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[54] **CURRENT TRANSFER BRUSHER**

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[30] **Foreign Application Priority Data**

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[52] **U.S. Cl.** **117/217,** 117/228, 310/252

[51] **Int. Cl.** **C23b 5/50**

[58] **Field of Search**.... 310/219, 231, 245, 248–253; 117/217, 228, 71

[56] **References Cited**

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[57] **ABSTRACT**

A current transfer brush is composed of refractory fibres, preferably high strength carbon fibres, with a metallic coating on the fibres which is composed of an under layer of a first metal and an over layer of a second metal. The over layer is of a highly conductive material such as silver and the under layer which improves coherence and adhesion of the over layer and thereby produces a very low brush voltage drop, is of a material such as nickel.

7 Claims, 2 Drawing Figures

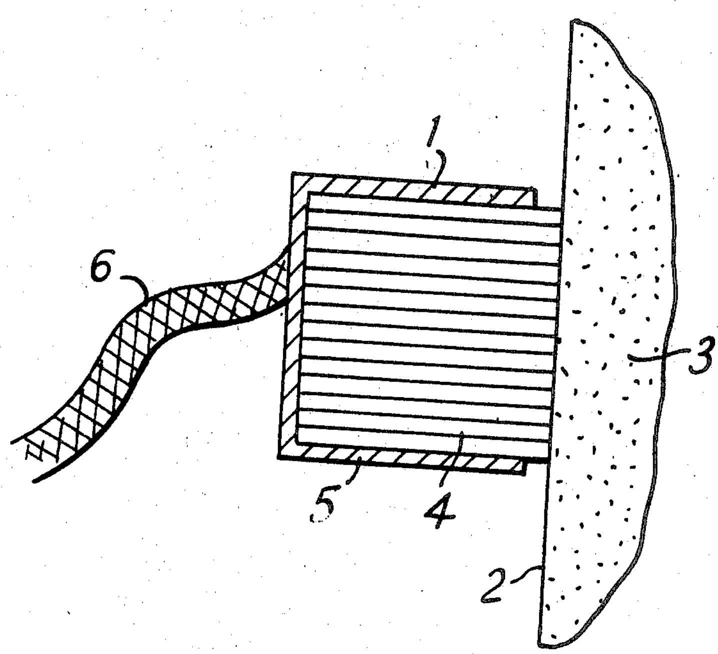


FIG. 1

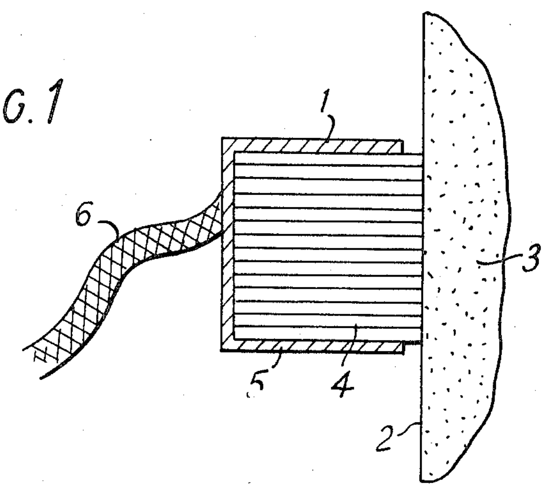
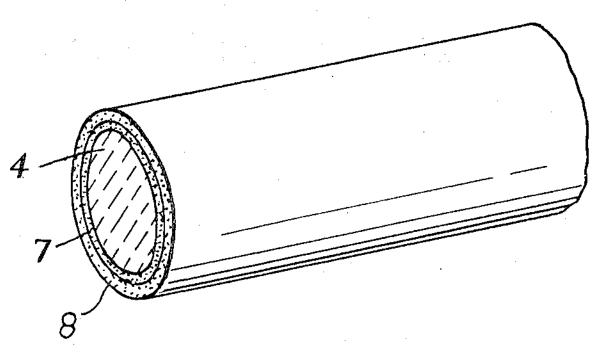


FIG. 2



CURRENT TRANSFER BRUSHER

The present invention relates to current transfer brushes consisting of refractory fibres, such as carbon fibres, coated with an eletrically-conductive metallic layer.

Such brushes form the subject of our British Pat. No. 1,191,234, French Pat. No. 70,30073 and U.S. Pat. No. 3,668,451 and are particularly valuable for use in homopolar machines where high speeds of rotation and large currents call for brushes which exhibit a low rate of wear when rubbing against a rapidly moving contact surface and which have high electrical conductivity. In these prior brushes the carbon fibres which are employed have very good mechanical properties because of their special method of production and they provide support for the layer of electrically conductive metal, such as silver, which probably carries most of the current. The thickness of the layer is limited because it is essential to maintain the flexibility of the fibre in order to give satisfactory wear rates. Therefore the electrical conductivity cannot be increased simply by using a thicker coating. Unfortunately it is found in practice that a layer of a particular thickness, calculated from the weight deposited per unit area, gives a conductivity lower by a factor of 10 or more than the expected value. Moreover the conductivity, and thus the voltage drop at the brush, varies from one sample to another and is different according to whether the brush is connected as a negative brush (from which electrons flow into the contact surface) or a positive brush (into which electrons flow from the contact surface).

The problem underlying the invention, therefore, is to improve the electrical properties of metal-coated fibre brushes without harming their mechanical properties and thereby suffering from increased wear rates. In accordance with the invention the solution to this problem is found in the provision of a brush composed of refractory fibres each of which has a metal coating composed of two layers of which the under layer is a homogeneous layer with a smooth surface while the outer layer is of high electrical conductivity, forms a homogeneous coating on the under layer, and has a high ionic mobility giving it the capacity for rapid diffusion across the surface of the under layer to fill cracks which may occur during operation.

It is believed that the formation of a satisfactory underlayer with good adhesion to a carbon fibre may require the formation of a thin carbide phase between the fibre and the underlayer. Hence the metals to be used for the underlayer are those with reasonably stable carbides namely titanium, vanadium,tantalum, chromium, molybdenum, tungsten, manganese, iron, cobalt, nickel, and boron. Of these the preferred materials are chromium, iron, cobalt, and nickel.

For the outer layer silver is the preferred material because of its high electrical conductivity and its resistance to oxidation. Gold also has suitable properties but is unlikely to be used because of its high cost. If the brushes are to be run in a reducing atmosphere, thereby avoiding the risk of oxidation, it is possible to use copper, aluminium, cadmium, zinc or lead, copper being preferred. It is also possible to use an alloy of silver and copper.

With a two-layer coating it has proved possible, for a coating of the same overall thickness, to obtain higher conductivity, i.e., lower voltage drop, than is possible with a single layer of either of the coating materials. This voltage drop is less variable from sample to sample and is less dependent on the direction of current flow between the brush and the contact surface. Moreover these results are obtained without any deterioration in the wear rate, in fact at high current densities there is even some reduction in the rate of wear, perhaps resulting from improved adhesion of the outer layer to the under layer under conditions of high thermal stress as compared with the adhesion of the material of the outer layer to the surface of the fibre.

A variety of deposition processes can be used for applying the two layers to the refractory fibres. The preferred process is that of electro-plating and details of how this may be applied are given in our British Pat. specifications Nos. 1,272,777 and 1,309,252. Other processes available include pyrolysis of an organometallic vapour, high vacuum evaporation, sputtering, and electroless plating (that is chemical reduction of metallic salts).

By way of example one embodiment of this invention will now be described in more detail and comparative information will be given to show how this embodiment with a two-layer coating affords substantially better results than a single layer of either of the coating materials separately. In this embodiment carbon fibres are coated with an under layer of nickel and an outer layer of silver.

The carbon fibres used are high strength fibres of RAE Type II produced as described in British Pat. specification No. 1,110,971 by carbonization of polyacrylonitrile fibres while holding them under tension. The average diameter of the filaments is 7.5 μ m. When such filaments are electroplated with silver to give an average coating thickness, calculated in terms of the amount of metal deposited per unit length of a tow consisting of as many as 10^4 fibres, of 1.0 μ m the electrical resistance is found to be 10 to 20 times higher than would be expected with a uniform layer of this thickness. This is thought to be due to the fact that the silver deposit is nodular and has areas of poor adhesion to the carbon fibre.

If such carbon fibres are electroplated with nickel alone as a single layer a smoother, more homogeneous deposit is formed and the electrical properties are more consistent. There is better correlation between the calculated layer thickness and the actual conductivity but the overall voltage drop is generally higher than for a silver layer.

If now a silver layer is electroplated onto a nickel layer there is a marked improvement in the electrical and mechanical properties. Measurements of voltage drop made with brushes running at a speed of 35m/sec on a silver-plated slip ring with a current density of 500 KA/m^2 are given in the following table for the various types of brush

Fiber coating	Positive Brush	Negative Brush
Nickel	1.5	0.40
Silver	1.2	0.25
Silver on nickel	0.20	0.15

The average coating thickness, as calculated from the weight of material applied, was approximately 1μ m for the silver layer alone, 0.7μm for the nickel layer alone, and 0.5μ m of silver over 0.7μ m of nickel.

In the case of a nickel-coated positive brush the initial voltage drop was similar to that of a negative brush but within a few seconds of commencing operation it rose to the higher value given in the table.

It will be seen from the table that in addition to the low value of voltage drop obtained for a negative brush with a two-layer coating there is a very important improvement in the voltage drop for a positive brush so that the performance of the brush is largely independent of the direction of current flow.

A silver layer applied directly to the carbon fibre by electro-plating from an alkali cyanide bath is nodular and shows areas of poor adhesion where the material will readily flake off under mechanical stress. It is believed that the unevenness of the deposit and its lack of adhesion are responsible for the fact that the resistance per unit length is 10 to 20 times higher than would be expected from the calculated average layer thickness. A nickel layer plated from an acid bath gives a more smooth and homogeneous layer which despite the presence of longitudinal cracks showed little tendency to flake off. The correlation between resistance and calculated layer thickness was better than with silver.

When silver is plated onto a smooth nickel under layer a higher nucleation density is obtained so that fewer nodules are produced and the adhesion of the silver is improved. The electrical resistance is close to that expected from the calculated thickness, indicating that a uniform homogeneous coating has been obtained. There is little evidence of cracking in the layers. It appears, therefore, that the silver layer, in addition to reducing the overall resistance along the coated fibre, improves the physical properties in three respects. Firstly, being a softer material, it fills in and cements together any cracks which are present in the nickel layer and thus helps to maintain electrical contact between the nickel and the fibre. Secondly it provides a source of mobile ions to diffuse into cracks formed in the nickel during operation, which again helps to maintain the electrical performance of the layer. Thirdly it reduces thermal gradients in the coating and thereby minimises stresses due to differential expansion.

The basic requirements for the materials of the two layers are as follows:

First Layer: high nucleation density on carbon fibre, preferably with some mechanism in the plating process, to limit the growth of large nodules. In other words, the ability to form thin homogeneous layers with smooth surfaces. Such layers may be internally stressed, and may tend to crack.

Second Layer: high nucleation density on first material, giving homogeneous layer. As plated, the material should have little internal stress, and should be of a thickness and resistivity appropriate to the application envisaged. In addition, the material should be capable of rapid surface diffusion, giving the ability to seal major defects occuring in the underlayer during brush operation.

It may be advantageous in some cases to have a coating composed of more than two layers with the electrical and mechanical properties graded from the inside layer to the outside layer.

One example of the invention is shown in the accompanying drawing, in which:

FIG. 1 is a cross-section of an electrical current transfer brush in accordance with the invention shown in engagement with a current transfer surface, and

FIG. 2 shows on an enlarged scale a fibre with a metallic coating employed in the brush of FIG. 1.

Referring to FIG. 1, an electrical machine comprises a current transfer brush 1 which is in contact with a surface 2 of an electrically conducting member 3. The member 3 may be, for example, a slip ring or commutator segment in a dynamo-electric machine or may be a continuous rail from which the brush 1 collects current, for example for traction purposes in vehicle systems. The brush 1 comprises a plurality of fibres 4 retained in mutual contact with each other along a major part of their length by a casing 5 of metallic material. A braid 6 of electrically conductive material carries current between the brush and windings or terminals of the machine.

Each of the fibres 4, as shown in FIG. 2, has a coating composed of a first layer 7 and a second layer 8. The composition and manner of formation of the fibres 4 and the layers 7 and 8 are as described previously and in this preferred construction high strength carbon fibres 4 are coated first with a nickel layer 7 and then with a silver layer 8. The fibres are held in close contact by the clamping action of the casing 5 and may be welded to each other along a portion of their length by way of the metallic fibres. It is important that the fibres should not be welded together at their free ends adjacent the transfer surface 2 since here they must be free to flex individually.

The braid 6 may be soldered, welded or rivetted to the casing 5 or alternatively may be connected directly to the fibres. The brush may be held in a conventional brush holder which is spring biassed towards the surface 2.

What is claimed is:

1. A current transfer brush comprising refractory fibres individually coated with a coating comprising a homogeneous under layer of a first metal closely adherent to the fibre and an over layer of a second metal with high electrical conductivity which adheres to the under layer.

2. A current transfer brush as claimed in claim 1 in which the under layer is composed of a metal selected from the group comprising titanium, vanadium, tantalum, chromium, molybdenum, tungsten, manganese, iron, cobalt, nickel, and boron.

3. A current transfer brush as claimed in claim 2 in which the over layer is of silver.

4. A current transfer brush as claimed in claim 1 in which the over layer is selected from the group comprising silver, gold, copper, aluminium, cadmium, zinc, and lead.

5. A current transfer brush comprising refractory fibres each of which is coated with an under layer of a metal selected from chromium, iron, cobalt, and nickel and an over layer of a metal selected from silver, gold, copper, and alloys of silver and copper.

6. A current transfer brush as claimed in claim 5 in which the fibres are carbon fibres.

7. A current transfer brush as claimed in claim 6 in which the under layer is of nickel and the over layer is of silver.

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