (Figure 10) are identical and each is
crescent shaped, but smaller than the outermost ribbon 20b, and with a kink 32 in its outer
edge, so that each ribbon 22 has three curved faces, namely a concave inner face 34 and a pair
of convex outer faces 36,38. In the example, there are thirty-five such ribbons 22.

When the cable 16 of Figures 8 to 12 is wound, the innermost ribbon 20a is wound with
its concave face against the central strand 18 and, at the thicker end, overlapping the face 38 of
the first ribbon 22. In general, the concave face 34 of each ribbon 22 in part overlaps the
convex face 38 of the next ribbon 22 in the spiral and in part overlaps the previous turn of the
spiral. Part of the concave face of the last of the ribbons 22 in the spiral overlaps the shorter
face of the ribbon 20b.
It will be noted that, although the cable 16 of Figures 8 to 12 uses specially shaped ribbons 20a, 20b, 22, whereas the cable 16 of Figures 3 to 7 uses ribbons 20, 22 that may be available 'off-the-shelf', the cable 16 of Figures 8 to 12 requires less deformation of the ribbons 20a, 20b, 22 as the cable 16 is wound.

It will be appreciated that many modifications and developments may be made to the cables 16 described with reference to Figures 4 to 12. Other shapes may be employed for the ribbons 22 that make up the bulk of the cable 16. The central strand 18 and the innermost ribbon 20, 20a may instead be provided by a single specially-shaped strand. The outermost ribbon 20, 20b may be omitted. The central strand 18 may take up a greater or lesser proportion of the overall cross-section of the cable 16. The ribbons 22 that make up the bulk of the cable need not necessarily be identical. For example, they may be grouped as two or more groups of ribbons of different widths, with the group of narrower/narrowest ribbons being towards the inner end of the spiral and the group of wider/widest ribbons being towards the outer end of the spiral.

One method of terminating the cables 16 described above will now be described with reference to Figures 13A-13E. In those drawings, the strands/ribbons of the cable 16 are not shown individually for reasons of simplicity and clarity.

Referring to Figure 13A, the end of the cable 16 is cut square. A collar 40 is then slipped over the end of the cable 16, as shown in Figure 13B. The collar 40 has an internal diameter at its end 42 that is further from the end of the cable 16 that is a clearance fit for the cable 16. The internal diameter of the collar 40 undulates between that end 42 and the end 44 nearer the end of the cable 16 so that the internal surface 46 of the collar 40 is non-cylindrical. The internal surface 46 of the collar 40 is coated with a layer 48 of thermoplastics material that is identical to or compatible with the thermoplastics material of the cable 16. The ends 50 of the ribbons of the cable 16 that project from the end 44 of the collar 40 are then splayed out, and a conical end 52 of a mandrel 54 is inserted axially into the centre of the splay, as shown in Figure 13C. From the conical end 52, the mandrel 54 extends as a generally cylindrical shank 56 to a shoulder 58. The shank 56 and conical end are coated with a layer 60 of thermoplastics material that is identical to or compatible with the thermoplastics material of the cable 16. Beyond the shoulder 58, the mandrel 54 has a screw-threaded stub 62. The mandrel 54 is hollow and opens out to a port 64 in the end of the stub 62. Referring now to Figure 13D, the collar 40 is then slid back along the cable 16 so that the end 44 of the collar 40 abuts the shoulder 58 of the mandrel 54 and so that the splayed ends 50 of the cable 16 are captured
between the mandrel 54 and the collar 40. It should be noted that, in order to enable this, in the region of the shank 56, the difference between the minimum cross-sectional area of the internal surface 46 of the collar 40 and the cross-sectional area of the external surface of the shank 56 of the mandrel 54 needs to be at least as great as the total cross-sectional area of the strand and ribbons of the cable 16. The assembly of Figure 13D is then placed in a machine (not shown) (i) that supports the collar 40 and mandrel 54, (ii) that heats the collar 40, mandrel 54 and ends 50 of the cable 16 so that the thermoplastic material of the ends 50 and of the coating layers 48,60 reaches a temperature at which it becomes soft and tacky (for example in the range of 200 to 450 degrees centigrade depending on type of material) and (iii) that, once the required temperature is attained, applies pressure using electrohydraulic vaporisation via the port 64 sufficient to cause the shank 56 of the mandrel 54 to expand radially so as to cause the shank 56 to conform to the non-cylindrical shape of the collar 40 and to cause the ends 50 of the cable 16 and the coating layers 48,60 to be compressed between the collar 40 and the expanded mandrel 54. The effect of the pressure and temperature is to combine the thermoplastic material of the ends 50 of the cable 16 and the coating layers 48,60 into a single homogenous mass 66, as shown in Figure 13E, with the reinforcing fibres of the cable 16 embedded in the homogeneous mass 66, and with the mass 66 held under pressure between the collar 40 and the shank 56 of the mandrel 54. The machine then removes the applied pressure and allows the assembly to cool, as a result of which the homogeneous mass 50 becomes bonded to the non-cylindrical inner surface of the collar 40 and the non-cylindrical outer surface of the shank 56 of the mandrel 54. The cool assembly is then removed from the machine. The collar 40 and mandrel 54 therefore form a termination fitting at the end of the cable 16. The end of the cable 16 can be connected to anything desired using the screw thread on the stub 62 of the mandrel 54.

Another method of terminating the cable 16 will now be described with reference to Figures 14A-14E. Again, in those drawings, the strands/ribbons of the cable 16 are not shown individually for reasons of simplicity and clarity. The method of Figures 14A-14E is similar to the method of Figures 13A-13E except in the following respects. As shown in Figure 14B, the collar 40 is a loose fit on the end of the cable 16 and has a cylindrical internal surface. As shown in Figure 14C, the mandrel 54 is solid, and its shank 56, rather than being cylindrical, has a shape that is similar to that of the mandrel 54 of Figure 13E after it has been expanded. Referring to Figures 14D and 14E, rather than the mandrel 54 being expanded inside the splayed ends 50 and the collar, the collar 40 is instead contracted around the splayed ends 50 and the mandrel 54 so that the collar 40 conforms to the non-cylindrical shape of the shank 56 of the mandrel 54. Furthermore, rather than employing internal pressure, the collar 40 is
electrically conductive and is contracted by electromagnetic action using a coil 68 through which a high electrical current is pulsed. A system for performing this action is available under the name Magnepress™ from IAP Research Inc, OH 45429, USA.

It will be appreciated that many modifications and developments may be made to the methods described with reference to Figures 13A to 14C. For example, expansion of the mandrel 54 may be employed in combination with contraction of the collar 40. The collar 40 may be contracted using other methods, such as mechanical swaging or crimping. The methods are not limited to being employed on cables as described with reference to Figures 3 to 12, and may also be employed, for example with cables as show in Figures 1 and 2 made from thermoplastic composites. The methods may also be developed for the termination of pipes and tubes of thermoplastic composites, as will now be described with reference to Figures 15A to 16.

Figure 15A shows a square-cut end of a thermoplastics pipe 70. In order to terminate the pipe 70, an electrically-conductive cylindrical mandrel 54 is inserted into the end of the pipe 70, as shown in Figure 15B. The mandrel 54 is coated with a layer 60 of thermoplastics material that is identical to or compatible with the thermoplastics material of the pipe 70, and the external diameter of the coated mandrel 54 is a snug fit for the internal diameter of the pipe 70. As shown in Figure 15C, a collar 40 is then fitted over the end of the pipe 70. The collar has a non-cylindrical portion 46 with an undulating internal diameter and is internally coated with a layer 48 of thermoplastics material that is identical to or compatible with the thermoplastics material of the pipe 70. Beyond the non-cylindrical portion 46, the collar 40 has an internal shoulder 72 against which the end of the pipe abuts. Beyond the shoulder 72, the collar has an external male screw thread 74. The assembly of Figure 15C is then placed in a machine (i) that supports the collar 40, (ii) that heats the collar 40, mandrel 54 and end of the pipe 70 so that the thermoplastic material of the end of the pipe 70 and of the coating layers 48, 60 becomes soft and tacky and (iii) that, once the required temperature is attained, expands the mandrel 54 radially (for example with an electromagnetic action caused by electrical current pulsed through the coil 68) so as to cause the mandrel 54 to conform to the non-cylindrical shape of the collar 40 and to cause the end of the pipe 70 and the coating layers 48, 60 to be compressed between the collar 40 and the expanded mandrel 54. The effect of the pressure and temperature is to combine the thermoplastic material of the end of the pipe 70 and the coating layers 48, 60 into a single homogenous mass 66, as shown in Figure 15D, with the reinforcing fibres of the pipe 70 embedded in the homogeneous mass 66, and with the mass 66 held under pressure between the collar 40 and the mandrel 54. The machine then allows the assembly to
cool, as a result of which the homogeneous mass 50 becomes bonded to the non-cylindrical inner surface of the collar 40 and the non-cylindrical outer surface of the mandrel 54. The cool assembly is then removed from the machine. The collar 40 and mandrel 54 therefore form a termination fitting at the end of the pipe 70. The end of the pipe 70 can then be connected to anything desired using the screw thread 74 on the collar 40, for example, as shown in Figure 16, to another pipe 76 that has been similarly terminated except for the use of a collar 78 having a complementary internal female screw thread.

It should be noted that the embodiments and examples of the invention has been described above purely by way of example and that many other modifications and developments may be made thereto within the scope of the present invention.
CLAIMS

1. A method of terminating an end of an elongate member formed of thermoplastic composite material, the end of the elongate member having a portion or portions arranged around an axis of the end of the elongate member, the method comprising the steps of forming an assembly of the end of the elongate member with a collar member and a mandrel member, and then working the assembly so as to secure the mandrel and collar members to the end of the elongate member; the assembling step comprising arranging the portion or portions of the end of the elongate member around the mandrel member and inside the collar member, at least one of the mandrel and collar members having a surface facing the portion or portions that is non-cylindrical and at least the other of the mandrel and collar members being deformable towards the portion or portions; and the working step comprising the steps of heating the assembly so that the portion or portions of the end of the elongate member become soft and tacky, then deforming said other member so that the portion or portions are compressed between the mandrel and collar members, and then allowing the assembly to cool so that the portion or portions become bonded to the mandrel and collar members.

2. A method as claimed in claim 1, wherein: the elongate member is a cable formed by a bundle of strands of the thermoplastic composite material, the end of each strand forming such a portion; the assembling step includes splaying out the ends of the strands around the mandrel member; the ends of the strands are compressed together during the deforming step to form a homogeneous mass between the mandrel and collar members.

3. A method as claimed in claim 2, wherein the mandrel member tapers in the direction away from the end of the cable.

4. A method as claimed in claim 3, wherein the mandrel member tapers to a point.

5. A method as claimed in claim 1, wherein the elongate member is tubular.

6. A method as claimed in any preceding claim, wherein: the mandrel member is deformable and hollow; and the deforming step comprises applying pressure inside the mandrel member to expand the mandrel member radially.

7. A method as claimed in any preceding claim, wherein the collar member is deformable, and the deforming step comprises contracting the collar member.
8. A method as claimed in any preceding claim, wherein the deformable member is deformed by electromagnetic action.

9. A method as claimed in any preceding claim, wherein the assembling step includes disposing filler material between the end portion or portions of the elongate member and one or both of the mandrel and collar members.

10. A method of terminating an end of an elongate member formed of thermoplastic composite material, substantially as described with reference to the drawings.

11. An elongate member of thermoplastic composite material terminated by a method as claimed in any preceding claim.

12. A machine for use in performing a method as claimed in any of claims 1 to 10, the machine comprising means for supporting either or both of the mandrel and collar members, means for so heating the assembly and means for so deforming said other member.

13. A tension cable comprising a bundle of elongate strands of flexible material each wound helically along the length of the cable each for bearing a proportion of a tensile load applied to the cable, wherein each strand is a ribbon having an elongate cross-section having a width extending in the radial direction of the cable and a length extending around the centre of the cable, the ribbons as viewed cross-sectionally of the cable being wound in a spiral series.

14. A cable as claimed in claim 13, wherein, in cross-section, the ribbons are four-sided having a pair of opposed shorter sides and a pair of opposed longer sides, and, for a majority of the ribbons, the shorter sides of the ribbon abut the shorter sides of the ribbons before and after that ribbon is the spiral series.

15. A cable as claimed in claim 13, wherein, in cross section, the ribbons are three-sided having a longer side and two shorter sides, and, for a majority of the ribbons, the longer side of the ribbon in part overlaps one of the shorter sides of the ribbon and after that ribbon in the spiral series and in part overlaps the previous turn of the spiral.

16. A cable as claimed in any of claims 13 to 15, wherein the ribbons are arranged as at least one group of a multiplicity of the ribbons, and the ribbons of the or each group are made from stock having an, or a respective, identical cross-sectional shape and size.
17. A cable as claimed in any of claims 13 to 16, wherein at least the ribbon at the end of the spiral series nearer the centre of the cable is made from stock having a different cross-sectional shape and size to the stock from which the majority of the ribbons are made.

18. A cable as claimed in any of claims 13 to 17, wherein at least the ribbon at the end of the spiral series further from the centre of the cable is made from stock having a different cross-sectional shape and size to the stock from which the majority of the ribbons are made.

19. A cable as claimed in any of claims 13 to 18, wherein the cable has a further, generally-central, strand around which the spiral series of ribbons is wound.

20. A cable as claimed in claim 19, wherein the generally-central strand has a generally circular cross-section.

21. A cable as claimed in any of claims 13 to 20, wherein the strands are of thermoplastic composite material.

22. A cable as claimed in any of claims 13 to 21, and terminated by a method as claimed in any of claims 2 to 4, or any of claims 6 to 10 when directly or indirectly dependent on claim 2.

23. A cable substantially as described with reference to the drawings.
**Patents Act 1977: Search Report under Section 17**

**Documents considered to be relevant:**

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<tr>
<th>Category</th>
<th>Relevant to claims</th>
<th>Identity of document and passage or figure of particular relevance</th>
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<tbody>
<tr>
<td>X</td>
<td>1-4, 7-8, 11</td>
<td>GB2279085 A (COMMANDER) see abstract and figures: rope moulded between mandrel and collar</td>
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<tr>
<td>A</td>
<td>1-4</td>
<td>GB1139841 A (ICI LTD) see figures: rope secured between mandrel and collar</td>
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<tr>
<td>A</td>
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<td>GB2236546 A (LINEAR COMPOSITES LIMITED) see abstract and figures: rope secured by mandrel and collar</td>
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<tr>
<td>A</td>
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<td>DE29801592 U (HEWING GMBH) see figures and WPI abstract Accession Number 1998-482403: tube retained by mandrel and collar</td>
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<td>GB2278173 A (VULKAN LOKRING GMBH) see abstract and figures: pipe retained by inner and outer sleeves</td>
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<tr>
<td>A</td>
<td>1-5</td>
<td>JP51134768 A (KUBOTA LTD) see figures and WPI abstract Accession Number 1977-02558Y: pipe end deformed by mandrel and collar</td>
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**Field of Search:**

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC:

- D1T; F2G
- Worldwide search of patent documents classified in the following areas of the IPC:
  - B65H; F16G; F16L

The following online and other databases have been used in the preparation of this search report:

- Online: WPI, EPODOC