Electrical Chatter and Modal Response of Pin-Receptacle Contacts

Brandon Furman, Utah State University
Luke Nester, Texas A&M University
Mentors: Rob Fliceck, Rob Kuether, Karl Walczak, Jonel Ortiz
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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
• 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.
• 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.
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


