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SOFTMAT

Mechanical characterization of an epoxy resin used for high-field superconducting magnets at cryogenic temperatures

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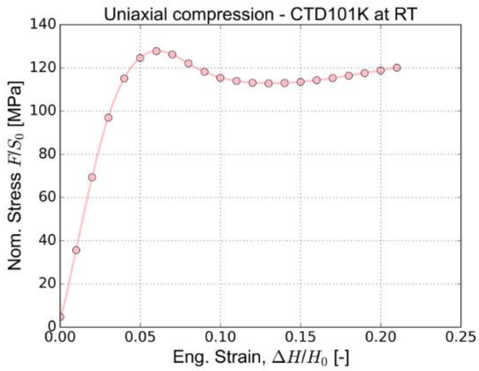
Overview

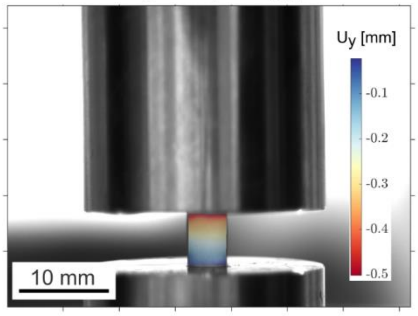
Superconducting accelerator magnets are being developed for enhanced magnetic fields in the Future Circular Collider (FCC) at CERN, which means that the superconductive coils will be exposed to even higher electromagnetic (Lorentz) forces[1]. The thermal events (e.g., local heating from mechanical cracks) result in the accompanied loss of the super-conductive state[2]. To ensure its stability, an epoxy resin system is developed at cryogenic temperature to protect Nb_3Sn superconducting cables during normal operation. An accurate thermo-mechanical constitutive model is a necessity for the coil design.

We aim to characterize its elasto-viscoplastic property from T_g (~400K) down to cryogenic temperatures (77K) and find an effective model to describe the dependence of its yield stress on the plastic flow rate and temperature.

Detailed Description

The epoxy system from Composite Technology Development Inc., CTD101-K, is a high-performance resin at cryogenic temperatures as well as for its resistance to high energy radiation[2]. Uniaxial compression test allows to interrogate the yield stress of brittle materials at cryogenic temperatures. An *in situ* full-field measurement offers more information via image-based analyses[3] at a wide range of temperatures, which ultimately explains the events more than the stress-strain curve. An effective and widely employed Eyring equation[4,5] describes the non-linear behavior of solid polymers at different temperatures and applied strain rates.





Project tasks will include:

- Perform mechanical compressive experiments at a wide range of temperatures and strain rates from quasi-static to dynamic.
- Apply digital image correlation (DIC)[3] for local measurements.
- Optimize Ree-Eyring model[4,5] to fit the experimental dataset.
- For those who are interested in Deep Learning, a neural network-based method will be investigated as well and compared.

Prerequisite: Mechanics, a programming language (Python or Matlab)

This project is a part of CHART (Swiss Accelerator Research and Technology) and it will involve collaborations among researchers from D-MAVT, PSI, CERN and CEA (France) etc.

References

[1] Schoerling, D.; Zlobin V. A., "Nb3Sn Accelerator Magnets"; *Springer Cham*, 2019.
[2] Brem *et al, Cryogenics* 115, (2021) :103260.
[3] Sutton et al (2009), *Image Correlation for Shape, Motion and Deformation Measurements*.
[4] Ree, Eyring; *J. Appl. Phys.*, 26 (7), 793-800 (1955)
[5] Govaert, L. E., Vegt, van der, A. K., & van Drongelen, M. (2019). *Polymers: From Structure to Properties*. Delft Academic Press. Chapter 7.2