What Is Silicon Steel?

Silicon alloy steel containing 1.0 to 4.5% silicon and less than 0.08% carbon is called silicon steel. It has the characteristics of high magnetic permeability, low coercive force and large resistivity, so the hysteresis loss and eddy current loss are small. Mainly used as magnetic materials in motors, transformers, electrical appliances and electrical instruments. In order to meet the needs of punching and shearing when manufacturing electrical appliances, a certain degree of plasticity is also required. In order to improve the magnetic induction performance and reduce the hysteresis loss, the lower the content of harmful impurities, the better, and the flat shape and the good surface quality are required. [1]

In 1900, RA Hadfield reported that iron-silicon alloys with a silicon content of 2.5% to 5.5% had higher magnetic properties than iron. Production of hot rolled silicon steel sheets began in 1903. In 1934, GossNP developed (110) [001] cold-rolled oriented silicon steel, and its magnetic properties were significantly improved along the rolling direction of the steel plate. It is suitable for making transformers. In 1935, the American Armco Steel Company began production, and then again Production of cold-rolled non-oriented silicon steel. In 1949, Amco made 0.05mm and 0.1mm thick cold-rolled oriented silicon steel strips for military industry. In the early 1960s, the United States began mass production of low-carbon electrical steel with silicon content <0.5%. In the late 1960s, some countries ceased production of hot-rolled silicon steel. In 1968, Japan's Nippon Steel & Iron Corporation developed and produced Hi-B steel. In the mid-1970s, Japan successively developed several new grades of oriented silicon steel, non-oriented silicon steel, and low-carbon electrical steel. In 1986, Japan Steel Pipe Company produced high silicon steel products with a silicon content of 6.5%. China produced hot-rolled silicon steel in 1954, made and produced cold-rolled oriented silicon steel strips in 1959, and produced cold-rolled and non-oriented silicon steel in 1979. The annual output of electrical steel in the world is more than 6 million tons, accounting for 0.9% to 1.3% of the total steel output. The annual output of Japan, the former Soviet Union and the United States exceeds 1 million tons, of which oriented silicon steel accounts for about 25%, and low-carbon and low-silicon electrical steel accounts for about 65%.

Silicon steel uses iron core loss (abbreviated as iron loss) and magnetic induction strength (abbreviated as magnetic induction) as the guaranteed magnetic value of the product. Low silicon steel loss can save a lot of electricity, prolong the operating time of motors and transformers, and simplify the cooling system. Electricity loss due to silicon steel loss accounts for 2.5% to 4.5% of the annual power generation, of which transformer iron loss accounts for about 50%, 1-100kW small motors account for about 30%, and fluorescent lamp ballasts account for about 15%.

Silicon steel has a high magnetic induction, and the exciting current of the iron core is reduced, which also saves power. The high magnetic induction of silicon steel can make the designed maximum magnetic induction (B_m) high, the core size small, light weight, saving silicon steel, wires, insulating materials and structural materials, etc., which reduces the loss of motors and transformers and manufacturing costs, and facilitate Assembly and transportation. The motor with the iron cores formed by the toothed round punches works in the running state. The silicon steel plate is required to be magnetically isotropic and made of non-oriented silicon steel. Transformers that are laminated into cores from strips or wound into cores from strips work in a stationary state and are made of cold-rolled oriented silicon steel with large magnetic anisotropy. In addition, silicon steel is required to have good punching and shearing properties, smooth and flat surface and uniform thickness, and good insulation film and small magnetic aging.

According to the manufacturing process and application, electrical steel is divided into three categories: hot-rolled silicon steel, cold-rolled electrical steel and special-purpose silicon steel. The silicon content, specifications and main uses are shown in Table 1.

Table 1 Classification and application of electrical steel

category			Silicon content /%	Nominal thickness / mm	The main purpose
Hot rolled silicon steel (non-oriented)	Hot rolled low silicon steel (motor steel)		1.0 2.5	0.5	Household motors and micromotors
	Hot rolled high silicon steel (transformer steel)		3.0 4.5	0.35, 0.50	transformer
Cold rolled electrical steel	Cold rolled non-oriented electrical steel (motor steel)	Low carbon electrical steel	0.5	0.50, 0.65	Household motors, micro-motor small transformers and ballasts
		Silicon steel	> 0.5 3.5	0.35, 0.50	Large and medium-sized motors, generators and transformers
	Cold-rolled oriented silicon steel (transformer steel)	Oriented silicon steel	2.9 3.3	0.18, 0.23, 0.27 0.30, 0.35	Large, medium and small transformers and ballasts
		High magnetic orientation silicon steel			
Special purpose silicon steel: Cold-rolled oriented silicon steel strip			2.9 3.3	0.03, 0.05, 0.10	Pulse transformer, magnetic amplifier, high frequency transformer and welding machine
Cold rolled non-oriented silicon steel strip			3.0	0.15, 0.20	High frequency motors and generators
Cold rolled non-oriented silicon steel for magnetic switch			3.0	0.70	Relays and magnetic switches
Cold rolled high silicon steel			6.5	0.1 0.5	High-frequency motors, transformers, and magnetic shields

The requirements for the properties of silicon steel are:

1. Low iron loss, which is the most important indicator of the quality of silicon steel sheet. Each country divides the grade according to the iron loss value. The lower the iron loss, the higher the grade.

2. High magnetic induction strength (magnetic induction) under strong magnetic field, which reduces the volume and weight of the iron core of the motor and transformer, saving silicon steel sheets, copper wires and insulation materials.

3. The surface is smooth, flat and uniform in thickness, which can improve the filling factor of the iron core.

4. Good punching performance is more important for manufacturing miniature and small motors.

5. The surface insulation film has good adhesion and weldability, which can prevent corrosion and improve punchability.

Silicon steel pickling

The scale descaler and the hydrochloric acid tank are used to remove the oxide of the hot-rolled steel strip to prevent defects on the surface of the cold-rolled product.

Silicon steel cold stamping

In order to ensure the thickness and material of different applications, the reduction ratio is set at 40% -90%, and advanced control equipment such as automatic thickness control and automatic shape control are implemented.

Silicon steel annealing

It is a process to soften the hardened steel strip material in the cold stamping process. Through metal heating and rapid cooling, deep-processing steel and high-tensile steel are produced, and boxing (shrouding) annealing and continuous annealing methods are used.

Silicon steel insulation coating

When a silicon steel sheet is processed into an iron core, in order to improve its workability and prevent eddy current loss equivalent to the thickness of the steel sheet, continuous coating equipment is used to spray insulating coating liquid on the top and bottom of the steel sheet. [2]

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