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(54) Mineral insulated electric cable manufacture.

(57) A method of manufacturing mineral insulated electric cable comprises locating one or more conductor rods in a metal tube, introducing mineral insulating powder into the tube and then drawing the filled tube through one or more reducing dies to reduce the diameter of the tube to the required size, wherein the die, or at least one of the dies is continuously subjected to ultrasonic radial vibrations.

The method has the advantage that greater reductions in diameter of the tube can be achieved between annealing steps due to reduction of damage to the conductor rods and the metal tube by the mineral insulating powder.

EP 0 573 313 A2

This invention relates to a method of manufacturing mineral insulated electric cables, that is to say cables of the kind comprising at least one elongate conductor insulated from a surrounding sheath of metal or metal alloy, and where there is more than one elongate conductor from the other conductor or conductors, by compacted mineral insulating powder, usually but not necessarily magnesium oxide.

In methods of manufacturing mineral insulated electric cables currently employed or hitherto proposed, mineral insulating powder and a conductor rod or conductor rods are simultaneously introduced into a metal tube, the powder is densely packed in the tube and around the conductor rod or rods, and the filled tube is then caused to travel through means by which the filled tube is reduced to the required cross-sectional size.

The present invention is particularly concerned with manufacture of mineral insulated electric cable by a method in which the filled tube is reduced to a required cross-sectional size by causing the filled tube to pass through one or more than one die.

In a typical conventional process for the manufacture of mineral insulated cable in which the diameter of the cable is reduced for example by about 90%, the cable may be passed through differently sized dies twenty or more times and after each pass or every few passes through a die the cable must be annealed before continuing with the process, so that, during manufacture, the cable may be annealed ten to twenty times. The annealing contributes significantly to the cost of manufacture of the cable since each annealing step may last typically three hours.

Also, in such a method over the period of time in which a die is in use, the nominal cross-sectional area to which a filled tube is reduced can gradually increase, and the standard of surface finish of the reduced filled tube can gradually deteriorate, as the die becomes worn and, as a consequence, production of mineral insulated electric cable must be interrupted for a worn die to be replaced. Where a filled tube is caused to pass through a plurality of dies in order for its cross-section to be reduced to the required size, frequent interruption of production to replace a worn die can be uneconomic.

According to the present invention, there is provided a method of manufacturing mineral insulated electric cable which comprises locating one or more conductor rods in a metal tube, introducing mineral insulating powder into the tube and then drawing the filled tube through one or more reducing dies to reduce the diameter of the tube to the required size, wherein the die or at least one of the dies is continuously subjected to ultrasonic radial vibrations.

The method according to the present invention has the advantage that, in many circumstances it is possible to increase the degree of reduction in cross-sectional area of the filled tube during a single pass through a die. The degree of reduction in cross-sectional area that can be achieved in general will depend on a number of factors, for example on the metal employed for the sheath, on the number of passes through the drawing dies and on other processing conditions. Whereas it is not normally possible to reduce the cross-sectional area of the filled tube by more than 35% between annealing steps employing conventional techniques except by employing a number of drawing steps, according to the invention a reduction in the cross-sectional area of 40% or more may consistently be achieved between annealing steps, at least for a range of sheath metals, and usually with only one or two drawing operations. This has the effect that the number of passes through the dies can be reduced during manufacture of the cable and, more importantly, also the number of annealing steps with a consequent considerable reduction in time required for manufacture. Thus, for example in a typical process in which a filled tube is drawn down to about one eighth of its original diameter, the number of annealing steps can be reduced from about thirteen to ten or fewer, e.g. about eight. The ability to increase the degree to which the filled tube can be reduced on a single pass through the die is due at least partly to the surprising observation that the so called "powder damage" to the internal conductor(s) and to the internal surface of the tube is significantly reduced, at a given die reduction ratio, according to the invention. The powder damage is the damage to the relatively soft (e.g. copper) internal conductor(s) of the filled tube caused by the mineral insulating powder as it is compacted during passage of the tube through the die. This damage can cause irregularities in the conductor(s) and even breakage. The degree of powder damage increases with the degree to which the tube is reduced in cross-section in a single pass through the die, and the reduction of this damage as compared with conventional pulling methods enables higher reduction ratios to be employed.

The filled tube may be drawn through a die as described for example in British Patent Specifications Nos: 1,389,214 and 2,251,570A. Preferably, the frequency of the ultrasonic radial vibrations of the die or of at least one of the dies is in the region of 20kHz. Preferably, also, the or each ultrasonically radially vibrated die is lubricated using a lubricant conventionally employed in the drawing down of filled tube in a method of mineral insulated electric cable manufacture as hereinbefore described.

Reduction in cross-sectional size of a filled tube by passage through one or more than one ultrasonically radially vibrated die to a required size may be effected in one or more than one drawing down operation. Preferably, in the or each drawing down operation, on emerging from the die, or from the last of a plurality of dies, the reduced filled tube is annealed. The filled tube may be annealed by any appropriate method, for example by being placed in an annealing oven, bell annealing or by in-line annealing.

In addition to greater cross-sectional reduction of the filled tube the method according to the invention also has the advantage that a die which is ultrasonically radially vibrated will be normally subjected to less wear - and hence have a substantially longer service life - than a comparable die which is not ultrasonically radially vibrated, and an ultrasonically radially vibrated die will usually provide a better surface finish on a filled tube than that provided by a comparable die which is not ultrasonically radially vibrated. Moreover, the energy required to draw a filled tube of a predetermined cross-sectional size and at a predetermined speed through one or more than one ultrasonically radially vibrating die to reduce its cross-section to a predetermined size is substantially less than that required to draw a comparable filled tube at the same speed through one or more than one conventional die to reduce its cross-section to the same predetermined size.

Mineral insulated electric cables having a sheath of any one of the metals or metal alloys currently employed in the manufacture of such cables for example copper can be manufactured by the improved method of the invention but the improved method of the invention is especially suitable for use in the manufacture of mineral insulated electric cable having a sheath of an alloy that cannot be readily cold worked. The method may be employed with advantage where the sheath is formed from stainless steel, nickel based alloys (Inconels, Incoloys and Hastalloys), copper-nickel alloys, ferritic, austenitic stainless steels, precipitation hardened stainless steels, nickel-copper alloys (Monels) and cobalt based alloys. These alloys can be used for producing mineral insulated cables for thermocouples in conjunction with conductors formed from thermocouple alloys (e.g. types K,N,J,E,T) and also for mineral insulated heating cables in conjunction with conductors formed from resistance alloys (e.g. Nichrome alloys, Kutherm, Ferry and copper). The number of conductors may be 1 or 2 in heating cables or 2,4 or 6 in thermocouple cables.

Mineral insulating powders normally employed in mineral insulating cable may be used in the process according to the present invention, for example alumina, silica, magnesia, calcium oxide or combinations thereof, but other powders may also be used.

The metal tube into which the mineral insulating powder and conductor rod or rods are simultaneously fed may be a preformed tube or it may be a tube which is continuously formed by transversely folding an advancing strip of ductile metal and continuously welding the abutting edges of the folded strip together to form a welded seam.

The invention also includes a mineral insulated electric cable manufactured by the improved method of manufacturing mineral insulated electric cable as hereinbefore described.

The following examples illustrate the invention:

<u>Example 1</u>

Ten tubes of a Nickel base alloy (ALLOY 600) were packed with an insulating powder (Magnesium Oxide) and a pair of equispaced Type K thermoelement rods. The diameter of a short length of one end of the tube was then reduced by swaging to a size small enough to pass through the hole in the first (largest) drawing die. The die size used was selected to give a reduction in cross-sectional area of the starting tube of 42.4% in a single pass through the die.

Each tube, lubricated with a suitable lubricant, was pulled through the die using a conventional draw bench fitted with an ultrasonic drawing die powered from power pack capable of delivering approximately 3 kilowatts of ultrasonic energy at approximately 20 KHz. Tubes were drawn at conventional speeds and at ultrasonic power levels of zero and 3 kilowatts at a frequency of 20.98 KHz.

The first two tubes were drawn without ultrasonic energy being supplied to the die. The resulting cables were heavily scored and totally unsuitable for further processing. This experiment was repeated on the remaining eight tubes from the batch with the application of 3 kilowatts of ultrasonic energy applied to the die. All eight tubes were drawn without any evidence of surface damage.

Following an annealing heat treatment, these eight tubes were processed through a series of drawing dies each reducing the cross-sectional area of the tubes by between 41.4 and 43.6% in a single pass. Each pass being followed by an annealing heat treatment. Using ultrasonic assisted drawing the cables were processed without producing unacceptable surface damage from a starting diameter of approximately 18mm to a finishing diameter of 6mm.

The cable in an annealed condition was subjected to the same testing and inspection standards as cable processed without the aid of ultrasonic assistance. Testing procedures on the cables were voltage withstand, insulation resistance between conductor rods and the outer sheath (the Alloy 600), conductor rod resistance and sheath punctures (holes which completely penetrate the outer sheath wall thickness).

In addition, the cables were also examined metallographically to compare the surface roughness of the inside wall of the sheath and that of the conductor rod, (caused by abrasion by the insulating powder during drawing down) with the surface finish normally produced when tubes are processed by conventional drawing and annealing in a series of smaller reduction steps. These examinations confirmed that the degree of surface damage to the metallic components was similar to that normally observed.

Example 2

Example 1 was repeated using cables consisting of a stainless steel (BS970 Part 1 310 S31) tube filled with the same grade of magnesia and 2 Type K thermoelements. Reductions in area of 41.4 to 43.6% were consistently achieved with ultrasonic assisted drawing which could not be achieved by conventional drawing. In addition the extent of surface damage to the metallic components of the cables was acceptable.

Example 3

Example 2 was repeated with five cables consisting of a stainless steel tube (BS970 Part 1 321 S31), the same grade of magnesia and two pairs (i.e. 4 conductor rods) of Type K thermoelements. The same results were observed.

Example 4

Example 3 was repeated with cables consisting of a stainless steel tube (BS970 Part 1 321 S31), the same grade of magnesia and one Nichrome (Nickel chromium alloy) conductor. The same results were observed.

Example 5

Example 3 was repeated with cables consisting of a stainless steel tube (BS970 Part 1 316 S11), the same grade of magnesia and four Nickel 201 conductors. The same results were observed.

Example 6

Examples 1 and 2 were repeated with the exception that the tubes were drawn through two dies before they were annealed. In this way reductions in area of 45 to 47% were achieved.

Claims

1. A method of manufacturing mineral insulated electric cable which comprises locating one or more conductor rods in a metal tube, introducing mineral insulating powder into the tube and then drawing the filled tube through one or more reducing dies to reduce the diameter of the tube to the required size, wherein the die or at least one of the dies is continuously subjected to ultrasonic radial vibrations.

2. A method as claimed in claim 1, wherein the tube is reduced in cross-sectional area by at least 40% when passed through the or at least one of the reducing dies.

3. A method as claimed in claim 1 or claim 2, wherein the tube is annealed not more than ten times during drawing.

4. A method as claimed in any one of claims 1 to 3, wherein the tube is formed from stainless steel, a nickel based alloy or a cobalt based alloy.

5. A mineral insulated electric cable formed by a process as claimed in any one of claims 1 to 4.