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PROCESS OF TREATING SILICON IRON STRIP

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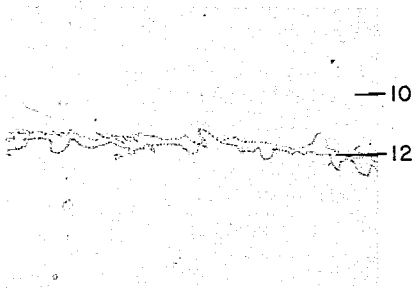


Fig. 1

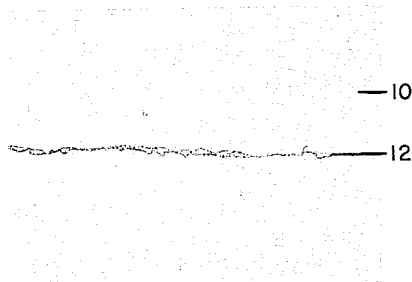


Fig. 2

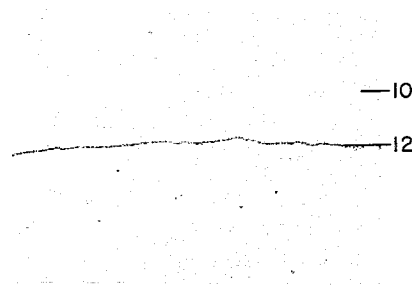


Fig. 3

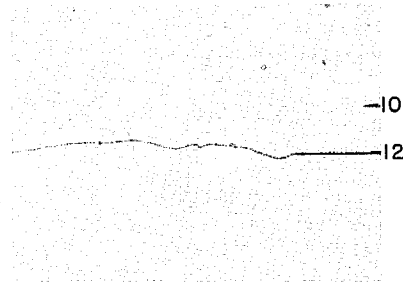


Fig. 4



Fig. 5

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PROCESS OF TREATING SILICON IRON STRIP

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2 Claims. (Cl. 148—111)

This invention relates to the process of producing light gauge magnetic strip material and in particular to the production of silicon-iron magnetic strip material having a thickness of 0.001 to 0.007 inch.

Heretofore magnetic materials, such as silicon steels containing between 1.5% and 4.5% silicon with extremely low amounts of carbon, usually less than 0.007% have been subject to a number of rolling and heat treating operations in order to reduce the gauge of the material to the range between 0.010 and 0.018 inch in thickness prior to the final cold rolling to the extremely light gauge in the range between 0.001 and 0.007 inch in thickness. Prior to the final cold rolling to the desired gauge, the magnetic material is subjected to an annealing heat treatment at an extremely high temperature to develop certain magnetic properties therein. However, it has been found that the silicon-iron strip materials so processed were not always capable of being cold rolled to such light gauge. For some unknown reason, certain of the silicon-iron strip materials appeared to possess an inherent brittleness despite the fact that identical processing steps had been applied to each unit in producing the fully annealed strip having a thickness of 0.010 to 0.018 inch.

Since the magnetic material from which the desired light gauge material is to be rolled, is usually subjected to an annealing heat treatment at a temperature of about 2000° F., an extremely large grain size is developed in these materials, thereby rendering the material less ductile than the fine grained starting material. While the large grain size is desirable in the end use, it produces fabrication difficulties because of its lower ductility in rolling to the final gauge size of between 0.007 and 0.001 inch in thickness. Thus while the material possesses a large grain size after the annealing treatment which results in lower ductility than the starting material, it is apparent that the remaining ductility must be preserved without destroying the grain size or orientation characteristics.

An object of this invention is to provide a heat treatment to be applied to the fully annealed silicon-iron magnetic strip material to increase its ductility without destroying its extremely large grain size to facilitate the cold rolling thereof to a thickness of between 0.001 and 0.007 inch.

A more specific object of this invention is to provide for heat treating fully annealed silicon-iron magnetic material at a temperature in the range between 1400° F. and 1550° F. for a time period of from about one minute to about four minutes to increase the ductility thereof without adversely affecting the grain size or orientation characteristics of the said material whereby the strip material is readily cold rolled to a thickness of between 0.001 and 0.007 inch.

These and other objects of this invention will become apparent to one skilled in the art when taken in conjunction with the description and the drawings in which:

Figure 1 is a photomicrograph taken at magnification of 500 times of fully annealed silicon-iron magnetic strip material;

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Fig. 2 is a photomicrograph taken at a magnification of 500 times of the fully annealed silicon-iron strip material after being subjected to a heat treatment at 1200° F. for one minute;

Fig. 3 is a photomicrograph taken at a magnification of 500 times of the material of Fig. 1 after being subjected to a heat treatment at 1300° F. for one minute;

Fig. 4 is a photomicrograph of the material of Fig. 1 taken at a magnification of 500 times after being subjected to a heat treatment at 1400° F. for one minute; and,

Fig. 5 is a photomicrograph of the material of Fig. 1 after being subjected to a heat treatment at 1500° F. for one minute.

In its broader aspects, this invention comprises a heat treatment which is applied to a fully annealed silicon-iron magnetic strip material prior to final cold rolling to the desired light gauge, at a temperature within the range between 1400° F. and 1550° F. for a time period ranging between one and four minutes depending upon the thickness of the magnetic material. The steel to which the process of this invention is applied comprises silicon in the range between 1.5% and 4.5%, an initial carbon content of about 0.04% maximum carbon and the balance iron with incidental impurities.

The silicon-iron steel to which this invention is applied is produced in accordance with well-known steel mill practice, an ingot of such steel being hot rolled in one or more rolling operations until it has been reduced to strip form having a thickness of about 0.080 inch. Such hot rolled strip material is then cold reduced in one or more cold rolling operations with one or more intermediate normalizings until an intermediate desired gauge of between 0.010 and 0.018 inch in thickness has been reached. The cold rolled strip material is then box annealed in a decarburizing atmosphere at a temperature of about 2000° F. to reduce the carbon content to below 0.007%, develop the magnetic characteristics, and render the strip ductile as is well-known in the industry. In practice it is found that such processing is not uniformly effective in producing maximum ductility as the strips of silicon steel so produced vary in their inherent brittleness even after identical heat treatments.

While the reason for such erratic ductility characteristics is not altogether understood, it has been determined that even though the carbon content of the fully annealed steel is reduced to a value below 0.007% through the decarburizing anneal, sufficient carbides agglomerate at the grain boundaries in the form of a substantially continuous envelope to seriously detract from or impair the ductility of the fully annealed material. When the light gauge strip is produced in accordance with known practices, the effect of the agglomeration of carbides appears to be more pronounced where a large grain size has been imparted to the fully annealed strip.

In accordance with this invention, in order to overcome the adverse effect of the agglomeration of carbides found in the fully annealed silicon-iron strip material, the strip is subjected to an annealing treatment at a temperature in the range of between 1400° F. and 1550° F. for a time period ranging between one minute and four minutes depending upon the thickness of the magnetic material, the thickness usually being in the range between 0.010 and 0.018 inch. After treatment within the temperature range for the given time, the heat treated silicon-iron is usually quenched at a rate sufficiently fast to prevent any carbide precipitation at the grain boundaries. In practice it is found that air quenching is sufficient on materials of light gauge, for example, about 0.018 inch in thickness. Such heat treatment effectively breaks up the continuity of the carbide envelope so that sufficient ductility is developed in the fully annealed strip with the re-

sult that such treated strip can be readily cold roll reduced to the desired light gauge of between 0.001 and 0.007 inch. In all cases the treated silicon-iron strip is pickled to remove any oxide film which may have been formed during the processing prior to cold rolling to final gauge.

The effect of the treatment of this invention is illustrated and can be explained on the basis of the photomicrographs of Figs. 1 through 5 of the drawing. Each of the photomicrographs are of the same material, namely, a 3.30% silicon-iron fully annealed strip of a thickness of 0.012 inch and having extremely large ferrite grains 10 but subjected to different heat treatments, the photomicrographs being taken at a magnification of 500 times with the samples having been given a nital etch. In Fig. 1 there is shown the fully annealed but inherently brittle material described hereinbefore, such strip material having the band or envelope of agglomerated carbides 12 between adjacent grains 10. The band of agglomerated carbides 12 is quite broad and seriously detracts from the ductility of the fully annealed magnetic strip material. When such fully annealed strip is heat treated at a temperature of 1200° F. for one minute it is found that the ferrite grains 10 retain their extremely large size but that the band of agglomerated carbides 12 between the adjacent ferrite grains 10 becomes somewhat narrowed as clearly illustrated in Fig. 2. However, the band of agglomerated carbides 12 is still quite broad after such heat treatment and the magnetic material remains quite brittle. When the strip is subjected to a heat treatment at a temperature of 1300° F. for a time period of one minute, it is found that the layer of agglomerated carbides 12, as shown in Fig. 3, is partially dispersed into the adjacent ferrite grains 10 but that an envelope of the carbides 12 still remains surrounding each grain to impair the ductility of the magnetic strip material. However, upon increasing the temperature of treatment to between 1400° F. and 1550° F. in accordance with this invention, the continuity of the band of agglomerated carbides 12 is sufficiently broken and in some cases disappears as illustrated in the photomicrographs of Figs. 4 and 5 so that the magnetic strip material possesses sufficient ductility to permit it to be rolled to the desired final gauge. As shown in Fig. 4, the major portion of the band of carbides has been destroyed or eliminated by the treatment at 1400° F. for one minute. When the treatment is at 1500° F. it is found that the banded carbides 12 which were quite evident in Fig. 1 are substantially eliminated, only a faint trace thereof being found at the grain boundary interface as shown in Fig. 5. It will be noted that in each of the photomicrographs of Figs. 4 through 5, that the large grain size of the ferrite grains 10 has not been disturbed but that the band of agglomerated carbides 12 found in the fully annealed strip and in such strip as treated at a temperature below 1400° F. has been, for all practical purposes, eliminated. It is pre-

ferred to treat the fully annealed strip material at not more than 1550° F. as exposure of the strip to such higher temperatures in air causes excessive oxidation of the silicon-iron strip.

As was stated hereinbefore the reason for the agglomeration of the carbides at the grain boundary interfaces is unknown, however, its effect upon the ductility has made itself known. The simple heat treatment of this invention effectively improves the ductility and requires no special skills nor apparatus. The time at temperature is sufficiently short that heavy scaling is not encountered nor is a protective atmosphere required. Further the effect of the processing to produce the fully annealed strip and develop an extremely large grain size and to develop the magnetic characteristics thereof is not detrimentally affected but instead the ductility of the inherently brittle material is improved.

I claim:

1. In the process of rolling extremely thin gauge magnetic material to less than 0.007 inch in thickness from a silicon steel containing between about 1.5% and 4.5% silicon and less than 0.007% carbon and being of a thickness in the range between 0.010 inch and 0.018 inch in thickness which has been box annealed in a decarburizing atmosphere, the improvement comprising, subjecting the fully annealed silicon steel to a heat treatment at a temperature in the range between 1400° F. and 1550° F. for a time period ranging between one minute and four minutes, cooling said steel at a rate sufficiently fast to prevent carbide precipitation at the grain boundary, and cold roll reducing the thickness of the silicon steel to between 0.001 and 0.007 inch in thickness.

2. In the process of rolling extremely thin gauge magnetic material to a thickness in the range between 0.001 and 0.007 inch in thickness from a silicon steel containing about 1.5% to 4.5% silicon and less than 0.007% maximum carbon said steel having a thickness in the range between 0.010 and 0.018 inch in thickness which has been box annealed in a decarburizing atmosphere, the improvement comprising, subjecting the fully annealed silicon steel to a solution heat treatment in the range between 1400° F. and 1550° F. for a time period ranging between one minute and four minutes to distribute agglomerized carbide in solution within the adjacent grains to thereby enhance the ductility of said steel, cooling the steel at a rate sufficiently fast to prevent carbide precipitation between the grains, and cold roll reducing the thickness of the silicon steel to between 0.001 and 0.007 inch in thickness.

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