

Electric Cable Joints

This invention relates to joints for electric power cables insulated with crosslinked polyethylene (XLPE) and to methods of making them; it is primarily (but not exclusively) concerned with joints for high voltage and supertension power cables.

XLPE is the only class of solid polymeric material at present in regular use for the dielectric of cables operating at the highest voltages (say over 200kV) where the practicable alternatives are impregnated paper or impregnated paper/polypropylene laminate tape.

Such cables can only be delivered to installation sites in relatively short lengths (rarely as long as a kilometre), and so large numbers of joints have to be made "in the field" to complete an installation of any substantial length. Best current international practice is to cut back the cable ends in the usual way and after jointing the conductors and re-establishing the conductor screen to join up the cut-back ends of the dielectric by assembling a suitable mould, filling it with plastified crosslinkable polyethylene and heating to crosslink it and cause it to adhere to the cut-back ends of the cable dielectric. After the mould has been removed, the outer parts of the joint are formed in various conventional ways.

Especially as the metal of the conductor constitutes a large-capacity heat sink whose temperature is difficult either to predict or to measure and

measurement of the temperature of the material in the mould is almost impossible, it is difficult to control the time/temperature exposure to ensure a proper degree of crosslinking throughout the body. Further, there is a risk of contamination of the material under site conditions and this cannot be countered by filtration as experience shows that the shear exposure of crosslinkable polyethylene in forcing it through a filter pack is liable to induce premature crosslinking.

The main object of the invention is to provide a joint for XLPE cables, and a method of making it, that does not require crosslinking in the field.

In accordance with one aspect of the invention, a joint between lengths of cable with XLPE dielectric comprises a screened conductor connection, a solid moulded dielectric body adhering to the screened conductor connection and to the cable dielectric, a dielectric screen covering and adhering to the moulded body, and at least one outer protective layer and is characterised in that the said moulded body is of an unfilled thermoplastic polypropylene composition.

The invention includes a method of making such a joint characterised by the steps of forming a screened conductor connection, enclosing it in a mould, injecting a polypropylene composition into the mould under conditions of temperature and pressure such that it adheres to the screened conductor joint and to the part of the cable dielectric within the mould, cooling the

mould, if found necessary or if preferred while maintaining it under pressure, and after removing the mould applying a dielectric screen and outer protective layer.

Preferably the method includes the step of filtering the polypropylene composition as it is injected into the mould.

While polypropylene is in some respects less satisfactory than XLPE as a high-voltage cable dielectric, its properties are adequate for service under the more protected conditions encountered in joints and are compatible with those of XLPE. In particular, the softening point of around 160°C is adequate to the conditions; the intrinsic breakdown strength may be as much as 35% higher than that of XLPE and its dielectric loss tangent is practically the same at 0.0003.

As the polypropylene is thermoplastic, uniform temperature conditions can be assisted, if desired, by allowing polypropylene to flow through the mould for a time before establishing the pressure/cooling conditions for solidification. Material passed through the mould in this way can be recycled, though preferably to a less demanding application.

Ordinary grades of polypropylene, with a suitably chosen stabilization package, can be used in the way described, but we have found that substantially better adhesion to the XLPE can be achieved by using "functionalized" polypropylenes, especially the ones

containing acid anhydride groups, free acid groups (-COOH) or ester groups. Functionalized polypropylenes may be formed either by co-polymerization or by grafting, but in any case are available on the market.

Polypropylenes grafted with maleic anhydride or with acrylic acid (which may graft as polyacrylic acid) (Sold by BP Chemicals Ltd under the trademark POLYBOND) have given good results. Functionalised polypropylene may be blended with ordinary polypropylene, e.g. to adjust melt flow characteristics.

The polypropylene composition is free from substantial amounts of filler, but may include antioxidants and other "minor" additives for their usual purposes.

The invention will be further described, by way of example, with reference to the accompanying drawing, which is a diagrammatic longitudinal section of a mould in which a cable joint in accordance with the invention is being made.

Two ends of a single-core 400kV XLPE supertension cable 1,2 with 1000mm^2 solid copper conductors are prepared for jointing by cutting back in the usual way. The dielectric 3 of each cable is about 27mm thick and is tapered at 4 over a length of about 0.8m. The conductors are joined by compression ferrules 5 and the conductor screen re-established across the ferrules by application of the usual "semiconducting" tape 6 (alternatively heat-consolidated tape or a heat-shrink sleeve can be used).

A suitable steel mould 7 is carefully cleaned and applied to the joint area to form a cavity 8 with a radius (except at the tapered ends) 40mm greater than that of the cable dielectric. The mould has an inlet port 9 and two outlet ports 10,11. The mould is pre-heated to 160°C and molten "POLYBOND" maleic-anhydride-functionalized polypropylene at about 250°C is injected through the inlet port 9 from a portable extrusion device 12 fitted with a fine mesh sieve pack 13 located before the breaker plate of the extruder and dimensioned such that the injected material is substantially free of particulate contaminants larger than 100 micrometres. The injected material initially flows through the mould and out of the outlet ports 10,11 to purge the mould of air and raise its temperature to a uniform value of around 210°C. To assist purging of air, expansion reservoirs 15,15 connected to the outlet ports 10,11 are preferably connected to a vacuum pump (not shown) during this step. Once stable conditions have been established, the inlet port 9 is closed (say by a screw-operated valve 14) and the vacuum pump disconnected: if desired the air pressure in the reservoirs 15,15 may be raised to around 0.2MPa to minimise risk of contraction voids forming. Once flow stops, there is no input of heat to the mould, and it is allowed to cool slowly to a temperature at which the polypropylene is solid. The applied pressure can then be withdrawn and the mould 7 removed. After trimming mould flash, if necessary, the dielectric screen

and outer layers of the joint can be formed in any convenient way.

It may be noted that although a temperature in the region of 210°C is needed to ensure good bonding of the injected polypropylene to the crosslinked polyethylene insulation of the cable, it is undesirable to pre-heat the mould above about 160°C before air has been purged from it, because this would risk oxidative degradation of the insulation.

In some cases, instead of using separate reservoirs 15,15 the outlet ports 10,11 may be closed by valves (not shown) and the mould kept topped up and any required pressure maintained by continuing to drive the extrusion device 12.



CLAIMS

- 1 A joint between lengths of cable with XLPE dielectric comprising a screened conductor connection, a solid moulded dielectric body adhering to the screened conductor connection and to the cable dielectric, a dielectric screen covering and adhering to the moulded body, and at least one outer protective layer, characterised in that the said moulded body is of an unfilled thermoplastic polypropylene composition.
- 2 A joint as claimed in claim 1 in which the polypropylene composition comprises is a functionalized polypropylene.
- 3 A joint as claimed in claim 1 in which the polypropylene composition comprises a functionalized polypropylene containing acid anhydride groups, free acid groups or ester groups.
- 4 A joint as claimed in claim 1 in which the polypropylene composition comprises a functionalized polypropylene containing maleic anhydride groups.
- 5 A joint as claimed in claim 1 in which the polypropylene composition comprises a functionalized polypropylene containing acrylic acid groups.
- 6 A joint for electric cables with XLPE dielectric substantially as described with reference to the Example.
- 7 A method of making a joint as claimed in any one of Claims 1-6 characterised by the steps of forming a screened conductor connection, enclosing it in a mould, injecting an unfilled polypropylene composition into the



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mould under conditions of temperature and pressure such that it adheres to the screened conductor joint and to the part of the cable dielectric within the mould, cooling the mould, and after removing the mould applying a dielectric screen and outer protective layer.

8 A method as claimed in claim 7 including the step of filtering the polypropylene composition as it is injected into the mould.

9 A method of making a cable joint as claimed in Claim 8 comprising allowing the said polypropylene composition to flow through the mould before establishing the pressure/cooling conditions for solidification.

10 A method as claimed in any one of claims 7-9 in which pressure is maintained in the mould while it is cooled.

11 A method of making a cable joint in accordance with any one of claims 1-6 substantially as described with reference to the drawings.