

UNITED STATES PATENT OFFICE

2,582,382

PRODUCTION OF ELECTRICAL STEEL STRIP

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No Drawing. Application November 23, 1946,
Serial No. 711,830

10 Claims. (Cl. 148—12.1)

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This invention relates to the production of electrical steel strip. In recent years the demands of the electrical industry for steels having good magnetic properties as to core loss and permeability have increased tremendously and many processes have been devised for attaining these desirable properties. In general, such processes are rather long and expensive.

In general, if it is desired to produce a steel having certain magnetic properties, it is necessary to start with silicon steel stock of a certain analysis because the electrical properties of the final end product are dependent upon the silicon content of the steel used as a starting material.

It is an object of our present invention to produce with a given starting material electrical steel having properties better than would normally be expected of that particular starting material. As a variant of this object, it is an ancillary object of our invention to provide a process whereby electrical steel of a certain quality may be produced starting with a material of lower silicon content than would normally be necessary in order to produce the desired end product.

This invention has to do particularly with electrical steels produced by a process in which the first step involves hot rolling to gauge. When steel sheets or strip are hot rolled the product will be covered with oxides commonly known as mill scale. It has been conventional as a step in present processes to acid pickle the material in order to remove the mill scale. It is an object of our present invention to eliminate the pickling step by conducting an annealing operation in a reducing atmosphere whereby the hot mill scale is reduced, and a surface unusually conducive to long life of punching dies is formed.

Another object of our invention is to improve the quality of the product by decarburizing the steel at the same time as the mill scale is being reduced and concurrently to improve the quality of the steel by annealing to produce an increase in grain size.

We find that there are two temperature ranges which are valuable in that they favor decarburization. One range is from substantially 1400° F. to substantially 1725° F., and the other is from substantially 1900° F. to substantially 2150° F. For producing material having only moderate magnetic properties the lower of these ranges will also contain a temperature which will anneal satisfactorily and in such cases it is an object of our invention to conduct the decarburization, mill scale reduction, and anneal to develop the re-

quired magnetic properties concurrently within this range.

For producing material of somewhat better magnetic properties a higher temperature anneal between the two decarburizing temperature ranges may be desirable. In this case it is an object of our invention to conduct the decarburization and mill scale reduction within the lower temperature range, and then to conduct the anneal to develop the magnetic properties at a higher temperature.

For optimum magnetic properties, an anneal as high as the upper decarburizing temperature range will be required and in this case it is a further object of our invention to conduct the decarburization, mill scale reduction, and anneal to develop the magnetic properties concurrently within this upper range.

In general, the objects of our invention include the production from relatively low silicon steel sheet stock of electrical steel strip having improved electrical properties which would not ordinarily be expected of the particular starting material, and to produce electrical steel strip which has an excellent die life.

These and other objects of our invention which will be pointed out in more detail hereinafter or which will be apparent to one skilled in the art upon reading these specifications, we accomplish by that series of method steps of which we shall now describe exemplary embodiments.

In the production of silicon steel strip of desirable electrical properties it has been customary to hot roll the starting material into sheets of the required gauge. The sheets have been given a light cold rolling pass for flatness and subjected to a box anneal for the purpose of enhancing the electrical and physical properties; and the box anneal has been followed by an acid pickling operation. After being pickled, the sheets have been scrubbed and dried, welded end to end to form a strip and then given a coating for the purpose of giving the material a higher surface electrical resistivity.

According to our present invention, we hot roll the material to gauge as before and give it a light cold rolling pass for flatness, but instead of proceeding with the box anneal as above outlined, we immediately weld the sheets end to end to form a strip and then subject the strip to an open anneal without carrying on a pickling operation, so that the hot mill scale is still on the strip; whereby, if our present teachings are observed, the material is decarburized, the hot mill scale is reduced, and the grain size is in-

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creased for optimum electrical properties. By this procedure, less scrap is produced and the welds are annealed along with the strip, so that they have a greater resistance to breakage.

By an open anneal we do not mean that the furnace atmosphere is not controlled or confined; by an open anneal, we mean an anneal in a furnace in which the atmosphere is confined and controlled, and in which the strip is open to the action of the furnace atmosphere on both sides. In order to produce a reduction of the ordinary mill scale, it is necessary that the furnace atmosphere be reducing. We have preferably carried out our treatment in a furnace in which an atmosphere of dissociated ammonia is maintained, but an all-hydrogen atmosphere or other hydrogen-bearing atmosphere which is reducing with respect to iron oxide will be effective. The scale is attacked both by the reducing atmosphere and the carbon in the steel, and as a result of the combined reaction between the carbon, the scale, and hydrogen, the steel is decarburized and the mill scale is reduced to iron containing micro particles of silica.

This reduced scale adheres well to the base metal and can readily be given a subsequent surface insulating treatment according to the procedures disclosed and claimed in the copending application of Carl E. Gifford, Serial No. 620,055, filed October 3, 1945, now Patent No. 2,501,846, dated March 28, 1940.

There are two ranges of temperature which favor decarburization. In the production of material up to what is known commercially as "Special Electric Grade" (having a core loss down to about .83 watt per pound in 29 gauge material) a good decarburizing and annealing range is from substantially 1400° F. to substantially 1725° F.

To make higher quality material such as "Intermediate Transformer Grade" or better (having a core loss of less than .83 watt per pound) a good decarburizing and annealing range is from substantially 1900° F. to substantially 2150° F.

Thus, in the manufacture of lower grade electrical steels up to and including "Special Electric Grade" our process involves hot rolling the material into sheets of the required gauge, light cold rolling for flatness, welding the sheets end to end to form a strip, and subjecting the strip to an open anneal at a temperature of from substantially 1400° F. to substantially 1725° F. in a reducing atmosphere. By this procedure, we attain greater economy in furnace operation with excellent magnetic qualities in the product, which will also have a superior die life, together with an increased economy by virtue of a less extensive processing of the material.

In the production of higher grade electrical steel such as "Intermediate Transformer Grade" (having a core loss less than .83 watt per pound), we carry out the same procedure outlined above, except that we operate the furnace at a temperature between substantially 1900° F. and substantially 2150° F. As a result of this treatment, we achieve a material having better electrical properties than would normally be expected from a steel of the particular silicon content of the starting material; while achieving also an improvement in die life, greater ductility in the material, and the same reduction in processing, as outlined above.

As an alternative to the last mentioned procedure, we may operate the bulk of the furnace at a temperature from substantially 1400° F. to

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substantially 1725° F. for decarburization, and maintain only the final portion of the furnace at a temperature between substantially 1900° F. and substantially 2150° F. for additional grain growth. We are able to achieve greater economy in furnace operation in this way because only a portion of the furnace is operated at high temperature.

In general, therefore, we will operate the furnace at the lower temperature range (1400° F. to 1725° F.) for the entire operation, and only where an annealing temperature for achieving proper grain size is found to be over 1725° F. would we raise the temperature in the final portion of the furnace to the required temperature. If the final annealing temperature must be above 1900° F. then, of course, we may operate the entire furnace at a temperature above 1900° F., because as pointed out above, the range from substantially 1900° F. to substantially 2150° F. is also a range which favors decarburization. The annealing time is about one minute in the hot zone for an element of the strip, in 29 gauge material. For heavier gauges this time must be increased.

We have pointed out above that we can use a material of relatively low silicon content to produce an electrical steel of higher quality. As an example, in the production of a material having a core loss not exceeding .72 watt per pound at 10 kilogausses and 60 cycles per second in 29 gauge material, it has been necessary to use a starting material containing about 3.60 per cent silicon. By the use of our new process we have produced a material having substantially the same electrical properties starting with a material containing only 2.60 per cent silicon, and have produced a material having a better ductility and die life, and have produced it more cheaply.

It will be clear that numerous modifications may be made without departing from the spirit of our invention, and we therefore do not intend to limit ourselves except as pointed out in the claims which follow.

Having now fully described our invention, what we claim as new and desire to secure by Letters Patent is:

1. The method of economically producing electrical steel strip having surface properties conducive to long life of punching dies, from silicon steel, which comprises hot rolling silicon steel to sheets of final gauge, welding a number of said hot rolled sheets end to end to form a strip, and subjecting said strip, with its surfaces still covered with the hot mill scale, to an open anneal in a reducing atmosphere within the divided range from substantially 1400° F. to substantially 2150° F., exclusive of the range between substantially 1725° F. and substantially 1900° F., whereby to effect decarburization of the steel and reduction of the scale thereon, to provide a product devoid of loose surface substances and hence not requiring pickling.

2. The process of claim 1 wherein said open anneal is a heat treatment at a temperature of from substantially 1400° F. to substantially 1725° F.

3. The process of claim 1 wherein said open anneal is a heat treatment at a temperature of from substantially 1900° F. to substantially 2150° F.

4. The process of claim 1 wherein the strip is decarburized at a temperature from substantially 1400° F. to substantially 1725° F., after which the

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temperature of the strip is raised to a temperature within a range extending from substantially 1725° F. to substantially 2150° F., whereby to produce improved magnetic properties.

5 The method of economically producing electrical steel sheet stock which comprises hot rolling silicon steel to sheets of final gauge and subjecting the stock with its surfaces still covered with the hot mill scale to an open anneal in a reducing atmosphere within the range of substantially 1400° F. to substantially 2150° F., whereby to effect substantial reduction of the scale thereon to provide a product devoid of loose surface substances tending to flake off upon punching, of improved punching performance as respects die life, having a lowered carbon content, and enhanced magnetic characteristics.

6 A silicon steel sheet stock having an enhanced die life and good electrical properties as produced by the process of claim 5.

7 A silicon steel sheet stock having an enhanced die life and good electrical properties, as produced by the process of claim 5, and bearing upon its surface an insulative phosphate coating.

8 The process claimed in claim 5 including the step of forming on the surface of the said strip an insulative phosphate coating.

9 A silicon steel sheet stock in the form of

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a welded strip, having an enhanced die life and good electrical properties, as produced by the process of claim 5.

10 A silicon steel sheet stock in the form of a welded strip, having an enhanced die life and good electrical properties, as produced by the process of claim 5, and bearing upon its surface an insulative phosphate coating.

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