Numerical and Experimental Investigation of the Electromechanical Behavior of REBCO Tapes

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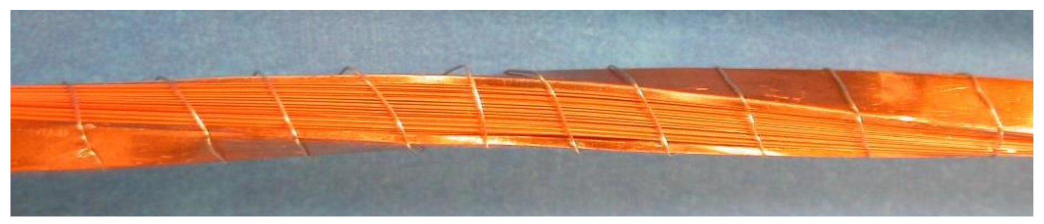
Introduction

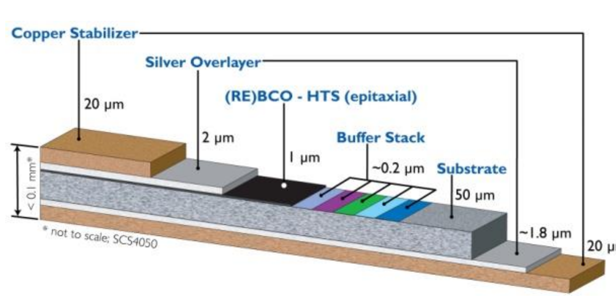
Second generation REBCO high temperature superconducting (HTS) tapes have excellent mechanical properties and high current capabilities. These characteristics have made them the focus of various high field magnet applications, which require the development of high current density cables.

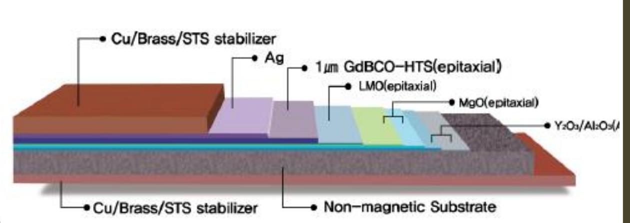
One of the present high current density HTS cables suitable for large magnets applications is the **Twisted Stacked-Tape Cable (TSTC)** .



This work characterizes the electromechanical behavior of two commercially available REBCO tapes (SuperPower and SuNAM) under **tension** and **combined tension-torsion** using structural finite element analysis (FEA) and experimentation at 77 K and in self-field conditions.

	SuperPower	SuNAM
Type	SCS4050-AP	SCN04150
Processing	IBAD-MOCVD	IBAD
Width	4.027 ± 0.057 mm	4.062 ± 0.008 mm
Thickness	0.092 ± 0.001 mm	0.144 ± 0.001 mm
Substrate	Hastelloy C-276 *(50 μm)*	Stainless Steel *(100 μm)*
Cu Stabilizer	Electroplating *(40 μm)*	Electroplating *(40 μm)*
Critical Current 77 K & self-field	112 ± 3 A	229 ± 6 A

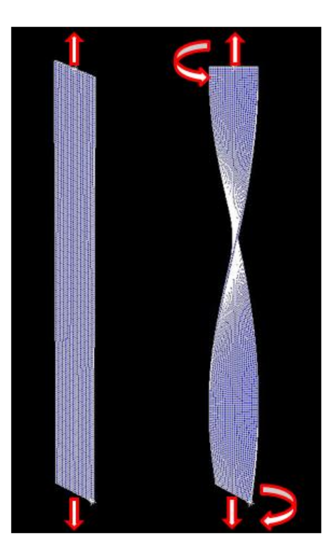


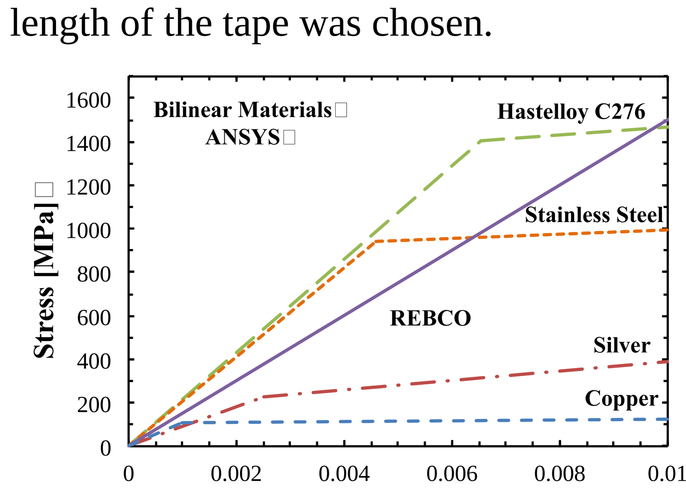


Finite Element Analysis

Structural finite element analysis (FEA) using ANSYS® was done to investigate the electromechanical behavior of REBCO coated tapes under tension and combined tension-torsion loads. The FEA tension-torsion model was used to determine the stress-strain characteristics, torque magnitudes and to predict critical current based on an analytical model.

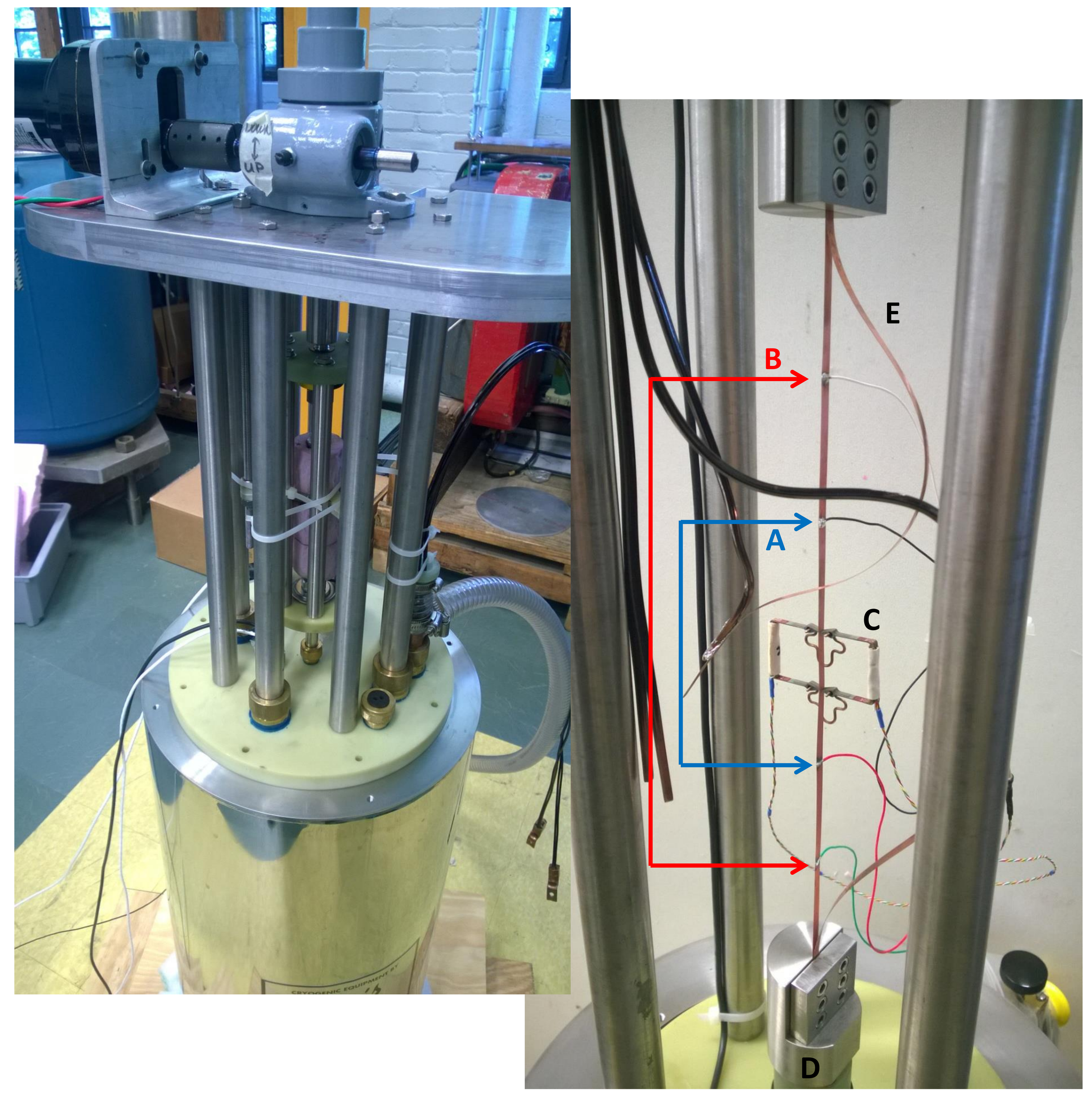
The REBCO tape was modeled using 3D 8-node SOLSH190 structural solid-shell elements with built in layered composite capabilities. The tape was meshed with one element through its thickness and the appropriate layer definitions and properties were defined using shell section commands. Sufficient mesh density through the width and length of the tape was chosen.





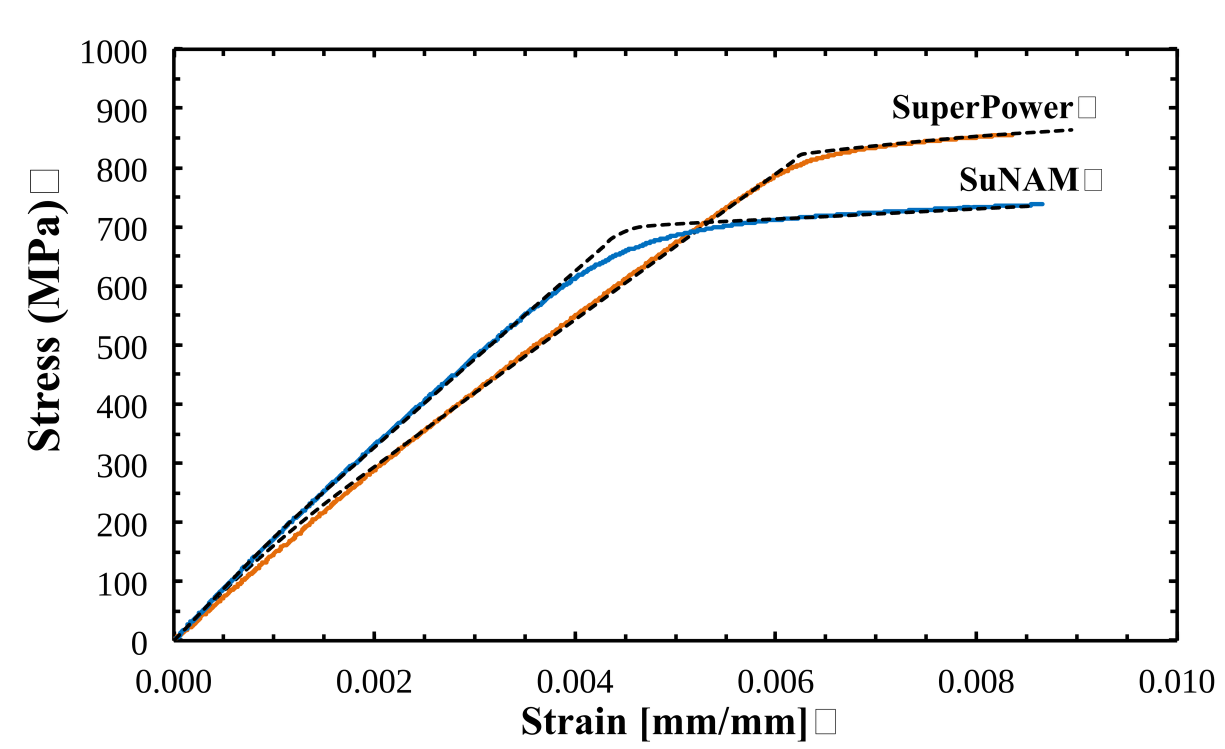
The rotation was applied to one end through a pilot node constraint while the other end remained fixed. The tension was applied to the areas on the ends of the tape using a surface pressure load (shown above).

Experiments



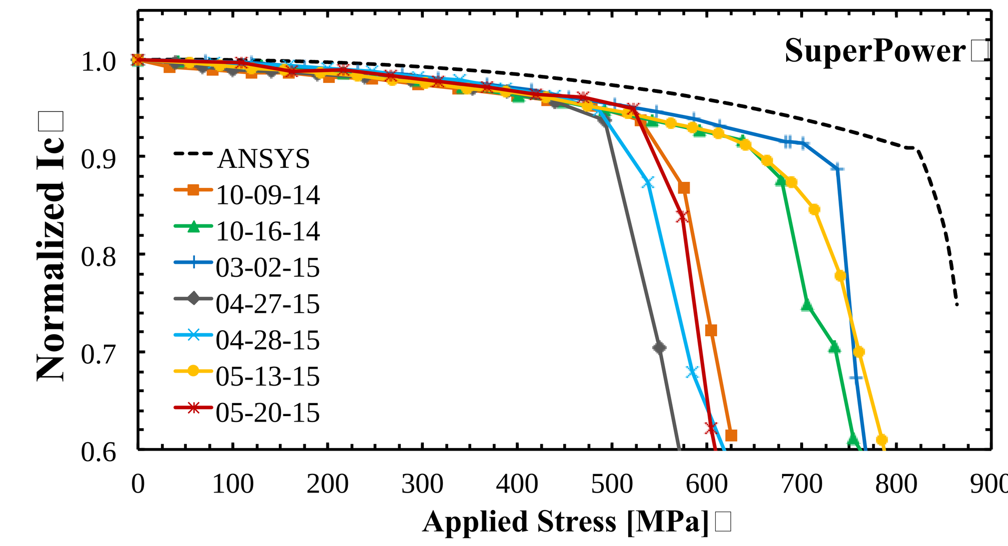
- Critical current was measured in **self-field** at **77 K**
- **Single** REBCO tape samples 100 and 300 mm long were tested
- **Two pairs of voltage taps** were soldered to the sample
- **Stainless steel** compression style **sample holders** were used
- High current SuperPower 12 mm YBCO tape was used as **flexible current leads**
- **Axial displacement** was applied using an **electric motor** and a
- anti-backlash **machine screw actuator**
- **Torque** was monitored using a low capacity **torque sensor**
- **Load** was recorded using a 250 lb (1112 N) donut style **load cell**
- **Axial displacement** was measured using a 15 mm stroke
- linear variable differential transformer (**LVDT**)
- **Double extensometers** (Nyilas-style) measured axial strain in tension samples and were used for **calibration**

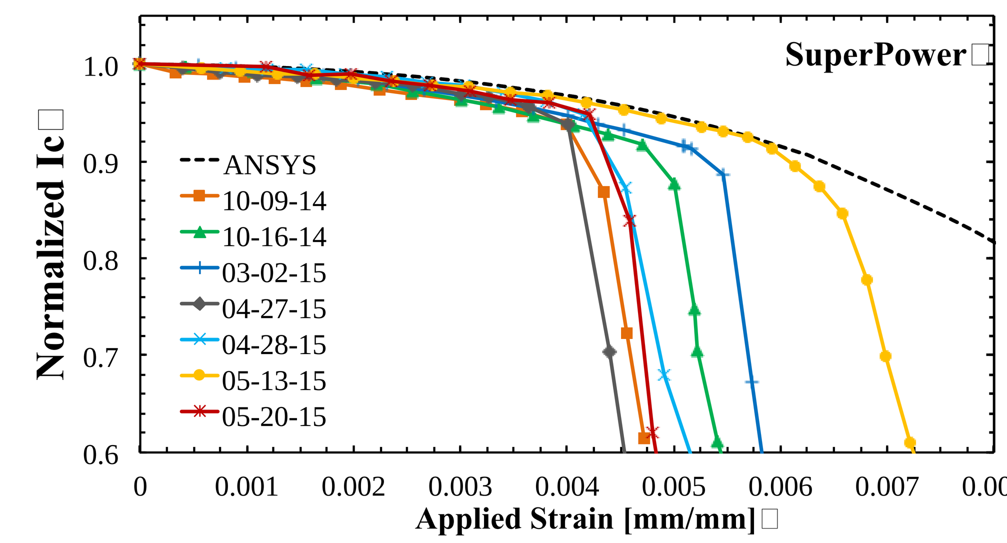
Stress-Strain Characteristics



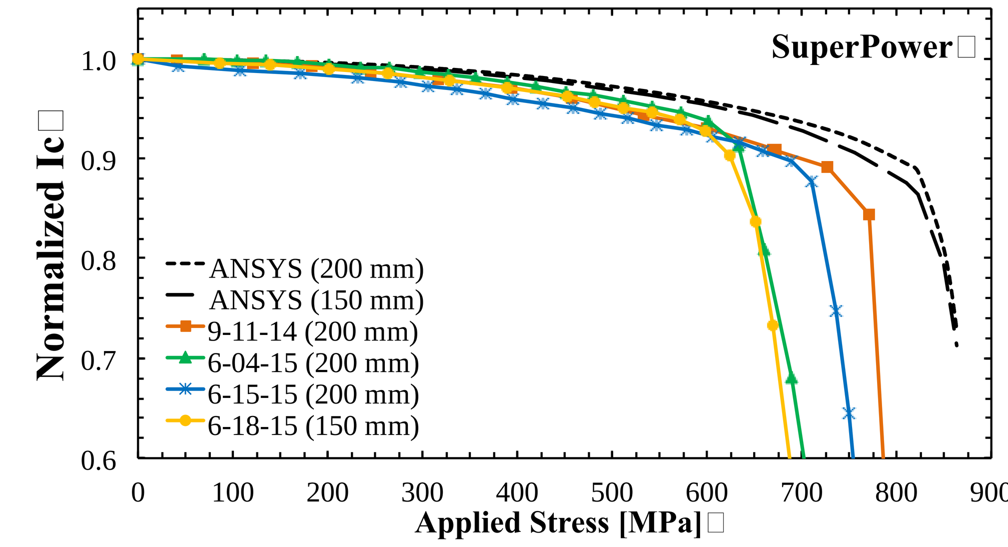
SuperPower

Pure tension

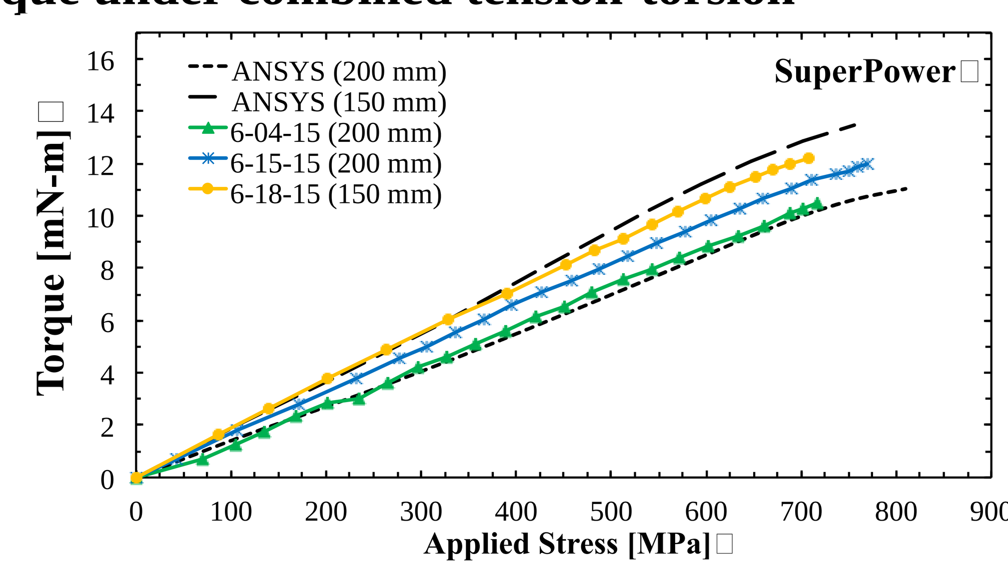




Combined tension-torsion

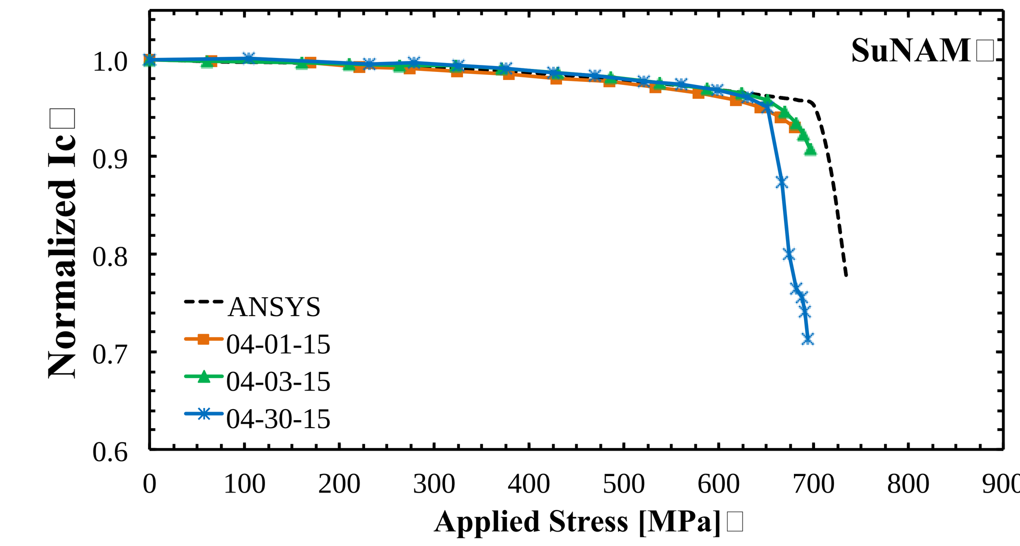


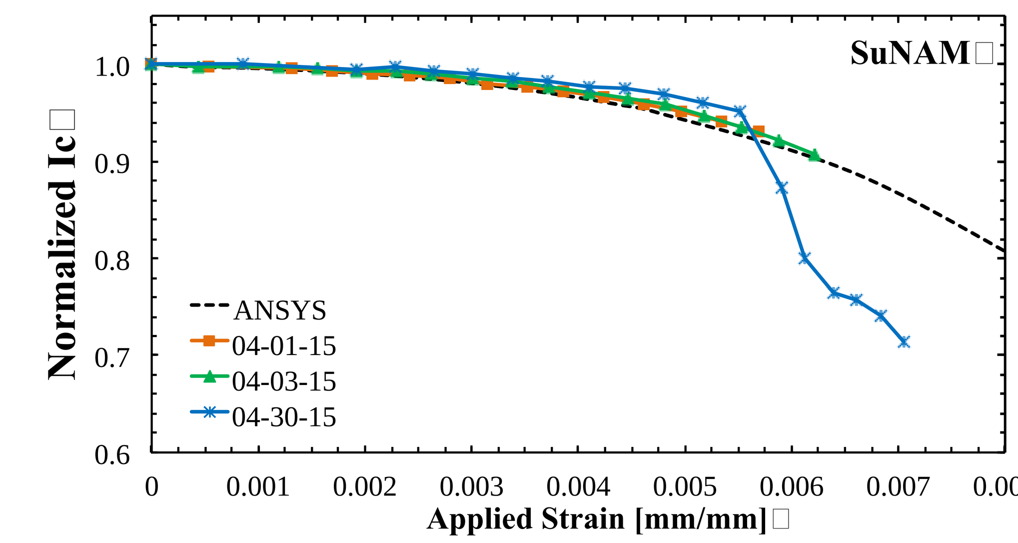
Torque under combined tension-torsion



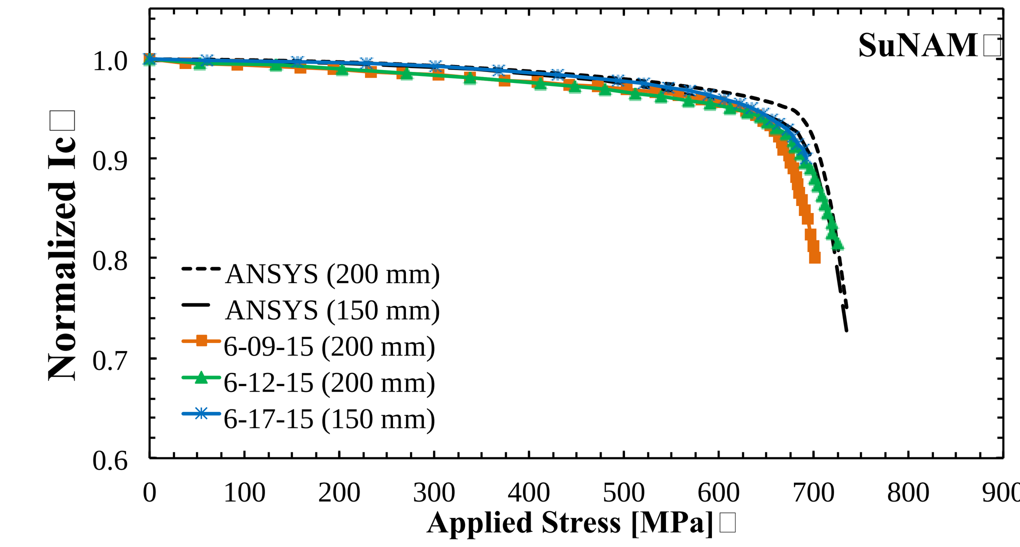
SuNAM

Pure tension

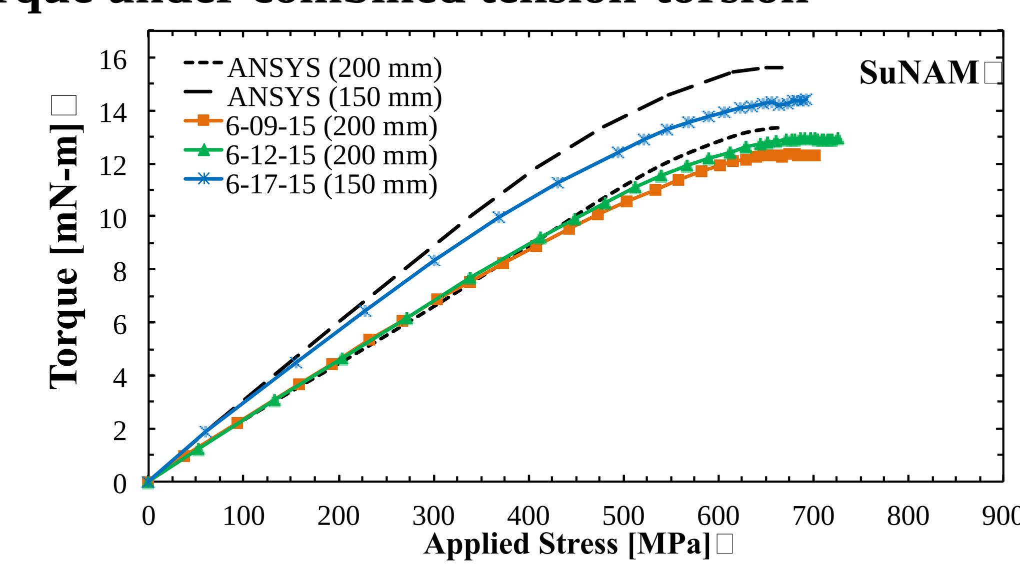




Combined tension-torsion



Torque under combined tension-torsion



Discussion and Conclusion

It was found that the normalized critical current behavoir of SuperPower and SuNAM tapes under tension and combined tension-torsion were very different. The SuNAM tape closely matched the numerical data and experienced degradation near the yield point of the tape (~700 MPa). The SuperPower tape experienced degradation at lower strain (0.4%-0.6%) and lower stress (~600 MPa) than the numerical data predicted. The SuperPower tape also displayed greater variability in results between samples even if the experiments were performed very consistently.

Acknowledgements

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