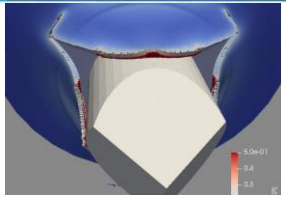
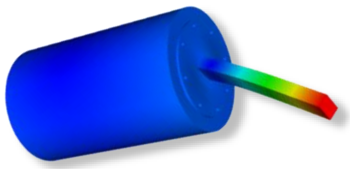
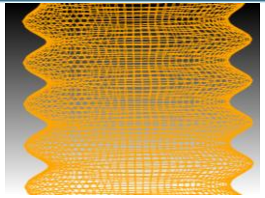
Sandia National Laboratories

Electrical Chatter and Modal Response of Pin-Receptacle Contacts in Oil

N-O-MAD Research Institute



THE UNIVERSITY OF NEW MEXICO

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8/6/2024

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U.S. DEPARTMENT OF ENERGY NNSA National Nuclear Security Administration

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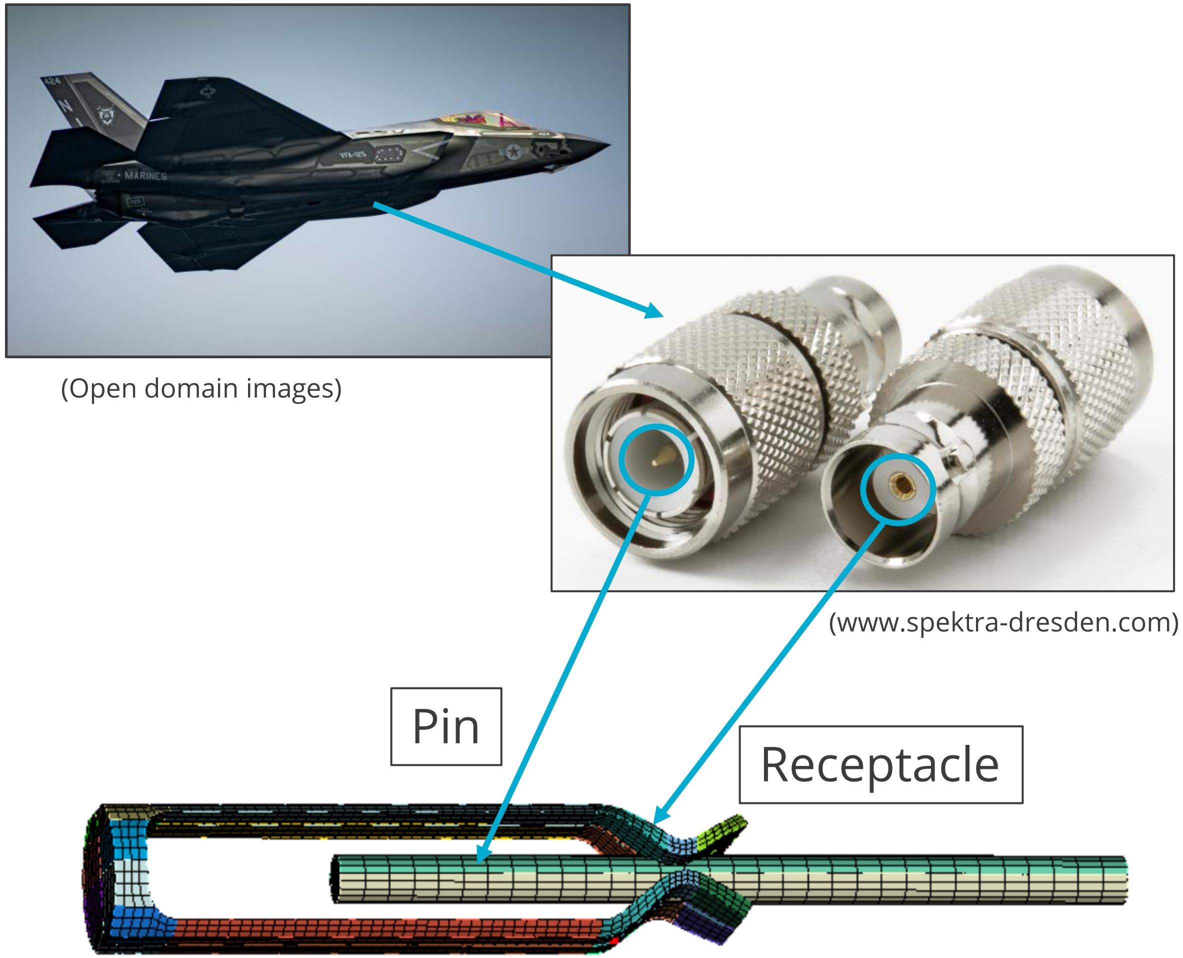
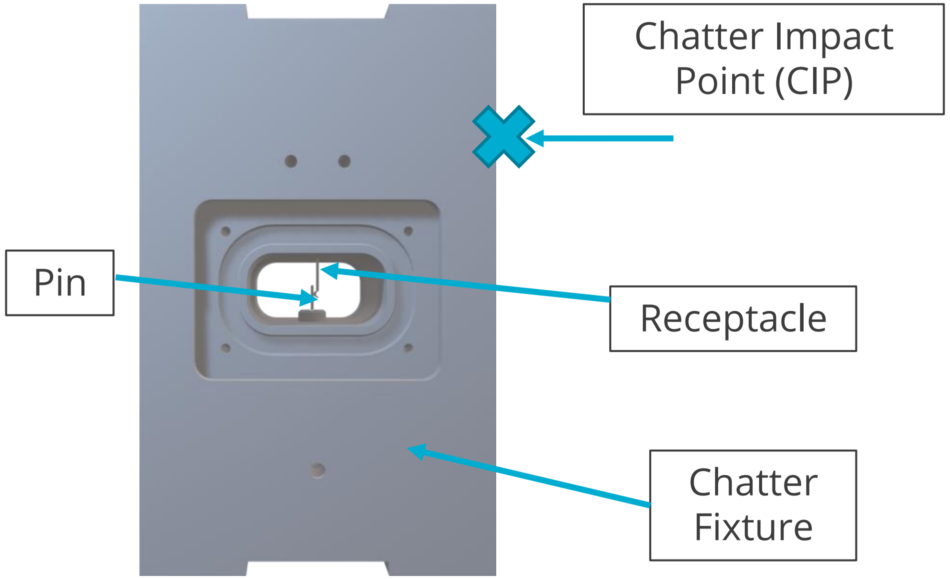
Background: Electrical chatter and pin-receptacle systems

- Electrical switches are used across a multitude of engineering applications and therefore subjected to extreme mechanical environments.
  - These conditions can cause an undesirable phenomenon known as **electrical chatter**, an abrupt increase in electrical resistance across a contact point under vibration or shock.
  - Chatter negatively impacts the signal integrity and degrades the electrical contact performance of switches.
- Pin-receptacle geometry is commonplace among electrical connections.
  - e.g., BNC cables, PCB sockets, and more.
  - Vulnerable to separation during resonance.
  - Behavior can be altered by changing the surrounding fluid, (e.g. oil).



Novelty and Objectives

- Our project seeks to characterize chatter both experimentally and computationally in the pin-receptacle structure.
  - Specifically, what causes chatter and when it occurs for the purposes of predicting the phenomenon.
  - The chatter fixture houses both the pin and receptacle via lock rings and allows for rigorous chatter testing.
  - Windows in the chatter fixture allow for O-Ring seal for testing in oil environments.
- Prior NOMAD projects had researched chatter in air, but our group not only wanted to validate previous data but characterize chatter in oil environments



(https://support.newgatesimms.com/how-electrical-connector-lubricants-work/)

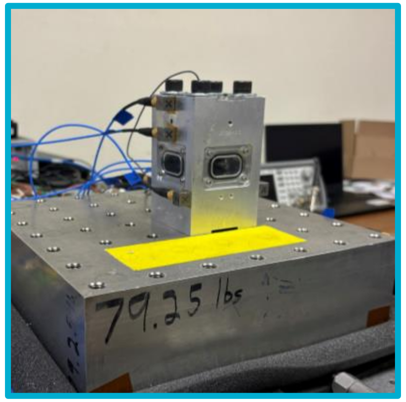
Outline

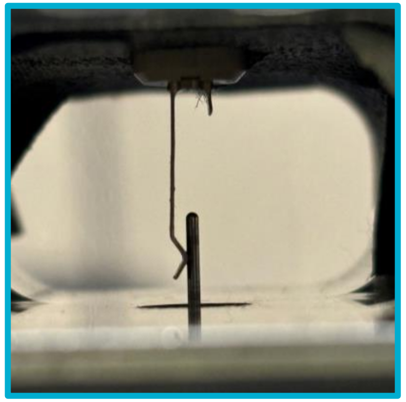
1. Team Introduction and Problem Statement
2. Experimental Setup and Computational Stategies
3. Modal Results: Comparison of FE modal analysis and simplified model to experimentally derived modal properties
4. Chatter Results: Comparison of experimental chatter using different oils and its relationship with simulated chatter events
5. Conclusions and Future work

2. Experimental Set Up and Computational Strategies

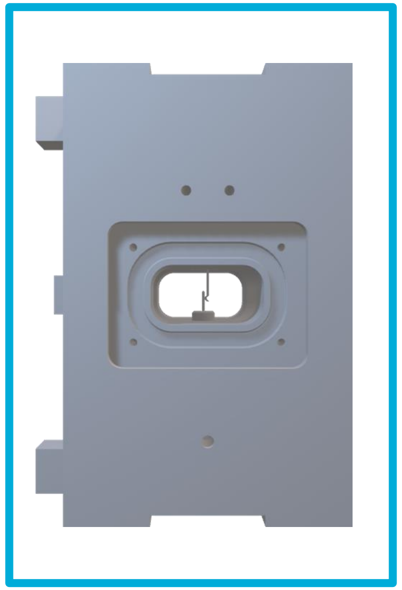
Capturing Chatter Workflow

Experimental Model → High-fidelity FEM → Simplified Chatter Model

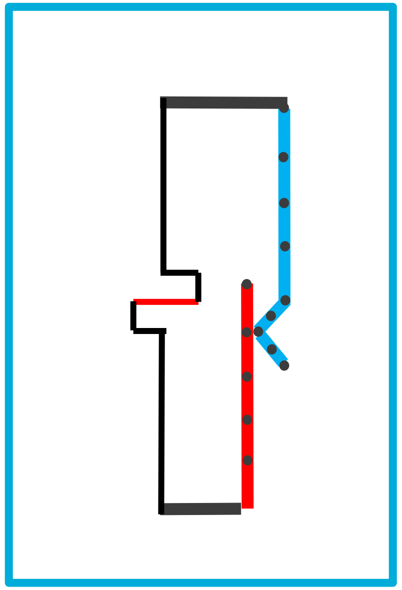




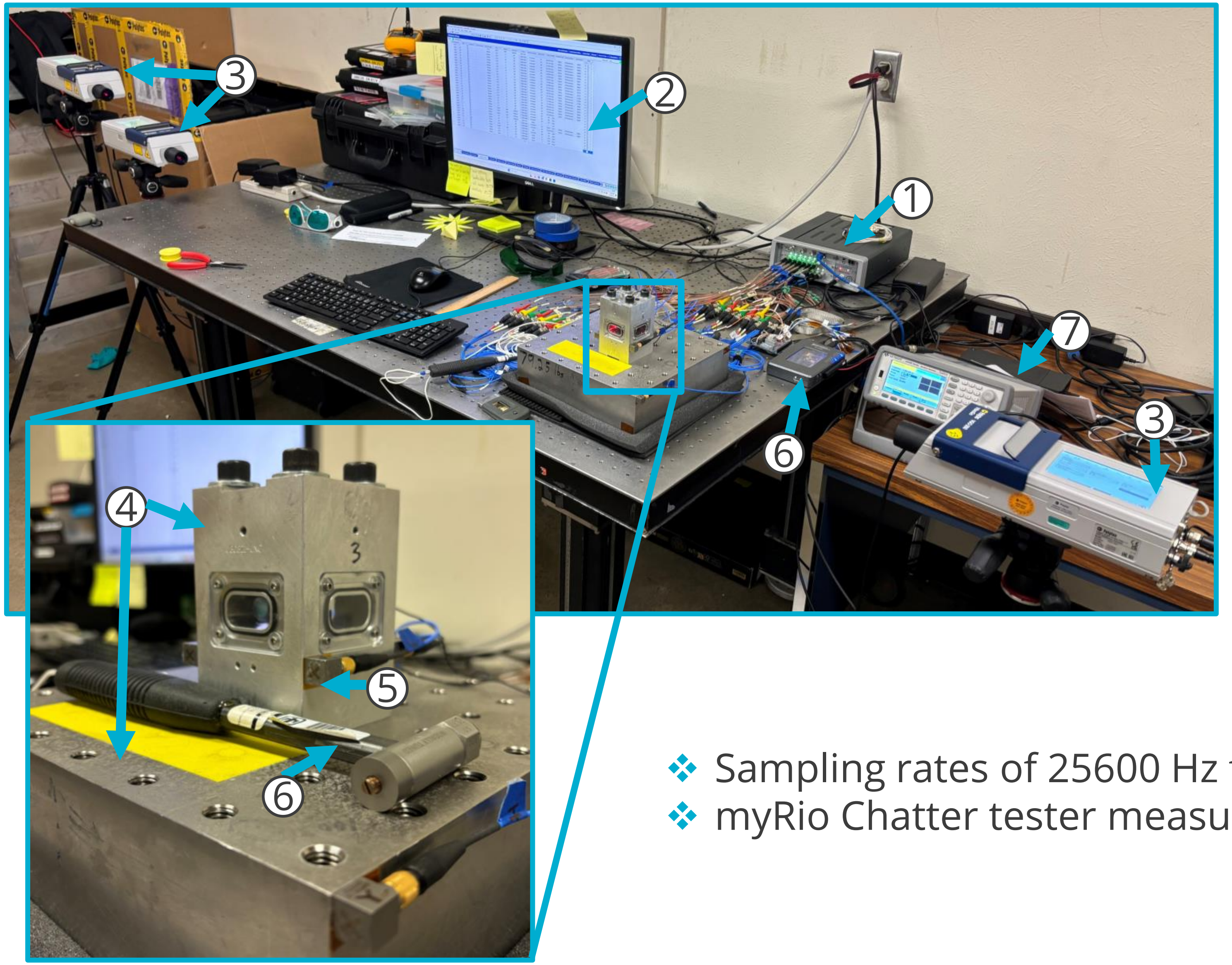
- Precise contact definition between pin-receptacle
- Models all experiment component: bolts, chatter fixture, mounting block



- Captures primary cantilever mode of chatter fixture
- Simulates contact/preload between pin-receptacle



Experimental Setup

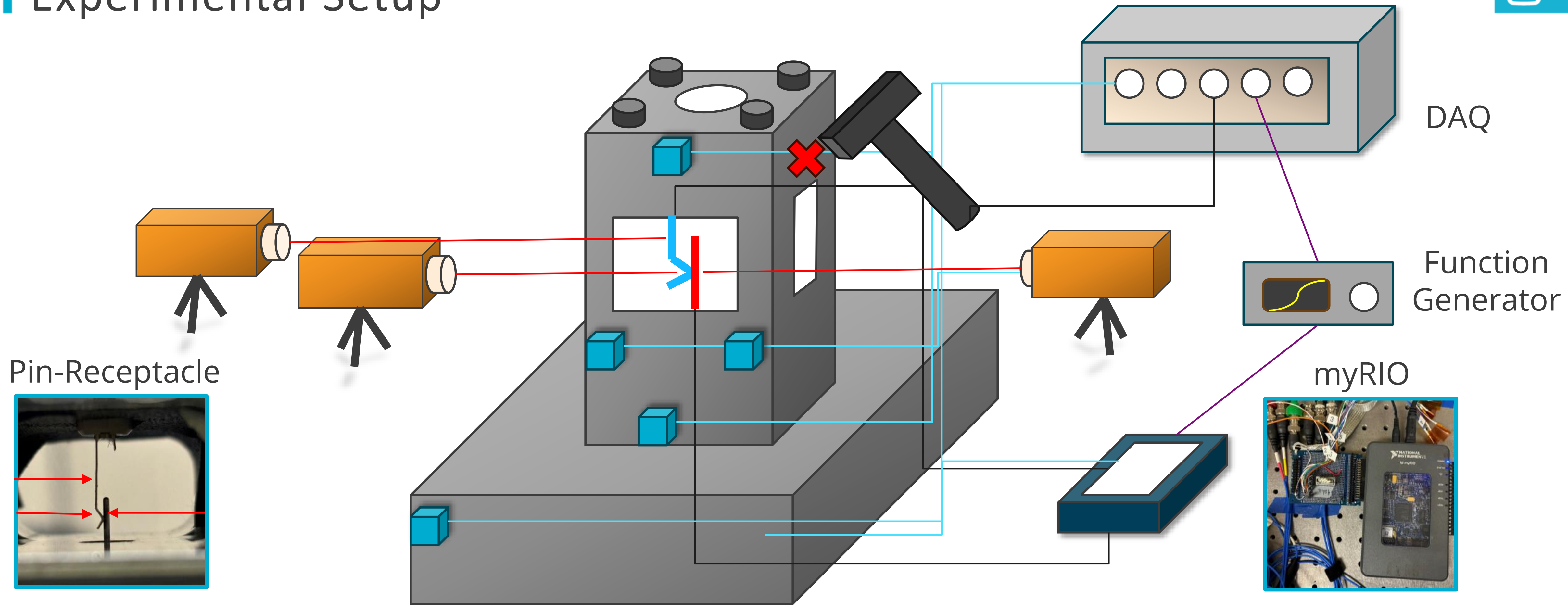


Instruments Used

1. Data Acquisition System (DAQ)
2. TestLab Impact Testing Software
3. Laser Doppler Vibrometers (LDV)
4. Chatter Fixture/Mounting block
5. Triaxial Accelerometers
6. Modal Hammer
7. myRIO Chatter Tester
8. Function generator

- Sampling rates of 25600 Hz for accelerometers and LDV
- myRio Chatter tester measures at 40MHz with 120ohm

Experimental Setup



<u>Modal Testing</u>

Roving Hammer Test → Polymax Curve Fitting → Modal Parameters

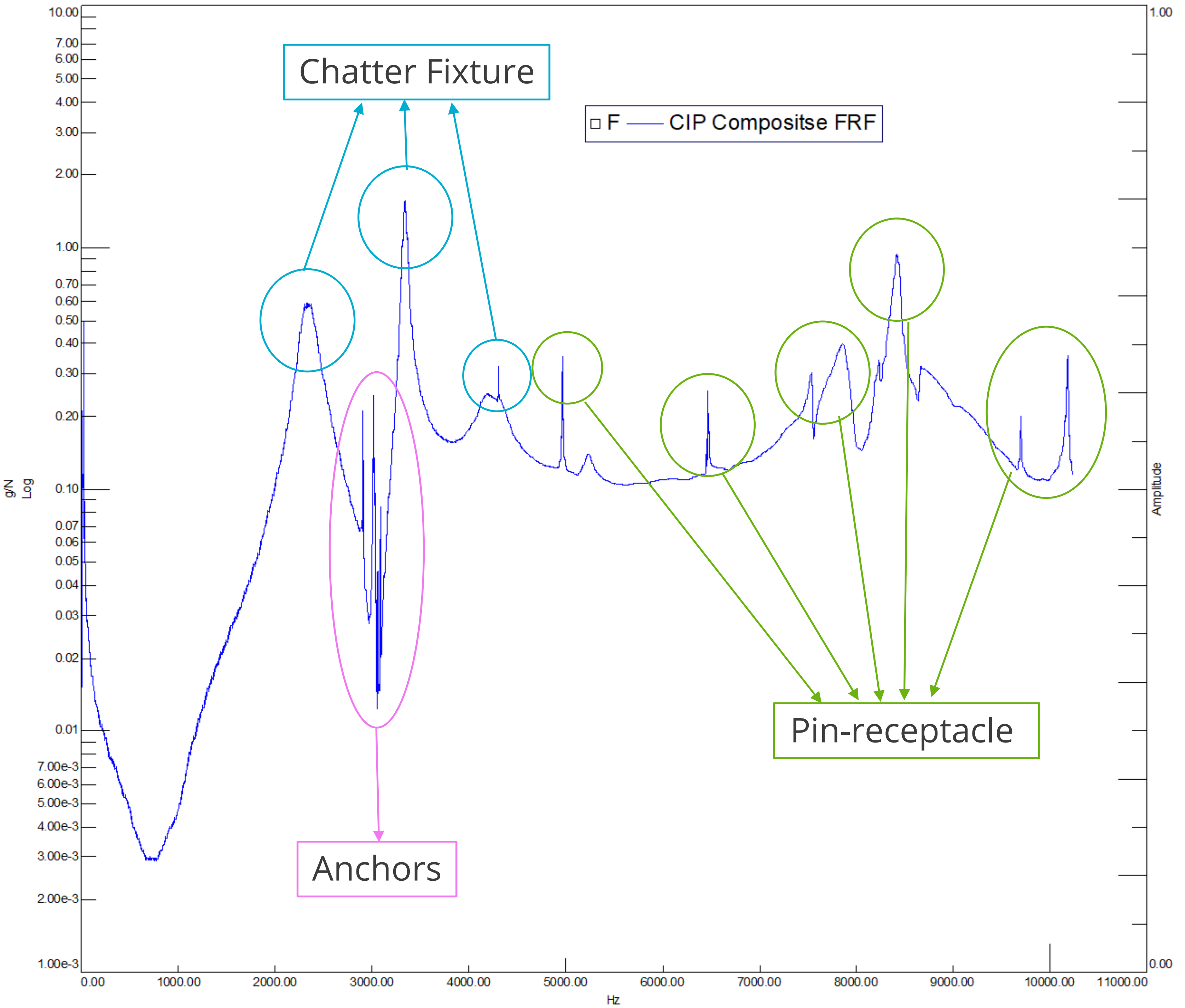
<u>Chatter Testing</u>

myRIO Chatter Test → Analyze Chatter Data

3. Modal Test Results

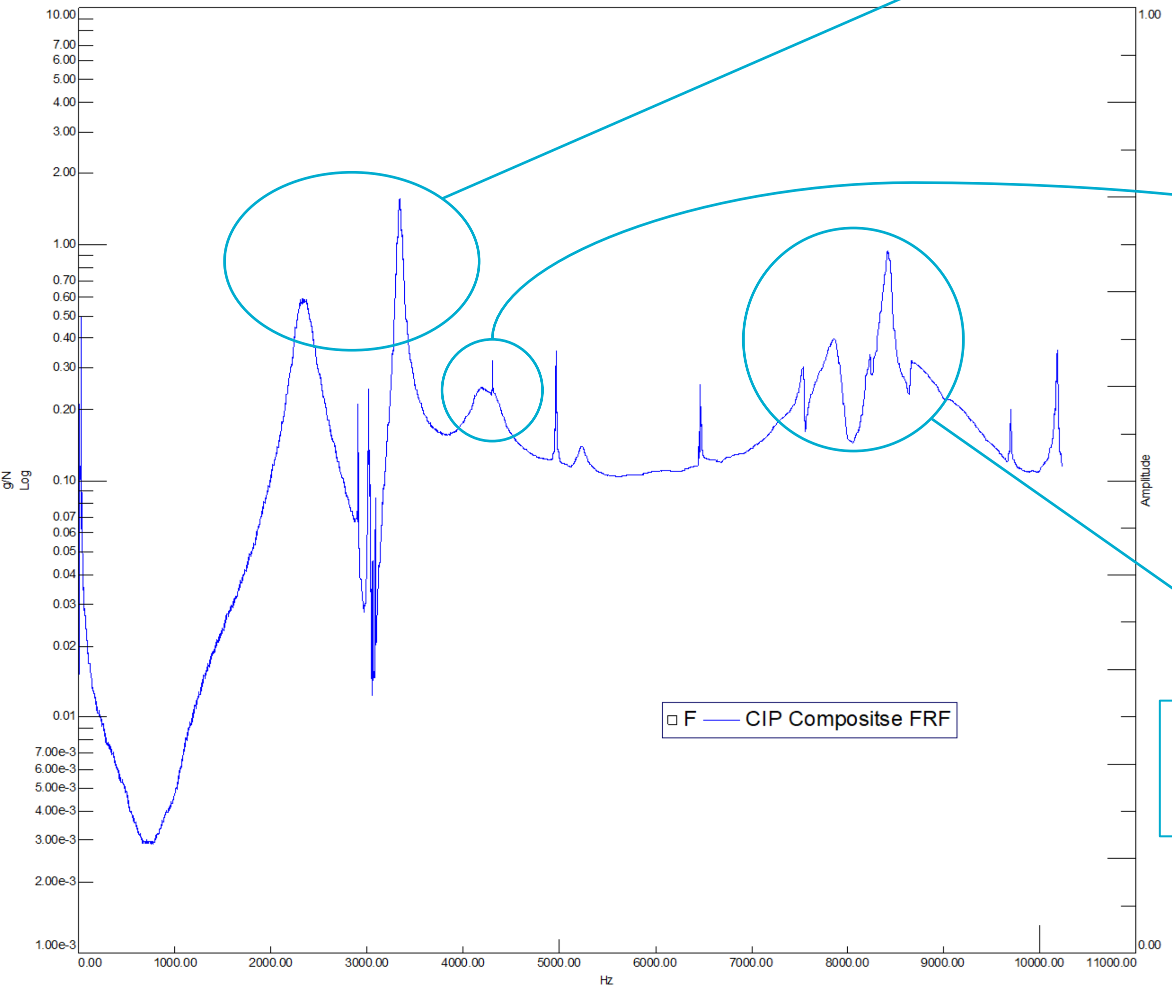
Experimental Modal Results: Full Assembly

- Through software analysis, the modal behavior of the fully assembly was characterized through the Composite Frequency Response Function (FRF)
- This graph displays a composite of the 27 Frequency Response Functions (FRF) produced by impacting at the Chatter Impact Point (CIP).
- Served as a reference for oil data and its impact on modal testing



Comparison with FEM

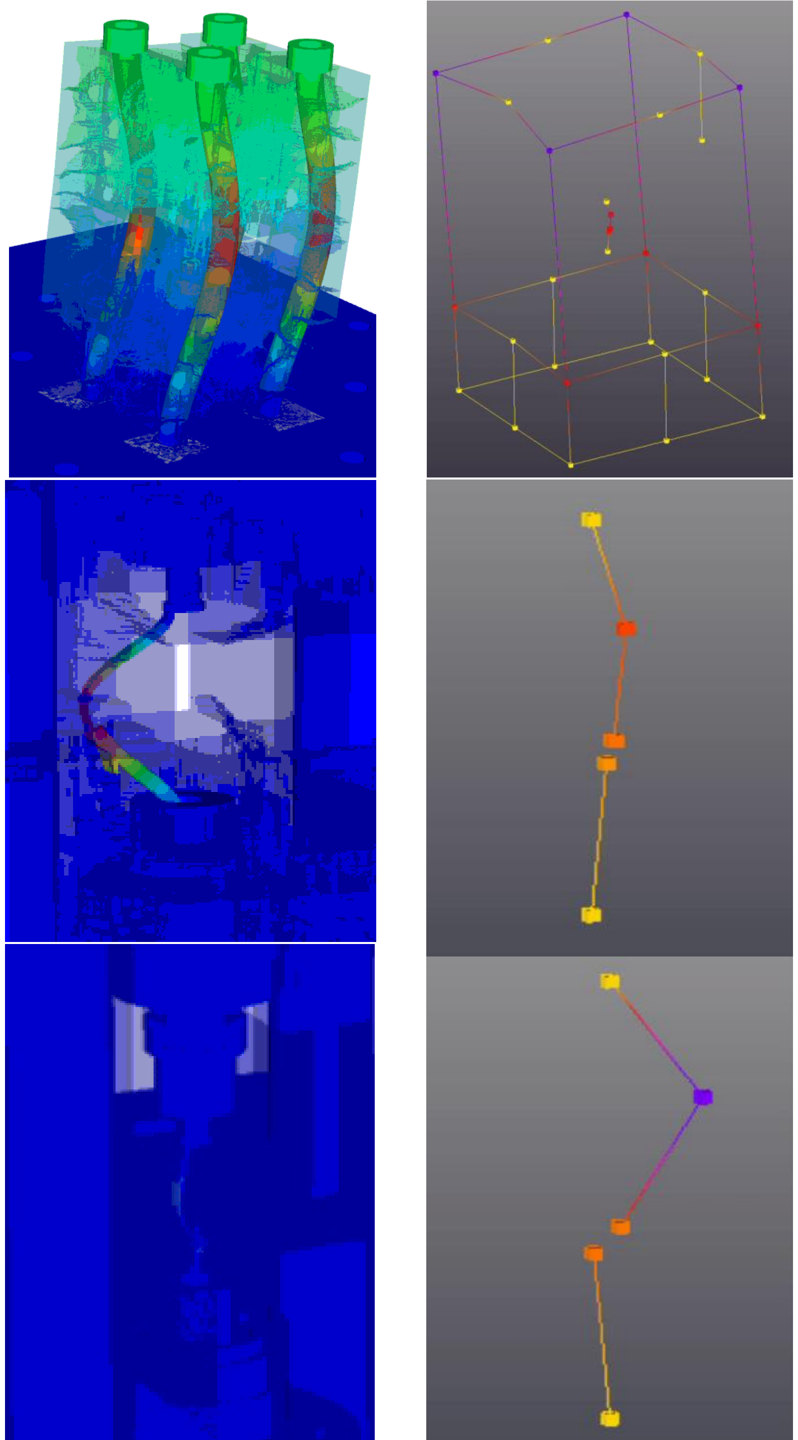
- Modal analysis of a finite element model was used to validate the experimental results and Composite FRF modes.



Fixture Cantilever Modes

1st P-R bending

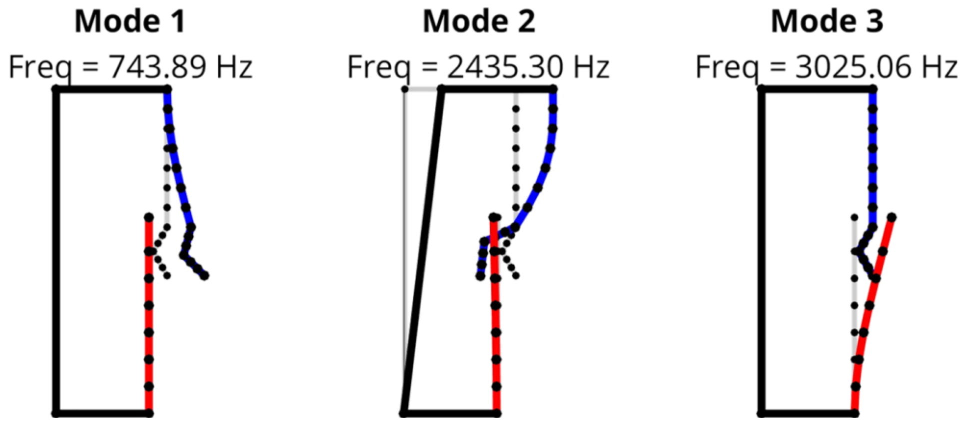
2nd P-R bending



Simplified Pin-Receptacle System Modal Properties

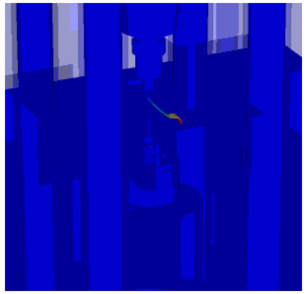
Uncoupled Pin and Receptacle System

Simplified Pin-Receptacle Model

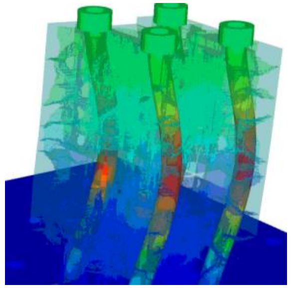


High Fidelity Pin-Receptacle FEM

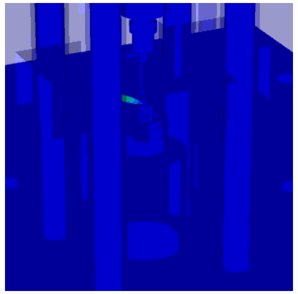
724.6 Hz



2399.2 Hz

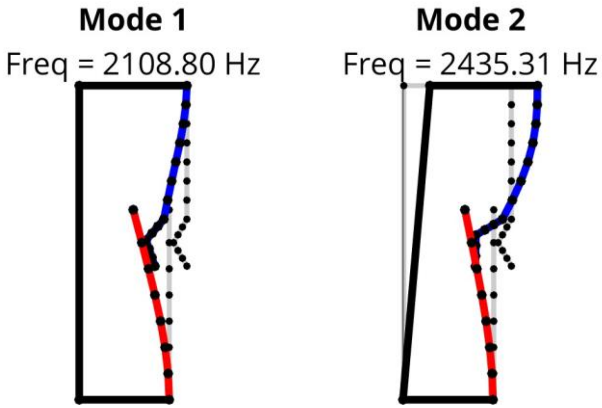


7453.1 Hz



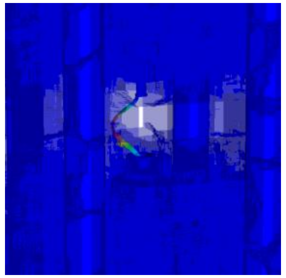
Coupled Pin and Receptacle System

Simplified Pin-Receptacle Model

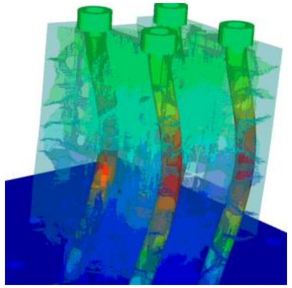


High Fidelity Pin-Receptacle FEM

5799.2 Hz



2399.2 Hz

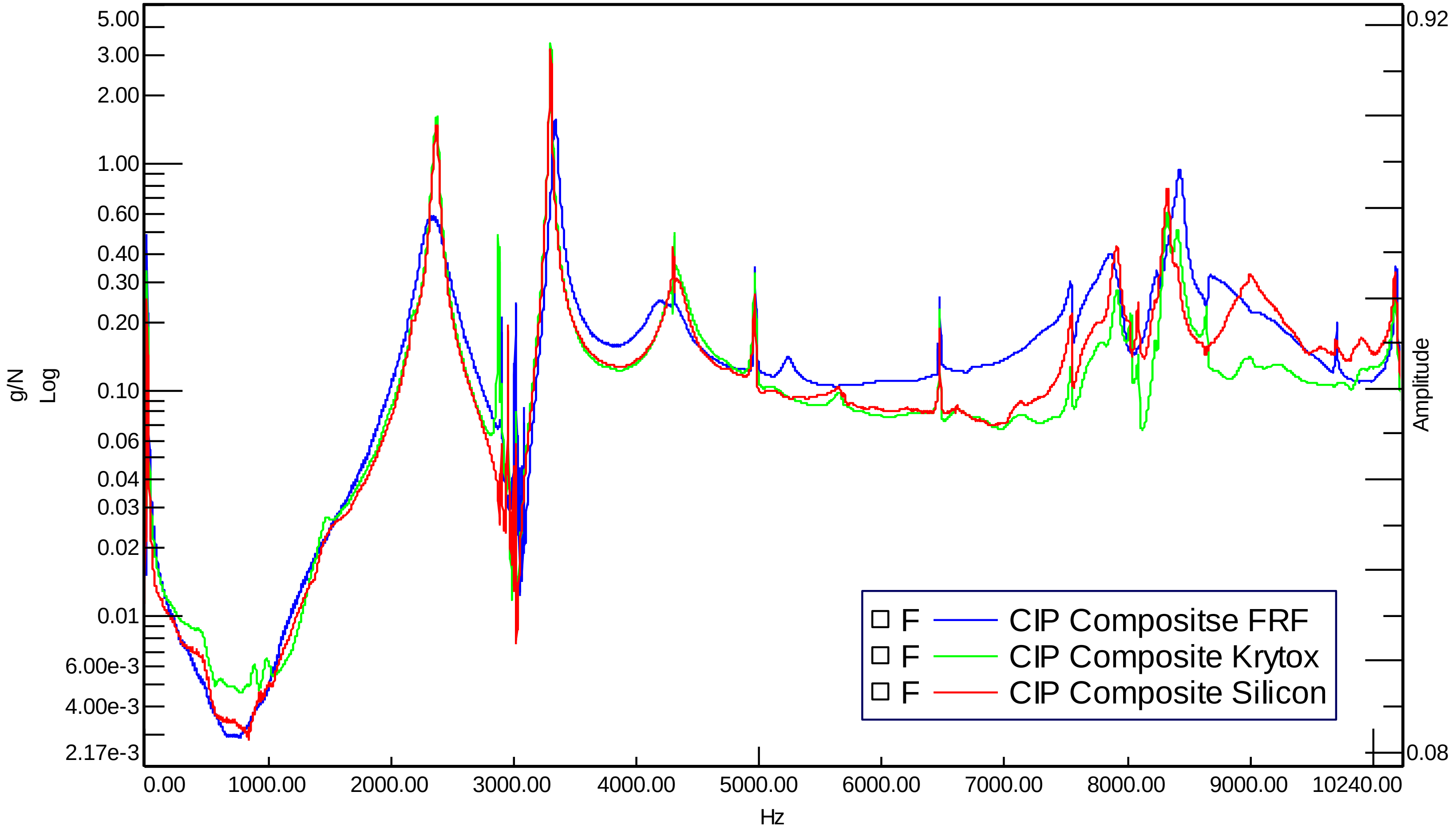


Experimental Modal Results Using Some Oil

- By taking the composite FRF of the no oil, some Krytox oil, and some Silicon oil; it was found that very small shifts in the natural frequencies and amplitudes occurred.

No Oil

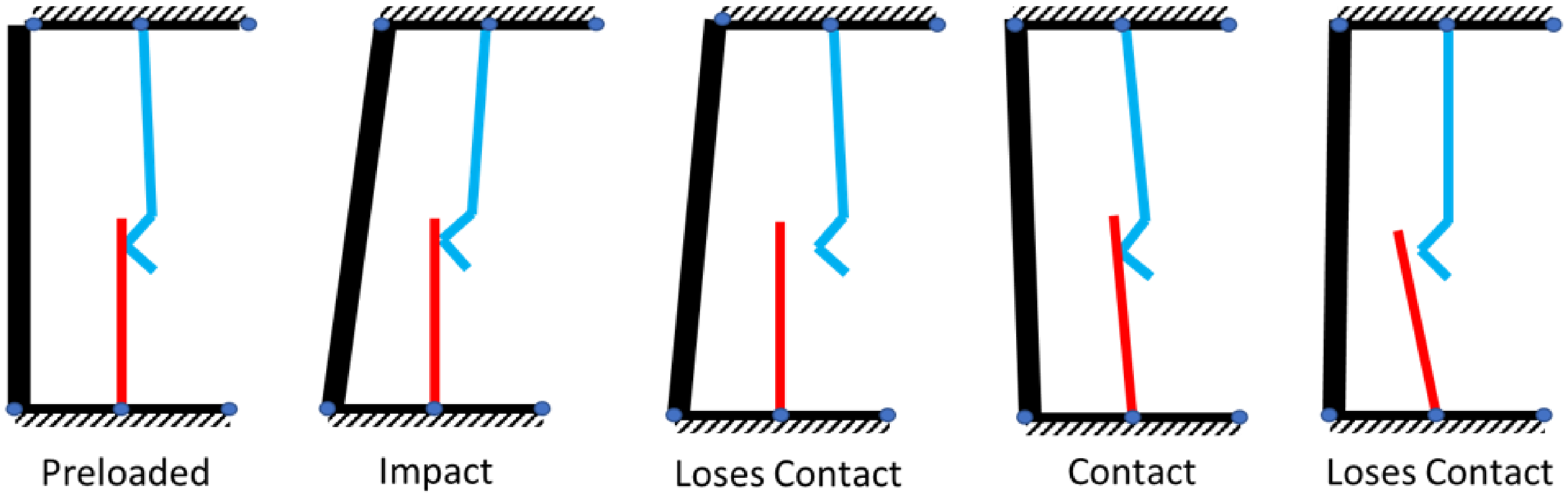
Some Oil



4. Measuring Chatter

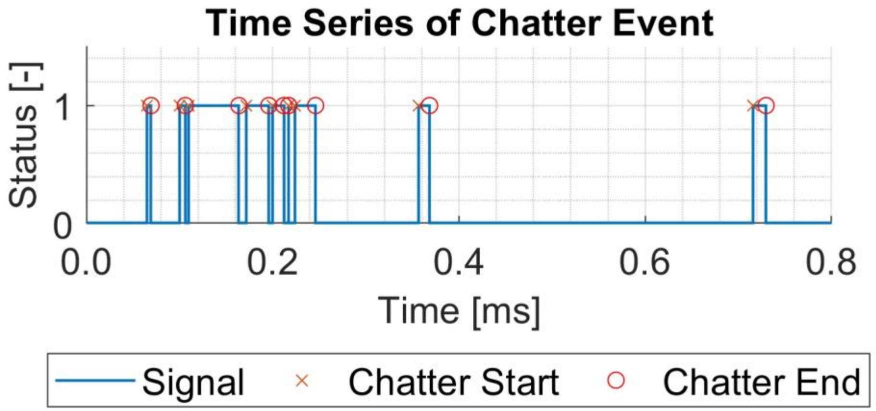
What is Electrical Chatter

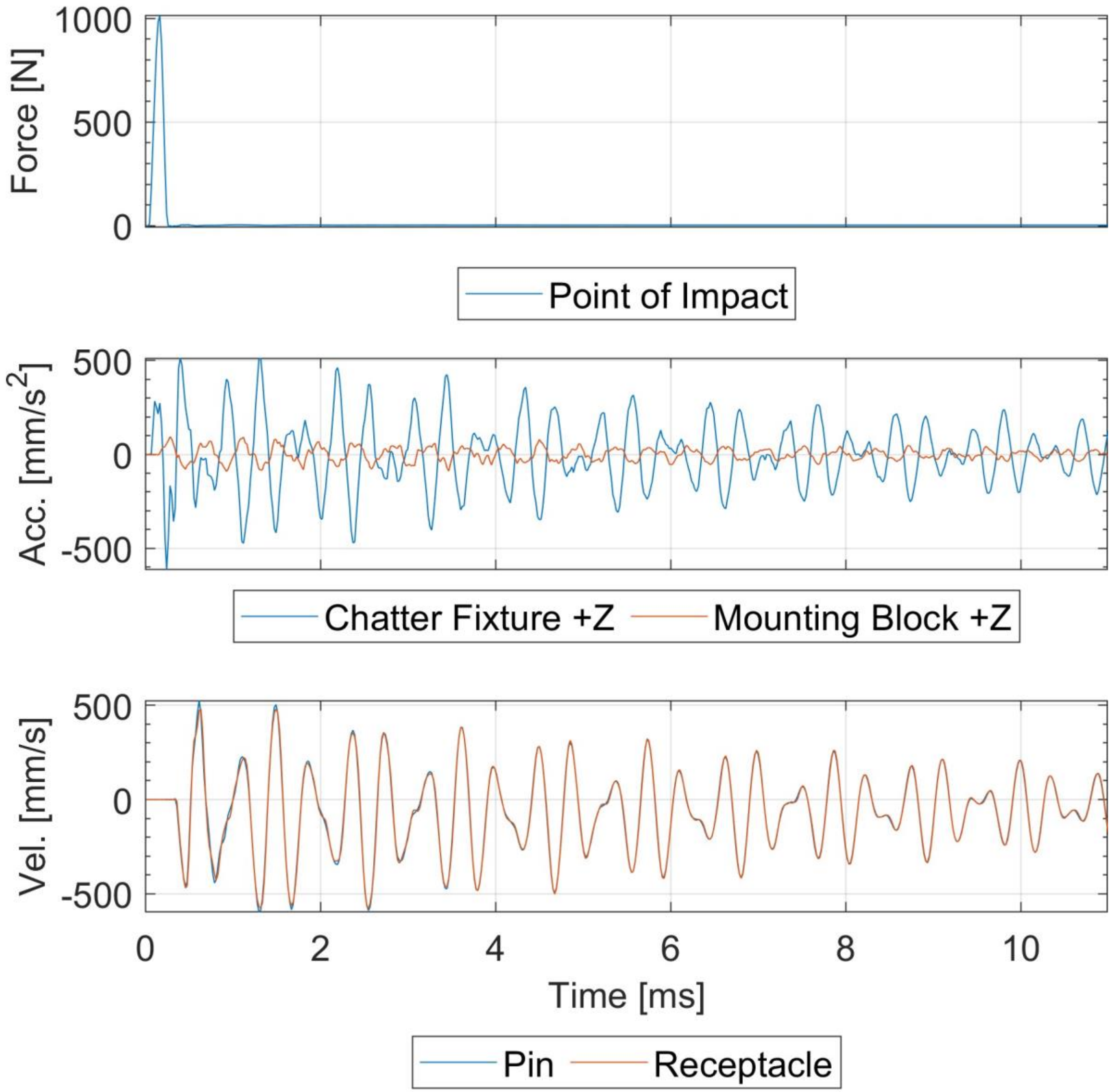
- Chatter occurs at the lost of contact between the pin and receptacle often at the scale of 0.1 milliseconds.
- Due to the natural frequency of the pin and receptacle being different, when the two systems come apart, they will vibrate at different frequencies, coming into and out of phase during free vibration which would result in impacts that causes chatter.



Capturing Electrical Chatter Using Impact Testing

- By impacting the chatter fixture at the CIP, the pin and receptacles were excited
- Using the two data acquisition systems, the acceleration and velocity of the fixture and pin-receptacles were measured as well as the occurrence of chatter.

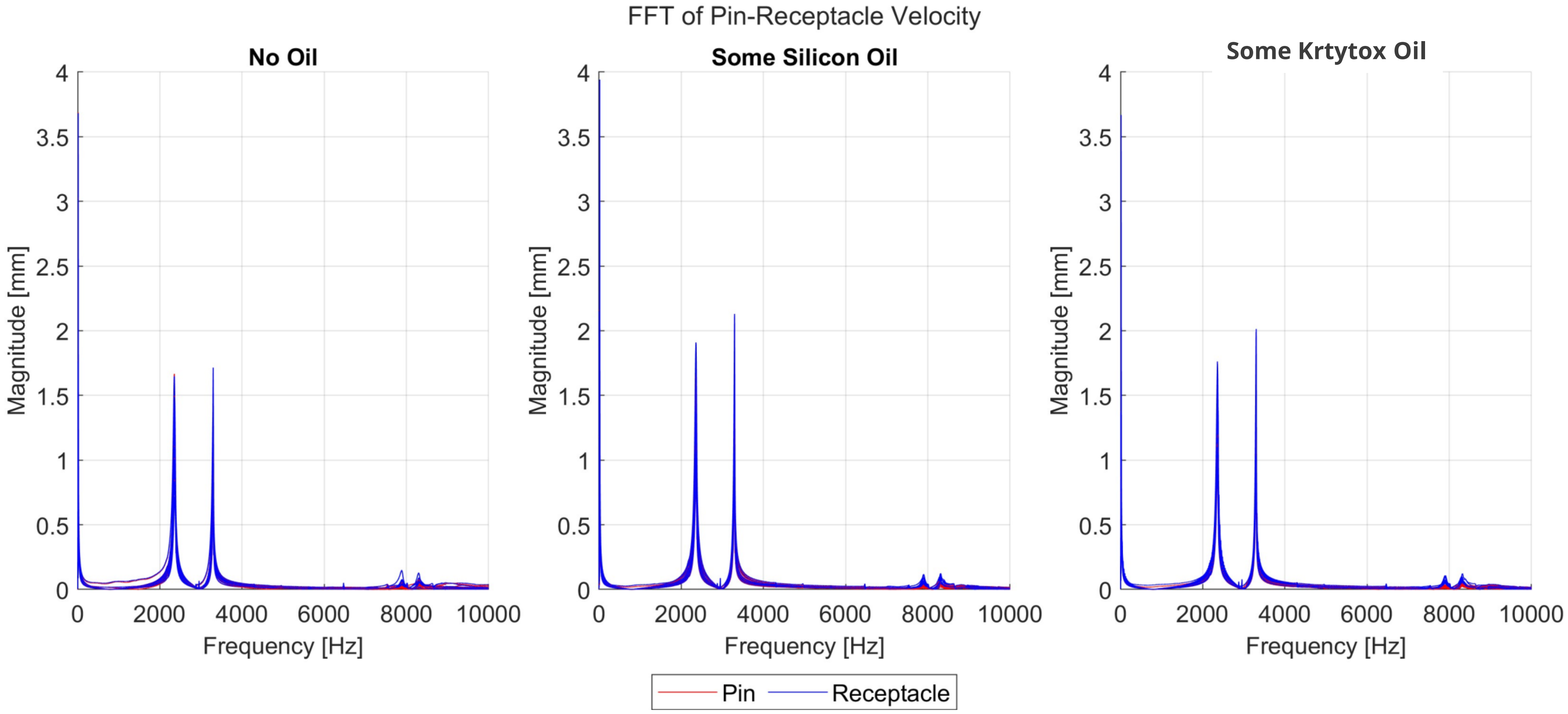




Frequency Content of Pin-Receptacle

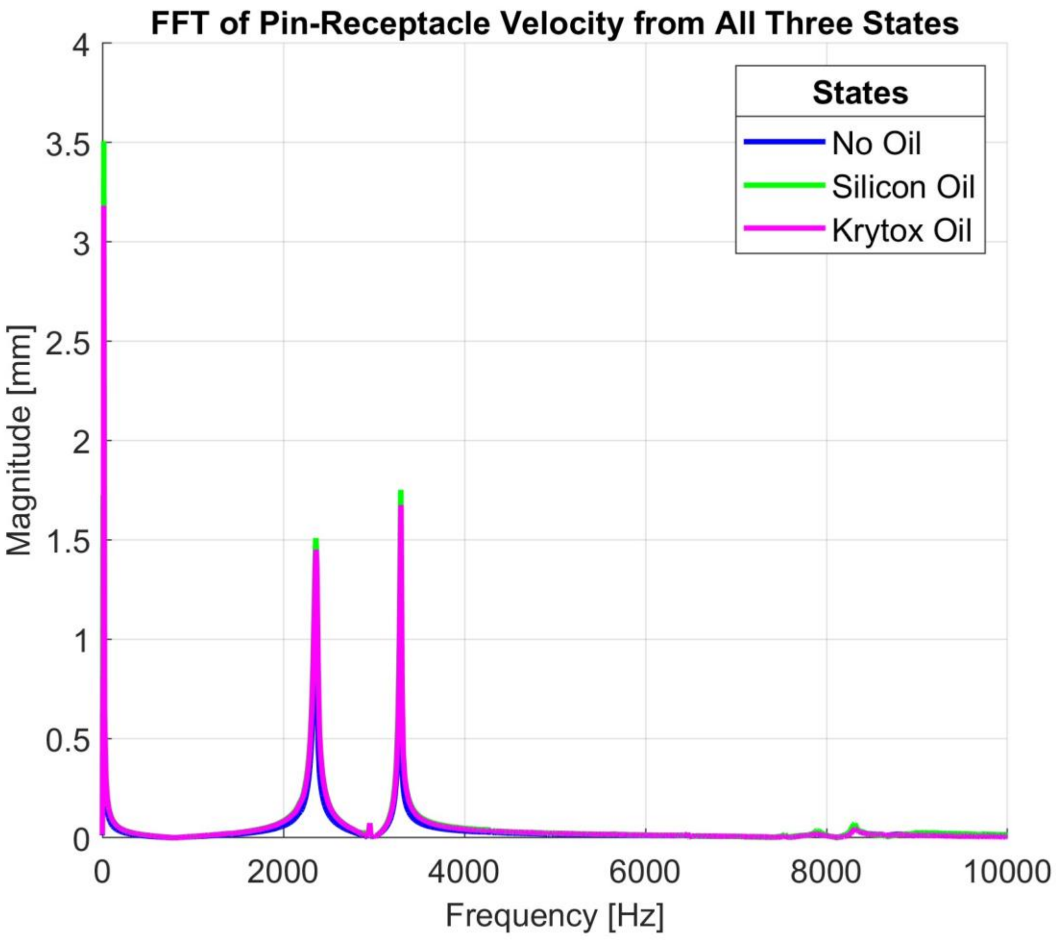
- Using a Fast Fourier Transform (FFT), the frequency content of the time history was graphed. The dominant frequencies excited during chatter tests are shown to be those of the cantilever frequencies of the chatter fixture and pin-receptacle.

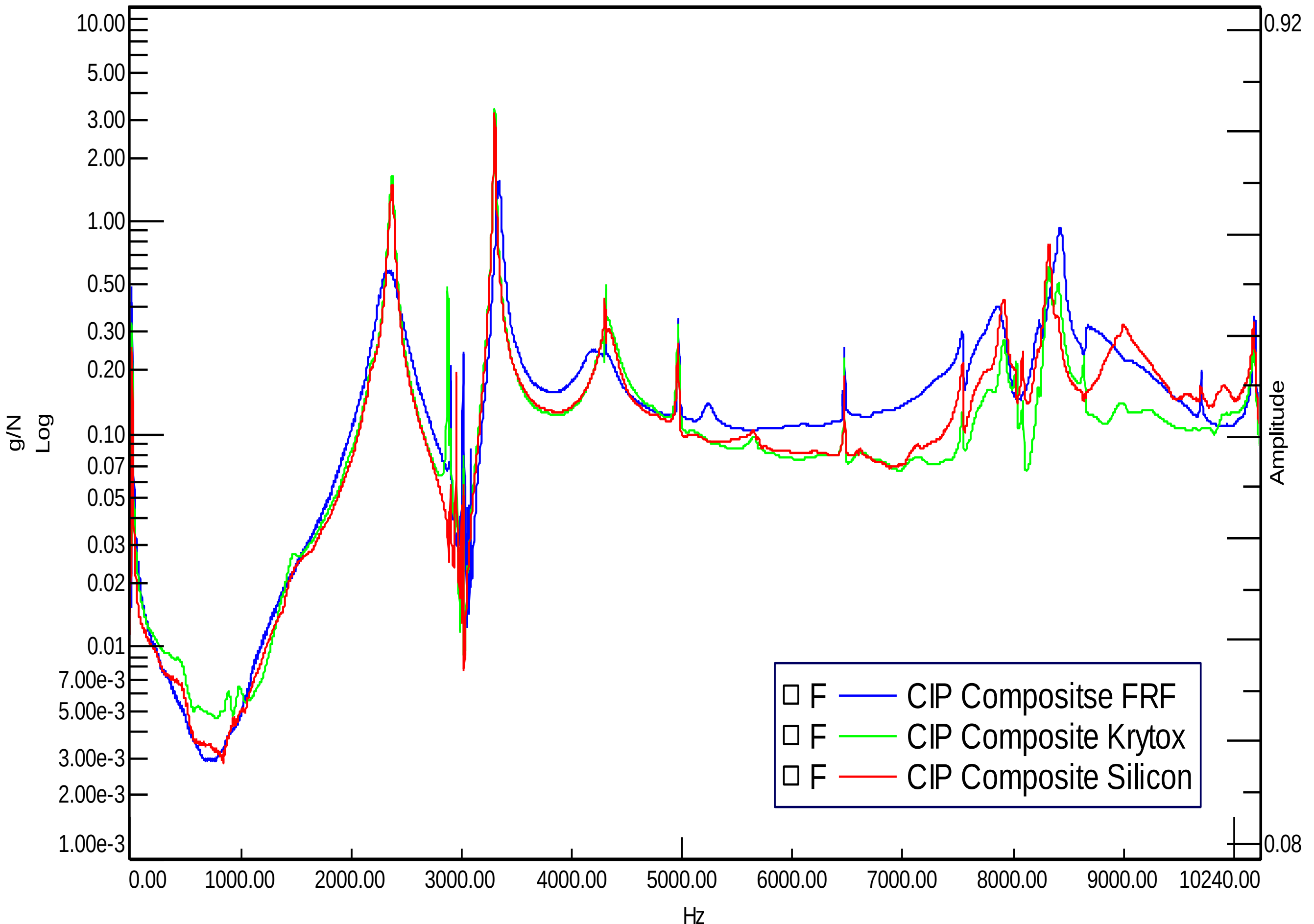
- Despite different levels of excitation, the natural frequencies do not change.
  - Tested between 300N and 3000N



Comparing Response Frequency with Modes of Entire System

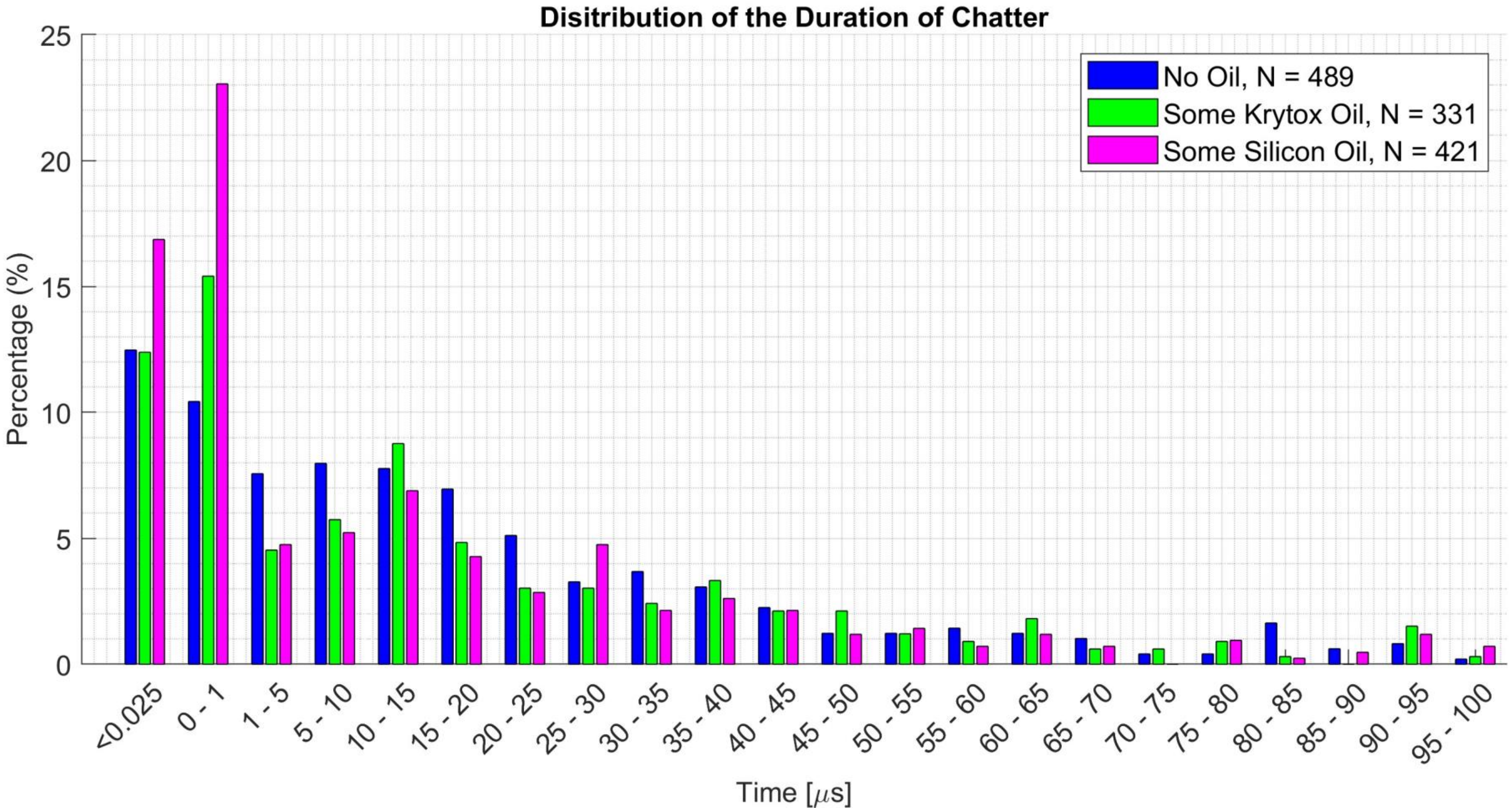
- By comparing the FRFs and FFTs of all three fluid states, the most significant natural frequencies are being activated in the chatter tests.
  - Chatter fixture and pin-receptacle modes are causing the chatter as seen in the FFT and verified by the FRF





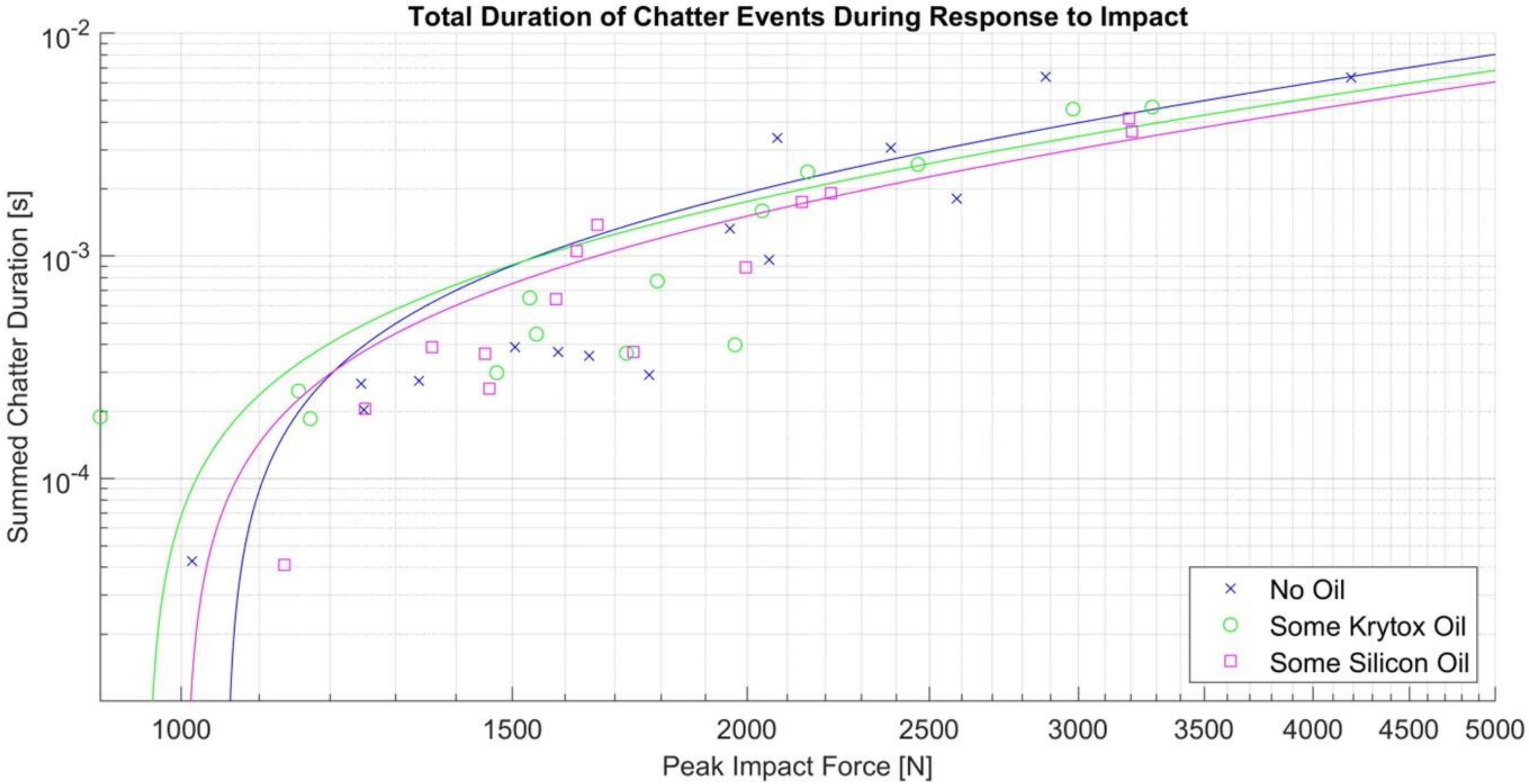
Distribution of the Duration of Chatter Events from Impacts

- Most of the chatter events are still < 0.1 milliseconds or 10μs. The chatter event frequency does not seem sensitive to the presence of some oil.



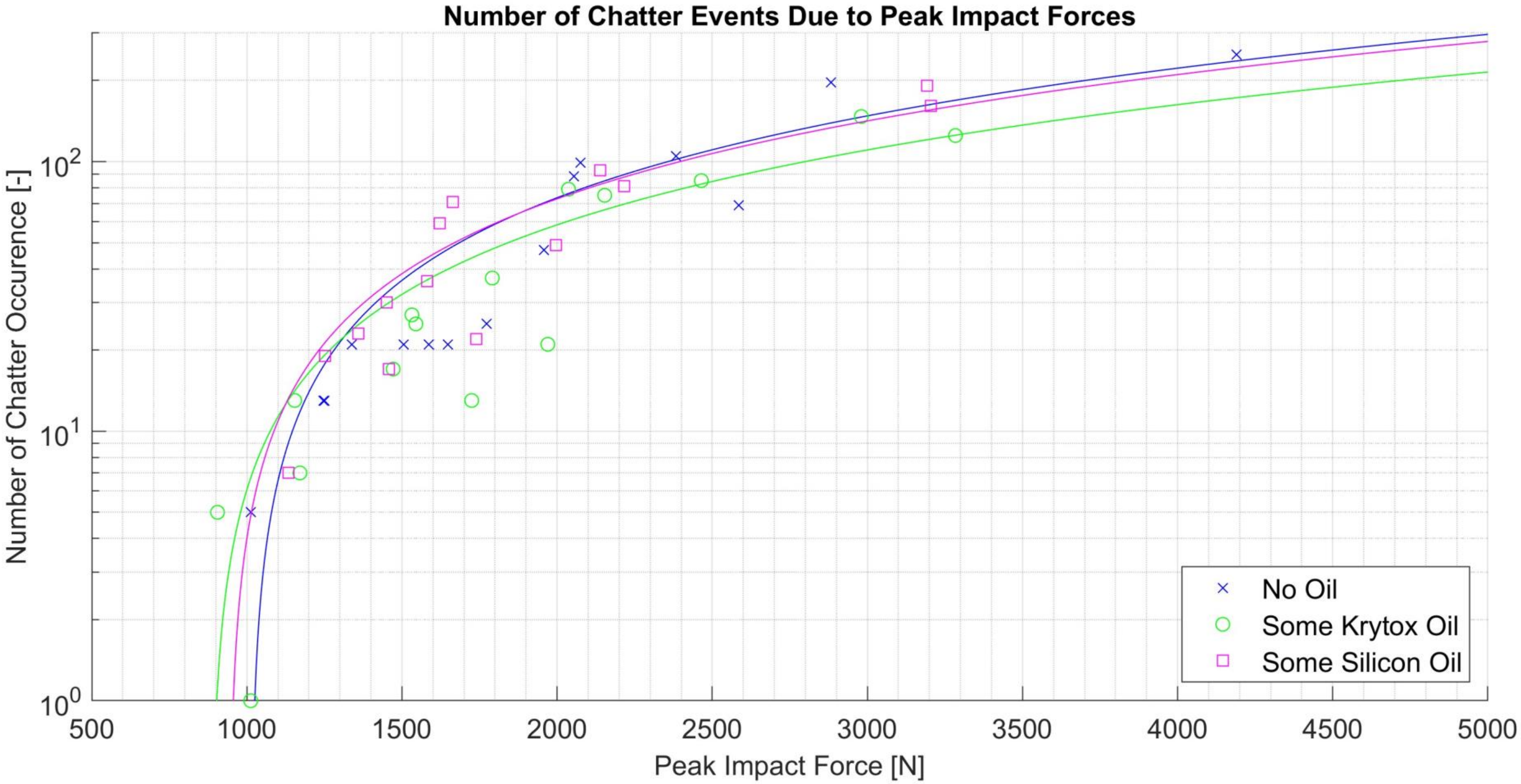
Total Duration of the Chatter Events During Single Impact

- As peak impact force increases, the total duration of the chatter events also increases. This is likely caused by the increased energy inputted into the system



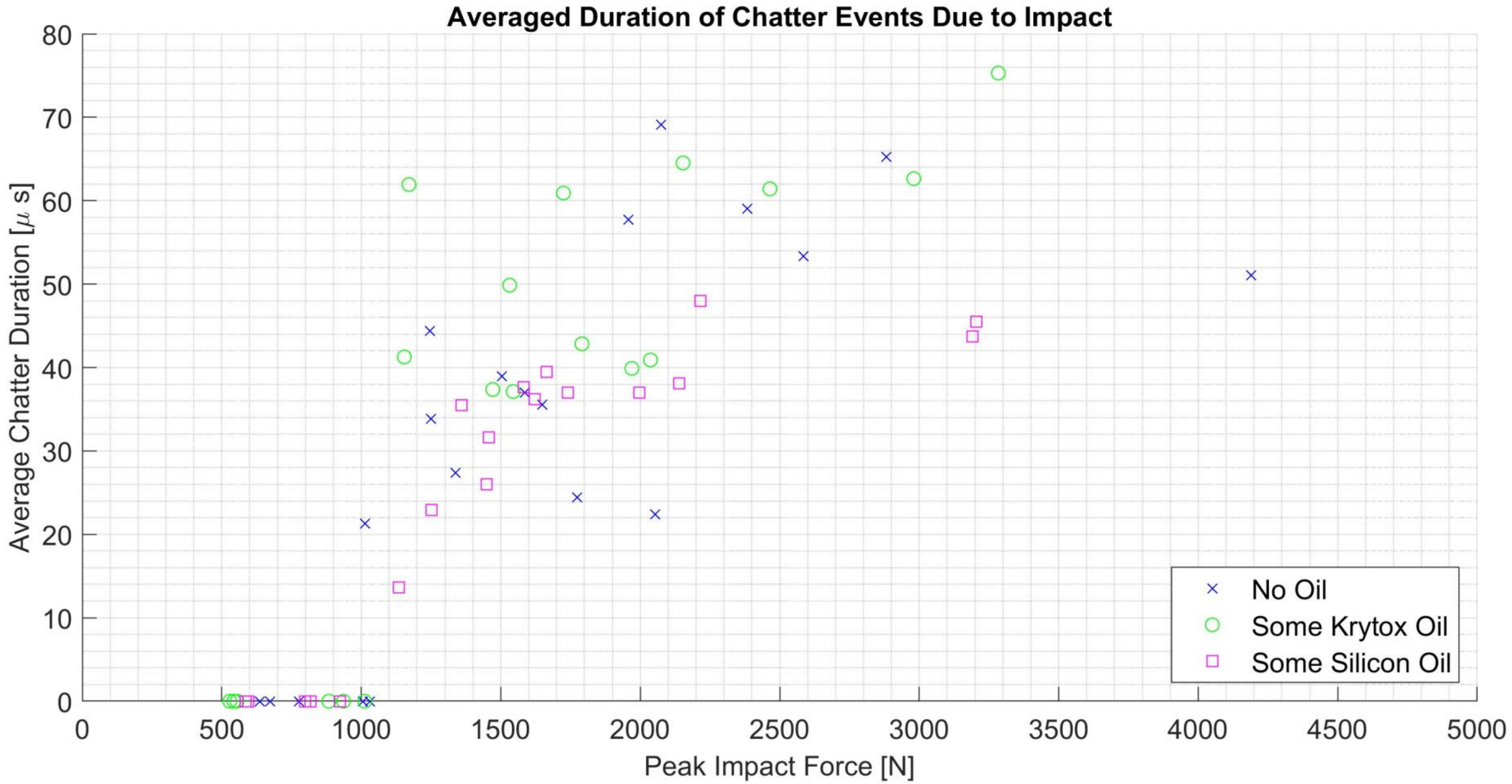
Number of Chatter Events Per Single Impact

- Forces <1,000N seem to not excite chatter. Number of chatter events seem to follow a linear curve, with small differences due to limited oil supply.



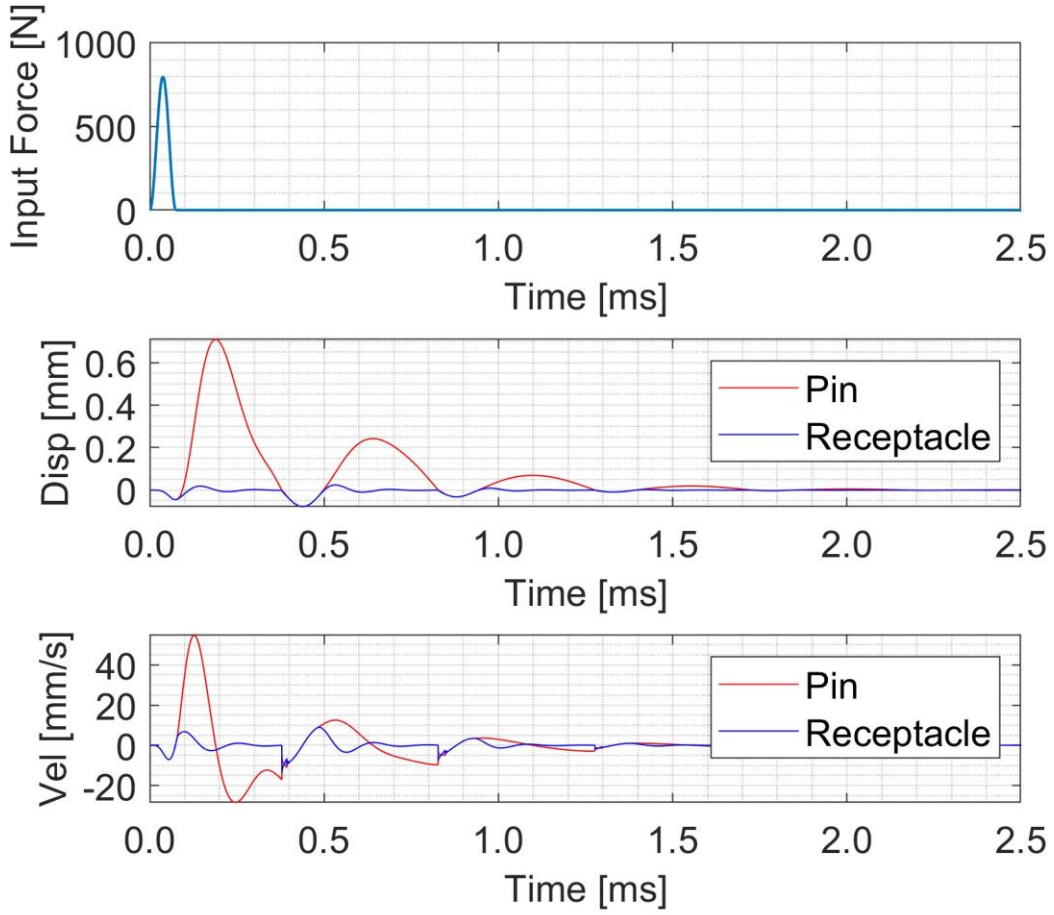
Average Duration of Chatter Events During Single Impact

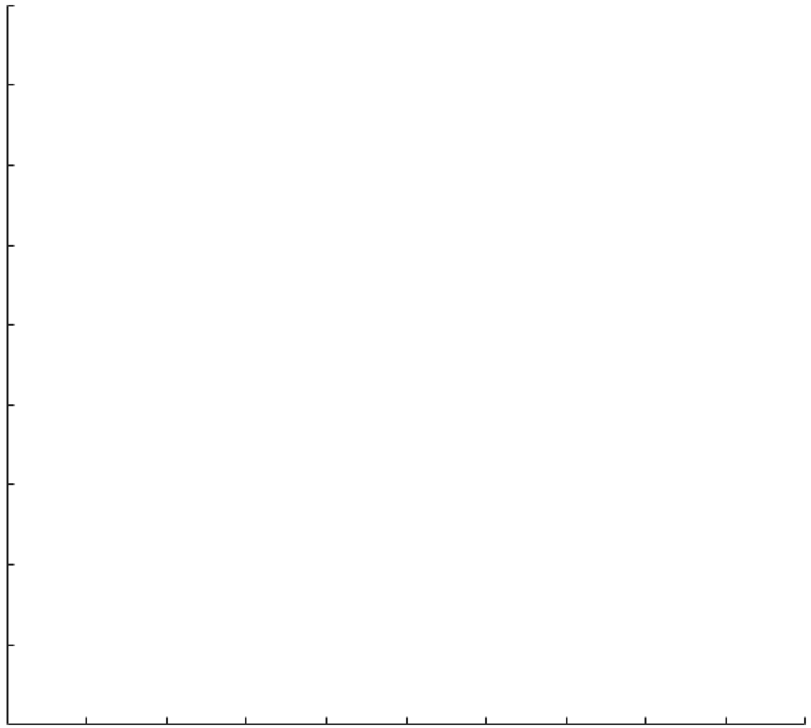
- As impact force increases, the average duration of chatter seems to flatten out. The length of chatter events seems to regress towards a mean duration even with higher force levels.



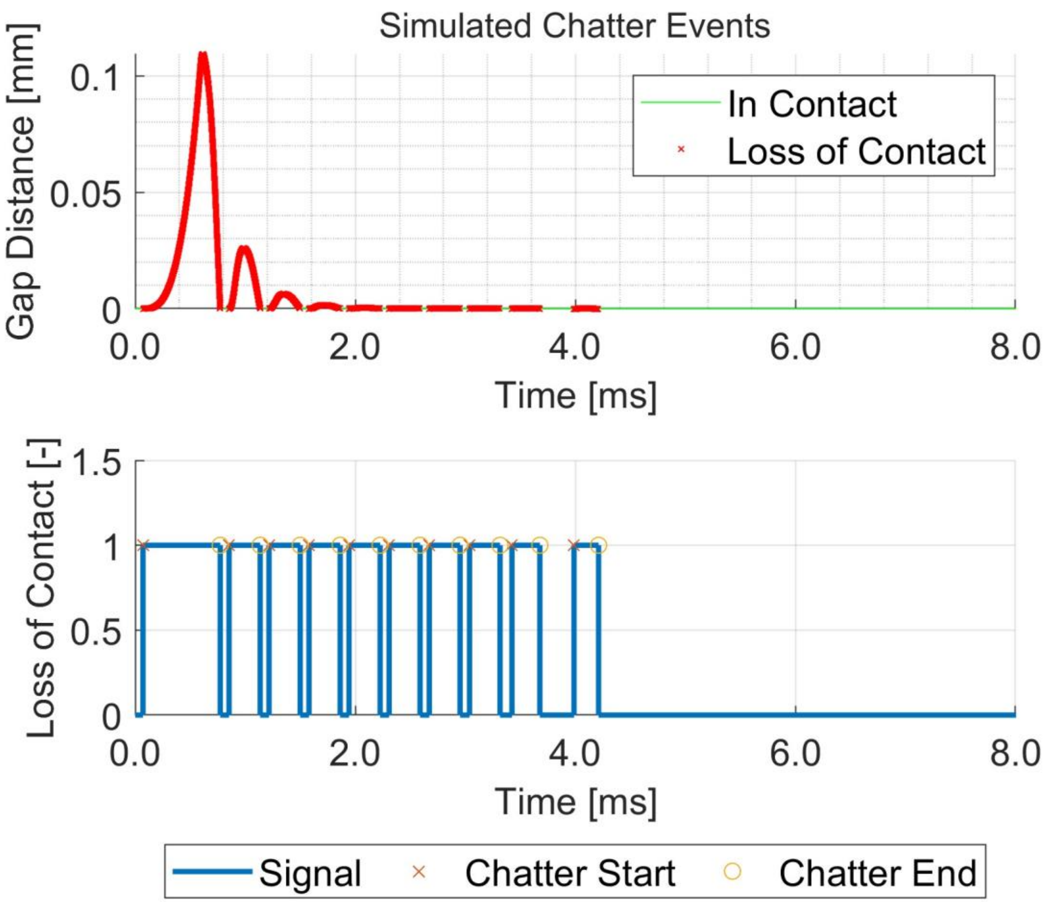
Simulated Chatter Data

- The simplified pin-receptacle system is capable of capturing displacement, velocity, and acceleration that can be compared with experimental measurements





Predicting Chatter Events with Simplified Simulations



- A haversine input can be varied to match the peak input force and duration of an experimental impact
- Calculating the gap distance between the contact nodes degrees of freedom, the point at which chatter occurs can be simulated
- Additional verification of modal parameters of each individual system (pin, receptacle, anchors, chatter fixture) should be adjusted to match test results

5. Conclusions and Future Work

Conclusions

Modal

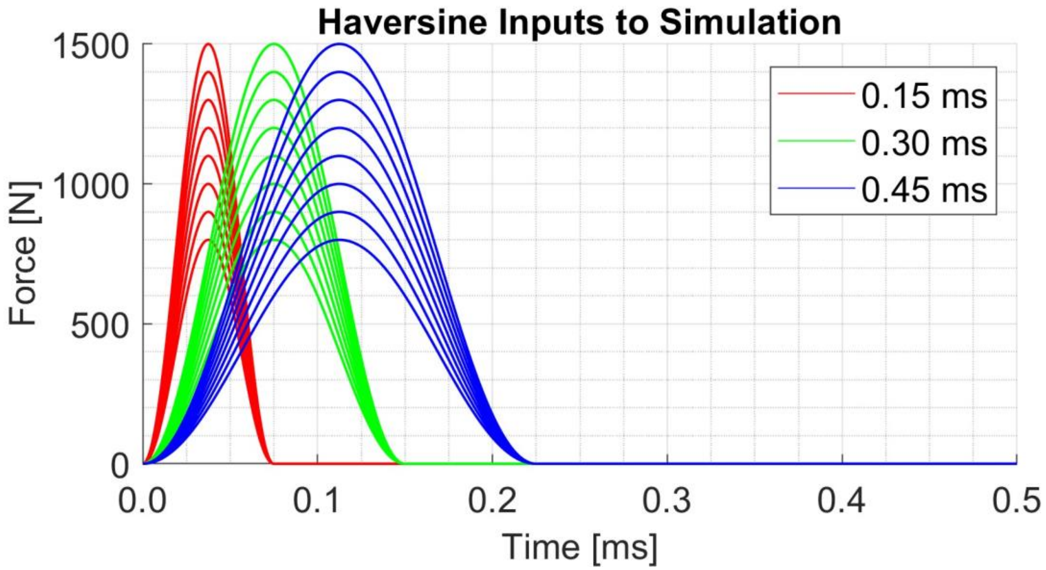
- While small shifts of frequencies and amplitudes occurred, the modal properties of the entire system in air showed agreement with both Krytox oil and Silicon oil
- The most significant natural frequencies and mode shapes were the cantilever fixture modes and pin-receptacle modes activated in both modal and chatter testing, and are therefore the cause of chatter
- The natural frequencies that caused chatter does not change significantly with respect to input force as found by comparing twenty levels of input force for all three oiled states

Chatter

- For our runs, our chatters events for no oil (50%) , Krytox oil (59%), and Silicon oil (65%) lasted <30μs.
- The number of chatter events seems proportional to the input force after impacting the fixture with 1000N in the direction of the pin-receptacle
- The summation of the duration of all the chatter events increased as the input force level increased.
- The average duration of the chatter events did not increase or plateau to a characteristic duration

Future Work

- Submerge the pin-receptacle system in oil and investigate the hydrostatic effects on the modal and chatter behavior of the system.
  - Inspect how a full oil environment leads to higher damping and/or lower amplitudes in the data
- Refine and calibrate the chatter simulations to represent the physical behavior of chatter fixture and pin-receptacle system.
  - Collect further impact tests to corroborate simulations with varying haversine inputs and correlating it with chatter statistics



Acknowledgements

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We loved our experience at NOMAD and want to thank all the people that supported us throughout the summer. Thank you tremendously for all your help.

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Thank you!

Any questions?