

UNITED STATES PATENT OFFICE

2,084,336

MAGNETIC MATERIAL AND METHOD OF
MANUFACTURE

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No Drawing. Application June 30, 1934, Serial
No. 733,250

3 Claims. (Cl. 148—12)

My invention relates to the manufacture of magnetic material and, in particular, to the production of silicon steel in sheet form suitable for use in building up laminated cores for motors and transformers.

In my application Serial No. 755,575, filed December 1, 1934, for Method of rolling magnetic material, I have disclosed a method for producing hot rolled silicon steel strip intended for the production of electromagnetic core material in thin sheet form. The present invention is concerned with the reduction of hot rolled strip produced by the method of the copending application, to final gauge and the treatment thereof to bring out the desired magnetic qualities, such as high magnetic permeability at high flux densities, and low energy loss due to hysteresis and eddy currents.

Methods are already known for the production of silicon steel in sheet form having relatively satisfactory magnetic characteristics. Also known are methods of producing an alloy steel of high nickel content having good characteristics. The best magnetic characteristics it is possible to obtain are required for the manufacture of transformer cores. This material is generally made about .012" to .015" thick, because one of the components of the total energy lost in an electromagnetic core, namely, the eddy current loss, is proportional among other things to the thickness of the laminations. For other uses, such as motor or generator cores, and the cores of transformers in which the highest efficiency is not a necessary characteristic, thicker material, which can be made more cheaply and has less desirable magnetic characteristics is generally used. It is to this latter class of material that the present invention relates, rather than to the more costly, thinner gauge material having the best magnetic characteristics it is possible to obtain.

As disclosed and claimed in my copending application before mentioned, the hot rolled strip is produced as follows: I take an ingot of the desired content of silicon, say around 3%, and subject it to rolling to form a slab. In rolling the slab, I prefer to finish the rolling while the metal is at a temperature of 1900° F. or below.

It is the rolling of the slab into strip form which seems to exercise the greatest effect upon the final results obtained. I have found that the greatly improved results are produced by heating the slab to a temperature of between about 2000° and 2100° F. for a period of time sufficient to permit thorough penetration of the heat into all

parts of the slab uniformly, the time depending somewhat on the silicon content, and the nature of the practice followed in casting and finishing the ingot. For a 3% silicon steel, I prefer to heat the slabs to a temperature between about 2000° and 2050° F. and hold them at that temperature until the slab is thoroughly heated throughout, to the same temperature in all parts.

After heating to a temperature in the vicinity of 2000°–2100° F. for the time specified, which heating may be conducted in a convenient manner in any desired type of furnace, I remove the slabs from the heating zone and permit them to cool to a temperature such that when they have been rolled to final gauge, the temperature has decreased to a value sufficiently below the temperature of the first heat treatment to which the finished strip is subjected (usually about 1600° F.) to insure quick response to recrystallization on such subsequent heating. I prefer to finish the hot strip at 1450° F. or below, although good results may be obtained even if the strip is finished at a temperature as high as 1500° F. or 1550° F. Usually, it is satisfactory to permit the slabs to cool from their initial temperature to about 1900° before the rolling is started. In the ordinary continuous mill, the temperature will have been reduced from that figure to about 1450° by the time the rolling has been completed. It is possible to finish at a lower temperature, say 1200 or 1300° F. with equally satisfactory results, the prime consideration being to finish at a temperature not much higher than 1450°.

In carrying out the present invention, I take a hot rolled silicon steel strip produced as explained above, preferably having a silicon content of about 3%, and subject it to an initial heat treatment which comprises heating the strip by passing it through a continuous furnace, to a temperature of about 1600° or 1700° F. The temperature at which the furnace is maintained and the speed of travel of the strip therethrough are preferably so controlled, as indicated by tests on the finished product, as to produce material having the desired characteristics.

After the strip has passed through the furnace, it is cooled. Preferably, the cooling should take place in a non-oxidizing atmosphere although this is not essential. The rate of cooling does not appear to affect the results obtained. The strip is then cold rolled to final gauge, for example, .017" or .024". For the cold rolling, I prefer to employ a so-called "Steckel" mill, that is, a four-high mill having small work rolls supported by large backing rolls journaled in anti-friction

bearings. The reduction of the strip, of course, is effected by a plurality of passes thereof through a single stand, or by a single pass through a multiple stand mill. After the strip has been cold rolled to gauge, it is subjected to a final heat treatment by bringing it to a temperature in the neighborhood of 2000° F. This treatment may be effected in the same manner as the initial heat treatment, by passing the strip through a continuous furnace.

I have found that while the rate of heating, the final temperature, and the time at which the strip is maintained at the final temperature, are very important, I am unable at present to lay down any rules for the determination of these factors other than that they may readily be fixed by experiment. By changing these factors slightly on successive runs and comparing the characteristics of the resulting products, it is relatively simple to choose the proper values for any particular lot of hot rolled strip. In the final heat treatment, the strip is preferably removed from the furnace immediately upon reaching the desired final temperature, to limit grain growth which, if permitted to continue, exerts an adverse effect upon the watt loss and permeability of the product. The importance of the initial treatment, furthermore, is evidenced by the fact that if it is omitted, the product is decidedly inferior even when compared with the product now in use.

On testing the product in a torsion magnet as developed by Weiss, for magnetic moment, which indicates generally the magnetic qualities of the material, it is found that it is superior to present-day silicon steel in sheet form of corresponding gauge for similar uses. As shown by Honda, "Magnetic Properties of Matter", page 6, there is a relation between the magnetic moment and the magnetic qualities which are desirable in core material. The magnetic moment is, of course, a fundamental concept in the study of magnetic properties. Such material as now available is made by hot rolling to final gauge in multiple thickness, that is, in packs, on the conventional two-high or three-high hot mill. The product of my invention is characterized by a high degree of uniformity and, while its magnetic properties are not comparable to those of more costly materials of thinner gauge produced expressly for transformer cores where the highest efficiency is necessary, the product is notably superior to material now used for similar purposes and can be

produced at a cost less than that of the present-day electrical steel, and less than that of the very best silicon steel for high efficiency transformers.

As an indication of the qualities of the product of my invention, tests show that a typical specimen, .017" thick, had a permeability of 1200 at a flux density of 16000 lines per sq. cm., and a watt loss of about 0.57 watt per lb. at 60 cycles. These figures compare with a permeability of 300 at a flux density of 16000 lines per sq. cm. and a watt loss of 0.86 watt per lb. at 60 cycles for silicon steel of similar gauge, intended for similar uses, produced by the method of hot rolling in multiple thickness or packs. The product is also characterized metallurgically, by a fine-grained structure and random orientation of the grains.

Although I have disclosed herein but one preferred practice of the invention, it will be apparent that numerous changes therein may be made without departing from the spirit of the invention or the scope of the appended claims.

I claim:

1. A method of making magnetic material, including the steps of heating a slab predominantly of steel and iron and containing about 3% silicon, to a temperature of about 2000° F., rolling the slab into strip, finishing the rolling thereof when the strip is at a temperature of about 1450° F., heating the strip to about 1600 or 1700° F., cooling the strip, cold rolling the strip substantially to finished gauge, and finally heating the cold rolled strip to a temperature in the neighborhood of 2000° F.

2. The method defined by claim 1, characterized by forming the slab by hot rolling an ingot and finishing the hot rolling of the ingot into slabs at about 1900° F.

3. A method of making magnetic material including the steps of heating a slab of silicon steel containing about 3% silicon, to a temperature of about 2000° F., rolling the slab into strip, controlling the temperature of the slab during the rolling so as to finish the hot rolling thereof while the material is at a temperature of about 1450° F., heating the resulting strip to about 1650° F., cooling the strip, cold rolling the strip substantially to its finished gauge, and finally heating the cold rolled strip to a temperature of about 2000° F.

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