

1

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HEAT TREATMENT OF FERROUS STRIP MATERIALS WITH SEPARATOR COATING

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No Drawing. Filed Dec. 30, 1957, Ser. No. 705,779
6 Claims. (Cl. 148—14)

The invention relates broadly to the heat treatment of metallic strip in coils where an annealing separator must be used; but without limitation, it will be described in connection with the treatment of silicon-iron materials.

There are many instances in which ferrous stocks of sheet gauge must be subjected to heat treatments at such high temperatures as to require the use of an annealing separator, if the materials are not to stick or weld together. In addition, and especially for highly oriented silicon-iron stocks, there are certain treatments which require the presence for other purposes of a coating substance on the surface of the stock at the time the stock is subjected to high temperatures.

For example, in United States Patent 2,385,332, Carpenter, Bell and Heck taught a way of forming on the surface of silicon-iron a thin and uniform glass-like coating useful as a means for providing interlamination resistivity in transformer cores, electrical machinery, and the like.

Subjecting the sheet gauge stock to a heat treatment at a temperature of substantially 1350° to 1650° F., in an atmosphere containing hydrogen and also containing water vapor within the range of about 2% to about 35%, resulted not only in a decarburization of the stock, but also in the formation of silica at and near the surfaces of the stock. If then the stock was covered with magnesia, a fusion of the silica and magnesia could be brought about with the formation of a resistive glass coating determined in thickness by the quantity of silica at or near the stock surfaces. The formation of the glass, however, required a temperature of about 2100° F.

It was usual to form a coating substance by slurring magnesia (MgO) in water; but the result of this operation was the hydration of a great part of the magnesia, forming magnesium hydroxide. Before the glass coating could be formed, it was necessary not only to drive off the water acting as a vehicle in the coating substance, but also to drive off the water of constitution of the magnesium hydroxide, and for this it was necessary to heat the treated sheet stock for at least a brief interval to a temperature up to about 1100° F.

Little difficulty was encountered in handling individual sheets or strip materials in strand form in a continuous furnace, since it was possible to control the atmosphere differentially in different parts of the furnace. Variations of the process appeared such as applying the magnesia to the stock prior to decarburizing and then decarburizing and dehydrating the coating in a single operation, as in U. S. Patent 2,492,682. A slurry of magnesium hydroxide could be made to have a consistency which not only made it relatively easy to coat the sheets or strip materials, but which had a reasonable resistance to abrasion and displacement when the vehicle water was driven off.

In many procedures for the manufacture of highly oriented silicon-iron sheet stocks, so-called open or continuous anneals were not found to be desirable at certain parts of the routing. Box anneals, in which the temperatures could be more exactly controlled, which permitted heating and cooling the stock at definite predetermined rates, and which permitted holding the stocks at given temperatures for relatively long periods of time, were found desirable for various reasons having to do with the development of magnetic properties.

Attempts were made to box anneal silicon-iron sheets in

2

stacked condition, where the sheet surfaces were coated with magnesium hydroxide, the vehicle water having previously been driven off, usually by passing the coated sheets through a drying furnace. In general, these attempts met with a fair degree of success. It was possible to control the temperature in the annealing boxes to different values at different times; and it was also possible to control the atmospheres therein. It was found that, although water of hydration would be driven off at temperatures between about 660° and 1100° F., there would be a reasonable diffusion of atmosphere between the sheets so that it became possible to provide the glass coating described above, by changing the atmosphere within the annealing box as required in accordance with a pre-arranged schedule and varying the temperature of the heat treatment as required, first, for driving off the water of constitution of the magnesium hydroxide, and second, for the formation of the glass coating at the final high temperature.

The water of constitution of magnesium hydroxide begins to be liberated at about 660° F.; and in sheet annealing, by delaying the annealing cycle during the water liberation period, it was found possible to remove most of the water of constitution without having it react with the iron.

What the practical art was able to do with stacked, magnesium hydroxide coated sheets in a box annealing operation, has not been found hitherto practicable with coiled strip stock. It is a fundamental object of this invention to provide a mode of heat treating ferrous strip materials, and in particular oriented silicon-iron, in coiled form when their surfaces are covered initially with magnesium hydroxide or like separator substances.

This and other objects of the invention, which will be set forth hereinafter or will be apparent to one skilled in the art upon reading this specification, are accomplished by that procedure of which an exemplary embodiment will now be described.

There are many advantages in the use and handling of ferrous materials in strip form and in coiled condition. Endless lengths of strip materials are readily coated with magnesium slurry after being uncoiled; and when the coating (which is usually done by spraying or otherwise depositing the slurry upon the surfaces of the strip and then metering the resultant layer with rubber rolls or the like) has been accomplished, the water vehicle may be driven off by passing the strip through a drying furnace, whereupon it may be recoiled. The convolutions of a properly wound coil are not pressed together under pressures comparable to those existing near the bottom of a stack of sheets; and when a coil of coated material is formed, the separator substance on the interior convolutions is protected in normal coil-handling operations. There is thus less likelihood of the displacement of the coating; and there should be better opportunity for the diffusion and exchange of atmospheres between the convolutions in an annealing box. Nevertheless, attempts to treat coated coils as coated stacked sheets had previously been treated, resulted in embrittlement of the stock and exaggerated inequalities in the stock itself, together with burned edges.

Investigations to determine why this was so, led to the conclusion that the relatively more successful practice with stacked sheets was due largely to a more even and rapid heat transfer into the mid-sections of the stack. In a box annealing operation, during the heating cycle, the heat is for the most part transmitted into the interior of the box through the sides of the box or annealing cover. Due to the horizontal disposition of the sheets in a stack, the heat applied to the outer faces of the stack was more easily transmitted to the interior thereof through the bodies of the sheets themselves, since the sheets were so disposed

that their bodies lay in the direction of normal heat transmission.

In the box annealing of coils at high temperatures, the coils must be placed on end on the annealing box or platform since otherwise at the high temperatures the coils will sag and become distorted due to heat softening. Thus, in the initial heating of the charge, the direction of normal heat transfer was from convection to convection through insulating layers of the annealing separator. In any heating cycle of normal length, it became necessary to heat the outer convolutions of the coils to a temperature very much higher in order to attain a temperature of 660° F. or higher at inner parts of the coils. This made it impracticable to control the atmosphere within the furnace in accordance with a prearranged schedule such as that referred to above.

It was not found possible to cure the difficulty by slowing down the rate of heating and maintaining the charge at a temperature of less than about 1100° F. for an additional length of time. The annealing cycle became unduly long; temperature gradients existing in the coils produced unsatisfactory and non-uniform materials; and the continuous evolution of large quantities of water even toward the end of a prolonged low temperature heating cycle exhibited an exaggerated tendency to produce embrittlement.

Briefly, in the preferred practice of this invention, the coated coils are first heat treated while lying on their sides with their end portions directed toward the application of heat. When this is done, the direction of heat transfer coincides with the planes of the convolutions, and it becomes possible to drive off the water of constitution of the magnesium hydroxide rapidly. By the same token, it becomes possible to sweep the moisture laden gas out of the furnace by the introduction of a suitable fresh atmosphere so that no parts of the coils are subjected to undue concentrations of moisture vapor for prolonged periods of time.

The heating of the coils on their sides may be done at a temperature which is high enough to insure that all portions of the coil reach a temperature above about 660° F. and for a sufficient time to drive off the water of constitution of the magnesium hydroxide. In this step no parts of the coils should be heated to a temperature above about 1100° F. The heat treatment may be carried on in an annealing box, or carried on by passing the coils through a continuous furnace of sufficient length to accomplish the purpose. The coils may be rotated during their travel through the furnace in order to obtain the most uniform heating. A rapidly recirculated protective atmosphere, may be dried between passages through the furnace and will serve to remove water vapor discharged from between the laps of the coils. If the heating occurs in a box, a similar atmospheric change will be practiced. In either event, if the coils are not heated at this stage to a temperature above about 1100° F., the coils will not sag or become distorted due to heat softening. If the heating is done rapidly, so that a substantial temperature differential exists within the coils, it is desirable to arrest the heat treatment without permitting any parts of the coils to attain a temperature substantially above 1100° F., and maintain the temperature until it is certain that all of the water of constitution has been driven off.

After the coils have been treated as above described, they then may be stacked on end on an annealing base or platform, or on end above each other on suitable supports, and annealed at high temperature, say, from 1900° to 2200° F. in the ordinary manner. At such high temperatures, i.e. at red heat or above, the transmission of heat between different parts of the coils is very much more uniform, providing of course, that the water of constitution of the magnesia has been driven off in the preceding step.

While the invention has been described in connection with magnesia, it can be employed in connection with other annealing separator substances. For example, similar results at the same temperatures can be obtained by using basic magnesium carbonate as the separator substance. Other materials useful as annealing separators, and conveniently applied as water slurries where water of constitution exists in the separator substance, or is taken up by it when slurried with water, may be employed in the practice of this invention.

Modifications may be made in the invention without departing from the spirit of it. The invention having been described in an exemplary embodiment, what is claimed as new and desired to be secured by Letters Patent is:

1. A method of heat treating ferrous metallic strip with the use of an annealing separator containing water of constitution capable of being driven off at a temperature lower than the highest temperature to be reached in the said heat treatment, which comprises coating metallic strip with said separator, coiling the coated strip, and, in a first stage positioning the coils so formed with their axes in a substantially horizontal direction and with both ends open to the atmosphere and applying heat primarily to the ends of said coils so as to heat all parts of said coils to a temperature at which said water of constitution is driven off while avoiding a temperature at which said coils sag due to heat softening, removing the evolved water of constitution from the vicinity of said coils, and in a second stage positioning said coils with their axes substantially vertical, and heating them to a higher temperature by applying heat thereto primarily transversely to the axes of said coils.

2. The method claimed in claim 1, in which said coils are heated in said first stage to a temperature of at least about 660° F. but not exceeding about 1100° F.

3. The method claimed in claim 2 wherein said coils are heated in said second stage to a temperature of substantially 1900° to 2200° F.

4. The method claimed in claim 3 wherein said annealing separator consists essentially of magnesium hydroxide.

5. The method claimed in claim 4 wherein said coils are heated in said first stage in a continuous furnace with circulating atmosphere, and wherein said coils are heated in said second stage in an annealing box in a non-carburizing reducing atmosphere.

6. The method claimed in claim 4 wherein said coils are heated in both stages in an annealing box.

References Cited in the file of this patent

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