Novel Machine Insulation Materials for Transportation Electrification Applications

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Nanostructured Insulation Material 1: Stator ground wall insulation with higher thermal conductivity

Aim

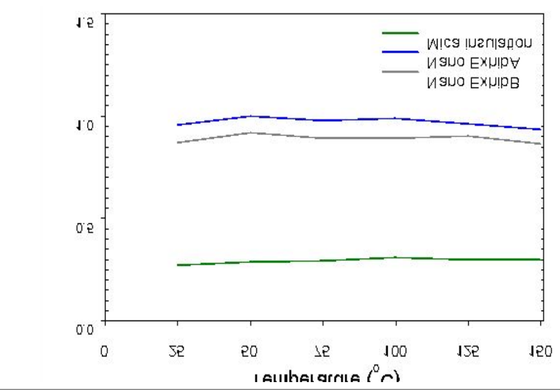
- Evaluate new nano-structured insulation materials in marine propulsion motors
- Compare medium voltage motor performance with mica vs. new nano-structured material as stator groundwall insulation

Material properties

NIMs exhibit largely enhanced thermal conductivity of >0.9W/(m·K) over that of micaceous insulation materials (MIMs) at only ~0.25W/(m·K) [1]

NIM properties

- High thermal conductivity **>0.8 W/(m·K)**
- High breakdown strength **>40 kV/mm**
- Low dielectric constant <5.5
- Low dielectric loss factor <2.5% at 155°C



Material evaluation

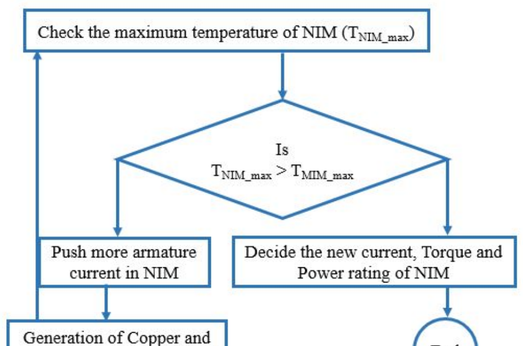
The electromagnetic and thermal analyses were performed using ANSYS Maxwell. A customized MV induction machine was simulated based on NIMM and MIMM. The machine design was conducted using the RMxprt tool in ANSYS Maxwell, which is a template-based tool for fast design of electric machines. The motor physical, electrical and thermal parameters used in simulations are mentioned in [2].

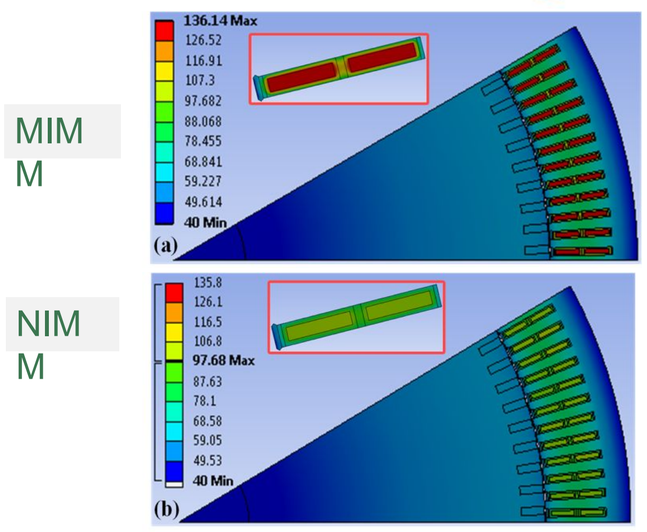
Ansys RMxprt
Geometry design

Ansys Maxwell
Material assignment, Electromagnetic analysis

Ansys Workbench
Connects Maxwell & Thermal
Import losses as thermal load

Ansys Steady State
Thermal analysis



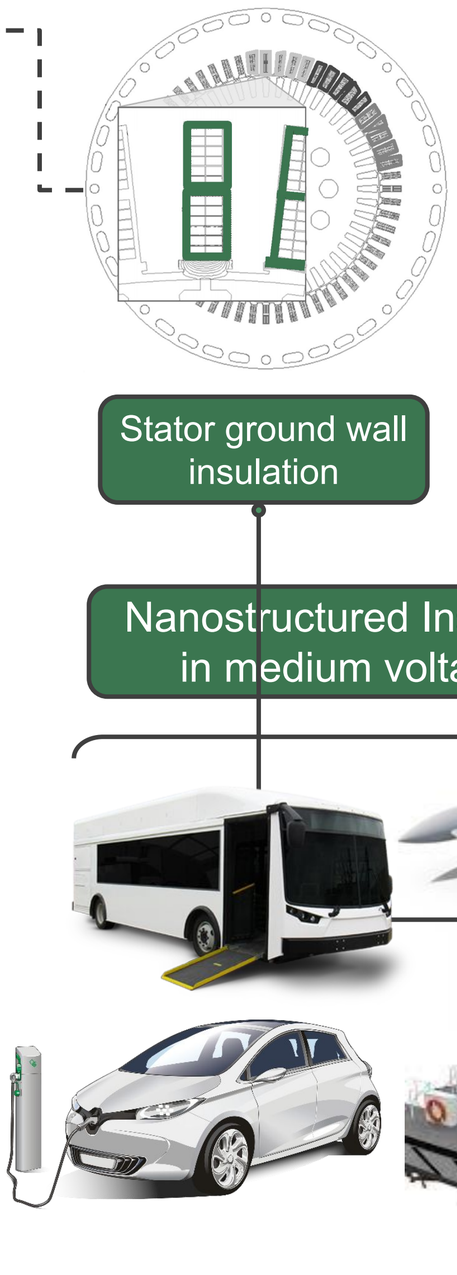


Key takeaways

- New nano-structured insulation material improves the motor torque by 14% compared to mica.

References

1. H. H. Nguyen, **A. Y. Mirza**, et al., "Investigation of 2D Nano-Structured Winding Insulation for High Torque Density Medium-Voltage Motor," in IEEE Access, vol. 9, pp. 2274-2282, 2021.
2. Y. Liu, H. Nguyen, A. M. Bazzi and Y. Cao, "Torque enhancement and re-rating of medium-voltage induction machines using nano-structured stator winding insulation," 2017 IEEE Electric Ship Technologies Symposium (ESTS), 2017, pp. 232-237.



Transportation electrification is one of the key enablers to achieve a greener future. Efficiency, reliability and longevity of the motor drives used in electric cars, ships, airplanes is very critical. New insulation materials with better thermal and electrical properties can help motor drives improve their torque density. In this poster, we share the applications and capabilities of two new nano-structured insulation materials in transportation electrification applications.

- **NIM Stator ground wall insulation improves the motor torque by 14% due to higher thermal conductivity**
- **NIM Stator turn insulation has a 2X higher time to breakdown than industrially available insulation materials**

Performance of these new-nanostructured materials is very promising and holds a huge potential to revolutionize the transportation electrification industry.

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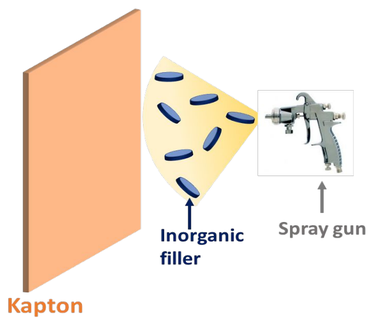
Nanostructured Insulation Material 2: Stator turn insulation with longer breakdown time

Aim

- Evaluate time to breakdown of polyimide films under medium-voltage square-wave excitations
- Evaluate the effect of inverter switching frequency on breakdown time

Material properties

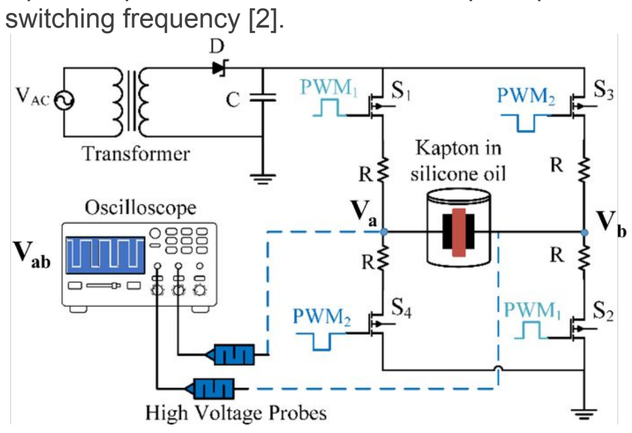
The polymer nanocomposites show an increased resistance to partial discharges and low charge accumulation. The high aspect ratio and the platelet shape of the nanoclays, which require a pathway around the fillers for electrical treeing propagation due to the anisotropic feature of the MMT cause larger breakdown time [1].

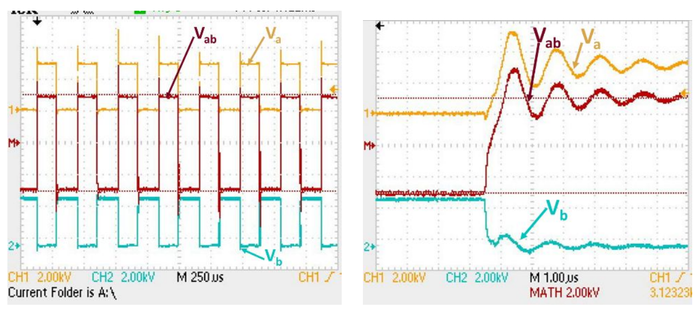


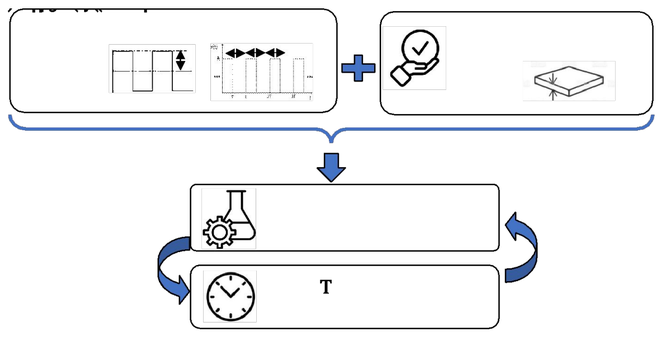
The coating precursor was prepared by dispersing MMT nanosheets in ethanol/toluene using tip ultra sonication for 1h. Polyvinyl butyral (PVB) was added in the solution and dissolved via magnetic stirring. The solid weight content part is 5% in the solution, and the weight ratio MMT:PVB is 1:4.

Material evaluation

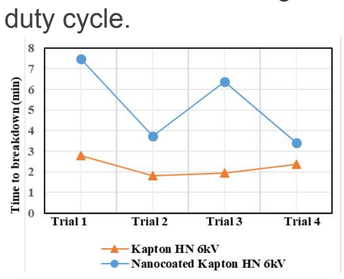
A medium-voltage H-bridge inverter testbed was used to stress insulation materials. The testbed has a capability to operate up to 30kV DC, 3mA input to give a +/-15kV bipolar square waveform as the output up to 4 kHz switching frequency [2].



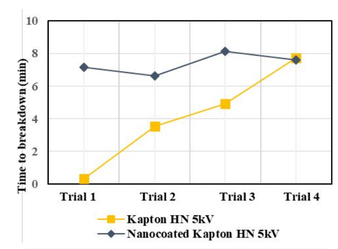




Four samples of Kapton® HN and nano-coated Kapton® HN were tested at peak-peak voltages of 5kV and 6kV at a switching frequency of 3 kHz and 50% duty cycle.



Kapton vs. NIMM @6kVpp



Kapton vs. NIMM @5kVpp

Key takeaways

- NIM Stator turn insulation has a 2X higher time to breakdown than industrially available insulation

References

1. A. Y. Mirza, A. Konstantinou, Y. Cao and A. M. Bazzi, “Novel Machine Insulation Material for Transportation Electrification Applications” IEEE Transportation Electrification Conference (ITEC), 2022 (Accepted).
2. **A. Y. Mirza,** W. Chen, H. Nguyen, Y. Cao and A. M. Bazzi, "High-Voltage High-Frequency Testing for Medium-Voltage Motor Insulation Degradation," 2018 IEEE Energy Conversion Congress and Exposition (ECCE), 2018, pp. 2444-2447.