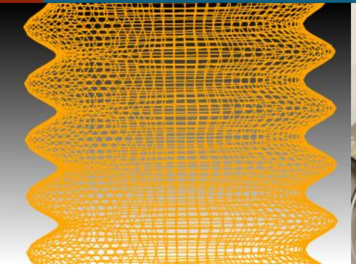
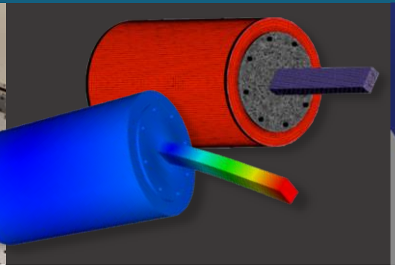
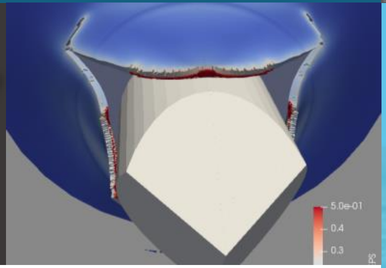
Electrical Chatter and Modal Response of Pin-Receptacle Contacts







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Background and Motivation

- Chatter refers to an abrupt increase in electrical resistance across a contact when subjected to shock or vibrations.
  - Can be detrimental to signal transmission if frequent enough, or long enough duration.
  - The purpose of this project is to understand what causes chatter, and when it occurs.

- Previous NOMAD projects have focused on chatter before, but further research still needs to be conducted.
  - Originally, the end goal of the project was to characterize chatter in oil, but the project pivoted to focus on gaining a better understanding of the system in air.

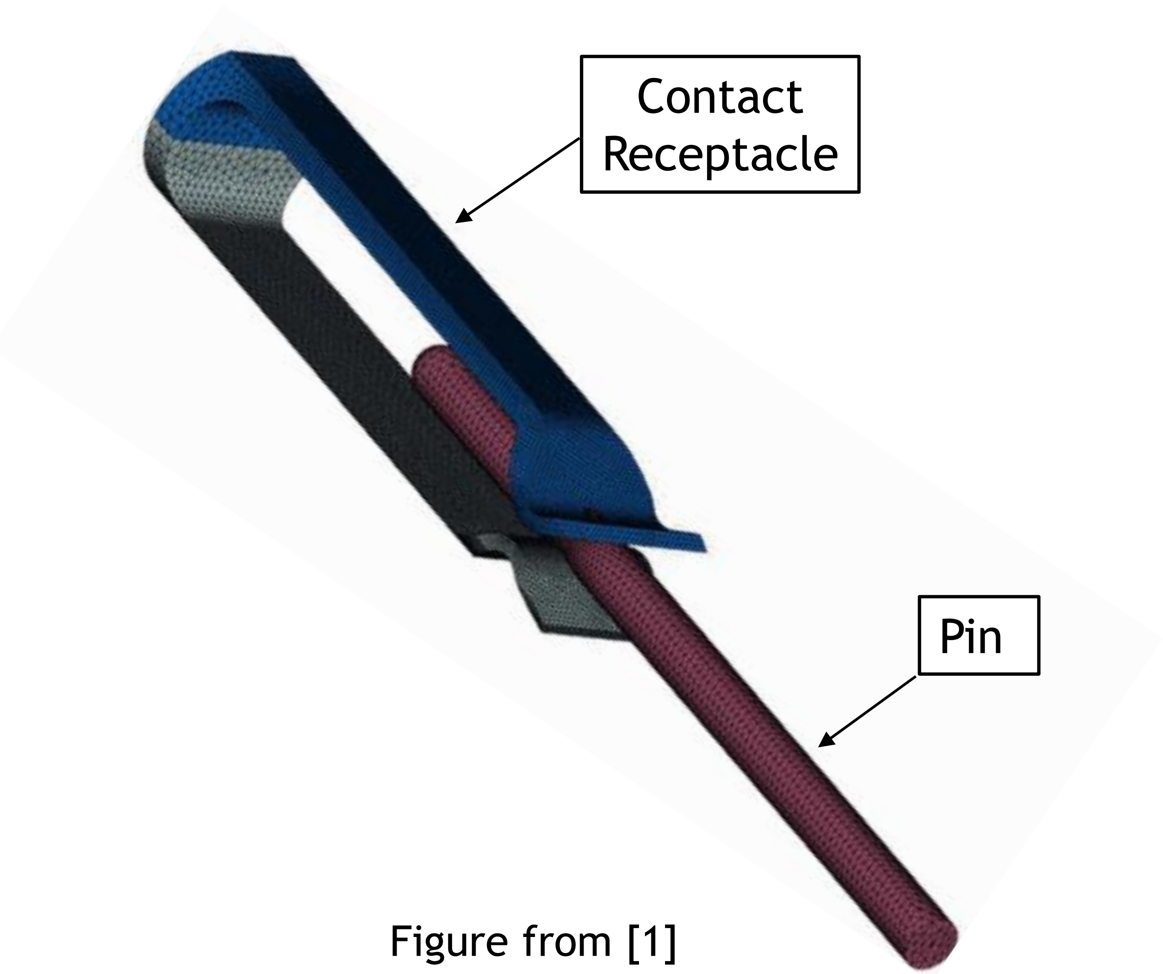
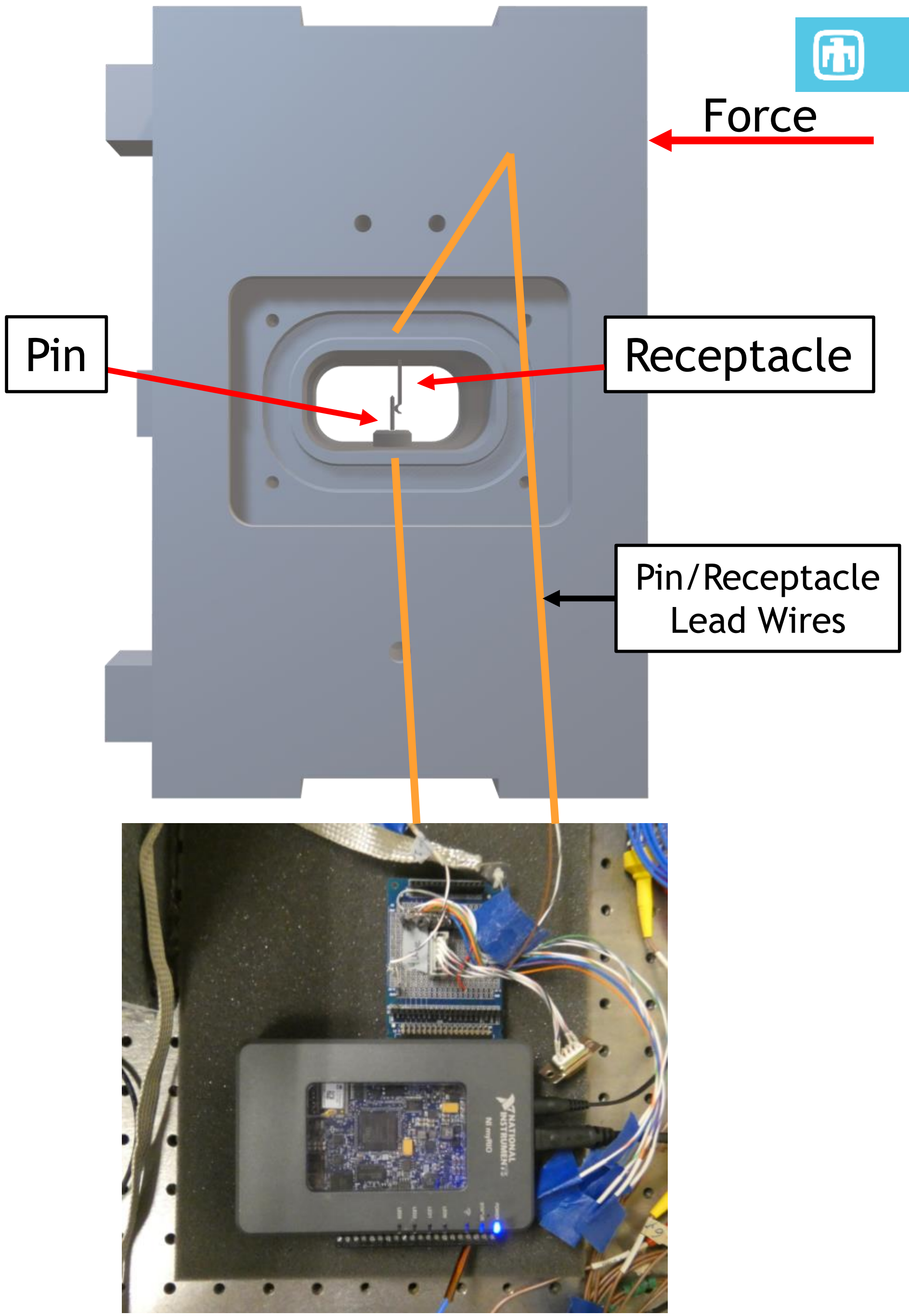


Figure from [1]

Pin and Receptacle Fixture

- Fixture designed to enable more rigorous characterization of chatter.
- Pin and receptacle housings are locked into the fixture via retaining rings.
- Windows allow for non-contacting measurements of the pin and receptacle.

- National Instruments myRIO used to detect chatter in the pin/receptacle.
  - 120 Ohm resistance threshold for chatter detection.
  - 40 MHz sampling rate to detect short-duration events.

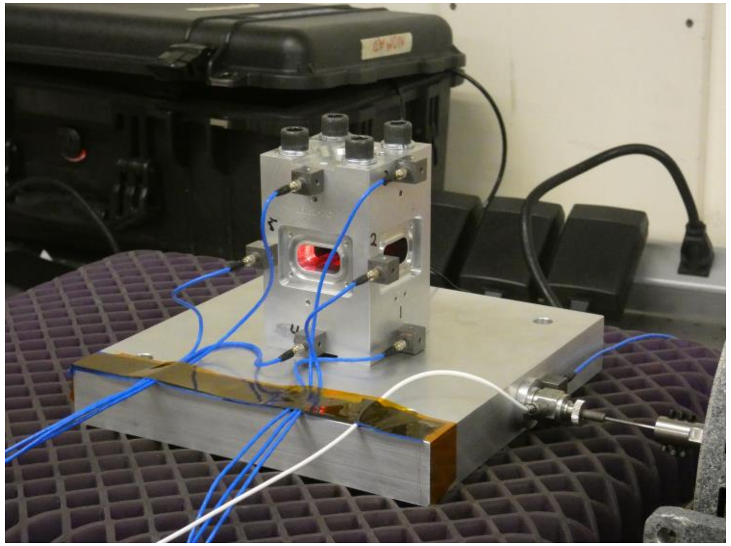


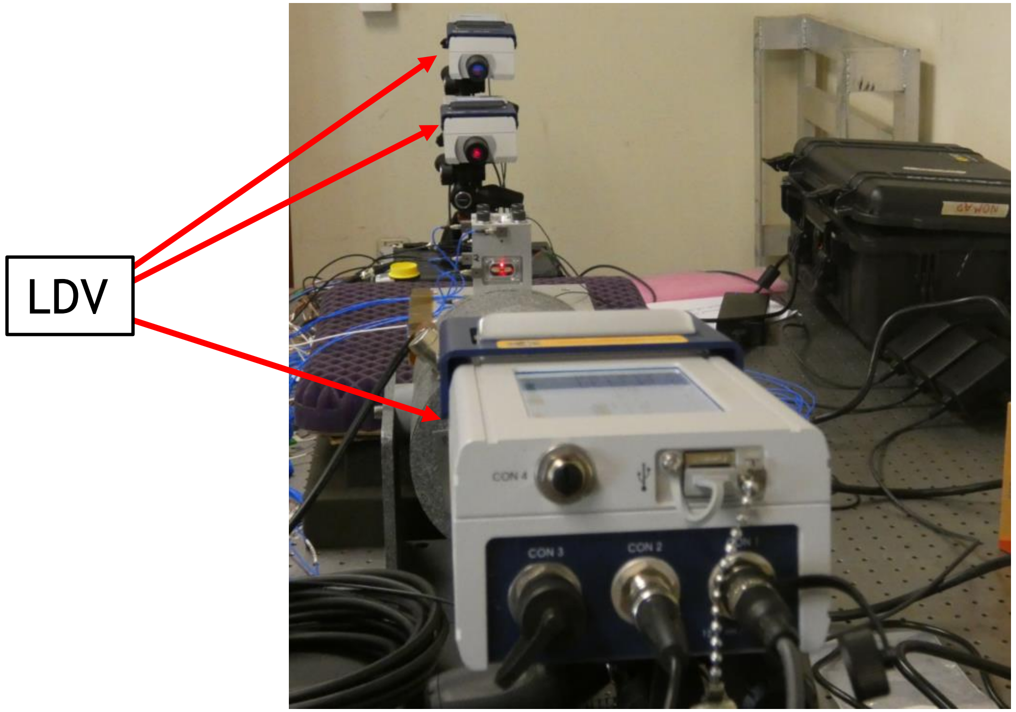
Initial Setup

- Fixture bolted to a large base plate.
  - Excitation applied to base plate via a 25 lbf modal shaker.
  - Base plate supported by a gel base to mimic a slip table.

- Six accelerometers mounted to fixture to estimate boundary conditions for pin and receptacle.
  - The fixture has its own modes that may affect the amplitude and phase at the base of the pin and receptacle.

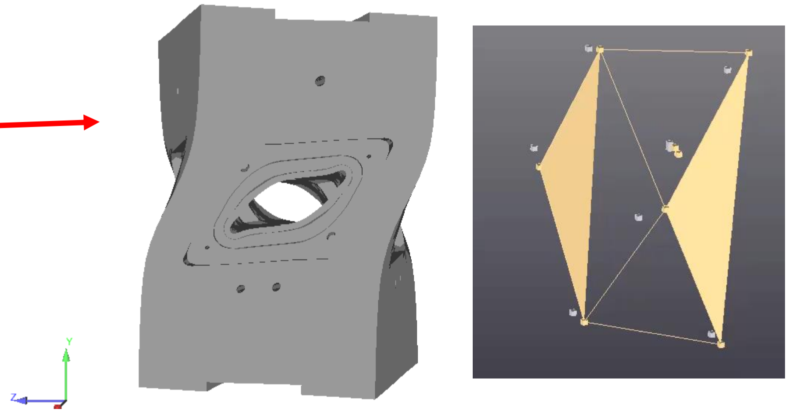
- Three laser doppler vibrometers (LDVs) for non-contacting measurement pin and receptacle velocities.
  - Lasers positioned on both sides of the fixture.

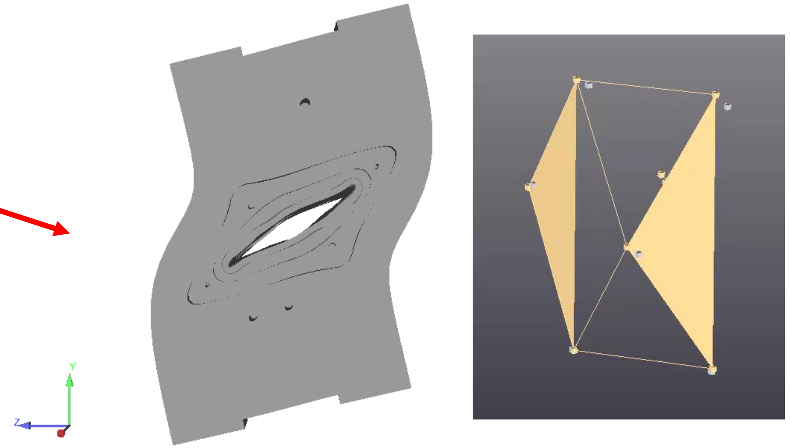




Fixture Modes

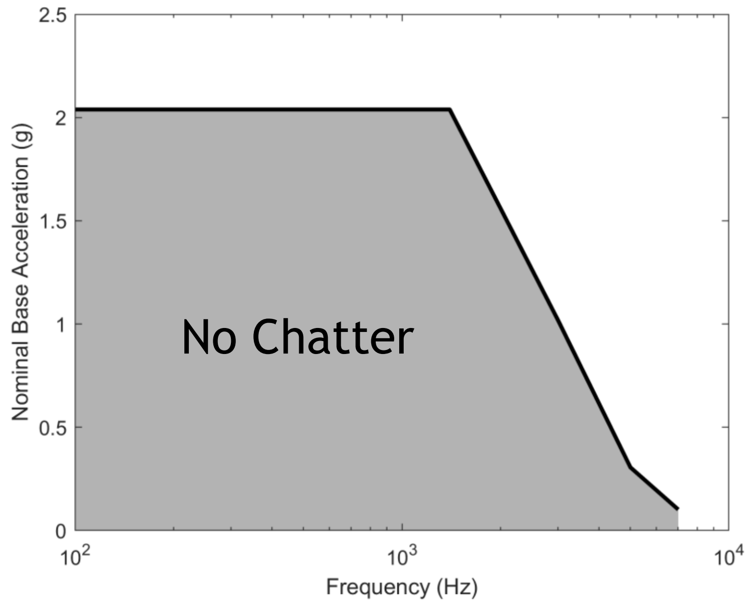
- Using Cubit, Sierra, and Ensight a few modes of the fixture were predicted
  - Mode 1: 2434.41 Hz
  - Mode 2: 3570.21 Hz
  - Mode 3: 3581.62 Hz
  - Mode 4: 3966.02 Hz
  - Mode 5: 4012.23 Hz
  - Mode 6: 4179.14 Hz



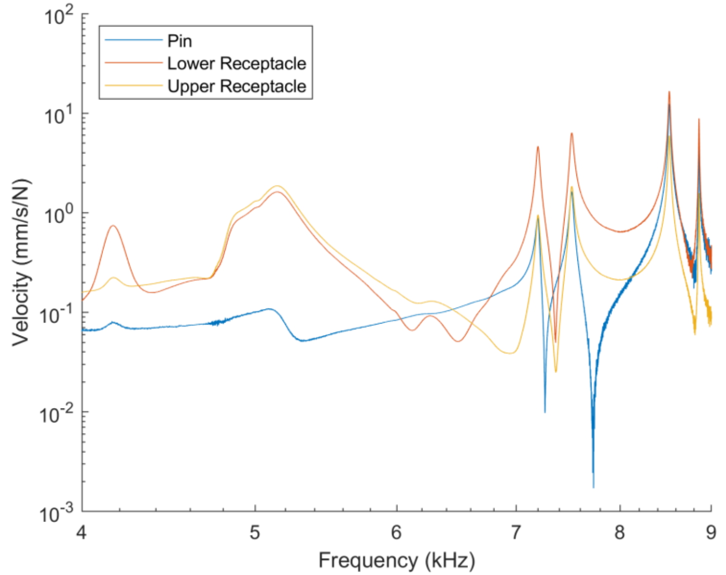


Luke, Brandon, and the Quest for Chatter

- Shaker/amplifier combination only able to achieve full force rating up to about 1400 Hz. Sharp decrease in achievable force after that point.
  - Around 2 g's of base excitation below 1400 Hz.
  - 1 g at 3000 Hz.
  - 0.3 g's at 5000 Hz.



- Likely candidate for first mode of the pin/receptacle pair in the vicinity of 7000 Hz.



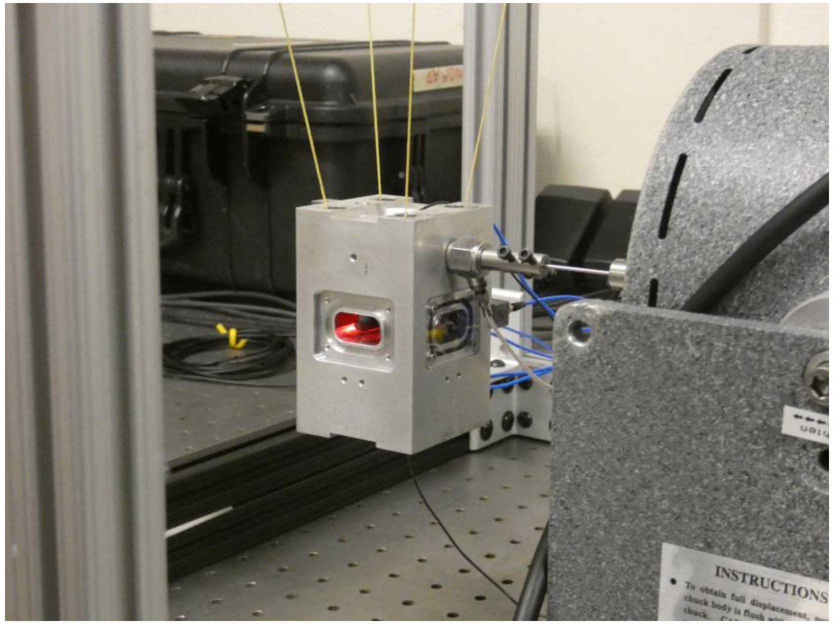
- With this acceleration profile we were not able to achieve chatter.
  - The only way to get more acceleration is to reduce the mass.

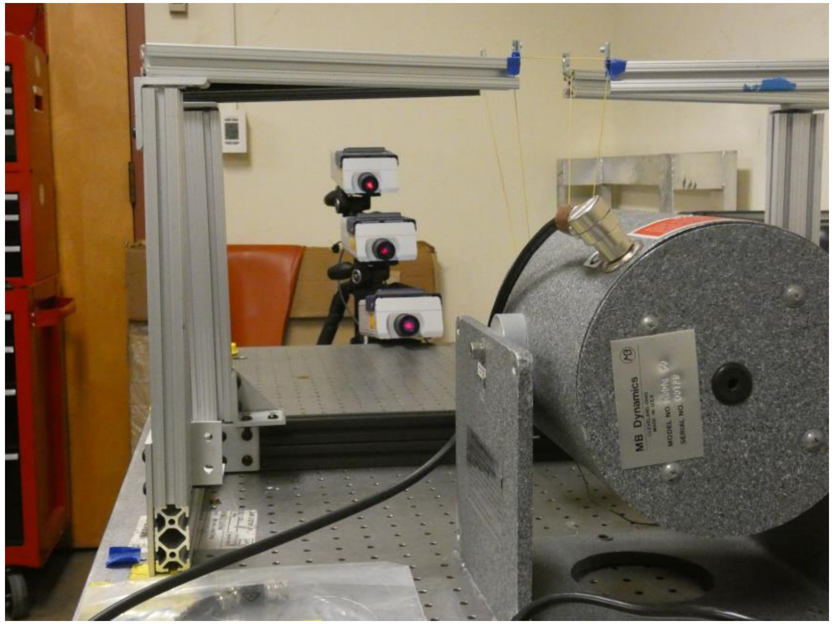
The Final Setup

- Base plate removed to reduce mass and enable larger acceleration at pin and receptacle.

- Final configuration had the fixture suspended from a T-slot frame via Kevlar strings.
  - Excitation applied at the top of the fixture results in pendulum motion.
    - Different acceleration at pin and receptacle.
  - Excitation applied through the center of mass results in translational motion.
    - Same acceleration at pin and receptacle.

- Necessitated moving all three LDVs to the same side.
  - Some error likely introduced due to proximity of beams.

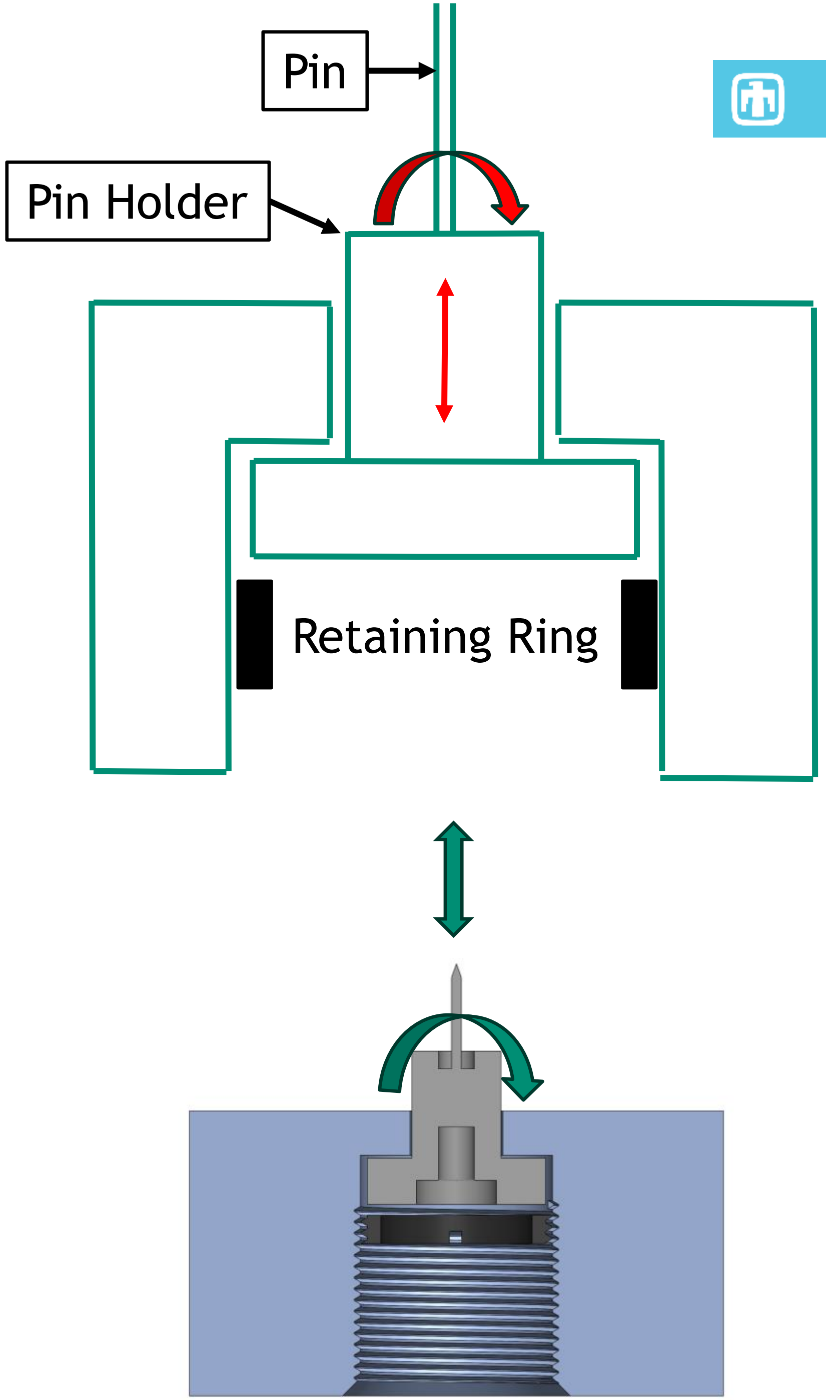




A Change to Induce Chatter

- Ultimately, we were unable to induce chatter with rigid boundary conditions for both the pin and receptacle.

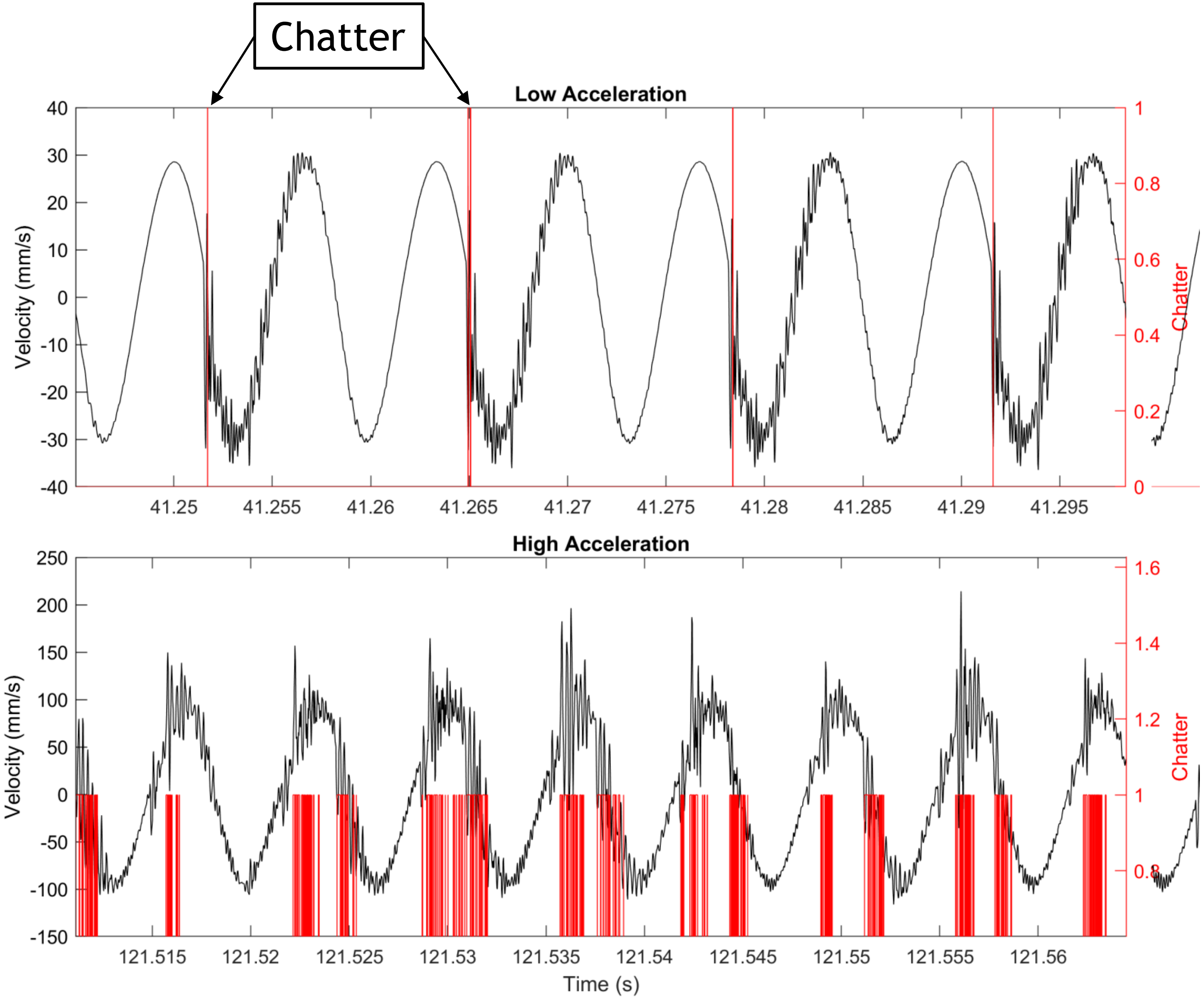
- Chatter is achievable if the pin holder is left uncompressed.
  - Pin essentially floating inside the fixture. Able to move vertically and rotate slightly. Limited by the geometry of the fixture.
  - The boundary conditions are worse posed, but this is a compromise for achieving chatter with a smaller shaker.



Experimental Results – LDV Measurements of Chatter

- At low excitation levels chatter occurs reliably and periodically.
  - Separation and impact results in sudden changes in velocity. Easily detectable with the LDVs.
  - Every other cycle at 150 Hz.
  - Ringing after every chatter event.

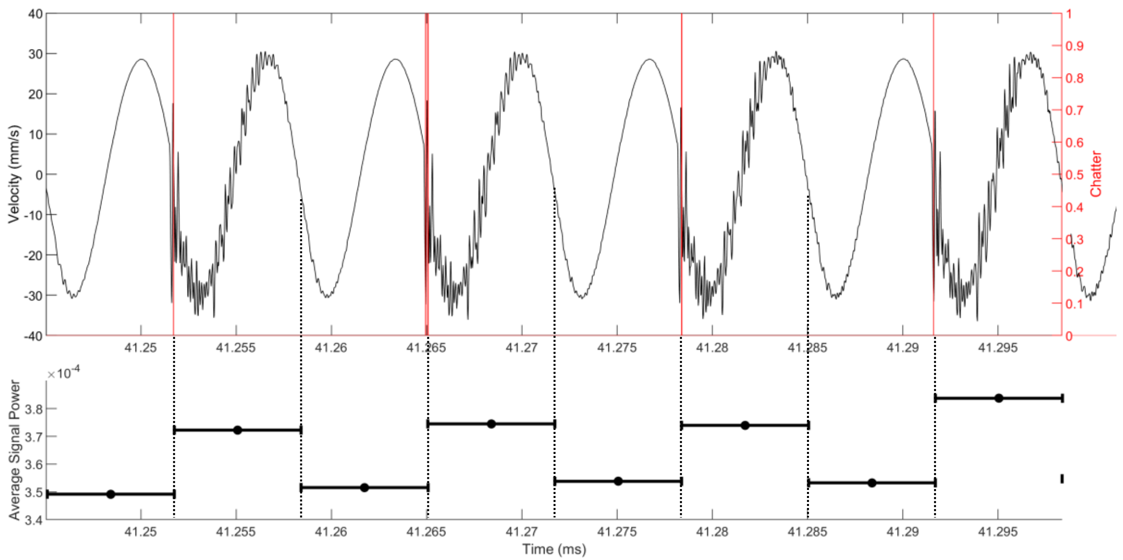
- At higher excitation levels chatter exhibits chaotic behavior.
  - Duration and positioning in the waveform essentially random



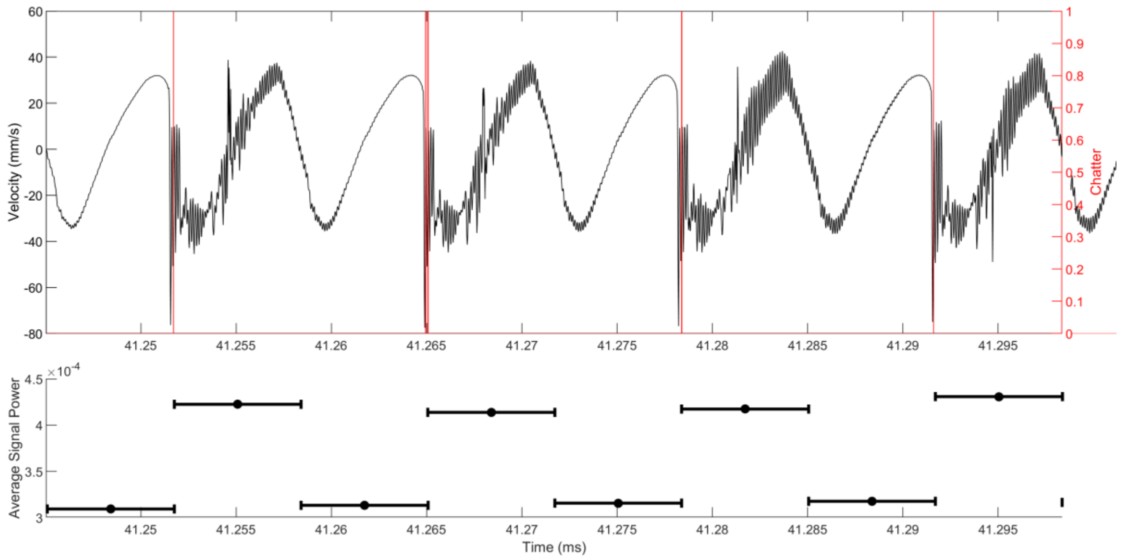
Experimental Result – Energy Transfer During Chatter

- Average signal power increases in both the pin and receptacle in the cycle following a chatter event. Two possibilities
  - Potential energy in the pin/receptacle contact released as kinetic energy.
  - Impact between the pin holder and the fixture.
    - Seems unlikely because that should happen every cycle.

Receptacle Response

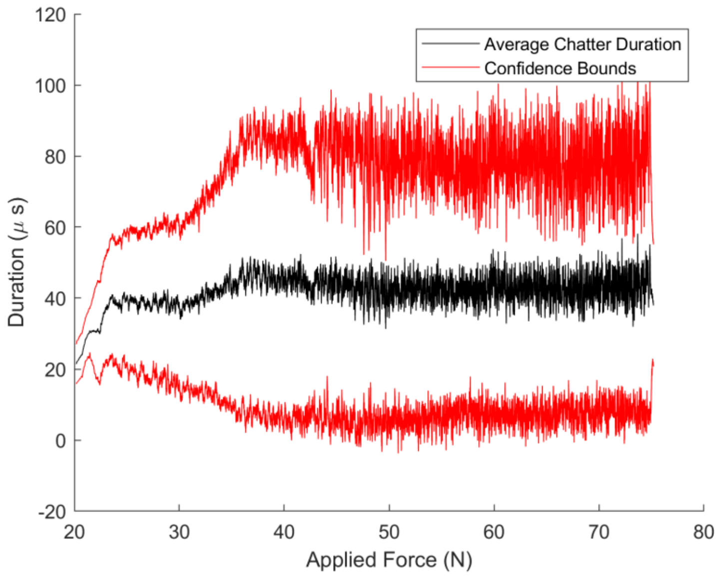


Pin Response



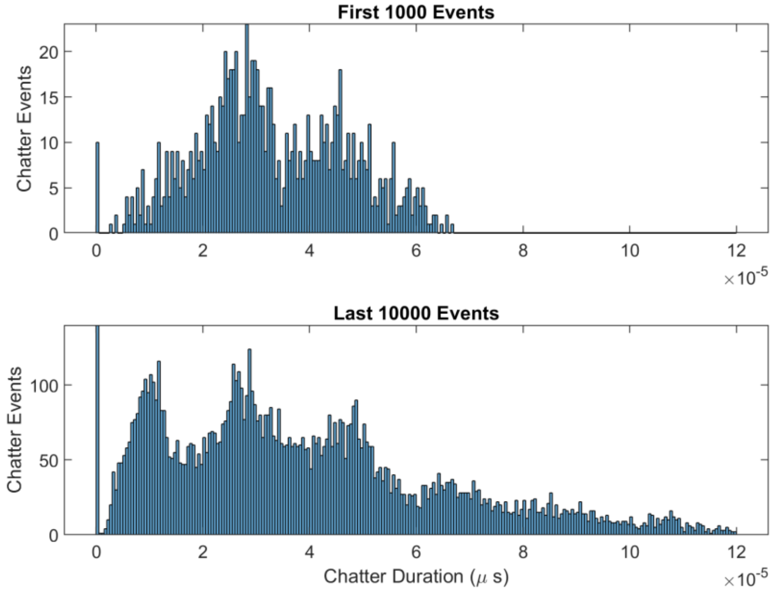
Experimental Results – Statistical View

- Chatter events are initially short duration.
  - Average chatter duration initially shows a rapidly increases with force.
  - Duration decouples from applied force at approximately 40 N in this test.

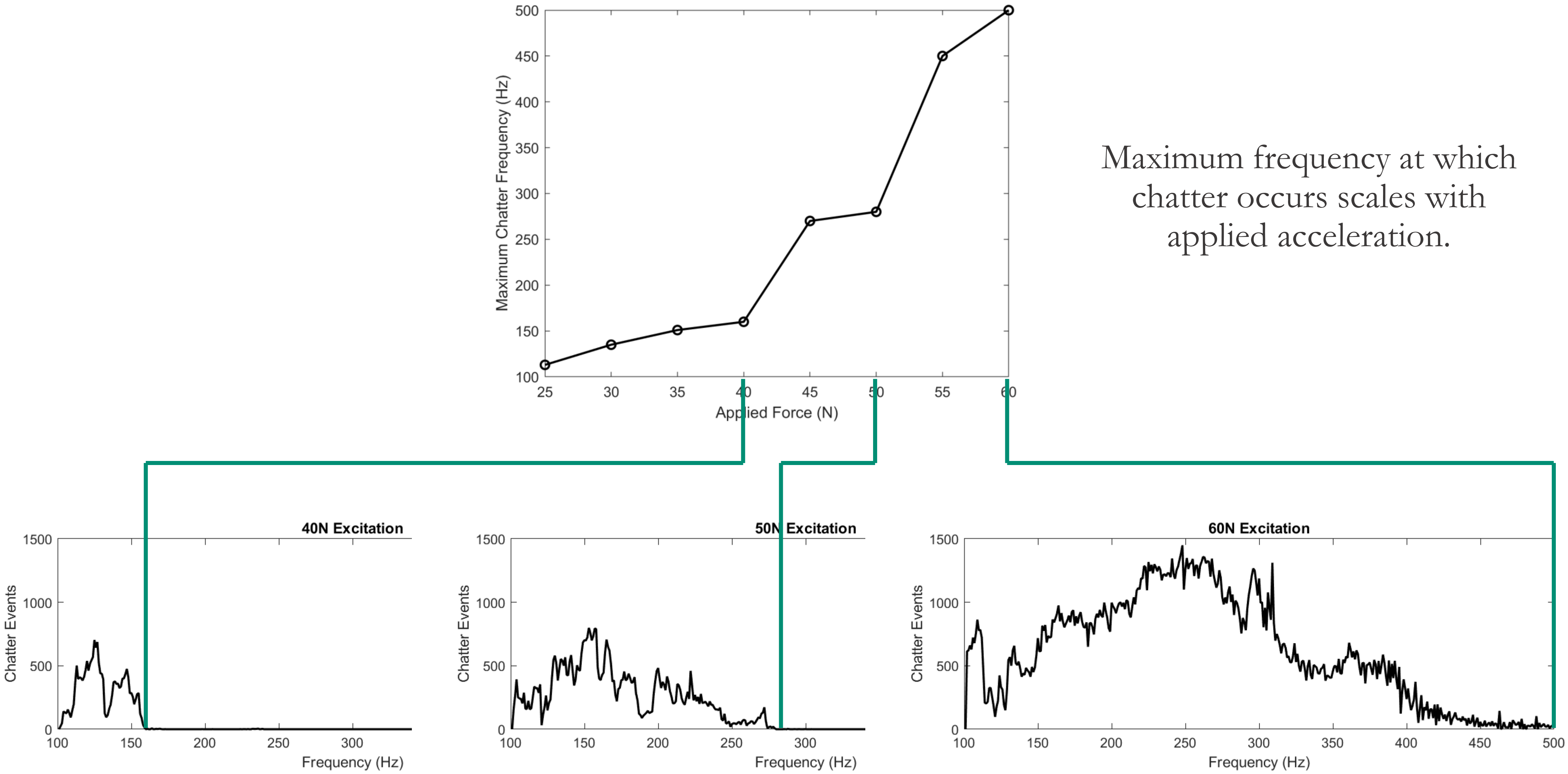


- At low force levels chatter durations appear to be normally distributed.

- At higher force levels distribution appears bimodal or log-normal.



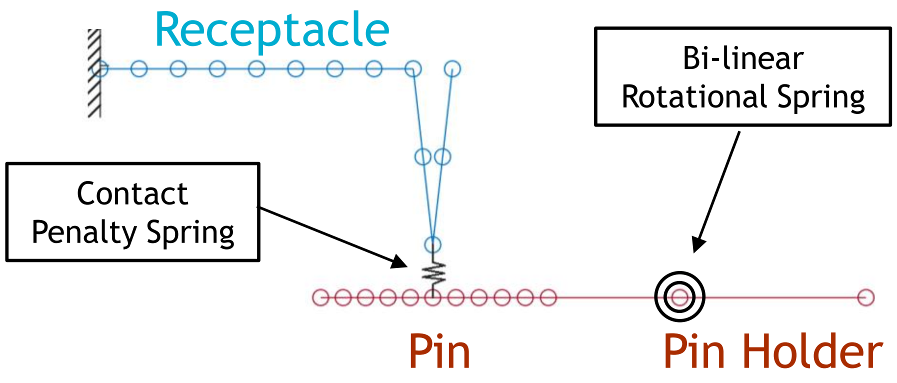
Experimental Results – Maximum Chatter Frequency



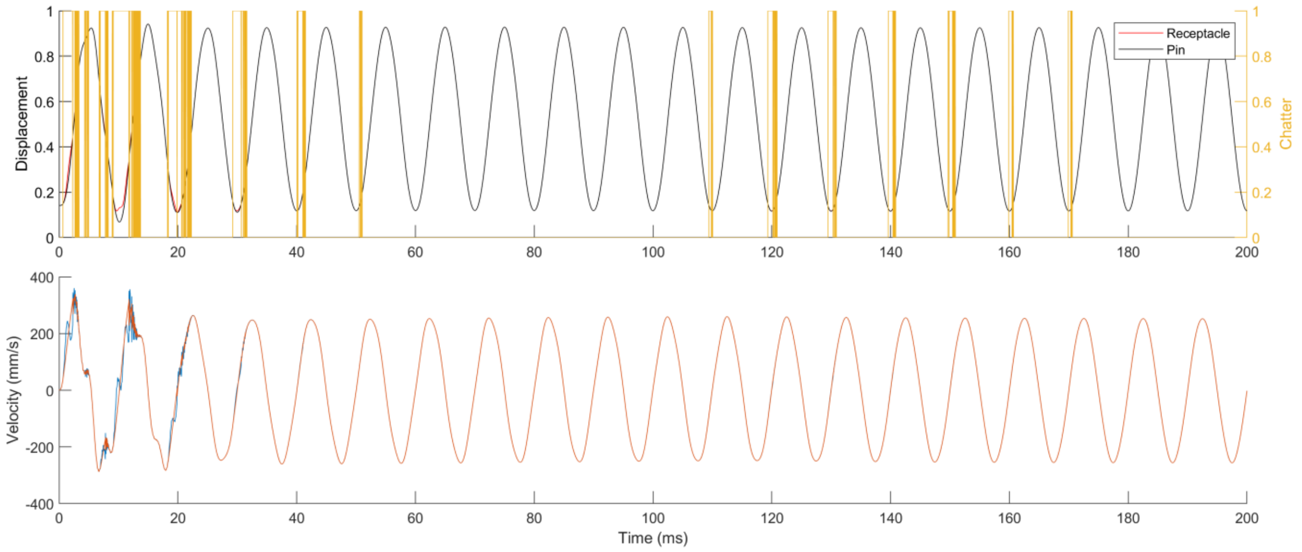
Maximum frequency at which chatter occurs scales with applied acceleration.

Modeling (In Progress)

- Simplified model has the receptacle clamped and the pin positioned on a rotational spring support.
  - Bi-linear penalty spring between receptacle and pin at contact point.
    - Activates when receptacle and pin overlap. Zero otherwise.
  - Bi-linear rotational spring at the pin base.
    - Allows free rotation within a range.
- This model better predicts the part of the cycle in which chatter occurs
  - Still misses chatter duration and ringing in the velocity waveform.



Modelled Pin/Receptacle Displacement and Velocity



Conclusions & Future Work

- Excite and understand chatter more in depth in air.
  - Use a larger shaker to induce chatter in a fully tightened assembly.
  - May also be able detect smaller-scale chatter events by reducing resistance threshold in chatter detector.
  - Characterize chatter across a wide band of frequencies.

- Test the fixture while filled with oil
  - Understand how oil affects response of system.
  - Oil likely to increase the damping of the system, but also introduces hydrostatic load on pin/receptacle.

- Further develop models to predict system behavior and chatter

Acknowledgements

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References

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[2] B Johnson, C. Schumann and F. Rafeedi, "Final Presentation: Investigation of Electrical Contact Chatter in Pin-Receptacle Contacts," Sandia National Laboratories, Albuquerque, NM, USA, 2019.

[3] B. Dankesreiter, M. Serrano, J. Zhang, B. R. Pacini, K. Walczak, R. Flicek, J. Kelsey and B. Zastrow, "Investigating the Potential of Electrical Connection Chatter Induced by Structural Dynamics," in 40th International Modal Analysis Conference (IMAC XL), Orlando, FL, USA, 2022.

[4] K. M. Johnson, "Characterization of a Small Electro-Mechanical Contact Using LDV Measurement Techniques (SAND2018-1206C)," Sandia National Laboratories, Albuquerque, NM, USA, 2018.

[5] K. M. Johnson, "Characterization of a small electro-mechanical contact using non-conventional measurement techniques," University of New Mexico, Albuquerque, NM, USA, 2017.