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INSULATING COATING FOR MAGNETIC SHEET MATERIAL AND METHOD FOR PRODUCING THE SAME

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The present invention relates to coated magnetic sheet material and a method of making the same. More particularly, the invention concerns refractory coating material which can be applied to magnetic sheet material such as silicon steel to separate stacked sheets of this type when subjected to heat treatment in multi-ply assembly.

The forms of magnetic sheet material with which the invention is concerned include strip material such as used in wound transformer cores, and cut or punched laminations forming stacked transformer cores and other electrical apparatus.

In the process of treating magnetic sheet material of this type to adapt it for use in transformers or other electrical devices, the sheet material is generally wound in the form of a roll, or cut and arranged in a plurality of stacked sheets, and placed in these forms in an annealing furnace for the purpose of developing the magnetic properties of the sheet material. During the heat treatment in the furnace with the sheet material either in wound or stacked form, the adjacent surfaces of the magnetic sheet material are in contact with each other over comparatively large areas, with the result that at the elevated temperatures employed for developing the magnetic qualities of the material, the adjacent laminations or turns of the material tend to stick together unless some means is provided for separating the surfaces during the heat treatment.

In the past, magnesium hydroxide (or magnesium oxide to which magnesium hydroxide converts upon heating) has been used as a coating material for this purpose. However, when this coating material is subjected to the elevated temperatures of the annealing stage, it reacts with the silicon in the silicon steel sheet and as a result there is formed a glass-like coating composed of magnesium silicate which is quite hard and very adherent to the surface of the sheet material. This coating, in fact, has proved so hard that substantial damage has resulted to the punching die (or other cutting device) employed for producing the desired shapes of magnetic sheet material, so that the life of the die was unduly shortened. In order to avoid this disadvantage, it has been the practice in the past to remove the glassy coating prior to the punching operation, and after the latter process has been completed the insulating coating was re-applied to serve as an insulation barrier to reduce eddy current loss in the laminated core formed by the sheet material in its use in a transformer, motor or the like. Such removal of the glassy coating required a substantial amount of labor and was unduly expensive in terms of time and cost.

On the other hand, while types of separator coatings other than magnesium oxide or hydroxide are known, such other coating compositions have not proved as effective as magnesium oxide or hydroxide in removing the sulfur from the silicon steel being processed, a function which is relatively important in the proper processing of electrical steel.

It is an object of the invention to provide an improved separator coating for metallic sheet material which avoids the above-described disadvantages.

It is a particular object of the invention to provide a separator coating for electrical silicon steel sheet material which has the function of desulfurizing the silicon steel in the normal annealing procedures while being

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readily removable after such annealing to enable the silicon steel sheet to be punched into the desired shape without undue damage to the punching apparatus.

Other objects and advantages will become apparent from the following description and appended claims.

With the above objects in view, the present invention relates to a method of providing a separator coating on silicon steel sheet material normally containing about 2–5% silicon which comprises applying upon the silicon steel sheet material a coating of magnesium oxide, applying on the thus-coated sheet material a coating of aluminum oxide, and heating the thus-coated sheet material.

As a result of such a process, a coating is formed on the surface of the sheet material which functions effectively as a separator layer between stacked sheets of the silicon steel material while contributing to the purification of the material during the heat treatment, and yet can be readily removed so as to avoid damage to the die in subsequent punching operations.

In a usual process of producing electrical grade silicon steel of known type, strips of silicon steel having about 2–5% silicon and about 14 mils thick are coated with a layer formed of magnesium hydroxide $Mg(OH)_2$ and after being wound into a coil, the coated strip is heated at about 1075 to 1200° C., preferably about 1175° C., for eight hours for developing the magnetic properties of the steel by inducing properly oriented crystal grain growth and removing certain impurities such as sulfur. This heat treatment is often referred to in the art as a "grain growth anneal." As a result of such heat treatment, the magnesium hydroxide loses water of hydration and reacts with the silicon in the surface region of the silicon steel strip to form a hard, tightly adherent, glass-like coating of magnesium silicate (Mg_2SiO_4) on the strip surface.

In accordance with the invention, the formation of such a glass-like coating is effectively avoided by applying a layer of aluminum oxide on the magnesium hydroxide coating prior to subjecting the steel strip to the subsequent heat treatment (grain growth anneal). It has been found that such application of aluminum oxide results, after the final anneal, in a powdery coating on the steel surface from which it is easily shaken or rubbed off. Although a coating of aluminum oxide used alone on the steel surface has little or no desulfurizing effect on the silicon steel during grain growth anneal, it has been found that the use of aluminum oxide in conjunction with magnesium oxide or hydroxide in accordance with the invention does not significantly interfere with the desulfurizing function of the magnesium material.

The following is an example of a process employed in practicing the invention, it being understood that the procedure described is set forth simply for purposes of illustration and is not intended to limit the scope of the invention:

Example I

Silicon steel sheets (24" x 6") containing 3¼% silicon and having a thickness of 14 mils are dipped into a slurry composed of 7% by weight MgO in water. The thus-applied coating of $Mg(OH)_2$ is dried by using infra-red lamps at about 200° C. to remove excess water. This process leaves a dry white powder of $Mg(OH)_2$ coating the surface of the steel sheet. Aluminum oxide (Al_2O_3) in the form of a white powder is applied to the thus-coated steel by dry dusting (or by dipping the sheet into a water slurry of the aluminum oxide) using an amount of the aluminum oxide which corresponds at least to a molecular weight proportion relative to the MgO content of the first coating. In this procedure, the magnesium oxide deposits in an amount of about .02 oz./ft.². Hence, at least enough aluminum oxide should

be present to deposit in an amount of about .05 oz./ft.², and an excess may be used without difficulty. The aluminum oxide coating is then dried with infra-red lamps. A number of sheets so coated were stacked and clamped between steel plates and annealed in a substantially pure argon atmosphere furnace at 1175° C. for eight hours, and then cooled.

As a result of this treatment there was produced a loosely-held white powder on the surface of the steel sheets, and the powdery coating thus formed could be readily removed by shaking or rubbing it off.

In comparative tests made to determine the desulfurizing effect of the combined magnesium hydroxide-aluminum oxide coating as compared to a coating of magnesium hydroxide alone, a number of silicon steel samples were prepared and treated in a manner similar to that described in Example I above except that no aluminum oxide coating was applied. These samples as well as those made in accordance with the Example I process were chemically analyzed to determine their sulfur content. The amount of sulfur in each group prior to anneal was determined to be .019%. Analysis of the magnesium hydroxide coated samples showed the presence of .0045% sulfur, while that of the combined magnesium hydroxide and aluminum oxide coated samples showed .0055% sulfur. It is evident from this test that there was little practical difference in the desulfurizing capability between the two types of coatings.

Apparently, only the combination of magnesium hydroxide with aluminum oxide produces the desired dual results of avoiding the formation of a tightly adherent, glassy coating while removing sulfur from the steel during the annealing process. For example, calcium oxide, a refractory oxide heretofore used as a separator coating, will still produce a glassy silicate coating even in the presence of aluminum oxide. Moreover, while the combination of zirconium oxide with aluminum oxide may produce a non-glassy separator coating, this combination is unsatisfactory because these materials alone or in combination will not contribute to desulfurizing of silicon steel.

There is thus provided in accordance with the invention a novel process of providing a separator coating for silicon steel sheet material which is readily removable to enable the silicon steel sheet to be punched into desired shape without undue damage to the punching apparatus, while still permitting effective desulfurizing of the steel during the usual annealing process. The invention may also have particular application to those silicon steel processes where the separator coating must be removed

prior to treatments applied after the final grain growth anneal whether a punching or cutting operation is involved or not.

While the present invention has been described with reference to particular embodiments thereof, it will be understood that numerous modifications may be made by those skilled in the art without actually departing from the scope of the invention. Therefore, the appended claims are intended to cover all such equivalent variations as come within the true spirit and scope of the invention.

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

1. The method of providing a separator coating on silicon steel sheet material which comprises applying on the sheet material a coating of magnesium oxide, applying on the thus-applied coating a coating of aluminum oxide in an amount of at least about .05 oz./ft.² of the surface coated, and heating the thus-coated sheet material at elevated temperature for developing the magnetic properties thereof.

2. A method of providing a separator coating on silicon steel sheet material which comprises applying on the sheet material a suspension of magnesium hydroxide and drying the thus-applied material, applying on the thus-applied coating of aluminum oxide in an amount of at least about .05 oz./ft.² of the surface coated, and heating the thus-coated sheet material at a temperature of 1075 to 1200° C.

3. A method of providing a separator coating on silicon steel sheet material which comprises applying on the sheet material a suspension of magnesium hydroxide and drying the thus-applied material, applying on the thus-applied coating a coating of aluminum oxide in an amount of at least about .05 oz./ft.² of the surface coated, and heating the thus-coated sheet material in multi-ply assembly at elevated temperature for developing the magnetic properties thereof with said coatings separating the plies.

4. Silicon steel sheet material having thereon a loosely adherent coating formed in accordance with the process defined in claim 1.

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