Patented Mar. 5, 1940

2,192,756

UNITED STATES PATENT OFFICE

2,192,756

TREATMENT OF FERROUS METAL

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No Drawing. Application February 24, 1937, Serial No. 127,405

1 Claim. (Cl. 148—4)

The present invention relates broadly to the treatment of ferrous metals. It is particularly directed to an improved method of treating sheets or punchings of silicon steel used for magnetic purposes in electrical devices, for example, in the construction of magnetic cores for transformers, dynamo-electric machinery and other electrical apparatus.

One object of the invention is to form on the surfaces of sheets or strips of magnetic material, such as silicon steels, a tightly adhering, electrically insulating film or coating comprising iron oxide and thereafter to anneal said oxide-coated material to improve the useful magnetic properties of the metal without detrimentally affecting the oxide film on the surfaces thereof.

Another object of the invention is to provide an improved method of electrically insulating and annealing stacked punchings of magnetic material without the individual punchings becoming firmly bound to each other during the annealing process, the disadvantages of which are well known.

By the present invention the stated objects, as well as others, are attained by a method that is practical and economical.

The novel features which are characteristic of my invention are set forth in the appended claim. The invention itself, however, will best be understood by reference to the following specification.

It is well known that laminations of steel, when packed in either small or large receptacles and annealed in a suitable furnace, such as an electric furnace, in air or other oxidizing atmosphere at temperatures above about 550° C., stick together with increasing tenacity with rise in temperature and prolongation of treatment. The oxygen present in the furnace atmosphere results in oxidation of the surface layers and the formation of a scale which seriously impairs the magnetic properties of the steel at low density and materially reduces its magnetic properties at medium and high density. At higher temperatures the metallic oxides (for example, ferrous and ferric oxides) or other compounds of iron which may be present in the surface layers apparently fuse together, causing the laminae to become bound to each other. Heretofore it has been necessary to pound the bound laminae, either by hand or by machine, to separate them. The laminae must be separated before stacking or assembling operations, and such operation adds to the cost of the finished work. The presence of excess oxide, if not removed by a pickling treatment, lowers the high density permeability and increases the hysteresis losses, while pounding of the bound laminae results in distortion of the individual pieces and causes poor stacking when assembled in electrical devices. Further, when distorted pieces are stacked they lower the magnetic quality of the whole, due to stresses and strains set up in clamping, riveting, or otherwise assembling such laminae.

It has been known heretofore that annealing of steel sheets, strips or punchings in a gaseous atmosphere consisting essentially of hydrogen prevents oxidation of the pieces, permits the use of higher temperatures and, generally, improves the magnetic properties of the steel. However, annealing in such an atmosphere does not eliminate sticking together of individual pieces nor does it furnish insulation against eddy or circulating current when the laminae are assembled together in electrical devices. Further, such a method necessitates the subsequent application of an insulating coating to the steel parts. This, in turn, requires the installation of costly enameling equipment and additional floor space for such equipment. When operations are on such a limited scale as to warrant the use of only small equipment, costs heretofore generally have been so excessive as to prohibit annealing of magnetic materials in an atmosphere of hydrogen.

I have found that the following method, which is illustrative of how this invention may be carried into effect, obviates the practical difficulties previously encountered. The method is economical, since it eliminates steps that heretofore have been deemed necessary in accomplishing similar ultimate results. It is effective in improving the magnetic properties of sheet steel and in practically eliminating binding between individual pieces in contact with each other.

In accordance with the present invention sheets of magnetic material may be superimposed to form a laminated mass thereof. Thus, sheets of silicon steel punched to a size and shape desired for magnetic use in a particular electrical device are stacked in small or large annealing trays. In certain cases vertical stacking of the laminae is preferred. When the sheet steel is slightly curved, the punchings likewise have a slight curvature. I have found that the individual punchings may be straightened during the herein-described heat-treating process by stacking the laminae in the annealing trays vertically, that is on edge. In that event relatively small stacks of punchings, for example about 1 to 3 inches thick, may be arranged in the trays in such a manner that adjacent stacks have opposite direction of curvature. Addi-

tional straight or bowed punchings may be forced into the layer, so that the layer fits tightly in the trays. The laminae are so positioned as to be coextensive with the sides of the tray. When punchings thus stacked are heated in accordance with my invention, the curvature is removed and all strains are relieved before the annealing tray, made of alloy, has lost its strength. As a result, straight laminations are secured from the treatment.

The loaded trays are placed in a suitable furnace, such as an electric elevator-type furnace, at temperatures ranging from room temperature up to and including the annealing temperature. In the furnace the stacked pieces are heated first in an oxidizing atmosphere of, for example, air or oxygen at a temperature sufficiently high and for a period of time sufficiently long to form a tenaciously adhering, electrically insulating film of oxide on the surfaces of said pieces. The exact time and temperature of the oxidation treatment are dependent upon such influencing factors as the size of the furnace, the size of the charge, the temperature of the furnace when the loaded trays are placed therein, and so forth.

Just after the furnace has been charged and during part or all of the preheating or oxidizing stage, a vent in the furnace is opened to exhaust by normal escape or under vacuum all volatile contaminating matter such as moisture and oil that are usually present on the surfaces of the punched steel as a result of the punching operation. The length of time this vent is kept open depends upon the size of the furnace and charge and the particular temperature employed at this stage. If moisture and oil or carbonaceous matter resulting from the decomposition of the oil are not removed, the presence of such contaminants results in excessive oxidation and blistering of the metal surfaces and materially reduces the low density permeability of the steel. As the expanding hot gases escape from the furnace during this stage of the operation, air is drawn into the furnace to replace the escaping gas. This flow of air aids in obtaining the proper degree of oxidation of the surfaces and, also, in removing carbonaceous matter which, if not removed, is a further cause of sticking of punched steel laminae as well as a cause of short circuiting of electrical heating elements. If the punchings are cleaned and dried, for example by washing with a volatile liquid in which oil is soluble and then dried at a temperature sufficiently high to remove excess solvent and moisture, venting of the furnace in the manner described may not be necessary in obtaining non-sticking, electrically insulated steel laminae of good magnetic properties.

When a tightly adhering, electrically insulating film of oxide of the desired thickness has been developed on the surfaces of the magnetic material, as determined in general by past experience in an oxidizing treatment of particular articles of magnetic material in a particular amount and in a furnace of a particular size, a light flow of hydrogen is passed into the furnace. If desired, the flow of hydrogen into the furnace may be started shortly before the oxide coating has reached its maximum thickness. The hydrogen is dried or otherwise treated to remove moisture before entering the furnace. The hydrogen provides in the furnace, after formation of an oxide coating on the surfaces of the magnetic material, a non-oxidizing gaseous atmosphere. This enveloping atmosphere may be inert or slightly reducing throughout the annealing period and temperature range, but in all cases must be essentially non-oxidizing. Such procedure avoids excessive oxidation, with its attendant disadvantages, and permits the use of higher annealing temperatures which, in turn, result in a substantial improvement in the magnetic properties of the material. Further, in the case of laminated or stacked sheet material or punchings of silicon steel or of other magnetic material, the described procedure apparently prevents fusion of surface components and practically eliminates binding or sticking together of individual pieces. During this stage of the process the hydrogen reacts, at a temperature of about 700° C. and thereabove, with combined or absorbed oxygen present in the surface layer or coating, or in any so-called "surface scale" which may be present, and, further tends to decarburize the steel.

The amount of hydrogen introduced into the furnace is so controlled and regulated that the initial insulating coating of oxide on the metal surfaces is not completely reduced. In other words, the amount of hydrogen present in the enveloping gaseous atmosphere, as well as the duration of the annealing period, is insufficient to affect detrimentally the usefulness of said oxide coating as electrical insulation. It is important that excessive reduction of the oxide coating be avoided, since excessive reduction may result in additional oxidation on cooling and a binding together of the individual pieces, which, as hereinbefore pointed out, is highly undesirable.

As illustrative of the amount of hydrogen used, it is mentioned that for an electric elevator-type furnace having an internal volume of about 37 cubic feet, and when containing about 1200 to 1400 pounds of silicon steel punchings, for example, radio magnetic core laminations, stacked in annealing trays, hydrogen is introduced therein at the rate of about 10 to 15 cubic feet per hour.

The hydrogen may be introduced immediately after the formation of the desired thickness of oxide coating or during its formation at any temperature above about 700° C. and below the maximum annealing temperature employed, which is about 1300° C. At about 700° C. and thereabove, hydrogen is able to diffuse through silicon and other forms of magnetic steel, so that in practicing this invention passage of hydrogen between the laminae is not dependent solely upon that which enters at the edges of the sheets or punchings. Hydrogen may be introduced at heat-treating or annealing temperatures ranging between about 700° C. and about 1300° C., and advantageously at a temperature of about 800° C. When the furnace is of the size and contains an amount of stacked or superimposed sheet steel punchings hereinbefore mentioned by way of illustration, the hydrogen advantageously is introduced for a period of about 2½ hours after a temperature of dissociation of the components of the surface coating or film on the punchings has been reached.

At the end of the heat-treating or annealing operation the trays containing the annealed, oxide-coated sheets or punchings of magnetic material are either cooled in the furnace in a non-oxidizing atmosphere to a suitable temperature, for instance to about 600° C., before exposure to air; or they are removed from the furnace and covered with a sheet steel drum and cooled therein in what is essentially a non-oxidiz-

ing atmosphere to about 600° C. before the trays are exposed to the air.

If desired, a continuous furnace may be used in carrying this invention into effect. In such case, a zone for the removal of moisture, oil, and other volatile surface contaminants advantageously may be provided ahead of the oxidizing zone, using, for example, waste heat from the annealing zone for heating the oil- and moisture-removing zone.

Treatment of magnetic material in accordance with this invention provides definite advantages and economies in preparing such material for use in electrical devices. Due to the comparatively small amount of hydrogen or equivalent reducing gas which is used, costs are substantially lower than when a full hydrogen anneal is employed. Electric furnace heating elements and annealing trays have a longer life. Labor costs are reduced, since there are no bound laminae to be separated. Application of an insulating coating other than the insulating layer of oxide formed during the process becomes unnecessary. Improved magnetic properties are obtained, since the excessive oxidation heretofore obtained at high temperature anneals in an oxidizing atmosphere is avoided. The process permits the use of annealing temperatures considerably in excess of those heretofore possible when annealing in air or other oxidizing atmosphere, with advantages well known to those skilled in the art. As illustrative of the improvement in the properties of silicon steels annealed in accordance with this invention, it is mentioned that in certain cases the low density permeability of the annealed steel has been doubled, the core loss has been reduced about 20 per cent, and the maximum permeability has been improved about 40 per cent.

The method herein set forth is particularly effective in the treatment of curved laminae stacked vertically in trays as previously described. By practicing my invention, sticking of laminae which ordinarily occurs between individual punchings when stacked tightly on edge in an annealing tray is prevented. Elimination of the curvature in the laminae eliminates the strains which occur when stacked, warped sheets are clamped together to form a core. Thus a further improvement in magnetic and electrical properties is obtained.

Magnetic materials that may be treated in accordance with this invention include any of the various grades of silicon or common steels used for the manufacture of electrical apparatus, such as steel that has been cold reduced, hot rolled, mill annealed or otherwise mill treated, such as pickled, alkaline coated, and so forth. In accordance with another embodiment of the present invention, steel laminations such as used in electric motors may be assembled in proper position in the iron shell of the motor and the entire assembly, including the iron shell, then may be heat treated in a manner such as herein described.

In lieu of pure hydrogen, other reducing but non-carburizing gases, or suitable mixtures thereof, with or without the presence of inert or other gases, may be used in carrying this invention into effect; for instance, carbon monoxide, a mixture of hydrogen and carbon monoxide, or a gaseous mixture containing carbon dioxide, nitrogen, carbon monoxide and hydrogen. Whatever the reducing gas or mixture of gases employed, it is important that it be one which is reducing but non-carburizing at the annealing temperature. By the expression "non-carburizing" I mean that the gas shall not give up carbon to the sheet steel material which is subjected to the action of the gas.

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

A method of treating sheets of ferrous magnetic material which comprises superimposing said sheets to form a laminated mass thereof, heating the superimposed sheets in an oxidizing atmosphere at a temperature sufficiently high and for a period of time sufficiently long to form a tenaciously adhering, electrically insulating film or coating comprising iron oxide on the surfaces of said sheets, immediately thereafter annealing the oxide-coated sheets, at a temperature not substantially exceeding about 1300° C., in an enveloping gaseous atmosphere containing a reducing but non-carburizing gas, and limiting the proportion of the said gas in the said gaseous atmosphere throughout the whole annealing period so that the amount thereof is sufficient to prevent the oxide-coated laminae from adhering to each other but insufficient to reduce completely the oxide film, said film in its final state comprising iron oxide and retaining its tenaciously adhering, electrically insulating properties.

ROBERT T. REARDON.

CERTIFICATE OF CORRECTION.

Patent No. 2,192,756. March 5, 1940.

ROBERT T. REARDON.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 1, second column, line 55, for the word "directions" read direction; page 3, second column, line 39, in the claim, before "oxide-coated" insert hot; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 9th day of April, A. D. 1940.

(Seal)

Henry Van Arsdale,
Acting Commissioner of Patents.