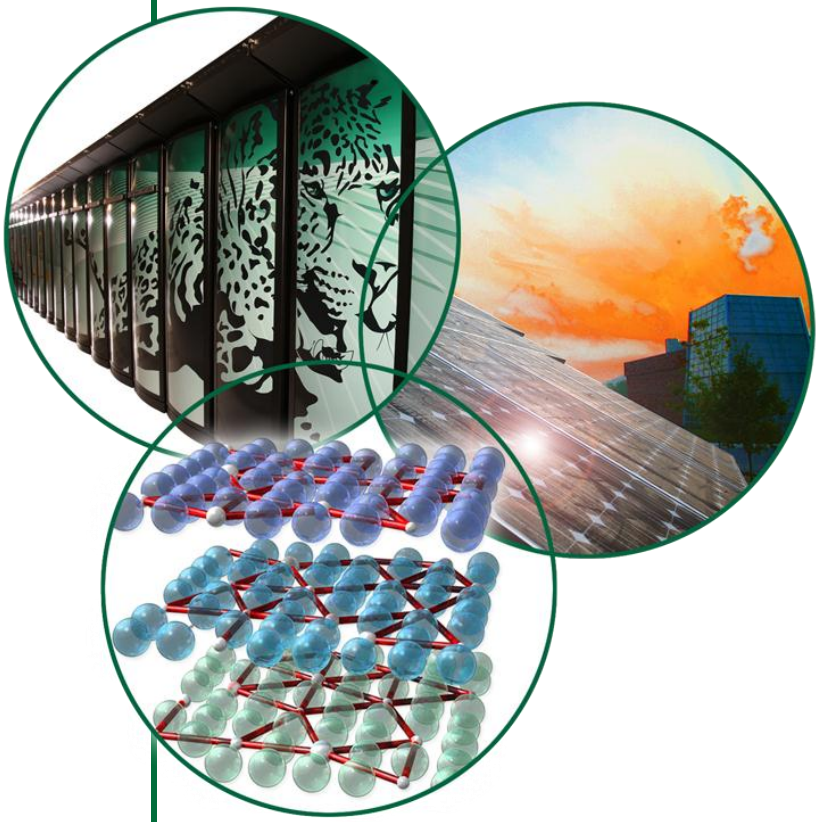
Modeling Thermal-Structural Interactions of HFIR's Fuel Plates using COMSOL Multiphysics



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May 09, 2011

U.S. DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY
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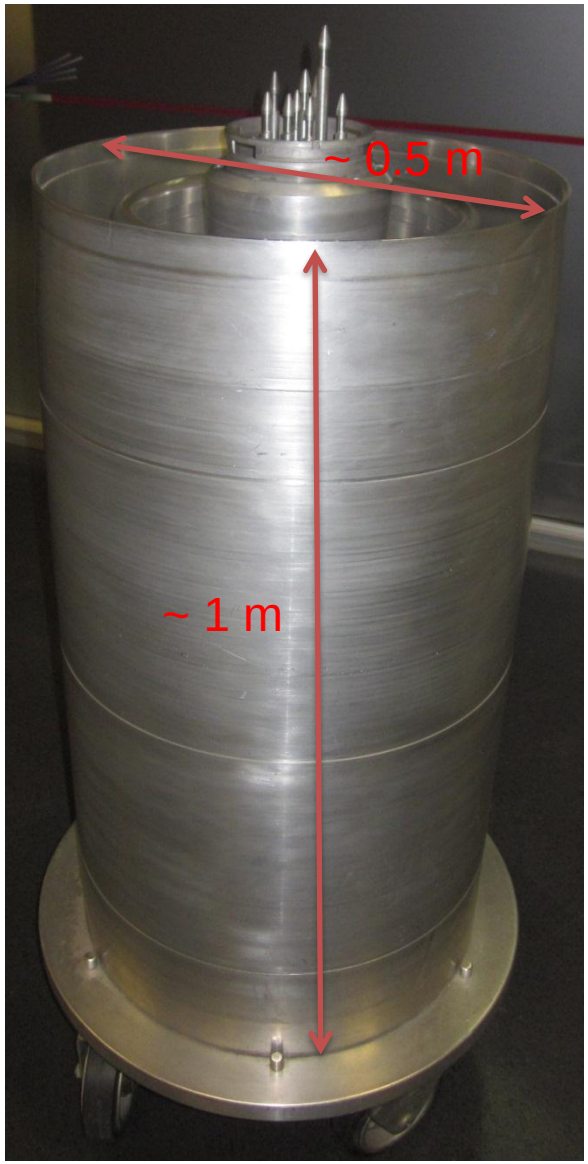
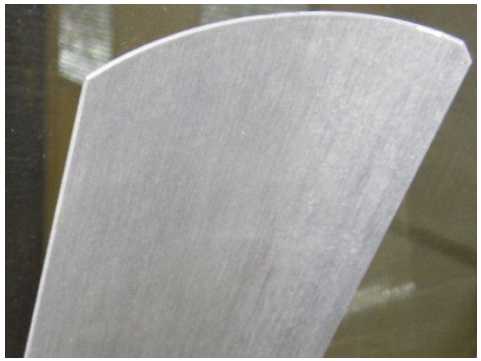
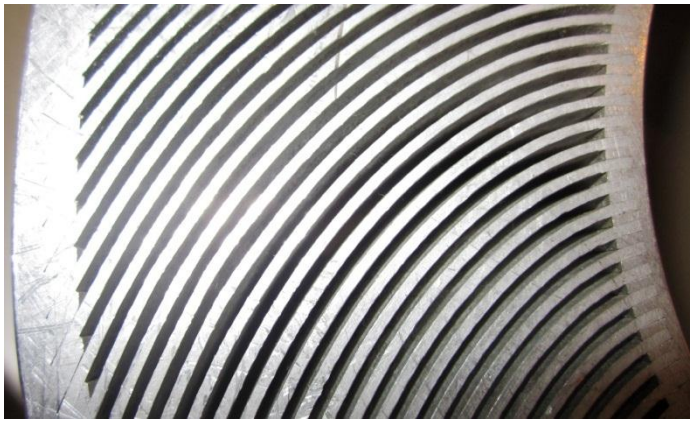
Outline

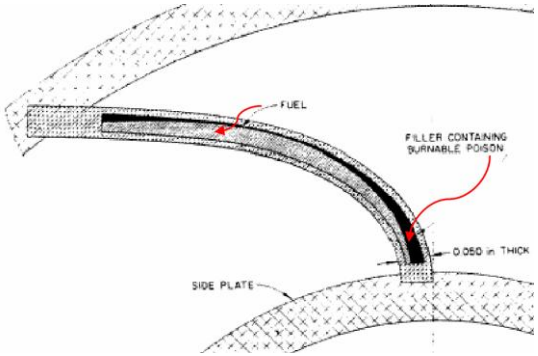
- An overview of HFIR's core and fuel plates
- Experimental investigation of thermal expansion of HFIR's outer fuel plate (Year 1968)
  - Documented in "Cheverton-Kelley" Report – ORNL-TM-2325
- COMSOL simulation results for the experiment
- Coupling turbulent flows, conjugate heat transfer and thermally induced structural deflections in COMSOL simulations
- Conclusions

HFIR Core - in real



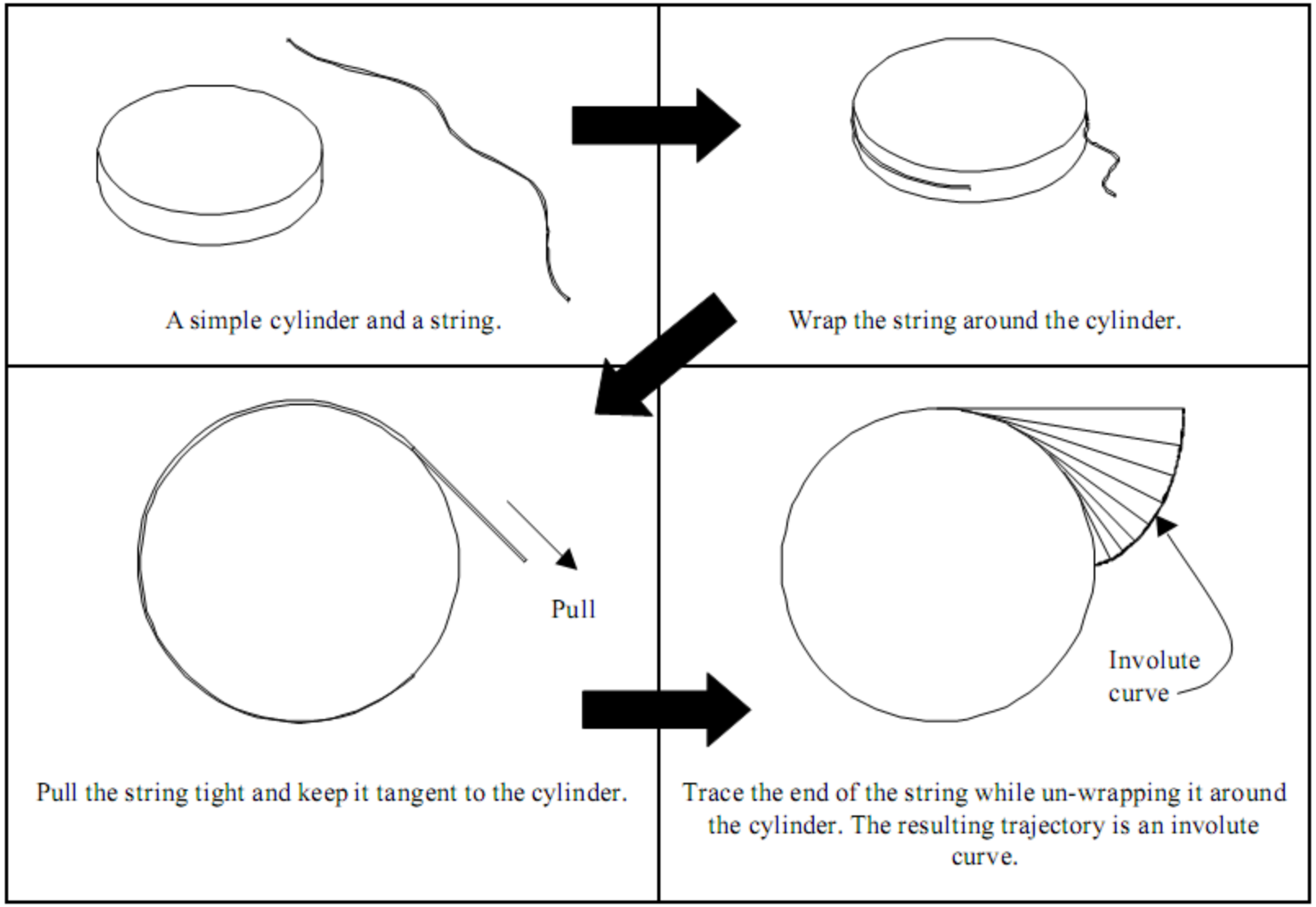






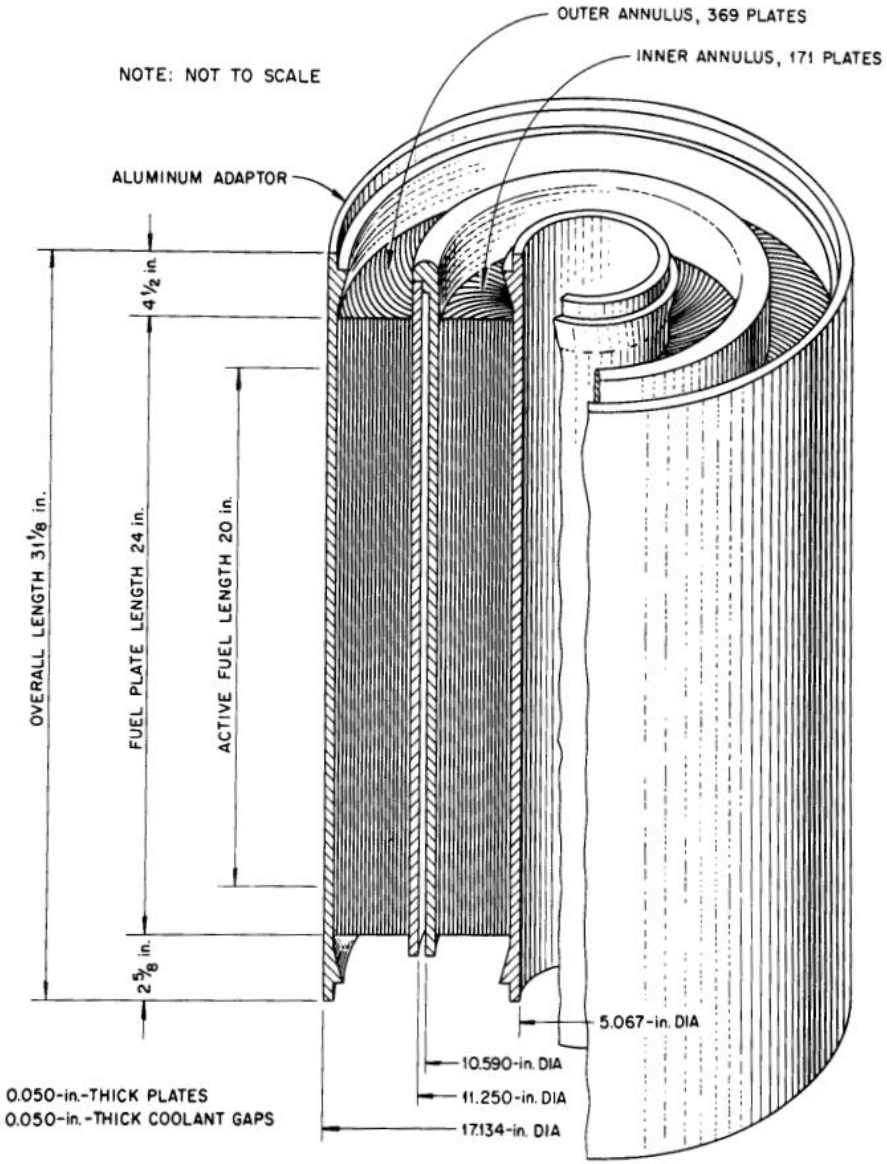
Non-uniform radial distribution of fuel

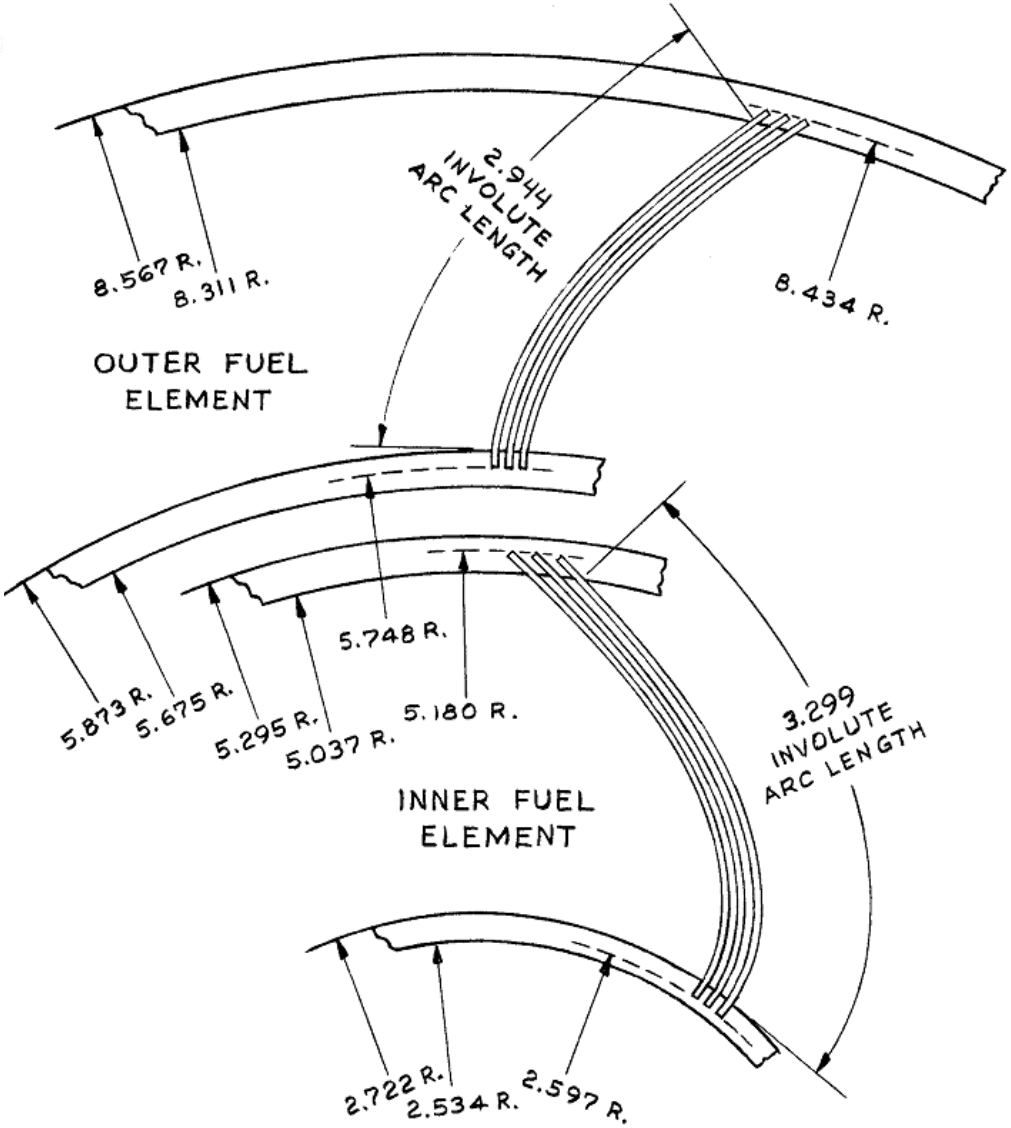
What involute shape exactly means ?



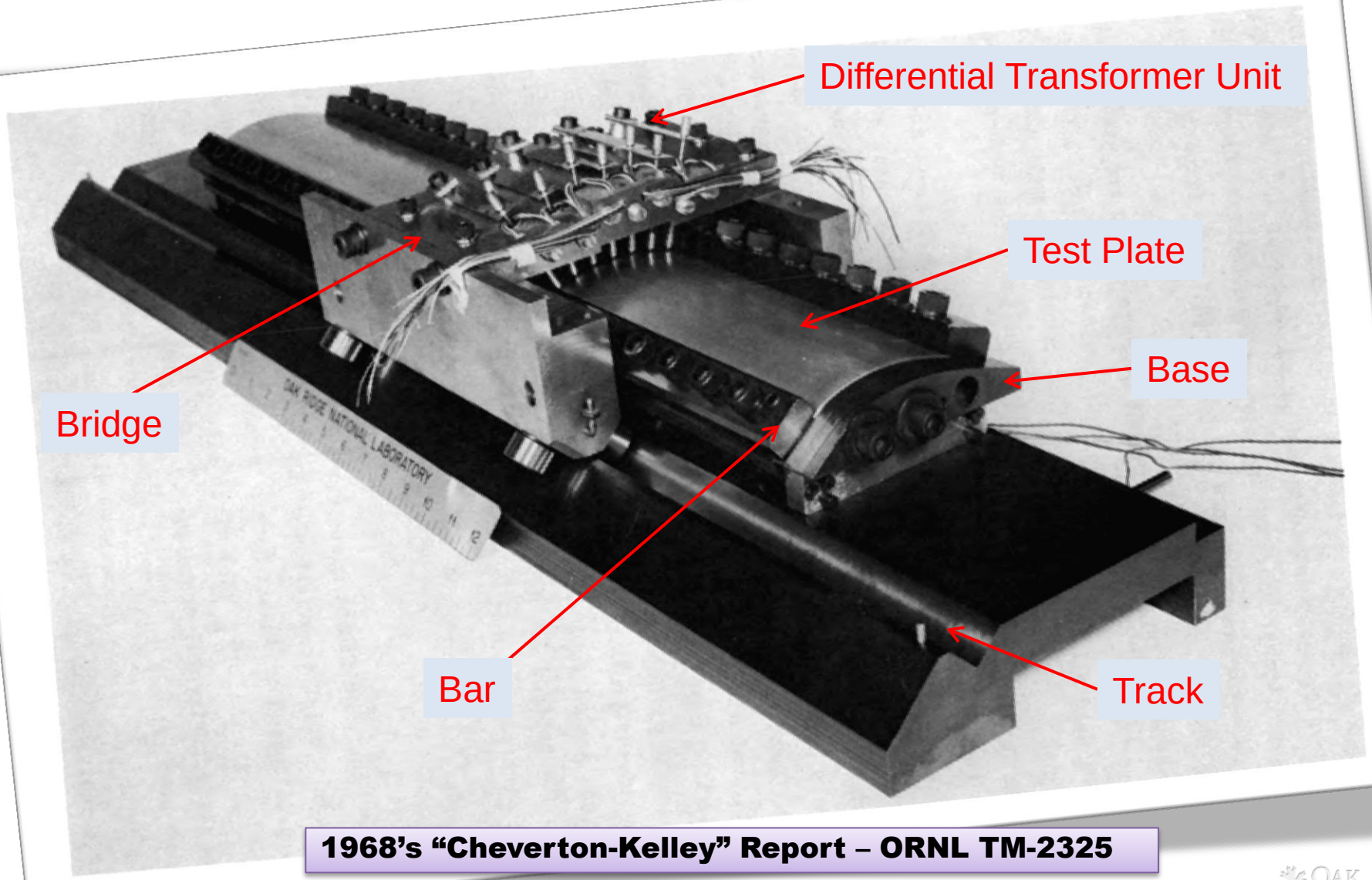
There are two key parameters that control the involute curve: the diameter of the cylinder and the angle that the string is un-wrapped around the cylinder. In the example above, the string is un-wrapped 90° around the cylinder.

HFIR Core - dimensions



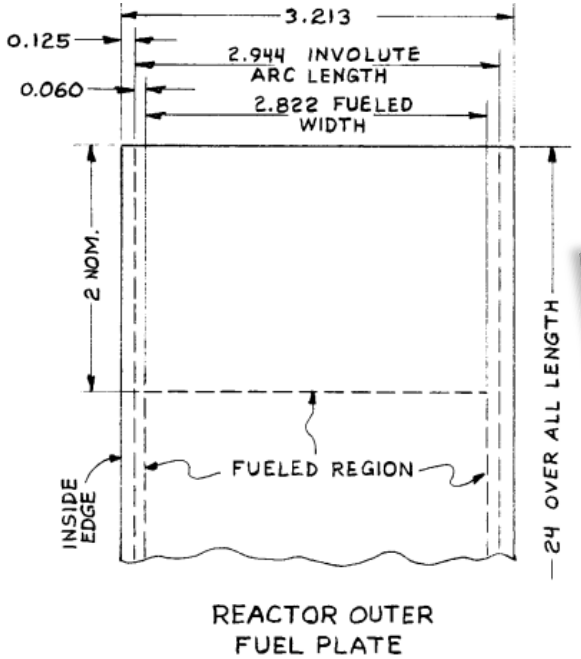


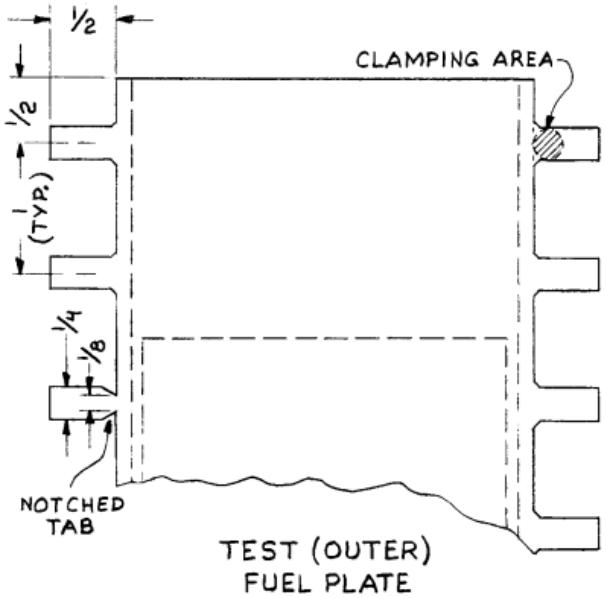
HFIR Fuel Plate Deflection Experimental Assembly

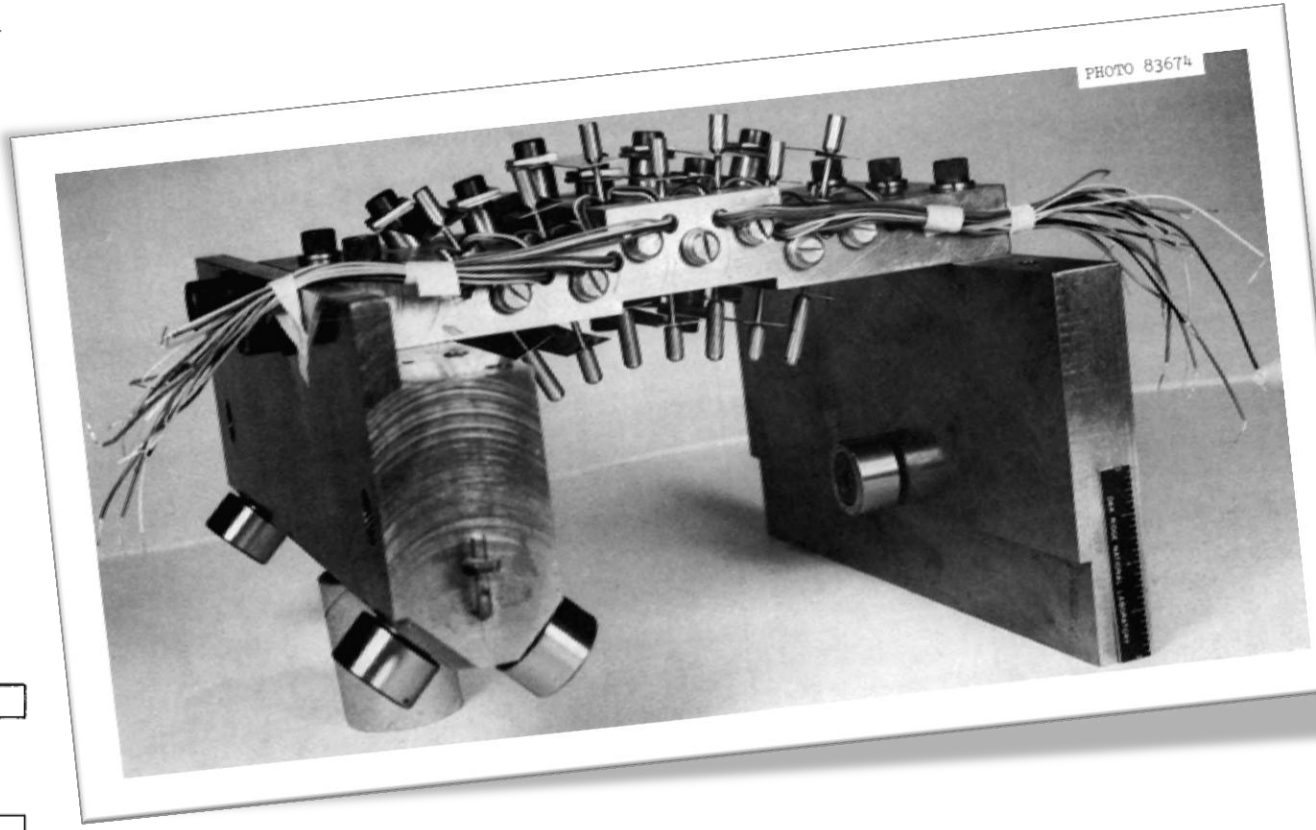


1968's "Cheverton-Kelley" Report – ORNL TM-2325

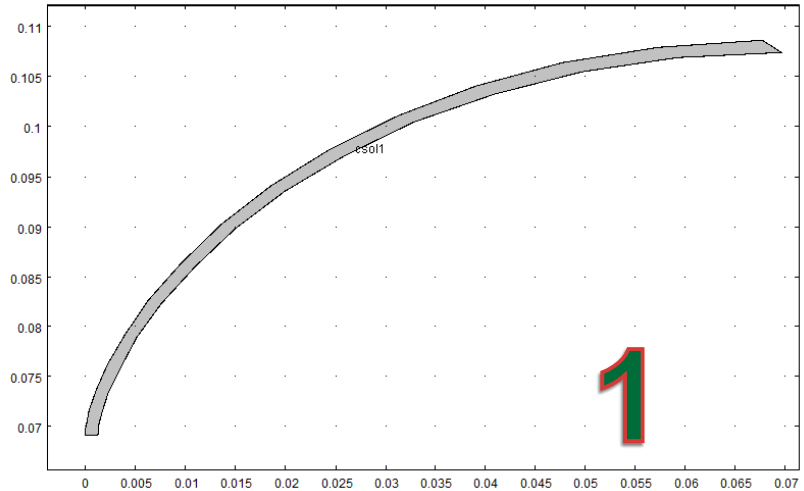
Outer Plate and Test Plate



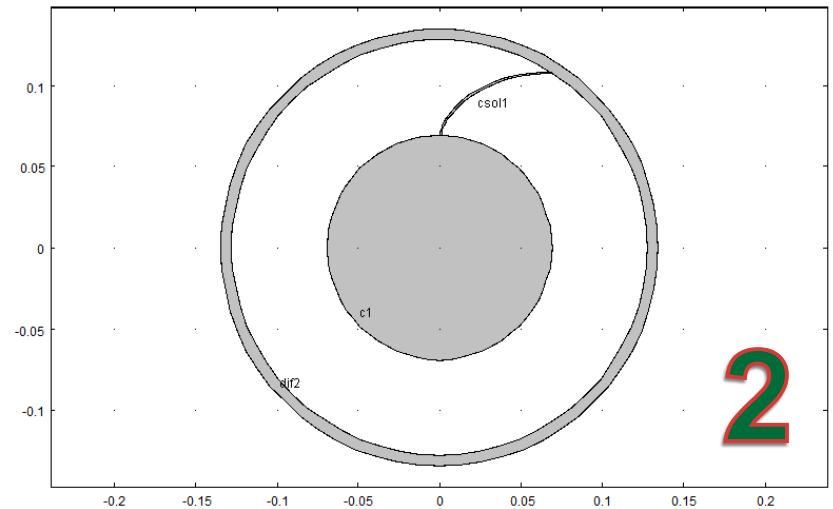




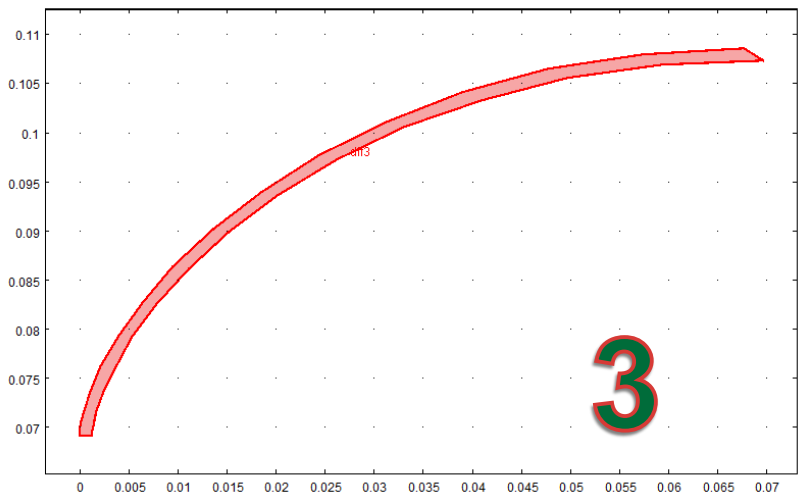
Steps to create a 3D plate in COMSOL



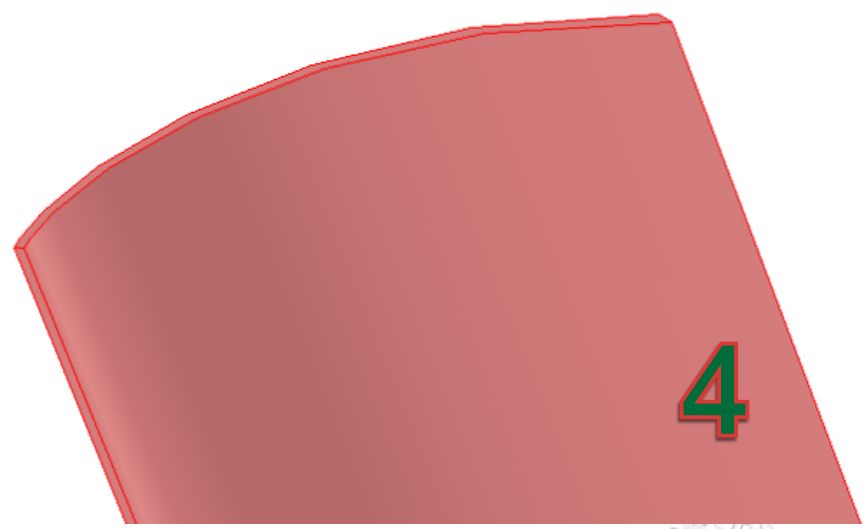
Connect the curve ends and convert to a surface



Create inner and outer circles, and apply the difference operator

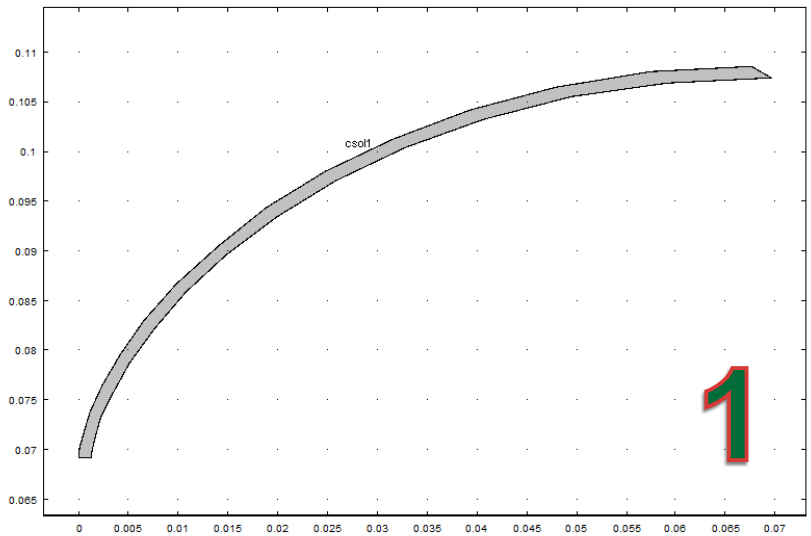


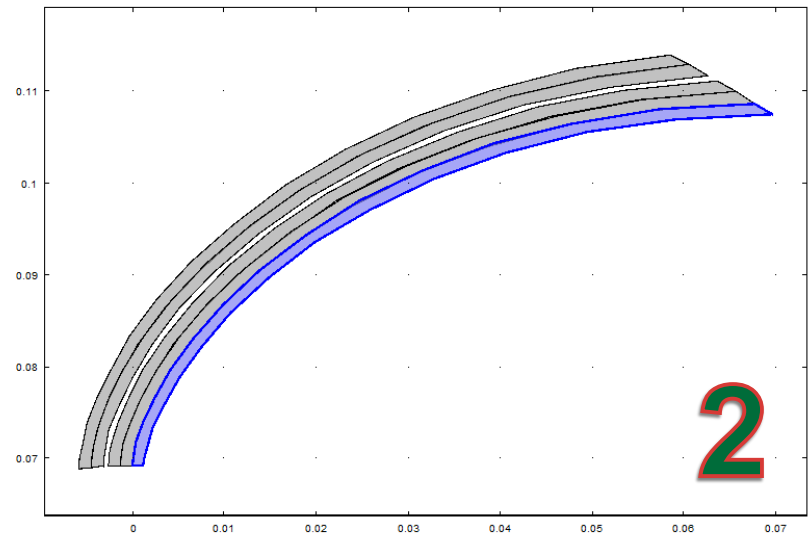
Taking the difference of the plate and circles

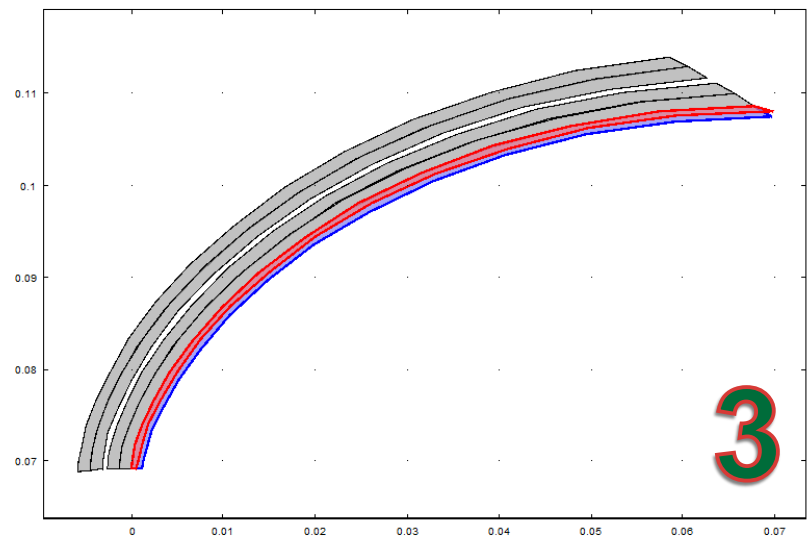


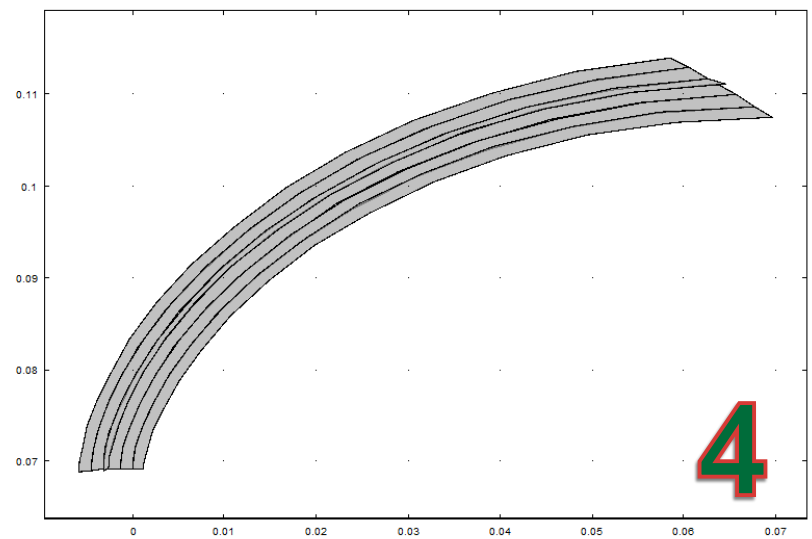
Extrude in the z-direction

Graphical steps for creating narrow/wide channels

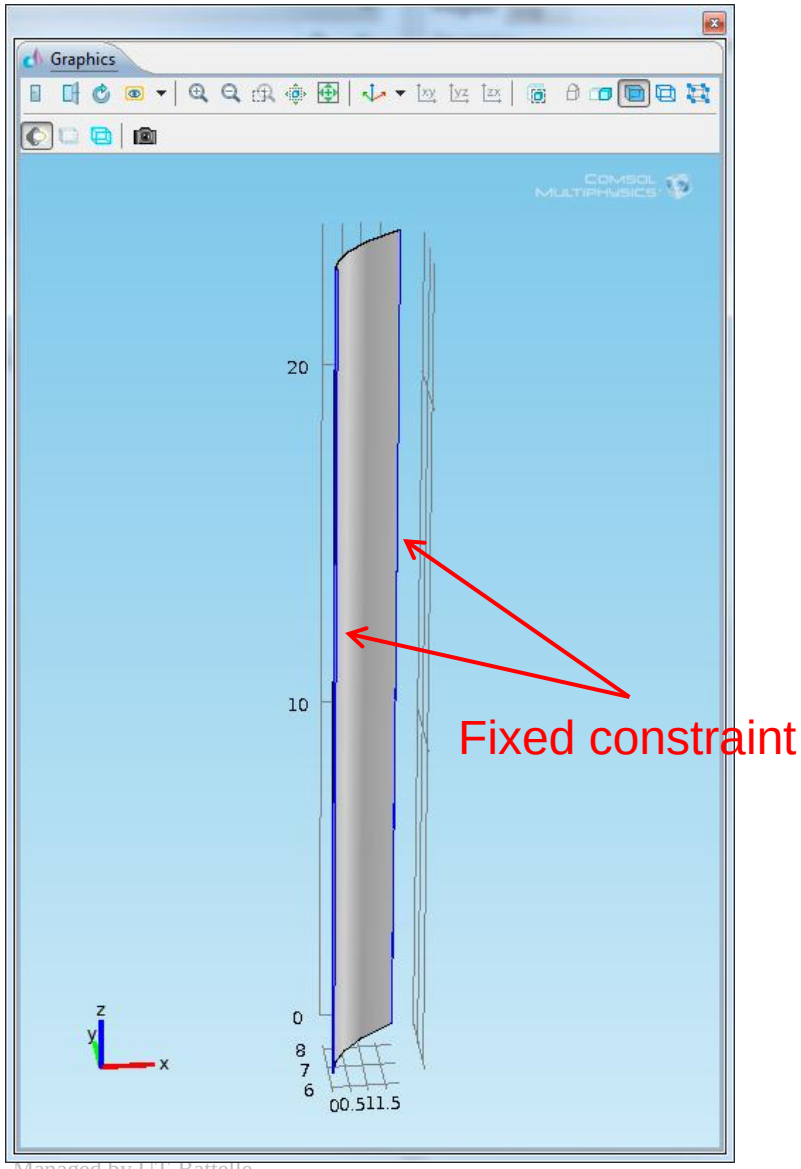


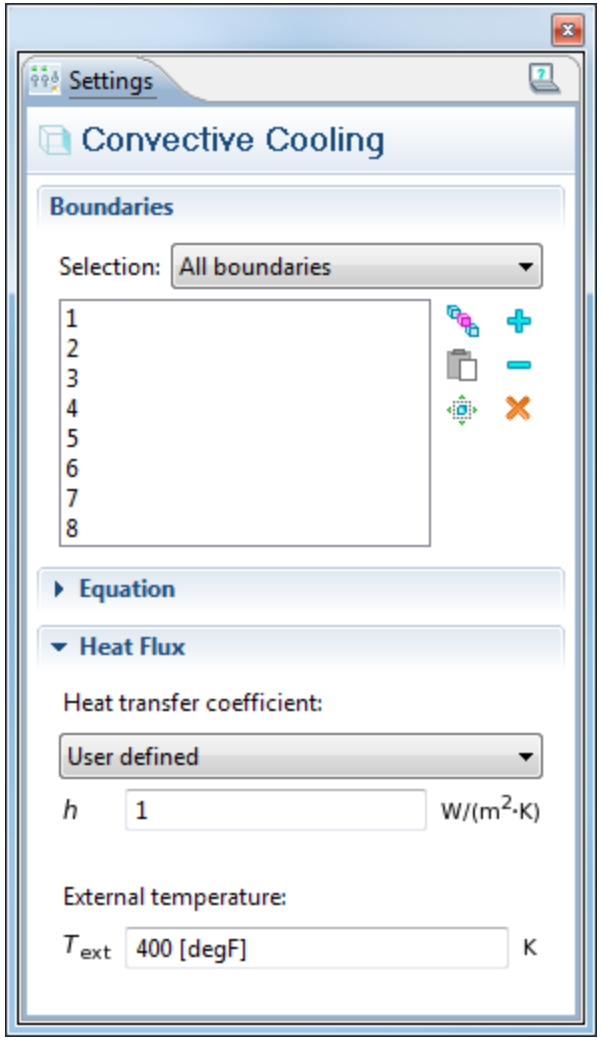




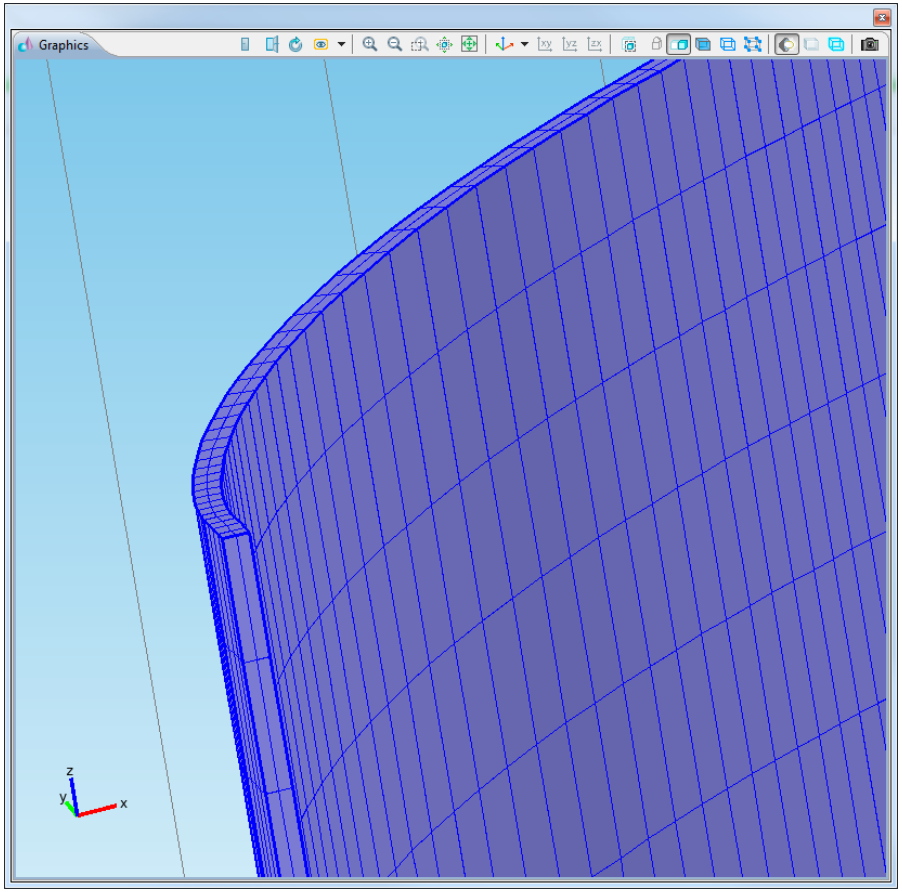


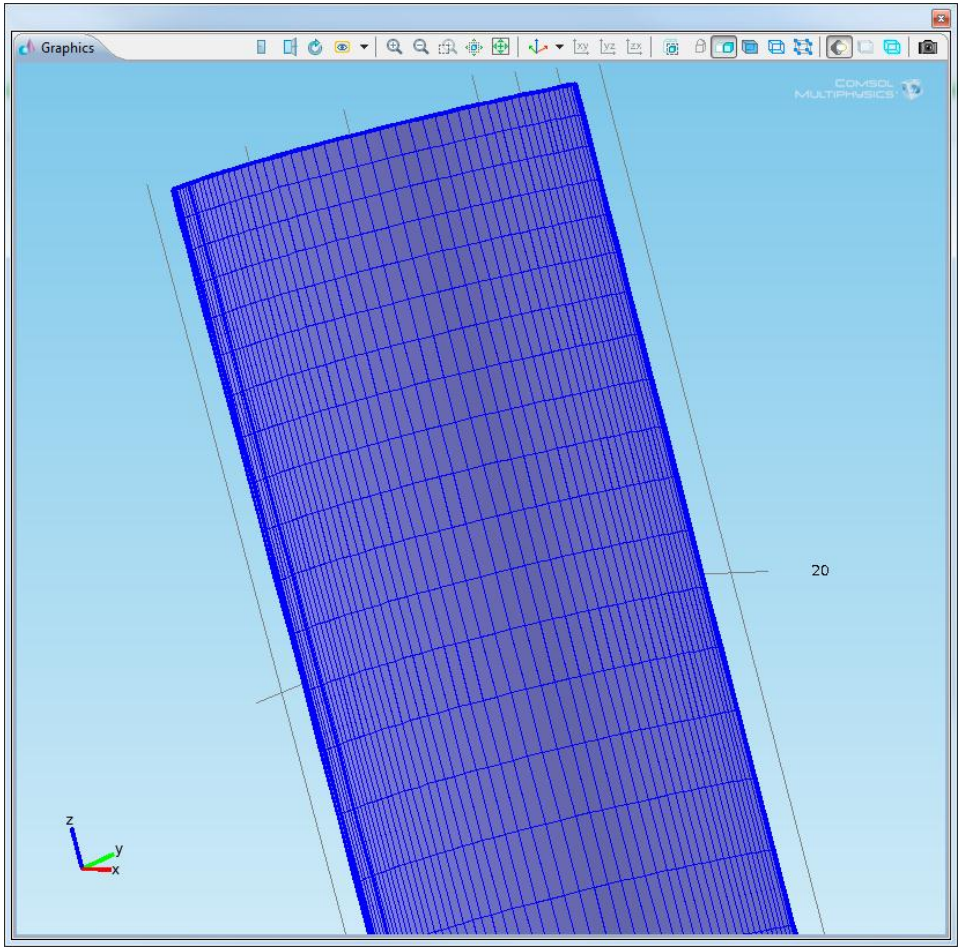
Aluminum test plate with both sides constrained



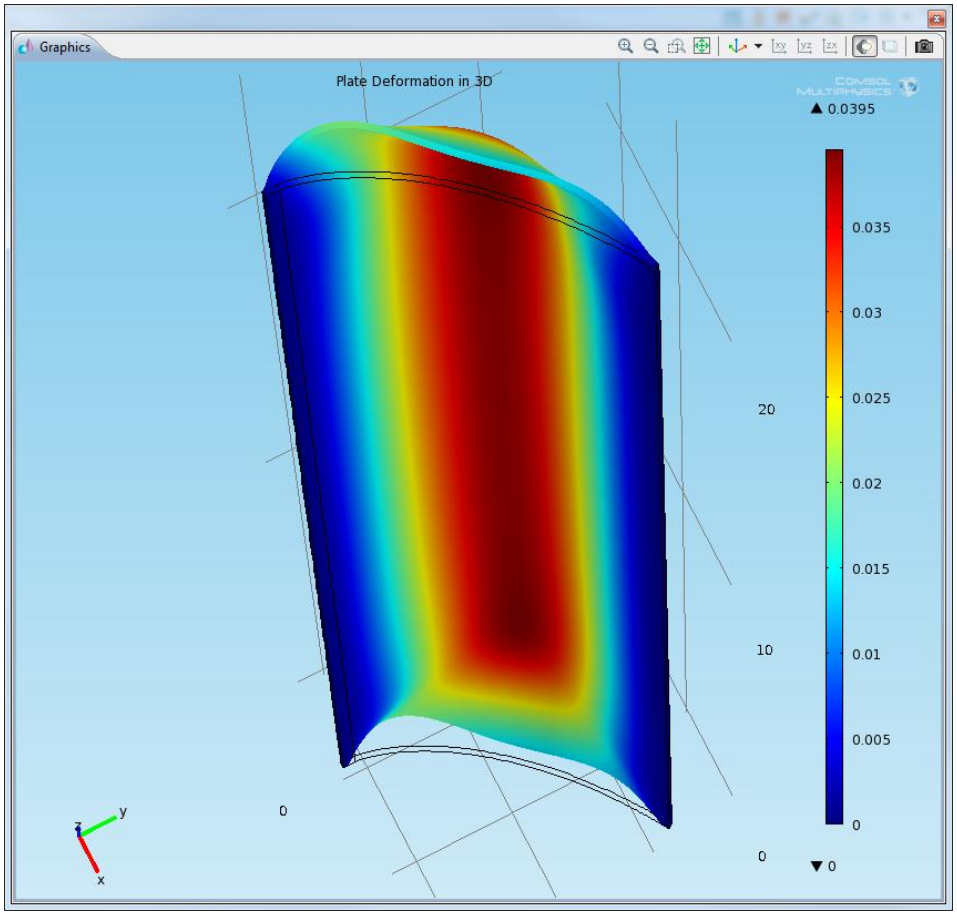


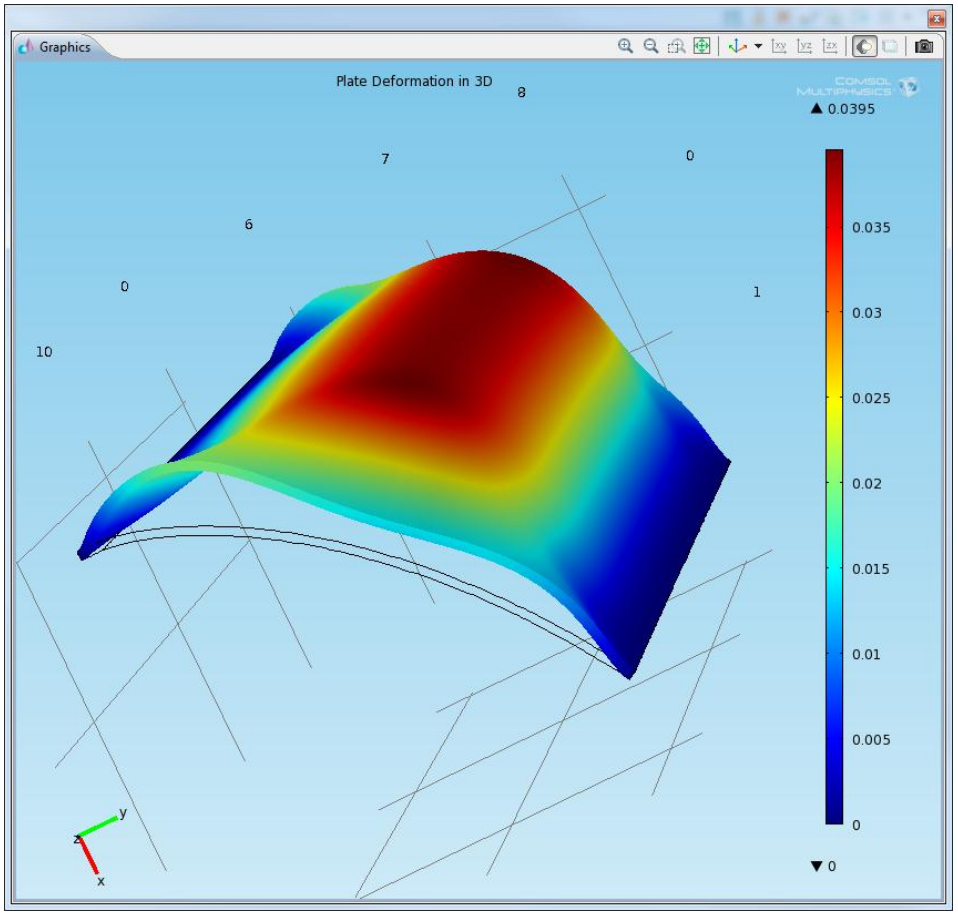
Mapped Meshing



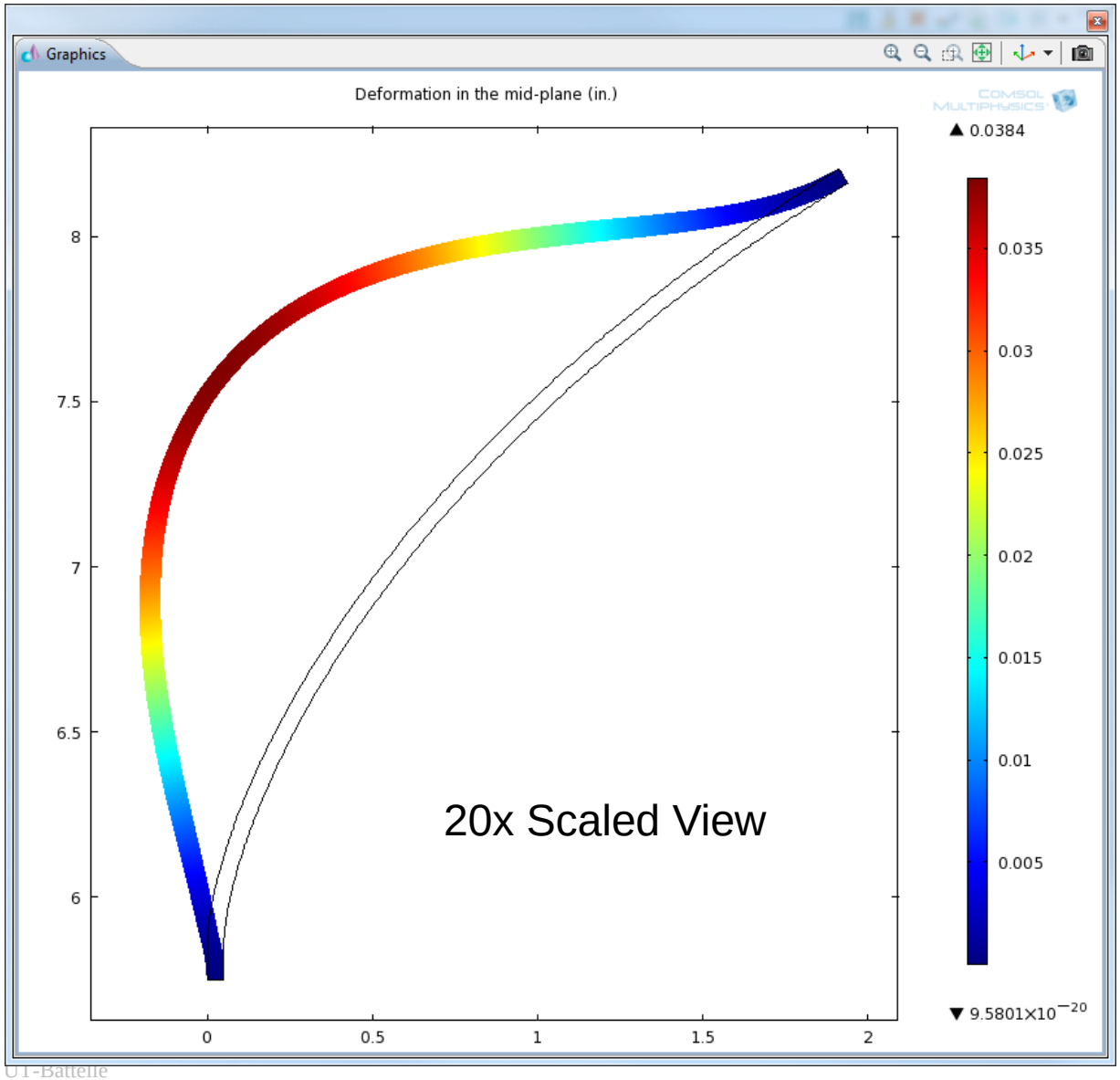


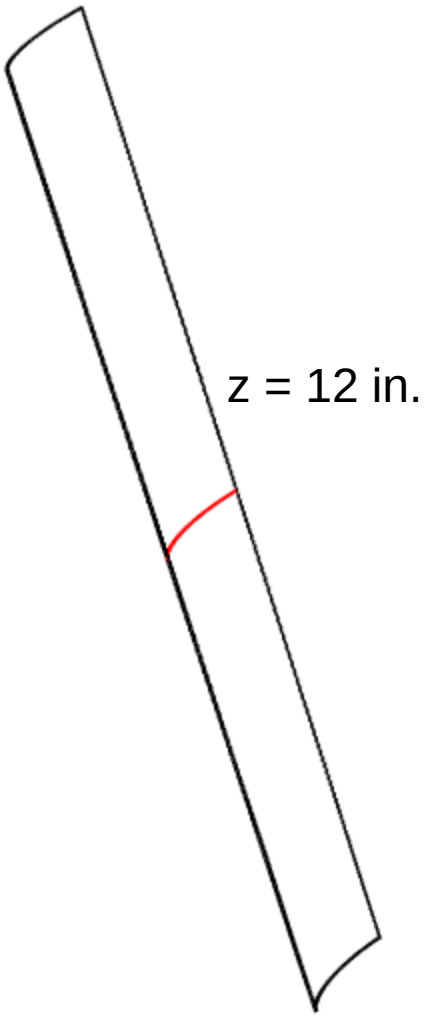
3D Deformation (20x scaled view)





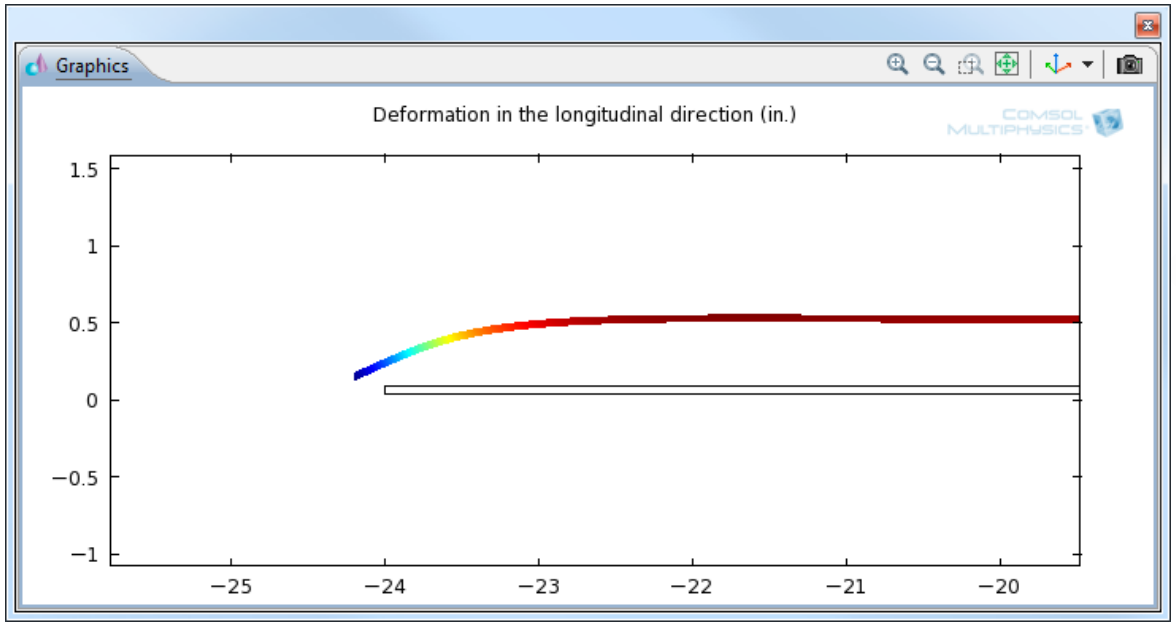
Deformation in the mid-height edge of the plate

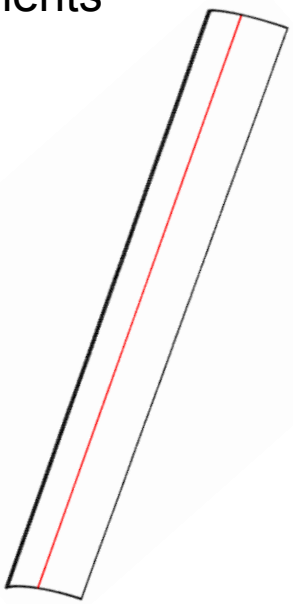




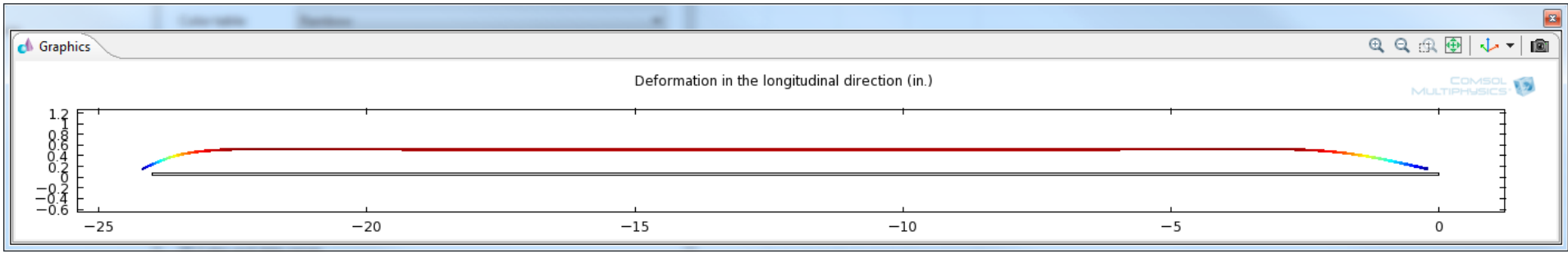
Deformation in the radial mid-plane

At the location of transformer # 4
in “Cheverton-Kelley” experiments

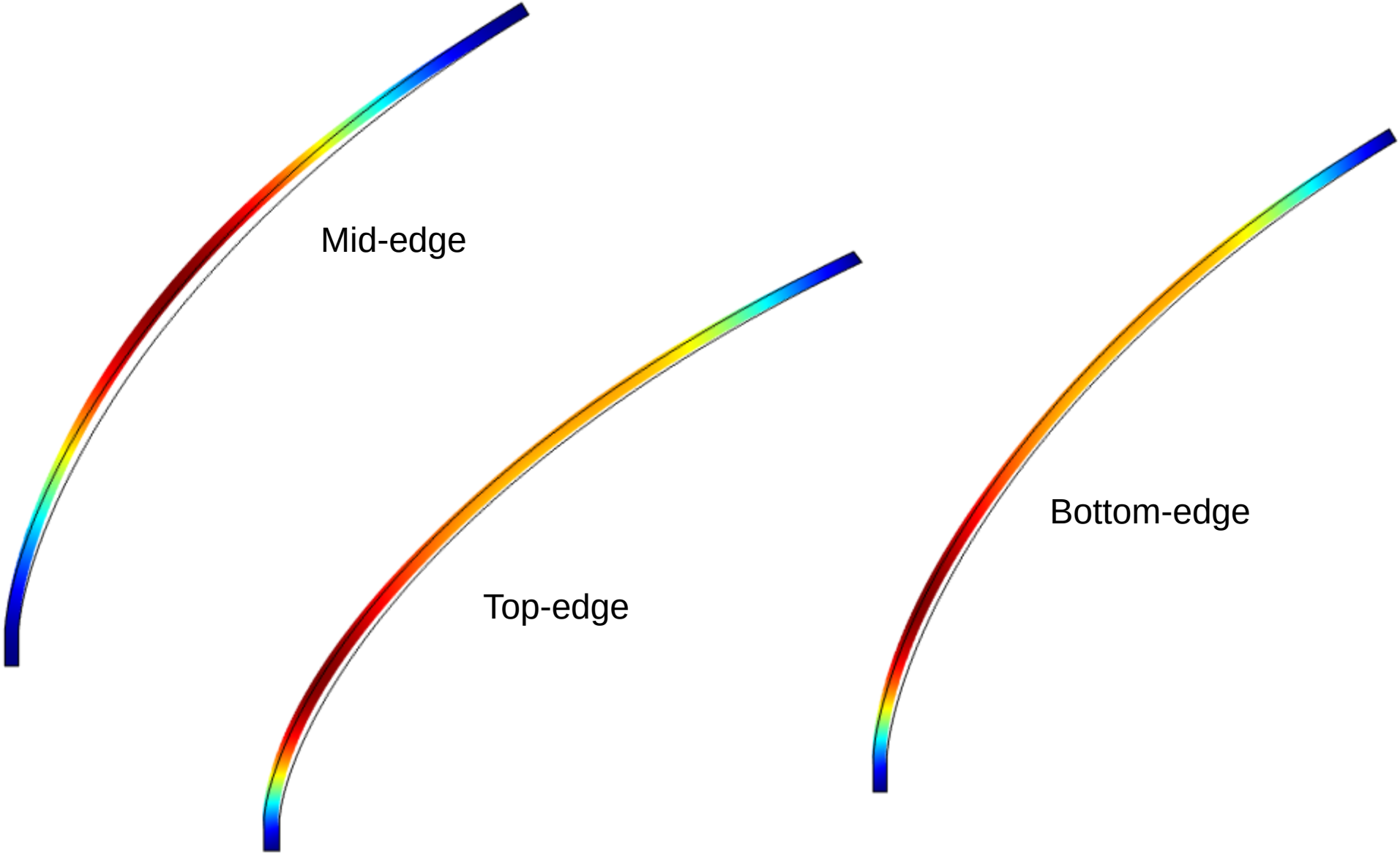




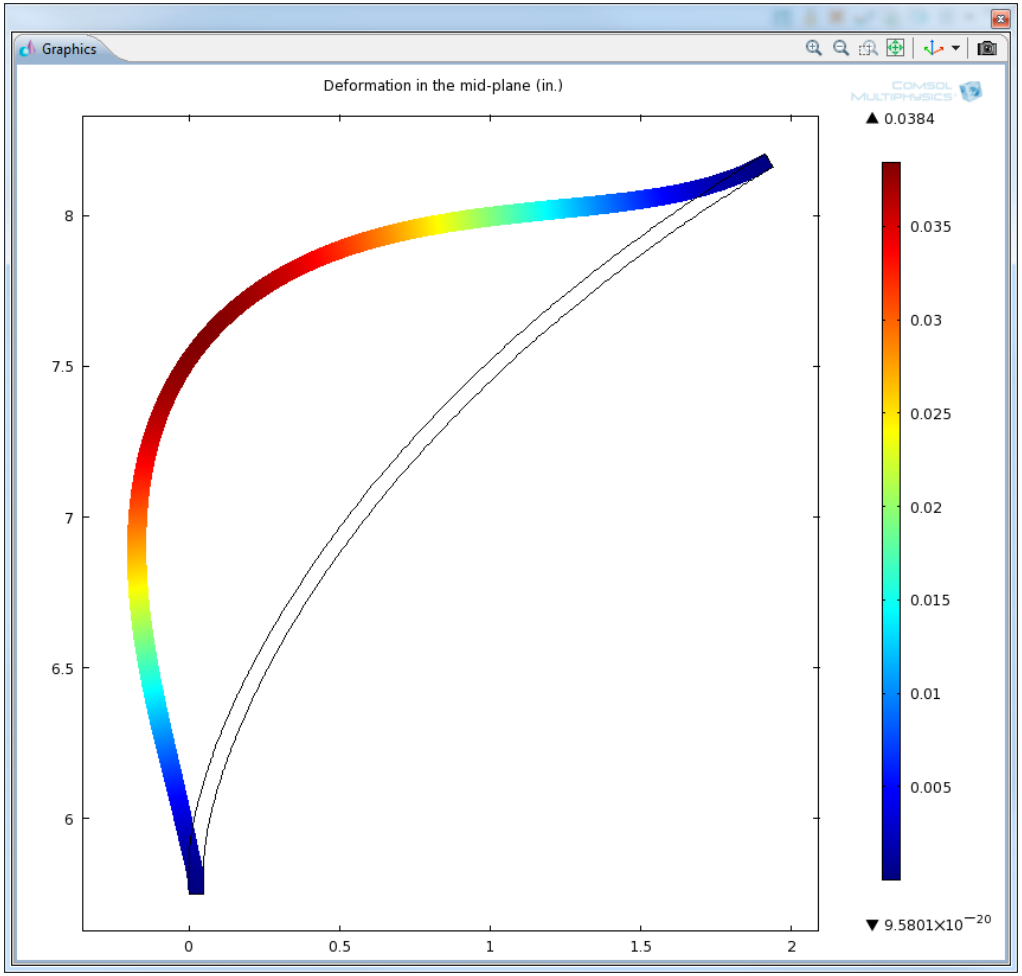
20x Scaled View

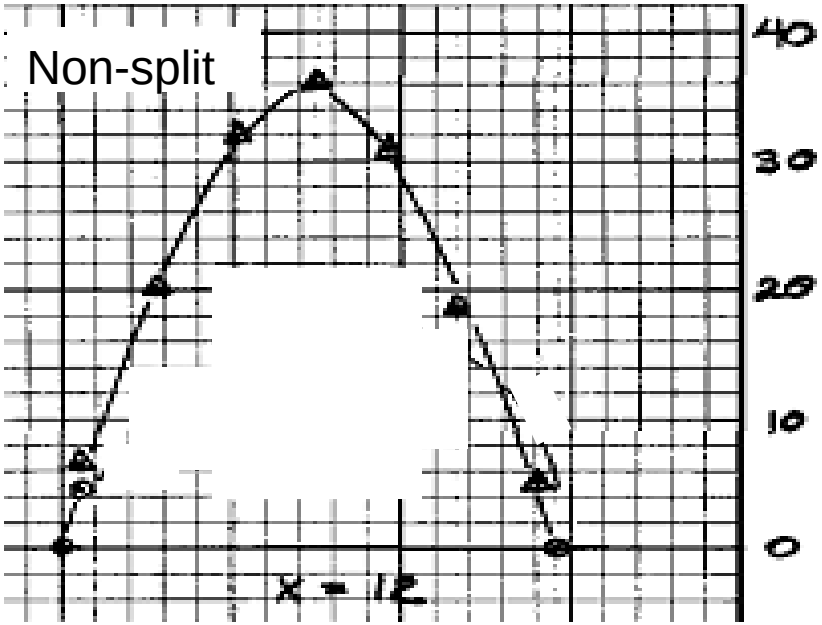


Un-scaled deformations in 2D

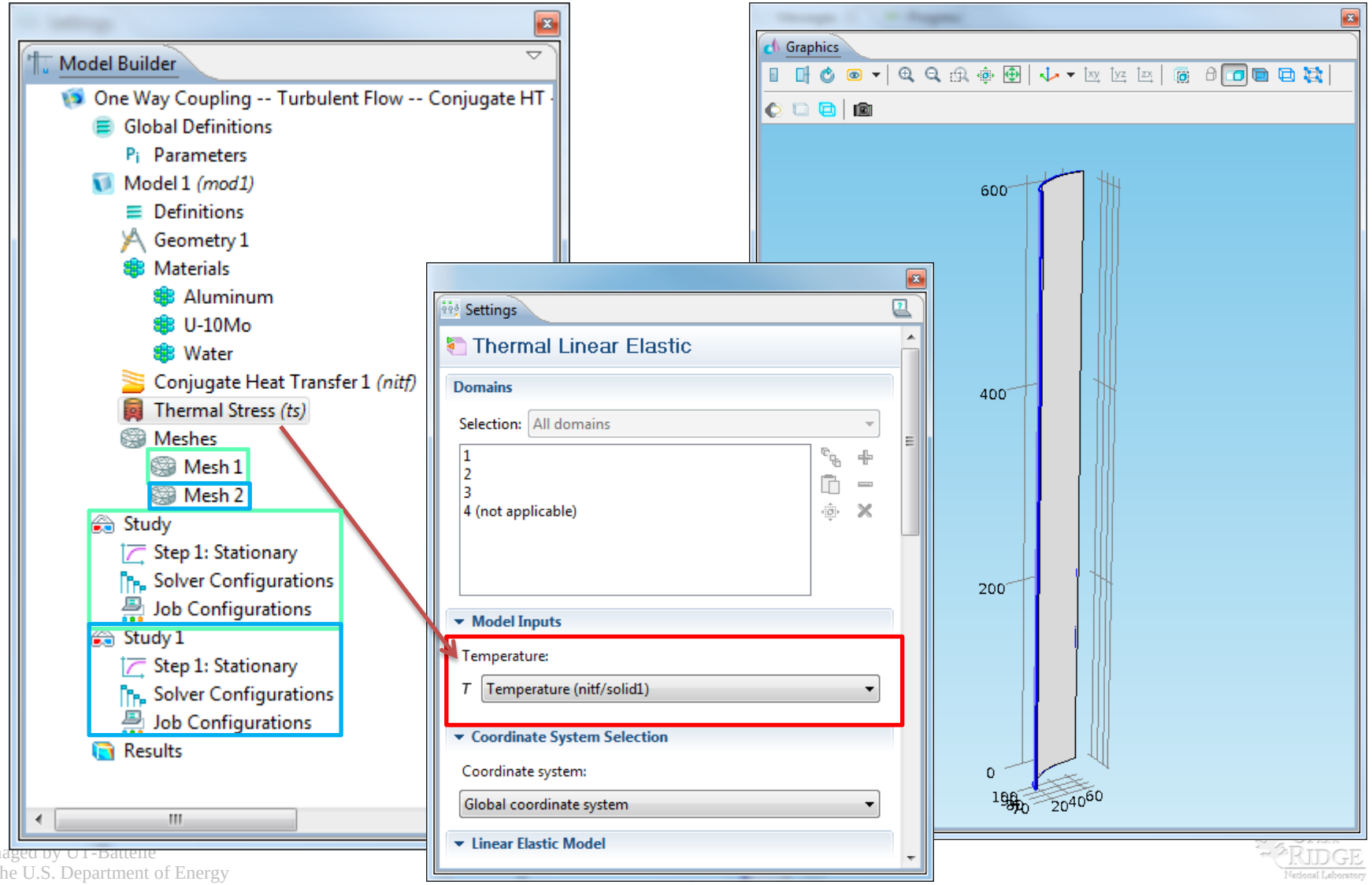


Comparison of simulation results with experiments

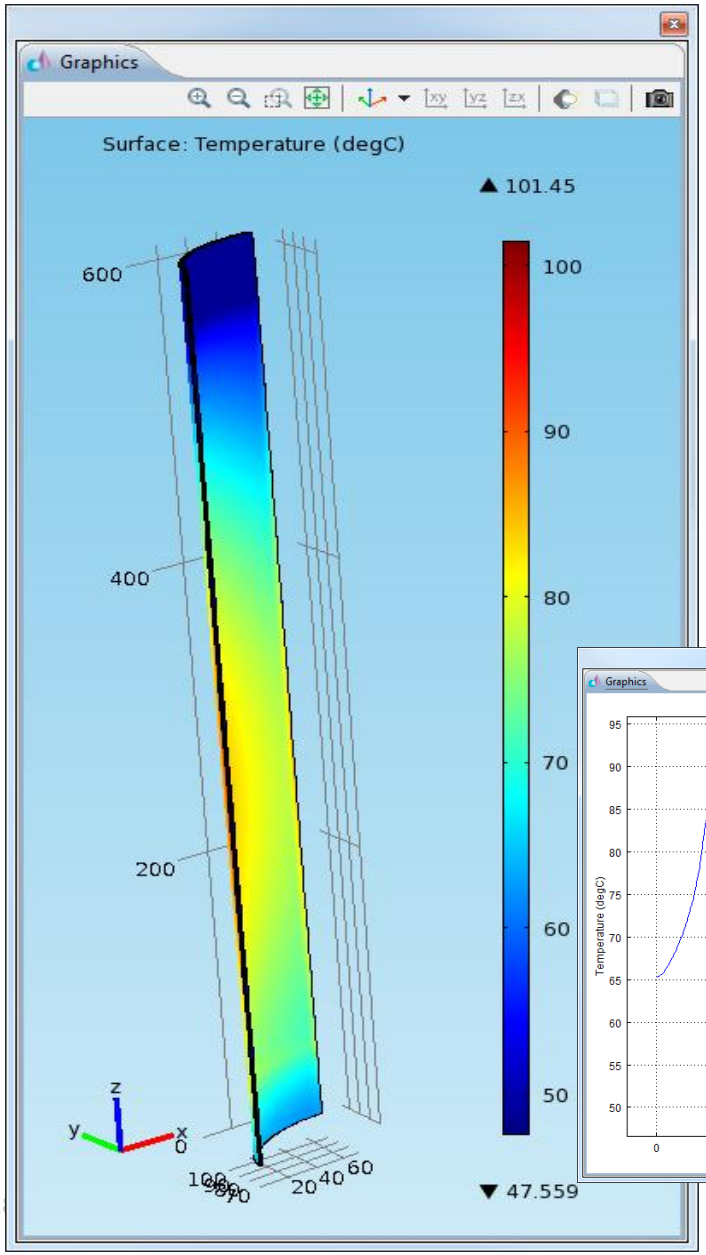


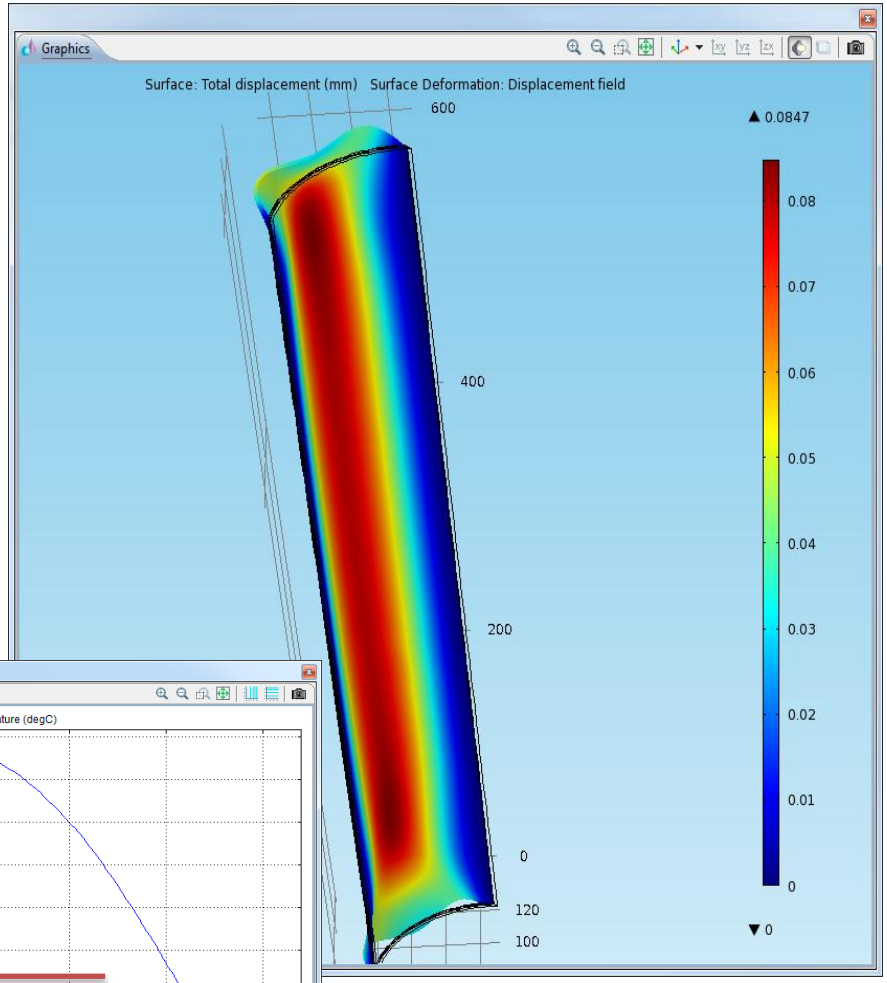


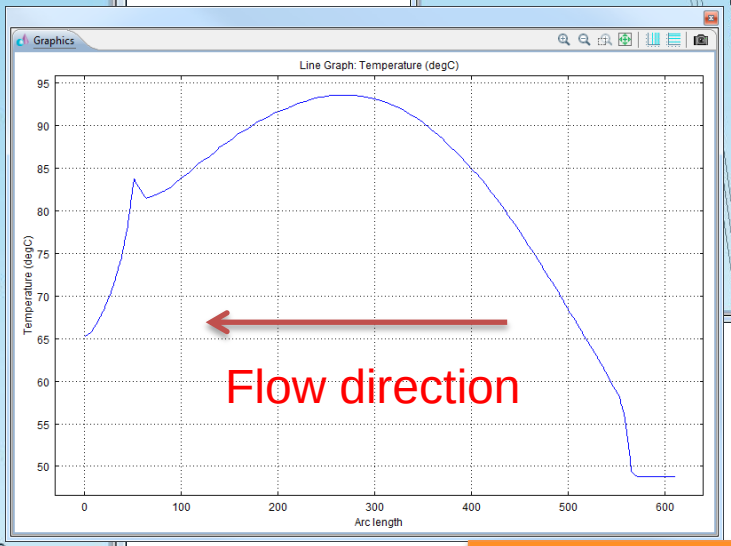
Coupling turbulent flows, conjugate heat transfer and thermal-structural interactions



Results from the one-way coupling







Work underway for the two-way coupling task

Conclusions

- COMSOL is able to accurately capture the thermal expansion behavior of the Al outer plate when convectively heated
- COMSOL is able to provide feedbacks between different physics, and offers flexibility in multi-physics couplings
- The ultimate goal of this exercise is to analyze multi-plate multi-channels (regular/irregular) scenarios with all the relevant physics coupled

Suggestions for COMSOL

- More work needed on COMSOL's CAD and meshing interface to make it more robust
- GUI needs to be more flexible (should allow multiple object handling -- copying, pasting, deleting, saving etc.-- to be able to reuse pre-created objects either in the same model or a new model file)

Thank you for your attention.