Feb. 23, 1971 TAKASHI SUZUKI 3,565,685

INSULATED CONDUCTORS AND METHOD OF MANUFACTURE THEREOF

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FIG. 1

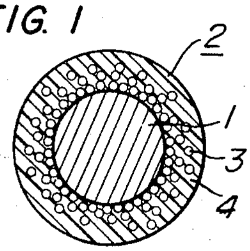


FIG. 2

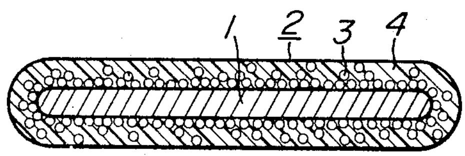
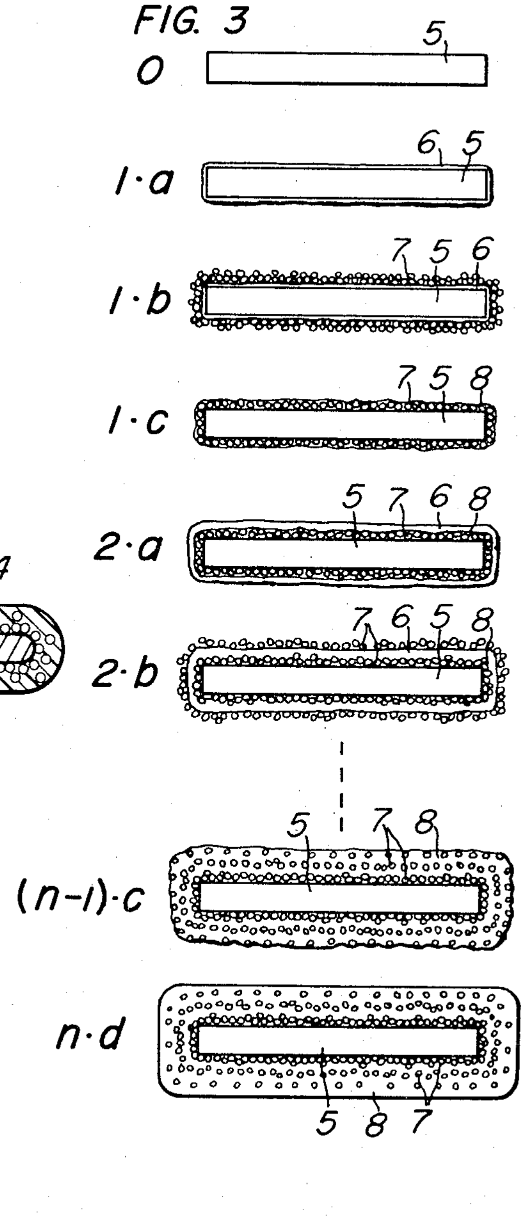


FIG. 3



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INSULATED CONDUCTORS AND METHOD OF MANUFACTURE THEREOF

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U.S. Cl. 117—218 3 Claims

ABSTRACT OF THE DISCLOSURE

The invention pertains to a method for producing and the resulting product which is an elongated rod shaped or strip shaped electric conductor having formed on the surface thereof an electric insulating coating consisting of a synthetic thermosetting resin having inorganic fine particles therein. The percentage content of the inorganic fine particles is progressively higher in a layer of the coating closer to the surface of the substrate conductor.

This invention relates to an elongate rod-shaped or strip-shaped electric conductor having an insulating inorganic fine particle-containing synthetic thermosetting resin coating formed on the surface thereof, and to a method of manufacturing the same.

Rod-shaped or strip-shaped insulated conductors having a synthetic resin coating thereon have been used as a coil in transformers, motors, etc. It is known that the presence of fine particles of inorganic substance having good electric insulating property, such as alumina, silica, beryllia, rutile or mica, in the synthetic resin coating is advantageous in improving the heat resistance, the thermal shock resistance and the heat conductivity of the coating, and in reducing the percentage of volume contraction of the coating as well as in lessening a degradation of the bonding strength of the coating relative to the substrate conductor upon heat-deterioration of the coating.

It is also known that the presence of such substance in the coating, on the other hand, results in marked degradation of the flexural strength as well as the surface smoothness of the coating, making the coiling operation difficult.

It is, therefore, an object of the present invention to provide conductors having an insulator coating thereon which retains the advantages but minimizes the disadvantages described above, and to provide a method of manufacturing such conductors.

It is another object of the invention to provide conductors having formed on the surface thereof an electric insulator coating consisting of a synthetic thermosetting resin and fine particles of insulating inorganic substance contained therein, the percentage of content of said inorganic fine particles in said coating being progressively higher in a layer closer to the contacting surface of said coating and said substrate conductor.

The insulated conductors according to the present invention are of great industrial advantage because the bonding strength of the insulator coating is less degraded upon heat-deterioration of the conductor, the lowering of the apparent flexural strength of the coating caused by the fine particles contained therein is very small for the percentage of content of said fine particles is small in the proximity of the coating surface and accordingly the flexibility is high at said portion of the coating, the coating has excellent surface smoothness and in that the thermal shock resistance is great.

The present invention will be described in further detail with reference to the accompanying drawings, in which:

FIG. 1 is a sectional view of an insulated conductor

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according to the present invention wherein the substrate conductor is a wire;

FIG. 2 is a sectional view of an insulated conductor according to the present invention wherein the substrate conductor is a strip; and

FIG. 3 is a set of sectional views illustrating in sequence the steps of manufacturing an insulated conductor according to the method of this invention.

Referring to FIGS. 1 and 2, reference numeral **1** designates a substrate conductor, **2** an insulator coating formed on said substrate conductor **1**, **3** fine particles of inorganic substance in said insulator coating and **4** a synthetic thermosetting resin material constituting said insulator coating.

The present invention is characterized by the fact that the percentage of content of the inorganic fine particles **3** in the insulator coating **2** is made higher in a layer closer to the substrate conductor **1** as shown.

The insulated conductor of this invention can be manufactured by at least two methods. According to one method, fine particles of inorganic substance are dispersed in a synthetic thermosetting resin varnish. Namely, varnish coating materials containing a varying amount of inorganic fine particles are prepared and coated on a substrate conductor from the one having a larger content of the inorganic fine particle to the one having a smaller content of the same in sequence in superposed relation, while baking the individual layers of coating material each time when the coating material is applied. Dip coating or die coating known in the art may be employed in practicing this method. According to another method, a synthetic thermosetting resin and fine particles of inorganic substance are alternatively attached on the surface of a substrate conductor. Namely, the step of forming a thermosetting resin adhesive layer on the surface of a substrate conductor, the step of attaching fine particles of inorganic substance onto the surface of said adhesive layer and the step of heat-setting said adhesive layer, and if necessary the step of removing excess inorganic fine particles from said adhesive layer, are repeatedly carried out in the order mentioned, and finally a thermosetting resin is coated on the top layer of the coating and baked.

The above-described method will be described more practically with reference to FIG. 3. In FIG. 3, reference numeral **5** designates a substrate conductor, **6** a thermosetting resin adhesive layer formed on the surface of said substrate conductor, **7** fine particles of inorganic substance and **8** the thermosetting resin layer after the heat setting. The markings **1**–*a*, **1**–*b*, . . . indicate the respective steps of forming a thermosetting resin adhesive layer, wherein character *a* indicates the state upon completion of the step of forming a thermosetting resin adhesive layer, *b* indicates the state upon completion of the step of attaching a fine particle of inorganic substance, *c* indicates the state upon completion of the step of heat-setting the adhesive layer and *d* indicates the state upon completion of the step of coating and baking the final layer of thermosetting resin, and numerals **1**, **2** . . . *n* indicate the frequency of the respective steps. In the manufacture of the present insulated conductor by the method described above, it is necessary to increase the amount of the thermosetting resin adhesive material applied on a unit area of the conductor as the frequency of coating increases from the first time coating to the final coating. The coating may be performed by the dip coating or the die coating method commonly used in the art. The inorganic fine particles may be attached onto the surface of the individual thermosetting resin adhesive layers by spraying them on said surface, attracting them onto said surface by making use of electrostatic force or by dipping the thermosetting resin adhesive-coated substrate conductor into the particles of inorganic substance.

Suitable synthetic thermosetting resin materials usable in practicing the methods described above, include insulating varnishes, such as formal, polyester, epoxy, polyurethane and polyimide; solventless polyester or epoxy resin; and emulsion paints of various synthetic thermosetting resin dispersed in water. As inorganic fine particles powders of alumina, silica, magnesia, beryllia, zirconia, talc, mica, glass, calcium carbonate, etc. are preferably used.

The optimum content and distribution of the inorganic fine particles in the insulator coating formed on a substrate conductor are variable depending upon the type of coating material and the coating method used. However, so far as the experiments reveal, a satisfactory result can be obtained when the resin component is 80 to 100% by volume in the outer layer of the insulator coating and 10 to 50% by volume (the balance being inorganic fine particles) in the inner layer of the insulator coating or in the layer adjacent to the boundary between said insulator coating and a substrate conductor.

EXAMPLE 1

Five coating materials of different composition depicted below were coated and baked on the surface of a copper wire of 1.0 mm. in diameter individually in sequence, whereby an insulator coating having a thickness of 30μ was formed.

Coating Material:	Polyvinyl formal varnish to silica powder (average particle size 2μ) ratio (by weight)
1	2:5
2	3:4
3	4:3
4	5:1
5	1:0

Coating materials 1 to 4 were baked once and coating material 5 was baked three times after application.

Separately from the sample insulated wire prepared in the manner described above a control sample was prepared by forming a 30μ thick insulator coating on the surface of the same copper wire by baking the same polyvinyl formal varnish on said surface 15 times.

The two samples of insulated conductors were heated at 200° C. for 24 hours and then subjected to a torsional peeling test, with the results shown below:

		Number of torsion
Insulator coating with silica powder	Before heating	200
	After heating	97
Insulator coating of varnish only	Before heating	250
	After heating	35

EXAMPLE 2

An elongate aluminum strip (purity 99.4% Al) having a thickness of 0.2 mm. and a width of 20 mm. and having the edges thereof ground and polished mechanically to remove burr, was dipped in a solution of an epoxy ester-type insulating varnish (solid content 45%) diluted with a solvent to a solid content of 5%. After removal from the solution, the aluminum strip was heated at 110° C. for 2 seconds to remove the solvent from the coating formed on the surface thereof, whereby an adhesive coating was obtained on the surface of the aluminum strip which was slightly viscous at normal temperature. Then, the aluminum strip was passed through an alumina powder having an average particle size of 4μ, to have said alumina powder attached to the surface thereof in an excessive amount and thereafter a varnish was baked on said surface at 250° C. for 2 minutes. The excess alumina powder was removed by a cotton brush.

Thus, the first cycle of powder-attaching and varnish-baking operation was accomplished. Thereafter, such operation was repeated 2 to 5 times (the final operation) in the same manner as described above. The weight of the coating formed after each cycle of operation and the concentration of the varnish used in each cycle of the operation, etc. are shown in the table below:

Cycle of operation	Concentration of varnish, percent of solid component	Amount of varnish coating after each cycle of operation, g./m.^{2}	Amount of powder attached at each cycle of operation, g./m.^{2}
1st	5	1	8
2nd	5	2	9
3rd	5	3	8
4th	5	4.5	8
5th	25	9	

As a result, an insulator coating of 32μ in thickness was obtained wherein the percentage of alumina content was larger in a layer closer to the substrate conductor. Another sample having an insulator coating of about 30μ in thickness was produced by a different method using a varnish only, and both samples were compared with each other by lapping them around a bar of 2.0 mm. in diameter after heating them at 200° C. for 5 hours. The insulator coating containing alumina powder showed only small cracks therein, whereas the insulator coating containing no powder was peeled from the substrate conductor.

What is claimed is:

1. An insulated conductor comprising a substrate conductor having formed on the surface thereof an insulator coating consisting of a synthetic thermoset resin and fine particles of insulating inorganic substance, the percentage of content of said inorganic fine particles in said insulator coating being higher in a layer closer to the surface of said substrate conductor.

2. A method of manufacturing the insulated conductor comprising repeating the step of applying and baking onto the surface of a substrate conductor a liquid synthetic thermosetting resin coating composition containing fine particles of insulating inorganic substance, wherein said coating composition contains a progressively reduced content of said inorganic fine particles in successive ones of said steps.

3. A method of manufacturing an insulated conductor wherein a cycle of operation comprising forming a thermosetting resin adhesive layer on a substrate conductor, attaching fine particles of insulating inorganic substance onto the surface of said adhesive layer, thermosetting said adhesive layer, and the step of removing excess fine particles of insulating inorganic substance from the surface of said adhesive layer, is repeated at least twice and thereafter a thermosetting resin composition is applied and baked onto the surface of the resultant coating layer, the amount of the synthetic resin layer formed by each cycle of operation per unit area of the surface of a substrate conductor being progressively increased as the frequency of said cycle of operation increases.

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