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[54] **PROCESS TO IMPROVE MAGNETIC CHARACTERISTICS OF CARBON STEEL**
4 Claims, 1 Drawing Fig.

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[51] **Int. Cl.** **H01f 1/14,** C21d 1/00
[50] **Field of Search** 148/31.55, 120, 121, 122, 12.1, 16

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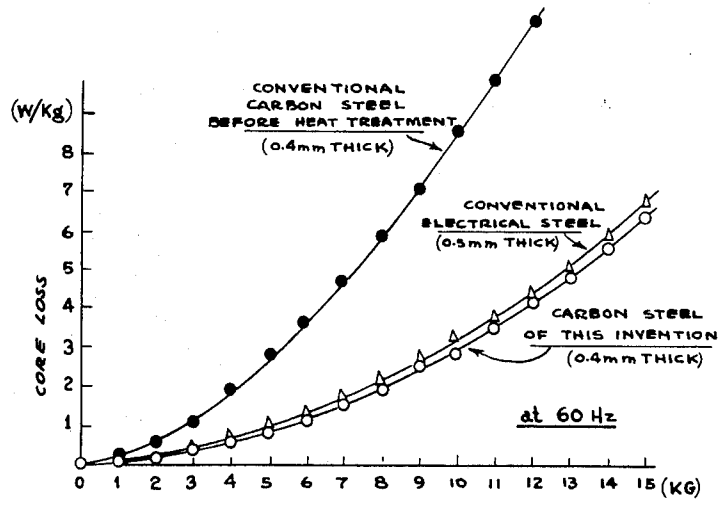
ABSTRACT: The process to improve magnetic characteristics of conventional low-carbon, rimmed steel having the chemical composition, carbon: <0.25 weight percent, silicon: <0.5 weight percent, manganese: <1.65 weight percent, phosphorus: <0.05 weight percent, sulfur: <0.05 weight percent, copper: <0.5 weight percent, and other elements: <0.1 weight percent, comprising:

A first stage of raising the temperature of carbon steel above the A_3 transformation temperature of approximately 850–910° C. wherein the α-phase$\rightarrow\gamma$-phase transformation takes place in a controlled atmosphere with a dew point of approximately 5° to 50° C., or a water vapor pressure of 6.9–92.5 Torr.

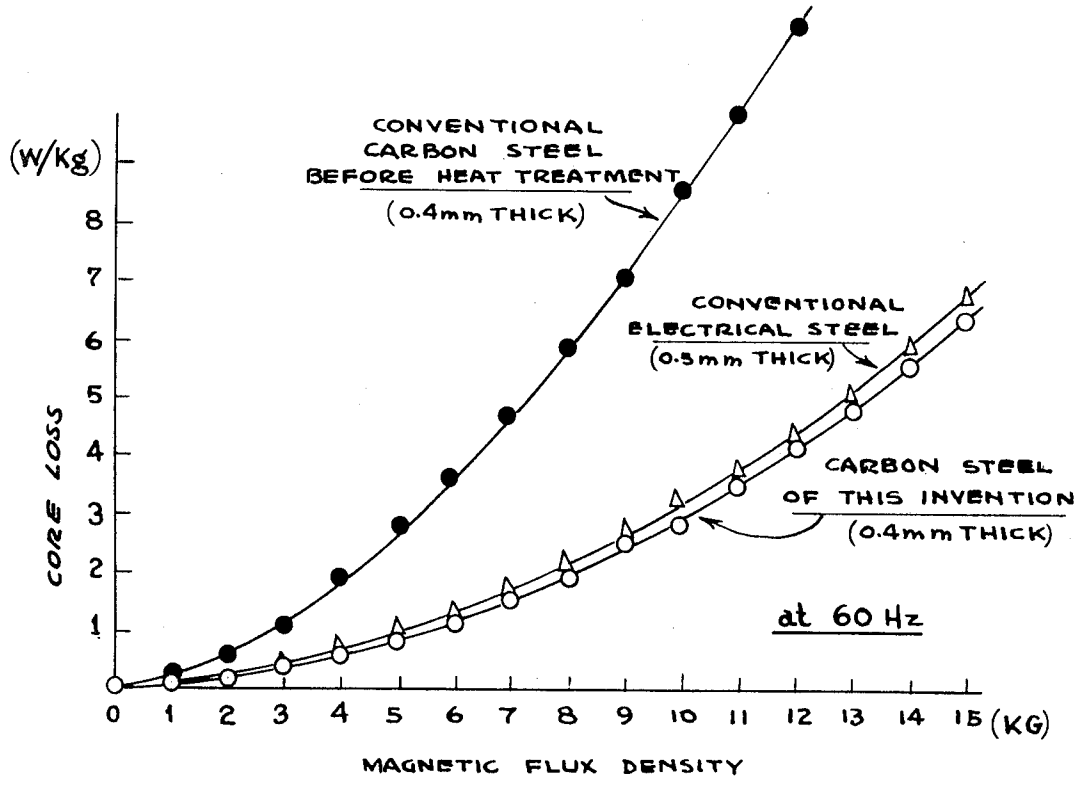
A second stage of lowering rapidly the temperature of the carbon steel below 723° C., but not lower than 600° C., maintaining the carbon steel at this temperature for 3 to 10 hours in a weakly oxidizing atmosphere.

A third stage of lowering and maintaining said carbon steel at a temperature of 300 to 400° C. for 1 to 2 hours for the purpose of obtaining large ferrite grains in which less than 0.01 weight percent of carbon is present dissolved in the matrix and the residual carbon is present at ferrite grain boundaries, and not in the matrix.

A low-carbon, rimmed steel having a ferrite matrix and chemical composition: less than each of the following: 0.25 weight percent carbon, 0.5 weight percent silicon, 1.65 weight percent manganese, 0.05 weight percent phosphorus, 0.05 weight percent sulfur, 0.5 weight percent copper, and 0.1 weight percent other elements, and wherein the ferrite matrix is in the form of grains sufficiently large in particle size to be less than 10 particles per $mm.^2$, said grains having less than 0.01 weight percent of carbon dissolved in the ferrite matrix, and the residual carbon being present at ferrite grain boundaries and not in the ferrite matrix.



THE CORE LOSS OF CARBON STEEL AFTER HEAT TREATMENT, CARBON STEEL BEFORE ANNEALING & CONVENTIONAL ELECTRICAL STEEL.



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PROCESS TO IMPROVE MAGNETIC CHARACTERISTICS OF CARBON STEEL

This invention relates to the use of conventional low-carbon, rimmed steel sheet for a core of transformers and other electric devices and to a process to improve the magnetic characteristics of conventional low-carbon, rimmed steels.

As is well known, the magnetic materials used for transformers must possess high saturated magnetic flux density, high permeability, high electrical resistance, and low core loss.

In general, the art used many types of electrical steels as magnetic materials but, for economy, carbon steels are generally less expensive than electrical steels and would be therefore preferred if it were not for the undesirable magnetic characteristics of conventional low-carbon, rimmed steel.

It is the primary object of the present invention to improve the magnetic characteristics of conventional low-carbon, rimmed steels in order that such lower cost conventional low-carbon, rimmed steels may be used in magnetic systems.

This and other objects of the present invention will be apparent from a careful study of the following specification accompanied by the drawing wherein the FIGURE is a graphic representation of the comparison of the carbon steel treated according to the present invention and conventional low-carbon, rimmed steel and electrical steel.

Carbon steels to which the present invention relates have the following chemical composition:

carbon: <0.25 weight percent, silicon: <0.5 weight percent, manganese: <1.65 weight percent, phosphorus: <0.05 weight percent, sulfur: <0.05 weight percent, copper: <0.5 weight percent, and other elements: <0.1 weight percent.

The process of this invention consists of three stages.

First stage—the temperature of given carbon steels is raised above A_3 transformation temperature of 850°–910° C. wherein α-phase$\rightleftarrows\gamma$-phase transformation takes place for 0.1 to 2.0 hours in an oxidizing atmosphere with the chemical composition;

CO: 0–10 volume percent, CO_2: 6–13 volume percent, H_2: 0–5 volume percent, N_2: residual, while keeping the water vapor pressure between 6.9 Torr to 92.5 Torr, enough to promote decarburization, desulfurization, and dephosphorization. The dew point of the atmosphere must be kept between 5° to 50° C. for this purpose. This is because carbon, sulfur, and phosphorus are injurious to magnetic properties of carbon steels. During the first stage, the carbon steels are purified, and the original rolled structure is destroyed until no crystal anisotropy remains.

Second stage—The temperature of the carbon steel is lowered as rapidly as possible below 723° C. but not lower than 600° C., and kept at this temperature for 3 to 10 hours. Through this quick lowering of temperature, stress energy induced by transformation is stored in the carbon steels, and this energy promotes the growth of ferrite grains. While the process is in progress, the dew point of the atmosphere must be lower than 5° C. and the chemical composition of this atmosphere in this stage is as follows:

CO: 2–12 volume percent, CO_2: 6–12 volume percent, H_2: 1–15 volume percent, N_2: residual. The atmosphere is preferably weakly oxidizing.

During this treatment, the cementite in the matrix precipitates along grain boundaries, the grain size becomes coarse, and the magnetic characteristics of the carbon steels are improved.

Third stage—The temperature of carbon steels is lowered slowly in order to avoid the appearance of thermal stress, and is kept at 300° to 400° C. for 1 to 2 hours. The chemical composition of this atmosphere in this stage is the same as that in the second stage. After this treatment, the carbon steels are taken out of the furnace.

The FIGURE shows the magnetic characteristics of the carbon steel sheets treated by the process mentioned above, together with those of conventional low-carbon, rimmed steel before annealing, and a conventional electrical steel for comparison.

EXAMPLE 1.

A low-carbon, rimmed steel sheet with the following chemical compositions: carbon: 0.08 weight percent, manganese: 0.28 weight percent, phosphorus: 0.015 weight percent, sulfur: 0.020 weight percent, and other elements <0.10 weight percent, was heat-treated as follows:

The temperature of material was elevated to 920° C. and kept at this temperature for 1 hour. The percentages of controlled atmosphere were as follows:

CO_2: 13 volume percent, N_2: residual, dew point: 25° C.

After rapidly lowering the temperature of the carbon steel to 710° C. the steel was kept at this temperature for 6 hours to obtain large ferrite grains. During this second stage, the percentages of controlled atmosphere were as follows:

CO: 8.7 volume percent, CO_2: 6.5 volume percent, H_2: 9.5 volume percent, N_2: residual, dew point: 4° C.

After the second stage, the temperature of carbon steel and lowered to 350°C. and kept for 1 hour. The percentages of controlled atmosphere were the same as that in the second stage. After this treatment, the carbon steel was taken out of the furnace, the core loss of the steel thus treated was 5.5 watts/kg. at 14 kilogauss, and 60 Hz.

EXAMPLE 2

A low-carbon, rimmed steel sheet with the following chemical composition:

carbon: 0.15 weight percent, manganese: 0.40 weight percent, phosphorus: 0.017 weight percent, sulfur: 0.030 weight percent, and other elements are less than 0.10 weight percent, were treated as follows:

The temperature of the material was raised to 920° C. at first and kept at this temperature for 1.5 hours. The percentages of controlled atmosphere were as follows:

CO_2: 13 volume percent, N_2: residual, dew point: 35° C.

After rapidly lowering the temperature of the carbon steel to 710° C. we kept at this temperature for 7 hours to promote the growth of ferrite grains. During this second stage, the percentages of controlled atmosphere were as follows:

CO: 8.0 volume percent, CO_2: 7.0 volume percent, H_2: 8.0 volume percent, N_2: residual, dew point: 4.0° C.

After the end of the second stage, the temperature of carbon steel was lowered to 350° C. and kept for 1.5 hours at this temperature. The percentages of controlled atmosphere were the same at that in the second stage. The temperature of the steel was then lowered uniformly to 200° C. and kept for 1 hour at this temperature in the gas atmosphere with the same composition as before. After this treatment, the carbon steel was taken out of the furnace. The core loss of the steel thus obtained was 5.7 watts/kg. at 14 kilogauss and 60 Hz.

The low-carbon, rimmed steel produced in accordance with the present invention has superior magnetic properties and having its ferrite matrix in the form of grains sufficiently large in particle size to be less than 10 particles per square millimeter. These grains also have loss than 0.01 weight percent of carbon dissolved in the ferrite matrix with the residual carbon being present at the ferrite grain boundaries rather than in the ferrite matrix.

From the foregoing detailed description, it will be evident that there are a number of changes, adaptations and modifications of the present invention which come within the province of those skilled in the art. However, it is intended that all such variations not departing from the spirit of the invention be considered as within the scope thereof as limited solely by the appended claims.

I claim:

1. The process to improve magnetic characteristics of carbon steels comprising

a first stage including raising the temperature of carbon steel above the A_3 transformation temperature wherein the α-phase $\rightleftarrows$ γ-phase transformation takes place, and maintaining the dew point of the atmosphere between 5° to 50° C.

a second stage including lowering and maintaining the temperature of the carbon steel below 723° C. but not lower than 600° C., for 3 to 10 hours in a controlled atmosphere;

a third stage including lowering and maintaining the temperature of the carbon steels at 300° to 400° C. for 1 to 2 hours.

2. The process of claim 1 wherein the carbon steels have a composition of carbon: <0.25 weight percent, silicon: <0.5 weight percent, manganese: <1.65 weight percent, phosphorus: <0.05 weight percent, sulfur: <0.05 weight percent, copper: <0.5 weight percent, and other elements: <0.1 weight percent, for the purpose of obtaining large ferrite grains in which less than 0.01 weight percent of carbon is present dissolved in the matrix and the residual carbon is present at ferrite grain boundaries, and not in the matrix.

3. The process of claim 1 wherein the atmosphere in the first stage is approximately 0–10 percent by vol. CO, 6–13 percent by vol. CO_2, 0–5 percent by vol. H_2, and residual N_2.

4. The process of claim 3 wherein the atmosphere of the second and third stages are 2–10 percent by vol. CO, 6–12 percent by vol. CO_2, 1–15 percent by vol. H_2, and residual N_2.

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