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⑤④ **Method for producing cube-on-edge oriented silicon steel.**

⑤⑦ An improvement in the manufacture of cube-on-edge oriented silicon steel; the improvement comprises coating the surface of the silicon steel with a manganese-bearing material prior to texture annealing, whereby secondary grain growth is inhibited during texture annealing to achieve reduced watt loss.

METHOD OF PRODUCING CUBE-ON-EDGE
ORIENTED SILICON STEEL

This invention relates to a method of producing cube-on-edge oriented silicon steel in the form of sheets is known for use in various electrical applications including transformer cores. With cube-on-edge silicon steel the alloy is characterized by secondary recrystallization in the (110) (001) position, which is termed the cube-on-edge position. This material in sheet form has the direction of easy magnetization in the direction of rolling. In applications for this material, and specifically when used in the manufacture of transformer cores, the material is required to have reduced watt loss, because the consumption of electrical energy decreases as iron loss decreases. Reduced watt loss may be promoted by achieving fine secondary grain size during texture annealing.

It is accordingly an object of the present invention to provide a method whereby during the texture annealing of cube-on-edge silicon steel the secondary grain growth is inhibited to provide a relatively fine grained material after texture annealing with reduced watt loss.

Broadly, in the practice of the invention a silicon steel which has been conventionally processed by hot rolling and cold rolling with intermediate anneals is surface coated with a manganese-bearing material prior to texture annealing and is texture annealed in the conventional manner with said manganese-bearing material thereon. A manganese-bearing material particularly suited for use in the invention is $Mn_3(NO_2)$. It has been found that the presence of the manganese-bearing compound during annealing inhibits secondary grain growth and thus reduces watt loss. This may be further enhanced if the steel is serrated prior to texture annealing. Although the practice of the invention finds utility with cube-on-edge oriented silicon steels generally, it is particularly adapted to steels of this type within the following composition limits in percent by weight:

<u>Steel</u>	<u>Mn</u>	<u>C</u>	<u>S</u>	<u>Si</u>	<u>B</u>	<u>Fe</u>
SX-14	.025-.045	.020-.060	.005-.040	2.70-3.50	.0005-.0030	Bal.
SX-11	.050-.080	.020-.060	.020-.035	3.00-3.70	-	Bal.

By the practice of coating steel with a manganese-bearing compound and texture annealing with the compound being present on the steel, said practice is believed to be effective for the purpose by diffusing manganese into the steel during annealing, which promotes primary grain coarsening by interaction with the solute sulfur, which sulfur would tend to inhibit grain growth. Hence a region is provided in which primary grain growth occurs and restricts the growth of secondary grains through this region. It would appear that the extent of grain refinement of the secondary grains after texture annealing depends on the spacing of the regions of primary grain growth on the areas of application of the manganese-containing material, provided that the width of the treated region is sufficient to act as a barrier to the secondary grains. This effect may be supplemented by creating similar barriers by subjecting the steel to serrating or the like.

The silicon steel composition used in the specific examples, and identified as SX-14, was of the following nominal composition in percent by weight:

	<u>Mn</u>	<u>S</u>	<u>C</u>	<u>Si</u>	<u>B</u>	<u>Fe</u>
	.035	.016	.030	3.15	.0010	Balance

Epstein packs of final normalized SX-14 composition, identified as Heat No. 154684, were coated with a water slurry comprising 300cc of water, 46gm. of MgO and 2gm. of H_3BO_3 . This material with the coating thereon was then texture annealed in a hydrogen atmosphere in the conventional manner. Specifically, the texture annealing consisted of charging the material into a furnace at a temperature of $760^{\circ}C$ ($1400^{\circ}F$) heating at a rate of $10^{\circ}C$ ($50^{\circ}F$) per hour to a temperature of $1177^{\circ}C$ ($2150^{\circ}F$), holding at temperature for 12 hours and then cooling to $649^{\circ}C$ ($1200^{\circ}F$), at which time the material was removed from the furnace. One of the Epstein packs, prior to the above slurry coating, was painted with a mixture of 30cc of 50% Mn $(NO_3)_2$ and an inert thickner, which was applied in 1mm stripes perpendicular to

the sheet rolling direction at intervals of 10mm; this painted coating was then air dried. This Epstein pack constituted treatment in accordance with the practice of the invention; whereas, the second pack was used as a control and typified a conventional practice. Following the texture annealing procedure, as described above, the average lineal dimension of the secondary grains of the conventional, control pack specimen in the sheet rolling direction was 13mm. In contrast, the average lineal dimension of the secondary grain of the specimen treated with $Mn(NO_3)_2$ in accordance with the practice of the invention was 7mm; these grains it was observed were often separated by the aforementioned bands of smaller primary grains where normal grain growth was stimulated by the application of the manganese-bearing compound.

In a second specific example, a single Epstein strip of final normalized SX-14 composition from the same heat as in the aforementioned Example 1 was scribed with a metal scribe to produce serrations in the strip perpendicular to the rolling direction at intervals of 10mm. After the scribing operation, the strip was slurry coated and texture annealed under the conditions described above with respect to the first specific example. Following this texture annealing, the average lineal dimension in the sheet rolling direction of the secondary grain in the scribed strip was 9.5mm.

CLAIMS

1. A method of producing cube-on-edge oriented silicon steel, characterized by reduced watt loss, including the steps of hot-rolling, cold-rolling with intermediate annealing and a final texture annealing, characterized in
5 comprising surface coating said steel with a manganese-bearing material prior to texture annealing and texture annealing said steel with said coating thereon, whereby secondary grain growth is inhibited during texture annealing.

2. A method according to claim 1, characterized in
10 that said manganese-bearing material is $\text{Mn}(\text{NO}_3)_2$.

3. A method according to claims 1 or 2, characterized in that said steel is serrated prior to texture annealing.

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