

CHATS – AS | October 9-11, 2013

Finite Element Investigation of HTS Tapes for Twisted Stacked-Tape Cabling Methods

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Luisa Chiesa (*Tufts*)

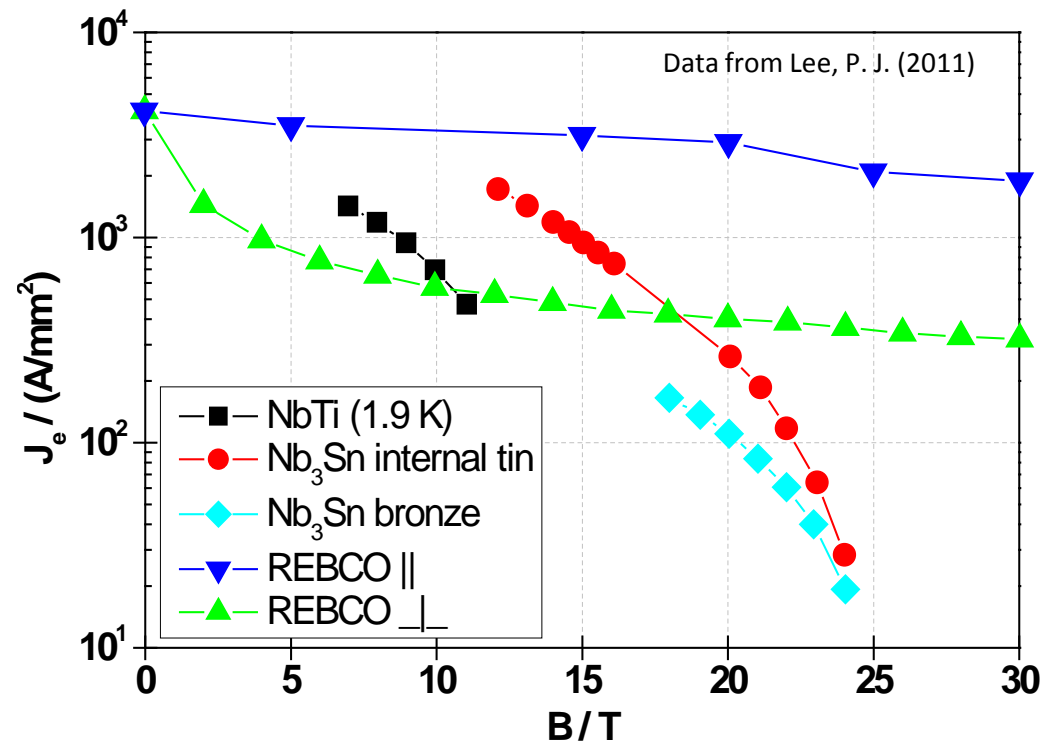
Makoto Takayasu (*PSFC, MIT*)



Mechanical Engineering Department

Recent developments in HTS make them of interest in many superconducting applications

- ❖ Higher operational temp.
- ❖ Higher current density
- ❖ Less degradation at high field



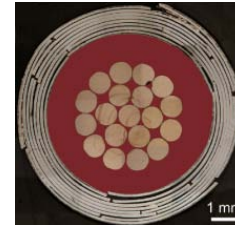
P. J. Lee et al, "A transformative superconducting magnet technology for fields well above 30 T ...", 2011

Twisted stacked-tape cable (TSTC)



M. Takayasu, et al, "Investigation of twisted stacked-tape cable conductor," Adv. Cryo. Eng., 54, Plenum, N.Y., 273-280, 2012.

Conductor on round core (CORC) cable



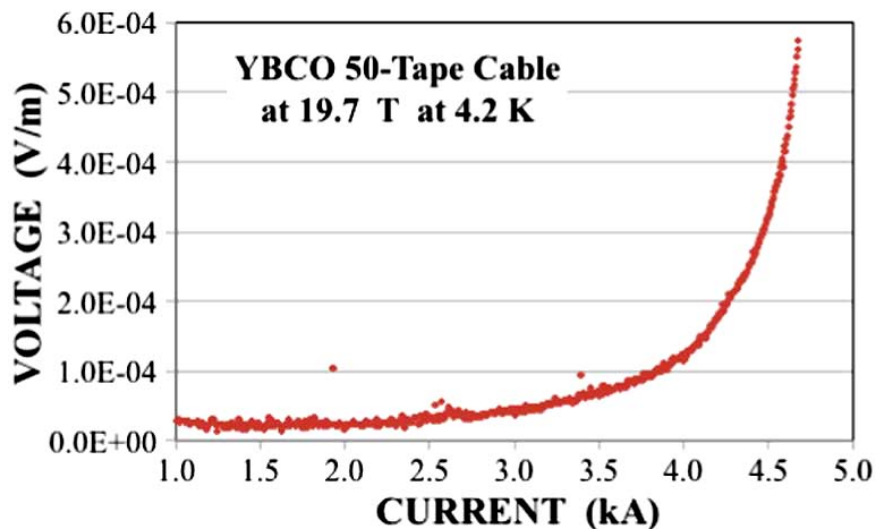
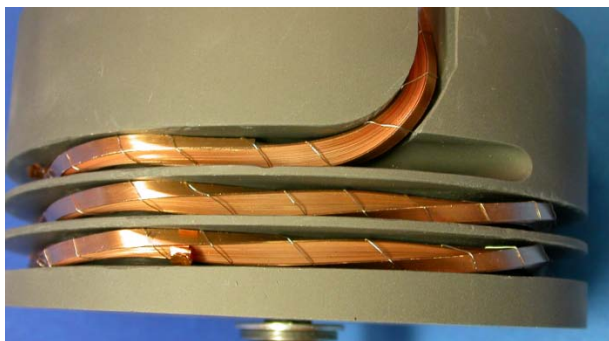
D.C. van der Laan et al, Supercond. Sci. Technol. 24 042001, 2011

Roebel assembled coated conductor (RACC) cable

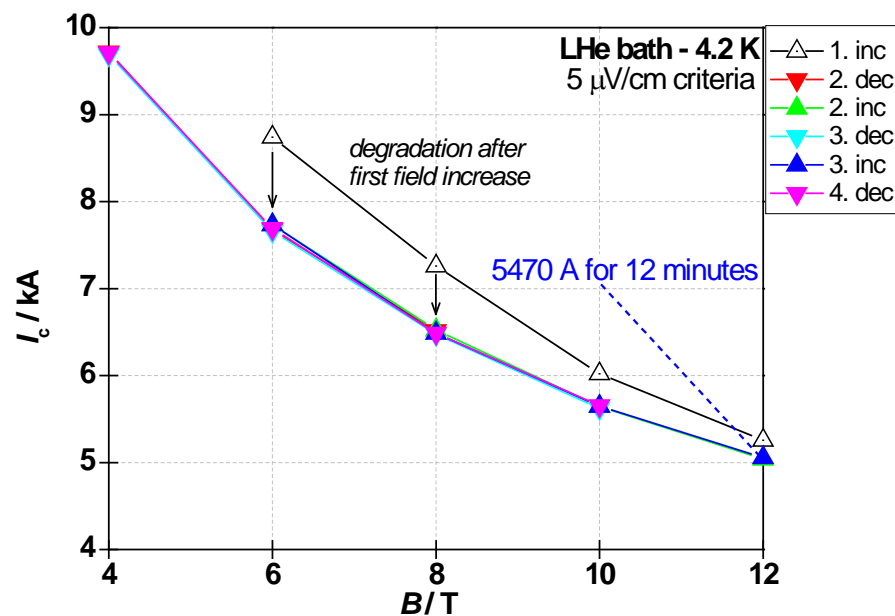


W. Goldacker et al., "2007 ROEBEL assembled coated conductors (RACC) preparation, properties and progress" IEEE Trans. Appl. Supercond.17 3396-401

50-Tape YBCO Cable (4.2 K & 19.7 T)



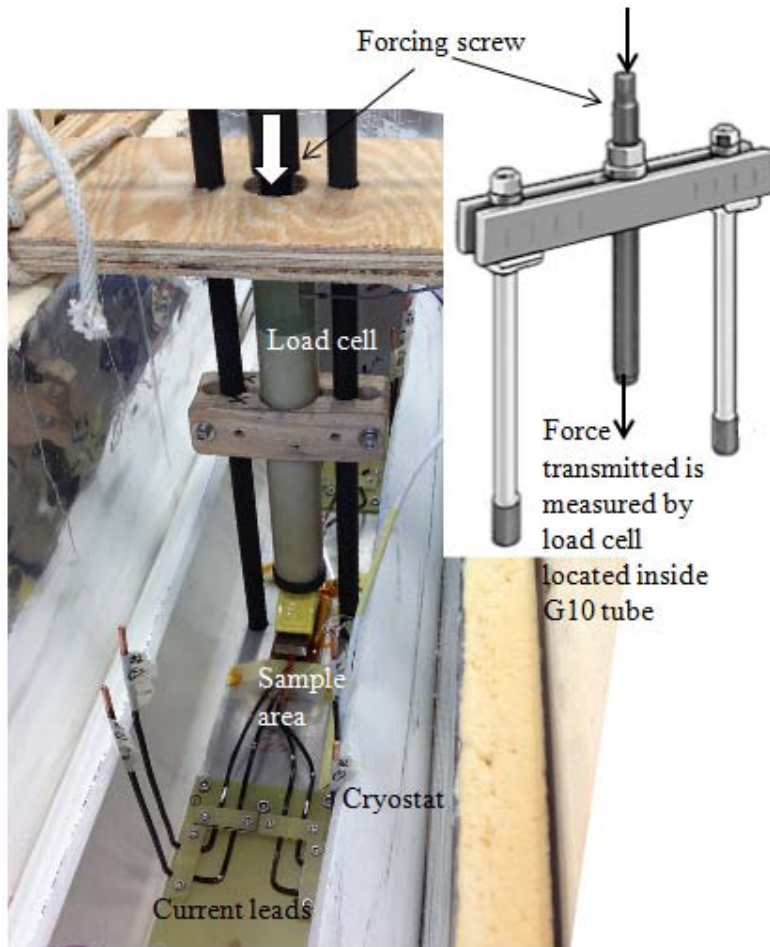
40-Tape YBCO Cable (4.2 K & 4-12 T) Place inside conduit filled with solder



C. Barth et al., "Measurements of HTS cables in a temperature range of 4.2 K to 80 K and background fields up to 12 T", presented at ASC, 2012

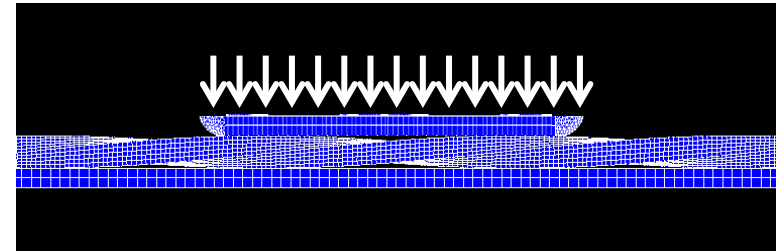
M. Takayasu et al., "Conductor characterization of YBCO twisted stacked-tape cables", IEEE Trans. on App. Supercond., 23 4800104, 2013.

Transverse compression on cables

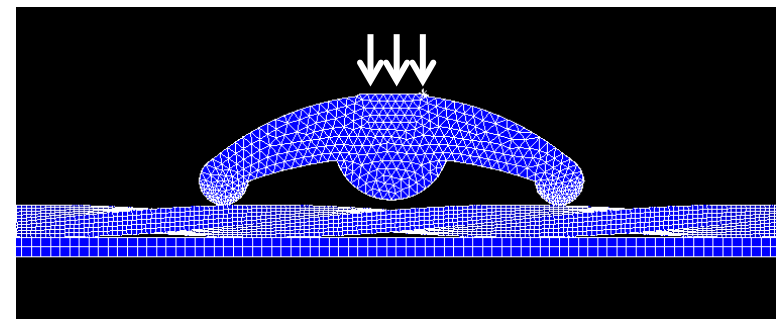


24-Tape YBCO Cable with solder & 40-Tape YBCO Sheathed Cable

Uniform Distributed Load

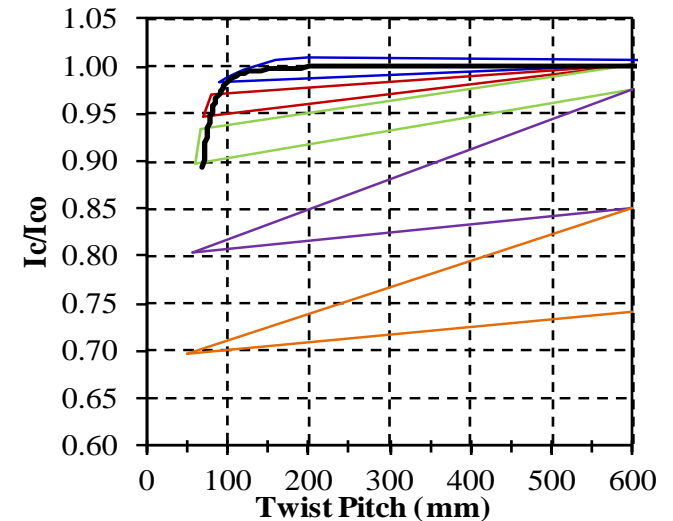
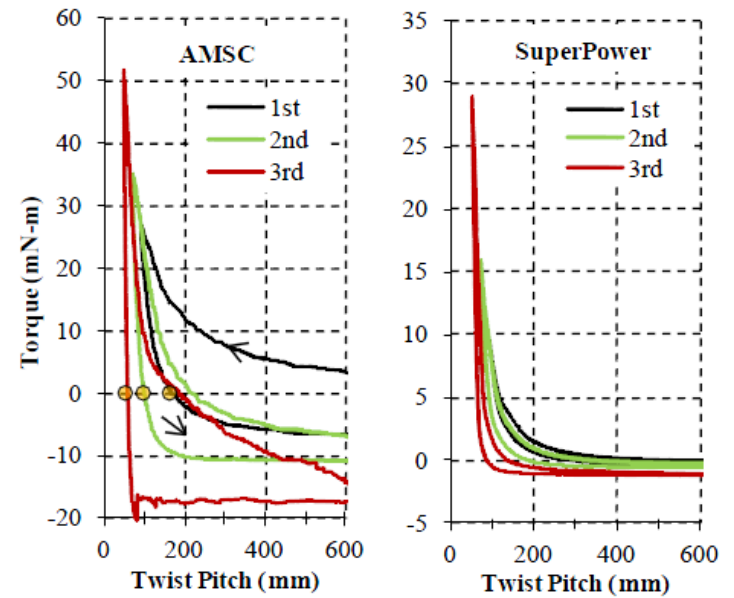
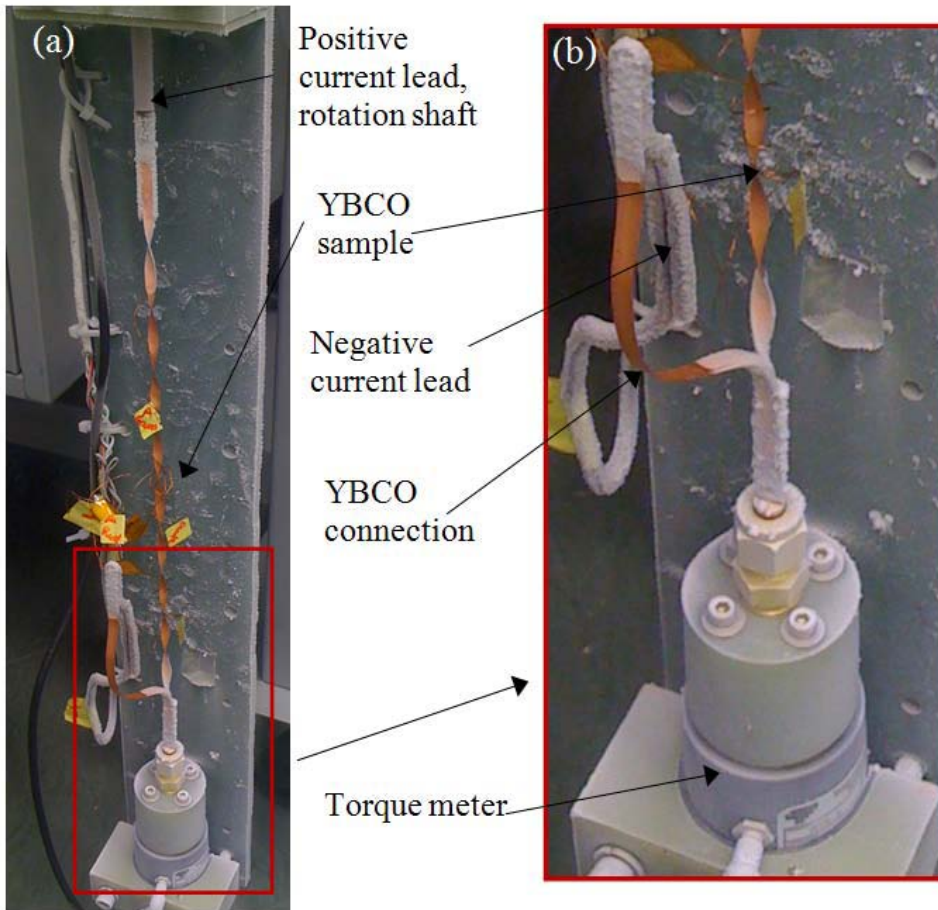


2 Point Pressing Load



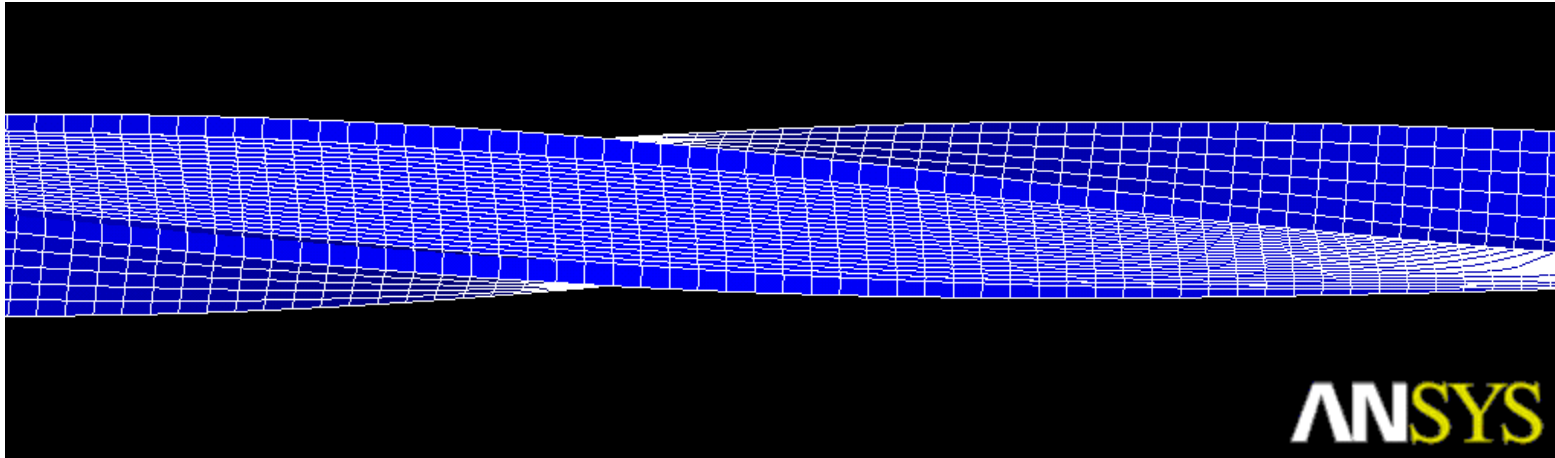
L. Chiesa and M. Takayasu, "Electromechanical investigation of 2G HTS twisted stacked-tape cable conductors", MT23 2013.

Single YBCO tapes under torsion (77 K)



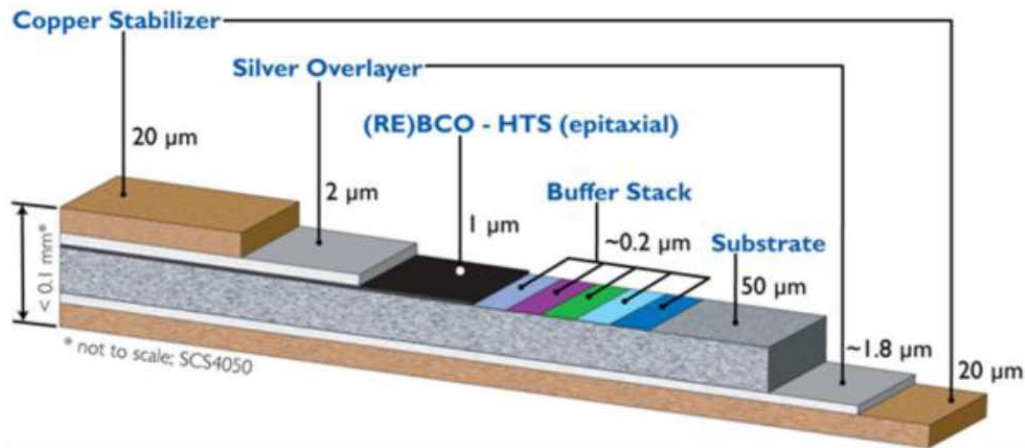
L. Chiesa and M. Takayasu, "Electromechanical investigation of different type YBCO tapes for twisted stacked-tape cabling", ASC 2012.

Investigation of electromagnetic effects using structural finite element analysis (FEA)

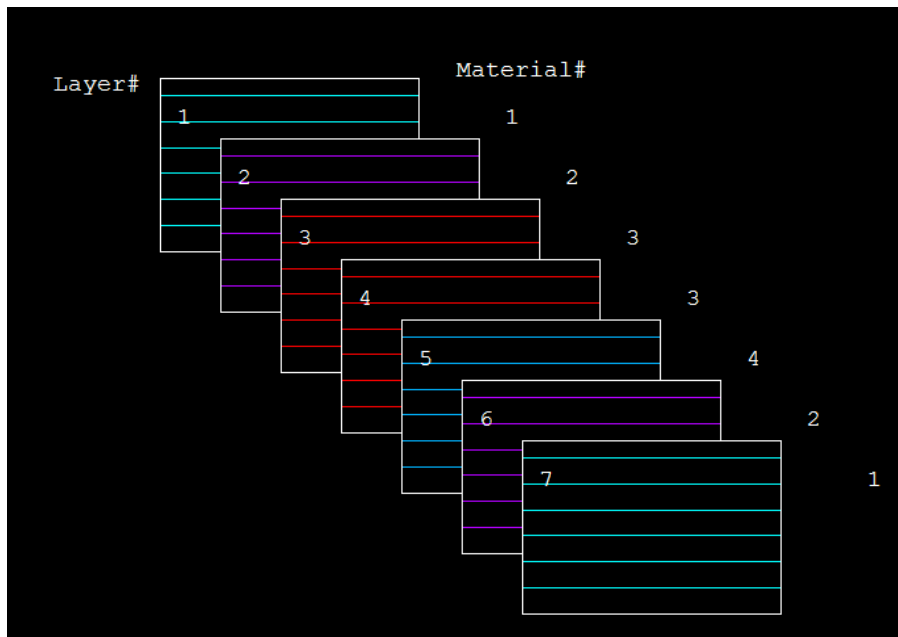
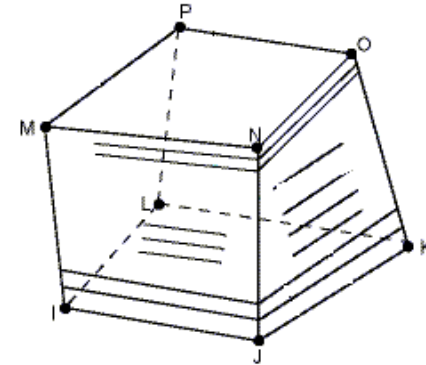


- ❖ Accurately model layered composition of YBCO tapes
- ❖ Realistically model the contact interactions between stacked tapes
- ❖ Twisted stacked tapes creating the TSTC conductor
- ❖ Replicate electromagnetic load on the twisted-stacked cables

YBCO Composite Tape



SOLSH190 – Solid Shell Element



Copper (Cu)

Silver (Ag)

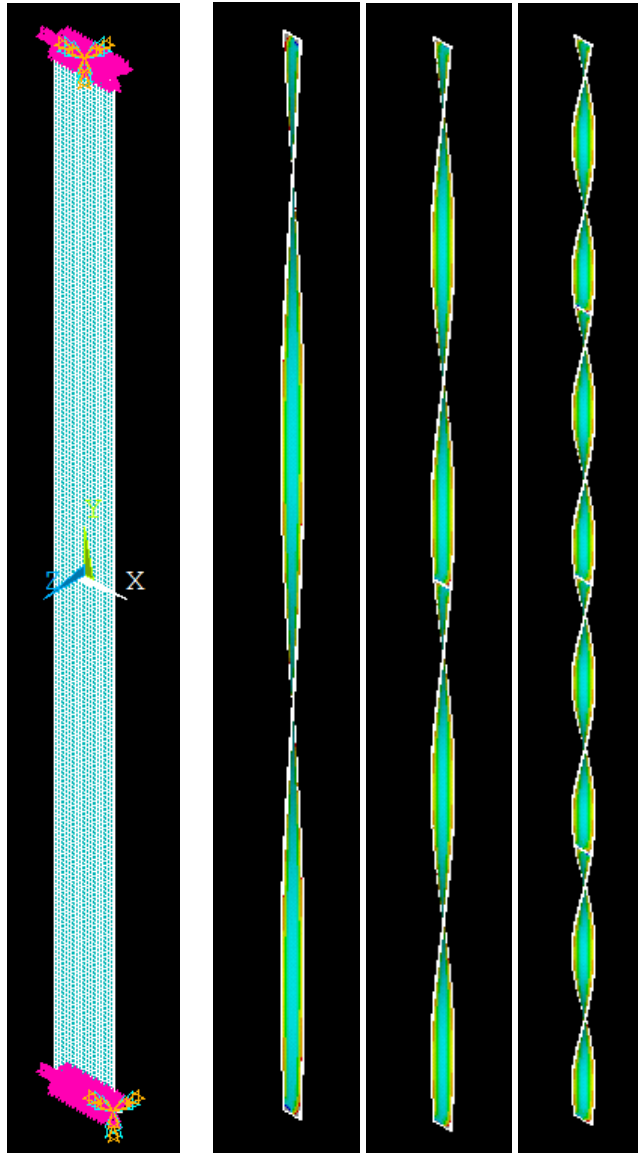
YBCO/Buffer ($\text{YBa}_2\text{Cu}_3\text{O}_7$)

Substrate (Hastelloy C-276)

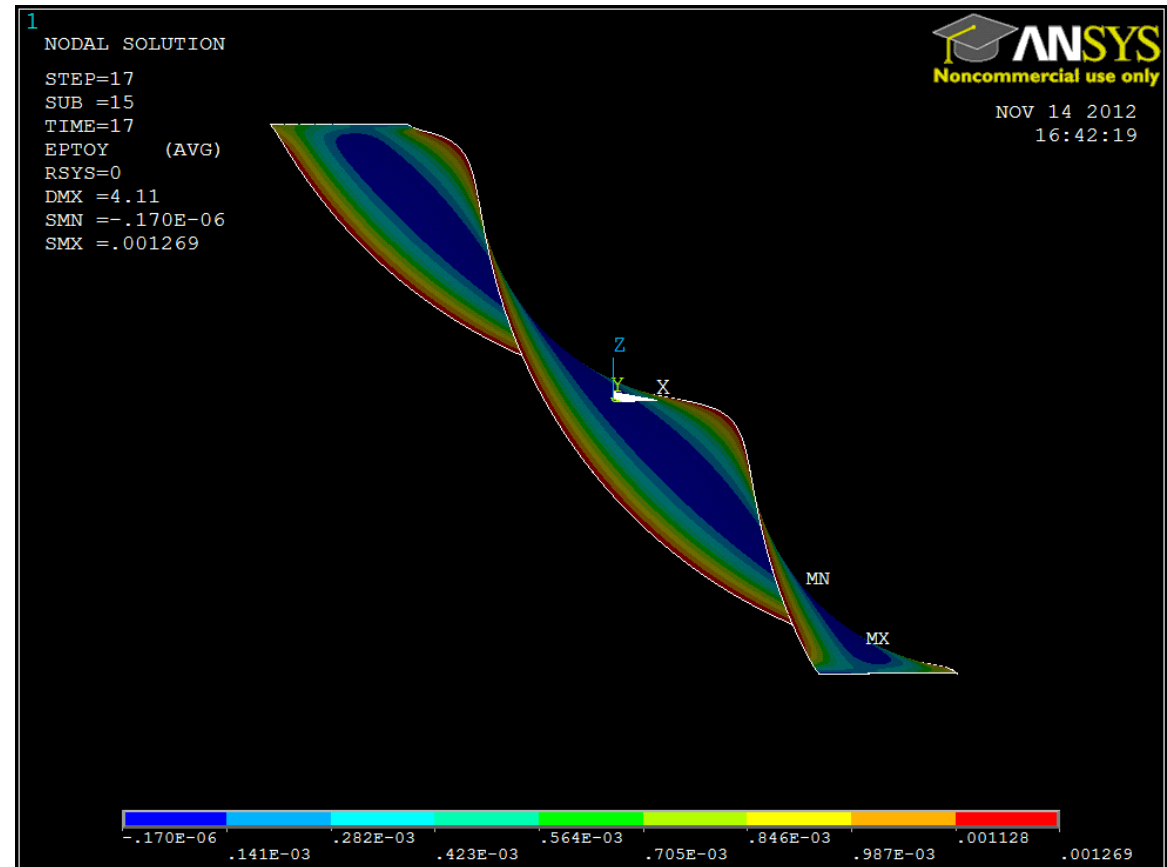
M. Sugano et al., "Bending Strain Analysis Considering a Shift of the Neutral Axis for YBCO Coated Conductor with and without a Cu Stabilizing Layer," Supercond. Sci. Technol. 24, 075019, 2011

C. C. Clickner et al., "Mechanical properties of pure Ni and Ni-alloy substrate materials for Y-B-Cu-O coated superconductors", Cryogenics, 46, 2006

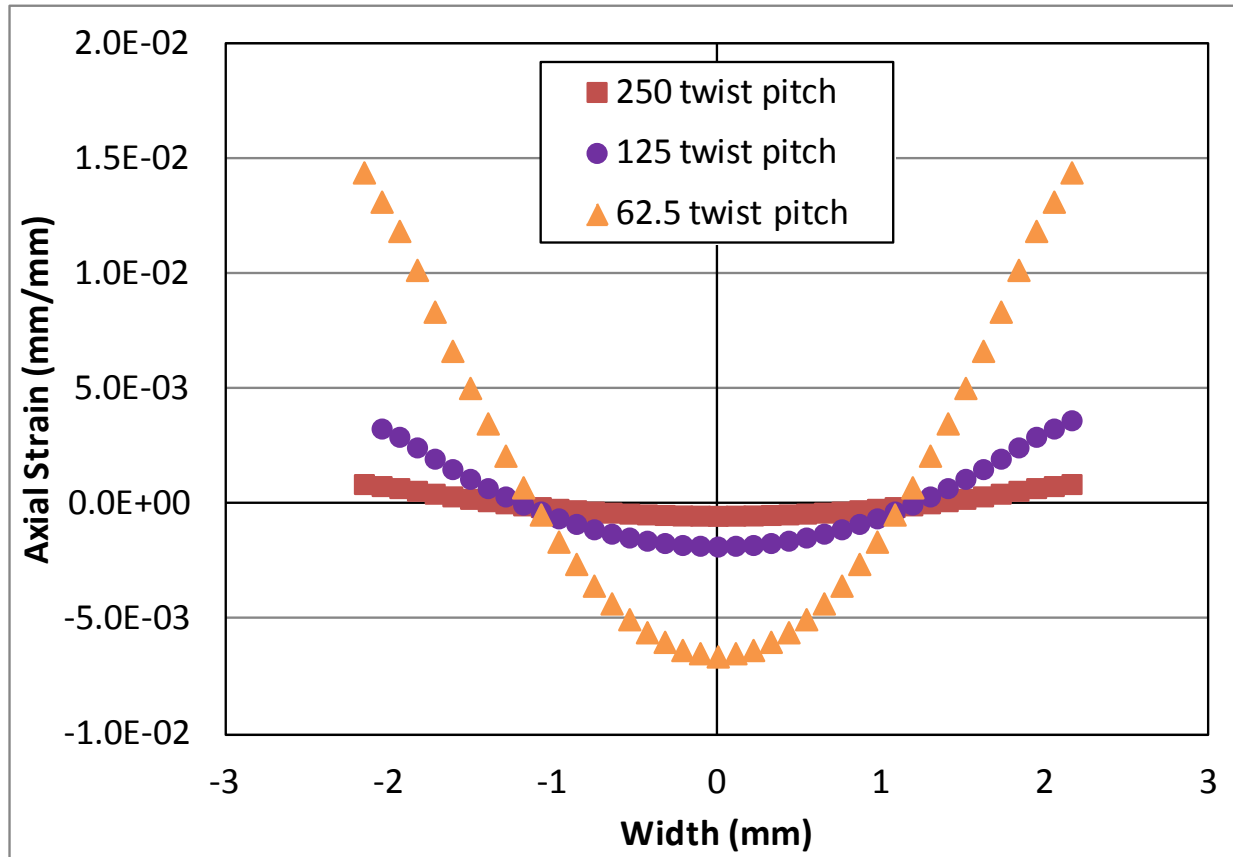
Single Tape Modeling



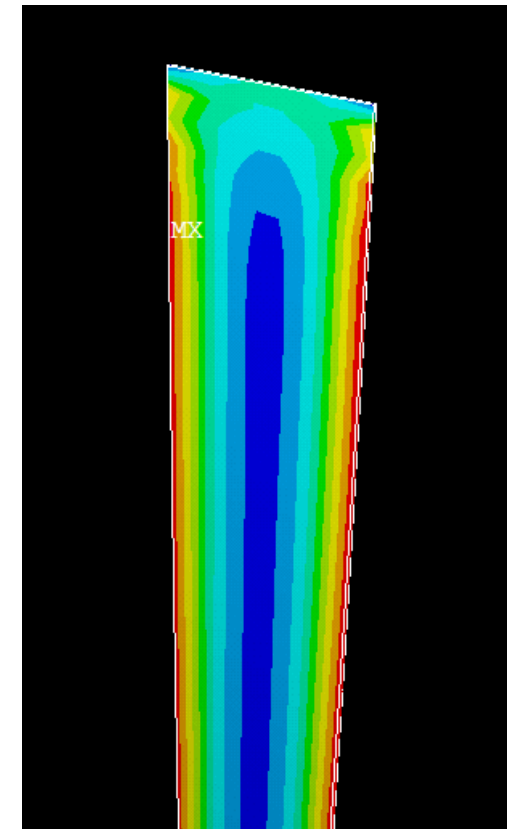
Twist Pitches: 250, 125 & 62.5 mm



ANSYS Results



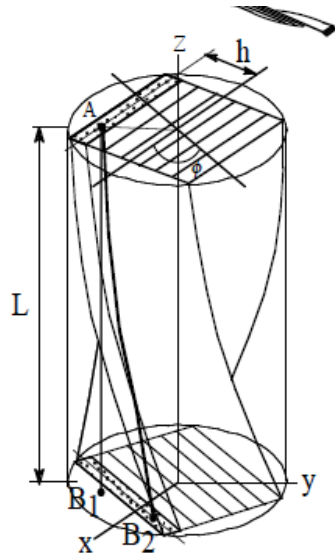
Contour Plot



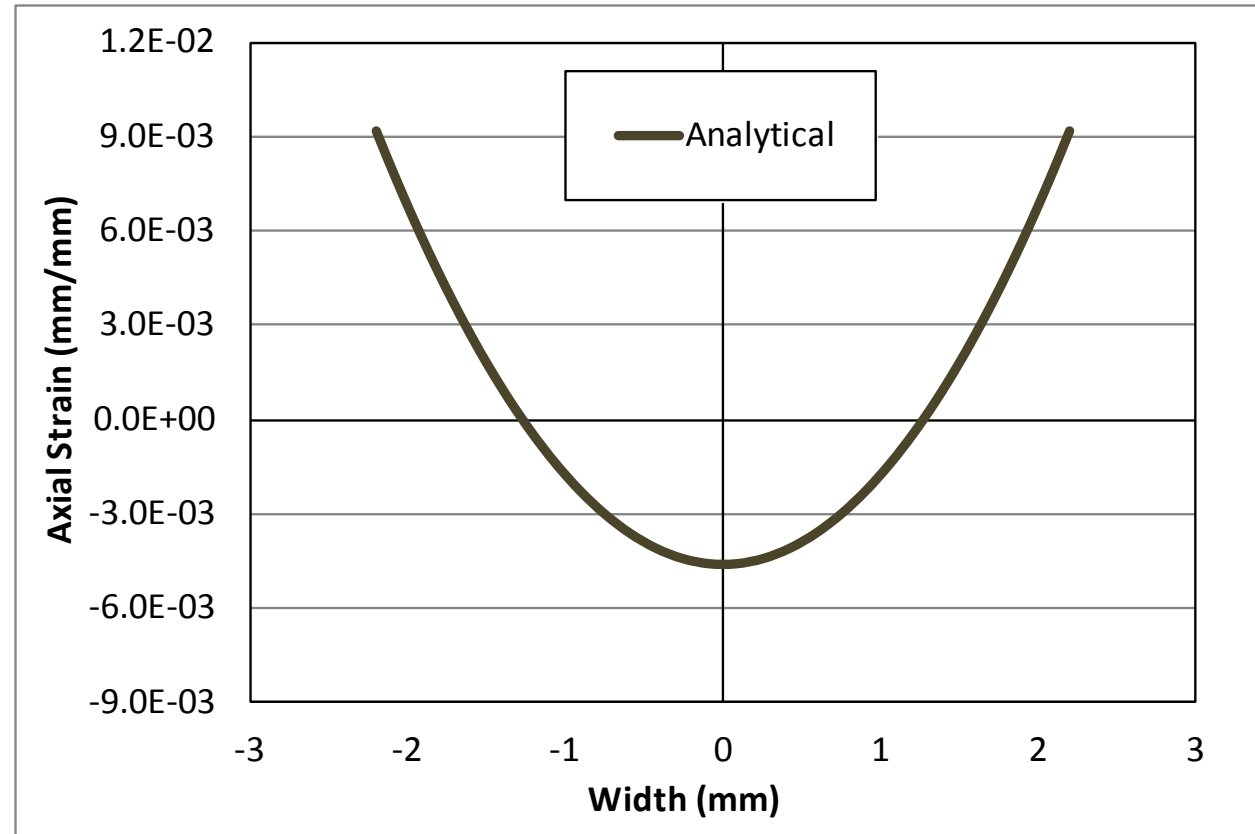
Single Tape Validation

Twist pitch 62.5 mm

Analytical Model



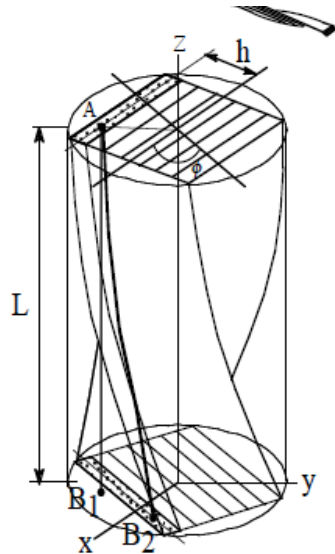
$$\epsilon_x = \epsilon_t + \epsilon_o = \frac{\theta^2}{2} \left(x^2 - \frac{w^2}{3} \right)$$



M. Takayasu et al., "HTS twisted stacked-tape cable conductor", Supercond. Sci. Technol. 25 014011, 2012.

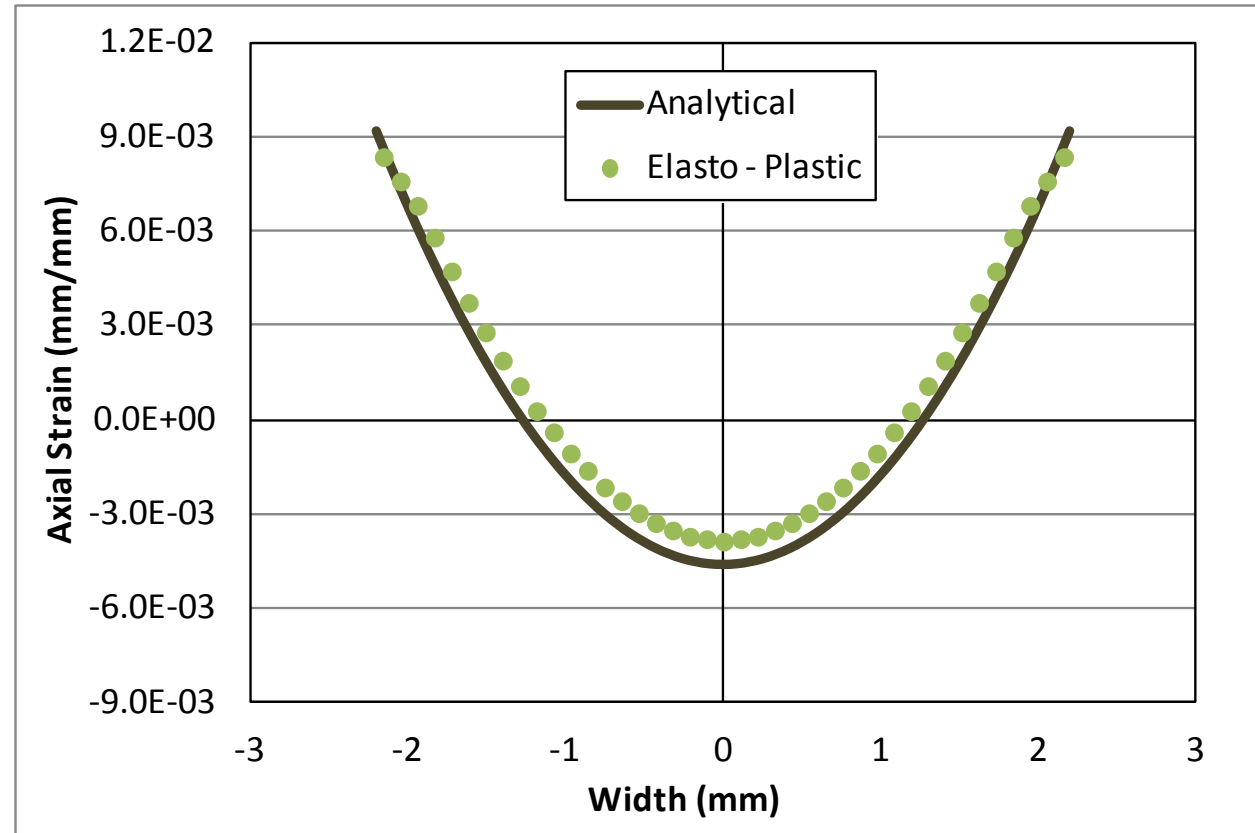
Single Tape Validation

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Twist pitch 62.5 mm

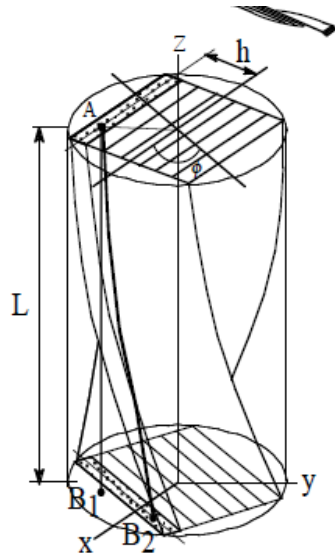


M. Takayasu et al., "HTS twisted stacked-tape cable conductor", Supercond. Sci. Technol. 25 014011, 2012.

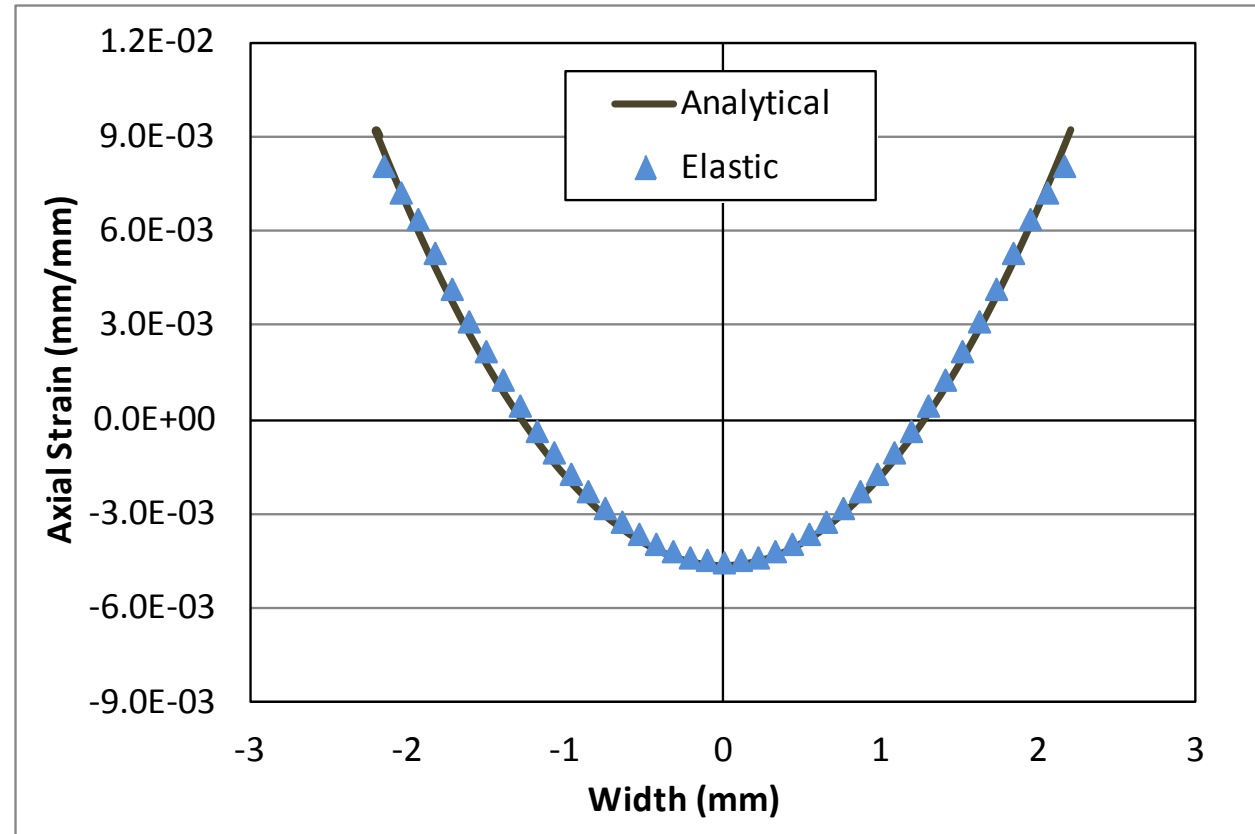
Single Tape Validation

Twist pitch 62.5 mm

Analytical Model

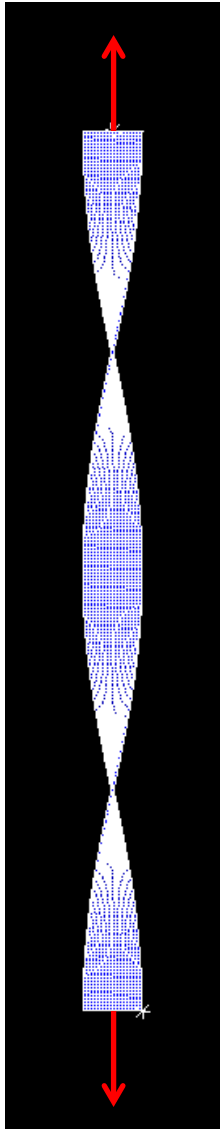


$$\epsilon_x = \epsilon_t + \epsilon_o = \frac{\theta^2}{2} \left(x^2 - \frac{w^2}{3} \right)$$

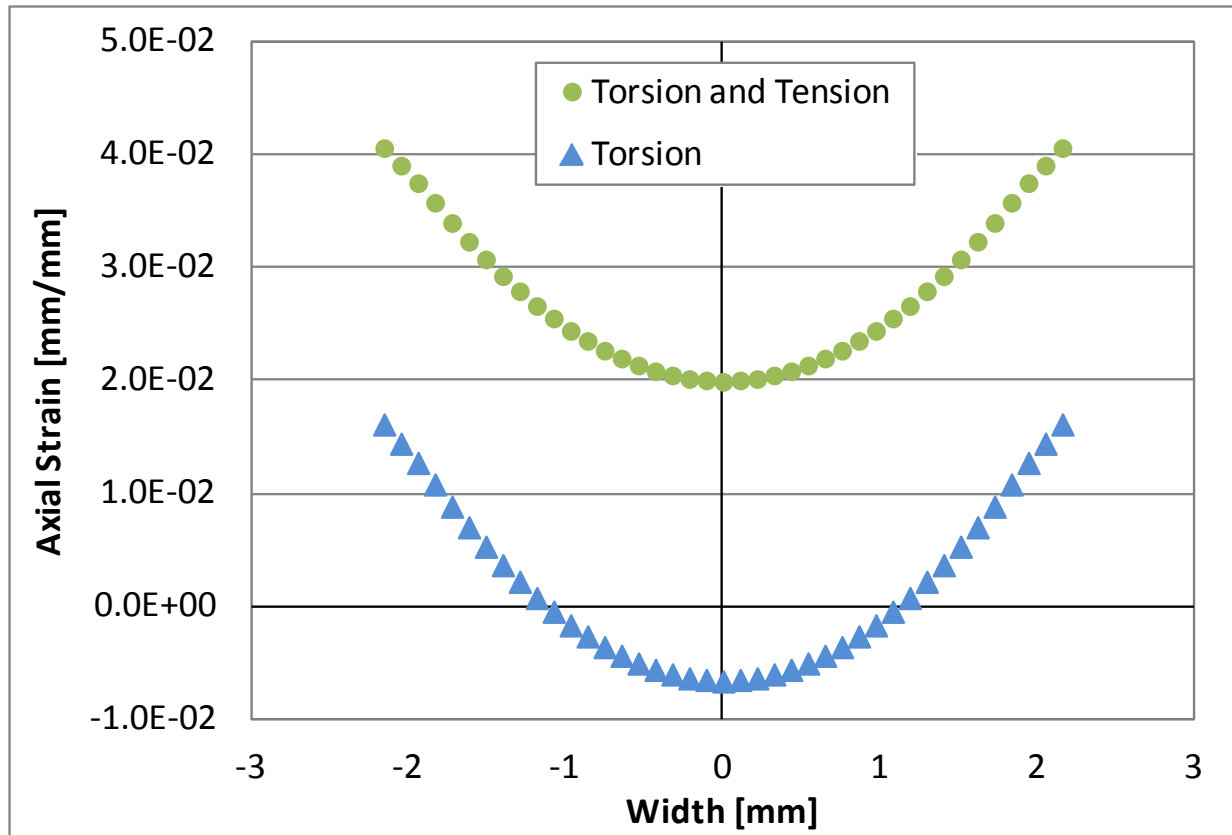


M. Takayasu et al., "HTS twisted stacked-tape cable conductor", Supercond. Sci. Technol. 25 014011, 2012.

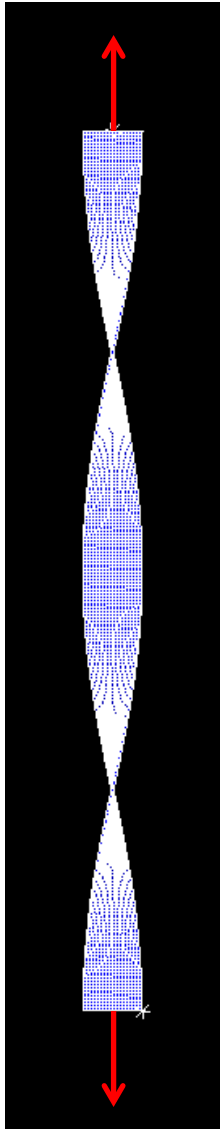
Single Tape With Tension



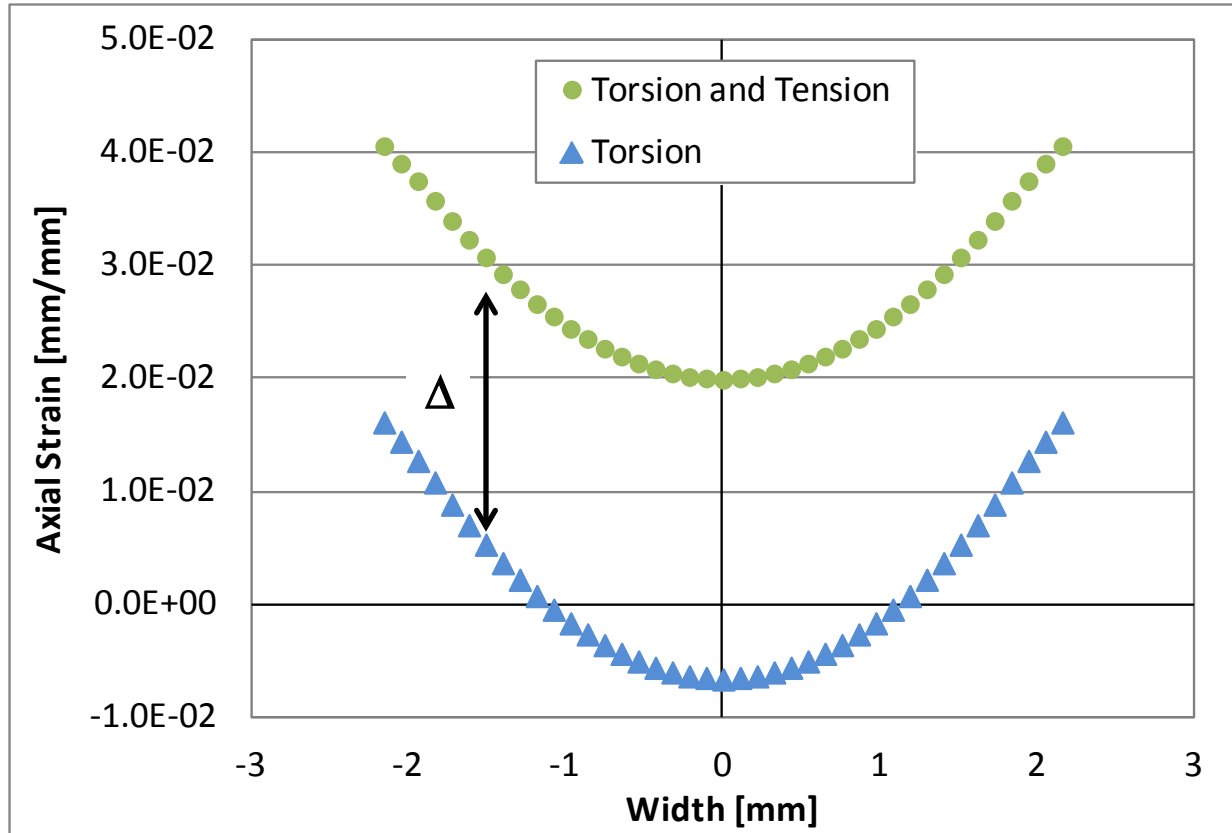
Axial Tension (Twist pitch 62.5 mm)



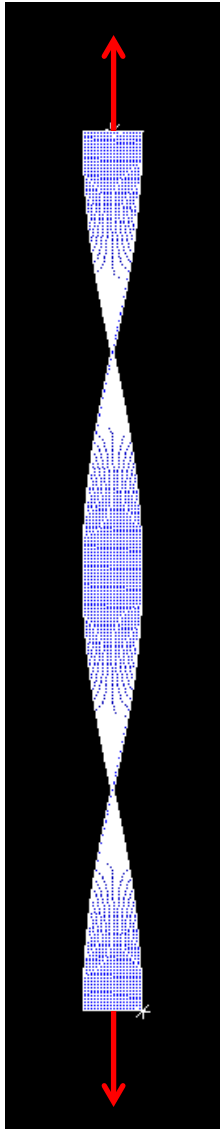
Single Tape With Tension



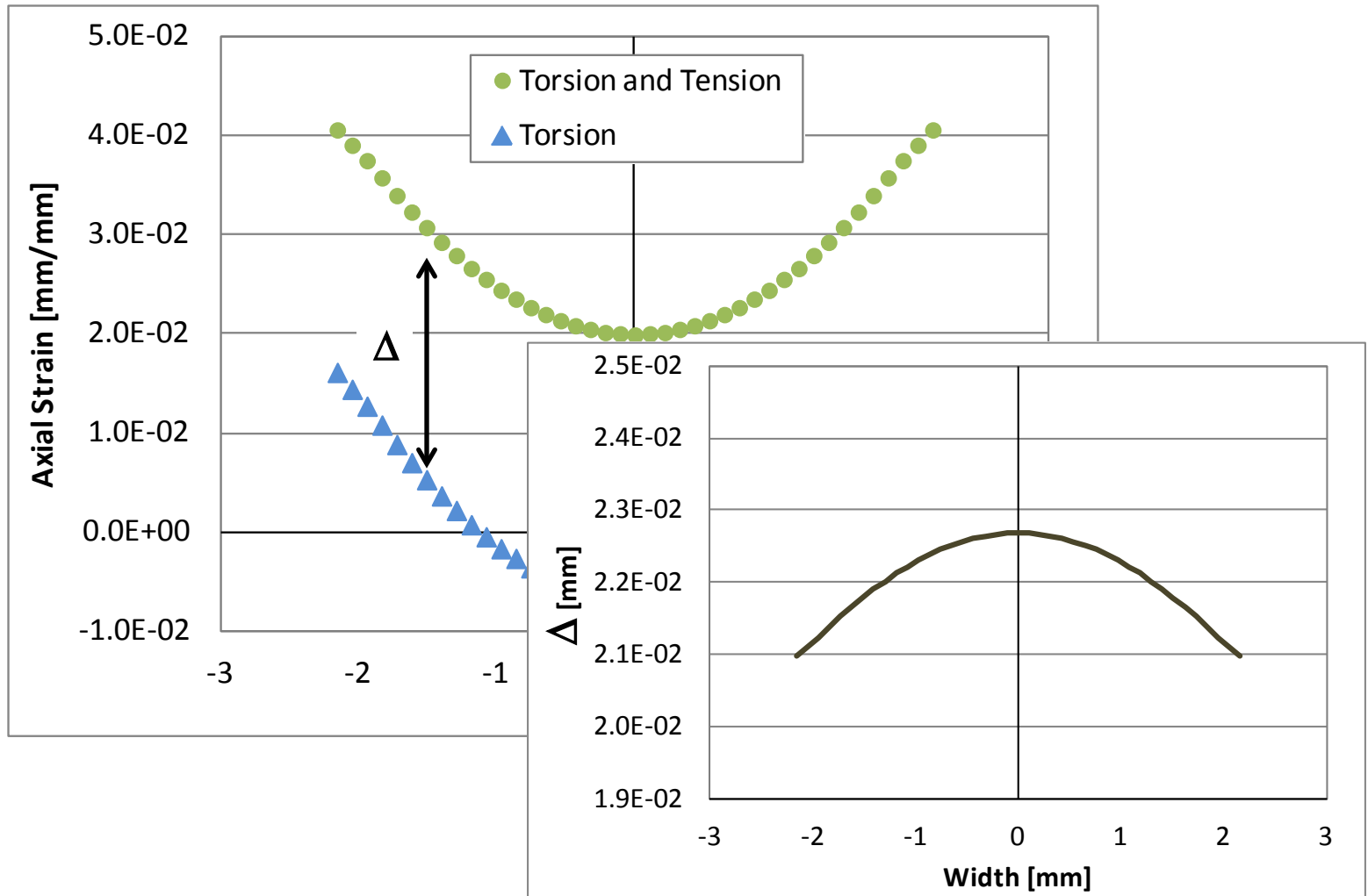
Axial Tension (Twist pitch 62.5 mm)



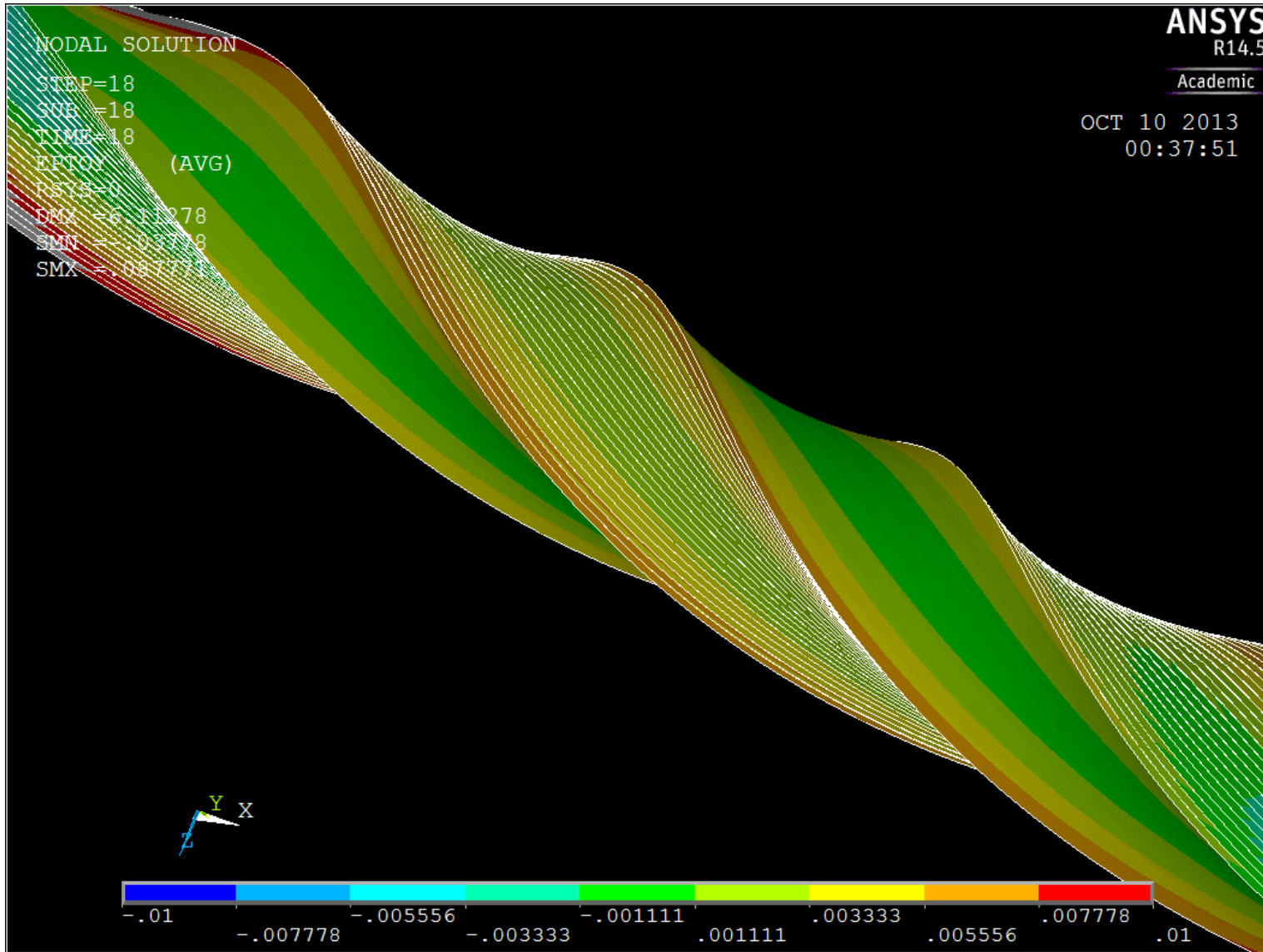
Single Tape With Tension



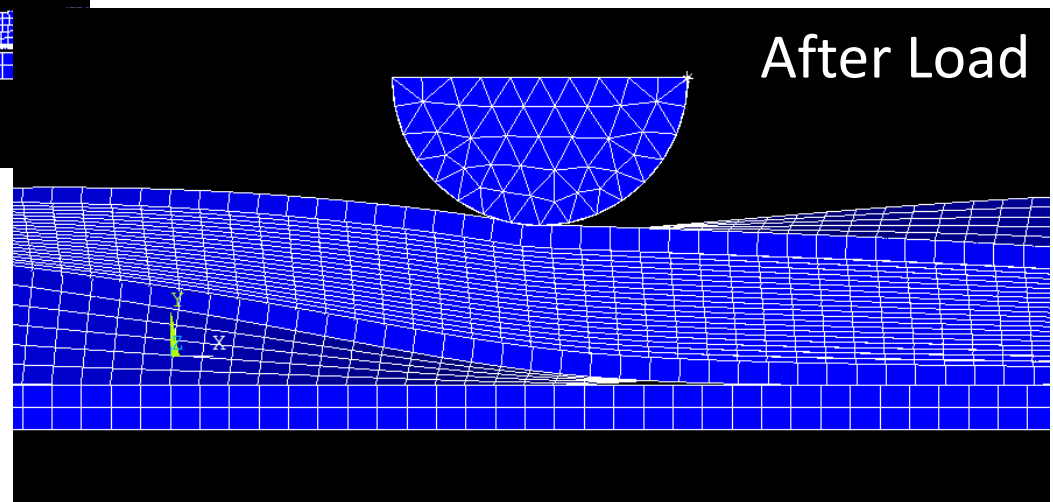
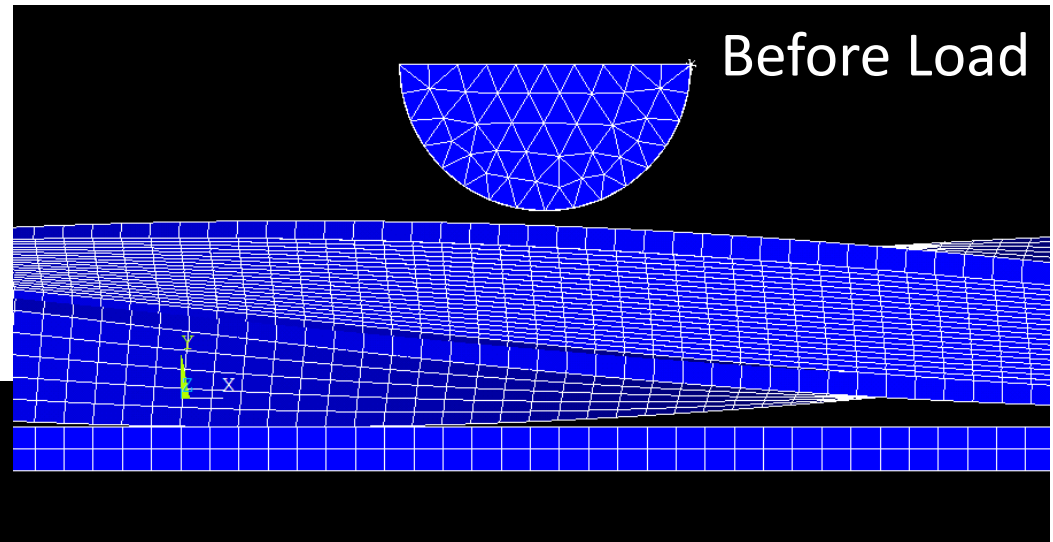
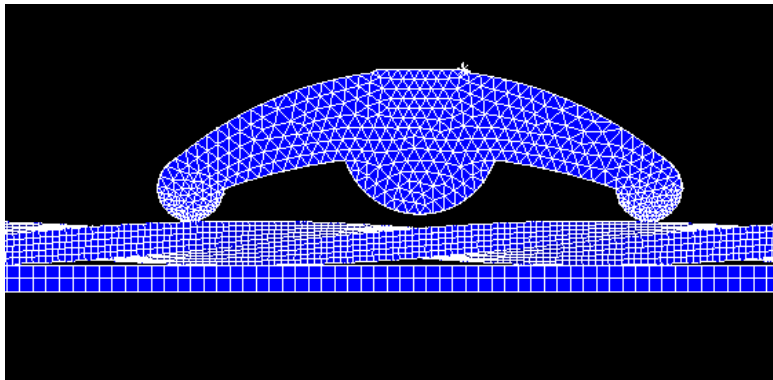
Axial Tension (Twist pitch 62.5 mm)



Full Cable Modeling



Loading of Cable



Successfully modeled single YBCO tapes in torsion

Developed a model of twisted stacked-tape cables (TSTC)

Experimented with mechanical loading of cable



Validate the accuracy of the TSTC model

Apply electromagnetic loads on the cables in order to understand their effects on TSTC conductor in high field, high current.