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M3Or1A-03: Development of measurement tools and protocols for shear strength measurements of cryogenic epoxy interfaces

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Cryogenic epoxies must have application-relevant electrical, thermal, and mechanical characteristics for safe operation for the life of the device. Appropriate testing techniques and protocols are necessary for epoxy material selection and qualification. Epoxies for cryogenic applications need to be tested at the cryogenic conditions of the device. We have developed a novel test protocol to evaluate samples' interfacial shear stress (IFSS) at room temperature that tracks load transfer and isolates the failure mode between materials. As part of our continued research, we are modifying the apparatus and technique to measure the IFSS of two cryogenic epoxy interfaces with other materials. The first interface is between the cryogenic epoxy and high-temperature superconducting (HTS) material to explore the epoxy as the electrical insulation for HTS power cables. Our research identified cryogenic epoxies with mechanical flexibility at room temperature and showed promise as electrical insulation. The stress/strain evolution of the interfacial bonding between the epoxy and HTS tapes to failure was measured to assess its ability to support the loading under cryogenic conditions. Measurements were performed in a bath of LN2 to evaluate the interfaces after multiple thermal cycles. The probability of delamination of the epoxy coating from the conductor was assessed. Delamination and void formation at the HTS tape/epoxy interface will cause partial discharge and the eventual failure of the electrical insulation systems of HTS cables.

The second aspect of the study investigated the mechanical interfaces of thermal insulation blanket mount retainers with cryogenic storage tanks. The adhesive properties of the cryogenic epoxies need to prevent delamination from the storage tank wall at cryogenic temperature. Test samples were characterized in a bath of LN2. Care was taken when performing the measurements to avoid excessive thermal shock. Microscopy was performed to assess the fracture modes for both the electrical insulation and thermal insulation blanket retainers. The viscoelastic performance of the cryogenic epoxies was tested using frequency sweeps at various temperatures. The models of thermomechanical fracture developed were validated to assess the digital twin accuracy. The model assumed viscoelastic conditions, and the time-temperature superposition (TTS) principle was employed to extend the simulation prediction to an extensive range of frequencies and temperatures. The results of the models and experiments were used in designing and evaluating material thermomechanical performance and bonding strength to understand interfaces at extreme conditions. Commentary will also be provided on potential modifications to the experimental setup to allow measurements at cryogenic temperatures, and the data will be discussed in the context of the applications.

Author: Ms DE LEON, Ana (FAMU-FSU College of Engineering)

Co-authors: Ms MULLINGS, Alexia (FAMU-FSU College of Engineering); TANK, Mehul (FAMU-FSU College of Engineering); RUDD, Roy (Center for Advanced Power Systems); CHEETHAM, Peter (FAMU-FSU College of Engineering); PAMIDI, Sastry (FAMU-FSU College of Engineering); Dr SWEAT, Rebekah (FAMU-FSU College of Engineering); INGROLE, Aniket (NHMFL)

Presenter: INGROLE, Aniket (NHMFL)

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