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PROCESS FOR PRODUCING DUCTILE MAGNETIC COBALT-IRON ALLOY MEMBERS

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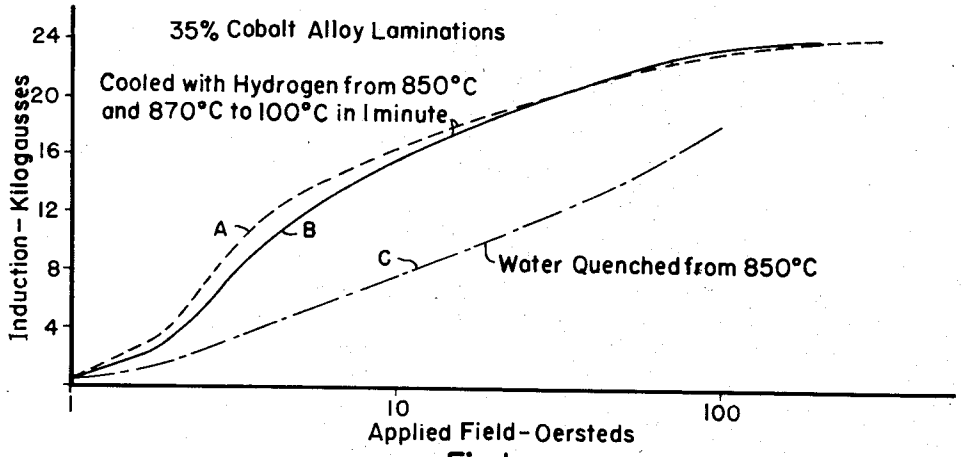


Fig. 1.

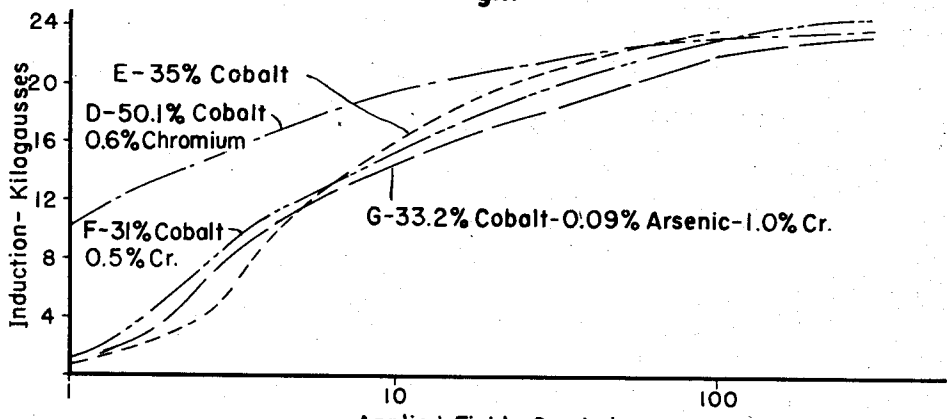


Fig. 2.

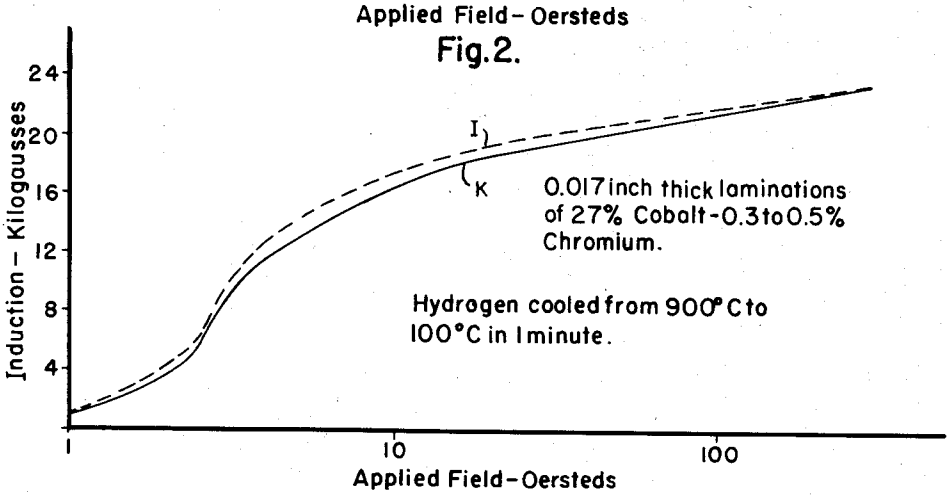


Fig. 3.

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PROCESS FOR PRODUCING DUCTILE MAGNETIC COBALT-IRON ALLOY MEMBERS

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3 Claims. (Cl. 148—122)

This invention relates to a process for producing ductile laminations of cobalt-iron alloys, said laminations having a high magnetic permeability and low losses.

Laminations of cobalt-iron alloy magnetic material suitable for use in alternating-current cores have been proposed heretofore. However, such cobalt-iron alloys are characterized by extreme brittleness at room temperature such that a rod of the cobalt alloy under some conditions may fracture if simply dropped several feet on to a concrete floor. Unless specially heat-treated to impart some ductility, laminations of the magnetic material will fracture if bent more than 30° around a bar of a diameter of 0.25 inch. Therefore, the building of electrical apparatus from such cobalt-iron alloys is attended with considerable difficulty.

A number of heat treatments for the laminations have been proposed in order to eliminate the brittleness of the alloy. A heat treatment comprising bringing the laminations to a temperature of 850° C. and then quenching in water appears to impart a considerable improvement in ductility. However, the magnetic properties of the alloy are severely degraded. In particular, the permeability of cobalt-iron laminations so treated may be reduced as much as 50% under a given magnetizing field. In other cases complex cycles involving many hours of heating at elevated temperatures and slow cooling in the furnace have been proposed for the cobalt-iron alloys and with these processes a certain measure of ductility is obtained along with reasonable magnetic properties. However, these latter processes are time consuming and expensive as well as not attaining the maximum ductility along with the maximum permeability and low losses.

The object of this invention is to provide a simple process requiring a fraction of an hour for producing iron-cobalt alloy laminations having a high permeability and low alternating-current losses and good cold ductility.

Other objects 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 may be had to the following detailed description and drawings, in which:

Figure 1 is a graph plotting induction against applied field for 35% cobalt alloy laminations treated by two different processes.

Fig. 2 is a graph plotting induction against applied field for laminations of different alloy compositions all treated in accordance with the present invention, and

Fig. 3 is a graph plotting induction against applied field for a specific alloy composition produced in accordance with the present invention.

Briefly, our invention is directed to a heating and controlled cooling treatment of bodies of certain cobalt-iron alloys to develop both high magnetic properties and ductility. The alloy may be in the form of bars, rods or sheets or laminations. The invention is particularly useful for sheets in the range of 0.002 inch to 0.050 inch in thickness. The alloy is composed of from 20% to

50% of cobalt, up to 3% of vanadium, up to 1% of manganese, up to 2.5% of chromium, up to 0.5% of arsenic, up to 0.5% of silicon, less than 0.1% of carbon, other impurities, such as nickel, sulfur, phosphorus and oxygen, not exceeding 0.5%, and the balance being iron, all parts being by weight. It should be understood that, except for the cobalt and iron, the remainder of the components may be present in such minute quantities that for all practical purposes they are not effective. In order to secure an alloy with better hot and cold working properties, it is desirable to have present vanadium or chromium and manganese in appreciable proportions, as set forth. It has been found that the addition of chromium of up to 2.5% produces a magnetic lamination having higher ohmic resistance so that the alternating-current losses are considerably reduced. The presence of arsenic has been found to be beneficial in providing an increase in permeability. Carbon should be maintained at as low a value as possible since it may result in undesirable ageing effects and in high losses and therefore its presence is undesirable in magnetic cores to be used with alternating-current fields. For these reasons, it is particularly desirable to keep the carbon below 0.03% by weight. The alloys of the present invention are not steels but rather irons, and are not suitable for the making of permanent magnets.

The components of the alloys of the present invention may be combined by any suitable metallurgical technique. We have secured good results by placing in an electrical furnace an extremely pure iron and cobalt rondels which have been preannealed in hydrogen for 24 hours in order to remove any carbon therein. The cobalt may contain small amounts of nickel which will carry over into the final melt. Vanadium and ferromanganese, similarly purified, may be introduced into the electric furnace in the desired proportions. A small amount of ferrosilicon may be added to function as a deoxidizer. Chromium and arsenic may also be added. The mixture is then melted under a non-carburizing, reducing atmosphere and cast into ingots which are thereafter rolled hot into bars and laminations.

Alternatively, powdered pure iron may be admixed with cobalt and one or more of the desired alloying elements, all in powdered form, the mixture of powder compacted at pressures of 10,000 p. s. i. or higher into a compact which is sintered for several hours at temperatures from 1400° C. to 1500° C. and then forged or rolled into bars and laminations.

After the cobalt-iron alloy sheet, bar or other shape has been formed by any suitable hot metal working procedure, it may be punched into suitable shapes, such as motor laminations, generator punchings, and the like. The punching operation introduces strains which it is desirable to eliminate by annealing.

After all of the working and forming operations have been performed on the laminations, and preferably prior to the assembly of the laminations into electrical apparatus, the laminations are subject to the heat treatment of the present invention to remove strains and to impart the maximum permeability and a high ductility to the laminations. This heat treatment comprises, first, heating the laminations in a substantially non-carburizing, non-oxidizing atmosphere to a temperature of from 800° C. to 925° C. for at least several minutes. By "substantially non-carburizing, non-oxidizing atmospheres" we mean atmospheres that, for the time the cobalt-iron material is exposed thereto, are not appreciably oxidized or increased in carbon content. If the shortest heat-treatment times are used, the atmosphere about the laminations may contain appreciable amounts of water vapor, oxygen and carbon dioxide without appreciable oxidation of the laminations. For example, we have heated cobalt-iron

laminations of a thickness of 0.017 inch for about 10 minutes in a gas-fired furnace in which the products of combustion comprised the atmosphere and we secured good results.

For the heat treatment we have secured good results using a moving belt type furnace in which the laminations are placed singly on a rapidly moving belt and traverse the heating zone of the furnace where they are heated to from 800° C. to 925° C. for some 5 to 15 minutes. However, we have employed batch type furnaces with success. After the laminations have been heated to the required temperature, they are then cooled therefrom to a temperature of about 100° C. at a rate of from 5° C. to 60° C. per second. The cooling should be done in a substantially non-oxidizing atmosphere. Preferably, the cooling is done with a stream of cold gas. This rate of cooling has been found to be quite critical. Thus cooling at the rate of 1 or 2° C. per second does not improve the ductility of the material. On the other hand, quenching in oil or water, which reduces the temperature of the laminations to 100° C. in approximately 3 to 5 seconds, causes a decided impairment in the magnetic properties.

Referring to Fig. 1 of the drawing, there are shown curves plotted from the magnetic characteristics under various applied fields for cobalt-iron alloy laminations heat-treated in accordance with the present invention and those in which the laminations were quenched at rates outside the present invention after annealing. The curve A in Fig. 1 is derived from permeability tests of 0.015 inch thick laminations composed of an alloy comprising 35% cobalt and about 64% of iron, the balance being composed of small amounts of nickel, silicon, manganese and impurities. The laminations were heated to 850° C. and then cooled in hydrogen to 100° C. in one minute. Substantially the same permeability results were secured on quenching at this same rate in nitrogen gas. The curve B is directed to the properties of the same alloy as that employed for the laminations of curve A, but the thickness of the laminations was 0.018 inch. The laminations used for curve B were heated to 870° C. for 30 minutes, then cooled in hydrogen to a temperature of approximately 100° C. in one minute. It will be noted that with an applied field of 100 oersteds, the induction in kilogausses in both curves A and B is slightly over 23, while with a field of 10 oersteds the induction in A is 16.4 kilogausses and in curve B the induction is 15.8 kilogausses.

Curve C of Fig. 1 was derived from the same 35% cobalt alloy, as employed in determining the data as curves A and B, made into laminations 0.017 inch thick. The laminations were annealed in hydrogen one-half hour at 850° C. and then quenched in water so that in 3 to 4 seconds the temperature of the laminations was reduced to 100° C. It will be noted that in curve C with an applied field of 10 oersteds, the induction is 7.6 kilogausses, that is, approximately half that obtained with the heat treatment of the present invention, as typified in curves A and B, and at 100 oersteds the induction in curve C is 18 kilogausses, that is, only 78% of the permeability of the laminated material heat treated in accordance with the present invention.

For the heat treatment of laminations of the cobalt-iron alloys of this invention as well as to provide for cooling at the critical rate disclosed herein, a number of substantially non-carburizing, non-oxidizing atmospheres are available. Examples of suitable atmospheres are dissociated ammonia, partly or completely burned ammonia that has been treated to reduce its moisture content to a dew point of below 40° C., partly combusted fuel gas that has been scrubbed of water and carbon dioxide, and completely reacted gaseous fuels that have been treated to remove water and moisture to a dew point of the order of 40° C. or less. Hydrogen and dissociated ammonia give excellent results in practice.

For cooling the laminations after the heat treatment to 800° C. to 925° C., it is a good practice to separate the laminations substantially from one another so that the cooling gas may penetrate readily and cool the surfaces at the proper rate. The cooling gas may be circulated in a water-cooled chamber so that the heat imparted by the laminations to the gas is conveyed to the walls of the chamber and the cool gas again flowed over the laminations to further reduce their temperature.

Fig. 2 of the drawing comprises the permeability curves of laminations of four different alloys produced in accordance with the present invention. The laminations of these cobalt-iron alloys were heated to temperatures of from 850° C. to 900° C. for approximately 10 minutes and then cooled at the rate of from 12° C. to 15° C. per second. The compositions of the alloys used in determinating the curves of Fig. 2 are as follows:

TABLE

Composition-weight percent

Curve	Co	Cr	As	C	(Ni, Si, V and Mn)	Fe
D	50.1	0.6		<0.02	About 0.5	48.8
E	35			<0.02	do	64.5
F	31	0.5		<0.02	do	68.0
G	33.2	1.0	0.09	<0.02	do	65.2

The impurities in the above alloys were of the order of 0.1%. These alloys were in the form of laminations of a thickness of 0.025 inch for curves D, F and G, and 0.017 inch for curve E. The laminations of curves D, F and G were heat-treated for 10 minutes at 850° C. in an atmosphere comprising approximately 80% nitrogen, 10% hydrogen, 7% carbon dioxide and 3% carbon monoxide, and the laminations were cooled with this same gas in about one minute to 100° C. The laminations of curve E were heated in hydrogen gas to 850° C. for 30 minutes and then cooled with a stream of hydrogen to about 100° C. in a minute.

It will be apparent from curve D in Fig. 2 that the 50.1% cobalt alloy laminations had outstanding magnetic permeability in fields of from 1 to 20 oersteds. At 100 oersteds, curve E showed superior induction though all the alloy laminations showed good permeability at this field strength. In core losses in watts per pound, the alloy laminations of curve G exhibited approximately 12% less losses as compared to the 31% cobalt alloy used in deriving curve F.

In Fig. 3, there are plotted curves of permeabilities derived from an alloy, composed of 27% cobalt, between 0.3 and 0.5% of chromium and the balance being iron except for small amounts of the order of 0.1% each, of nickel, silicon and manganese. In curve I, the metal, after casting into an ingot, was hot rolled to a slab 0.080 inch thick which was quenched from 1570° C. into water and then cold rolled to a lamination of a thickness of 0.017 inch. Thereafter, this sheet was punched into laminations and then annealed 900° C. in wet hydrogen for 40 minutes. The laminations were then cooled with a blast of hydrogen circulating through a water-cooled radiator so that the lamination was cooled in approximately 1 minute to 100° C. The lamination from which curve K was derived was similarly produced except that during the cold rolling the metal sheet was subjected to one quench from 1570° C. when 0.080 inch thick, and then given an intermediate quench in water before rolling to a final thickness of 0.017 inch thick sheet. The laminations after heat treatment in accordance with the present invention exhibit excellent magnetic properties considering the fact that the alloy comprised only 27% cobalt.

The best previous heat treatment available that required a series of steps and processing for 6 to 8 hours, when applied to the alloy used in determining curves A and B in Fig. 1, resulted in members whose maximum ductility was such that they could not be bent more than

90° around a quarter-inch rod. The laminations from which curves A and B were derived, on the other hand, were readily bent 150° around a quarter-inch rod. Furthermore, the tensile strength of the alloy laminations produced with the heat treatment of the present invention was 55,000 p. s. i. which was approximately 65% greater than that obtained when following the best available prior art treatment.

The laminations employed in producing the data shown in curves I and K in Fig. 3 at an induction of 20,000 kilogausses in an alternating current field had losses not appreciably different than that possessed by same magnetic laminations that were cooled slowly in the furnace for an hour to room temperature.

It will be appreciated that while the present process may be carried out by simply heating the laminations of the magnetic material to a temperature of from 800° C. to 925° C. for from 5 minutes to 15 minutes, such heat treatment may be prolonged beyond this time. We have heated laminations for from 40 minutes to one hour and then cooled the laminations from the heat-treating temperature to room temperature at the rate of 5° C. to 60° C. per second without observing any change in the high permeability and good ductility that we have found to be obtained with shorter heat-treating times as used in the practice of the invention.

The same heat treatment may be applied to bars and rounds of substantial size, for example, 0.5 inch by 4 inch by 3 feet bars.

Since certain obvious changes may be made in the above processes and different embodiments of the invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or taken in connection with the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

We claim as our invention:

1. The process for treating laminations of a magnetic material composed of from 20% to 50% cobalt, up to 3% vanadium, up to 1% manganese, up to 2.5% chromium, up to 0.5% of arsenic, up to 0.5% silicon, less than 0.1% of carbon, other impurities not exceeding 0.5%, and the balance being iron, comprising solely the steps of heating the laminations in a substantially non-carburizing, non-oxidizing atmosphere to a temperature of from 800° C. to 925° C. for at least several minutes and thereafter cooling the laminations in a substantially non-oxidizing atmosphere from this temperature to approximately 100° C. at a rate of from 5° C. to 60° C. per second, whereby the laminations have a high magnetic permeability of over 20,000 gausses at 100 oersteds, a ductility sufficient to enable laminations 0.025 inch thick to be bent at least 90° around a ¼ inch radius without failing and possess low electrical losses in an alternating current field.

2. The process for treating members of a magnetic sheet material of a thickness of from 0.002 to 0.050 inch thick after cold working, the laminations composed of a magnetic material composed of from 20% to 50% cobalt, up to 3% vanadium, up to 1% manganese, up to 2.5% chromium, up to 0.5% of arsenic, up to 0.5% silicon, less than 0.1% of carbon, and other impurities not exceeding 0.5%, and the balance being iron, comprising solely the steps of heating the laminations to a temperature of from 800° C. to 925° C. in a hydrogen containing atmosphere for at least 5 to 15 minutes in order to relieve strains induced by the cold working, and then passing a substantially non-oxidizing cooling gas over the laminations to reduce their temperature to approximately 100° C. at a rate of from 5° C. to 60° per second, whereby high magnetic permeability, low losses and good cold ductility are secured.

3. The process of claim 2 wherein the substantially non-oxidizing gas comprises mainly hydrogen.

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