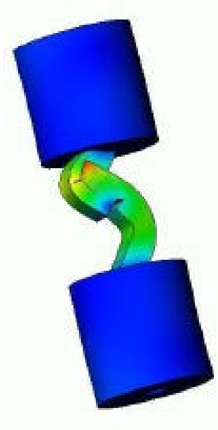
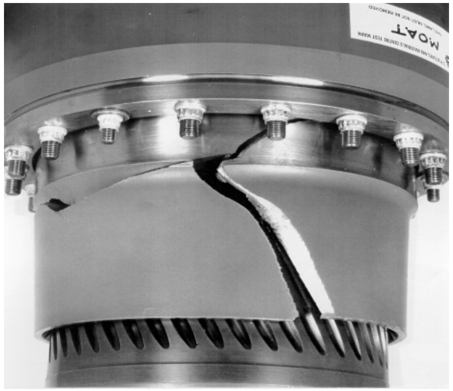
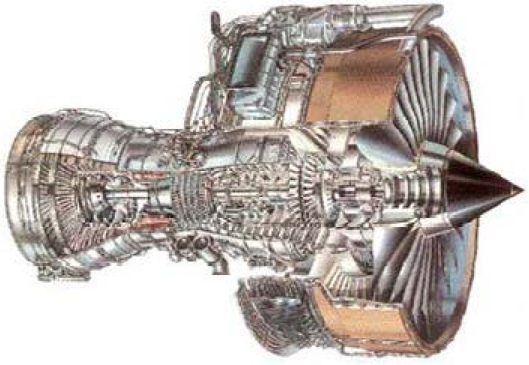
Exceptional service in the national interest







Investigation of Electrical Contact Chatter in Pin-Receptacle Contacts

Students: Brianna Johnson, Chris Schumann, and Fadi Rafeedi

Mentors: Rob Flicek, Kelsey Johnson, Karl Walczak, Cory Medina, Dane Quinn, Benjamin Zastrow, Rob Kuether

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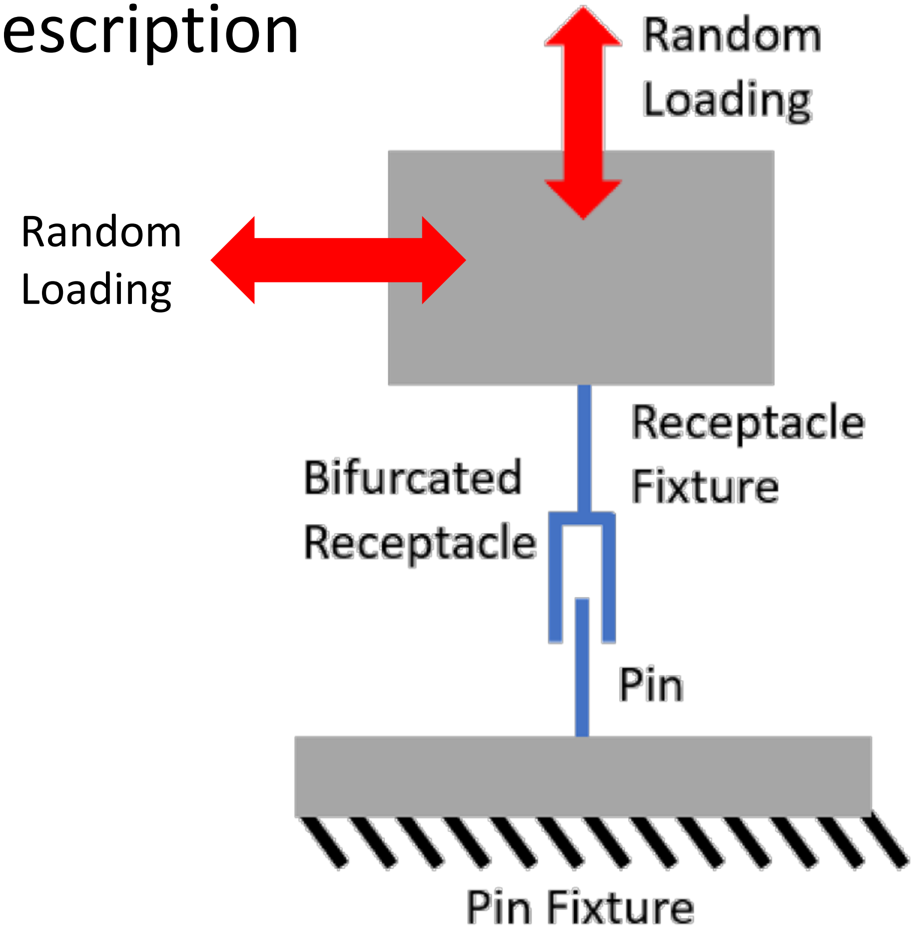
SAND2019-8709 PE

Outline for Presentation

- Motivation & Project Description
- Modal Testing
- Chatter Testing
- Data Processing
- Closing Remarks

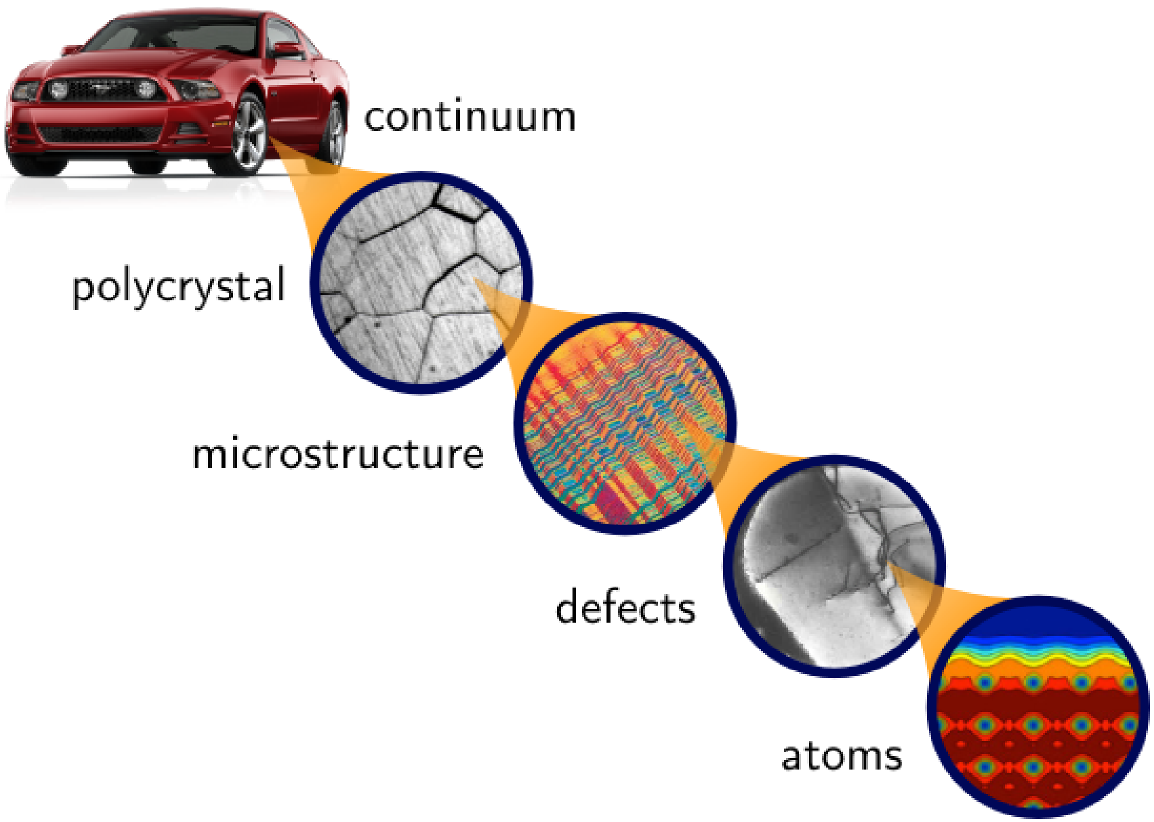


Motivation

- **Electrical contact chatter** refers to the sudden degradation of electrical current flow through a closed circuit
- Generally defined as the electrical resistance of the contact exceeding a threshold for a specified duration of time
  - 150 Ohms for 25 ns for our project
- Observed to occur when electrical contacts are subject to severe **random vibration environments**
- Previous experiments were system level, could not record inputs to pin and receptacle
- **What causes chatter?**
- **How can we predict chatter?**

Chatter is a Multiscale Physics Problem

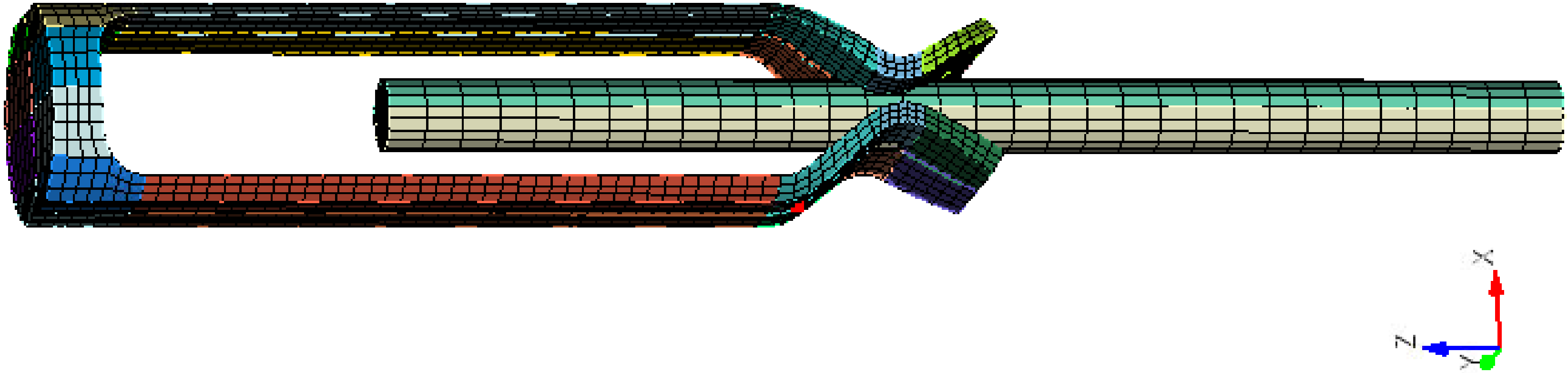
- Component (cm) to surface texture (nm)
- Short timescale (ns)
- Disciplines such as:
  - **Contact mechanics**
  - **Structural dynamics**
  - Tribology
  - Lubrication
  - Electrostatics
  - Etc.



https://solids.uccs.edu/images/multiscale.png

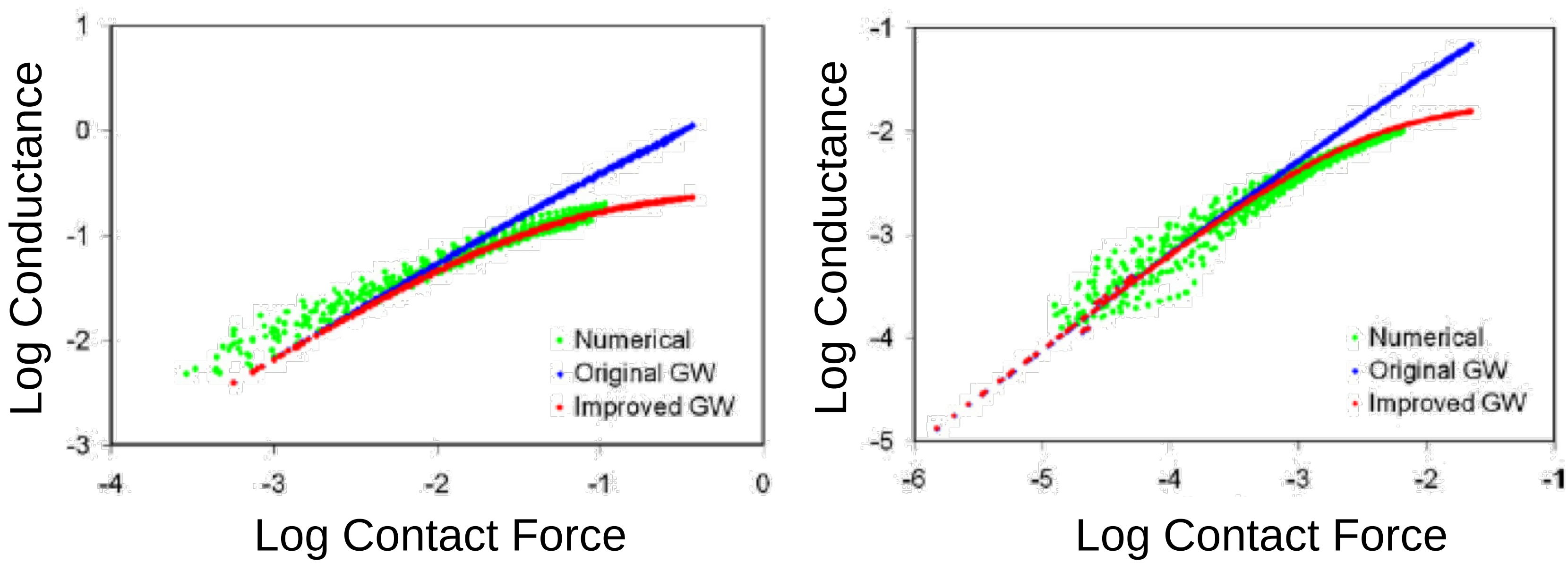
Computational Contradictions

- Detailed contact mechanics models are often **quasi-static**
- Chatter is a **high frequency dynamic** event
- Balance between critical timestep and a mesh fine enough to accurately capture contact



Contact Force to Contact Resistance

- Linear relationship between contact force and contact resistance (Ciavarella, et al., 2008)

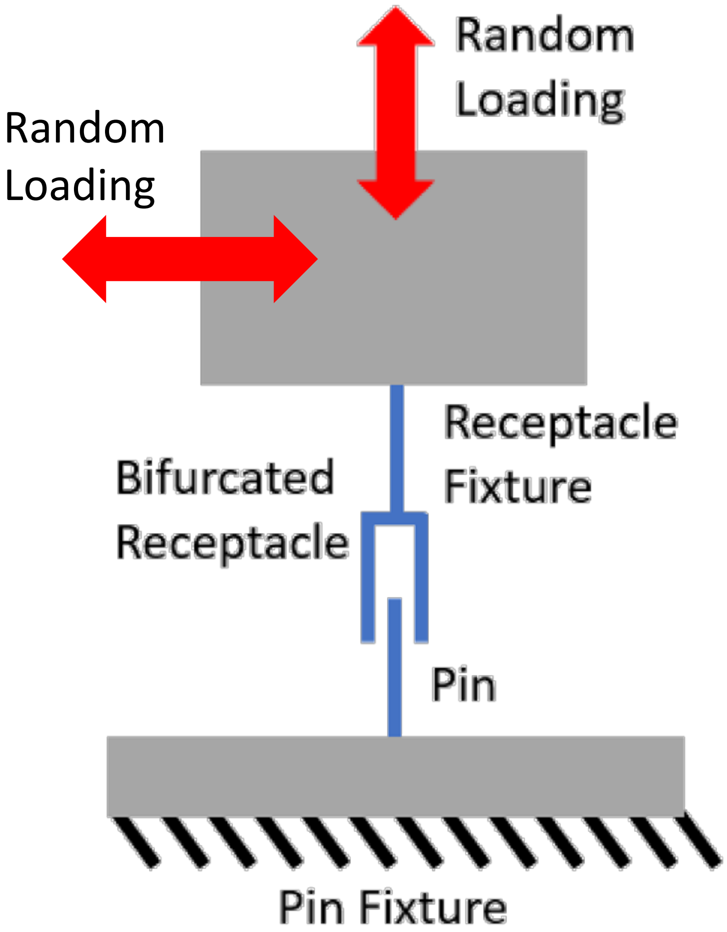


Ciavarella, et al., Inclusion of “interaction” in the Greenwood and Williamson contact theory 2008

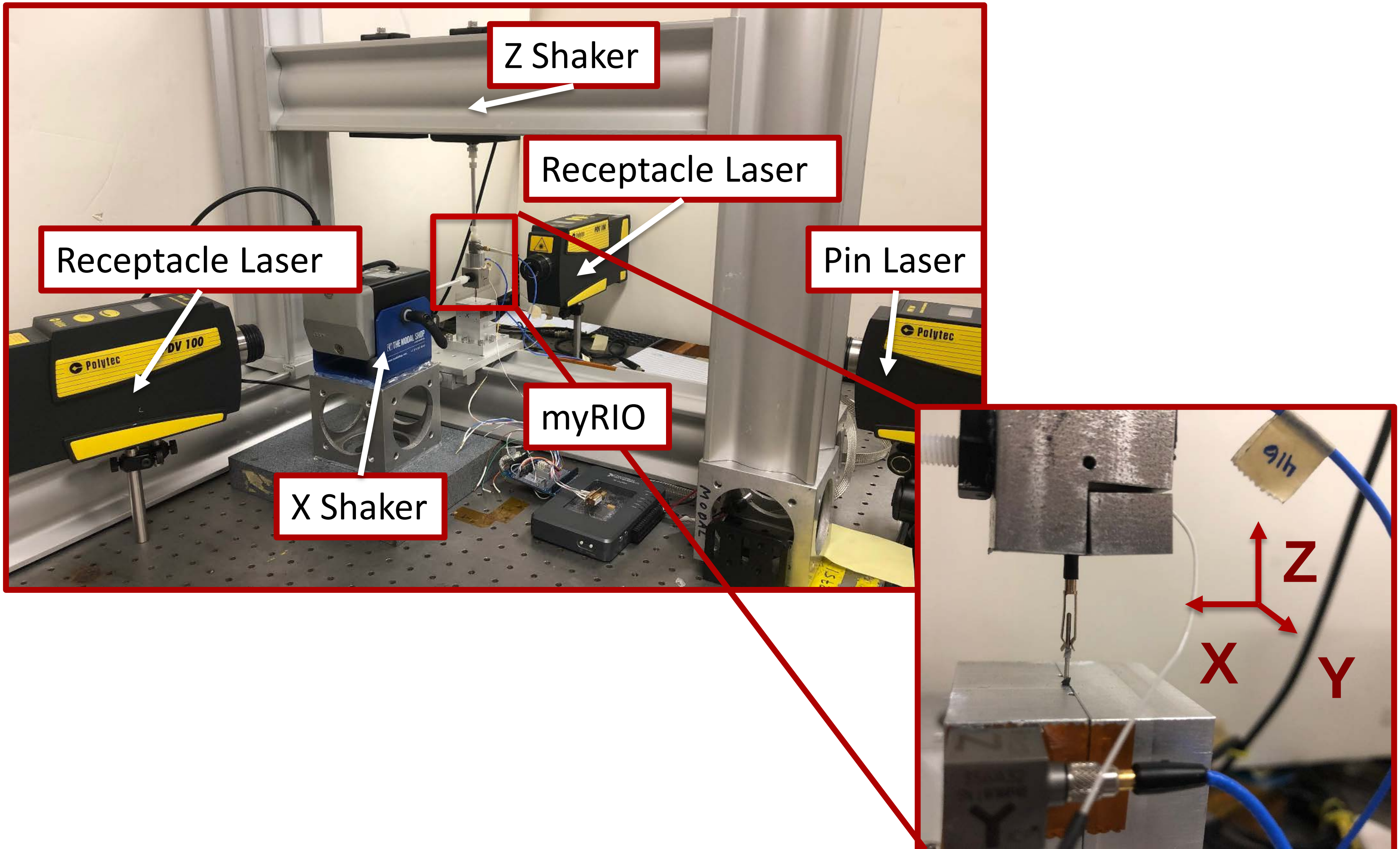
- Use contact force as a metric of chatter to correlate events between test and FEM

Project Objectives

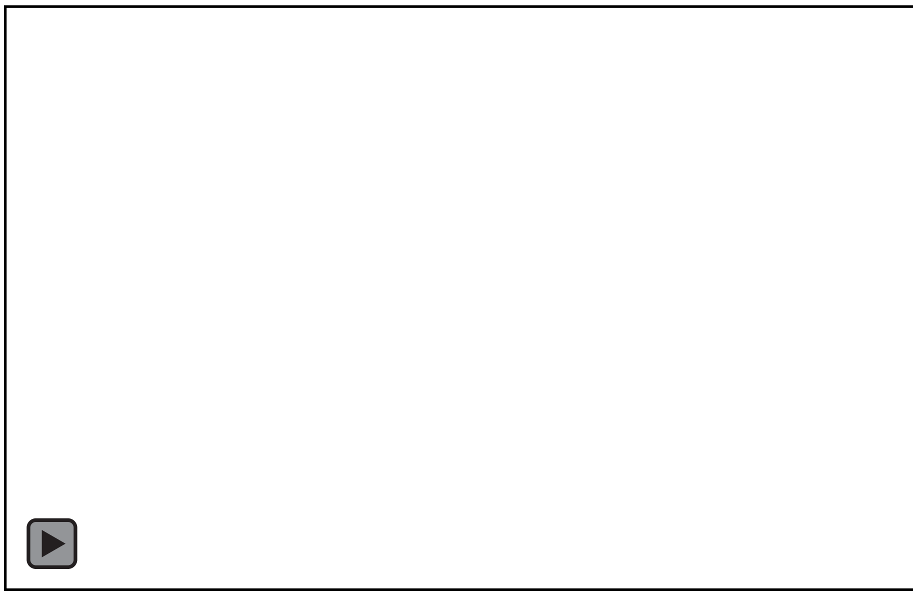
- **Goal: To perform a fundamental investigation of the physics governing chatter using a single electrical circuit with contact between a pin and a bifurcated receptacle**
- Tasks
  - Modal tests of parts and assembly
  - Record chatter from random vibration environments
  - Create FEM to simulate test results
  - Study relationship between system inputs and chatter



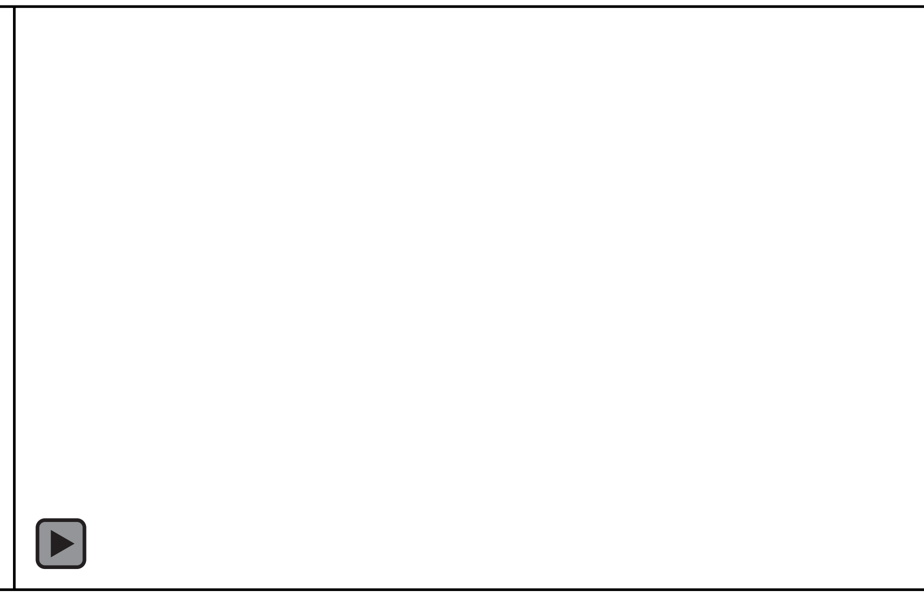
Test Setup - Mechanical



Modal Testing



Mode 1: 758 Hz

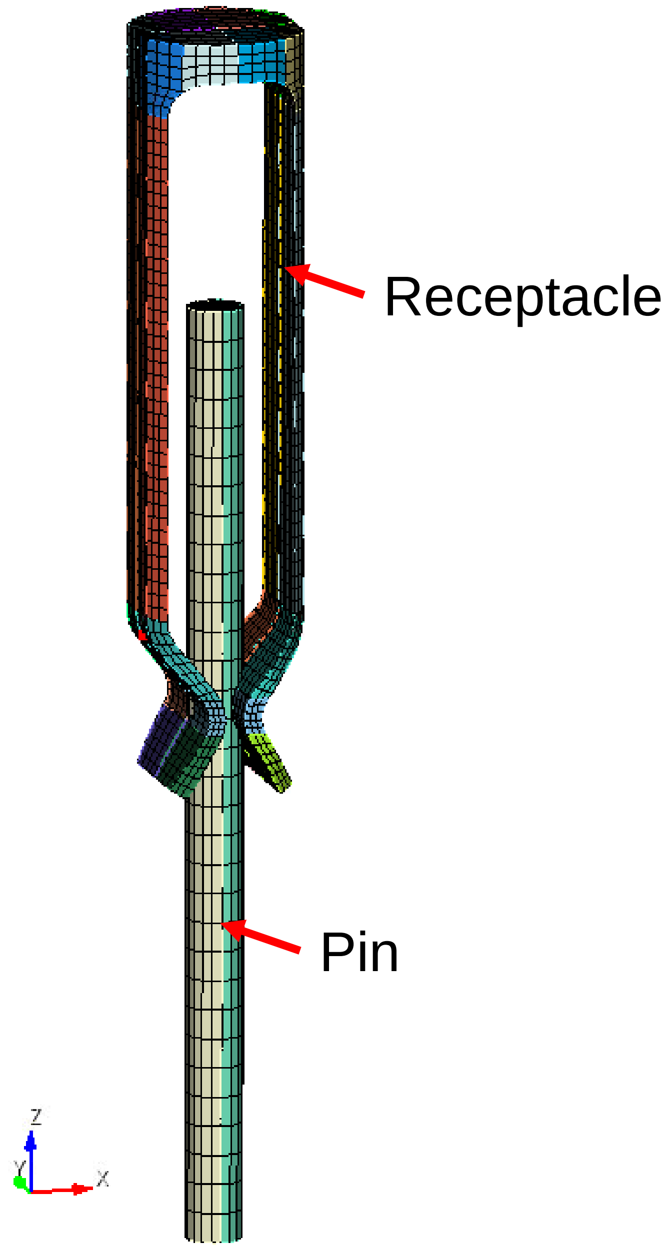


Mode 2: 780 Hz

Finite Element Model

- Geometry
  - Pin: created in cubit, simple shape
  - Receptacle: uploaded from manufacturer file

- Mesh:
  - Low element count (5k) to reduce runtime
  - Coarse pin model to reduce artificial chatter



Receptacle Updating

Test Natural Frequencies 758Hz & 780Hz → Sensitivity of FEM Frequencies to Material Props → Finite Difference Updating of FEM

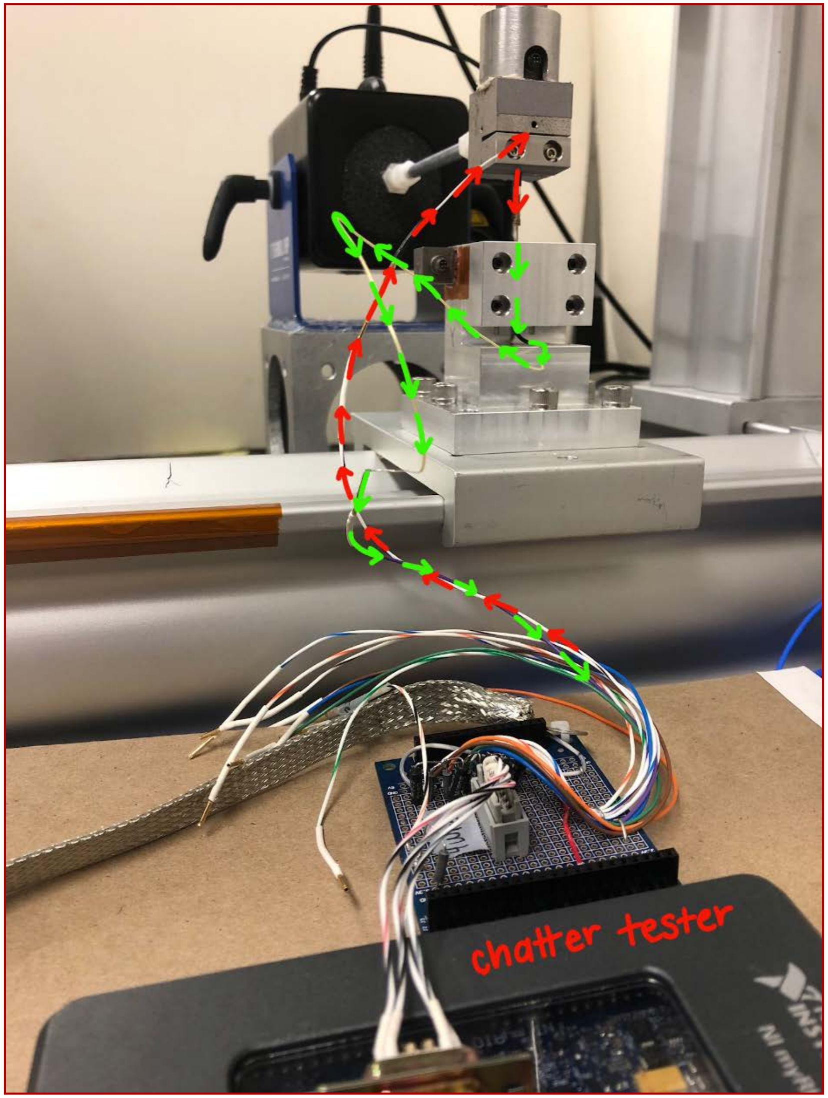
Receptacle Mode 1

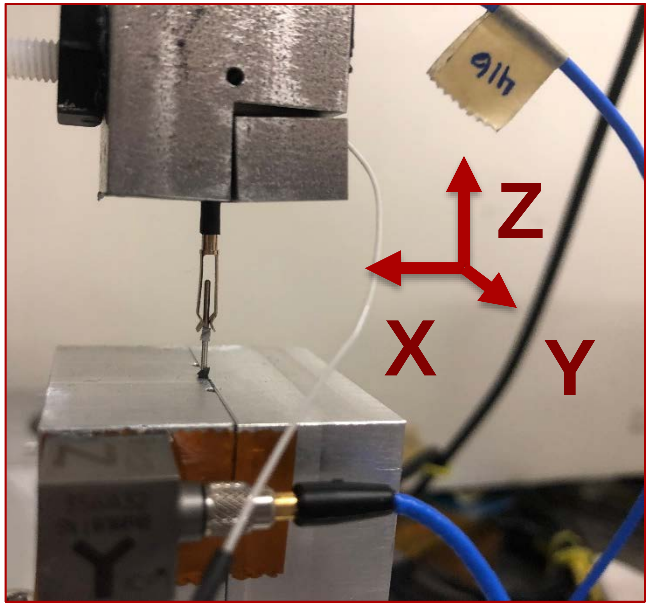
Mode Description	Experimental Frequency [Hz]	Updated FEM Frequency [Hz]	% Error
In-phase 1st bending mode	757.7	770.3	1.66%

Receptacle Mode 2

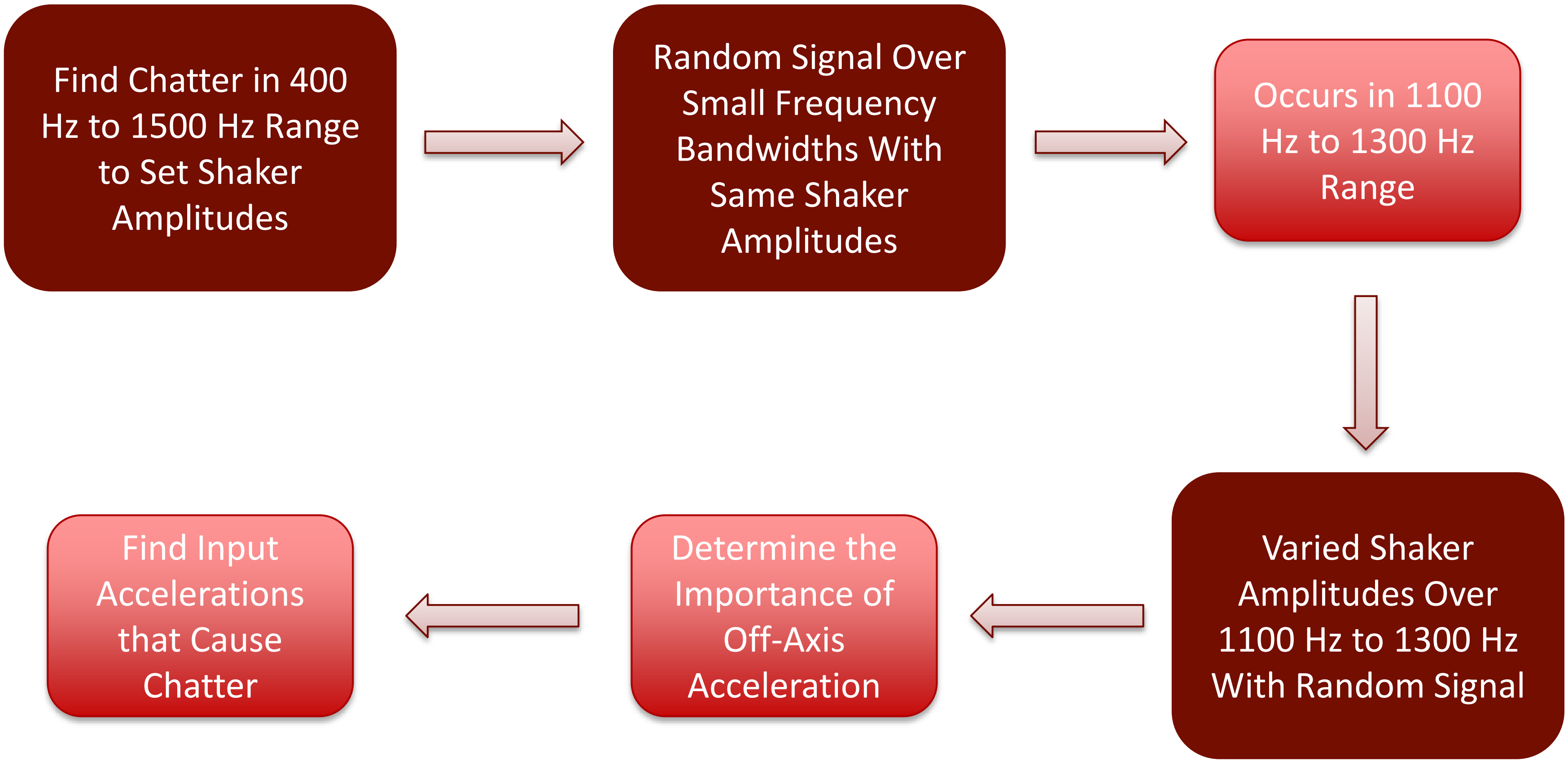
Mode Description	Experimental Frequency [Hz]	Updated FEM Frequency [Hz]	% Error
Out-of-phase 1st bending mode	780.0	770.4	-1.24%

Test Setup - Electrical

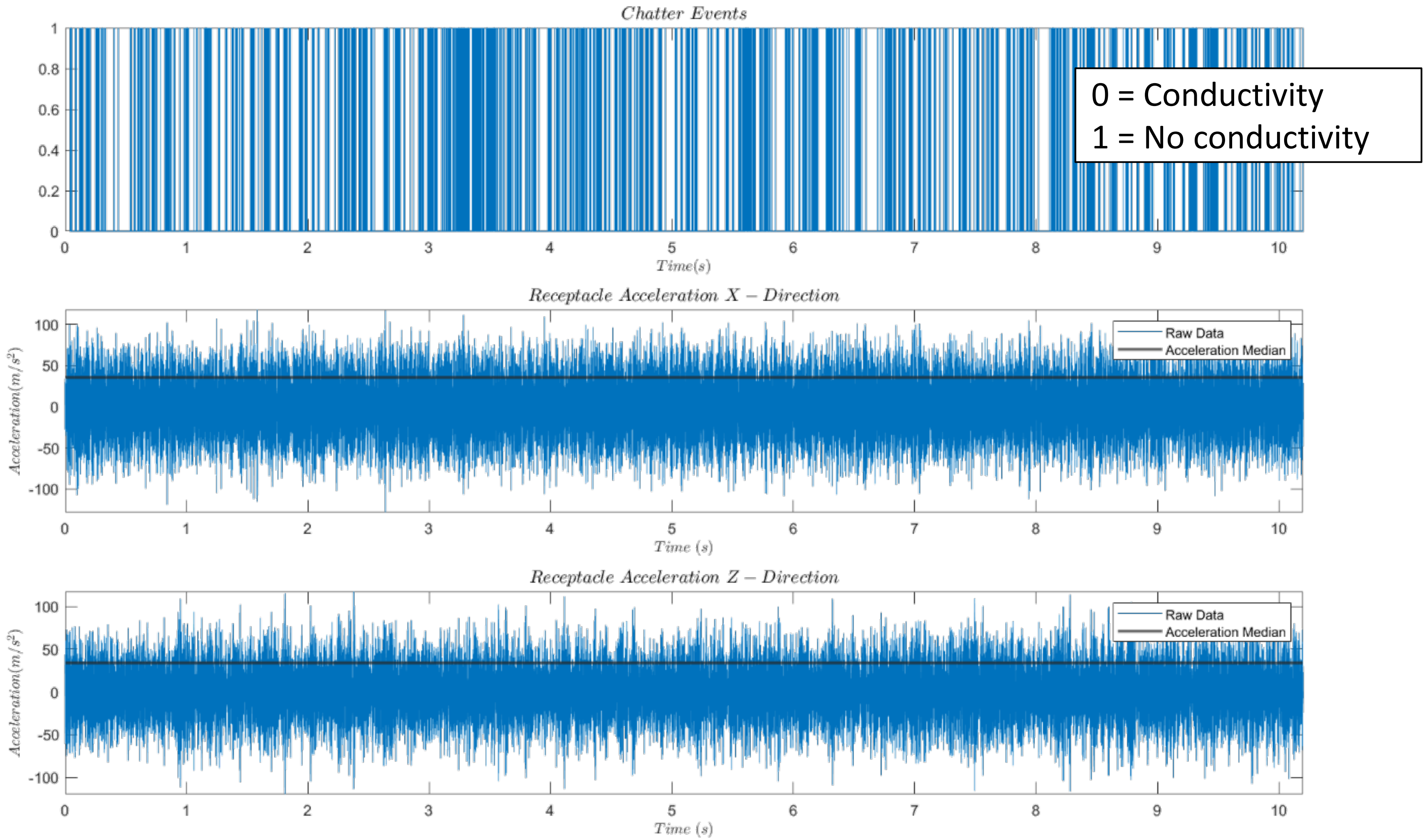




Chatter Test Experimental Design

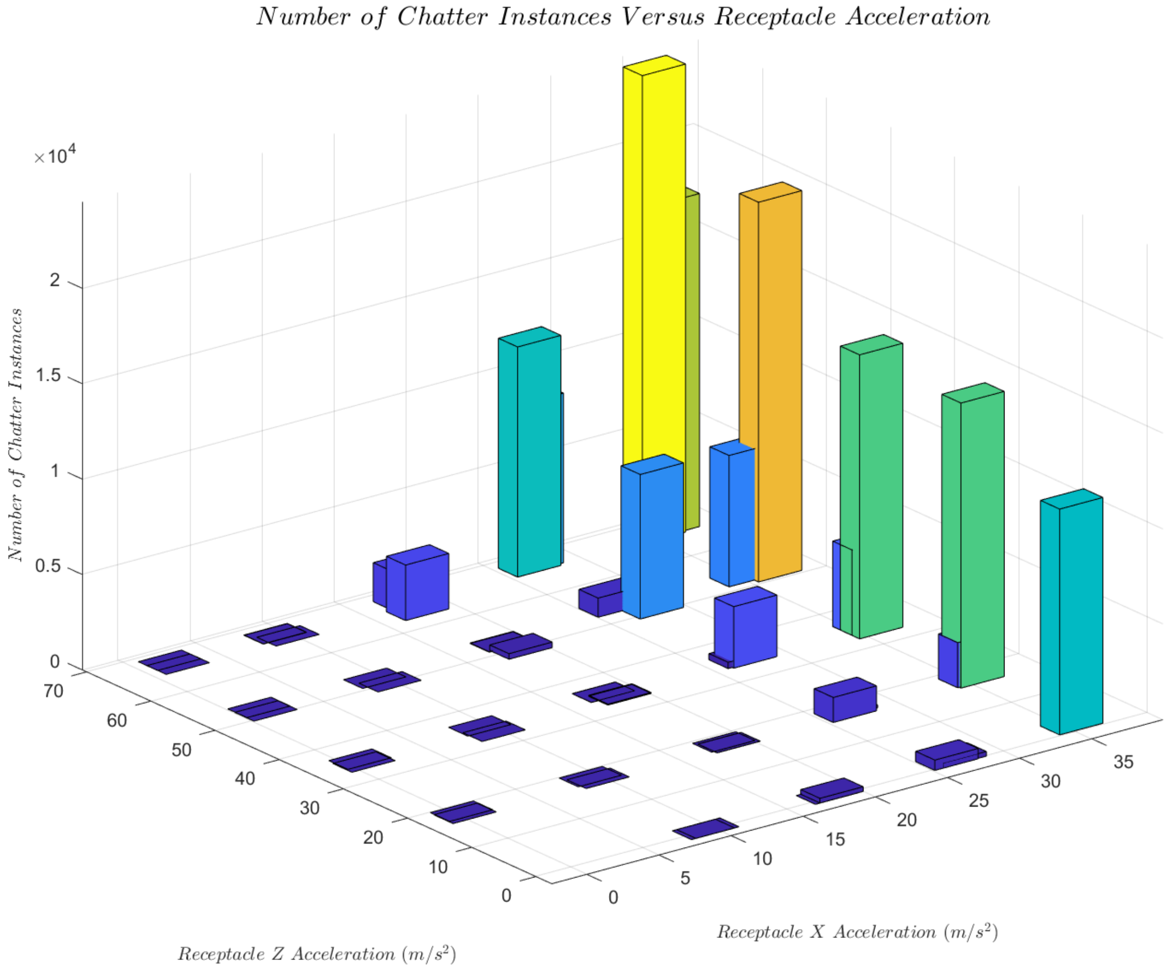


Raw Test Data



Analysis Across Multiple Runs

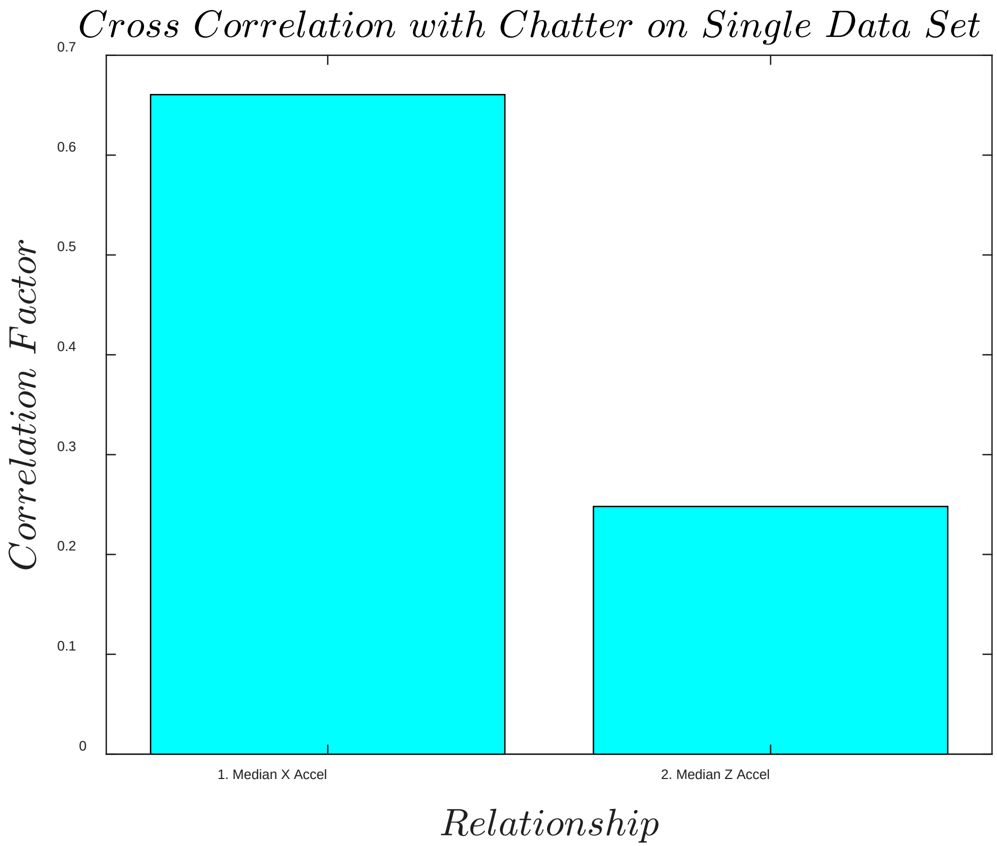
Combination of Accelerations for Chatter



Chatter requires Off-Axis Excitation to occur

The most chatter occurs with maximum X and Z Acceleration

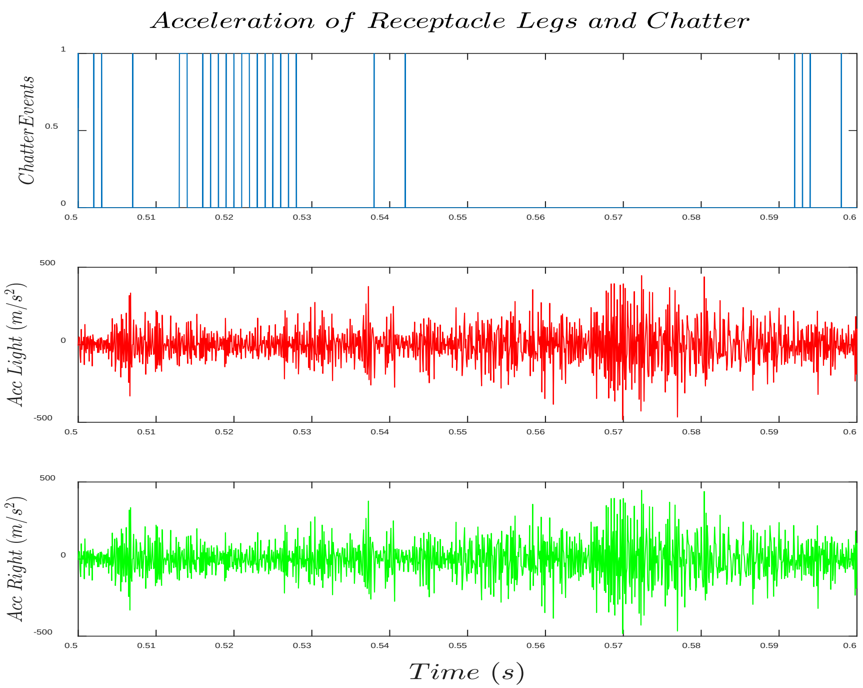
Correlation of Accelerations to Chatter Across Multiple Data Sets



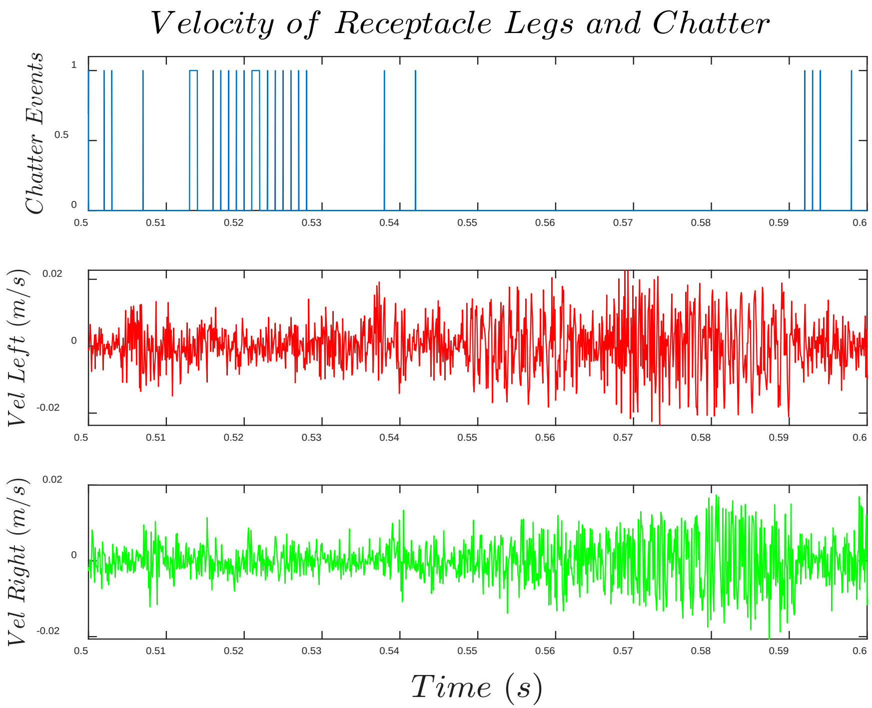
- Cross correlation between chatter and multiple variables was calculated.
- This compares which variables correlate to chatter more.

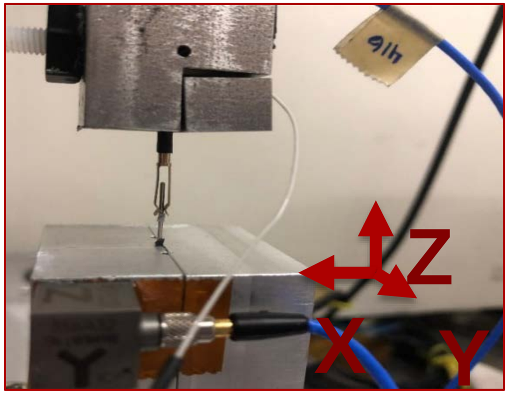
Analysis Across Single Sets

Acceleration and Velocity of Receptacle Legs (Outputs)

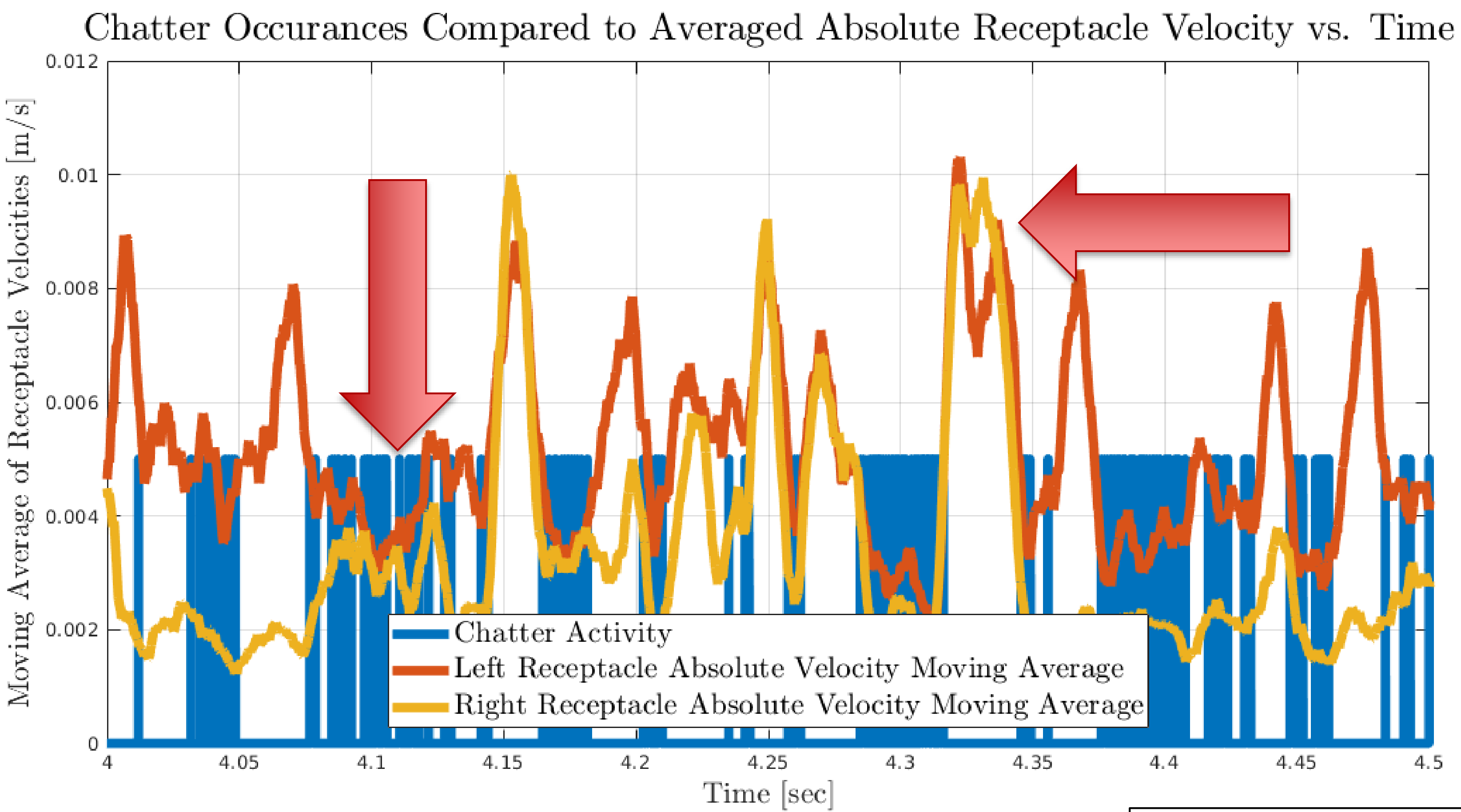


0 = Conductivity
1 = No conductivity



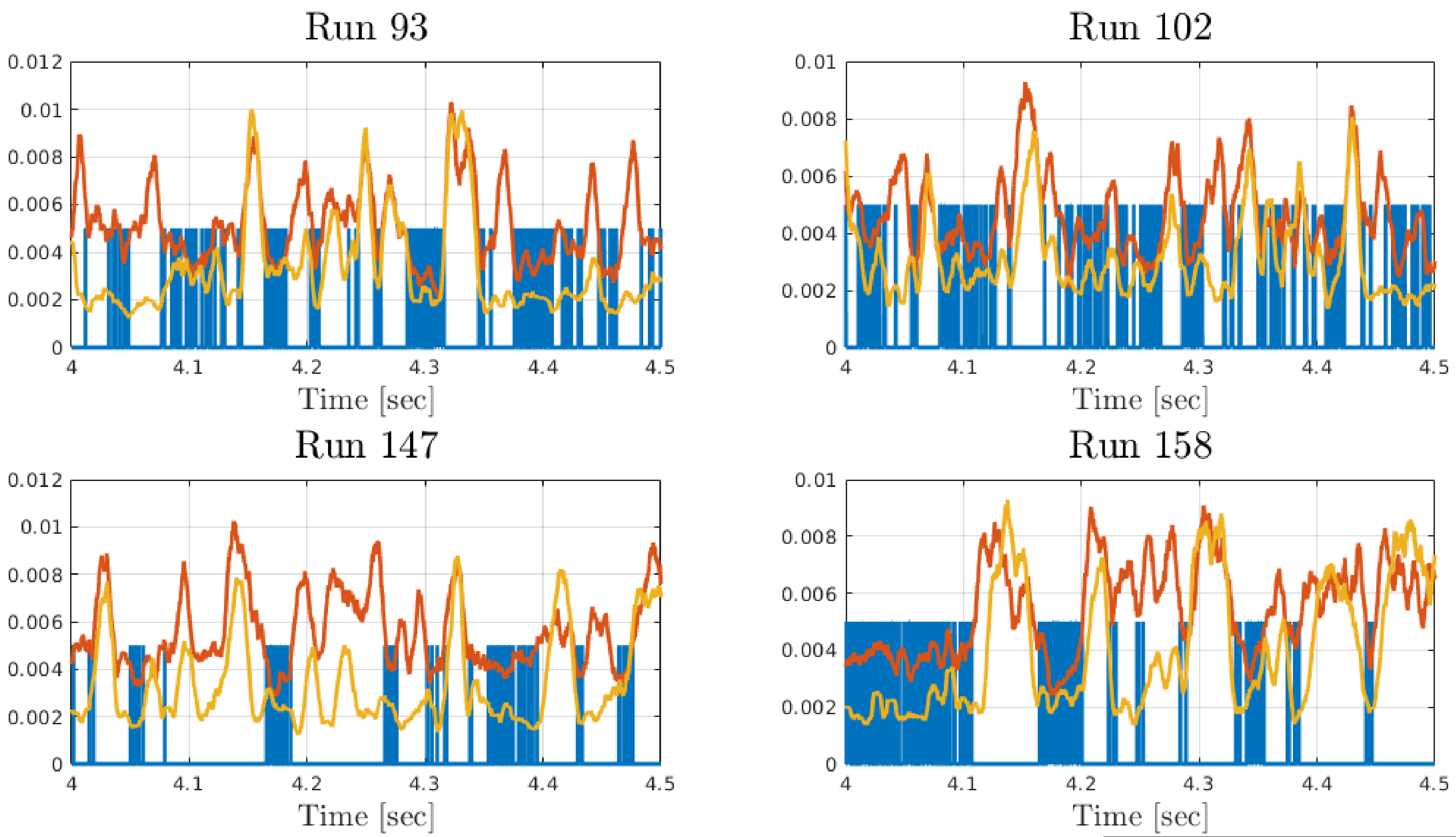


Receptacle Velocity to Chatter



0.0 = Conductivity
0.005 = No conductivity

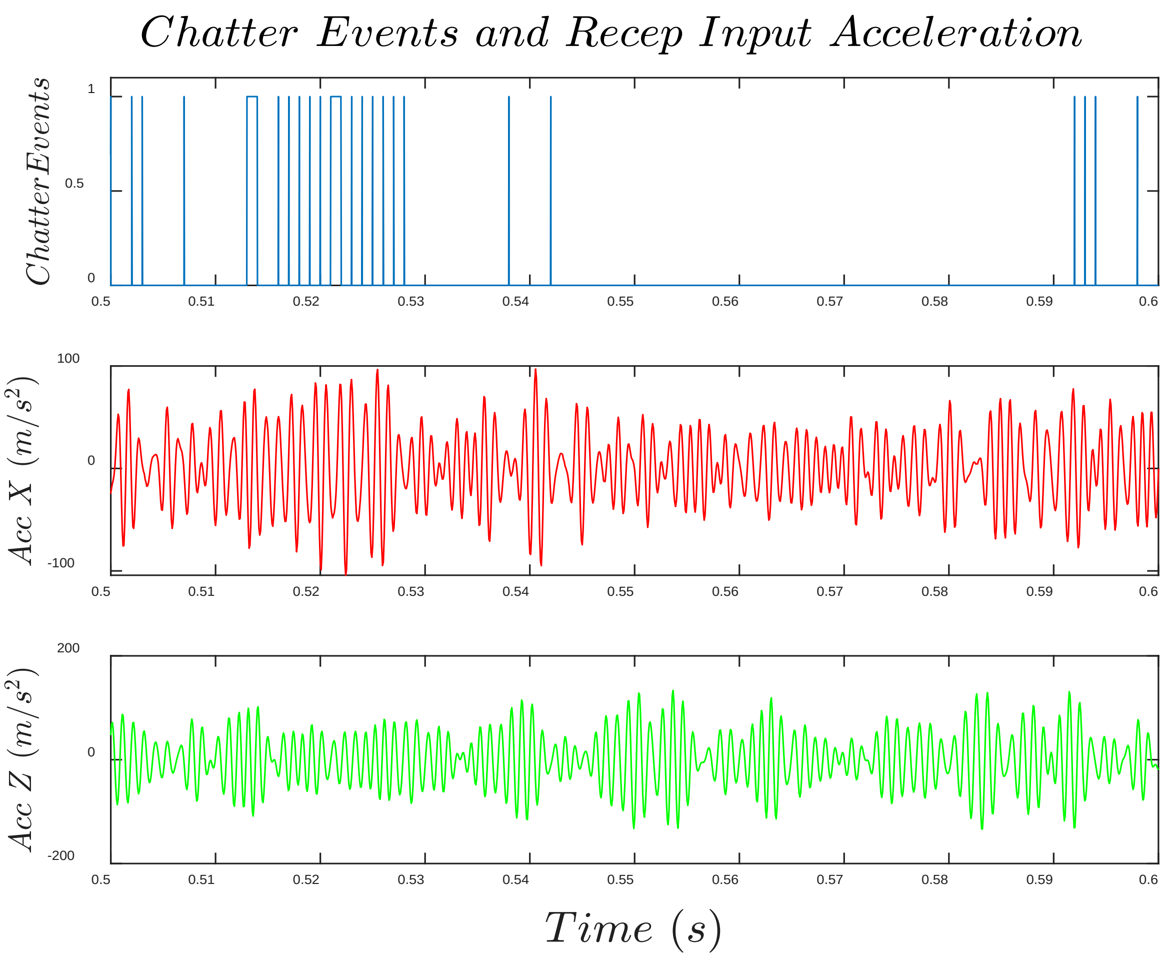
Receptacle Velocity to Chatter

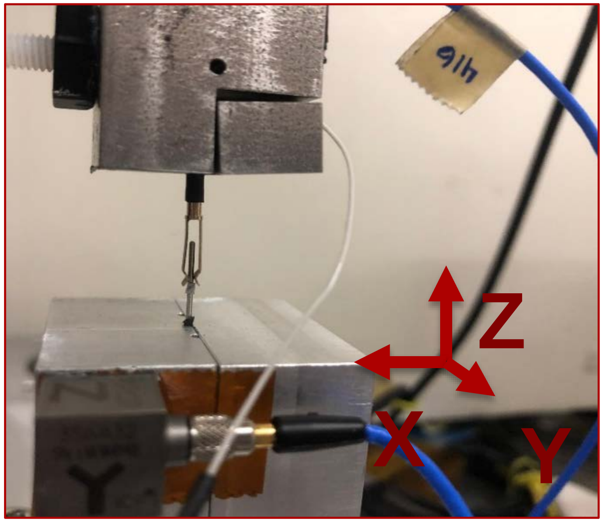


0.0 = Conductivity
0.005 = No conductivity

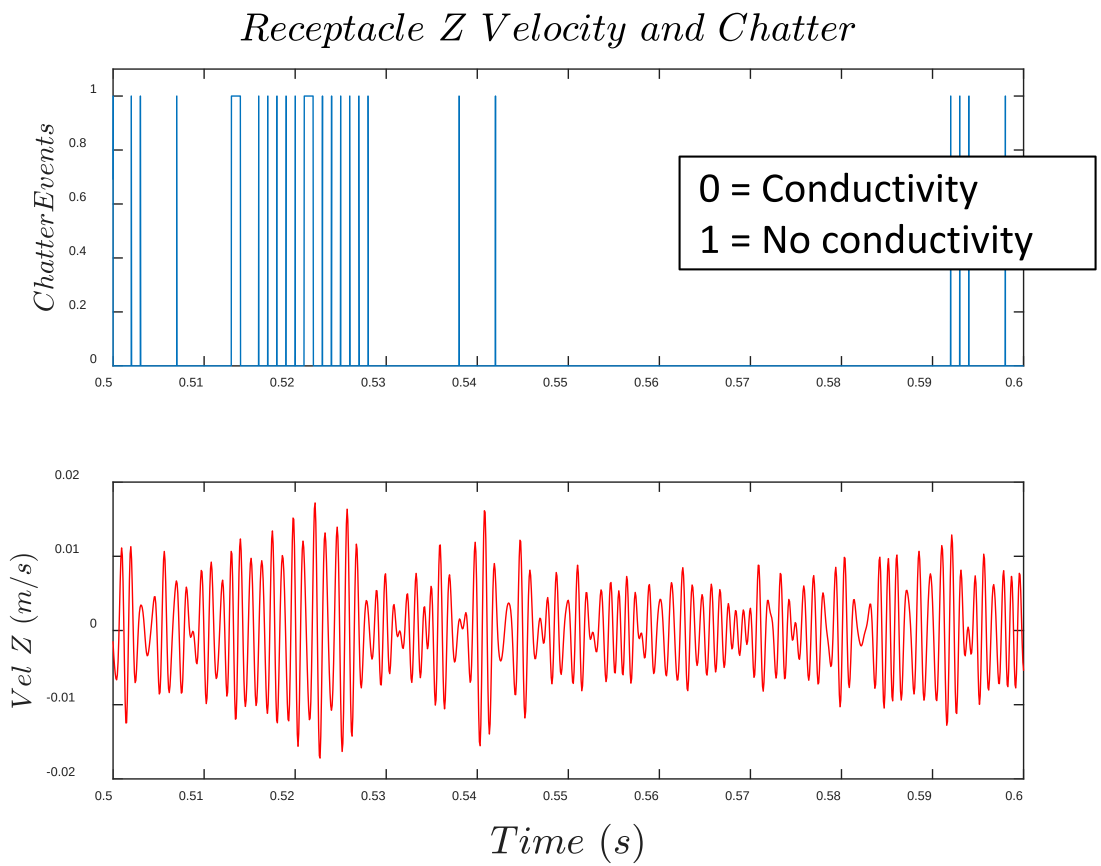
Input Acceleration and Chatter

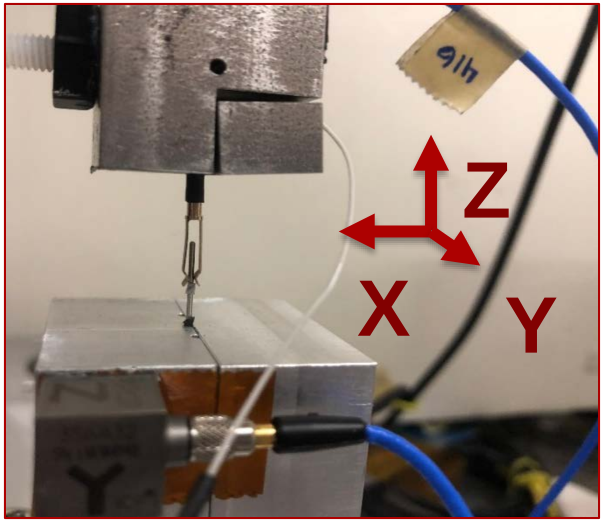
0 = Conductivity
1 = No conductivity



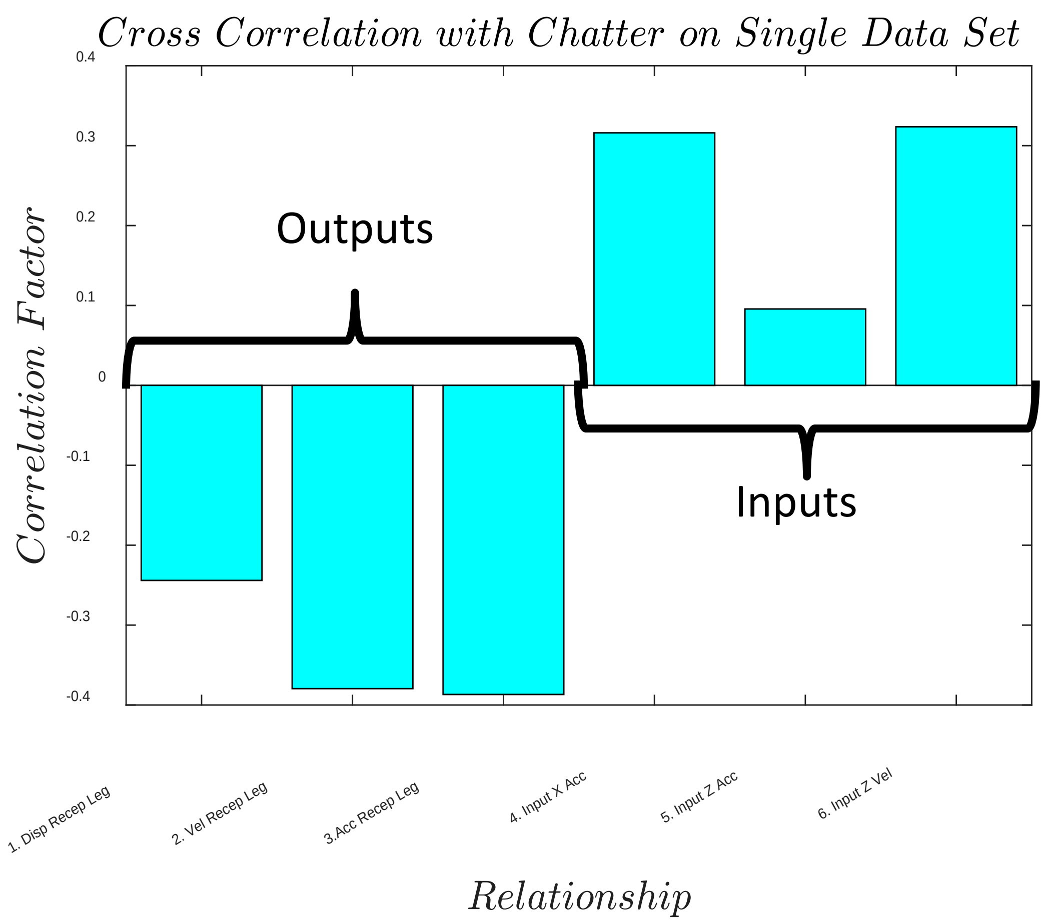


Receptacle Z Input Velocity





Correlation Across a Single Set

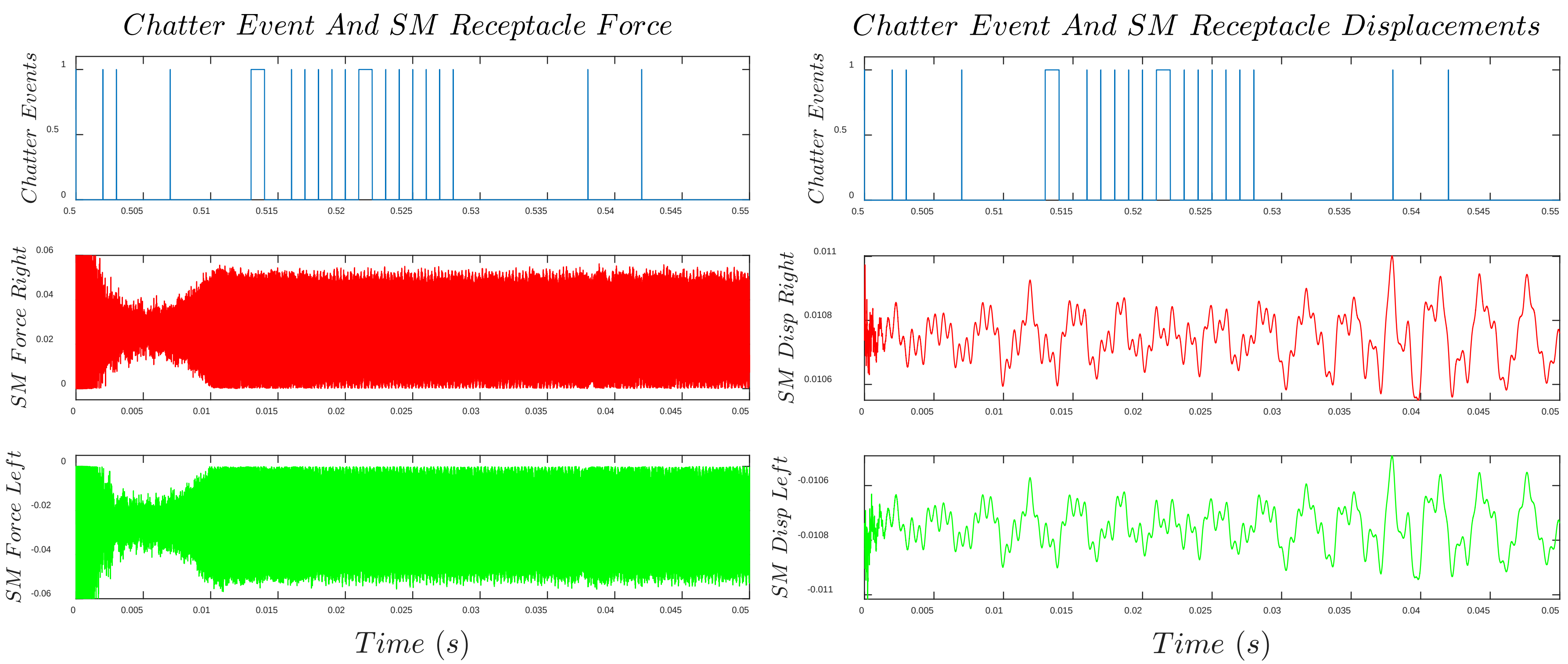


- Cross correlation between chatter and multiple variables was calculated.
- This compares which variables correlate to chatter more.

SM Analysis Results

SM Response to Experimental Inputs

SM Receptacle Displacement to Chatter



0 = Conductivity
1 = No conductivity

Challenges and Limitations

- Lasers
  - Did not use reflective tape in order to keep accurate system dynamics
  - Time delay between laser data and accelerometer
- Chatter Tester
  - LMS channels sample at 204.8 kHz per channel
  - Chatter Tester samples at 40 MHz
- System Mode around 1300 Hz
  - Appeared to be the same area where chatter occurred most
- Same Inputs – Different Results

Closing Remarks

- Ran the first chatter test to obtain acceleration inputs to pin and receptacle
- Created explicit dynamic and linear transient models of pin and receptacle that can use accelerometer data as inputs to simulate test
- Found a high correlation between off-axis motion and chatter occurrence over multiple runs
- Continued work is being done to process data and correlate FEM model to test data

Acknowledgements

- This research was conducted at the 2019 Nonlinear Mechanics and Dynamics Research Institute supported by Sandia National Laboratories and hosted by the University of New Mexico.

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