Electrical steel coils at Companhia Siderúrgica Nacional (CSN), in Volta Redonda, Rio de Janeiro State

More efficient metals

Technological innovations enhance performance of steel used in electric motors and power transformers

PUBLISHED IN JANUARY 2017

The global demand for more efficient consumption of electrical energy is driving the evolution of steel used in the manufacture of refrigerator compressors, air conditioners, generators, and transformers. In production since the early 20th century, a magnetizable metal called electrical steel, composed basically of iron and silicon, can transform electrical energy into mechanical energy. A steady push is underway to improve the performance of this material and meet the needs of conventional manufacturing industries, such as the home appliance sector, and more state-of-the-art technologies, including electric car design. In the 1990s, Brazilian steelmaker Companhia Siderúrgica Nacional (CSN) and a team of researchers from the São Paulo Institute for Technological Research (IPT) collaborated to develop a project under a FAPESP program called Research Partnership for Technological Innovation (PITE). The company's electrical steel production system was successfully overhauled as a result, bringing a 30% increase in product efficiency. The latest innovation comes from Minas Gerais-based steelmaker Aperam (formerly Acesita). In the closing quarter of 2016, the enterprise completed a series of improvements to its production processes, enabling it to begin manufacturing an even more energy-efficient material: high-permeability grain-oriented (HGO) steel.

CSN

Motors consume half of all electrical energy worldwide

“This technology lowers core loss during the energy transformation process by as much as 30% in the metals,” says Aperam engineer Rubens Takanohashi. Core loss refers to the energy dissipated as heat during alternating magnetization and demagnetization of the metal. HGO steel is an outgrowth of one of two other types: grain-oriented (GO) electrical steel, a high-performance metal used in transformers, which change and adapt the voltage in alternating current electrical circuits, and non-grain-oriented (NGO) electrical steel, used in motors, compressors, and generators. GO steel displays a core loss of approximately 1.25 watts per kilogram of material, a figure that drops to approximately 0.95 watts with HGO. The difference may seem minor, but it is quite significant given that the loss occurs across all transformers in Brazil. “The Brazilian market was demanding it,” says Takanohashi. “This material makes it possible to produce more efficient transformers that are 10% to 15% smaller, while taking less feedstock to manufacture and facilitating transportation of the equipment.”

The Aperam factory in Timóteo, Minas Gerais, has the only GO steel plant in Latin America and now boasts the only HGO plant as well. The new facility is one of 15 operating in 10 countries. The startup of HGO production required an investment of $19 million over two years. Rather than purchasing a technological package, the company opted to devise an in-house solution; this demanded eight years of investigations at the Aperam Research Center in Timóteo, where six researchers are assigned to developing electrical steels.

Aperam steel plant in Timóteo, Minas Gerais (*above*). IPT experiment: steel sheet wrapped in copper wire (*right*)

Brazil consumes approximately 45,000 metric tons (mt) of GO electrical steel every year. The world steel market is estimated to consume nearly 12.5 million mt per year of electrical steel, divided into 2.5 million mt of GO and 10 million mt of NGO. In Brazil, the total consumption of both types of finished products plus semi-finished products stands at approximately 400,000 mt per year. The Aperam plant has an annual production capacity of 60,000 mt of GO steel and a current yearly output of 55,000 mt, which supplies the domestic market and other countries in Latin America. Making the new HGO steel will not boost the company’s capacity but will shift its product profile. According to Takanohashi, Aperam currently has no projections about the future proportion of HGO in its product mix. He states that “It will depend on demand.”

ECO-EFFICIENT MOTORS

Steel sheets are composed of billions of crystals. While the crystal grains vary in size, their diameter averages approximately 100 µm (1/10 of a millimeter). In electrical steel, the crystals are cube-shaped, and the greater the number of crystals oriented with one side of the cube parallel to the direction in which the sheet is rolled, the better its magnetic property. “Although technological advances have yielded ‘recipes’ that afford good control over crystal orientation on a steel sheet, science hasn’t yet been able to explain how this occurs,”

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Aperam manufactures new electrical steel products that are used to make smaller, more efficient transformers

says metallurgical engineer Fernando Landgraf, CEO of IPT.

Landgraf leads an electrical steel research group at the Department of Metallurgical and Materials Engineering of the University of São Paulo's Polytechnic School (Poli-USP), where he is a professor. The group evaluates crystal size, spatial orientation, impurities, and crystal defects. Both the IPT and the Polytechnic School have been researching magnetic materials since 1982. In the 1990s, a team of researchers led by Landgraf applied its experience in magnetic research to designing solutions for the electrical steel market.

According to Landgraf, research into more efficient electrical steel is currently a global concern and an integral part of the drive for energy savings. He states that "It is estimated that 50% of the electric power produced worldwide every year is consumed by motors. Approximately 3% of this energy is dissipated through core losses. These numbers can be reduced by developing more efficient electrical steel."

SECOND FAMILY

In the early 1990s, CSN began making NGO electrical steel to supply manufacturers of motors used in low-efficiency electrical equipment such as car parts and in kitchen appliances including blenders and microwave ovens. The company's next challenge was to design a second family of electrical steel to enter markets that demand greater energy yield, including makers of refrigerator compressors, air conditioners, and industrial motors.

Nilza Cristina Sabioni Boechat Zwirman, manager of specifications and product systems with CSN's division of Research, Development, and Innovation, says that the company was then working on research that explored the possibility of adding chemical elements such as silicon, phosphorous, and aluminum to electrical steel to enhance its magnetic properties. The IPT began collaborating with CSN in 1994, when institute researchers attempted to bring steelmakers, stampers, and motor manufacturers together to form a technological consortium. The group never materialized, but CSN took an interest in the research and proposed an exchange effort. The partnership was born as a project under PITE, a program launched by FAPESP in 1994 to fund initiatives developed jointly by research institutes and businesses.

At that point, the IPT team was already aware that controlling grain orientation is important when producing NGO steel; they also knew that certain impurities, such as exceedingly tiny crystals, impair the magnetic properties of the steel. "CSN had previously focused on making chemical improvements to electrical steel and had tried to link the microstructure of the metal and the control of impurities to core losses. Our studies helped them rethink their production processes," says Landgraf. According to Zwirman, by adjusting production processes, CSN could manufacture a steel product that displays a 30% lower electrical energy loss than the product line previously offered in its catalog.

Zwirman explains that developing a line of electrical steel of medium efficiency allowed CSN to keep pace with a robust market trend in recent years: energy efficiency labeling for electrical equipment. In Brazil, the National Institute of Metrology, Quality, and Technology grants the National Energy Conservation Seal, while the National Program for Electrical Energy Conservation (PROCEL) offers the PROCEL Seal. The IPT-CSN contract was one of the first signed under the PITE program. "PITE was really important. If the costs of innovation hadn't been shared, it's unlikely the research would have moved forward," states Landgraf. The joint IPT-CSN efforts took nearly four years. Since project completion, the company has produced over 500,000 mt of electrical steel, mainly for the Brazilian market.

Zwirman believes the partnership extends beyond financial investment in the project. "It afforded a valuable opportunity to share skills," she says. According to her, CSN contributed by opening the doors to its industrial park and providing steelmaking experience, while the IPT chipped in with technical know-how, laboratories, and ties to other institutions. In addition, the Nuclear and Energy Research Institute (IPEN) furnished its knowledge on how to measure the distribution of grain orientation, and the Center for the Characterization and Development of Materials (CCDM), at the Federal University of São Carlos (UFSCar), offered assistance in the realm of transmission electron microscopy (TEM) of steel structure. ■ **Domingos Zaparolli**

Project

Development of electric steels (No. 95/03988-7); **Grant Mechanism** Research Partnership for Technological Innovation (PITE); **Principal Investigator** Fernando Landgraf (IPT); **Investment** R$137,096.77 (FAPESP) and R$154,500.00 (CSN).

PHOTOS 1 APERAM 2 IPT 3 APERAM