PRODUCTION OF ISOTROPIC ELECTRICAL STEEL

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The specialized dynamo steel shop at the Novolipetsk Metallurgical Combine was designed to annually produce 480,000 tons of high-quality electrical steel conforming to the standards of the international market. The product mix of the shop consists of 78 grades of isotropic electrical steel and 28 grades of special-purpose low-carbon steel included in domestic and foreign standards.

The strategy adopted for developing the commercial production of isotropic electrical steels provides for the use of nearly every type of equipment that exists for making such products, including automated systems to monitor and control the production processes, check product quality in the production line, and plan and manage production. The complex that was built is based on a continuous technology for making isotropic steel which was developed and introduced by scientists and engineers at the NLMK and TsNIIchermet (Central Scientific Research Institute of Ferrous Metallurgy).

The isotropic electrical steel is made in the oxygen-converter shop in 160-ton oxygen converters. The steel is then cast on a vertical continuous caster into slabs with dimensions of (240–250) × (1120–1280) mm and a weight of up to 30 tons.

The integrated technology provides for blowing of the molten steel with inert gases, recirculation vacuum degassing, and treatment of the steel outside the furnace with synthetic slags (SSs) and solid slag-forming mixtures (SSMs).

A modern curvilinear caster was placed in operation in 1998. The caster makes it possible to significantly improve the quality of the surface of the slabs and reduce the number of nonmetallic inclusions in the metal.

The shop also has equipment for thermostatting and annealing slabs of high-alloy steels.

The slabs are hot-rolled on a continuous 2000 strip mill to obtain starting strip with dimensions of (2.0–2.5) × (1080–1280) mm.

Sheet-rolling shop (SRS) No. 2, which began operation in 1986, is one of the most modern shops in the world for making cold-rolled isotropic electrical steel.

The complex of production equipment provides for heat treatment of the hot-rolled starting strip in a protective atmosphere at temperatures up to 1150°C, treatment of the strip by a hydrochloric acid solution in a continuous pickling unit, cold reduction on a continuous four-stand 1400 mill to thicknesses as low as 0.35 mm (with the possibility of monitoring the transverse profile of the strip), heat treatment of the cold-rolled strip in continuous annealing units with the use of combination decarbonizing-recrystallizing annealings in controlled nitrogen-hydrogen atmospheres at temperatures up to 1050°C, and the application of electrically insulating coatings – including coatings that are heat-resistant and improve stampability.

The production cycle also provides for the following additional operations: preparation of the hot- and cold-rolled strip and a check of the quality of its surface, heating of coils of high-alloy steels before preparation of the hot-rolled strip, heat treatment of the hot-rolled starting strip, pickling, and cold reduction. The inclusion of these operations in the production process strengthens the guarantee of quality of the finished product and makes it better-suited for subsequent industrial processing.

Modern automated control systems control the production process and perform technical and technological diagnoses in the course of production.

The line of continuous annealing furnaces includes equipment for nondestructive in-line evaluation of the magnetic properties of the steel.

The technology and the production process as a whole are controlled by three computer centers.
The shop has mastered the technology and successfully introduced production of the following steels:
- unalloyed (silicon-free) low-carbon steels SFX and XC – (0.5–1.0) × (1000–1200) mm;
- an alloy steel with a total content of silicon and aluminum of 0.6–2.5% – (0.5–0.65) × (1000–1200) mm;
- a high-alloy steel with a total content of silicon and aluminum of 3.2–3.8% – (0.35–0.5) ×(1000–1200) mm;
- an unalloyed electrical steel and an alloy electrical steel (with up to 3.1% Si) delivered in the semifinished state – (0.5–0.65) × 1000 mm.

The shop was the first in the country to master a technology for making “slotted” masks for color-television picture tubes from strip metal rolled from decarbonized (0.002–0.004% carbon) starting strip 0.5 mm thick and cold-worked starting strip 0.5–0.7 mm thick.

The shop has successfully introduced the production of 0.4-mm-thick decarbonized rolled products of category SV for factories that make electrooptic devices. These rolled products are also used in the production of semi-work-hardened, flexible, and ultra-flexible strip 0.3 mm thick for the combine’s “Stinol” refrigerator factory.

The quality of the finished products fully meets the requirements of domestic and foreign standards (ASTM, JIS, DIN, European norms).

During the period 1989–1991, the shop annually produced about 500,000 tons of finished rolled products made of electrical and carbon steels. However, due to the subsequent (1992–1993) drop in output which occurred in almost every industry in connection with the transition to a market economy, it became necessary for the shop to master the production of new types of products and make them competitive on the world market.

The contraction of the Russian sales market caused by business failures and plant conversions in the military-industrial complex led to a reduction in the demand for isotropic electrical steel in Russia and a need to sharply increase the percentage of exported products.

During this period, sheet-rolling shop No. 5, with the involvement of scientific-research institutes, mastered new technologies directed toward improving the quality of its products and significantly expanded the product mix. During the last eight years, scientists and engineers at the combine have developed, patented, and obtained Russian Author’s Certificates for more than 25 new methods of making isotropic electrical steel in shop No. 5. The improvements that have been made to existing technologies and the new technologies that have been developed are based on technical advances in domestic and foreign practice.

Among the prerequisites for obtaining high magnetic properties in isotropic electrical steel are optimization of grain size and the formation of a certain percentage of grains with the (001) orientation in the texture of the hot-rolled or normalized strip. Due to structural and textural heredity, the grain size and the percentage of grains having the indicated orientation in the finished steel are in large part determined by the structure and texture of the hot-rolled strip – which in turn depend to a significant extent on the conditions which exist during hot rolling and heat treatment.