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METHOD OF HEAT TREATMENT

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This invention relates to a method of heat treating laminations or other magnetic components composed of iron alloy, and in particular aluminum or silicon iron alloys.

The major use for which this invention is concerned is the use of aluminum-iron alloy and silicon-iron alloy to produce magnetic components and especially laminations for inductive devices. It is well known in the art that any internal stresses within these alloys have a detrimental effect upon the magnetic properties of the alloys. The major portion of these stresses are generally relieved by means of annealing the material. In the case of very thin components, such as laminations, some method must be utilized to insure that the strip, or lamination, remains flat during annealing, since the thin strip may warp if these precautions are not taken. In the case of laminations, when the warped laminations are stacked and bonded to form an inductive device the warped laminations would be forced to lie flat and internal stresses would again be prevalent.

When heat treating laminations for an inductive device, clamping each lamination in a manner to prevent warping is very inconvenient, therefore, the general practice is to stack a number of laminations together and apply an axial pressure thereto. Thus, a large number of laminations can be heat treated in a single operation.

However, in heat treating aluminum-iron alloys or silicon-iron alloys, and in particular when there is a large percentage of aluminum or silicon present, to produce the desired results a temperature of approximately 1800° F. is necessary. At this high temperature and with some axial pressure applied the stacks of laminations will actually fuse together in a weld-like manner. The present invention provides a method of preventing the fusing of stacked laminations during the heat treatment process.

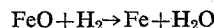
Previous to this invention attempts were made to coat the laminations with a foreign insulating material before placing them in stacks in preparation for the heat treatment. However, if bonding of the laminations into cores is attempted before removing the foreign insulating material much laminar separation occurs. The laminar separation is due to the fact that the bond between each lamination and the foreign insulating material is generally very poor. In the present invention a genetic insulating layer is formed on the surfaces of the laminations. Since this genetic layer is a portion of the lamination the laminations can be bonded without the long tedious task of removing the insulating film. Also, during the process of removing the insulating film there is a high rejection rate of the laminations because the extra handling causes bending and, thus, stresses in the material.

In the present invention the laminations or other thin strips which are to be heat treated are completely degreased, that is, all foreign matter is removed from the surfaces. The components are then placed in a furnace and arranged to allow free circulation of the furnace atmosphere. The components are heated to a temperature of approximately 1400° F. During the heating of the components a pure essentially dry hydrogen atmosphere should be maintained within the furnace during the time required to reach 1400° F. The atmosphere within the furnace will be sufficiently dry if a dew point of at least -35° F. is maintained. The components are first heated in a dry hydrogen atmosphere to reduce the mill

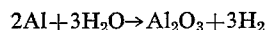
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scale on the surfaces of the components. The mill scale on the surfaces of the components is comprised of iron oxide and aluminum oxide or silicon oxide that loosely adheres to the surface. If an attempt is made to bond the components into a core or other device without removing the loosely adhering mill scale much laminar separation occurs. By this step of heating sufficiently in a dry hydrogen atmosphere the iron oxide in the mill scale is reduced to iron and will weld to the main body of the component, thus giving a tightly adhering surface.

The components to be oxidized are placed in the furnace and heated in a pure dry hydrogen atmosphere. During this phase of the heat treatment the atmosphere is reducing the iron oxide in accordance with the following reaction:



and oxidizing any free aluminum exposed to the furnace atmosphere during the reduction of the iron oxide according to the following reaction:



These two reactions occur simultaneously during the time required for the furnace to reach 1400° F. When the furnace reaches 1400° F. all of the free iron that was formed from the reduction of iron oxide is coated with a thin protective coating of aluminum oxide. At this temperature the wet hydrogen is introduced into the furnace. The components are held in the wet hydrogen atmosphere having a moisture content equivalent to a dew point of greater than approximately +55° F. for one hour. The purpose of this phase of the oxidization treatment is to "build up" the aluminum oxide coating to a sufficient thickness to prevent their welding during the final magnetic heat treatment. After the components have been held in the wet hydrogen atmosphere for the required time, pure dry hydrogen is introduced into the furnace. The furnace is allowed to cool naturally to 300° F. The furnace is then flushed with nitrogen gas and the parts are then removed from the furnace.

A similar reaction will take place when silicon-iron is the alloy. The silicon oxide forms a thin uniform coating over the laminations. A sufficiently heavy coating of silicon oxide will be produced if the laminations are retained in the wet hydrogen atmosphere at 1400° F. for approximately one hour. The atmosphere within the furnace is then changed to a dry hydrogen atmosphere and the laminations are furnace cooled to approximately 300° F. at which time they may be removed from the furnace.

It should be noted that the foregoing temperatures are simply preferred examples and are not meant to limit this invention in any way. The applicant intends to include all temperatures that are sufficient to accomplish the described results which constitute this invention. Also, the applicants have utilized aluminum-iron alloy and silicon-iron alloy to explain the invention but it should be understood that the applicants do not intend to limit themselves by this preferred embodiment. Accordingly, the applicants intend to include all alloys in which the alloying material will preferentially oxidize to form a genetic insulating layer on the surface of the alloy.

The preferentially oxidized laminations are now placed in stacks approximately one inch high and an axial load of approximately 8900 p.s.i. is applied thereto. To magnetically anneal the laminations the axially loaded stacks are placed in a furnace, and a heat treating process similar to that explained in the United States Patent 2,937,115 issued to Foster et al. is initiated as explained below. A pure dry hydrogen atmosphere should be maintained within the furnace. The axially loaded stacks are heated to a temperature of 1832° F. plus or minus 20° F. and

held there for approximately two hours. The stacks are then furnace cooled to a temperature of 1112° F. plus or minus 20° F. and held there for 15 minutes after which the furnace is flushed with argon gas. The axially loaded stacks are now removed from the furnace and quenched in agitated water maintained at a temperature of approximately 100° F.

The oxide coating, which is an insulating material, is of sufficient thickness to prevent fusing of the laminations while they are being annealed. Also, the oxide coating, or genetic layer, is actually a part of the lamination. Since the oxide coating is an integral portion of the laminations there will be no danger of laminar separation due to a loosening of the material between the laminations. This is important because there is no necessity for a lengthy cleaning procedure before the laminations are bonded into a core for an inductive device as there is in previous methods. A further advantage of this method of heat treating laminations is that the genetic insulating material will always have a uniform thickness. That is, the aluminum oxide coating is always even and there is no danger of warping or internal stresses due to nonuniform insulation between the laminations during annealing or bonding of the core. Thus, because the mill scale does not have to be scraped off before heat treating and because the oxide forms a tightly adhering insulating film that does not have to be cleaned off after heat treating, a great decrease in the amount of handling of each lamination has been accomplished as well as improving the magnetic properties of the laminations.

While we have described the preferred embodiment of this invention, further modifications and improvements will occur to those skilled in the art. We desire it to be understood, therefore, that this invention is not limited to the particular form explained and we intend in the appended claims to cover all modifications which do not depart from the spirit and scope of this invention.

We claim:

1. In the heat treating of stacks of laminations composed of aluminum-iron alloys and iron oxide in the form of mill scale to produce desirable magnetic properties, including heating said stacks under an axial load in a substantially dry hydrogen atmosphere at temperatures in excess of 1812° F., the improvement which comprises a method of producing an insulating film of aluminum oxide on the surfaces of said laminations to prevent inter-lamination welding, said method including:

- (1) simultaneously reducing the iron oxides and oxidizing the aluminum in said laminations by heating in an essentially dry hydrogen atmosphere having a dew point of not greater than approximately -35° F. until a temperature of approximately 1400° F. is reached;
- (2) raising the moisture content of said hydrogen atmosphere to the equivalent of a dew point of greater than approximately +55° F. and continuing said heating at 1400° F. for approximately one hour to produce a film of aluminum oxide contiguous with the surfaces of said laminations; and
- (3) reducing the moisture content of said hydrogen atmosphere and allowing said laminations to cool to below approximately 300° F.

2. In the heat treating of stacks of laminations composed of silicon-iron alloys and iron oxide in the form of mill scale to produce desirable magnetic properties,

including heating said stacks under an axial load in a substantially dry hydrogen atmosphere at temperatures in excess of 1812° F., the improvement which comprises a method of producing an insulating film of silicon oxide on the surfaces of said laminations to prevent inter-lamination welding, said method including:

- (1) simultaneously reducing the iron oxides and oxidizing the silicon in said laminations by heating in an essentially dry hydrogen atmosphere having a dew point of not greater than approximately -35° F. until a temperature of approximately 1400° F. is reached;
- (2) raising the moisture content of said hydrogen atmosphere to the equivalent of a dew point of greater than approximately +55° F. and continuing said heating at 1400° F. for approximately one hour to produce a film of silicon oxide contiguous with the surfaces of said laminations; and
- (3) reducing the moisture content of said hydrogen atmosphere and allowing said laminations to cool to below approximately 300° F.

3. In the heat treating of stacks of laminations composed of iron alloys and iron oxide in the form of mill scale, in which the alloying material is a metal having a greater reactivity to oxygen than iron, to produce desirable magnetic properties, including heating said stacks under an axial load in a substantially dry hydrogen atmosphere at a temperature sufficient to anneal the alloy, the improvement which comprises a method of producing an insulating film on the surfaces of said laminations to prevent inter-lamination welding, said method including:

- (1) simultaneously reducing the iron oxides and oxidizing said alloying material in said laminations by heating to approximately 1400° F. in a hydrogen atmosphere having a dew point of not greater than approximately -35° F.;
- (2) raising the moisture content of said hydrogen atmosphere to the equivalent of a dew point of greater than approximately +55° F. and continuing said heating at approximately 1400° F. for approximately one hour to produce an insulating film of the oxide of said alloying material on the surfaces of said laminations; and
- (3) reducing the moisture content of said hydrogen atmosphere by introducing dry hydrogen, and allowing said laminations to cool naturally to below approximately 300° F.

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