Ultra-High Speed, High-Temperature Motor
Project ID: elt254
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- **Objectives**
  - Two enabling technologies are needed to develop a 125 kW motor at 50 kW/L
    - Stator insulation materials capable of operating at 650°C.
    - Soft magnetic composites rated for operation at 60,000 RPM.
- **Impacts**
  - High-temperature insulation enables higher power densities and increased reliability against transient thermal loads.
  - Soft magnetic composites enable lower power losses during high-frequency operation and can be manufactured without energy-intensive melt-processing and welding operations.

Approach

High-Temperature Enamel
- Preceramic polymer resins are rated for temperatures approaching the melting point of copper wire
- Thin-film manufacturing methods allow precise control over dielectric strength and flexibility

Goal: increase current-carrying capacity to increase power density and reduce thermal failures

Soft Magnetic Composites
- Combining sol-gel methods with 3D-printing can produce composites with improved high-frequency performance over laminated steels

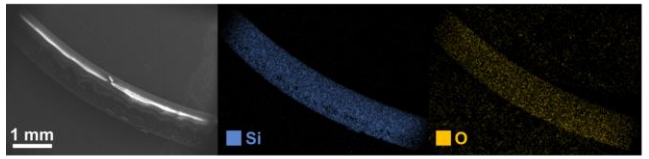
Goal: reduce magnetic switching losses to increase power density

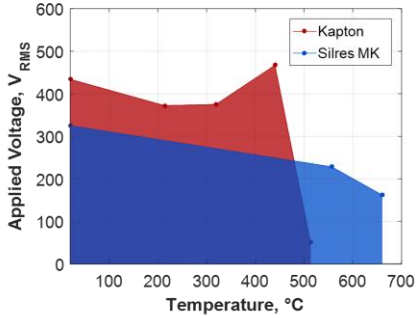
Milestones

Month/Year	Description of Milestone or Go/No-Go Decision	Status
Dec 2020	Optimize motor design with geometry, electromagnetic, and thermal design specifications that meet 125 kW, 50 kW/L, and 60,000 RPM at hotspot temperature of 650°C.	In progress
Feb 2021	Construct soft magnetic composite-based rotor core and stator section and determine BH curve characteristics.	In progress
May 2021	Establish communications between inverter and controller hardware for dynamometer testing.	In progress
Jun 2021	Validate the motor and inverter compatibility using hardware-in-the-loop testing to drive the motor finite-elements model.	In progress
Jun 2021	Demonstrate operation of the soft magnetic composite rotor at 60,000 RPM and operation of the winding enamel at 650°C.	In progress

Technical Accomplishments – Materials Development

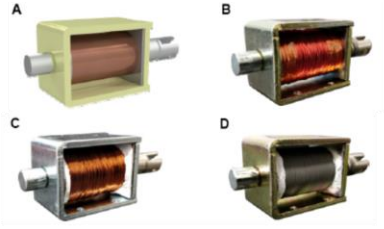
- Copper wire with preceramic enamel has been developed to compare with commercial Kapton enamel
- Dielectric tests (ASTM D1676) show that preceramic enamels operate 150°C higher than Kapton



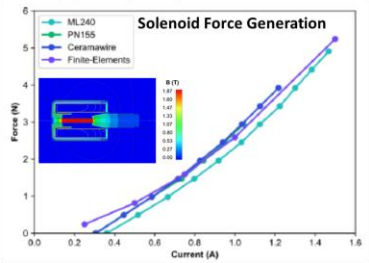


Preceramic enamels are rated for higher temperatures than Kapton enamels.

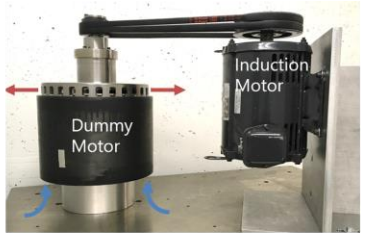
Technical Accomplishments – Motor Prototype and Test Stand



A) Solenoid design and prototypes fabricated with B) PN155, C) ML240, and D) ceramawire strand insulation.



A low-cost motor prototype has been developed to compare the force generation for different wire candidates.



- A vertical test stand has been constructed to test sample rotors from 0-60,000 RPM
- Soft magnetic composite rotors are being tested to observe critical speeds and harmonic modes for comparison with rotordynamics simulations

A test stand has been developed to validate the mechanical integrity of soft magnetic composites at 60,000 RPM