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

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Regal Beloit / Texas A&M University
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Project Objective

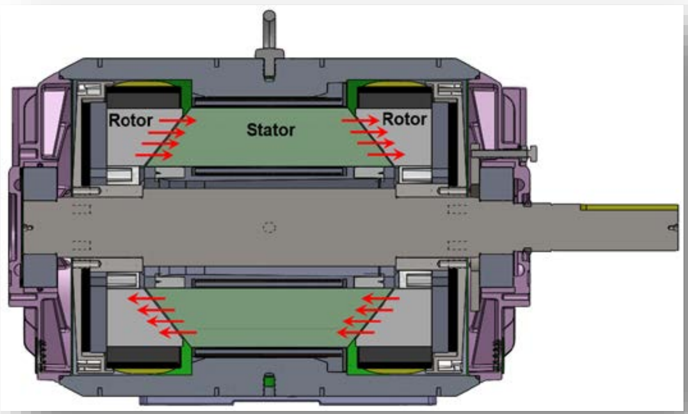
- Improve efficiency on existing 213T frame, 5kW, 1800 RPM electric motor to 96% or greater efficiency through the implementation of soft magnetic composites (SMC) in the stator
- The motor has moderately high efficiency (95%) at present, making the further reduction in losses challenging
- The losses must be evaluated motor-wide to enable beneficial tradeoffs in loss source and magnitude to meet the objective while continually considering manufacturability

Fundamental Knowledge to be Gained

- Can an electric motor with 96% efficiency be designed to be cost competitive with today's motors?
  - Evaluation can be made by comparing active material masses.
- Can the use of materials with typically adverse performance be balanced to produce a system-wide gain in performance?

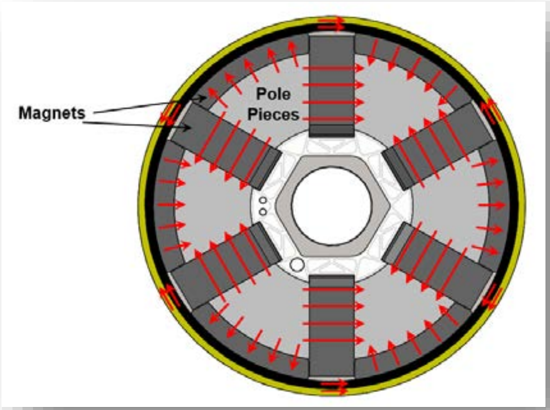
Technical Innovation

- Regal's NovaTorque motor is a dual-rotor, axial-flux, interior permanent magnet motor using ferrite magnets
- Stability of material price/supply drove ferrite magnet choice, resulting in the conical gap versus axial gap
- By using SMC in the rotor, the magnetic flux from 4 magnets per pole can be concentrated by a factor of ~3.7x, in 3 dimensions with low losses



Air Gap Flux Paths

Rotor Flux Paths



Technical Innovation

- The ratio of stator conical area to core area provides an additional flux concentration of 1.2x in the grain-oriented electrical steel (GOES)
  - While GOES is often used in transformers, it is very rarely used in motors
  - The axial flux paths in the stator are well suited to capitalize on the anisotropic properties of GOES
- Through the use of SMC flux collecting caps and balanced losses elsewhere in the motor, we can attain the performance objective
  - By increasing the surface area available, SMC caps will increase the stator flux, and hence torque

Technical Approach

- Motor losses of original design are to be analyzed, broken down, and assigned to design elements
  - SMC flux cap performance will be evaluated based on current knowledge, simulation, and performance testing
- These design elements can then be evaluated for individual optimization
  - Some elements may be evaluated numerically or through the use of FEA (Texas A&M)
  - Some elements may be evaluated by physical 2 or 3-point testing to characterize (Regal, Texas A&M)
- Various tradeoffs of performance and material mass (and relative cost) will be compared to establish best design

Technical Approach

- Risk: 95% to >96% efficiency is a >**20%** loss reduction
  - Optimizing systems, not just components through multiple variable analysis in FEA with a validated physical model
  - Validating significant trends with physical testing
- Challenge: Cost must be held in check because we are in a competitive market
  - Identifying material cost per watt saved, and trends to optimize
  - Adding material only if the gains show a significant value in terms of a 12-18 month payback on energy savings
- This motor topology has been in limited production, and is presently going through volume production ramp

Transition (beyond DOE assistance)

- Initial markets for NovaTorque-technology motors
  - OEM air handling
  - Retrofit air handling
  - OEM equipment – generators, industrial, pumps
  - Other high duty cycle variable speed applications
- Commercialization
  - Regal expects to make significant investments in marketing and manufacturing to promote and enable the use of the technology developed in this program.
  - Potential extension of technology to larger frame sizes (NEMA 250 and above)
- Market Drivers
  - The motor has value due to the dominant cost being in lifetime consumed power as opposed to purchase price. (Consider the total cost of ownership)
  - Higher efficiency would future-proof many applications

Measure of Success

- A higher efficiency motor means:
  - Increased attraction for customers
  - Improved operating costs over the life
  - Increased sales to support development of additional improvements.
- To a data center, from 92% to 96% for a 5kW fan would mean <u>per motor</u>:
  - Reduction in annual energy consumption by 1752 kW-hrs
  - Reduction in resultant additional heat load (for indoor applications)
  - Reduction of required grid resources
  - A potential value creation of over $2628 at $.10/kW-hr, and a 15 year life

Project Management & Budget

- Project duration is 2 years
  - 9 months – Budget Period 1
    - Baseline confirmation and initial modelling and testing
  - 9 months – Budget Period 2
    - Model based optimization and physical validations
  - 6 months – Budget Period 3
    - Construct sample motor, test and validate performance

Total Project Budget	
DOE Investment	$800,000
Cost Share	$200,000
Project Total	$1,000,000

Results and Accomplishments

- Currently Pre-Award.
  - Evaluating analysis tools available to participants
  - Developing approach plan for different aspects of the project.