Investigation of Electrical Contact Chatter in Pin-Receptacle Contacts

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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)

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

Introduction
Motivation
Modal
Chatter
Data
Conclusion
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

<table>
<thead>
<tr>
<th>Mode Description</th>
<th>Experimental Frequency [Hz]</th>
<th>Updated FEM Frequency [Hz]</th>
<th>% Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>In-phase 1&lt;sup&gt;st&lt;/sup&gt; bending mode</td>
<td>757.7</td>
<td>770.3</td>
<td>1.66%</td>
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</tbody>
</table>
# Receptacle Mode 2

<table>
<thead>
<tr>
<th>Mode Description</th>
<th>Experimental Frequency [Hz]</th>
<th>Updated FEM Frequency [Hz]</th>
<th>% Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Out-of-phase 1\textsuperscript{st} bending mode</td>
<td>780.0</td>
<td>770.4</td>
<td>-1.24%</td>
</tr>
</tbody>
</table>
Test Setup - Electrical

[Image of test setup with labels X, Y, and Z]

chatter tester

[Image of chatter tester setup]

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Chatter Test Experimental Design

Find Chatter in 400 Hz to 1500 Hz Range to Set Shaker Amplitudes

Random Signal Over Small Frequency Bandwidths With Same Shaker Amplitudes

Occurs in 1100 Hz to 1300 Hz Range

Varied Shaker Amplitudes Over 1100 Hz to 1300 Hz With Random Signal

Determine the Importance of Off-Axis Acceleration

Find Input Accelerations that Cause Chatter

Introduction  Motivation  Modal  Chatter  Data  Conclusion
Raw Test Data

0 = Conductivity
1 = No conductivity
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.
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)

**Introduction**

**Motivation**

**Modal Chatter Data**

**Conclusion**

0 = Conductivity
1 = No conductivity

![Acceleration and Velocity Graphs](attachment:image.png)
Receptacle Velocity to Chatter

Chatter Occurrences Compared to Averaged Absolute Receptacle Velocity vs. Time

0.0 = Conductivity
0.005 = No conductivity
Receptacle Velocity to Chatter

Run 93

Run 102

Run 147

Run 158

0.0 = Conductivity
0.005 = No conductivity
Input Acceleration and Chatter

**Chatter Events and Recep Input Acceleration**

- Chatter Events
- Acc X (m/s²)
- Acc Z (m/s²)

**Time (s)**

- 0 = Conductivity
- 1 = No conductivity
Receptacle Z Input Velocity

**Receptacle Z Velocity and Chatter**

- **Chatter Events**
  - 0 = Conductivity
  - 1 = No conductivity

**Vel Z (m/s)** vs. **Time (s)**

Introduction

Motivation

Modal

Chatter

Data

Conclusion
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

Introduction
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SM Receptacle Displacement to Chatter

**Motivation**

**Modal Chatter Data**

**Conclusion**

<table>
<thead>
<tr>
<th>Time (s)</th>
<th>SM Force Left</th>
<th>SM Force Right</th>
<th>Chatter Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.02</td>
<td>0.04</td>
<td>0.06</td>
</tr>
<tr>
<td>0.005</td>
<td>0.04</td>
<td>0.02</td>
<td>0.01</td>
</tr>
<tr>
<td>0.01</td>
<td>0.02</td>
<td>0.04</td>
<td>0.06</td>
</tr>
<tr>
<td>0.015</td>
<td>0.06</td>
<td>0.04</td>
<td>0.01</td>
</tr>
<tr>
<td>0.02</td>
<td>0.04</td>
<td>0.02</td>
<td>0.06</td>
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<tr>
<td>0.025</td>
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<td>0.01</td>
</tr>
<tr>
<td>0.03</td>
<td>0.04</td>
<td>0.02</td>
<td>0.06</td>
</tr>
<tr>
<td>0.035</td>
<td>0.06</td>
<td>0.04</td>
<td>0.01</td>
</tr>
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<tr>
<td>0.045</td>
<td>0.06</td>
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<td>0.01</td>
</tr>
<tr>
<td>0.05</td>
<td>0.04</td>
<td>0.02</td>
<td>0.06</td>
</tr>
</tbody>
</table>

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

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