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(72) Inventor DENNIS LAURENCE LEWIS

(19) THE PATENT OFFICE LONDON

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(54) IMPROVEMENTS IN OR RELATING TO THE MANUFACTURE OF ELONGATE OPTICAL FIBRE WAVEGUIDE STRUCTURES

(71) We, THE GENERAL ELECTRIC COMPANY LIMITED, of 1 Stanhope Gate, London, W1A 1EH, a British Company, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to the manufacture of elongate optical fibre waveguide structures of the kind consisting of one or more optical fibre waveguides surrounded by a loosely fitting tube of plastics material, which either may be the sheath, or an inner layer of the sheath, of an optical fibre cable of which the optical fibre or fibres constitute the core, being disposed loosely within the bore of the sheath, or may be, for example, an inner tube for incorporation within the sheath of a cable which includes a plurality of such inner tubes each containing one or more optical fibres.

The term "loosely fitting", as used herein with reference to the plastics tube or cable sheath, is to be understood to mean that the bore of said tube or sheath is of sufficiently large cross-section to permit freedom of movement of the fibre, or of each individual fibre, within it in both radial and axial directions. Such loose fit of optical fibre waveguides within a containing tube is advantageous in that it reduces optical losses in the wave guides in operation.

A structure of the above-described form, in which one or more optical fibres lie loosely in the bore of a plastics tube, is conveniently manufactured by continuously extruding a tube of plastics material, with a bore of appropriate cross-section, from an annular channel between a die component and a point component of an extruder die-head, and feeding an optical fibre or a bundle of optical fibres through a central duct in the point component and into the bore of the tube during the extrusion of the latter, provision being made within the extruder head for ensuring that the fibre or fibre bundle initially lies substantially along the axis of the bore of the tube and does not adhere to the tube wall, and the assembly of fibre or fibre bundle and surrounding extruded tube being pulled continuously from the extruder head and wound on to a drum. This procedure, however, has the disadvantage that it results in the introduction of tension into the optical fibre or fibres.

Thus in the first place, if the fibre or fibres is or are fed into the extruder head from a reel, as is usual, the friction of the reel bearing results in the application of some back tension to the fibre or fibres. A second, and more important, source of tension in the fibre or fibres is the drum winding procedure: since each fibre is free to move radially within the bore of the tube, any back tension on the fibre arising from reel bearing friction, or friction arising from the fibre pressing against the wall of the tube due to sagging of the fibre under its own weight, has the result that, when the cable is wound on to the drum, the fibre or bundle of fibres lies upon and is held under tension against the region of the tube wall nearest to the cylindrical surface of the drum. Hence the fibre or fibre bundle is pulled into the tube bore at a velocity lower than the velocity of travel of the fibre or fibres around the drum is somewhat shorter than that followed by the neutral axis of the tube (that is to say the longitudinal region of the tube which does not change length when the tube is bent) and hence by the tube as a whole, resulting in a corresponding difference in length between the fibre or fibres and the tube in the completed wound length of the tube-fibre assembly. Therefore, when the assembly is subsequently removed from the drum and laid in its operating location (in the case of a cable) or straightened for introductiin into a cable sheath, by the normal procedure, the fibre or fibres is or are stretched longitudinally and thus retained under tension within the tube or cable sheath.

Tension in optical fibre waveguides is undesirable since it causes appreciable optical loss, in operation, at bends in the cable, and we have found, in particular, that the tension produced as a result of the unreeling and drum winding procedures referred to above, in an optical fibre or fibres lying loosely in a tube bore as aforesaid, results in optical losses of the order of 10 dB/km or higher. The actual degree of tension in the fibre or fibres, and hence the magnitude of the resulting optical losses, depends upon the radial distance between the neutral axis and the inner wall surface of the tube (determined by the bore diameter of the tube), relative to the distance between the axis of the winding drum and the said neutral axis, for each turn of the tube-fibre assembly on the drum.

It is an object of the present invention to provide an improved method of, and apparatus for, manufacturing an optical fibre waveguide structure of the kind referred to, whereby the tension of the optical fibre or fibres, in the completed structure, can be reduced or substantially eliminated.

According to the invention, in a method of manufacturing an elongate optical fibre waveguide structure consisting of one or more optical fibre waveguides surrounded by a loosely fitting (as hereinbefore defined) tube of plastics material, which method includes the steps of continuously extruding a said tube from an extruder die-head, feeding an optical fibre waveguide or a bundle of optical fibre waveguides into the bore of the said tube during the extrusion thereof, continuously pulling the assembly of extruded tube and fibre or fibres from the extruder die-head, and winding the said assembly on to a drum, during the travel of said assembly between the extruder die-head and the said drum a length of the tube is elastically stretched longitudinally to a sufficient extent substantially to match the longitudinal stretching of the fibre or fibres therein which would occur as a result of said fibre feeding and drum winding steps, the length of the assembly incorporating the stretched length of tube is wound around one or more rotating cylindrical surfaces in such a manner that the fibre or fibre bundle therein is locked against the wall of the stretched tube so as to be incapable of movement relative to the tube, said length of the assembly is then unwound so that the fibre or fibre bundle is released, and said length of tube is then caused to relax prior to the winding of the assembly on to the drum, the tube stretching, fibre locking and releasing, and tube relaxing procedure being effected progressively and continuously along the whole length of the said optical fibre waveguide structure.

The tube stretching, fibre locking and tube relaxing procedure removes any back tension introduced into the fibre or fibres as a result of the friction of the fibre feed reel bearing, and also counteracts the fibre tensioning effect of the final drum winding, described above. As a result, over the whole length of the tube-fibre assembly wound on the drum, the length of the fibre or fibres is equal to that of the surrounding tube, and the fibres are substantially free from tension. The extent of elongation of the fibre or fibres which would occur as a result of the drum winding tension can be calculated from the known figures of the radius of the drum and the radius of the tube surrounding the fibre or fibres: for example if the distance from the axis of the drum to the neutral axis of an optical fibre cable lying around the cylindrical surface of the drum is 40 cm, the fibre or fibre bundle is stretched by 1/3% of its initial length. Hence, in carrying out the method of the invention for the manufacture of such a cable, each portion of the cable sheath must be stretched by slightly more than 1/3% of its initial length, to counteract the initial back tension on the fibre or fibres as well as the drum winding tension.

The apparatus for manufacturing an elongate optical fibre waveguide structure of the kind referred to by the method described above includes an extruder die-head and means for feeding an optical fibre or bundle of optical fibres loosely into the bore of a plastics tube extruded from said extruder head, means for continuously pulling the assembly of the extruded tube and fibre or fibre bundle from the extruder die-head, a rotatable drum on which said assembly is wound, and in addition, in accordance with the invention, means for retarding the said tube as the assembly travels towards the pulling means and, located between said retarding means and pulling means, fibre locking means consisting of one or more rotatable members having a cylindrical surface or surfaces on which the said assembly can be wound.

The mutual actions of the retarding means and pulling means result in longitudinal stretching of the length of the tube between said means, the winding of the assembly on the intervening fibre locking means also contributing to the stretching of the tube, and the tube is subsequently relaxed as it passes through the pulling means and on to the winding drum.

The fibre locking means preferably consists of a freely rotating drum, on which several turns of the tube-fibre assembly are wound after passing through the tube retarding means.

The pulling means may be of conventional form, suitably consisting of an opposed pair of rotatable endless articulated bands (generally known as, and hereinafter referred to as, a "caterpillar"), the bands being arranged to grip the travelling tube between them and to rotate in such a direction as to propel the tube-fibre assembly towards the winding drum. The tube retarding means suitably consists of a similar caterpillar, arranged to grip the tube and to rotate in the same direction as, but more slowly than, the pulling caterpillar, so as to retard the tube and thus cause the length of tube between the two caterpillars to be stretched. The operation of the two caterpillars must be so controlled that the pulling force is greater than the retarding force, to ensure that there is resultant forward propulsion of the tube-fibre assembly.

In some cases the plastics tube may incorporate bodies formed of other material: for example, where the tube constitutes the sheath of an optical fibre cable, elongate reinforcing members such as steel wires or aramid yarns may be embedded in the sheath, lying parallel to the optical fibre or fibres of the cable core. In such cases the stretching force applied to the tube may be increased to overcome any resistance to stretching which may result from the presence of reinforcing members.

A specific arrangement of apparatus for carrying out the method of the invention in the manufacture of an optical fibre cable will now be described by way of example, with reference to the drawing accompanying the Provisional Specification, which shows the arrangement diagrammatically, in side elevation.

The apparatus shown in the drawing consists of an extruder die-head 1, a first caterpillar 2, 3, a freely rotating drum 4, a second caterpillar 5, 6, and a rotatable winding drum 7. In operation of the apparatus, an optical fibre cable 8 is produced by extruding tube of plastics material, for example polyethylene, to form the cable sheath, and at the same time feeding a bundle of optical fibre waveguides and a plurality of steel wires, disposed in a circle around the fibres, through appropriate ducts within the extruder head, so that the fibres are introduced into the bore of the extruded tube, which bore is sufficiently wide to allow the fibres freedom of movement, and the steel wires are embedded in the wall of the tube. (Only the exterior of the cable sheath is shown in the drawing, and the structural details of the extruder head, which may be of known form, are not shown).

On commencement of the operation of the extruder, the initial length of cable emerging from the extruder head is manually passed through the caterpillar 2, 3, wound around the drum 4 in a sufficient number of turns to lock the fibres in the sheath, suitably four or five turns, passed through the caterpillar 5, 6, and the end of the cable is attached to the winding drum 7. Rotation of the caterpillars and the drum 7 is then started, the drum 4 also being rotated by the passage of the cable around it; the directions of rotation of all these components are indicated in the drawing by the respective arrows. The caterpillar 5, 6 is rotated more rapidly than caterpillar 2, 3, so that as the cable travels through the system the sheath is pulled forwards towards the drum 7 by caterpillars 5, 6 and is retarded by caterpillar 2, 3: hence the sheath is stretched longitudinally between the points A and B, the stretching force being applied to the whole length of sheath between these points, including the portion wound round the drum 4. The relative rates of rotation of the two caterpillars are adjusted to produce the required amount of stretching of the sheath: for example, if it is required to stretch the sheath by 1/3% of its initial length, the rate of rotation of caterpillar 2, 3 will be arranged to be 1/3% less than that of caterpillar 5, 6.

The optical fibres, initially loose in the bore of the sheath, are locked against the stretched sheath wall while the cable is passing around the drum 4; the fibres are released as the cable leaves the drum 4 and passes to the caterpillar 5, 6, and the sheath relaxes as it passes from point B to point C. Thus in the whole length of cable wound upon the drum 7, both the sheath and the fibres are substantially free from tension and are of equal length, the fibres lying loosely in the sheath bore.

WHAT WE CLAIM IS:—

1. A method of manufacturing an elongate optical fibre waveguide structure consisting of one or more optical fibre waveguides surrounded by a loosely fitting (as hereinbefore defined) tube of plastics material, which method includes the steps of continuously extruding a said tube from an extruder die-head, feeding an optical fibre waveguide or a bundle of optical fibre waveguides into the bore of the said tube during the extrusion thereof, continuously pulling the assembly of extruded tube and fibre or fibres from the extruder die-head, and winding the said assembly on to a drum, wherein during the travel of said assembly between the extruder die-head and the said drum a length of the tube is elastically stretched longitudinally to a sufficient extent substantially to match the longitudinal stretching of the fibre or fibres therein which would occur as a result of said fibre feeding and drum winding steps, the length of the assembly incorporating the stretched length of tube is wound around one or more

rotating cylindrical surfaces in such a manner that the fibre or fibre bundle therein is locked against the wall of the stretched tube so as to be incapable of movement relative to the tube, said length of the assembly is then unwound so that the fibre or fibre bundle is released, and said length of tube is then caused to relax prior to the winding of the assembly on to the said drum, the tube stretching, fibre locking and releasing, and tube relaxing procedure being effected progressively and continuously along the whole length of the said optical fibre waveguide structure.

2. Apparatus for manufacturing an elongate optical fibre waveguide structure by the method according to Claim 1, which apparatus includes an extruder die-head and means for feeding an optical fibre or bundle of optical fibres loosely into the bore of a plastics tube extruded from said extruder head, means for continuously pulling the assembly of the extruded tube and fibre or fibre bundle from the extruder die-head, a rotatable winding drum on which said assembly is wound, means for retarding the said tube as the assembly travels towards the said pulling means and, located between said retarding means and pulling means, fibre locking means consisting of one or more rotatable members having a cylindrical surface or surfaces on which the said assembly can be wound.

3. Apparatus according to Claim 2, wherein the said fibre locking means consists of a freely rotating drum on which several turns of the said assembly can be wound after passing through the tube retarding means.

4. Apparatus according to Claim 2 or 3, wherein the said tube retarding means and the said pulling means each consists of an opposed pair of rotatable endless articulated bands arranged to grip the travelling tube between them and to propel it towards the winding drum, the said pair of bands constituting the retarding means being arranged to rotate in the same direction as, but more slowly than, the said pair of bands constituting the pulling means.

5. Apparatus according to Claim 2, substantially as shown in, and as hereinbefore described with reference to, the drawing accompanying the Provisional Specification.

For the Applicants,
M. B. W. POPE
Chartered Patent Agent.

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1576339 PROVISIONAL SPECIFICATION

1 SHEET *This drawing is a reproduction of the Original on a reduced scale*