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METHOD OF PRODUCING SILICON STEEL SHEET OR STRIP

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8 Claims. (Cl. 148—12)

I shall describe my invention in an exemplary embodiment for low silicon steel strip, it being understood, as more fully set forth hereinafter, that it is not limited thereto. The choice of this field for the purpose of an exemplary disclosure is because it presents concretely all of the problems with the solution of which my invention is concerned.

The principal desiderata in the production of silicon steel strip are:

(1) Good magnetic properties,
(2) Satisfactory die life,
(3) Absence of coil set,
(4) High ductility, and
(5) High space factor.

The need for good magnetic properties and for a material which, when used as punching or stamping stock, will not wear out the dies too rapidly, and the need for a high space factor, are clear. Not only does material having no coil set work better in the punch presses, but the presence of coil set is likely to affect magnetic properties injuriously. Ductility and satisfactory die life are frequently interrelated, but not necessarily so.

My invention has for its fundamental object the production of silicon steels which are improved in these respects, and the provision of a process for making them which is highly economical and has a number of commercial advantages. By low silicon steel is meant a silicon content, generally of not more than 1.5%. Because the market for such products is very highly competitive, it is imperative that any method developed to meet the requirements should be an inexpensive one.

While the requirements for a good silicon steel product are clear enough, the difficulties in attaining such a product are quite complex due to the interplay of the factors involved, as will be pointed out hereinafter. As a consequence, ancillary objects of my invention will be clear to one skilled in the art upon reading these specifications; and the objects of my invention are attained by me in that certain process and product of which I shall now give the aforesaid exemplary embodiment, which has to do with the formation of low silicon steel strip. It should be understood that the teachings herein contained are not limited to the production of strip materials, but are equally applicable to sheets; and while my description will concern itself with strip, I do not desire the appended claims to be limited thereto, excepting where the language expressly requires.

For the purpose of comparison with the procedure of my present invention, I now outline an exemplary practise in the art as follows:

(1) Low silicon open hearth heats, containing say .05–.06% carbon, are hot rolled to .06 to .08 inch.
(2) The material is then pickled.
(3) The pickled strip is cold rolled to a thickness of approximately 10% greater than the desired finished gauge.
(4) The strip is then open annealed and pickled.
(5) The strip is then cold rolled to final gauge.
(6) The strip is then slit and coiled.
(7) The coils are box annealed.
(8) The coils are decoiled, roller leveled, recoiled and shipped.

Certain disadvantages appears in a process of this kind. The material originally contains say from .05 to .06% carbon, and no effort is made to lower this carbon content. During the final box anneal, large percentages of the carbon migrate to the surface and contribute to poor die life. The final box anneal is in itself an expensive and protracted operation. The material is likely to have coil set, by which is meant a permanent curvature after the last annealing, or a curvature in the unstrained portion. If an open anneal is carried on after the box anneal, this adds a step and more expense to the process, and may require a still further step of pickling. If an open anneal were substituted for the final box anneal on material of this carbon content, in an endeavor to avoid coil set, the magnetic properties would not be properly developed in the strip and the strip is likely to be found worthless commercially.

As distinguished from a process such as this, I follow a process which can be outlined as follows:

(1) The first step of the process will be the same, viz., the hot rolling of silicon steel to .06 or .08 inch, the steel containing say .05 to .06% carbon.

(2) The hot rolled material with the hot mill scale on it is then box annealed at a temperature between 1350° F. and 1450° F. to reduce the carbon, the carbon being in this way reduced preferably to less than .01%.

(3) The third step of my process corresponds to the second step of the preceding process and constitutes a pickle.

(4) The fourth step of my process is similar to the third step of the preceding process and comprises cold rolling the material to a gauge approximately 10% greater than the desired finished gauge.

(5) The fifth step of my process corresponds substantially to the fourth step of the preceding

process and comprises an open anneal at a temperature above 1400° F., followed by a pickle.

(6) The sixth step is the cold rolling to final gauge and corresponds to step 5 of the preceding process.

(7) I then substitute an open anneal at a temperature above 1500° F., preferably in a furnace with controlled atmosphere, for the box anneal which constitutes step 7 of the preceding process.

(8) As an eighth step, the material is slit and coiled for shipment.

My new product is a decarburized, cold rolled, open annealed, silicon steel strip which has superior magnetic properties, as measured by A. S. T. M. methods, no coil set, high space factor, high ductility and excellent die life. On a grade of silicon steel containing for example 1.20 to 1.40% silicon, I have obtained as low a watt loss as .96 watts per pound on 27 gauge strip, and 1.35 watts per pound on 24 gauge strip when tested straight grain, i. e., when the test is made on a sample tested in the direction of rolling, as cut, at 10 kilogausses, 60 cycles. The straight grain permeability at 16 kilogausses ranged from 500 to 550. In a grade of silicon steel containing, for example, 3.38% silicon, I have obtained as low a watt loss as .68 watts per pound on 29 gauge strip when tested straight grain as cut at 10 kilogausses, 60 cycles, and a straight grain permeability at 16 kilogausses of 800. It will be understood, of course, that core loss increases as the silicon content decreases, and that the figures given above are exemplary only, of materials commercially made in accordance with my process.

In connection with my process, it will be noted at once upon comparison, that it possesses a number of distinct advantages. While it embodies a box annealing step as such, yet this step is carried on at an advantageous point in the cycle as respects commercial economy. It is further to be noted that my box annealing step is also a decarburization step. A number of advantages result from this decarburization, and all three of the prime characteristics necessary in materials of this class are bettered thereby for reasons which will be clear from the foregoing. I have discovered that if silicon steel of approximately the gauge specified is box annealed with the hot mill oxide thereon, the material may very readily be decarburized. Although the hot rolled gauge may range up to .11 inch, I prefer to carry the material down to at least .07 inch, because in the lighter gauges the decarburization may be made complete with a shorter annealing time, and in some instances a continuous box anneal may be used. An excellent gauge for the hot rolled material I have found to be .06 inch. The box annealing temperature may range from 1200° F. to 1700° F.; but I prefer to operate as indicated, between 1350° F. and 1450° F. At these temperatures a relatively short soaking period is necessary, and I have found in general that the soaking period may be shortened to about two hours for low silicon steel, although this may vary with conditions. At 1200° F. however, a 24 hour soak was required for the same material to produce the same effect. No special atmosphere is required. Even a reducing atmosphere does not appear to prevent the decarburization.

Although I prefer to operate my box anneal to reduce the carbon to less than .01%, it is not always necessary to carry the decarburization to this extent to meet present specifications for low silicon material.

The material may be pickled in accordance with my third step immediately after the box annealing, or it may be given one cold rolling pass and then pickled, or it may be given a cold rolling pass, open annealed and then pickled. These alternatives are mentioned for the guidance of the man skilled in the art, only in case it is found difficult to pickle off the reduced scale after the box annealing.

It may be noted at this point that with the removal of the carbon, and with the cold rolling of the product, which constitutes step 4 of my process, the final annealing for the magnetic properties becomes a rapid open anneal which not only produces a better magnetic material, less expensively, but also produces a material which is not characterized by coil set. I have investigated temperatures for the final open anneal ranging between 1325 degrees F. and 1800 degrees F., and the time must of course be long enough to give good magnetic properties. For example, it requires about five minutes at 1325 for a low silicon material of the type for which specific data has been given above, while at 1700 degrees, the time may be shortened to 30 seconds. Hence I prefer to anneal at a temperature between 1700 degrees F. and 1800 degrees F., because of the increased production which this renders possible. If the open annealing is carried on in a furnace with controlled atmosphere, no final pickling is necessary, and this still further simplifies and decreases the cost of my process. The formation of a heavy oxide scale on the surface of the strip is likely to be an extraneous cause of poor die life; but if a heavy scale is formed during an open annealing in which the atmosphere was not properly controlled, it is of course, permissible to pickle the strip after the annealing.

The singular advantage in my process is that if the material is decarburized before the cold rolling, then grain growth and substantially complete strain removal will occur so rapidly in an annealing operation that a short open anneal with its commercial and metallurgical advantages can replace the customary box anneal. Cementite and pearlite are known to be detrimental to core loss qualities. My new material does not have a significant amount of cementite and pearlite. It also has a relatively very coarse grain.

I have been equally successful in rolling to either 24 gauge or 29 gauge, as well as intermediate gauges. Practically all silicon steel of this grade is rolled to these two gauges.

The fundamental steps in the exemplary process hereinabove described of the invention are the steps of decarburizing, cold rolling, and final open annealing. The strain rolling (steps 5 and 6) is optional, it being understood that core loss is improved by the strain rolling treatment. By this treatment is meant the interruption of the cold rolling at a point not far ahead of the desired final gauge for an open anneal (step 5) followed by a cold rolling to final gauge (step 6). By this treatment material more nearly isotropic in magnetic properties is obtained, having distinct advantages for rotating machinery over material having the same straight grained magnetic test but which has high directional properties.

On lower grades of magnetic steel which do not have to meet stringent magnetic require-

ments and which must be produced very cheaply, the strain rolling treatment may well be omitted. A better magnetic material can be produced from the same stock, however, by including the treatment. Considerations of cost may determine the choice. The best grades from the higher silicon steels should be given the treatment.

The cold rolling step of the strain rolling treatment for low silicon materials (step 6) may vary, say, from 5 to 12 or 15%; but from 7 to 10% seems to be commercially the most feasible range.

While I have described my process for low silicon materials as defined, it is not so limited. I have used it and determined its effects throughout the range of commercial materials, from silicon contents as low as .15% silicon to as high as 3.40% and 4% silicon. As the silicon content varies there are permissible changes in maximum final annealing temperatures, as well as the necessary or optimum percentages of strain rolling. It will be within the skill of the worker in the art, following my process to increase the temperatures of annealing as the percentage of silicon increases to obtain the best results, also to reduce the percentage of the cold rolling in step 6. As the percentage of silicon is increased from .15 to 4.0% the amount of strain rolling may be carried as low as 3%, if desired.

Modifications may be made in my process without departing from the spirit of my invention, as will be clear.

Having thus described my invention, what I claim as new and desire to secure by Letters Patent is:

1. A process of producing silicon steel having a silicon content of .15% to 4.0% which comprises reducing by hot rolling silicon steel containing carbon substantially within the range of .05 to .06% to a gauge which lies substantially between .06% and .11 inch, then decarburizing the hot rolled material by giving it a box annealing while the hot mill scale is still on its surfaces so as to reduce the carbon content of said steel to substantially no greater than .015%, then further reducing the material in gauge by cold-rolling.

2. A process of producing silicon steel having a silicon content of .15% to 4.0% which comprises reducing by hot rolling silicon steel containing carbon substantially within the range of .05 to .06% to a gauge which lies substantially between .06 and .11 inch, then decarburizing the hot rolled material by giving it a box annealing while the hot mill scale is still on its surfaces so as to reduce the carbon content of said steel to substantially no greater than .015%, then further reducing the material in gauge by cold-rolling, and developing the magnetic characteristics of the product thus obtained by a continuous anneal.

3. A process of producing silicon steel sheet or strip stock which comprises hot rolling silicon steel having a silicon content substantially between .15% and 4% and a carbon content substantially between .05% and .06% to reduce the said silicon steel to a gauge substantially between .06 and .11 inch and then reducing the carbon content of said silicon steel by box annealing the hot rolled stock with the hot mill scale thereon at a temperature between 1350° and 1450° F., cold rolling the material, and continuously annealing the material at a temperature above 1400° F.

4. A process of producing silicon steel sheet or strip stock which comprises hot rolling silicon steel having a silicon content substantially between .15% and 4% and a carbon content substantially between .05% and .06% to reduce the said silicon steel to a gauge substantially between .06 and .11 inch and then reducing the carbon content of said silicon steel by box annealing the hot rolled stock with the hot mill scale thereon at a temperature between 1350° and 1450° F., cold rolling the material and continuously annealing the material at a temperature above 1400° F., said cold rolling carrying the material to within 3 to 15% of final gauge, and after said continuous annealing again cold rolling the material so as to reduce it to final gauge, and giving the material a continuous anneal at a temperature above 1500° F.

5. A process of producing silicon steel having a silicon content of .15% to 4%, which comprises reducing by hot rolling silicon steel containing carbon substantially in excess of .015% to a gage which lies substantially between .06 and .11 inch, then decarburizing the hot rolled material by giving it a box annealing while the hot mill scale is still on its surface so as to reduce the carbon content of the steel to substantially no greater than .015%, then further reducing the material in gage by cold rolling.

6. A process of producing silicon steel sheet or strip stock which comprises hot rolling silicon steel having a silicon content substantially between .15% and 4% and a carbon content substantially in excess of .015% to reduce the said silicon steel to a gauge substantially between .06 and .11 inch, and then reducing the carbon content of said silicon steel to at most no greater than .015% by box annealing the hot rolled stock with the hot mill scale thereon at a temperature substantially between 1350 and 1450 degrees F., cold rolling of material and continuously annealing the material at a temperature above 1400 degrees F., said cold rolling carrying the material to within 3 to 15% of final gauge, and after said continuous annealing again cold rolling the material so as to reduce it to final gauge, and giving the material a continuous anneal at a temperature above 1500 degrees F.

7. A process of producing silicon steel having a silicon content of .15% to 4%, which comprises reducing by hot rolling silicon steel containing carbon substantially in excess of .015% to a gauge not greater than .11 inch and not lighter than .045 inch, then decarburizing the hot rolled material by giving it a box annealing while the hot mill scale is still on its surfaces so as to reduce the carbon content of the steel to substantially no greater than .015%, then further reducing the material in gauge by cold rolling.

8. A process of producing silicon steel having a silicon content of .15% to 4%, which comprises reducing by hot rolling silicon steel containing carbon substantially in excess of .015% to a gauge which lies substantially between .06 and .11 inch, then decarburizing the hot rolled material by giving it a box annealing while the hot mill scale is still on its surface so as to reduce the carbon content of the steel to substantially no greater than .015%, then further reducing the material by rolling to sheet gauge, and finally developing its magnetic characteristics by a heat treatment.

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CERTIFICATE OF CORRECTION.

Patent No. 2,236,519. April 1, 1941.

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It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 3, first column, line 41, claim 1, for ".06¢" read --.06--; 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 20th day of May, A. D. 1941.

Henry Van Arsdale,
Acting Commissioner of Patents.

(Seal).