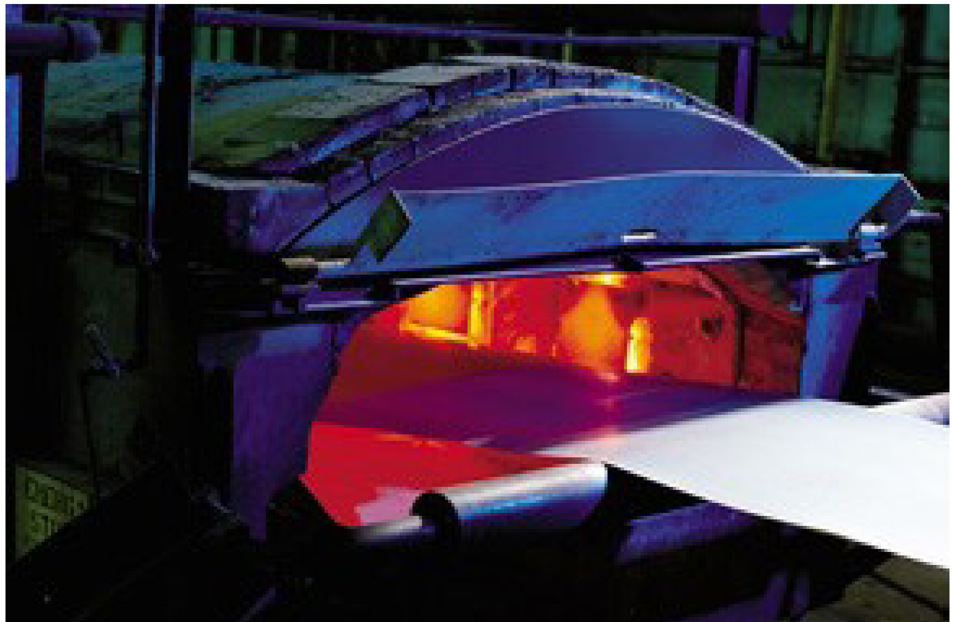
U.S. DEPARTMENT OF
ENERGY

Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY



Once laboratory-scale evaluation of the new steel alloys is completed, limited manufacturing trials will be conducted at AK Steel's production facilities in Zanesville, Ohio (pictured) and Butler, Pennsylvania. *Photo credit AK Steel Corporation.*

Development of New Steel Alloy to Reduce Core Losses in Electric Motors

Steel alloy containing silicon, aluminum, chromium, and manganese has the potential to increase electric motor efficiency

Energy losses in electric motors can be divided into five major categories: core, windage and friction, stator, rotor, and stray load losses. In order to improve motor efficiency, these different types of losses need to be reduced. Core losses, which are caused by the magnetization of the electrical steel in the motor core, are a significant portion of the total losses. These losses occur during low load conditions and during high frequency operation. To reduce high frequency core losses in a cost effective manner, inexpensive means to increase the resistivity of soft magnetic materials (electrical steel) need to be developed.

This project seeks to reduce core losses in electric motors and power generators through the development of a new steel alloy containing silicon (Si), aluminum (Al), chromium (Cr), and manganese (Mn). Today, the typical electrical steels used in motor cores contain up to 3.2% of Si with lower levels of other alloying elements such as Al and Mn. Raising the Si content of the steel increases its resistivity and, at 6.5% Si, the steel exhibits superior soft magnetic properties. However, such high Si contents make the steel increasingly brittle both during manufacturing of the steel and processing of finished steel into motor laminations. It is expected that a more complex Si-Cr-Al-Mn steel alloy can be used to achieve a resistivity level comparable to 6.5% Si without undue degradation of mechanical properties of the steel. The project seeks to identify the promising compositions for a new alloy, conduct manufacturability testing and assess its performance in motor demonstration testing.

Benefits for Our Industry and Our Nation

The Department of Energy (DOE) estimates that the development of cost-effective soft magnetic materials with increased resistivity have the potential to reduce core losses in electric motors and generators by approximately 37%. Potential benefits from such efficiency improvement include:

- Energy savings of over 2,100 gigawatt hours (GWh) per year in the industrial sector, or 0.37% of total energy annually consumed in industrial motors.
- Energy savings of 9,700 GWh per year in non-industrial motors, or 1.27% of total energy annually consumed by such motors.
- Energy savings of 0.44% of total United States electricity consumption.
- When combined with other efficiency improvements in electric motor technologies, these enhancements will contribute to the development of a new generation of electric motors and generators, improving the global competitive advantage of U.S. industry.

Applications in Our Nation's Industry

The new material being developed will result in higher efficiency motors suitable for a wide range of applications, including relatively slow speed, high torque density systems such as large commercial and industrial fans and manufacturing line conveyers. Moderate and high-speed applications, such as in-wheel motors in transportation systems, will also benefit from the new technology. Electronically controlled high efficiency motors for the blowers and fans used in the heating, ventilation, and air conditioning (HVAC) systems is the largest potential market for the new material and motor designs. The improved motors will also be suitable for hermetic compressors used in HVAC systems.

Project Description

The project objective is to evaluate and demonstrate the potential energy savings and manufacturability of Si-Cr-Al-Mn steel alloys for use in electric motor and generator cores. The goal is to develop a new alloy with high specific resistivity while maintaining desired mechanical properties of the material. Various alloy compositions will be evaluated for their magnetic and mechanical properties and manufacturability. The performance of the developed Si-Cr-Al-Mn steel alloy will be demonstrated in 5 horsepower (hp) [3.7 kW] induction motors and compared to conventional commercially available steels.

Barriers

- Reduced ductility due to higher silicon content of electrical steel, making it difficult to process, cold reduce or stamp laminations without material fracturing.
- Performance or manufacturability of new alloy(s) may exhibit undesirable or unforeseen characteristics.
- Manufacturing a more complex steel alloy increases its cost.

Pathways

In the past, AK Steel Corporation has used different processing methods to manufacture steel with higher silicon content. The company has also experi-mented with other materials, such as Cr, in its steel alloys. Building on this experience, the project team will evaluate different compositions of steel alloys containing Si, Al , Cr, and Mn. The project's goal is to identify a steel alloy that exhibits high resistivity—at least 80 micro-ohm-centimeter (μΩ-cm)—and good mechanical properties.

Once a promising alloy (or alloys) have been identified, its manufacturability will be evaluated in industrial scale trials. At least two industrial heats will be melted, continuously cast, and processed. The mechanical, microstructural, thermal, electrical, and magnetic properties of the produced steel will be analyzed. The generated magnetic property data will be used for motor design and optimiza-tion. Based on the composition of the new alloy and developed manufacturing process, a manufacturing cost analysis will be conducted.

In the last phase of the project, performance of the new alloy will be demonstrated in 5 hp [3.7 kW] induction motors. If modeling provides promising performance results, actual test motors will be manufactured and evaluated.

Milestones

This 3 year project began in 2017.

- Process and evaluate several laboratory heats of Si-Cr-Al-Mn steel alloys to optimize their mechanical, electrical, and magnetic properties (2018).
- Conduct industrial-scale trials encompassing melting, continuous slab casting, hot and cold rolling, and annealing to produce steels with optimized metallurgical and magnetic characteristics (2019).
- Determine manufacturing cost for the developed steel alloy (2019).
- Conduct electromagnetic modeling and testing to demonstrate the performance of the new steel alloys in 5 hp induc-tion motors (2020).

Technology Transition

The project team is in a good position to commercialize the developed Si-Cr-Al-Mn steel alloy. AK Steel is the only full-range producer of silicon electrical steels in North America. Regal Beloit Corporation, a member of the project team, is a large U.S. manufacturer of industrial and commercial motors. If the developed alloy meets established perfor-mance and cost targets, both project partners will work to introduce the new product to the market.

Project Partners

AK Steel Corporation
West Chester, OH
Principal Investigator: Jerry Schoen
Email: *jerry.schoen@aksteel.com*

Oak Ridge National Laboratory
Oak Ridge, TN

Regal Beloit Corporation
Fort Wayne, IN

For additional information, please contact

Steve Sikirica
Technology Manager
U.S. Department of Energy
Advanced Manufacturing Office
Phone: (202) 586-5041
Email: *Stephen.Sikirica@ee.doe.gov* ■

U.S. DEPARTMENT OF ENERGY
Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

For more information, visit:
energy.gov/eere/amo

DOE/EE-1578 · November 2017