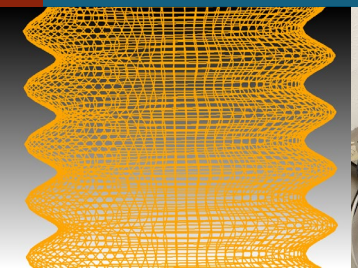
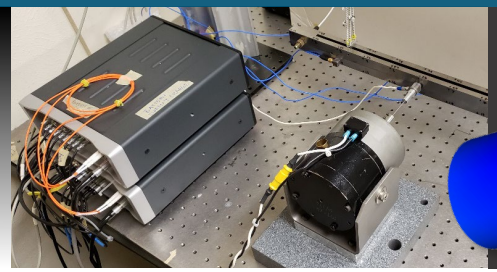
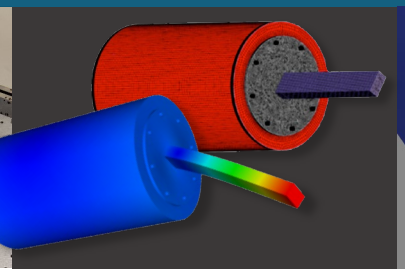
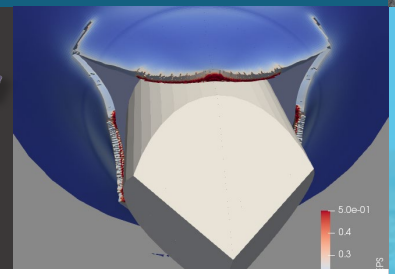
Layered Plate Damping









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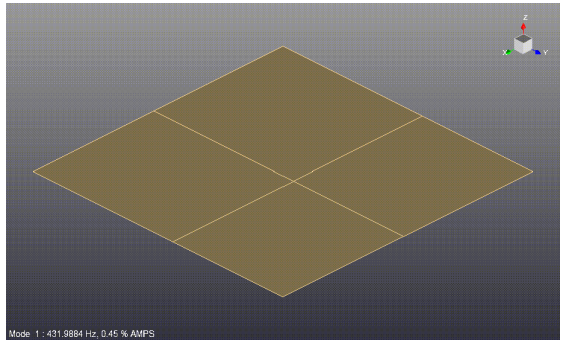
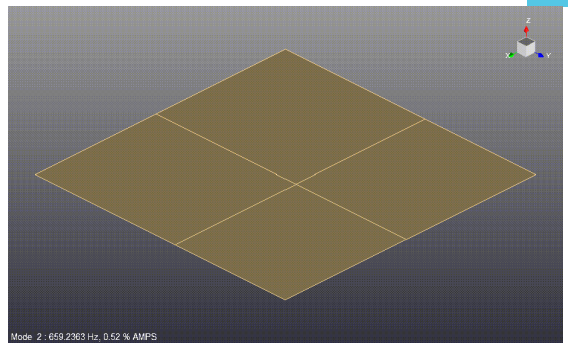
Introduction

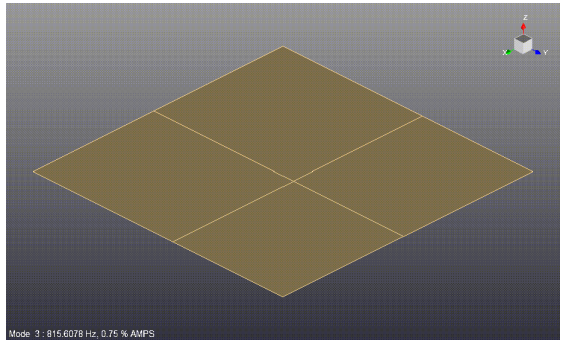
Objective: Determine the critical factors and their effects on the modal response of bolted layered plates

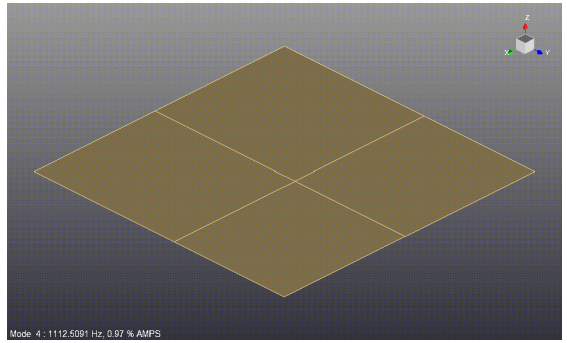
Motivation: Understanding the dynamic response of bolted plate systems

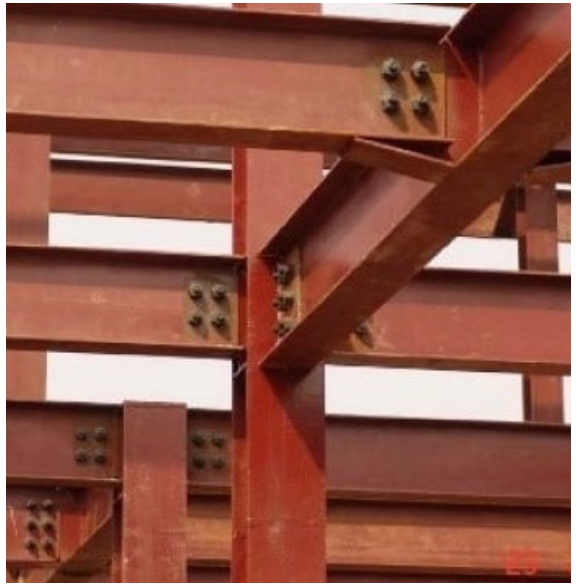
Method: Experimental modal analysis using a full factorial experimental design paired with finite element comparison





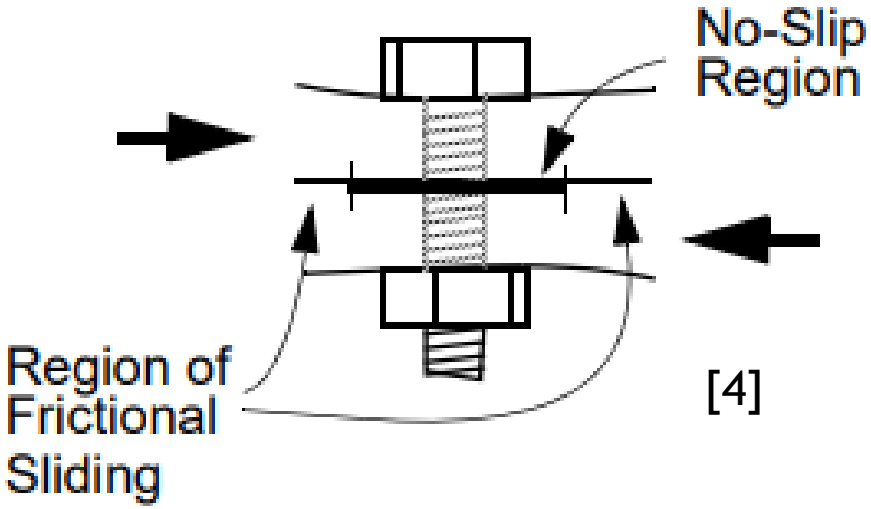






Critical Factors

- Damping is dominated by microslip - the localized slip between two bolted plates [1]
  - Upon excitation, the plate areas closest to the bolt will not slip while areas further away will slip
  - The interface can also separate given the direction of excitation
  - Described by dry Coulomb friction

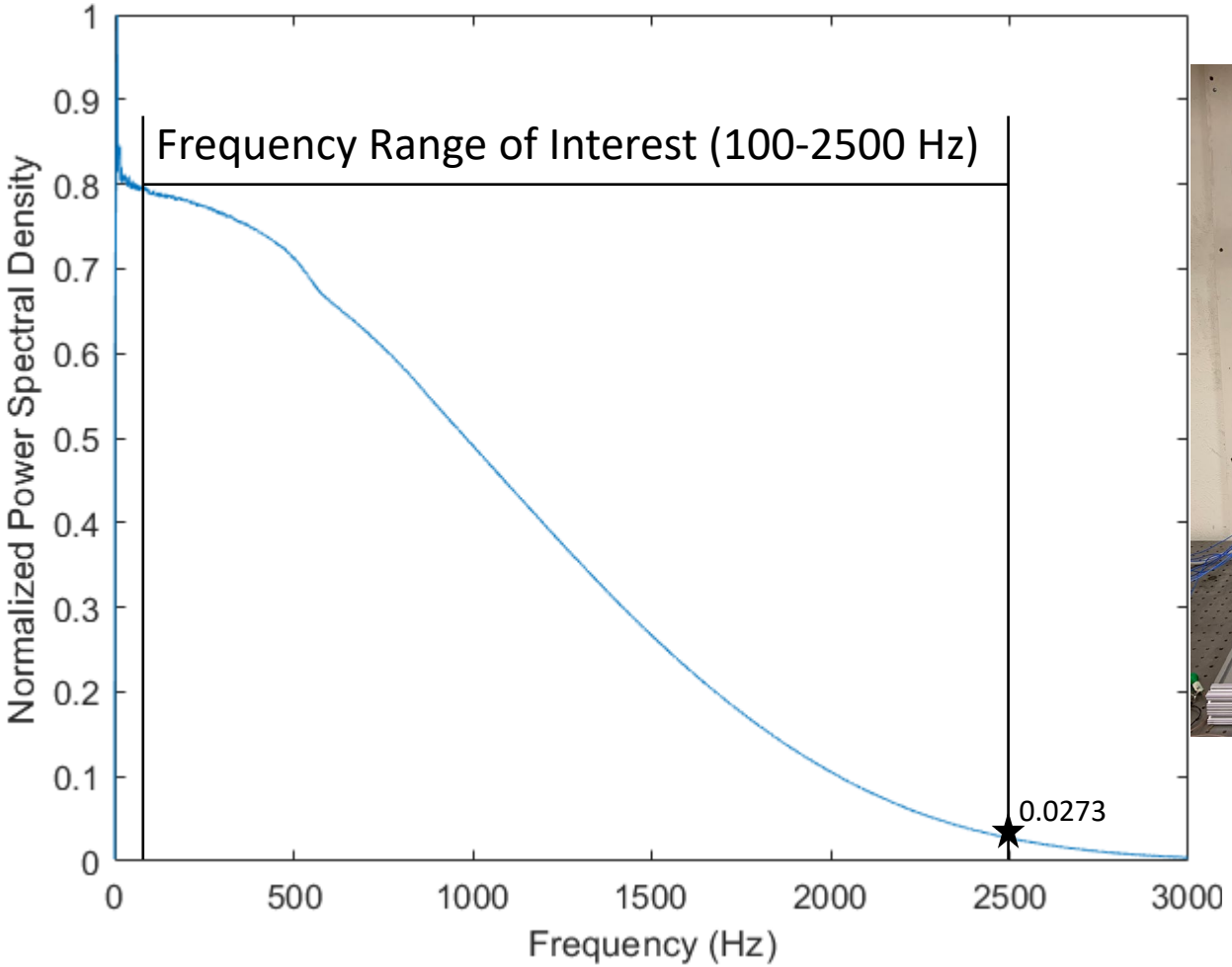


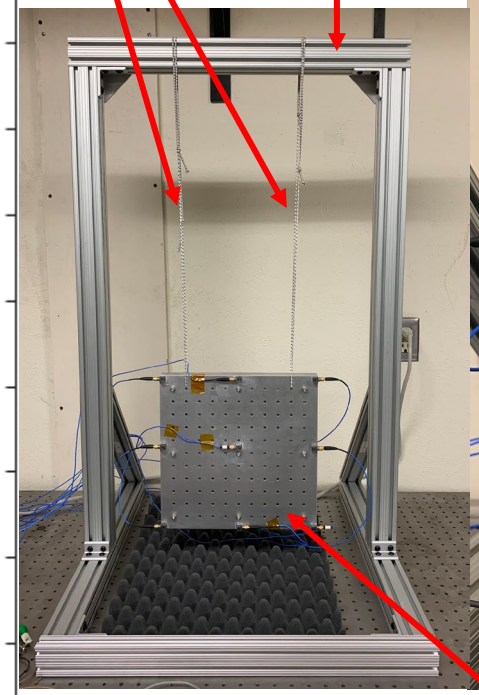
[4]

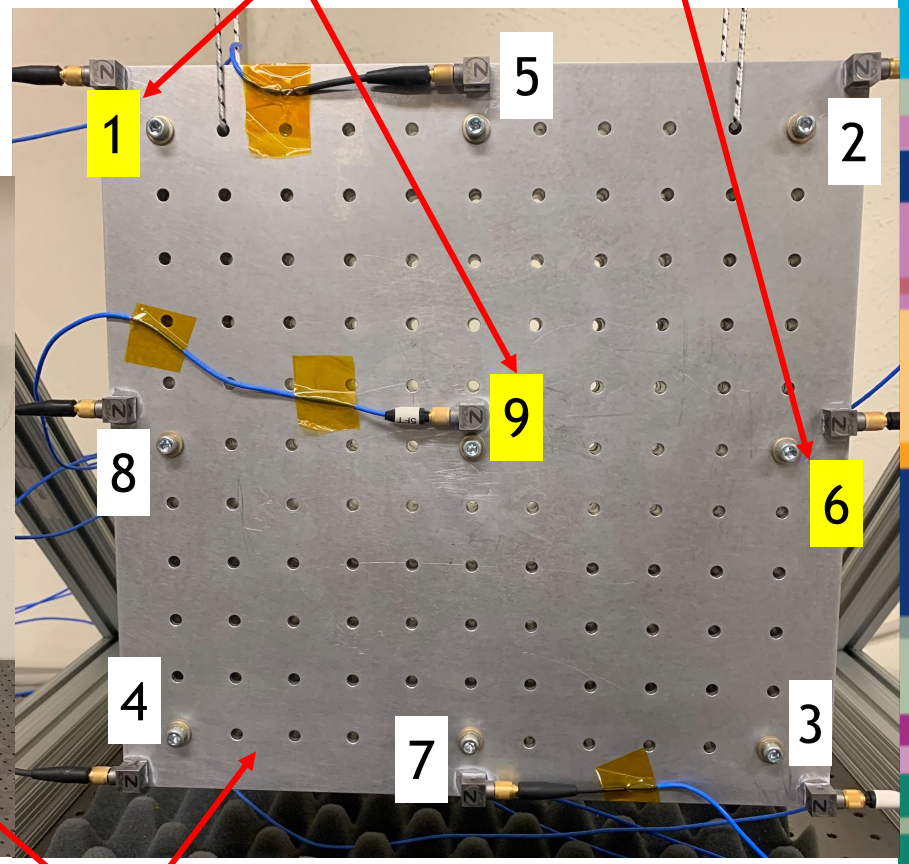
Factorial Design	Low Level	High Level	Expected Relationship with Frequency	Expected Relationship with Damping
Bolt Preload (in-lb)	25	50	Direct [2]	Inverse [2]
Bolt Spacing (in)	2	7.1	Unknown	Direct [3]
Total Thickness (in)	0.75	1.0	Direct	None
Number of Interfaces	1	2	Unknown	Direct
Impact Amplitude (lbf)	20-30	60-70	Unknown	Direct [4]

Experimental Test Set-up

- Accelerometer placement based on mode shapes of interest
- Free boundary conditions supported by bungee cords
- White plastic impact tip (084B04 PCB) inputs content in frequency range of interest







Experimental Metrics and Evaluation

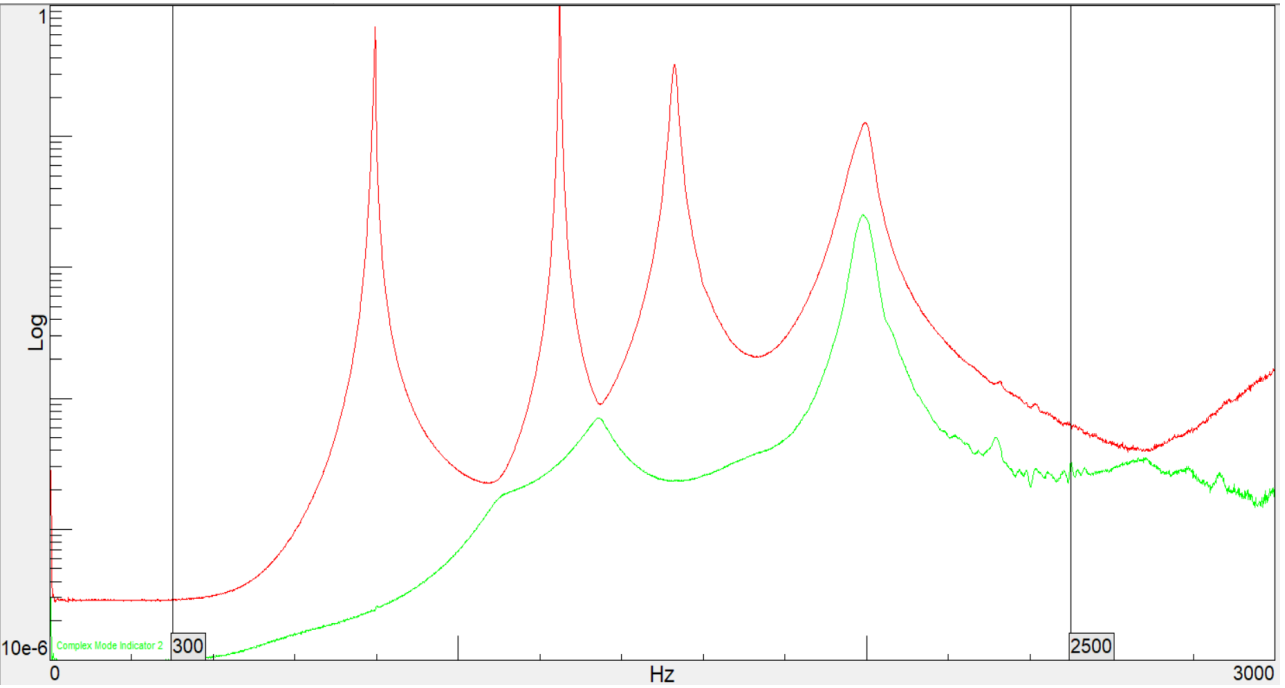
Siemens LMS

- Data acquisition and processing
- Extract natural frequencies, mode shapes, and modal damping by curve fitting

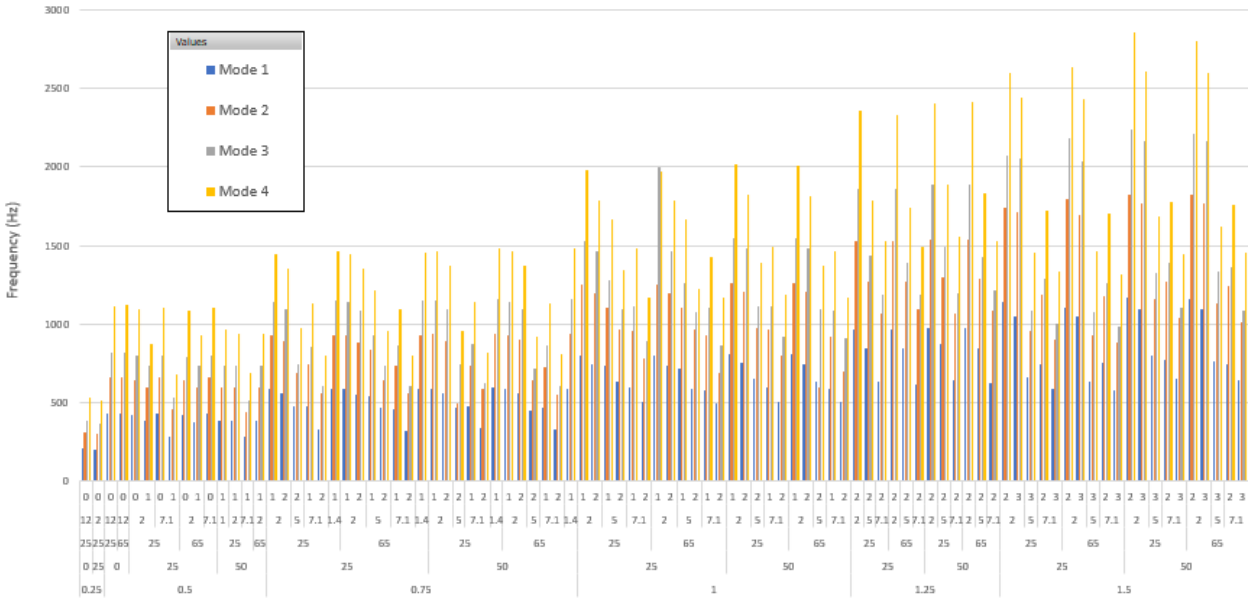
Excel and Minitab

- Data organization and visualization
- Determine factor importance and effects

Averaged FRF
(Configuration 5, Bolt Pattern 3, 25 in-lb Bolt Preload, Low Impact Amplitude)

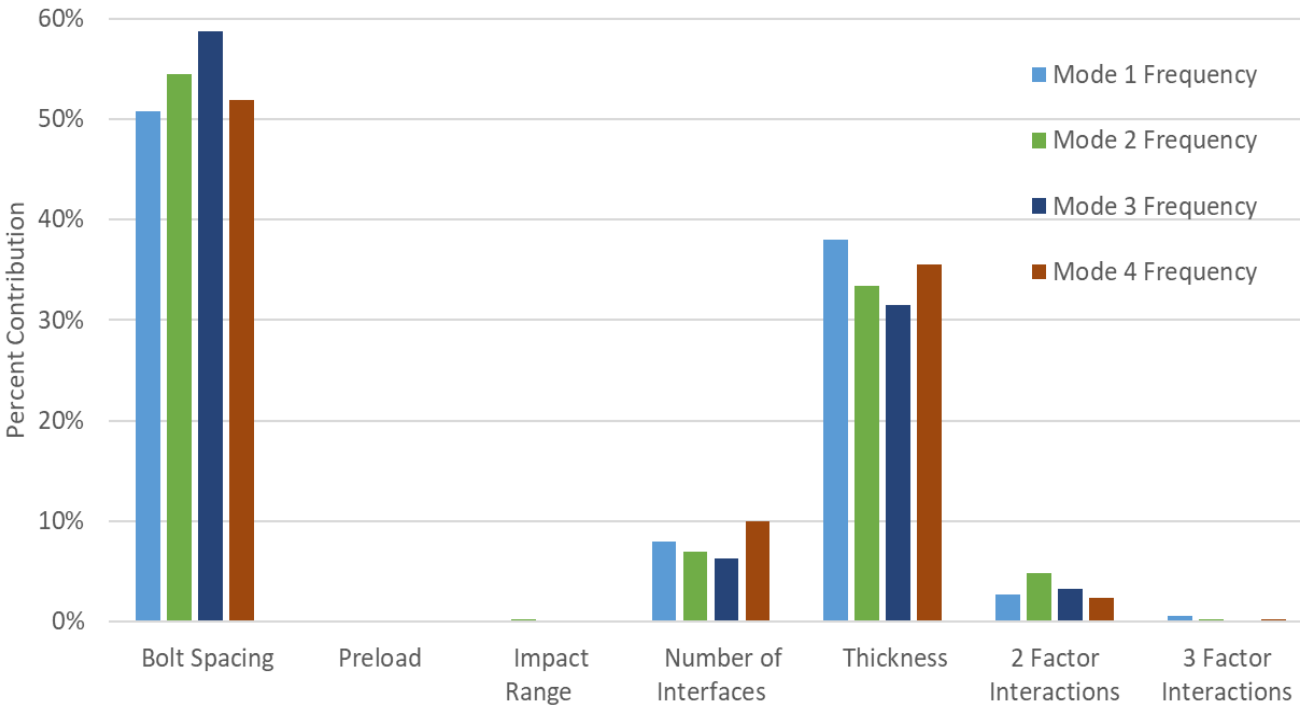


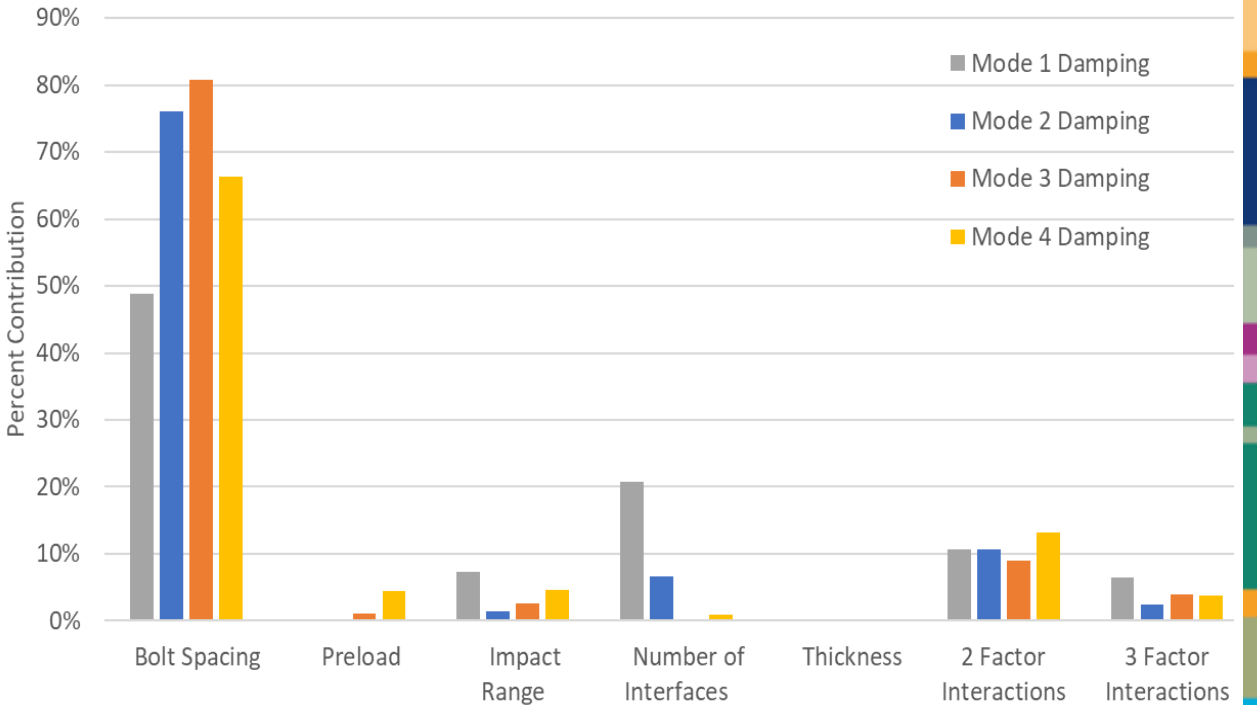
Natural Frequencies over all tests plotted in a PivotChart in Excel



Factor Importance

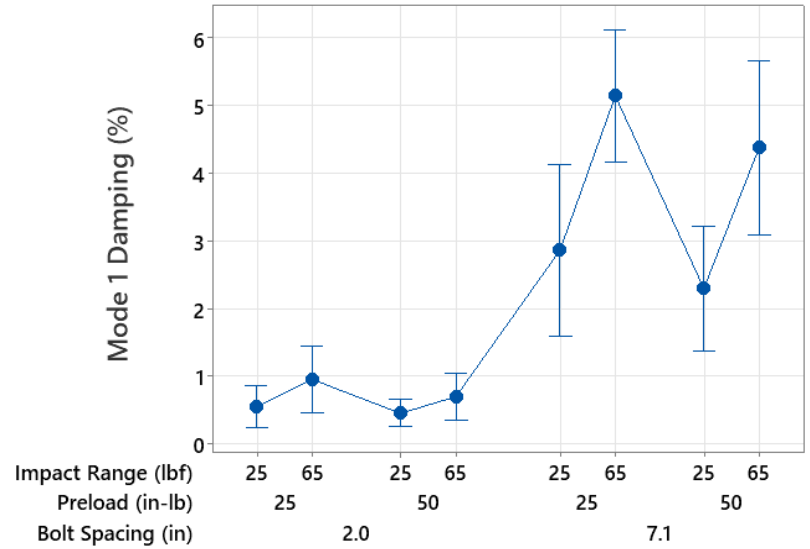
- Bolt spacing provides largest contribution to both damping and natural frequency
- Preload and impact amplitude has little effect on the natural frequency
- Thickness has little effect on damping
- Factor interactions much higher for damping than for natural frequency

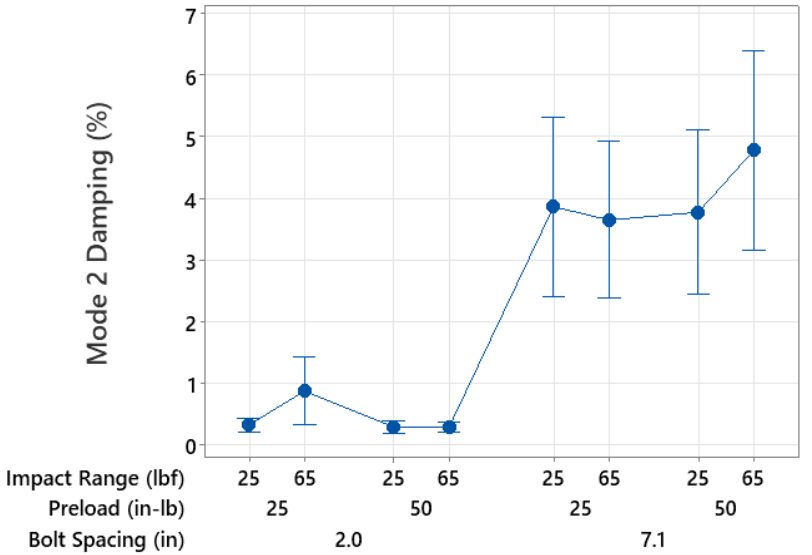


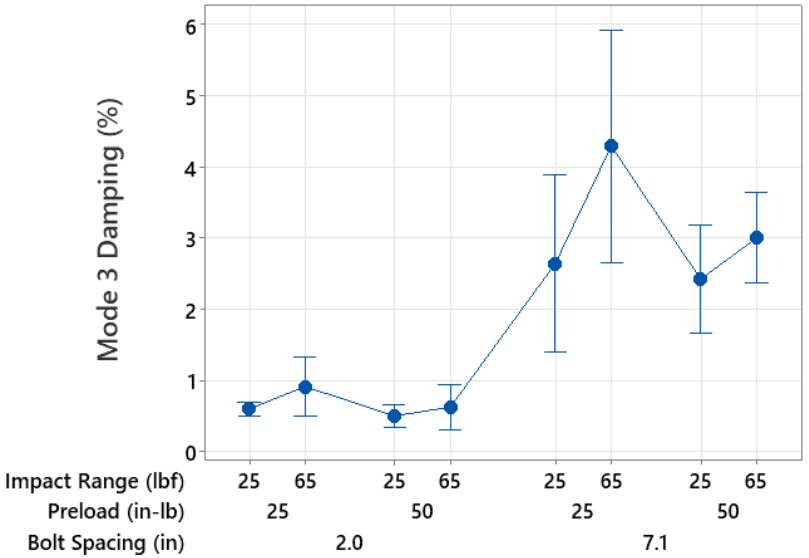


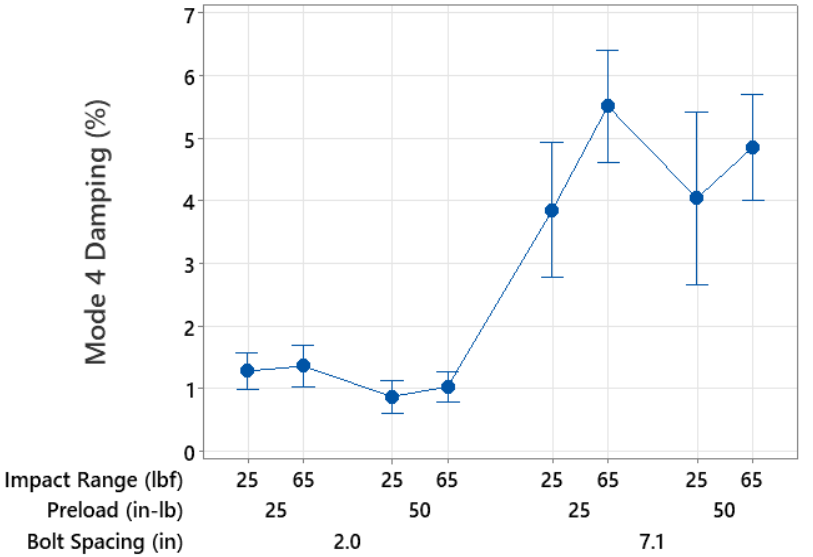
Effects on Damping

- As bolt spacing increases, damping and variability in damping increases
- Factor interactions play significant role in damping



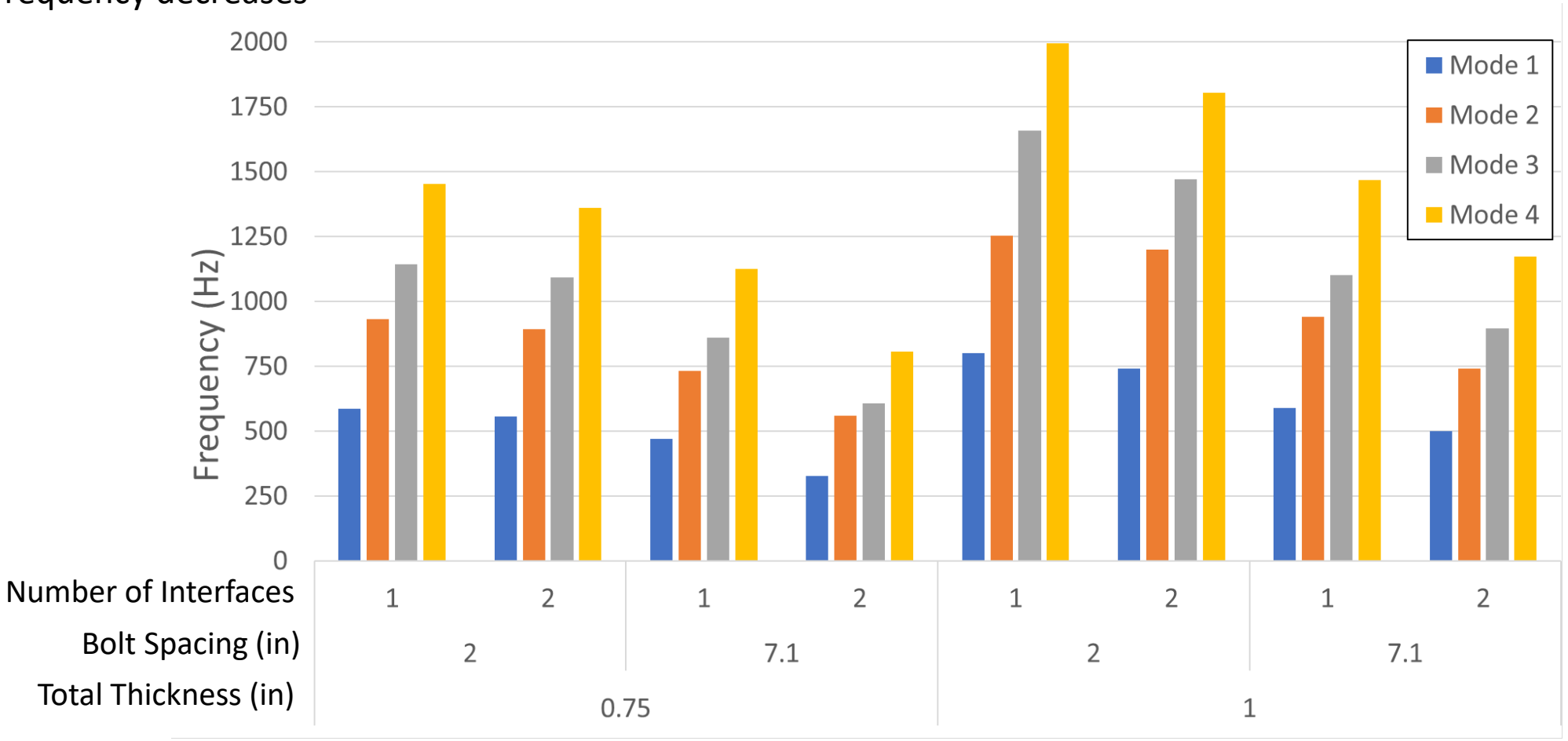






Effects on Frequency

- As number of bolts increases, natural frequency increases
- As number of interfaces increases, natural frequency decreases



Summary

- Bolt spacing is the most important factor in predicting both natural frequency and damping
- Factor interactions affect modal damping much more than it does the natural frequency

Questions?

References

[1] W. Chen, X. Deng, Structural damping caused by micro-slip along frictional interfaces, International Journal of Mechanical Sciences, Volume 47, Issue 8, 2005, Pages 1191-1211, ISSN 0020-7403, https://doi.org/10.1016/j.ijmecsci.2005.04.005.

[2] Saito, A., and Suzuki, H. (October 16, 2019). "Dynamic Characteristics of Plastic Plates With Bolted Joints." ASME. *J. Vib. Acoust*. February 2020; 142(1): 011002. https://doi.org/10.1115/1.4044865

[3] Ungar, Eric E., “Energy dissipation at structural joints; mechanisms and magnitudes”, Technical Documentary Report No. FDL-TDR-64-98, Air Force Flight Dynamics Laboratory, Wright-Patterson Air Force Base, Ohio, 1964.

[4] SEGALMAN, DANIEL J. *An Initial Overview of Iwan Modeling for Mechanical Joints*. United States: N. p., 2001. Web. doi:10.2172/780307.