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[54] **PROCESS FOR MAKING COPPER-CONTAINING ORIENTED SILICON STEEL**

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Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 229,233, Feb. 11, 1972, abandoned.

[52] **U.S. Cl.** **148/111,** 148/31.55, 148/112
[51] **Int. Cl.** **H01f 1/04**
[58] **Field of Search** .... 148/111, 112, 110, 31.55; 75/123 L, 123 R

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[57] **ABSTRACT**

A grain-oriented silicon steel made by constituting a silicon steel to contain from about 2.2–4.0% silicon and from about 0.24–0.75% copper, hot rolling it to a thickness of about 0.075–0.1 inches, cold rolling in one cold reduction to a thickness of 0.025 inches or less and then texture annealing for a time sufficient for secondary recrystallization and grain growth to be effected is disclosed.

5 Claims, No Drawings

PROCESS FOR MAKING COPPER-CONTAINING ORIENTED SILICON STEEL

CROSS REFERENCE

This application is a continuation-in-part of copending patent application Ser. No. 229,233, filed Feb. 11, 1972 now abandoned.

BACKGROUND OF THE INVENTION

A product that has become known as silicon steel is widely used because it can be made with very desirable magnetic properties. Silicon steels have high permeability to magnetic flux and small core losses and are therefor very useful in electrical devices involving electromagnetism.

Although all silicon steels have good magnetic properties, the silicon steels with the best magnetic properties are those that are known as oriented silicon steels. Oriented silicon steels have cube-on-edge crystal structure that is oriented in the direction of rolling. To obtain silicon steels with a high degree of orientation, prior art processes require very careful control of the chemistry of the steel and the sequence of process steps used to produce it in a thin, flat strip. For example, prior art processes required hot reductions of the steel followed by cold rolling in several reductions with intermediate anneals to preserve the high permeability and low core loss character of the silicon steel.

THE INVENTION

This invention is a process for producing grain-oriented silicon steels which employs a single cold rolling step and is accordingly much more economical than more extensive processes.

The process of this invention includes constituting a silicon steel to contain from about 2.20–4.0% silicon and from about 0.24–0.75% copper. In this specification all compositions are described in terms of percent by weight of the total composition unless otherwise specified. The silicon steel is hot rolled to a thickness of from about 0.075–0.1 inches and then cold rolled in one single cold reduction to a thickness of 0.025 inches or less. The cold rolled strip is then texture annealed for a time sufficient for secondary recrystallization and grain growth to be effected.

Copper is known to be an ingredient of silicon steel and with the increased usage of scrap, copper is present in trace amounts in almost all silicon steels. However, in the process of the present invention it has been found that a very limited and critical range of copper must be present to obtain the desirable properties from the simplified process that involves a single cold rolling

step from a specific hot rolled gauge to a thickness of 0.025 inches or less. The steel must contain from about 0.24–0.75% copper and preferably from about 0.3–0.5%. In accordance with this invention it has been found that when the critical composition limits of copper are not employed or when the critical process steps for preparing the silicon steel in final useful form are not employed, obtaining highly oriented silicon steel with good permeability and low core losses cannot be accomplished.

Although silicon steels may contain large amounts of silicon, the silicon steels of this invention are those containing from about 2.2–4.0% silicon and preferably from 2.5–3.0% silicon. There is a relationship between silicon and copper such that the desirable high permeability and low core loss characteristic of an oriented silicon steel cannot be retained in a process using a single cold reduction when the critical compositions of both copper and silicon are not in the ranges set forth herein.

The final texture annealing may be accomplished in accordance with the prior art and it will be at a temperature and for a time suitable for the specific composition of the alloy. Texture annealing ordinarily is effected at temperatures in the range of 2,000°–2,300°F and preferably at about 2,150°F.

DETAILED DESCRIPTION OF THE INVENTION

A number of silicon steels were produced, some in accordance with this invention and some not in accordance with this invention; however, all were produced with similar conventional steps. The steels were constituted, cast and hot rolled by conventional means to thicknesses between 0.075 and 0.1 inches. The hot rolled band was then treated conventionally to remove scale and heat treated before cold rolling.

The heat treated and descaled steel was then cold rolled directly to gauge, i.e. to 0.025 inches or less, after which it was texture annealed at 2,150°F.

The copper and silicon content of these steels and data obtained from analyzing them are set forth in Table I. The compositions in Table I indicate that all steels include the critical silicon composition of the present invention, but some contain less than the critical amount of copper and some contain in excess of the critical amount of copper. The steels of this invention were rolled to four different gauges ranging from the maximum thickness of the invention, 0.025 inches to a gauge of 0.0108 inches. Specimens of each steel at each thickness were analyzed for permeability and core loss with the exception of two specimens at 0.0108 inches which were not suitable for analysis. These data are set forth in the following table.

TABLE I

		Magnetic Quality for Various Gauges							
		.025"		.0185"		.014"		.0108"	
Si (%)	Cu(%)	WPP at 15KB	μ at 10H	WPP at 15KB	μ at 10H	WPP at 15KB	μ at 10H	WPP at 15KB	μ at 10H
						1—			
2.50	<.01	1.80	1672	1.26	1620	1.65	1550	1.25	1460
2.72	<.01	1.33	1731	.97	1729	.93	1580	.98	1511
3.00	<.01	1.46	1722	1.03	1692	1.04	1529	1.19	1454
3.20	<.01	1.46	1720	1.00	1690	1.04	1540	1.20	1450
3.20	.15	1.54	1590	1.32	1550	1.04	1530	—	—

TABLE I – Continued

		Magnetic Quality for Various Gauges .025"		.0185"		.014"		.0108"	
Si (%)	Cu(%)	WPP at 15KB	μ at 10H	WPP at 15KB	μ at 10H	WPP at 15KB	μ at 10H	WPP at 15KB	μ at 10H
2.50	.24	1.41	1797	0.91	1824	0.75	1755	0.83	1612
2.50	.40	1.31	1814	0.84	1833	0.77	1744	0.87	1598
2.50	.42	1.55	1782	1.05	1810	0.82	1781	1.27	1456
2.75	.39	1.56	1820	1.00	1842	0.70	1845	0.55	1829
3.00	.39	1.40	1752	0.94	1786	0.68	1788	0.61	1755
3.20	.30	1.36	1660	1.04	1600	1.04	1700	—	—
2.50	.58	1.61	1768	1.08	1830	0.73	1801	0.67	1737
2.75	.59	1.40	1825	0.93	1818	0.74	1773	1.04	1534
3.00	.59	1.28	1799	0.85	1832	0.80	1680	1.00	1508
3.20	.75	1.34	1650	1.20	1550	1.04	1480	0.83	1440
2.50	.81	2.19	1471	1.60	1490	1.42	1475	1.50	1416
2.50	1.00	2.33	1430	1.96	1406	1.69	1405	1.58	1390
2.75	1.00	1.95	1476	1.81	1424	1.61	1408	1.55	1390
3.00	1.00	1.98	1470	1.68	1434	1.60	1400	1.53	1392

It is evident from the data in Table I that alloys containing in excess of 0.75% copper are characterized by large core losses and low permeability compared with the same alloys containing the critical quantity of copper. To a lesser but very definite extent, the alloys having less than the critical quantity of copper also exhibit greater core losses than equivalent alloys containing copper in the critical range.

The more desirable core losses and permeabilities of the alloys of this invention are obtained as the final gauge gets thinner. It is clear from the data that the desirable low core loss and high permeability properties increase rapidly as the thickness of the final cold rolled gauge increases from .0108 inches to 0.025 inches.

In summary, the process of the present invention provides for an economical method for making highly oriented silicon steel, a process employing a single cold rolling step instead of multiple cold rolling steps with intermediate annealing. The process has been demonstrated to depend upon the presence of critical amounts of copper and silicon within the silicon steel and upon cold rolling to a gauge less than 0.025 inches. The process as thus set forth permits obtaining oriented silicon steel with a single cold roll and is therefor a great improvement over prior art processes requiring multiple cold rolling steps with intermediate heat treatments.

It is evident that the usual methods for producing silicon steels conventionally employed will be used in the process of this invention. It is also contemplated that the compositions of silicon steels employed in this invention will include conventionally used materials to provide their own functions and will exclude those materials known to be destructive of the magnetic properties of silicon steels.

What is claimed is:

1. A process for producing grain-oriented silicon steel which comprises:

A. hot rolling a silicon steel consisting essentially of from about 2.20–4.0% silicon and from about 0.24–0.75% copper to a thickness of from about 0.075–0.10 inches,

B. cold rolling the hot rolled steel in one cold reduction to 0.025 inch thickness or less, and

C. texture annealing the cold rolled steel at a temperature of from about 2,000°–2,300°F and for a time sufficient for secondary recrystallization and grain growth to be effected.

2. The process of claim **1** wherein the steel contains about 0.3 to 0.5% copper.

3. The process of claim **1** in which the steel contains between about 2.5 and 3.0% silicon.

4. The process of claim **1** wherein texture annealing is effected at 2,150°F.

5. The process of claim **1** wherein said texture annealing is effected for a time sufficient to produce a product having a permeability of at least 1,550 μ at 10 H and a core loss of at most 1.40 WPP at 15 KB.

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