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COATING WIRE

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1 Claim. (Cl. 117—21)

This invention relates to the coating of electric wire and, more particularly, to an improved method of coating wire with a continuous film of a superpolyamide.

Numerous types of wire must be provided with coatings which must not only insulate the wire but must also resist break-down due to abrasion. Magnet wires, including not only small wires for use in small magnets and core windings but also larger wires for electric motor windings, and the like, have been the subject of extensive research in an effort to develop a thin coating which will resist abrasion in service and thereby prevent short-circuiting of wires with one another or with other conducting elements. For example, magnet wires have been coated with a relatively thin film of an enamel, such as enamels of the oleo-resinous type, to provide an abrasion-resistant coating which has sufficient insulating value with a relatively small increase in the overall diameter of the wire. As an index to the resistance of such a coating to abrasion, the coated wire commonly is tested on the standard rotary abrasion tester described in Industrial and Engineering Chemistry, vol. 31, No. 9 (September, 1939), pages 1067-1068. This abrasion testing machine comprises a rotatable squirrel-cage drum provided with "Carboloy" (a very hard steel composition) spokes. The wire to be tested is secured to an electrical contact at one end, is passed over the spokes of the cage and is held taut by a free hanging weight on the other end of the wire. The test consists in counting the number of rubs of the wire made by the spokes required to wear through the wire coating and to produce electrical contact between any one of the spokes and the wire when the drum is rotated at a speed of about 60 R. P. M. Under testing conditions in this machine, with a weight of 1.79 pounds on the wire, it has been found that a coating of conventional wire enamel is broken down at the end of about 250 to 400 rubs.

It has been proposed heretofore to coat either bare or enameled wire with a resin having higher abrasion-resistance than conventional wire enamel. This result has been obtained by passing either the bare wire or enameled wire, both types being referred to hereinafter as "wire," through a mass of the resin either in a molten state or dissolved in a solvent therefor. Such resins as have been found satisfactory heretofore are so viscous, either in the molten state or when dissolved in a solvent and maintained at an elevated temperature, that it has been necessary to draw the wire vertically through a mass

of the resin placed in the bottom of a vertical tower. This mode of operation can not be carried out with conventional wire coating apparatus of the wire-dipping type because of excessive thickness and unevenness of the coating film. The maximum abrasion resistance obtainable with the best resinous coating heretofore available has been about 5,000 rubs when tested on the abrasion testing machine with the same weight load as on the enameled wire referred to above.

We have devised a novel method of coating wire with a superpolyamide which may be carried out with conventional wire-coating apparatus and which results in the production of a tough, homogeneous, and continuous thin coating of the superpolyamide around the wire. The superpolyamides referred to herein are the compounds known as such in the art and comprise synthetic linear condensation polyamides containing a plurality of amide linkages and having a molecular weight of at least about 7000. The nylon products produced in accordance with U. S. Patents Nos. 2,071,253 and 2,130,948, and other like materials known to the trade as "nylon," are examples of these superpolyamides which are of high molecular weight, have relatively high melting points, and are characteristically viscous even at temperatures substantially in excess of their melting points.

An important feature of the method of our invention is that very thin coatings of superpolyamides may be applied. For example, coatings 0.001 inch and even substantially less in thickness may be produced by the method of the invention, whereas it is impossible to produce superpolyamide coatings less than about 0.004 inch in thickness by extrusion processes.

The method of our invention comprises passing a wire in contact with a fluid suspension of finely divided particles of a superpolyamide in such manner as to coat the conductor with the particles of superpolyamide, subsequently heating the coated wire to a temperature above the melting point of the superpolyamide, and maintaining the temperature of the wire above the melting point of the superpolyamide for a sufficient period of time to produce a tough homogeneous film of the superpolyamide about the wire. We have found that wires coated with finely divided particles of the superpolyamides are provided with a continuous thin coating thereof as a result of the flowing together of the particles of superpolyamide at a temperature above its melting point in the subsequent heating oper-

ation. The film of superpolyamide thus produced is sufficiently tough to withstand upwards of 25,000 rubs before breaking down when tested on the standard rotary abrasion tester under a load weight of 1.79 pounds on the wire.

The method of our invention includes the steps of dissolving a superpolyamide in a solvent therefor, precipitating the superpolyamide from the solution thereof in the form of finely divided particles, and then coating the wire with a suspension of these finely divided particles of superpolyamide prior to the heating operation. We have found that temperatures of about 500°–650° F. may be used with advantage in the heating operation, and within this range temperatures of about 525°–550° F. may be used with particular advantage.

We have found that superpolyamides comprising the polyamide obtained by condensation of tetramethylenediamine and adipic acid, having a melting point of about 553° F., and the polyamide obtained by condensation of paraxylylenediamine and sebacic acid, having a melting point of about 515° F., may be used with particular advantage in the process of our invention. However, it is understood that other superpolyamides of both similar and different origin may be used with advantage within the scope of our invention.

We have found, furthermore, that formamide may be used with particular advantage as a solvent for the superpolyamide in accordance with our invention although other solvents such, for example, as phenol, cresols, xylenols, p-butyl phenol, thymol or mixtures thereof, and similar solvents of the monohydric phenolic type, may also be used within the scope of our invention. The application of heat facilitates solution of the superpolyamide in the solvent, and for this purpose we have found that the temperature of the mixture should approach the maximum temperature which the solvent can withstand without deterioration or evaporation, or both, in order to obtain a solution containing enough superpolyamide for efficient operation in accordance with our invention.

As an example of our novel method of coating wire, 125 parts by weight of a superpolyamide comprising the polyamide derived from paraxylylenediamine and sebacic acid, having a melting point of about 515° F., were dissolved in 417 parts by weight of formamide, having a specific gravity of 1.337, to produce a solution containing about 23% by weight of the superpolyamide. The mixture was heated to a temperature of 380° F. in order to obtain complete solution of the superpolyamide in the formamide. We have found that with these compounds a water-white solution is obtained by heating them to a temperature ranging from about 370° F. to about 400° F. The above-noted proportion of superpolyamide was not completely soluble in the formamide at a temperature below about 370° F., and the formamide decomposed at temperatures in excess of about 407° F. About 1000 parts by weight of water (a non-solvent for the class of superpolyamides) at room temperature was then added to the formamide solution of superpolyamide after the solution had been cooled to a temperature of about 200° F. The water selectively dissolved the formamide and precipitated the water-insoluble superpolyamide in the form of finely divided particles. The particles of superpolyamide in this milky-white precipitate were so small that they could not be distinguished by macroscopic inspection. The precipitate was then

separated by decantation from the aqueous solution of formamide, and the formamide was then recovered from its aqueous solution by conventional means, simple distillation being used in this instance.

The separated precipitate, comprising finely divided particles of the superpolyamide, was then suspended in about 50–100% by weight of water to form a suspension having the consistency of a pasty mass. The suspension was stabilized with a relatively small proportion, about 1% by weight, of lauryl sulphate (commonly known by the trade name of "Gardinol"). Other synthetic organic dispersing agents or sulphonated oils or suitable soaps may be used for this purpose. However, in our experiments particularly effective stabilization was obtained by the use of sodium lauryl sulphate. This fluid suspension of the particles of superpolyamide was used as the bath into which the wire was immersed in accordance with conventional wire-coating procedure. In the example herein described a wire (No. 18 B. and S. gauge) having a diameter (bare) of 0.0405 inch was passed through this suspension-bath and emerged with a milky-white coating of fine particles of the superpolyamide. The coated wire was then heated by passing it continuously at a rate of 15 feet per minute through a vertically disposed oven of conventional design and which, in this particular example, had a length of about four feet. An entering temperature of about 200° F. was maintained in the oven, with the temperature increasing throughout the length of the oven to about 525° F., or somewhat higher, at the point where the wire emerged. The elevated temperature to which the coated wire was subjected in the heated oven caused the fine particles of superpolyamide to fuse and to flow together to form a substantially transparent homogeneous coating around the wire having a thickness of about 0.001 inch or less.

If a transparent coating is desired when using a superpolyamide which tends to discolor due to oxidation at an elevated temperature, the heating oven may be provided with an atmosphere of a gas such as carbon dioxide which is inert with respect to the superpolyamide and, preferably, inert with respect to the copper wire, although it should be noted that the atmosphere provided in the oven by evaporated fluid-suspension medium used in preparing the suspension-bath will generally suffice to prevent undue discoloration of the wire coating. The aqueous constituent of the suspension, as well as any dispersing agent present and any formamide which may have been carried over into the suspension, was driven off by evaporation or decomposition during the heating operation so that the resulting coating on the wire comprised substantially unadulterated superpolyamide.

During the heating operation, in the course of which the superpolyamide coating is raised to a temperature above its melting point, it shrinks and, upon cooling, forms a tough homogeneous coating about the wire. Additional coats of the superpolyamide may, if desired, be then applied over the first coating by again passing the wire through the suspension-bath and thence through the oven.

The homogeneous coating thus produced was flexible and did not crack when the coated wire was bent and twisted. This wire coating, when subjected to test in the abrasion-tester referred to above, withstood upwards of 30,000 rubs before breaking down thus representing a notable im-

provement over the 250-400 rub limit of conventional wire enamel and the 5000 rub limit of the best resinous coating known heretofore.

Although it is generally believed that the full strength of a superpolyamide is not realized until it has been subjected to mechanical working, we have found that the superpolyamide coating obtained in accordance with our invention possesses the abrasion-resistance characteristic of the mechanically-worked material. This result may be explained possibly by the mechanical working of the coating as the coating shrinks about the wire during cooling or possibly by the fact that the coating becomes tougher and more resistant to abrasion when it is subjected to abrasion during use. Whether or not this theoretical explanation is correct, however, is immaterial to our invention, for the superpolyamide coating produced in accordance with our invention exhibits the full abrasion-resistance of mechanically worked superpolyamide.

Although water was used in the foregoing example as the selective solvent capable of precipitating the superpolyamide from its solution, other non-solvents for the superpolyamide may be used with advantage. Such non-solvents include alcohol, ethyl acetate, benzene, hydrocarbons, and the like. One non-solvent may be used to precipitate the superpolyamide from its solution and the same, or another, non-solvent may be used in preparing the suspension of precipitated superpolyamide for the coating bath.

The otherwise substantially transparent superpolyamide coating obtained in accordance with our invention may be colored by incorporating dyes or pigments at an appropriate point in the production of the suspension of finely divided particles of superpolyamide applied to a wire. For this purpose many colored pigments including lead chromate, zinc oxide, carbon black, chrome red, and ultramarine may be employed, preferably by incorporating the pigment in the suspension of finely divided particles of superpolyamide applied as a coating to the wire. Mineral pigments in general are inert with respect to the superpolyamide and do not deleteriously affect the abrasion-resistance or other desirable properties of the coating. They color the coating, however, to permit circuit identification, and for such purpose they constitute advantageous ingredients in the coating bath. If several coats of superpolyamide are applied to the wire, any one or more of the coatings may be pigmented. If colored wire is desired, however, it is advantageous to have the last coating pigmented. Wires having a pigmented coating of the superpolyamide possess substantially the same physical properties, including a high degree of resistance to abrasion, as wires coated with unpigmented superpolyamides, except of course they are colored by the added pigment. Some organic dyes may be incorporated in the suspension-bath without subsequent decomposition in the heating operation, but the application of organic dyes to the superpolyamide coating has been found to be made with advantage on the finished coating. The finished coating of superpolyamide has a strong affinity for dyes such as those used in dyeing wools and silks so that successive lots of superpolyamide-coated wire may be dyed differ-

ent colors to meet demands for such a product without requiring separate differently colored baths for each colored wire.

The continuous thin coating of superpolyamide produced by our novel method exhibits sufficient electrical insulating characteristics to meet the average requirements of magnet wires and the like. Bare wire, therefore, may be coated directly with a superpolyamide in accordance with our invention and, where additional insulation or resistance to abrasion is desired, several such coats may be applied successively.

Although superpolyamides may be used alone on otherwise bare wire, a particularly advantageous wire structure is obtained by first coating the wire in the usual manner with one or more coats of an enamel of the type heretofore commonly employed, such as an oleo-resinous enamel, and by then coating the enameled wire with one or more coats of the superpolyamide. Superpolyamide coatings have been found to possess a somewhat less dielectric strength than the common known enamels, and so are less effective coatings so far as their electrical insulating properties are concerned. By applying the superpolyamide coating over a wire already coated with an enamel, however, an improved wire product is obtained possessing both a high dielectric strength and a high resistance to abrasion. In such a wire structure the superpolyamide coating serves primarily as an armor over the enamel, protecting it from damage due to mechanical causes. This construction is particularly advantageous in magnet wires such, for example, as are intended for use in winding coils to be subjected to a fairly high voltage between adjacent turns or layers, and which are subject to mechanical abuse either during winding of the coil or during transport or use thereof. Very thin coatings of the enamel may be applied to the wire, and likewise very thin abrasive-resistant coatings of the superpolyamide may be applied over the enamel by the method of the present invention. Accordingly it is possible to produce wires having a coating of enamel armored by an overlying coating of superpolyamide in which the total thickness of the coatings is less than 0.002 inch. Such wires are of particular use for winding coils where a high degree of electrical insulation is required in combination with a high degree of resistance to abrasion, and where the space factor available for the insulation is limited.

We claim:

The method of coating wire with a thin film of superpolyamide which comprises contacting the wire with a liquid precipitated aqueous suspension of fine particles of superpolyamide stabilized with a small proportion of sodium lauryl sulphate to form a uniform coating of the suspension over the wire, said particles being so fine that they are not macroscopically distinguishable, and heating the coating of the suspension to evaporate the liquid therefrom and to a temperature of from 500 to 600° F. to melt the particles together to form a homogeneous coating of the superpolyamide about the wire, and cooling to form a tough coating thereon.

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