PENNSTATE

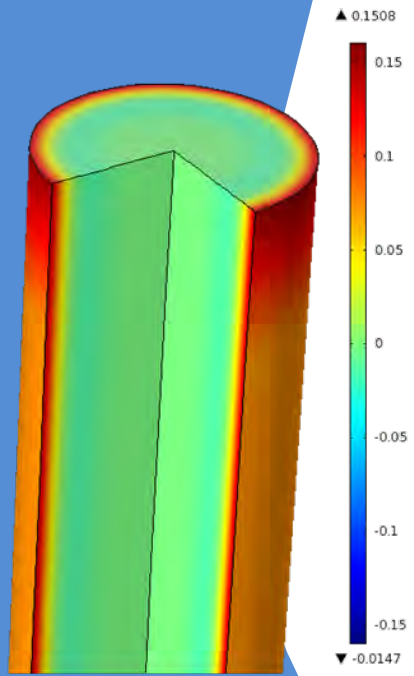
ARL

Time Domain Analysis of Eddy Currents in Saturating Magnetic Materials

Stephen C. Thompson
Applied Research Laboratory
The Pennsylvania State University

Presented at the COMSOL Conference, Boston, October 12, 2011

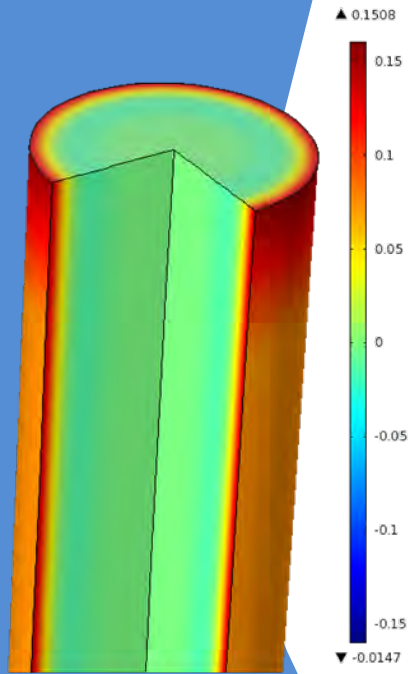
Eddy Currents are Well Understood



- Eddy Currents exist in an electrically conductive material subjected to oscillating magnetic field
- Oscillating B generates an oscillating circulating current in the conductor
- Oscillating current generates B that opposes (cancels) the original B except at the wall
- B (and J) are confined to the retion of the wall

Eddy currents

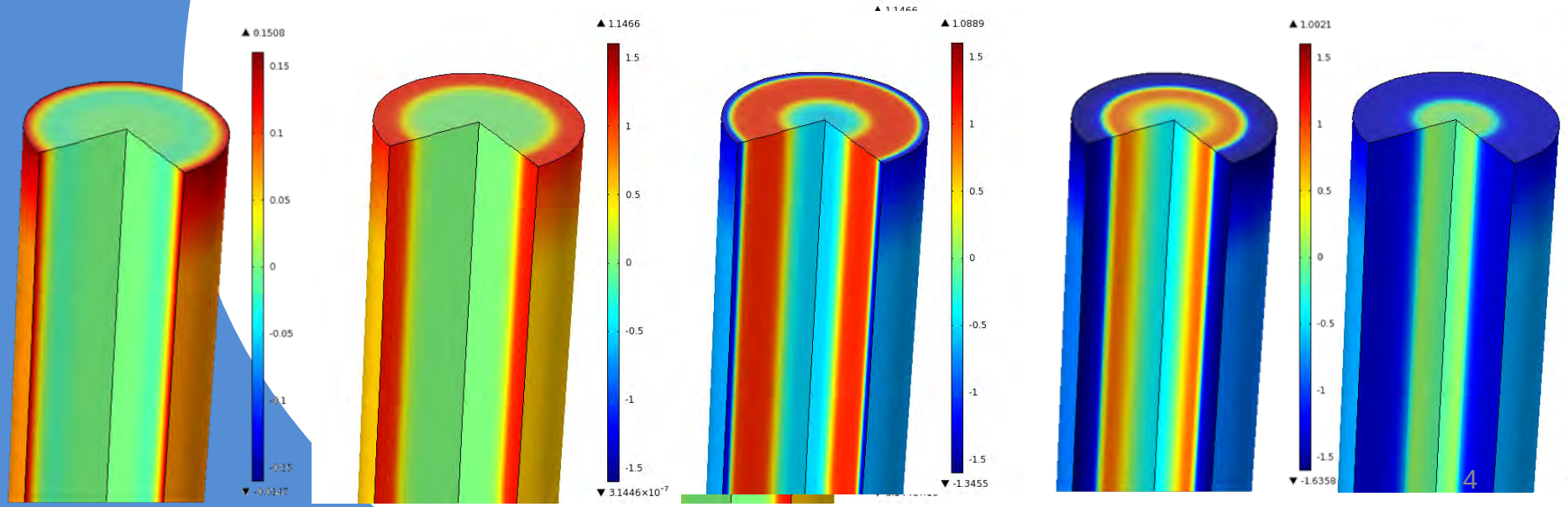
- Wall thickness: $\delta = \sqrt{\frac{2}{\omega\mu\sigma}}$



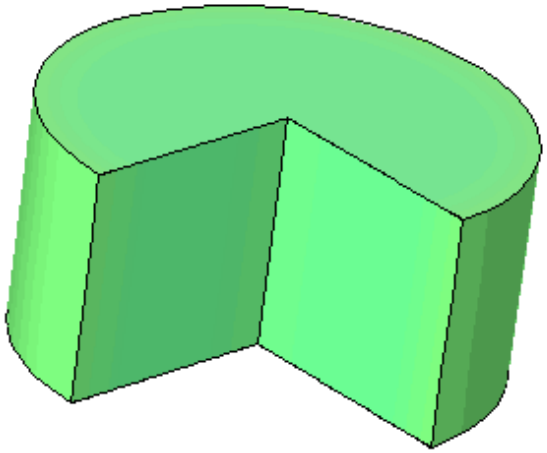
- If δ > material dimension, then the effect is negligible. Lamination of sheets and stranding of wires can often eliminate eddy currents
- But not always

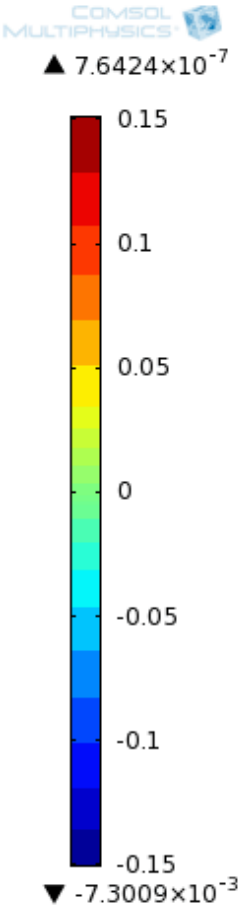
What happens when the wall saturates?

- Flux spills over to the center
- Fills as much of the volume as needed
- Saturation is reversed each half cycle

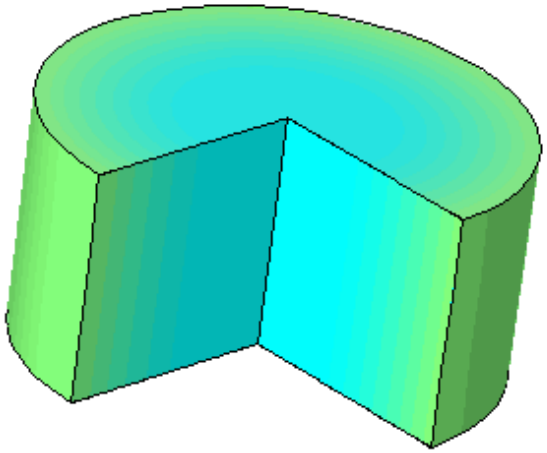


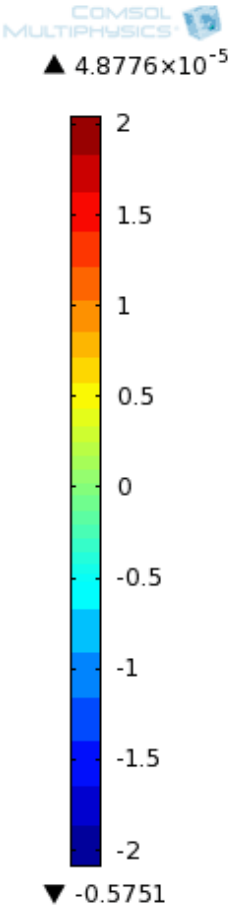
Low Amplitude Linear



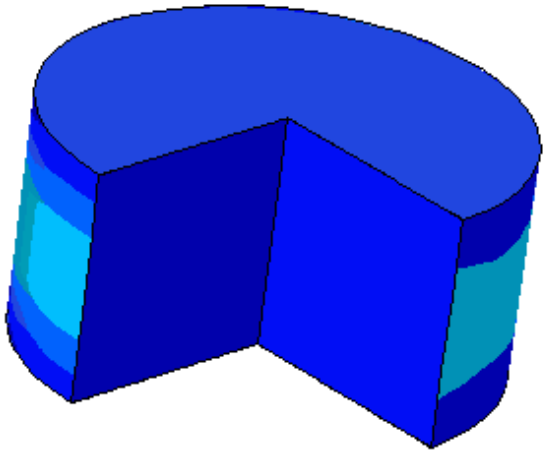


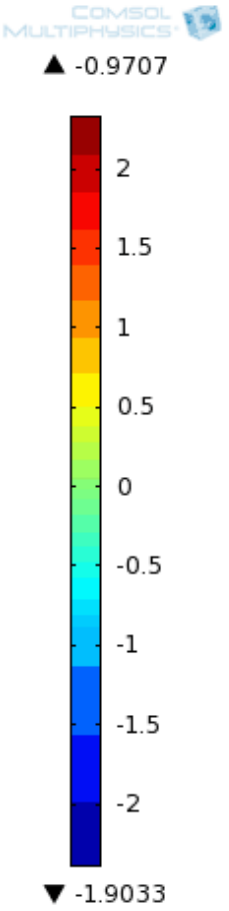
Intermediate Amplitude with Saturation



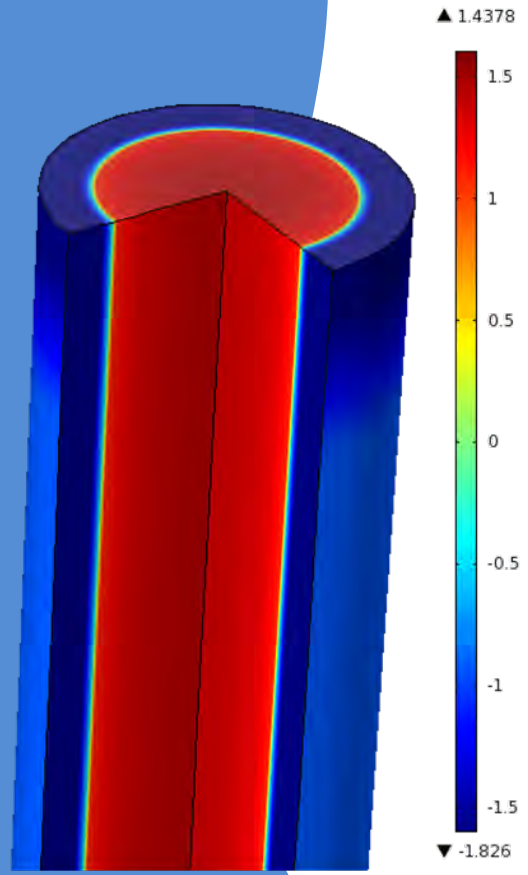


High Amplitude with Complete Saturation



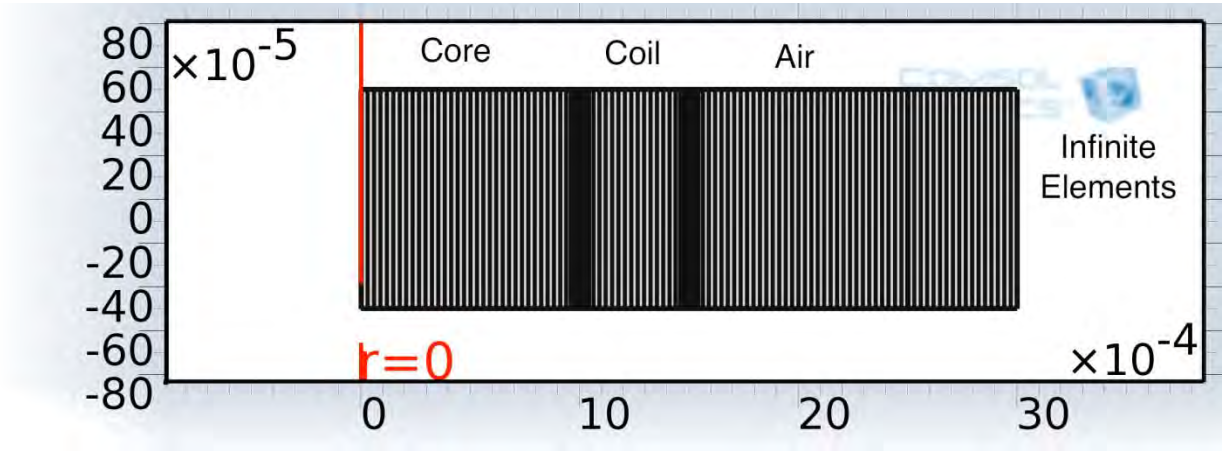


Difficult Problem for FEA



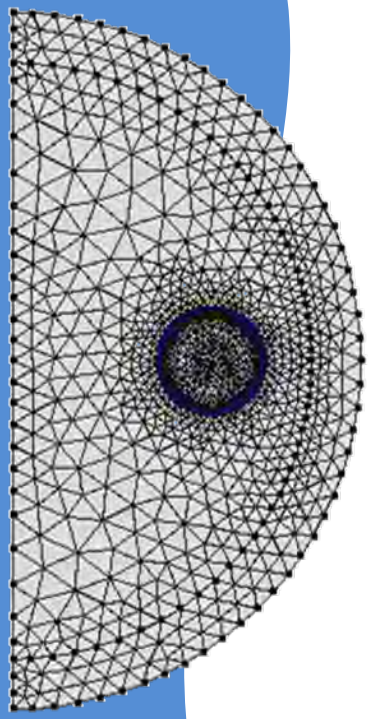
- Moving wall of saturation
- Wall is thin and moves through the entire volume
- This example is essentially one-dimensional (<2000 DOF)
- In two dimensions, useful approximations are possible
  - 2D axisymmetric toroidal core

Infinite Cylinder as a "1D" Problem



- 2D Axisymmetric geometry
- Core, coil, air, infinite domains
- Boundary Element Mesh at surface
- Periodic Boundary conditions in vertical direction

Solutions are Possible in Some Simple 2D Geometries



- Toroidal core with idealized coil
  - A true 2D axisymmetric case
  - A useful example required ~250k DOF

Others?

Realistic 3D Models?

Thank You.

Questions?