Apr 1st, 1:20 PM - 1:40 PM

Finite Element Analysis (FEA) of the Taper-Trunnion Interface in a Metal on Metal Hip Implant

Kyle M. Bradley
Cedarville University, KBradley@cedarville.edu

Timothy L. Norman
Cedarville University, tnorman@cedarville.edu

Thomas K. Fehring

Finite Element Analysis (FEA) of the Taper-Trunnion Interface in a Metal on Metal Hip Implant

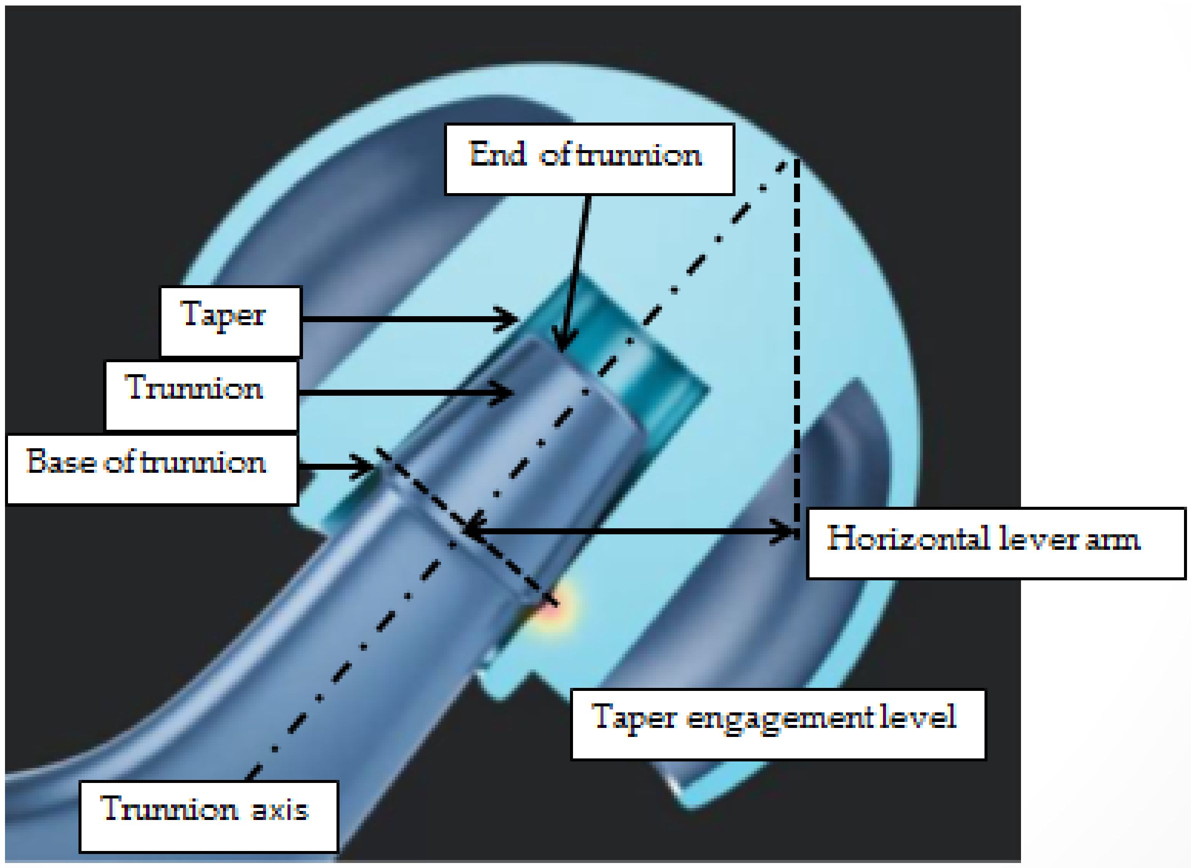
Kyle Bradley
T.L. Norman, PhD
T.K Fehring, PhD

Introduction

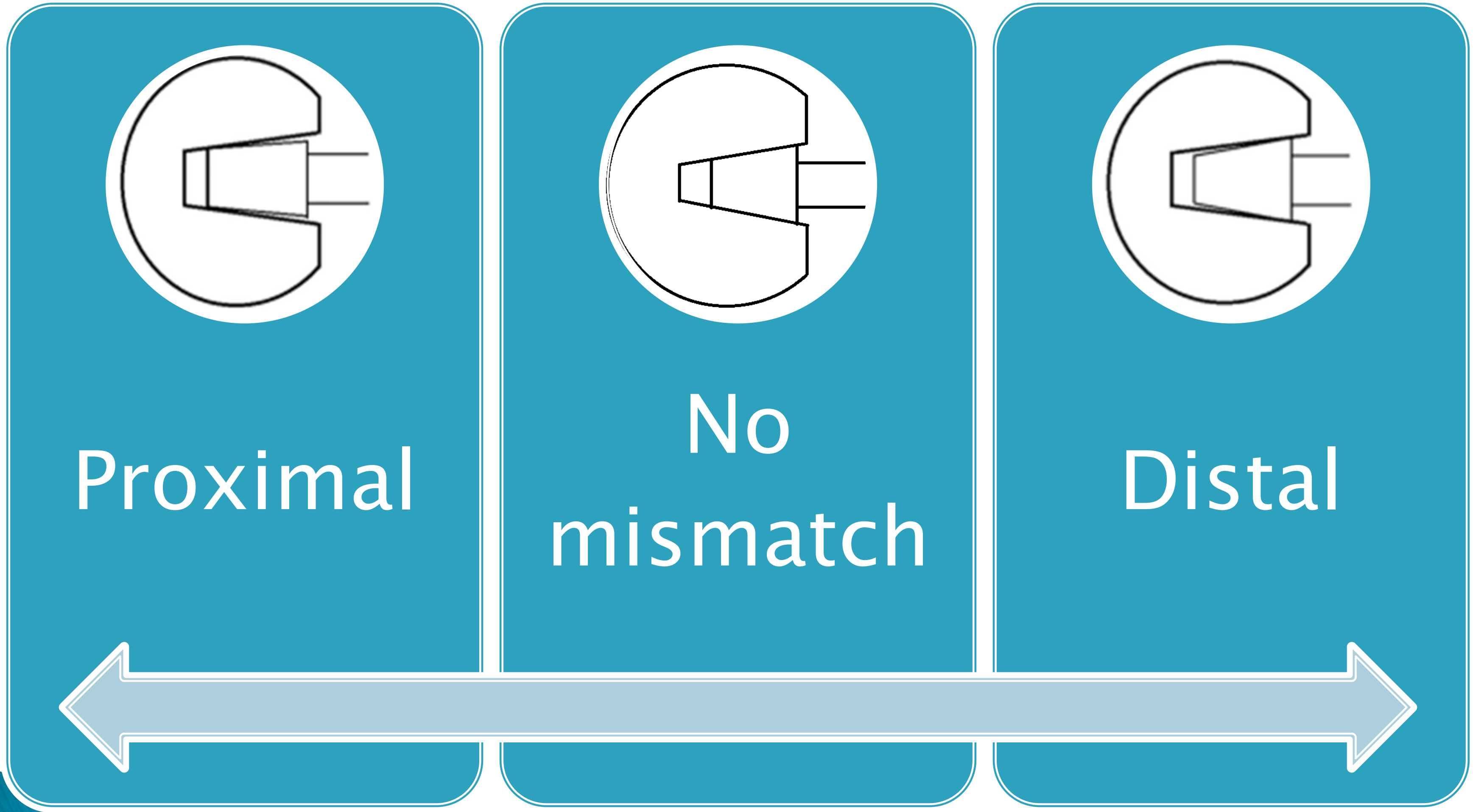
- The taper-trunnion interface has been identified as an area of material degradation in a metal on metal hip implant.
- This has resulted in an increase in revision surgeries due to metal ions being released into tissue and the bloodstream.

- Fretting corrosion is defined as repetitive, relative motion that removes the protective oxide layer of a material allowing the environment to corrode the material.

Introduction



Introduction



Introduction

- Finite Element Analysis
  - A numerical method for solving problems in solid mechanics, dynamics, thermodynamics, biomaterials, etc.
  - A mesh is used to divide the material into nodes, creating smaller elements

  - Input: boundary conditions, loading
  - Output: stresses, strains, and displacements at each node

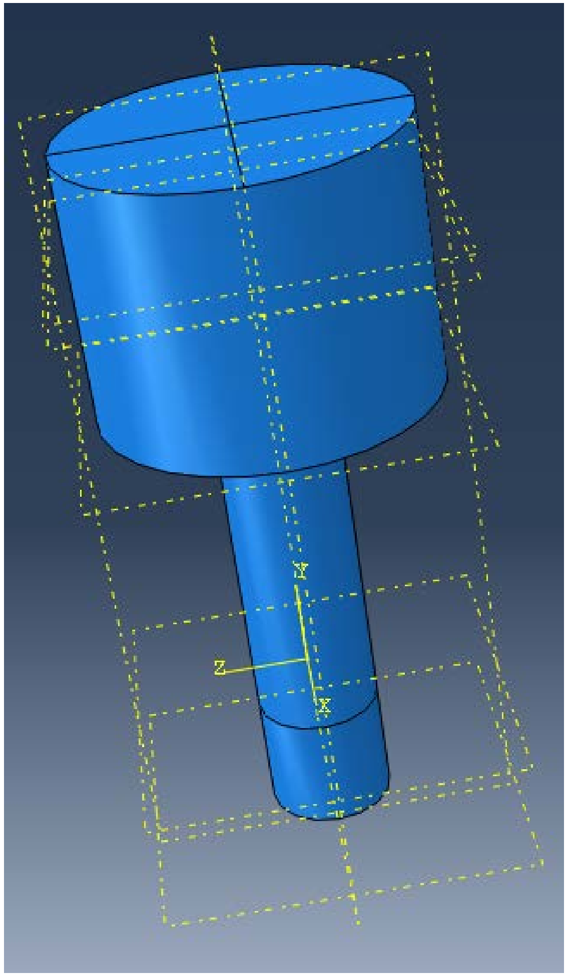
  - Finds an approximate solution
  - Abaqus (FEA Software) was used to run analysis.

Objectives

- Model the taper-trunnion interface in Abaqus (FEA program)
- Measure the contact stresses and the micromotion of the trunnion at the taper-trunnion interface after loading
  - Different angular mismatch values
  - Different roughness values
- Compare the results to experimental current flow data

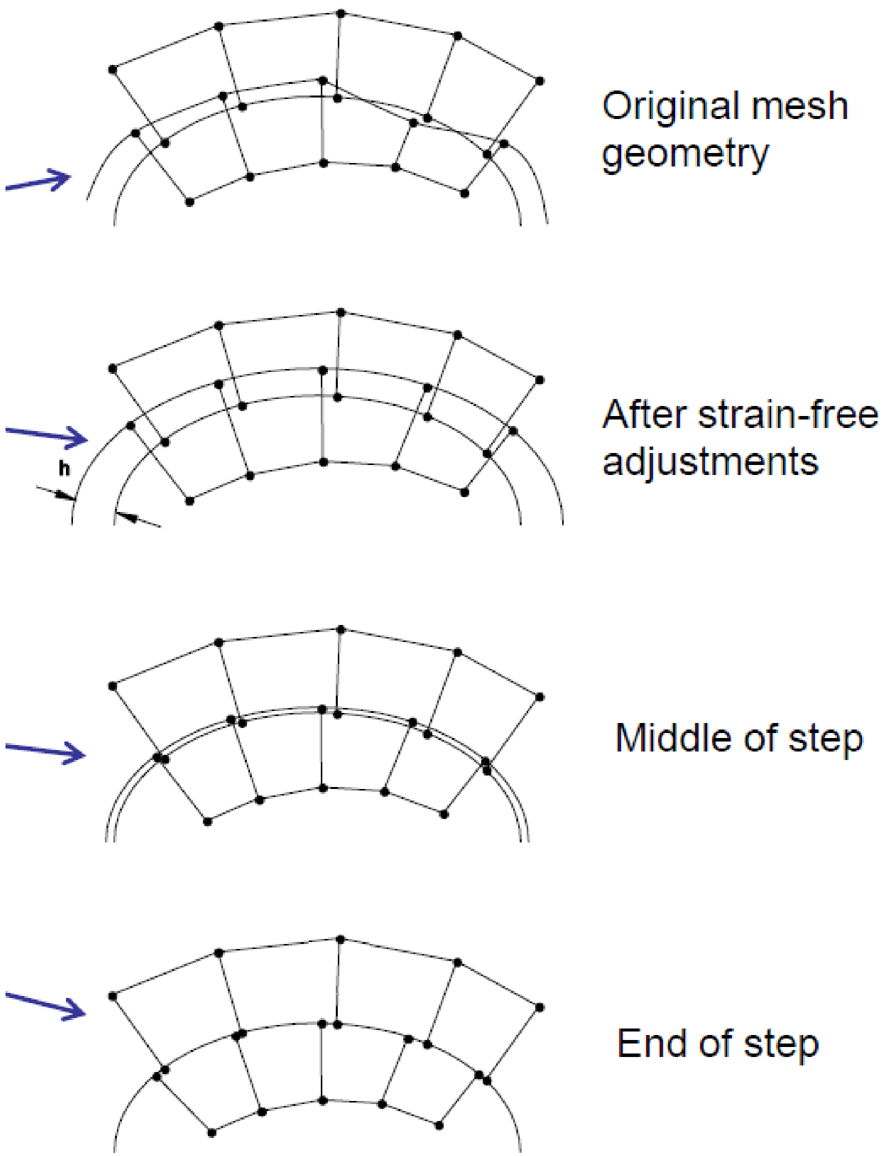
Methods

- Use simplified experimental model of a taper-trunnion interface.
- Major point of emphasis is a correct model of the contact mechanics
- Research the methods of modeling contact in Abaqus (select best one)
- Analyze results



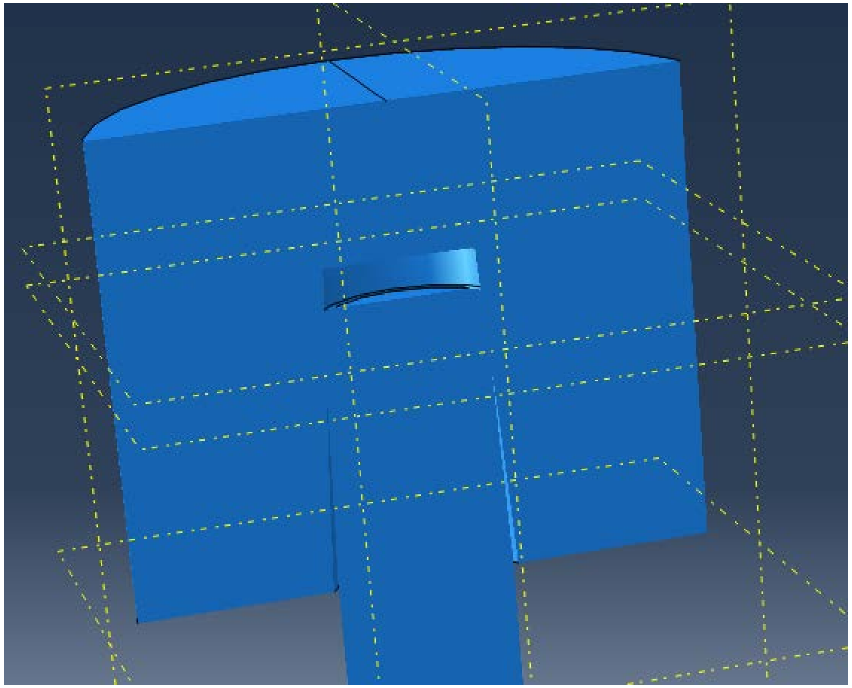
Methods

- Modeling surface-to-surface contact in Abaqus
  - Finite sliding vs. small sliding
  - Surface-to-surface contact vs. node to surface
  - Friction
  - Overclosure
  - Interference fit (shrink fit)



Methods

- Problem with previous models
  - Tie restricted motion at the taper-trunnion interface, “gluing” the parts together
  - Simulates no micromotion at the interface
  - Inaccurate results



Methods

- Reason for the Tie
  - Abaqus has difficulty resolving surface to surface contact situations
  - In this case, the surface of the taper and the trunnion were not in proper contact at the beginning of the simulation.

- Solution?
  - Applied an instantaneous concentrated force to the top of the head on the trunnion axis to set the head onto the trunnion before applying the physiological load (using steps)

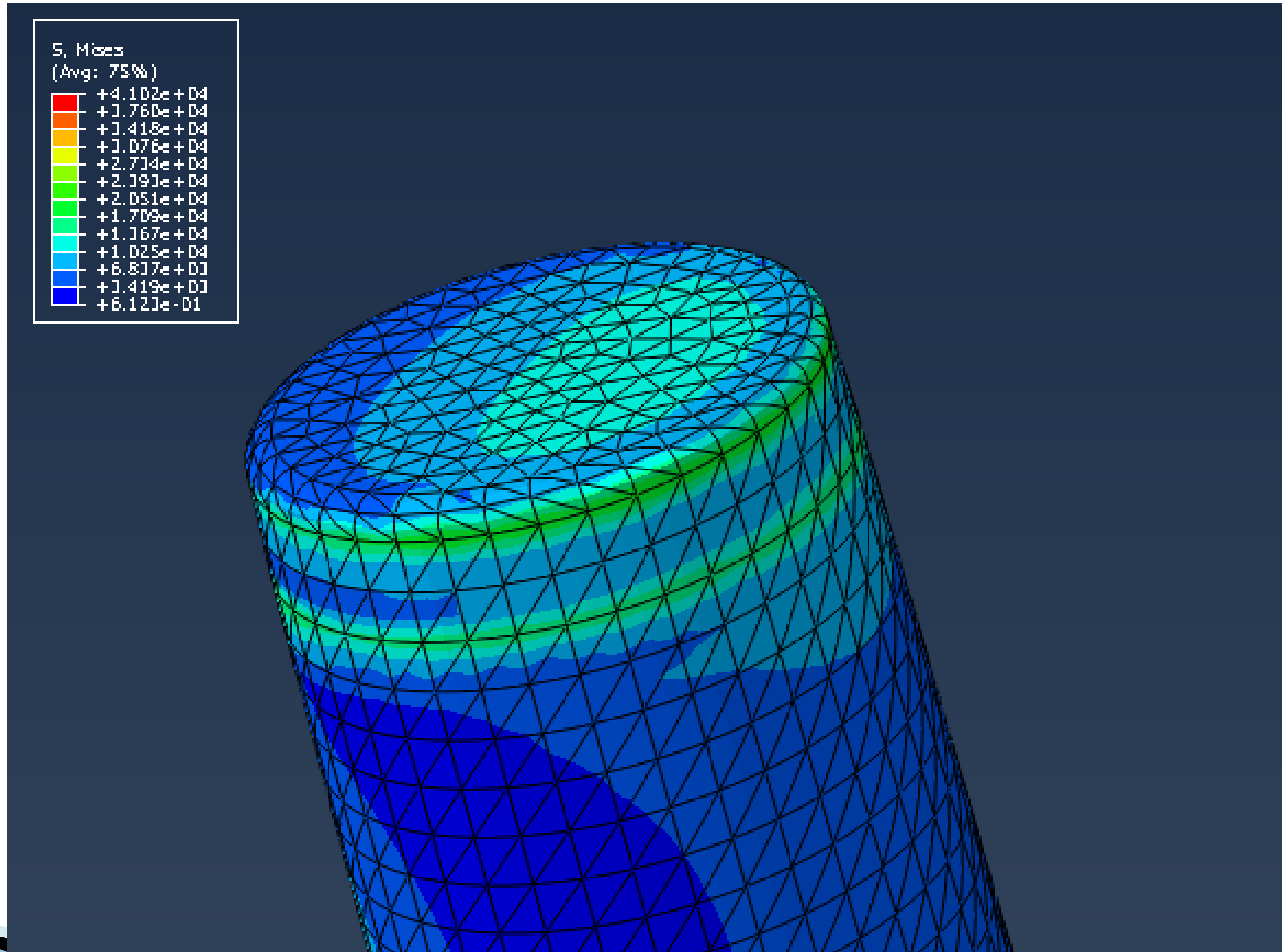
Methods

- Analysis
  - Initial Step
  - First Step
    - Apply an instantaneous impaction force of 991 pounds in -z direction. [1]
  - Second Step
    - Apply a physiological ramp load of 444.99 pounds in the -z direction and -110.95 pounds in the -x direction.
    - This conforms to the ASTM standard #1875-98 loading parameters for an electrochemical analysis of the fretting corrosion. [2]

[1] J.P. Heiney, S. Battula, G.A. Vrabek, A. Parikh, R. Blice, A.J. Schoenfield, G.O. Njus. "Impact magnitues applied by surgeons and their importance when applying the femoral head onto the Morse taper for total hip arthroplasty." *Arch Orthop Trauma Surg* (2009): 793-796.

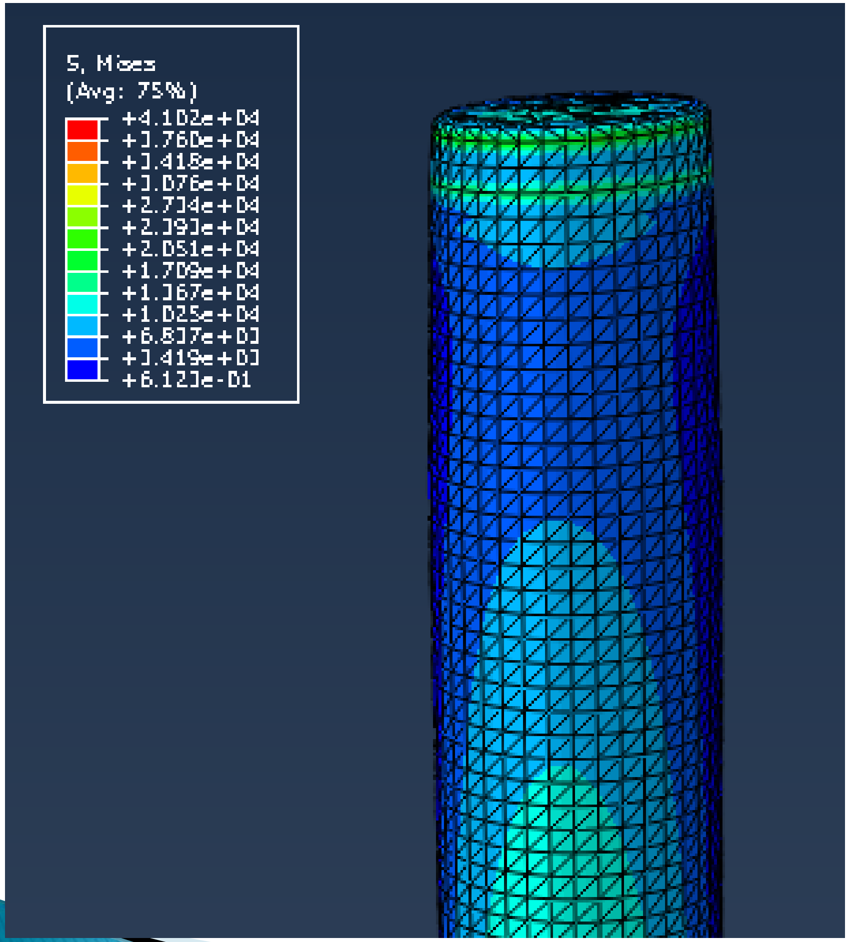
[2] "Standard Practice for Fretting Corrosion Testing of Modular Implant Interfaces: Hip Femoral Head-Bore and Cone Taper Interface." *ASTM International Designation: F1875-98* (2009).

Results

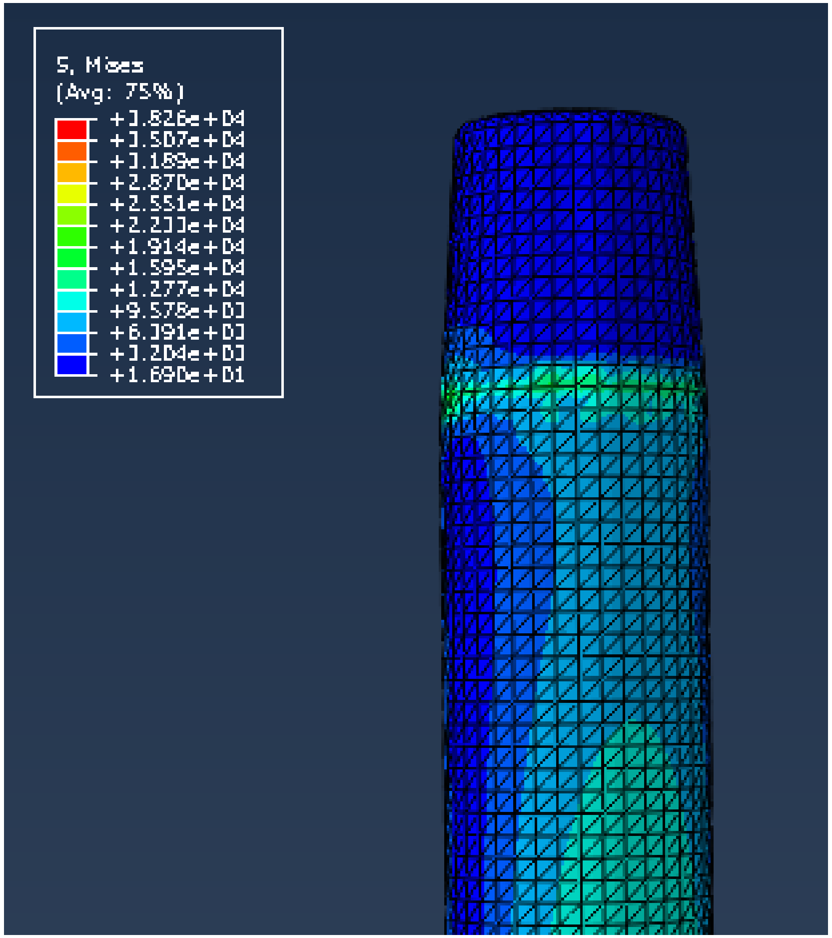

S, Mises
(Avg: 75%)
+4.102e+04
+3.760e+04
+3.418e+04
+3.076e+04
+2.734e+04
+2.393e+04
+2.051e+04
+1.709e+04
+1.367e+04
+1.025e+04
+6.837e+03
+3.419e+03
+6.123e-01

Results

Proximal Contact



Distal Contact



Results

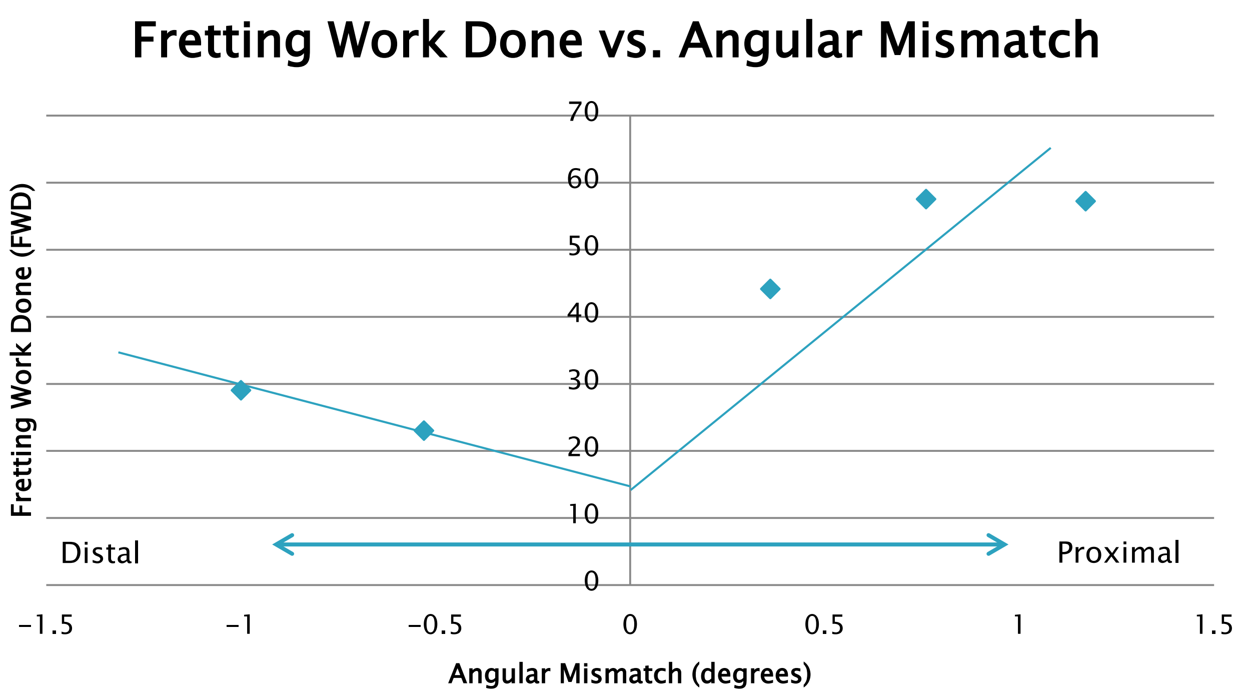
- Fretting work done (FWD) is an arbitrary comparative value assigned to estimate the amount of fretting corrosion. It is directly proportional to estimates of wear depth. [3]
- FWD = friction coefficient * micromotion * max contact stress

- By using both the comparative experimental analysis and the comparative numerical analysis, we had two different approaches that quantitatively compare the amount of fretting corrosion associated with each design configuration.

[3]F.E. Donaldson, J.C. Coburn, K.L. Siegel. "Total hip arthroplasty head-neck contact mechanics: A stochastic investigation of key parameters." *Journal of Biomechanics 47* (2014): 1634-1641.

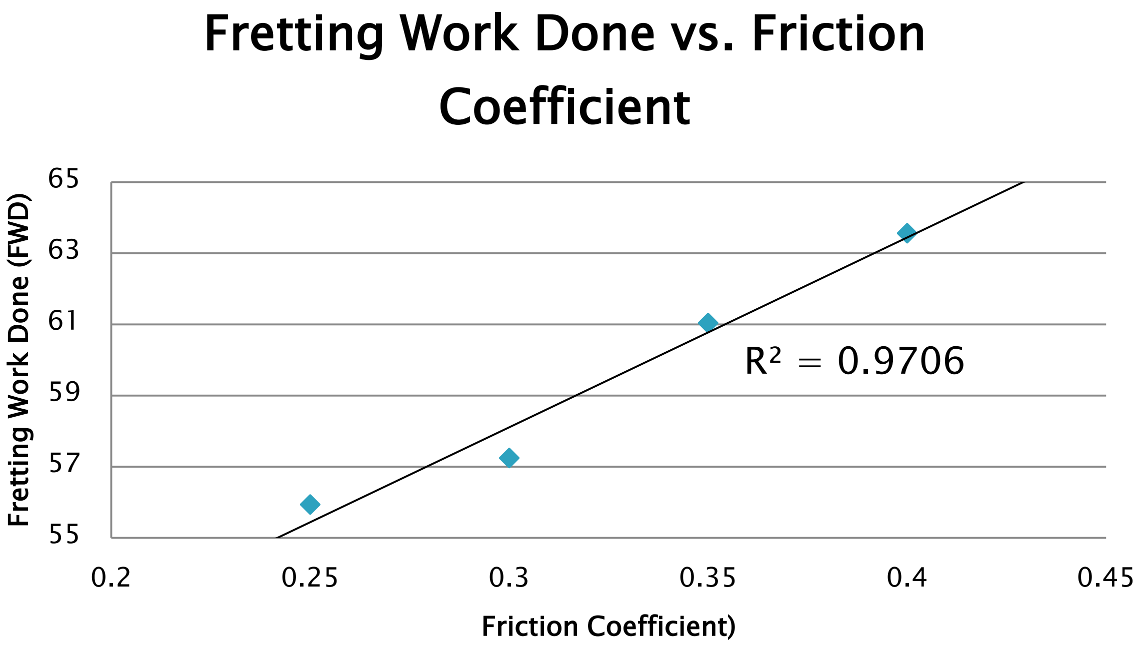
Results

- Angular Mismatch
  - Fretting work done (FWD) as a function of angular mismatch



Results

- Roughness
  - Fretting work done (FWD) as a function of roughness



Discussion

- Smaller angular mismatch values resulted in less FWD
- Distal contact resulted in less FWD compared to proximal contact

Discussion

- Changes in friction coefficient resulted in a linear relationship with FWD

Discussion

- Future research
  - Results for entire trunnion surface
  - Optimal angular mismatch value
  - Further research on the correlation between roughness and friction coefficient
  - More robust modeling

Acknowledgements

- Dr. Tim Norman Ph.D. (Academic Advisor)
- Dr. Thomas K. Fehring Ph.D. (Clinical Advisor)
- 2012-13 Cedarville Biomedical Engineering Design Team