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ELECTRICAL STEEL

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Original application February 18, 1932, Serial No. 593,783, and in Canada July 6, 1932. Divided and this application September 6, 1933. Serial No. 688,410

1 Claim. (Cl. 148—31)

This invention relates to electrical steels and is a division of my copending application, Serial No. 593,783, filed February 18, 1932, for Electrical steels and method of making same.

5 In an effort to improve the efficiency of different types of electrical apparatus, such for example as motors, dynamos, transformers and the like, it is customary to utilize a ferrous material, usually in the form of a series of sheets of laminae characterized by a high electrical efficiency from the standpoint for example of watt loss, magnetic permeability, low magnetic hysteresis and the like. In this connection it is known that sheets of iron-silicon, or iron-silicon-aluminum alloys constitute a superior material for this purpose.

My pending application above referred to describes and broadly claims the mechanical and thermal treatments which I have discovered are highly advantageous in imparting desired electrical properties to steels of this character, and also broadly claims my new and improved product. The present application is directed specifically to one of the several grades of electrical steels contemplated in my application above recited.

It is customary in the art to divide electrical steels into a number of different grades having reference to the particular use to which the steels are to be put. In my pending application above referred to I have set forth in detail several grades of electrical steels which may be made according to my invention and have tabulated the properties thereof. The present invention, as above stated, is particularly concerned with those electrical steels falling within a range hereinafter specified.

Present developments in electrical machinery and in methods of fabricating electrical steel parts therefor, have made it highly desirable that electrical steels be produced in strip form, the term "strip" being herein used in its commercially accepted sense in the metal rolling art. Unfortunately, it has been impossible to produce steels having the desired electrical properties in strip form because of process limitations. It is important that the strip be of suitable thinness in order to minimize eddy current losses, thereby to increase the electrical efficiency of the machine. It is impossible with present known methods to hot roll strip to the final thinness demanded by

makers of electrical machinery, and it has been necessary to cold roll the strip in order to get it down to the required gauge. Cold rollings, except in very limited amounts, has heretofore been considered unfeasible in the manufacture of electrical steels because such cold rolling introduces strains which are highly detrimental to the electrical properties. For this reason it has been considered necessary to have recourse to rolling processes such as pack rolling, whereby the steel was reduced substantially to final gauge while hot. These processes, however, are inapplicable to the manufacture of steel in strip form.

The present invention is preferably characterized by the step of deliberately introducing a strain by cold rolling in excess of any limits heretofore considered permissible, and thereafter subjecting the material having such excessive strain therein to a controlled treatment such that the strain in excess of the maximum limit is effectively removed, and only the desired strain for imparting the required electrical properties is retained. In this manner I retain only that amount of strain which has heretofore been determined as being decidedly beneficial, and make the process adaptable to the production in quantity of electrical steels. The adaptation to the strip process also enables the production of a product having materially greater lengths than has heretofore been possible, and thereby correspondingly reducing the fabricating costs in the manufacture of electrical apparatus. This will be readily apparent when it is considered that it is entirely possible to produce, in accordance with my invention, the desired grade of electrical steel in strip form having a length, for example, in the neighborhood of 1000 feet, and capable of being automatically fed to a suitable punch or the like such as utilized in the fabrication of the material. Heretofore electrical steels could only be produced in lengths not to exceed approximately 15 feet. Such individual pieces required individual handling and feeding to the punches and the like, and therefore required the constant attendance of an operator.

In the accompanying drawing I have shown more or less diagrammatically, by way of illustration only, certain preferred embodiments of the present invention. In the drawing, Figure 1 is a diagrammatic view, partly in side

elevation, illustrating the various treatment steps to which strip material may be subjected in accordance with the present invention;

Figure 2 illustrates a modified method of heat treating material produced in accordance with the present invention;

Figure 3 is a chart illustrating one method of effecting partial strain removal prior to final heat treatment;

Figure 4 is a diagrammatic view, partly in side elevation, illustrating a slightly modified form of treatment from that shown in Figure 1; and

Figure 5 is a view similar to Figure 4, illustrating still another embodiment of my invention.

While it will be understood that Figures 1, 4 and 5, respectively, illustrate different manipulative steps, processes or treatments to which the material is subjected in attaining the desired results, as the description proceeds, the relevancy of the different steps to the invention will become more clearly apparent.

Having reference more particularly to Figure 1 of the drawing, I have shown a slab 2 of desired composition suitable for use in accordance with the present invention. This slab is subjected to hot rolling, as commonly practiced in the art, in a suitable series of hot rolling mills 3 of such nature as to form a hot rolled strip, herein illustrated in the form of a coil 4. It may be assumed, by way of example only, that the hot rolled strip thus produced and which is substantially free from any cold working strains, has a thickness of .0625 inches, and any desired width. I prefer to use a minimum finishing temperature of approximately 1300° F. This hot rolled strip, in accordance with the present invention, is subjected to a cold rolling operation in a continuous mill 5, herein illustrated as comprising four roll stands of the four-high type arranged in tandem.

By way of illustration only, it may be further assumed that the setting of the cold rolling mills is such as to reduce the thickness of the hot rolled strip to approximately .024 inches, this being a reduction of .0385 inches, equal to approximately 61%. It will be apparent to those skilled in the art that the figures herein given are representative of thicknesses frequently produced in the cold rolling of steel for purposes other than the production of electrical steels.

The cold rolling operation, while it is effective for reducing the hot rolled strip to the desired finished gauge, introduces in such material, by reason of the reduction effected, a strain which is far in excess of the strain heretofore thought permissible in the production of steels to be used for electrical purposes. In accordance with the present invention, however, I take advantage of the strain introduction effected by such a cold rolling operation, and consider such strain as representing a desirable component and an undesirable component. In accordance with the present invention, the strip having these two strain components is subjected to a special heat treating operation of such nature as to retain the desirable component and eliminate the undesirable component.

It may be assumed that the strip leaving the cold rolling mill 5 is formed into a coil 6 for convenience in handling. This coil is then placed in a suitable coil box 7 located in the desired relationship to the charging end of a heat treating furnace 8 provided with suitable burners or resistors 9 effective for maintaining the desired temperature conditions therein. The coil 6 is progressively unwound from the coil box 7 and

passed in single thickness through the furnace 8 at a speed which is determined not only upon the temperature conditions existing within the furnace, but also upon the composition of the material undergoing treatment, the thickness of such material and the amount of strain introduced therein by the cold rolling operation. Upon leaving the heat treating zone provided by the furnace 8, the strip material may again be formed into a coil 10, which will be characterized, as will be hereinafter more fully explained, by the elimination of the undesirable strain component and will have only the desirable strain component remaining therein. This coil may then be subjected to a final heat treating operation as by subjecting it to a box annealing operation in coil form in an annealing box 11. Upon removal from the annealing box, the strip material in coil form may be sold as an article of manufacture for use in the fabricating of electrical equipment, or may be cut into individual sheets and so sold for fabrication. When retained in coil form it is possible to obtain all of the advantages hereinbefore referred to with respect to use in automatic fabricating machines with a minimum of expense, attention and handling.

In other cases, the coil 10 as formed at the delivery end of the heat treating furnace 8 may be sheared into individual sheets 12, which sheets when placed in superimposed relationship as illustrated in Figure 2, may be subjected to a box annealing operation in a suitable annealing box 14. After the desired annealing operation, the sheets 12 as such may then be sold for use.

In my application above referred to I have pointed out that the strain resulting from the cold rolling operation increases with the silicon content, and that with any given silicon content the undesirable strain component which is to be removed by the thermal treatment varies with the reduction effected by cold rolling, the strain increasing with increased reductions, and decreasing with decreased reductions.

In said application I have set forth in addition to these general principles a specific example of a heat treatment for strip containing approximately 1% of silicon, which strip had been subjected to a 61% reduction by cold rolling to attain a final thickness of .025 inches. As there stated, I have successfully employed a continuous heating furnace, as indicated at 8 in Figure 1, which furnace had a length of 30 feet and was maintained, at the point of highest temperature in the furnace, at approximately 1900° F.

In Figure 3 I illustrate diagrammatically the example given in said application, namely, the thermal treatment of strip containing 1% silicon and also illustrate the thermal treatment for a strip whose silicon content is within the specific range covered by this application.

The curve of Figure 3 is obtained by plotting the thickness of the material against the heating time in seconds, and the point A on the curve represents a total heating time of two minutes for a 1% silicon strip having a thickness of .025 inches. As stated, the furnace was 30 feet long and the strip was passed through it at a rate of 15 feet per second, thus giving a total heating time of two minutes or 120 seconds. I have estimated that in the particular furnace employed the heat penetrated sufficiently rapidly to bring strip of this thickness up to the desired minimum temperature in approximately 30 seconds. The additional 90 seconds of heating time was available for continued heating. Under the above

conditions the heat treatment eliminated the undesirable strain component and left the desirable strain component therein.

It is generally assumed that the rate of heat penetration varies directly with the thickness of the material; and hence if the strip being treated were only half as thick, that is to say, .0125 inches, then only 15 seconds would be required to bring it up to the desired minimum temperature. Adding to this the continued heating time of 90 seconds, the total time for treating such strip would be 105 seconds. This condition is indicated by the point B on the curve 50. As stated, if, as is generally assumed, the rate of heat penetration varies directly with the thickness of the material, the curve for determining the length of time for treating strips of different thicknesses will be a straight line connecting the points A and B. The points C, D, E and F have been marked on this line in Figure 3 to show the time required for heat treating strips having thicknesses, respectively, of .014, .016, .018 and .020 inches.

The curve 51 of Figure 3 illustrates diagrammatically the proper heating time for steel containing 3% silicon in the above described furnace. As shown by the point G of this curve, the heating time for material having a thickness of approximately .025 inches is 135 seconds, and following the same process of reasoning as set forth above with respect to 1% silicon steel, the heating time for strip having a thickness of .0125 inches would be 120 seconds, as indicated by the point H.

As set forth in my application above referred to, it may be necessary to adjust the thermal conditions to meet whatever limitations of mill practice may be encountered. It will be found that as the silicon content increases, the difficulties of hot rolling will increase, and therefore it may be expedient in many cases to terminate the hot rolling at some gauge which will require a greater percentage of reduction by cold rolling than is set forth in the above examples. Under these circumstances the thermal treatment may be readily adjusted to meet such conditions by following the principle above set forth.

As stated, the silicon content of electrical steels will be varied considerably depending on the desired grade of the final product. I have classified electrical steels made according to my invention as follows:

	Percent silicon
Armature grade-----	.3 - .7
Electrical grade-----	.75-1.5
Special motor grade-----	2.0 -3.0
Special dynamo grade-----	2.75-3.5
Regular transformer grade-----	3 -6
Special transformer grade-----	3 -6
Extra-special transformer grade-----	3 -6

My improved product is generically claimed in my application above recited, and the armature, electrical and special motor grades are also specifically claimed therein. The present application is directed to steels which I have herein classified for purposes of reference as the special dynamo grade. The several transformer grades are covered by my pending application, Serial No. 688,411, filed of even date herewith.

I tabulate below the electrical properties of the "special dynamo" grade, giving the electrical loss in watts per pound and per kilogram at frequencies of both 50 and 60 cycles at the assumed specific gravity indicated. In each case the watt loss is given for a flux density of 10,000—B and deter-

mined in accordance with specification A-34-28 of the American Society for Testing Materials.

Special dynamo (assumed sp. gr. 7.50)

Silicon 2.75-3.5—U.S. standard gauges

	30 G.	29 G.	28 G.	27 G.	26 G.	25 G.	24 G.
Watts per lb.—60 cycles-----	.85	.86	.90	.95	1.00	1.05	1.10
Watts per kg.—60 cycles-----	1.87	1.89	1.98	2.09	2.20	2.31	2.42
Watts per lb.—50 cycles-----	.68	.70	.73	.77	.82	.86	.90
Watts per kg.—50 cycles-----	1.50	1.55	1.61	1.70	1.81	1.89	1.98

It will be noted that my invention provides in this grade of material electrical steel in the form of strip containing from 2.75 to 3.5% silicon and having electrical properties characteristic of those obtained when a steel of substantially the same silicon content within such range is subjected to heavy reduction by cold work, followed by heating to remove part but not all of the strain thus imparted, cooling and then annealing, the watt loss property of such strip being not more than about 1.1 watts per pound in 24 gauge thickness, and decreasing as the thickness of the strip decreases.

With the embodiment of the invention illustrated more particularly in Figure 1 of the drawing, it will be understood that the coil material as delivered by the annealing box 11 for example, will have a coil set which will be reflected in the individual pieces formed therefrom. Inasmuch as it is customary to stack laminations in piles in the production of electrical equipment, this slight curvature reflected in the individual lamina may be objectionable. In accordance with the embodiment of Figure 2, the coil set may be eliminated, but in this case it is not possible to furnish to a customer a material in coil form with its consequent advantages. In cases where the advantages of a coil without the objection as to coil set are required, I may practice a method as illustrated diagrammatically in Figure 4.

In this figure, I have shown a furnace indicated as being a bell type electric furnace characterized by the ability to closely control temperature conditions. I may place within such furnace a coil produced in any desired manner, such for example as the product of the cold rolling mill 5 of Figure 1 and subject the coil to such accurately controlled heat treating conditions as to effect removal only of the undesirable strain component.

Thereafter this coil may be placed in a suitable coil box 16 and passed through a heat treating furnace 17 corresponding to the furnace 8 of Figure 1 and effective for giving the final heat treatment to the material. Instead of coiling the material at a point closely adjacent the top of the furnace 17, I may carry it to a point appreciably removed therefrom before forming it into a coil 18. The location of the coil 18 relatively to the furnace 17 will be such that the material will have cooled to such an extent that it will not have a tendency even when coiled to take a coil set, but will always tend to return to its substantially flat condition.

In Figure 5, I have also illustrated one method of practicing the invention by means of which the desired results may be obtained. In this figure I have shown an annealing box 19 having coils of material 20 therein. These coils may be the product either of a cold rolling mill as shown in

Figure 1, or of the usual hot mill. In the annealing box they are subjected to a suitable heat treating operation. Upon removal from the annealing box the coils may be placed in a suitable coil box 21 and fed therefrom between rolls 22 of a suitable mill effective for introducing a desired strain component into the material to the extent required to impart the desired electrical properties. Thereafter the material with this strain, representing only the desirable strain component, may be passed through a furnace 23 corresponding to the furnaces 8 and 17, and then at a suitably remote point coiled into a coil 24. In this coil 24 the material will possess the same attributes as the material in coil 18 of Figure 4.

In accordance with the embodiments of the invention of Figures 4 and 5, it is possible to produce as an article of manufacture a coil of electrical strip wherein the strip itself is substantially free from any objectionable coil set of the character referred to.

It will be understood that when practicing the form of the invention shown in Figures 1 and 2, the annealing box temperatures will be such as to effect final removal of the strain. I have found

that this temperature may vary within the range of from 1500 to 1700° F., although the lower temperature ranges of from 1550 to 1650° are preferable. The same will of course be true of the heat treating furnaces 17 and 23.

I have illustrated and described herein certain specific ways in which my improved product may be obtained, but it will be understood that this is by way of example only and that said product may be otherwise manufactured or produced within the scope of the following claim.

I claim:

As a new article of manufacture, electrical steel in the form of strip, containing from 2.75% to 3.5% silicon and having electrical properties characteristic of those obtained when a steel of substantially the same silicon content, within such range, is subjected to heavy reduction by cold work followed by heating to remove part but not all of the strain thus imparted, cooling, and then annealing, the watt loss property of such strip being not more than about 1.1 watts per pound in 24 gauge thickness, and decreasing as the thickness of the strip decreases.

EDWARD M. FREELAND.

30	105
35	110
40	115
45	120
50	125
55	130
60	135
65	140
70	145
75	150