DESIGN AND DEVELOPMENT OF LOW COST FLYWHEEL ENERGY STORAGE SYSTEMS

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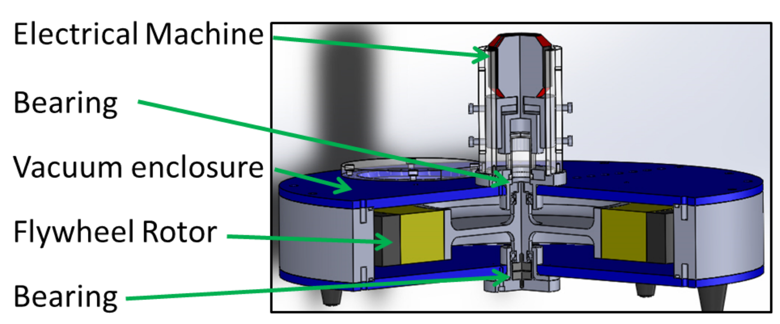
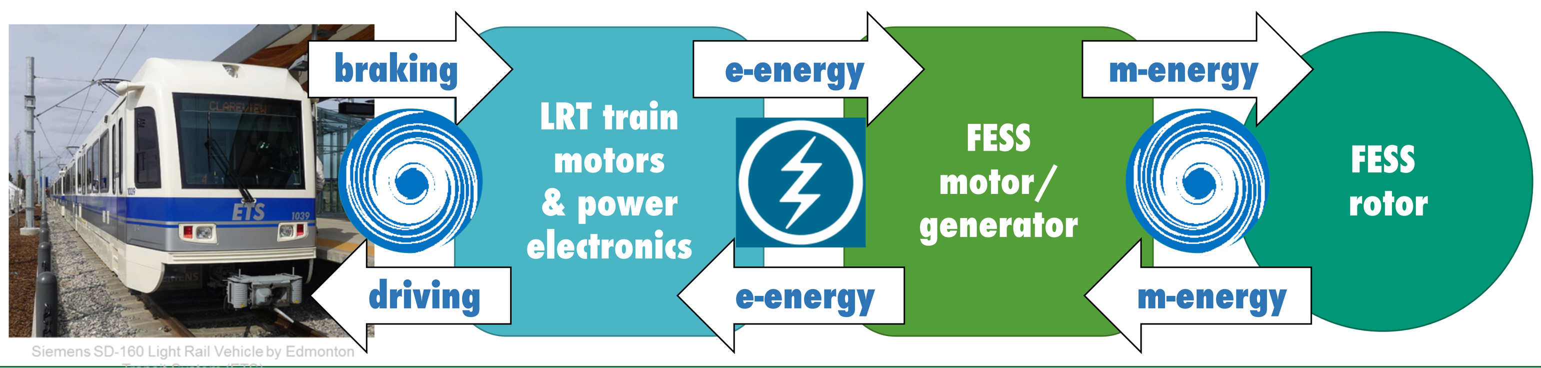
BACKGROUND

OVERVIEW - FLYWHEEL ENERGY STORAGE SYSTEM (FESS)

- FESS ➔ 'mechanical battery' stores surplus energy (e.g. from dynamic braking) in the form of kinetic energy in a rotating mass (rotor).
- Implementing a FESS for the Edmonton LRT could realize energy savings up to 31% and cost savings up to 11%.

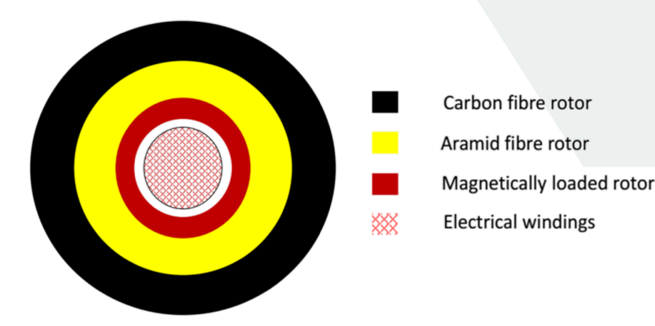




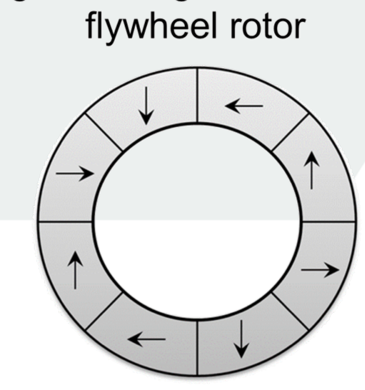
AIMS AND OBJECTIVES

- Develop design principles for low-cost FESS minimizing potential failure modes and maximize system performance
- Model material behavior using analytical and numerical methods to predict rotor failure modes, lifetime, and safe design regimes
- Develop multi-material magnetic filler loaded polymer using soft and hard magnetic particles to achieve high saturation magnetization and coercivity
- Characterization of stress and unstressed FRP rotor material creep behavior during operation.

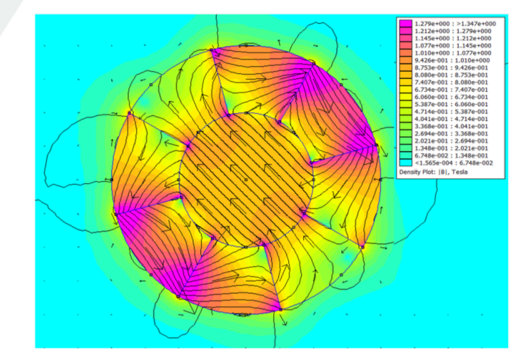
2D Flywheel rotor schematic



Magnet configuration for the flywheel rotor



Dipolar magnetic field within the rotor



PROJECT OVERVIEW AND RESULTS

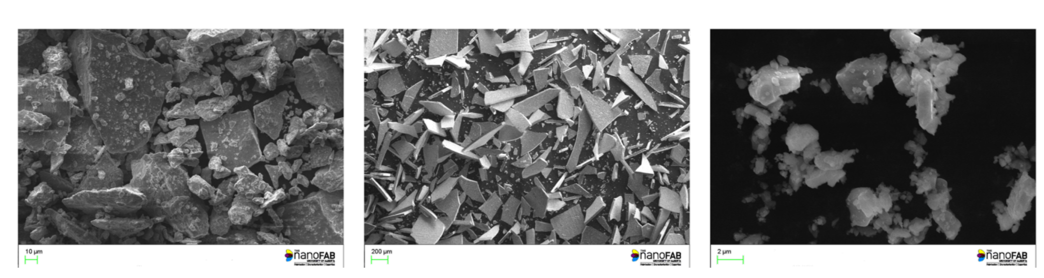
ELECTRICAL MACHINE FUNCTIONALITY INTEGRATION IN FESS

- A typical FESS employs a separate motor/ generator unit to spin the rotor to high speeds, then convert kinetic energy back to electricity.
- Magnetically loaded polymer composites developed using soft and hard magnetic particles are suitable for integration with FESS rotors.

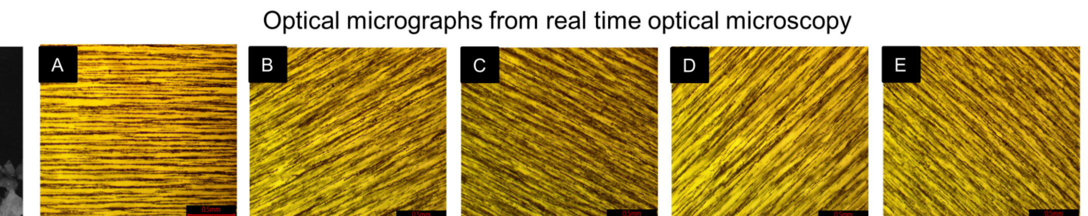
INNOVATION USING ADDITIVE MANUFACTURING (AM)

- Develop composites with localized particle orientation using material jetting process and construct Halbach array type magnetic rotor.
- External magnetic field produces particle alignment with chain-like microstructures that enhance magnetic properties
  ➔ Resultant properties are directionally dependent.
- Develop magnetic filler loaded polymers for AM with properties to resist gravitational settling and droplet deformation during the manufacturing process.
- Particle alignment validation using real time optical microscopy and image processing techniques enables process optimization for AM.

SEM images of Magnetic particles

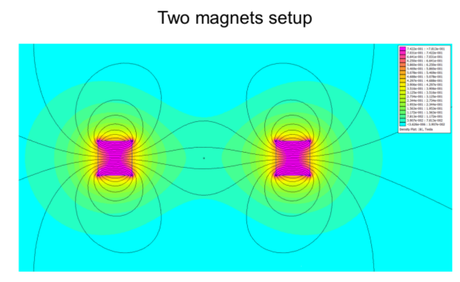


Optical micrographs from real time optical microscopy

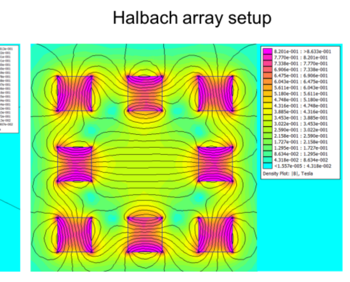


Micrographs of filler particles in liquid resin with angular orientations of (A) 0°, (B) 30°, (C) -30° (D) 45°, (E) -45°

Two magnets setup



Halbach array setup



Magnetic flux density comparison

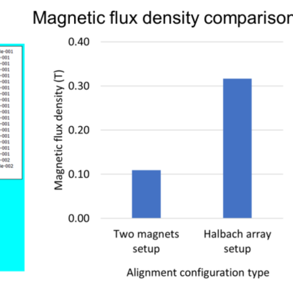
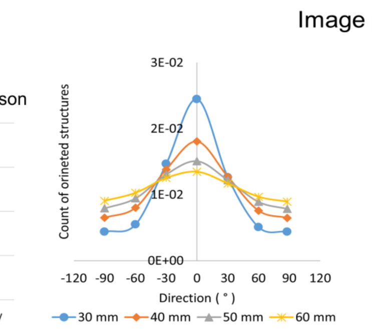
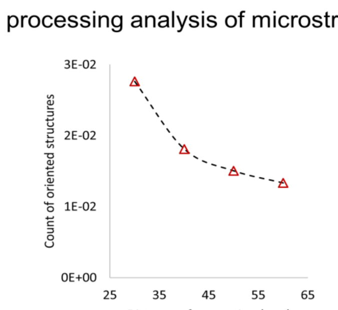


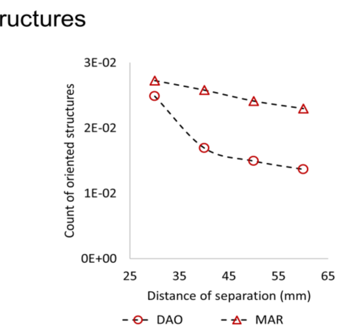
Image processing analysis of microstructures



Magnetic filler directionality analysis data for 0° angular orientation

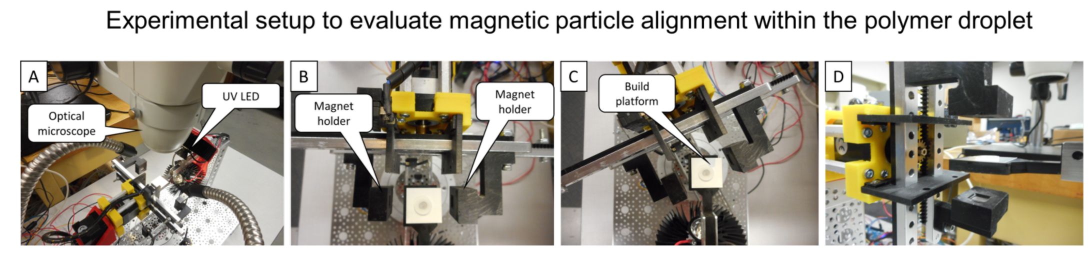


Influence of magnet separation distance on count of particles in the 0° direction

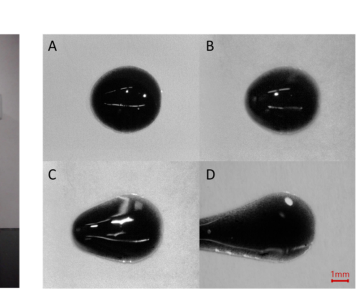


Evaluation of Direct Angular Orientation (DAO) and Magnetize and Rotate (MAR) alignment process

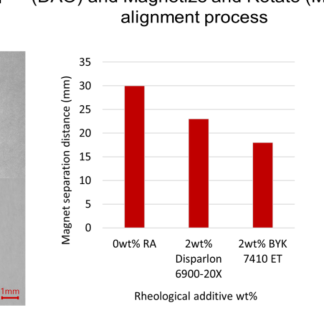
Experimental setup to evaluate magnetic particle alignment within the polymer droplet



Magnetic particle settling control



Droplet deformation in magnetic field



Stability control using rheological additives

OUTCOMES AND FUTURE DIRECTIONS

- Multi-material magnetic filler loaded polymers engineered for additive manufacturing process.
- Material jetting based additive manufacturing system with localized particle orientation capabilities.
- Magnetic composites with particles oriented at multiple angles creating a strong dipolar magnetic field suitable for Halbach array type flywheel rotor.
- Flywheel with integrated magnetic rotor eliminating the requirement of a separate electrical machine.
- Rotor material stress-strain model considering time- dependent material behavior.
- Significant design improvements for low cost flywheel energy storage systems.

PUBLICATIONS AND PRESENTATIONS

B. Nagarajan, A.F. Eufracio, A.J. Qureshi, P. Mertiny, "Additive manufacturing of magnetically loaded polymer composites: An experimental study for process development," In Proc. ASME 2017 International Mechanical Engineering Congress and Exhibition, Tampa, FL, USA, November 2017.
M. Skinner, M. Suess, M. Secanell, P. Mertiny, "Design of a composite flywheel rotor for long-term energy storage in residential applications," In Proc. The Canadian Society for Mechanical Engineering International Congress, Kelowna, BC, June 2016.

PARTNERS

In addition to Future Energy Systems, the research group is affiliated and collaborates with researchers of the Nasseri School of Building Science & Engineering at the University of Alberta, the Composite Research Network, ABBY-Net – the Alberta and Bavaria Interdisciplinary Research Network, and the NSERC Energy Storage Technology Network led by the Centre for Urban Energy at Ryerson University.

Nasseri School of Building Science and Engineering

CRN Composites Research Network

NSERC Energy Storage Technology Network

FES PROJECT OVERVIEW

T06-P03 GRIDS AND STORAGE

New technologies enable us to exploit renewable energy resources, but truly harnessing their energy requires the ability to control and adapt to the complex interaction between multiple sources and users. Smart grid technology will enable systems that can adapt to the variation in supply that is common from renewable sources, while new storage technologies will make it possible to retain energy generated at during peak times to be withheld for later use. Developing hybrid grids that can accommodate both AC and DC power, accommodating distributed generation, and effectively interfacing with legacy grid systems will be essential to our energy future.

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