Composition comprising 18% phosphoric acid and 27% aluminum hydrate in water.

Insulating film comprising the reaction product of the steel with a mixture of aluminum hydrate and phosphoric acid.

WITNESSES:

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This invention relates to an electrical insulating coating for silicon steels and the like for use in the making of laminated cores for electromagnetic apparatus.

The magnetic cores utilized in generators, transformers, electric motors, etc., are preferably made of laminated sheet steel with a coating of insulating material on each lamination. As is well known in the art, these cores are of laminate form instead of solid steel so that undesirable eddy currents are reduced to a minimum during use of the cores.

In preparing laminations of magnetic material either a roll of sheet steel or individual sheets are coated with an insulating material and then cut by a punch and die. As an increased number of punchings are made, the cutting edges of both the punch and die become worn, that is, the edges either become rounded or chipped, depending upon the degree of sharpness of the die face. This is particularly true when punching laminations from sheets of silicon steel which is relatively hard. As the punch and die edges become worn, small burrs form on the cut edges of the punchings. The height of the burr is proportional to the wear at the edges of the punch and die. These burrs are undesirable because they tend to cut through the insulating coating of the adjoining lamination when stacked, thereby short circuiting the laminations and nullifying the benefits of the laminated structure. In some instances, considerable damage or destruction of the core has occurred because of the lack of insulation between laminations. Further, the burr may reach a height which necessitates an additional grinding step to remove them in order to insure against short circuiting. When the burr height becomes excessive (about 2 to 4 mils), the punch and die must be either replaced, or its faces reconditioned, involving great expense and consumption of time.

An object of this invention is thus to provide an improved alumina-phosphate base insulating coating for sheets of magnetic material, which will enable a greatly increased number of punchings thereof by a punch and die before an undesirable burr height is reached, thereby prolonging the die life. Another object of the invention will in part be obvious, and will in part appear hereinafter. For a better understanding of the nature and objects of the invention, reference should be had to the following detailed description and drawing, in which:

Figure 1 is a schematic view, partly in section, of a form of apparatus that may be used in carrying out the invention, and

Fig. 2 is a fragmentary, greatly enlarged cross-section through a sheet of material prepared in accordance with the invention.

In accordance with this invention, I have discovered a thin insulating coating for magnetic sheet steels comprising the reaction product of an aqueous mixture of aluminum hydrate and phosphoric acid with the steel that will result in an increased number of punchings to be made from the sheets before the die must be reconditioned or replaced. The coating possesses electrically insulating properties superior to many coatings now applied to punchings for motors and the like.

In order to apply on a ferrous magnetic material the thin insulating film or coating of this invention, the sheets are coated with an aqueous mixture containing as its essential ingredients 3½% to 10% aluminum hydrate, 5% to 50% orthophosphoric acid (85%), and the remainder being water, the pH of the solution being more acidic than 0.8.

The proportion of aluminum hydrate to phosphoric acid (H₃PO₄) is maintained to provide at least 4.5 parts by weight of the phosphoric acid per part of the aluminum hydrate. The sheets with the applied coating are then passed through an oven where they are heated to a temperature ranging from 135° C. up to 500° C. or higher. The heat drives off the water leaving a thin coating of aluminum phosphate reacted with the ferrous metal of the sheet. The time in the oven of course depends upon the degree of temperature, a higher temperature requiring less time. Ordinarily a few seconds are sufficient, though longer periods are beneficial in that they assure a complete reaction.

While 85% orthophosphoric acid is indicated in the above formulation, it should be apparent that other strengths of orthophosphoric acid may be used. Thus if a weaker orthophosphoric acid is used, say 50%, then a proportionate reduction in the added water is made.

Aluminum hydrate has the general formula AlₙO₃·nH₂O where n is from 2 to 4 or greater. I have secured good results with aluminum hydrate having the average formula Al₉O₆·3H₂O, also written Al(OH)₃.

Sheets of various ferrous base metals may be treated in accordance with the invention. Thus silicon-iron sheets having up to 7% silicon may be coated therewith. Nickel-iron magnetic sheets with up to 85% nickel may be treated. Other magnetic sheets containing a high proportion of iron, alloyed with one or more other metals may be treated. The term "sheet steel" will be employed here-in-to include any of these.

If necessary, a wetting agent may be added to the aqueous aluminum phosphosilicate solution. This may be present in the order of from 3½% to 2% of the weight of the composition, the amount depending upon the degree of cleanliness of the steel. Examples of satisfactory wetting agents are the alcohol sulfates, for example,

\[ \text{CH₄(CH₂)₉CH₃SO₃Na} \]

the alkyl aryl sulfonates, for example,

\[ \text{C₈H₄(C₈H₄)₂SO₃Na} \]

and the alkyl sulfonates R CH₂SO₃Na, where R represents an alkyl group such as decyl.

It is not necessary to procure separately the aluminum hydrate and the phosphoric acid and to combine them to form the coating composition. There recently have been made available compositions corresponding to the above formulation of aluminum hydrate and phosphoric acid. These need only be dissolved in water for use.

The following is an example typical of the practice of the invention:

**Example**

A steel strip having 3.25% silicon content and of a 25 mil thickness, was coated with a solution of the following composition, in which all parts are by weight:

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phosphoric acid (85%)</td>
<td>31</td>
</tr>
<tr>
<td>Aluminum hydrate</td>
<td>6</td>
</tr>
<tr>
<td>Water</td>
<td>62</td>
</tr>
<tr>
<td>Wetting agent</td>
<td>1</td>
</tr>
</tbody>
</table>
The aluminum hydrate was added to the acid-water mixture at a temperature of about 90° C. It was completely dissolved in about five minutes with the aid of stirring. A clear, light yellow solution was formed.

This solution was applied to the silicon steel strip in apparatus such as illustrated in Fig. 1 of the drawing. A roll 10 of silicon steel strip 14 mounted on a stand 12 was submerged and the strip 14 was passed over a guide roll 16, hence under a roll 18 mounted within a tank 20 whereby the strip 14 was submerged in solution 22 therein having the above described composition. The strip 14, with its coating of aqueous composition acquired in passing through the solution, was passed through squeeze rolls 24 and 26 composed of a resilient material, such as rubber or felt. These rolls 24—26 control the thickness of the layer of the applied solution. The coating is less than one mil in thickness, though in some cases, more may be applied. The coated sheet strip was then heat-treated in the continuous baking oven 28 in which the air temperature was 485° C., the strip emerging from the oven at a temperature of about 135° C. The speed of the strip through the oven was about 3 ft. per second and the length of the oven was 5 feet. The strip 14 was pulled from the oven 28 by the tension control rolls 30 and 32 and then passed to a punch 34 and die 36.

Referring to Fig. 2 of the drawing, there is illustrated a greatly enlarged cross-sectional view through an insulated steel strip 14 showing an insulating coating 40 as applied by the process. The coating 40 generally has a thickness in the order of 2% or less of the thickness of the sheets.

Because the heat treated insulating coating is so thin, it enables the laminations to be formed into magnetic cores having a high space factor, that is, containing over 95% magnetic material.

Summarized in the following table are data showing the number of punchings which were made from sheets with different coatings in similar punch and die sets, before the burr height reached 4 mils:

<table>
<thead>
<tr>
<th>Coating on sheets:</th>
<th>Number of Punchings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phosphoric acid—aluminum hydrate</td>
<td>285,000</td>
</tr>
<tr>
<td>Water glass</td>
<td>100,000</td>
</tr>
<tr>
<td>Bare</td>
<td>50,000</td>
</tr>
</tbody>
</table>

From this tabulation, it can be concluded that the phosphate coating increased die life by a factor of nearly three, when compared to water glass, a standard coating material. Compared to bare or uncoated sheet, the coating of this invention enables nearly six times as many punchings to be made before the burr height reaches 4 mils.

Inspection showed that the punch and die used in the phosphoric acid-aluminum hydrate test to have less wear than shown by the punch and die used in punching the bare steel up to the same burr height. Therefore reconditioning of the former punch and die would be less expensive.

Dielectric resistance tests of many punchings produced with the insulating coating of the invention have shown a median value of from 20 to 25 ohms per square centimeter over the dielectric under lamination. These resistance values are many times those of other commercially used insulating coatings.

The apparatus illustrated in Fig. 1 is an example of only one means of carrying out the invention. The solution may be applied by spraying, flooding, or flow coating. Thus the tank 20 may be eliminated altogether and the sheet passed between rolls 24 and 26 with the solution being poured or dipped upon the rolls.

Since certain changes in carrying out the above process and certain modifications in the article which embody the invention may be made without departing from its scope, it is intended that all matter contained in the above description or shown in the accompanying drawing shall be interpreted as illustrative and not in a limiting sense.

I claim as my invention:

1. In the process of providing an insulating coating on ferrous sheets, the steps comprising applying to the surface of the ferrous sheets an aqueous solution comprising as its essential ingredients from $\frac{1}{2}$% to 10% by weight of aluminum hydrate, 5% to 50% by weight of phosphoric acid (85%), and the balance being water, the pH of the solution being more acid than 0.8, the ratio of H₃PO₄ to aluminum hydrate being at least 4.5 to 1 by weight, and heat-treating the applied solution on the surface of the ferrous sheets at a temperature of from 135° C. to 500° C. for a period of time sufficient to drive off the water and to react the whole to produce an adherent insulating coating.

2. An article of manufacture comprising a ferrous member and an insulating coating applied to the surface of the member, the coating being composed of the reaction product of the steel with a mixture of from $\frac{1}{2}$% to 10% by weight aluminum hydrate, 5% to 50% by weight phosphoric acid (85%), the ratio of H₃PO₄ to aluminum hydrate being at least 4.5 to 1 by weight, and the applied mixture being heat-treated at a temperature of at least 135° C. for a period of time sufficient to cause reaction to take place between the surface of the ferrous member and the applied mixture and not exceeding a temperature at which the coating decomposes.

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