U.S. DEPARTMENT OF
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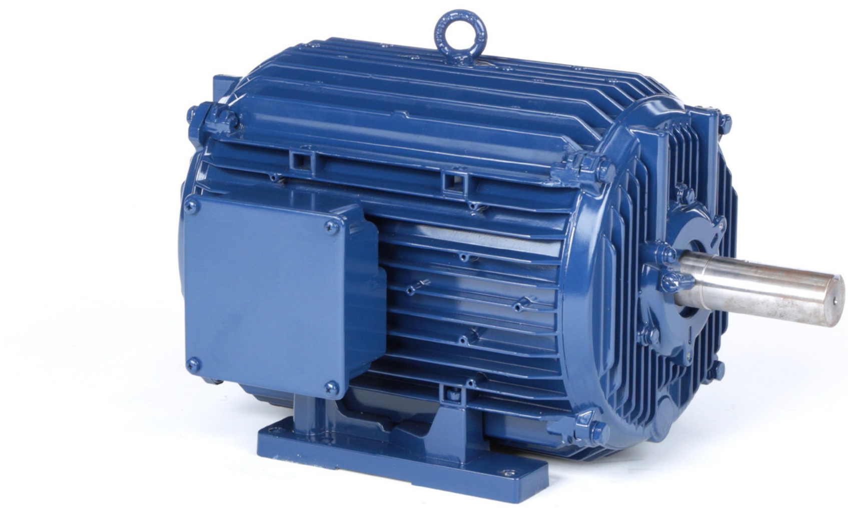
RENEWABLE ENERGY

Highly Efficient Conical Air Gap Axial Motor Using Advanced Soft Magnetic Composite Materials and Grain-Oriented Electrical Steel



The project builds on Regal Beloit's current highly efficient innovative axial flux brushless permanent magnet motor with a conical air gap and a two-hub interior permanent magnet rotor construction. *Photo credit Regal Beloit Corporation.*

Use of these materials combined with a new motor design is expected to result in an electric motor with 96% efficiency.

Energy losses in electric motors can be divided into five major categories: core losses, windage and friction losses, stator losses, rotor losses, and stray load losses. In order to improve motor efficiency, these different types of losses need to be reduced. One way to reduce some of these losses is to use amorphous and nanocrystalline soft magnetic materials, which exhibit greater electrical resistance, in different motor components. These materials, however, suffer from low magnetic permeability and low mechanical strength, making them challenging to incorporate into traditional motor designs.

This project seeks to improve motor efficiency by developing a new design that utilizes soft magnetic composite (SMC) materials and grain oriented electrical steel (GOES) in the rotors and stator.

In order to optimize efficiency gains from these materials and reduce other motor losses, a new motor model will be developed and used to evaluate alternative motor design options. The new motor design will build on a state-of-the-art high efficiency conical air gap axial motor. Finally, a 5 kilowatt (kW) prototype motor will be produced and evaluated.

Benefits for Our Industry and Our Nation

In order to realize efficiency gains in motors, use of amorphous and nanocrystalline soft magnetics materials can be combined with new motor designs and techniques. Use of these materials and new innovative designs have the potential to increase the efficiency of super-premium class induction motors from 92% to 96%, reducing motor losses by 50%.

These efficiency gains, when combined with other technical improvements in electric motor technologies, will contribute to the development of a new generation of electric motors and generators, enhancing the global competitiveness of U.S. industry and manufacturers.

Applications in Our Nation's Industry

The permanent magnet conical air gap design being developed is well suited for motors ranging from 3 to 20 horsepower (hp) within the low voltage integral horsepower market. In this power range, the primary markets for high efficiency motors are pumps, compressors, and fans for heating, ventilation, and air conditioning (HVAC) systems. These applications are particularly well suited for new high efficiency motors because many of the machines run at high duty cycles—that is, they operate a high proportion of the time.

Project Description

The goal of this project is to develop an ultra-high efficiency (96% or greater) total enclosed, fan-cooled, 5 kW, 1,800 revolutions per minute (RPM), 460 Volt motor that incorporates advanced soft magnetic materials. Based on an evaluation of a current state-of-the-art high efficiency motor, an electric motor performance model will be created and validated. Using the developed model, a new motor design will be created and a prototype built.

Barriers

- Advanced soft magnetic materials offer unique advantages over conventional electrical steel, but each of these advantages is only effective for a certain part of the magnetic flux path. Optimal use of the materials requires careful analysis and evaluation of trade-offs.
- Development of the new motor design relies on accurate modeling. Inaccuracies or bias in test results can negatively impact the developed models.
- Motor markets are price sensitive, and use of new advanced materials and novel motor designs may increase cost of the developed motor.

Pathways

In the first phase of the project, the research team will develop a mathematical model based on the highly efficient conical air gap motor design. The model will be validated by tests performed both at Regal Beloit and Texas A&M University research facilities. This dual testing will be conducted to ensure the accuracy of the developed model, as only a highly accurate model can be used to evaluate the efficiency impacts of various design changes.

In the second phase of the project, the developed motor model will be used to identify design changes that will enable the new motor to reach the efficiency goal of 96%. It is expected that the stator pole construction using SMC and GOES materials will have slightly higher hysteresis losses, but the increased stator flux from the addition of SMC material should be significant enough to decrease the overall losses. Because the new motor design will more effectively utilize magnetic flux, less expensive ferrite-based permanent magnets can be used instead of stronger rare earth magnets.

In the final phase of the project, a prototype 5 kW motor will be constructed and its performance will be validated at both Regal Beloit and Texas A&M laboratories.

Milestones

This 2 year project began in 2017.

- Create a validated mathematical motor performance model based on evaluation of the most efficient state-of-the-art motors (2017).
- Create a new motor design to meet the project's performance objectives, including 96% overall efficiency (2018).
- Construct a prototype motor and evaluate its performance (2019).

Technology Transition

Assuming the new technology is successfully developed and demonstrated, Regal Beloit intends to incorporate the highly efficient motors into its product lines. It is anticipated that the 96% efficient motors will be attractive to end users in markets with high duty cycles, such as pumps, compressors, and HVAC systems. The first motors expected to enter the market will be NEMA 5 kW and 7.5 kW, 1,800 revolutions per minute (RPM) models. Because motor markets are price sensitive, special emphasis will be placed on cost-effectiveness of the developed motors and manufacturing techniques.

Project Partners

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