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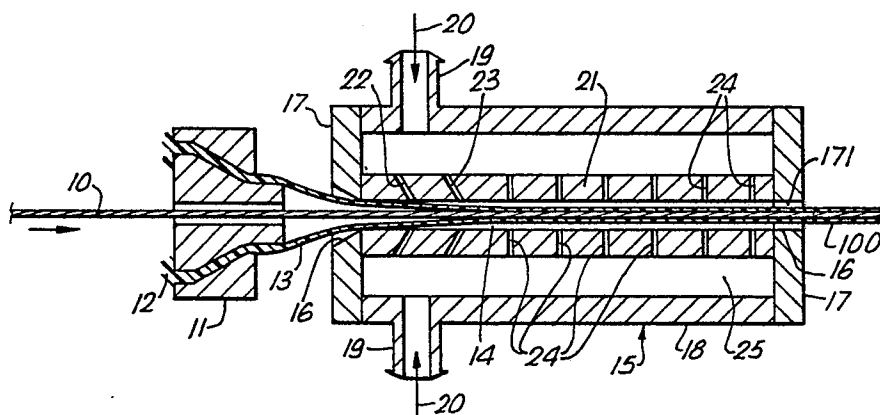
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54 **Insulated electric wire.**

57 Insulated electric wire is manufactured by the continuous extrusion of a tube of polymeric insulator (13), drawing an electric conductor (10) axially through the tube (13) the conductor drawing the tube to cause radial shrinkage of the tube onto the conductor, and directing cooling fluid (20) (via orifices 22, 23) at an intermediate portion (14) of the insulator tube so that the molecular orientation of the polymeric insulator is frozen and maintained. This reduces, and renders controllable, the force needed to strip the insulator.

Fig.1.



Insulated Electric Wire

This invention relates to insulated electric wire and to a method of manufacture of such wire. In the production of many electrical and electronic articles, various internal components are customarily connected with insulated wire. One mass production technique for making electrical connections, known as "wire wrapping", involves the use of a tool which, in one operation, removes the wire insulation and wraps the bared conductor around the connector "post" with sufficient force that a weld is formed between the metal post and the bared conductor. In this manner, a good electrical connection is made without recourse to soldering or crimping techniques.

If this technique is to function correctly, the force, known as the strip force, needed to remove the insulation must be below a predetermined value, the value of the force exerted by the stripping tool, and must be constant.

Wire insulation is usually applied to the conductor during manufacture by an extrusion process. The most suitable technique is known as "tubing", during which a cylinder of molten polymer is extruded around the moving conductor. The conductor is arranged to move more quickly than the extruded polymer, so that the polymer is drawn from the die by the conductor, and a conical geometry is produced with the conductor situated at the centre and the polymer film forming the surface of the cone. Drawing the polymer tube tends to align the molecules longitudinally, which in turn causes a radial shrinkage. This results in the polymer tube gripping the conductor tightly, which means that the insulator of the final product has a strong reaction to strip force. Moreover, the precise value of this reaction cannot readily be controlled during manufacture.

Accordingly, it is the purpose of the present invention to provide insulated electric wire with a predetermined reaction to longitudinal strip force which is substantially lower than is obtainable using conventional tubing extrusion processes.

The invention provides a method of manufacture of an electric wire, comprising forming continuously by extrusion a tube of polymeric insulator, drawing an electric conductor axially through the tube such that a leading portion of the conductor grips a leading portion of the insulator tube and draws the tube causing radial shrinkage of the tube on to the conductor, and directing cooling fluid at an intermediate portion of the insulator tube immediately upstream of the said leading portion so that the molecular orientation of the polymeric insulator is frozen and further radial shrinkage downstream is inhibited. Using this technique, it is possible to

control the radial pressure exerted by the insulator on the conductor, because any stretching of the tube downstream of the said intermediate portion has little effect on the molecular orientation of the insulator and consequently little effect on the radial pressure exerted. It follows that the reaction to longitudinal strip force is precisely controllable, and can be made substantially lower than would be the case if the intermediate portion of the tube were not cooled during manufacture.

In one form, the method comprises drawing the electric conductor at a speed greater than the extrusion speed, and forming a longitudinal tapering space between the inner wall of the tube and the electric conductor upstream of a point at which the tube and the conductor first engage.

Alternatively, the tube is formed using pressure extrusion in which the insulator is applied directly to the electric conductor. There is then still a leading portion of the conductor gripping the tube, and an intermediate portion at which the conductor is merely in contact with the tube, which is cooled by the cooling fluid.

The cooling fluid is preferably air, and is preferably maintained at a temperature of $21^{\circ} \pm 3^{\circ} \text{C}$. It is preferably directed at the outer surface of the tube.

Conveniently, the tube and the conductor are passed through a plenum chamber having jet orifices through which the cooling fluid is directed onto the outer surface of the tube.

The invention enables insulated electric wire to be produced with a low, controlled reaction to strip force, independently of the speed of extrusion of the insulator. By suitable control of the process conditions, the same reaction to strip force in the finished product can be achieved for a wide range of line speeds, for example from 50 to 150 metres per minute.

In order that the invention may be better understood, two methods according to the invention will now be described, by way of example only, with reference to the accompanying drawings, of which both Figure 1 and Figure 2 are schematic longitudinal sections through extrusion and quenching apparatus.

With reference first to Figure 1, an electrical wire 100 is produced by a tubing process, from a single strand copper wire 10, of 0.25mm diameter, and a PVDF (polyvinylidene difluoride) material 12 with appropriate additives for extrusion. The conductor 10 is drawn axially through a cross-head die 11, and then through a central passage 171 through a quenching chamber 15. The quenching chamber 15 has a generally cylindrical wall 18

closed by end plates 17 having central apertures 16. The quenching chamber 18 has an internal annular plenum chamber 25 which communicates with the central passage 171 through a row of fluid-directing jet orifices 22, 23, 24 formed in a cylinder 21 coaxial with the cylindrical wall 18. Two sets 22, 23 of the jet orifices at the upstream end of the quenching chamber 15 are inclined at 45° to the longitudinal axis, for directing cooling fluid in the downstream direction. Inlet ports 19 are provided in the outer wall 18 for pressurised air at a temperature of $21^\circ \pm 3^\circ \text{C}$.

In this example, the quenching chamber 15 is 100mm long, has an outer diameter of 55.5mm and an internal diameter of 5mm defining the axial passage 171. The jet orifice diameter is 1mm.

The polymer material 12 is extruded as a conical film 13 which engages at 14 with the conductor 10. Downstream of the point 14 at which the polymer tube first engages the conductor 10, the tube grips the conductor 10 frictionally, allowing the conductor 10 to draw the extrudate film 13 from the die. The portion of the film 13 immediately upstream of the point 14 is cooled from the outside by jets of air directed through the jet orifices 22, 23, and this quenches the polymer material, freezing its molecular orientation which is partially, but not wholly, longitudinal. Even though the polymer material is drawn longitudinally still further, downstream of the point 14, this has very little effect on the radial pressure exerted by the material on the conductor 10.

In this example, the line speed is 75 metres per minute, but speeds of between 50 and 150 are contemplated. In tests carried out using the apparatus described, the reaction to the longitudinal strip force, for a line speed of 75 metres per minute, was, on three samples, 260g, 290g and 270g. This compares with values of 380g, 400g and 390g measured with the quenching unit switched off. With a line speed of 50 metres per minute, and with the quenching unit switched on, values of 230g, 210g and 230g were obtained, and with a line speed of 150 metres per minute, values of 330g, 340g and 350g were obtained.

The temperature of the conductor wire also plays an important part. It has been customary to preheat the conductor wire, yet, with a line speed of 76 metres per minute, this produced strip force reactions of 450g, 480g and 510g on three different samples, with the quenching unit off. Clearly, better strip force results are obtained with no conductor preheating, but the greater influence on strip force reaction is the use of the quenching unit in accordance with the invention.

Although the invention has been illustrated with the use of air as the cooling fluid, other gases or even liquids could be used instead. Water, for

example, would have a greater cooling capacity.

The space between the conical polymer film 13 and the conductor 10 is maintained at a sub-atmospheric pressure by conventional means, as is customary.

A second embodiment of the invention illustrated in Figure 2, applicable to very small diameter wires, differs from that of Figure 1 in that the wire 10 is coated by pressure extrusion in a pressure extruder 110. The polymeric insulator 12 is applied directly to the wire 10, and becomes gripped by the wire downstream of the point 14. A predictable, relatively low strip force is provided in this manner.

Claims

1. A method of manufacture of an electric wire, comprising forming continuously by extrusion a tube of polymeric insulator, drawing an electric conductor axially through the tube such that a leading portion of the conductor grips a leading portion of the insulator tube and draws the tube causing radial shrinkage of the tube onto the conductor, and characterised by directing cooling fluid at an intermediate portion of the insulator tube immediately upstream of the said leading portion so that the molecular orientation of the polymeric insulator is frozen and maintained.
2. A method according to Claim 1, comprising drawing the electric conductor at a speed greater than the extrusion speed, and forming a longitudinally tapering space between the inner wall of the tube and the electric conductor upstream of a point at which the tube and the conductor first engage.
3. A method according to Claim 2, in which the cooling fluid is directed at the outer surface of the tube.
4. A method according to Claim 3, in which the space between the tube and the conductor upstream of the leading portion is maintained at a sub-atmospheric pressure.
5. A method according to Claim 1, in which the tube is formed using pressure extrusion in which the insulator is applied directly to the electric conductor.
6. A method according to any preceding Claim, in which the cooling fluid is air.
7. A method according to any preceding Claim, in which the cooling fluid is maintained at $21^\circ \pm 3^\circ \text{C}$.
8. A method according to any preceding Claim, in which the tube and the conductor are passed through a quenching chamber having jet orifices through which the cooling fluid is directed onto the outer surface of the tube.

Fig. 2:

