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MAGNETIC SHEET MATERIAL PROVIDED WITH A SEPARATOR COATING AND METHOD OF MAKING SAME

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The present invention relates to a separator coating for magnetic sheet materials. It is particularly concerned with a refractory coating which can be applied to magnetic sheet materials to function as a separator between adjacent laminations of such sheet materials during heat treatment thereof. The term "sheet material" as used herein and in the appended claims is intended to include both strip material used, for example, in forming a wound transformer core as well as the cut or punched laminations employed in forming stacked transformer cores and the laminated stator or rotor components of motors, generators and the like. Examples of magnetic sheet materials are nickel iron alloys, silicon steel, common iron, and similar materials used in the above-identified electrical apparatus.

In accordance with present-day practice, such magnetic sheet materials are supplied to the consumer or fabricator in the form of large sheets or as continuous strips conveniently wound to roll form for shipping purposes. After such material is cut or punched by the consumer to the size or shape which is to be employed in the fabrication of devices such as transformers, motors and the like, the product is given a final heat treatment for the purpose of developing its magnetic properties. This heat treatment is ordinarily a closed or box anneal, generally in a controlled atmosphere. If the material to be heat treated is still in the form of a strip of substantial length, the strip is conveniently wound into the form of a roll and placed in the annealing furnace in that form. If the material is in the form of plates or sheets of reasonable length or in the form of small punchings such as those employed in motor manufacture, these are stacked or packed into boxes for loading into the heat treating furnace. In either case, the material is heat treated in a multi-ply assembly in which the surfaces of adjacent laminations of the magnetic sheet material are in contact with one another over relatively large areas with the result that at the more elevated temperatures employed for developing the magnetic qualities of the material, the adjacent laminations tend to stick together unless some means is provided for separating the laminations during the heat treatment.

Heretofore, to prevent such sticking, a finely-divided refractory material, such as magnesium oxide, alumina, calcined dolomite, or zirconia, has been carefully dusted on to the surfaces of the magnetic sheet material or applied thereto in the form of a slurry in water just prior to the time the material is wound into the form of a core or

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roll or stacked in preparation for the box anneal. Because of the nature of the coating material, the manner in which it is applied, and the fact that it is easily dislodged during handling of the material, it was necessary that this operation be carried out immediately prior to the annealing step. Due to the ease with which such coatings could be brushed off by normal handling of the coated material, it was not possible to apply the coatings to the magnetic sheet material until after all of the preliminary operations such as punching or cutting had been carried out. Even the normal handling of the wound strip materials would frequently result in the refractory material being rubbed off or displaced from some surface areas to an extent such that sticking would take place during subsequent anneal of the wound core.

To simplify the coating process, it has been proposed that the separator material be applied in the form of a paint comprising the finely-divided refractory material suspended in a solution of a decomposable binder such as a solution of an alkyd resin, cellulose acetate or the like in suitable organic solvents. After evaporation of the solvent, the resinous component of the paint served to bond the refractory material to the surfaces of the magnetic sheet material in the form of a film which would not become loose or dislodged during normal handling operations, including the punching or cutting of a sheet or strip into suitable laminations. This process, however, involved on a commercial scale the use of large quantities of expensive binders and solvents. In addition, when such binders were used, the refractory layer remaining after decomposition of the binder during the annealing operation was no longer bonded to the magnetic sheet material. It could be brushed from the surfaces with the same ease as those separator coatings applied in the dry state or from a water slurry. This was apparently due to the fact that the individual particles of refractory oxide as applied to the magnetic sheet material were completely coated or surrounded by a layer of the resinous binder and actually spaced from the surfaces of the sheet material by this layer. Upon decomposition of the binder, the separation was still existent so that at no time during the process was there a substantial percentage of the oxide particles in such intimate contact with the surfaces of the sheet material as to obtain an actual bonding or adhesion of the particles themselves to the surfaces of the sheet material during anneal to form a permanent film thereon.

It is, therefore, an object of the present invention to provide an inexpensive, general purpose coating which can be easily applied to magnetic strip material and which will resist brushing off by normal handling of the strip material either while it is being punched into laminations or wound into toroidal cores, or being shipped. It is another object of the invention to provide a refractory separator coating which will adhere to the sheet material prior to and during the necessary annealing operations and which will not affect the magnetic quality of the sheet material after anneal. A further object of the invention is to provide a separator coating containing a decomposable binder which bonds the particles of separator material in such intimate contact with the surfaces of the sheet material that upon decomposition of the binder during the heat treatment, the particles of separator material actually adhere to the sheet material to form thereon a permanent inorganic layer having insulative qualities.

The refractory component of the coatings of the present invention includes any one or more of those finely-divided refractory or semi-refractory materials previously employed for this purpose. Examples of such materials are magnesia, alumina, calcined dolomite, zirconia, silica, or mixtures of two or more of these oxides.

The above objects and others which will become apparent from the following description of the invention have been attained by providing a coating for magnetic sheet materials comprising a water-soluble, colloidal cellulose ether, such as methyl celluose, as the heat-decomposable binder for the refractory separator material. It has been found that coatings of the methyl cellulose bonded refractory material tightly adhere to the surfaces of the said material so that the coated sheets may be shipped, handled, punched, or wound through tension devices without seriously affecting the adhesion of coating. Following anneal of the coated material in any of the atmospheres previously employed in the anneal of such magnetic materials, there is no impairment of the magnetic characteristics thereof and no sign of adhesion between laminations during the heat treatment.

Methyl cellulose, which is the preferred water-soluble cellulose ether, is a material obtainable commercially in the form of a dry powder which can be dispersed in water to obtain what appears to be a colloidal solution. Such a colloidal solution is an excellent base for preparing a suitable slurry or suspension of the refractory oxide. It has been found that the amount of the methyl cellulose which must be included in such a water slurry of the refractory oxide to obtain the desired bonding action between the dried coating and the magnetic sheet material is quite small and ordinarily will not exceed about 2 per cent by weight of the slurry. Even in those cases where punchings, for example, in the form of small transformer or motor laminations are punched from the coated material, it will be found that the methyl cellulose bonded coatings are not adversely affected by the punching operations. To obtain these results, the amount of methyl cellulose employed should comprise at least about 0.3 per cent to .5 per cent by weight of the total slurry. While the binding action of the cellulose ether is such as to permit the usual processing of the coated material, the cost of a cellulose ether coating is substantially less than the cellulose acetate and alkyd resin coatings heretofore employed. In addition, as compared with the cellulose acetate or alkyd resin coatings containing the same oxide or mixture of oxides, the dried methyl cellulose coatings are substantially thinner and hence provide a space factor advantage during the annealing operation.

Another advantage of the present invention is that the coating can be applied to the continuous strip material as it comes from the supplier. The coated material can be cut or punched into laminations or strips of the desired size and shape by the consumer and the coated products stacked or rolled into the form of a multi-ply assembly for the final anneal without further treatment in so far as the problem of separation of adjacent laminations in the assembly during the anneal is concerned.

In preparing a slurry suitable for the practice of the present invention, it is important that hot water, preferably at a temperature from 80 to 90° C. and in an amount comprising from one-fifth to one-third of the total water required in the final slurry be used to form a preliminary dispersion of the methyl cellulose in the form of a colloidal methyl-cellulose-water mixture. Upon agitation of the mixture of hot water and methyl cellulose, as, for example, after five minutes agitation, the methyl cellulose becomes substantially wetted after which the mixture is cooled and the remaining water at room temperature or colder is mixed with the cooled water dispersion of the methyl cellulose to form a stable colloidal dispersion of the methyl cellulose. The formation of the dispersion of the methyl cellulose in the total volume of water will be accelerated as the temperature of the mixture is lowered once the methyl cellulose has been wet by the hot water. The magnesia or other refractory material or materials can then be mixed with the resultant methyl cellulose dispersion or if desired the refractory material can be incorporated in the form of a slurry in the cold water which is mixed with the cooled water-methyl cellulose mixture. Preferably, the resultant dispersion of refractory material is cooled to at least room temperature prior to use.

Once the refractory oxide slurry has been applied in the form of a thin coating on the magnetic sheet material by any suitable means, such as by immersion, spraying, brushing, etc., the water should be removed therefrom by drying at temperatures which do not exceed about 150° C. and at a not too rapid a rate in order that the film forming properties of the dried methyl cellulose are not destroyed. If the water is removed too rapidly or at more elevated temperatures, the binding effect of the methyl cellulose may be destroyed so that the coating is easily brushed from the surface of the magnetic material during subsequent handling.

During the anneal of the coated sheet material, most of the refractory particles, for example, the magnesia particles become bonded to the surfaces of the sheet material to form a permanent inorganic film. This has been found to be the case with all of the magnetic sheet materials including nickel steels, common iron, etc. In some cases, as with silicon steel, this bonding may also be of a chemical nature resulting from the reaction of the magnesia, calcium oxide or the like with the constituents, such as silica, present in the natural scale on the steel. These thin coatings of a thickness of about 0.1 mil or less have insulating properties effective to electrically in-

sulate the laminations from one another during subsequent use in a transformer or the like.

In accordance with a further modification of the invention, the coating which is applied to the steel may contain two or more reactive oxides which at heat treating temperatures will react to form adherent electrically insulating coatings having better insulating values than those obtained with a single oxide. For this purpose, a small amount of colloidal silica can be incorporated into a slurry of magnesia or lime prior to the application thereof to the surface of the magnetic sheet material. For example, satisfactory coatings on the annealed product have been obtained by employing a slurry composed of 0.5 per cent by weight methyl cellulose, 7 per cent magnesium oxide and 2 per cent colloidal silica, balance water. When magnetic sheet materials, such as common iron, nickel steels, etc., having such a coating are heat treated at temperatures in excess of 800° C., there is a reaction between the refractory oxide and the silica to form on the surfaces of the material a thin insulating coating probably comprising a silicate of the refractory oxide as, for example, magnesium silicate. Similar results with the formation of a similar coating can also be obtained by the use of lime or calcined dolomite in place of magnesia.

In general, the slurry as employed in the practice of the present invention should preferably contain at least 2 per cent by weight of the refractory oxide. The maximum percentage of the refractory oxide will depend somewhat upon the ease with which it can be maintained in the dispersed or suspended form in the slurry and the maximum thickness of the final coating which can be tolerated. If desired, a second coating can be applied after the first has dried. In some cases it may be advantageous to form the desired coating by a process in which the sheet material is first coated with a dilute methyl-cellulose-water coating and after this coating has dried the sheet material is passed through a water suspension of the refractory oxide which adheres to the cellulose film. After this coating has dried, it will be found that the refractory oxide is bonded to the sheet material to substantially the same degree as when the oxide and cellulose are mixed prior to application to the sheet material.

During the anneal of the coated material at temperatures up to 1200° C., generally from about 700° to 1175° C., depending upon the particular magnetic material involved, and particularly during the earlier stages of the anneal when the material is being brought up to temperature, the methyl cellulose disintegrates into substantially volatile components, leaving the finely-divided refractory in intimate contact with the surface of the magnetic material to which it becomes bonded at the annealing temperatures.

A particular advantage of the present invention is that the magnetic material in continuous strip form can be coated with the methyl cellulose slurry by the manufacturer of the magnetic material just prior to the winding of the strip material into the form of rolls suitable for shipment to a consumer. This advantage will become more apparent when it is considered that ordinarily unrolling, coating and rerolling of the strip material constitute additional operations on the part of the consumer whereas the coating process readily fits into those operations subsequent to the final open anneal and prior to the winding of the strip material for shipment by the manufacturer thereof.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. The method which comprises providing magnetic sheet material with a coating composed of a suspension of a finely divided refractory separator material in water containing from about 0.3 to 2% by weight of methyl cellulose, drying the coating, at such a temperature and such a rate that the film forming properties of the methyl cellulose are not destroyed, mechanically processing the coated material to place it in the physical condition desired prior to the final anneal thereof to develop its optimum magnetic properties, and box annealing the coated sheet material in multi-ply assembly to develop the magnetic preperties thereof and to form on said sheet material a tightly adhering coating of the inorganic separator material.

2. The method for providing a magnetic sheet material with an adherent coating of finely divided refractory material adapted to act as a separator during the box anneal of the magnetic sheet material, which method comprises applying the refractory material to the surfaces of the magnetic material in the form of a suspension thereof in a methyl cellulose-water mixture containing from about 0.3 to 2% by weight methyl cellulose and immediately drying the coating at such a temperature and such a rate that the film forming properties of the methyl cellulose are not destroyed to form a tightly adherent coating of the refractory material bonded to the magnetic material by means of the methyl cellulose.

3. The method which comprises providing a continuous strip of magnetic material with a coating of a finely divided refractory material in water containing from about 0.3 to 2% by weight of methyl cellulose as a dispersing and bonding agent, drying the coated material at such a temperature and such a rate that the film forming properties of the methyl cellulose are not destroyed and subjecting the coated material to a box anneal to decompose the methyl cellulose binder into substantially completely volatile components leaving a layer of the refractory powder adhering to and separating the annealed laminations.

4. The method which comprises providing a continuous strip of magnetic material with a coating of slurry of a finely divided refractory oxide, water, and from 0.3 to 1% by weight methyl cellulose, drying the coating at such a temperature and such a rate that the film forming properties of the methyl cellulose are not destroyed to remove the water content thereof and subsequently box annealing the coated material to decompose the methyl cellulose component thereof and to leave on the surface of the magnetic material a tightly adhering coating of the refractory oxide.

5. The method for providing magnetic sheet material with an insulating coating during the anneal thereof, which method comprises applying to the material prior to anneal a coating of a slurry of finely divided magnesium oxide, colloidal silica and from about 0.3 to 2% by weight of methyl cellulose in water, drying said coating at such a temperature and such a rate that the film forming properties of the methyl cellulose are not destroyed and subsequently box annealing the coated material to a temperature up to 1200° C. to decompose the methyl cellulose and

to form an adherent insulating coating of the magnesium oxide and silica on the surface of said sheet material.

6. A magnetic sheet material having thereon a thin coating consisting of at least one finely divided refractory oxide and a small amount of methyl cellulose binder bonding the refractory oxide to said sheet material in such intimate contact with the surface of said sheet material that upon decomposition of the methyl cellulose during anneal of the coated sheet material particles of the refractory oxide form on the surface of the sheet material a permanent, inorganic, electrically insulating layer.

7. A silicon steel sheet material having thereon an adherent coating consisting essentially of a refractory oxide mixture consisting of magnesia and silica in finely divided form and a small amount of methyl cellulose binder bonding the refractory oxide mixture in such intimate contact with the surface of said silicon steel sheet material that upon decomposition of the methyl cellulose binder during anneal of the sheet material particles of the refractory oxide mixture form on the surface of the sheet material a permanent, inorganic, electrically insulating layer.

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