DESIGN AND DEVELOPMENT OF LOW COST FLYWHEEL ENERGY STORAGE SYSTEMS

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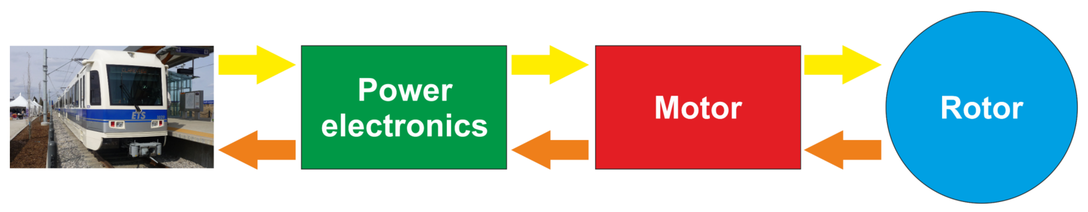
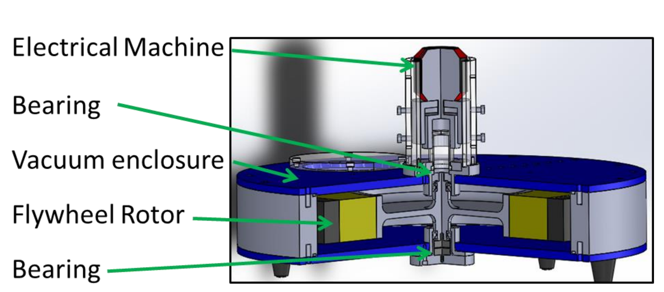
BACKGROUND

FLYWHEEL ENERGY STORAGE SYSTEM (FESS)

- A FESS is a ‘mechanical battery’ that stores surplus energy (e.g. from regenerative braking in vehicles) as kinetic energy in a rotating mass, i.e., the rotor.
- For example, modeling results showed: FESS for Edmonton LRT could realize energy savings up to 31% and cost savings up to 11 %.
- Current FESS technology employs a separate electrical machine (motor/generator unit) to spin the rotor to high speeds (FESS charging), and convert kinetic energy back to electricity (FESS discharging).

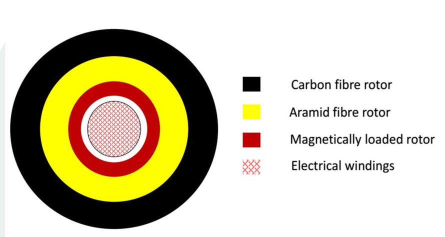




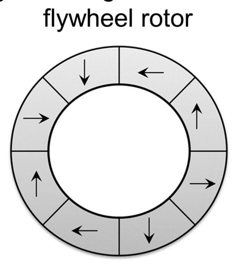
MULTIDISCIPLINARY OBJECTIVES

- Develop design solutions for low-cost FESS, minimize potential failure modes, and maximize FESS performance.
- Model material behavior (analytically and numerically) and characterize long-term behavior (e.g. creep) of polymer composite rotors prior to and during operation, to predict rotor damage, lifetime, and safe operation regimes.
- Design rotors with integrated electrical machine functionality, i.e. develop multi-material magnetic filler loaded composites using soft and hard magnetic particles to achieve high saturation magnetization and coercivity
- Characterize magnetic filler loaded polymers for additive manufacturing process using rheology, thermogravimetry and FTIR spectroscopy methods.
- Model and experimentally validate properties of composites with different filler shapes, sizes and volume fractions.

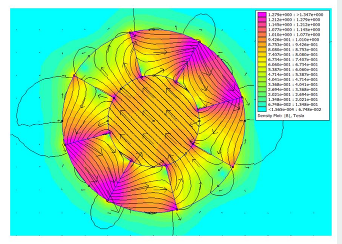
2D Flywheel rotor schematic



Magnet configuration for the flywheel rotor



Dipolar magnetic field within the rotor



PROJECT OVERVIEW

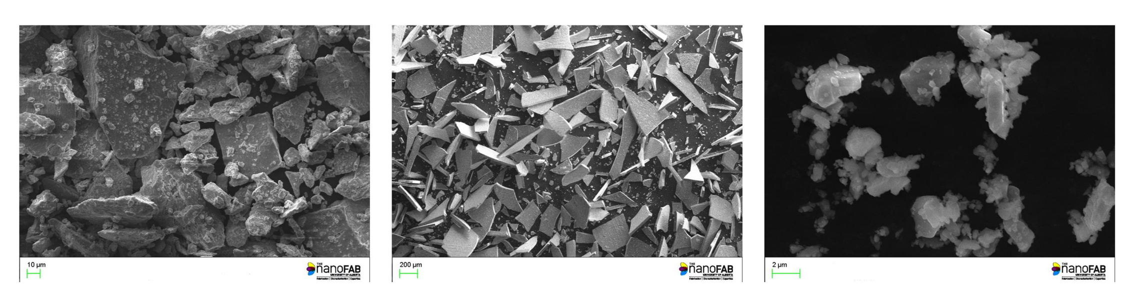
ELECTRICAL MACHINE FUNCTIONALITY INTEGRATION IN FESS

- Typical FESS technology employs a separate electrical machine to accelerate/decelerate the flywheel rotor
- Opportunities exist to provide the rotor with functionality to become part of the electrical machine.
- Functionality integration may be achieved using magnetically loaded polymer composites with soft and hard magnetic particles.

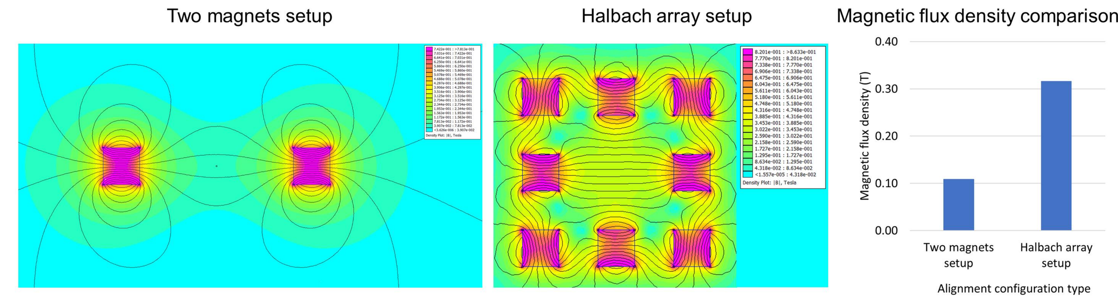
INNOVATION USING ADDITIVE MANUFACTURING

- Composites with localized particle orientation are developed using material jetting processes to construct Halbach array type magnetic rotor.
- Particle alignment step is performed by applying external magnetic field, which produces chain like microstructures that enhance properties like magnetic remanence, susceptibility, magnetic saturation and coercivity. Resultant properties are directional dependent.
- Magnetic filler loaded polymers are developed for additive manufacturing with properties to resist gravitational settling and droplet deformation during the manufacturing process.
- Particle alignment is being verified using real time optical microscopy and image processing techniques, enabling process optimization for additive manufacturing.

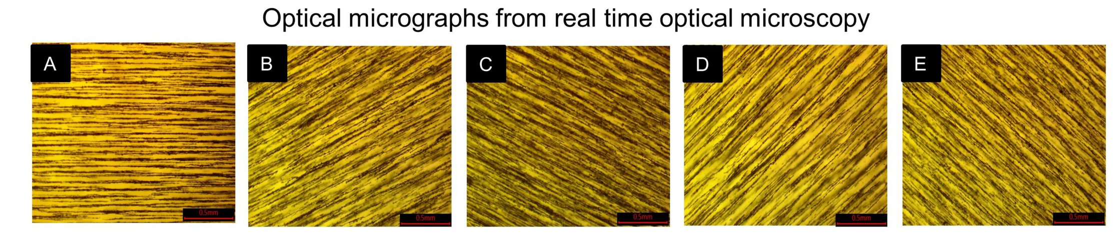
SEM images of Magnetic particles



Two magnets setup — Halbach array setup — Magnetic flux density comparison

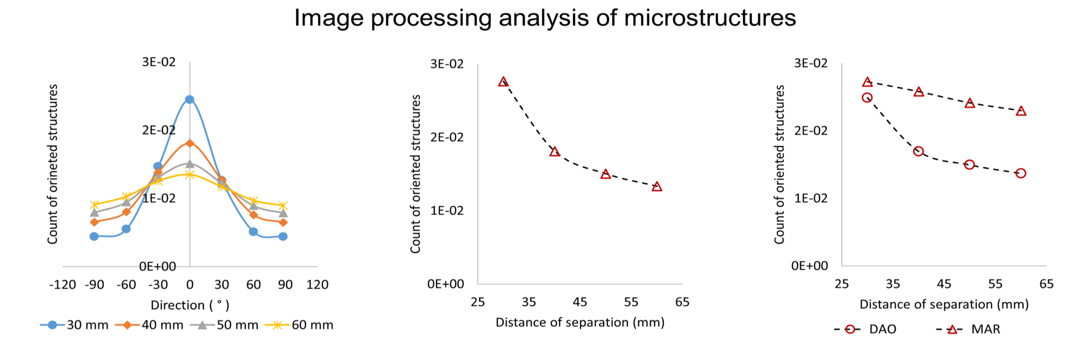


Optical micrographs from real time optical microscopy



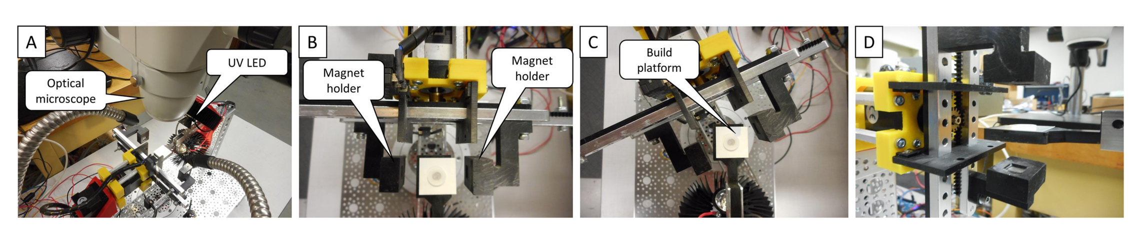
Micrographs of filler particles in liquid resin with angular orientations of (A) 0°, (B) 30°, (C) -30° (D) 45°, (E) -45°

Image processing analysis of microstructures



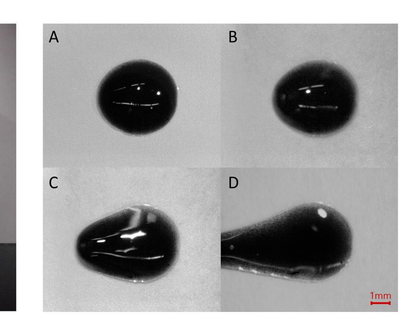
Magnetic filler directionality analysis data for 0° angular orientation — Influence of magnet separation distance on count of particles in the 0° direction — Evaluation of Direct Angular Orientation (DAO) and Magnetize and Rotate (MAR) alignment process

Experimental setup to evaluate magnetic particle alignment within the polymer droplet

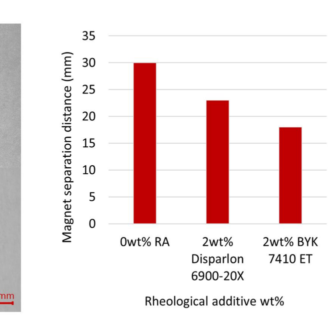


System capabilities include control of cube magnet separation distance, time for positioning magnets, angular position and duration of curing source activation

Magnetic particle settling control



Droplet deformation in magnetic field



Stability control using rheological additives

EXPECTED OUTCOMES

MULTIDISCIPLINARY RESEARCH OUTCOMES

- 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 (2017).“Additive manufacturing of magnetically loaded polymer composites: An experimental study for process development”. Accepted in Proc. ASME 2017 International Mechanical Engineering Congress and Exhibition, Tampa, FL, USA, 3-9 November 2017.

B. Nagarajan, M. Wiechmann, A.F. Eufracio, A.J. Qureshi, P. Mertiny (2017). “Characterization of magnetic particle alignment in photosensitive polymer resin: A preliminary study for additive manufacturing processes”, Additive Manufacturing (under review).

B. Nagarajan. “Electrical machine functionality integration in flywheel energy storage systems using magnetic polymer composites”, Presented at Energy and Mobility Seminar, Technical University Munich, Germany, 9-13 October, 2016.

THEME OVERVIEW

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.

EXTERNAL 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 and the NSERC Energy Storage Technology Network led by the Centre for Urban Energy at Ryerson University.

Nasseri School of Building Science and Engineering

NSERC Energy Storage Technology Network

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