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NON-DIRECTIONAL ORIENTED SILICON-IRON

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Fig. 1

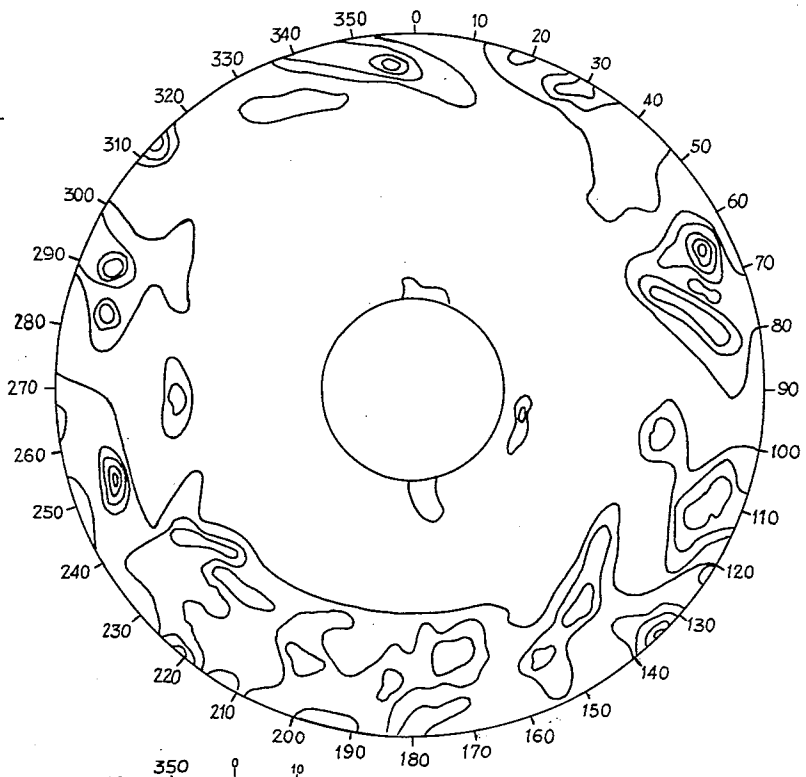
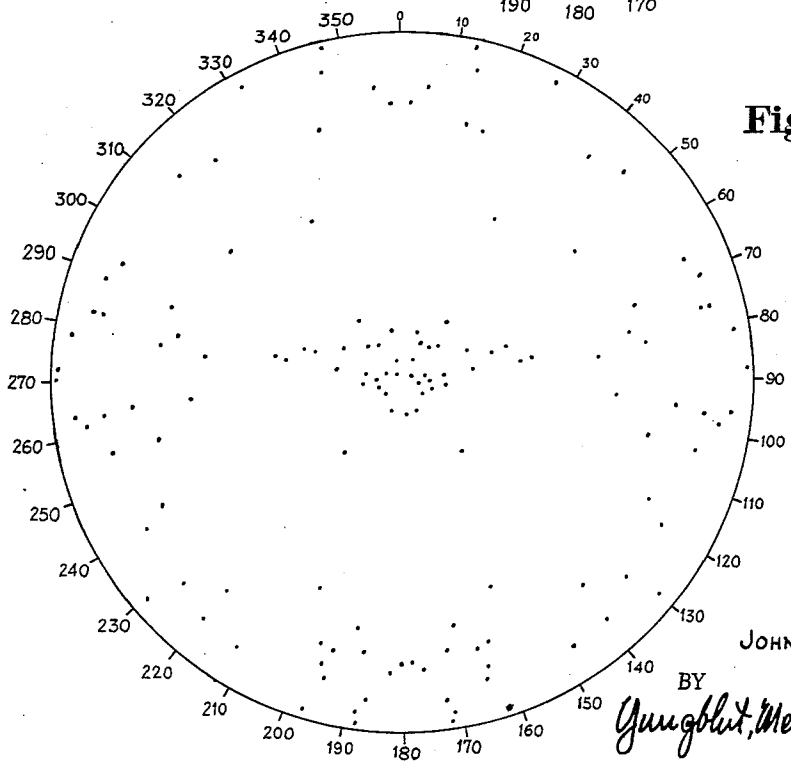


Fig. 2



INVENTOR.
JOHN M. JACKSON,

BY

Gunnoblet, Melville, Shaner & Foster

ATTORNEYS.

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NON-DIRECTIONAL ORIENTED SILICON-IRON

John M. Jackson, Middletown, Ohio, assignor to Armco Steel Corporation, Middletown, Ohio, a corporation of Ohio

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This is a continuation-in-part of application Serial No. 706,091, filed December 30, 1957, now U.S. Patent 3,061,486, issued October 30, 1962 for Non-Directional Oriented Silicon-Iron in the name of the same inventor.

Silicon-iron sheet stocks having a high degree of preferred orientation have come into widespread commercial use. For the most part, such silicon-iron sheet stocks have had a crystal orientation which may be designated as (110) [001] in the standard notation of Miller's indices; and the products have exhibited a high permeability in the rolling or straight-grain direction, but a poor permeability in all other directions.

There are numerous uses for silicon-iron sheet stocks in which a highly directional permeability is not desired. For example, in rotating electrical machinery where the laminations are punched as one piece, it would be of great advantage if the permeability could be made both high and substantially equal in all directions in the plane of the sheet stocks. So far as is known, this has never hitherto been accomplished in practice. Where a substantially equal permeability has been desired in all directions within the plane of the sheet stock, the practical art has endeavored to meet the need by producing stock characterized by random crystal orientation. The permeabilities in the various directions may be substantially equal in a randomly oriented material; but the permeabilities will be relatively low in all directions because of the random orientation. It is a primary object of this invention to provide a silicon-iron sheet stock having a non-directional permeability which is at the same time a higher permeability than has hitherto been obtainable in such material.

So far as is known, the art has not hitherto been able to utilize any aspect of crystal orientation in the manufacture of truly non-directional silicon-iron sheet stock. It is also a fundamental object of this invention to provide a non-directional product, and a process of making it, wherein crystal orientation is employed to increase the permeability in all directions in the plane of the sheet stock.

These and other objects of the invention which will be set forth hereinafter or will be apparent to one skilled in the art upon reading these specifications, are accomplished in that product and method of making it of which an exemplary embodiment will hereinafter be described. Reference is made to the accompanying drawings wherein:

FIGURE 1 is an X-ray pole density stereogram of (100) planes showing the orientation of the starting material employed in this invention.

FIGURE 2 is an optical stereographic projection of the (100) planes in the product of this invention, which in manufacture has been cold reduced 70% and annealed at a high temperature in hydrogen.

The invention is based on the concept that if in a silicon-iron stock the cubic crystals are so oriented that certain faces of the crystals lie parallel to the surfaces of the sheet stock while the cube edges which bound the said faces have a random orientation, the permeability will not only be substantially the same in all directions within the plane of the sheet but will also be substantially higher in all of these directions than that which can be obtained with a wholly random crystal orientation. The translation of this concept into actual practice involves two problems: first the provision of a starting material characterized by the crystal orientation just described, and second the successful reduction of the starting material to final thickness by rolling, followed by annealing, with the preservation of the said orientation, i.e., with the avoidance of the production of some other orientation which would impart substantial directional properties to the product.

When molten silicon-iron is solidified against a planar cooling surface, crystals will form and grow against that surface having a cube face parallel thereto, but having no preferred orientation in any other direction. In other words, when silicon-iron alloy solidifies against a plane surface, a fiber texture is produced having the fiber axis in the same direction as the heat flow, and the (100) plane normal to the fiber axis.

If the silicon-iron is cast, say, into an ingot mold having substantially equal transverse dimensions, it will be evident that portions of the ingot will have the stated crystal orientation related to each of the four lateral walls of the mold. The result of hot rolling such an ingot will therefore be to produce a hot rolled material substantially characterized by a random crystal orientation. However, if the silicon-iron alloy is cast in a mold in which the length and breadth are both many times the thickness, the resultant casting will be characterized by the desired orientation excepting at the edges. It is possible to minimize the edge effect by insulation at the edges of the mold; but in any event the edge portions of the casting may be trimmed off before the materal is rolled. Thus it becomes possible to make relatively thin, slab-like material for hot rolling which is characterized by the desired orientation.

The desired orientation can be produced even more cheaply and conveniently by utilizing a continuous casting apparatus and method which result in the production of endless lengths of relatively thin materials (say half an inch or less in thickness), having a width many times greater (say at least twenty times) than their thickness. While there are many types of direct casting equipment which may be employed, reference is made for an exemplary showing to United States Patent No. 2,640,235, issued June 2, 1953, in the name of C. W. Hazelett. Such a machine is capable of producing castings of sheet width in thicknesses ranging generally from 0.1 to 0.5 inch in thickness, and in indefinite lengths which are advantageous for the purposes of this invention, although these dimensions are not limiting.

Cast material having the described orientation is capable of being hot rolled without losing that orientation. If, however, the material is formed by direct casting as a thin enough product it becomes possible to carry on the remainder of the reduction by cold rolling. The cast material may be subjected to a conventional anneal before cold rolling.

The result of cold rolling a silicon-iron alloy sheet stock is normally to elongate and partially fragmentize the grains, tilting them also in the direction of rolling. The highly oriented, highly directional silicon-iron products of the prior art have been made by subjecting the silicon-iron to one or more stages of cold rolling with intermediate and final anneals. The amount of the cold rolling is important. It is believed that the cold rolling tilts the grains or crystals into high energy positions, the subsequent heat treatments causing the crystals to assume some related low energy position, whereby a high degree of preferred orientation is produced.

In the practice of the present invention, where the starting material is either a hot rolled or a cast material in which the (100) planes of the crystals are parallel with the sheet surface, it has been found possible to subject the material to a substantial cold rolling treatment followed by an anneal without essentially altering the

crystal orientation. While not wishing to be bound by theory, it is believed that any high energy position to which the crystals are tilted still has the original orientation as its related low energy position. But the amount of cold work which may be done is critical. It has been found that 70% reduction is optimum for about 3% silicon content. If the reduction is diminished to 60% or increased to 80%, departures from the desired orientation begin to become apparent upon X-ray analysis. Consequently the range for the cold reduction is given herein as from substantially 60% to substantially 80%, for silicon-iron containing about 2.90 to 3.30% silicon.

By way of example of a specific material to which the invention has been applied, the following is given:

C	.024
Mn	.082
S	.018
Si	2.90

Balance being substantially all iron.

It should be understood, however, that this analysis is exemplary merely and not limiting. The invention may be applied to silicon-iron alloys containing from about 2.0 to 3.5% silicon. As the amount of silicon decreases, the amount of cold work which may be done increases. Thus, as an over-all range of cold reduction commensurate with the last mentioned range of silicon content, from about 55% to 85% is given.

The other ingredients may vary substantially, particularly in view of the use to which the product may be put. Where a low carbon content is desired, say .007% or less, decarburization may be practiced in conjunction with any annealing treatment to which the material is subjected in accordance with known practices. The manganese content will usually lie between 0.04% and 0.40%.

After the cold rolling, the material is annealed, preferably in hydrogen, at temperatures between substantially 1400° F. and 2200° F.

Materials having the formula shown herein and treated as above described have exhibited straight-chain permeabilities at $H_m=10$ oersteds of 1550, cross-grain permeabilities of 1520, and only slightly lower permeabilities in directions lying between the straight-grain and cross-grain.

In another test on material of this same general character, the straight-grain permeability was measured and permeabilities at various angles from the straight-grain direction were calculated taking into account the rotation of each individual grain from the straight rolling direction, the following results being obtained:

Estimated Permeability H–10 at Angle Shown to Rolling Direction

0°	30°	45°	60°	90°
1,590	1,460	1,480	1,530	1,540

It will be noted that there is less than a 10% variation in permeability when comparing any two directions in the plane of the sheet.

FIGURE 2 of the drawing is illustrative of the crystal orientation of these materials as determined by the optical goniometer. FIGURE 1 is an X-ray pole figure of the cast material, indicating that the orientation is substantially identical.

It is characteristic of the cold rolling and annealing treatments hereinabove described, when applied to material having the described initial orientation, that they may be repeated on the product without changing its essential orientation. In other words, if the hot rolled or cast gauge is such that more than one cold rolling treatment is desired to carry it to final gauge, a plurality of such treatments may be performed providing each such treatment embodies a cold rolling with a reduction as hereinabove set forth, and providing each such treatment is followed by the described anneal. The annealing treatments herein described may be box anneals or open anneals as desired. By an open anneal is meant a heat treatment in which the material in single strand or sheet form is sent through an elongated furnace in which both sides of the material are open to the atmosphere of the furnace, which atmosphere, however, is preferably a non-carburizing reducing atmosphere.

Modifications may be made in the invention without departing from the spirit of it. The invention having been described in certain exemplary embodiments what is claimed as new and desired to be secured by Letters Patent is:

1. A cold rolled silicon-iron alloy sheet stock containing substantially 2.0 to 3.5% silicon and characterized by a crystal orientation in which (100) planes of a majority of the cubic crystals lie parallel to the surfaces of the sheet stock, with the edges of the cubes substantially randomly oriented in the plane of the stock, the said sheet stock being characterized by a substantially uniform permeability in all directions within the plane of the sheet stock.

2. A cold rolled silicon-iron alloy sheet stock containing substantially 2.0 to 3.5% silicon and characterized by a crystal orientation in which (100) planes of a majority of the cubic crystals lie substantially parallel to the surfaces of the sheet stock, with the edges of the cubes substantially randomly oriented in the plane of the stock, the said sheet stock being characterized by no more than a 10% variation in permeability in all directions within the plane of the sheet stock.

3. The sheet stock claimed in claim 2 wherein the permeability in any direction within the plane of the sheet stock is not less than substantially 1450 at H–10.

References Cited in the file of this patent

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