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Sandia National Laboratories

Investigation of electrical chatter in bifurcated contact receptacles

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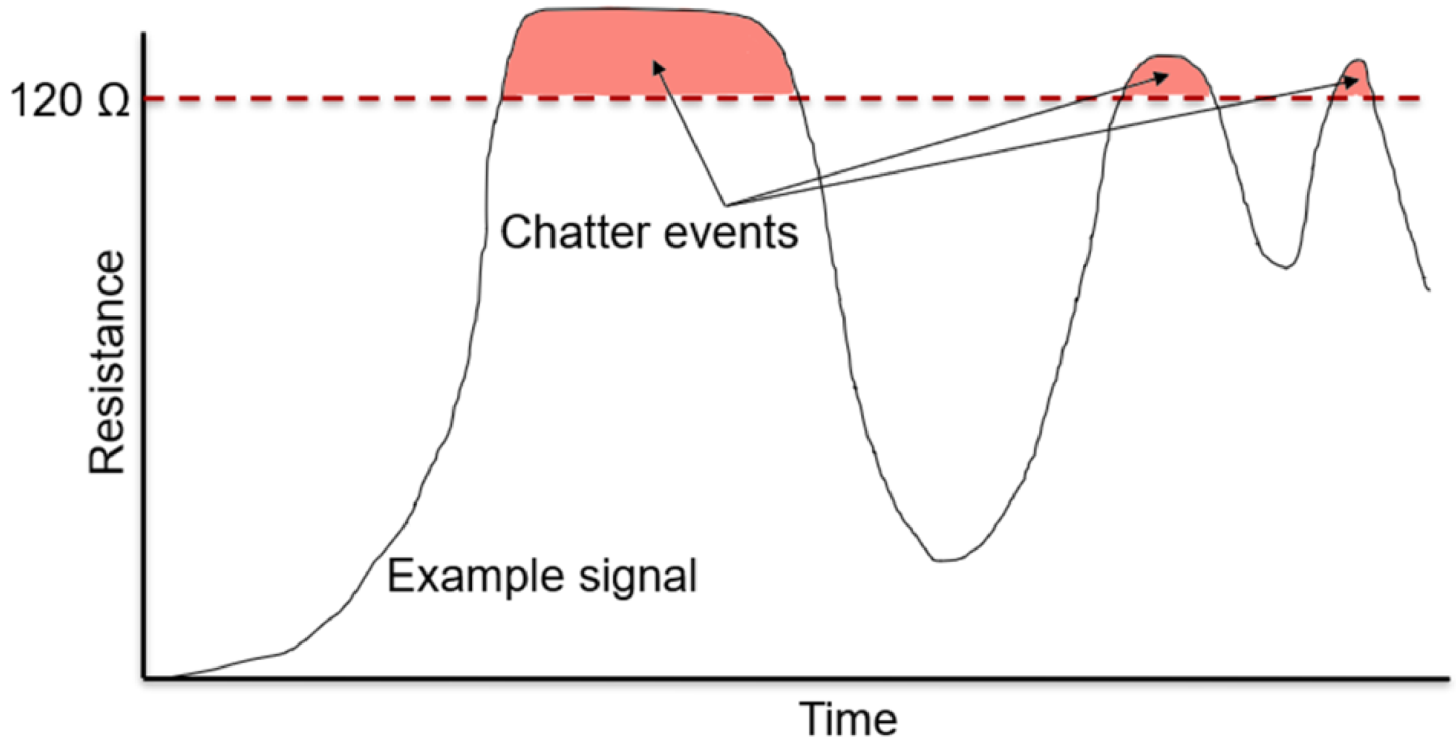
What is electrical chatter?

Chatter is the sudden increase in a switch's electrical resistance above a specified threshold

Chatter can corrupt or prevent the transmission of electrical signals, an issue of particular concern in many aerospace and transportation applications



How do we typically address chatter?

Apply a random vibration environment and measure electrical resistance

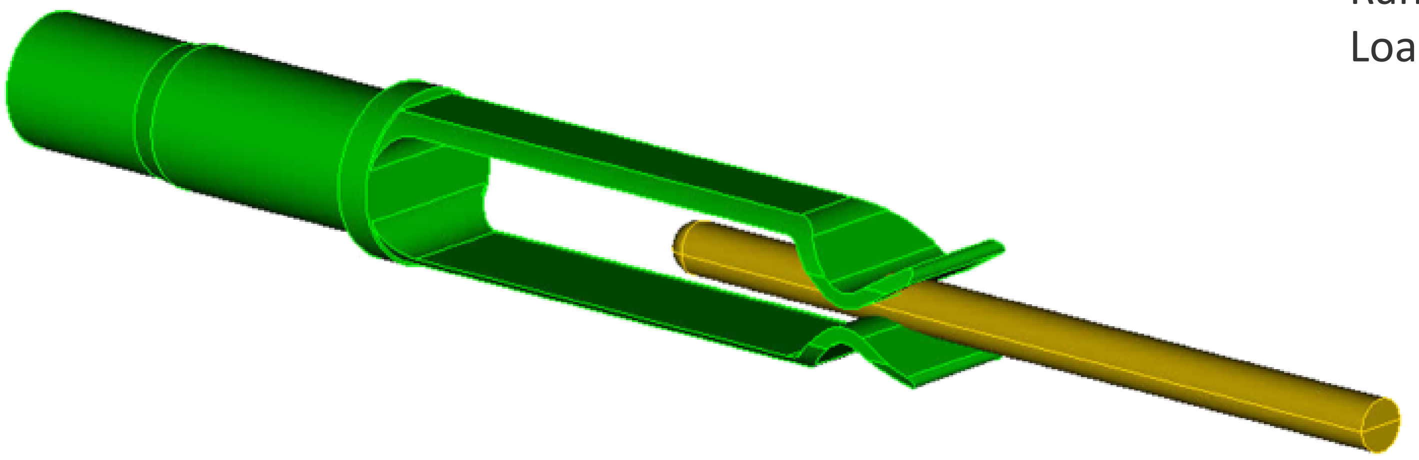
Some numerical approaches have been attempted, such as a Craig-Bampton reduction method by Krishna and Padmanabhan, but none have been successful at representing the full dynamic behavior

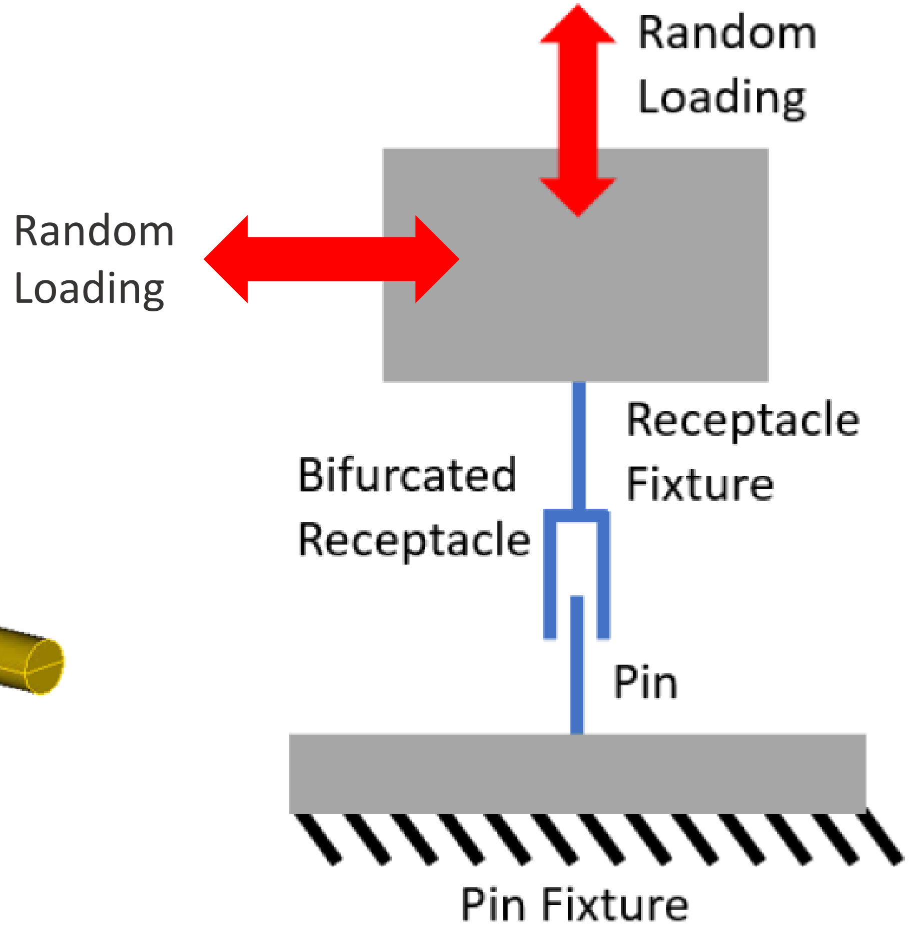
The lack of numerical methods stems from the difficulty of simulating severe nonlinearities and dynamic environments simultaneously

I. R. P. Krishna and C. Padmanabhan, "Experimental and numerical investigations of impacting cantilever beams part 1: first mode response." Nonlinear Dynamics, vol. 67, no. 3, pp. 1985-2000, 2012.

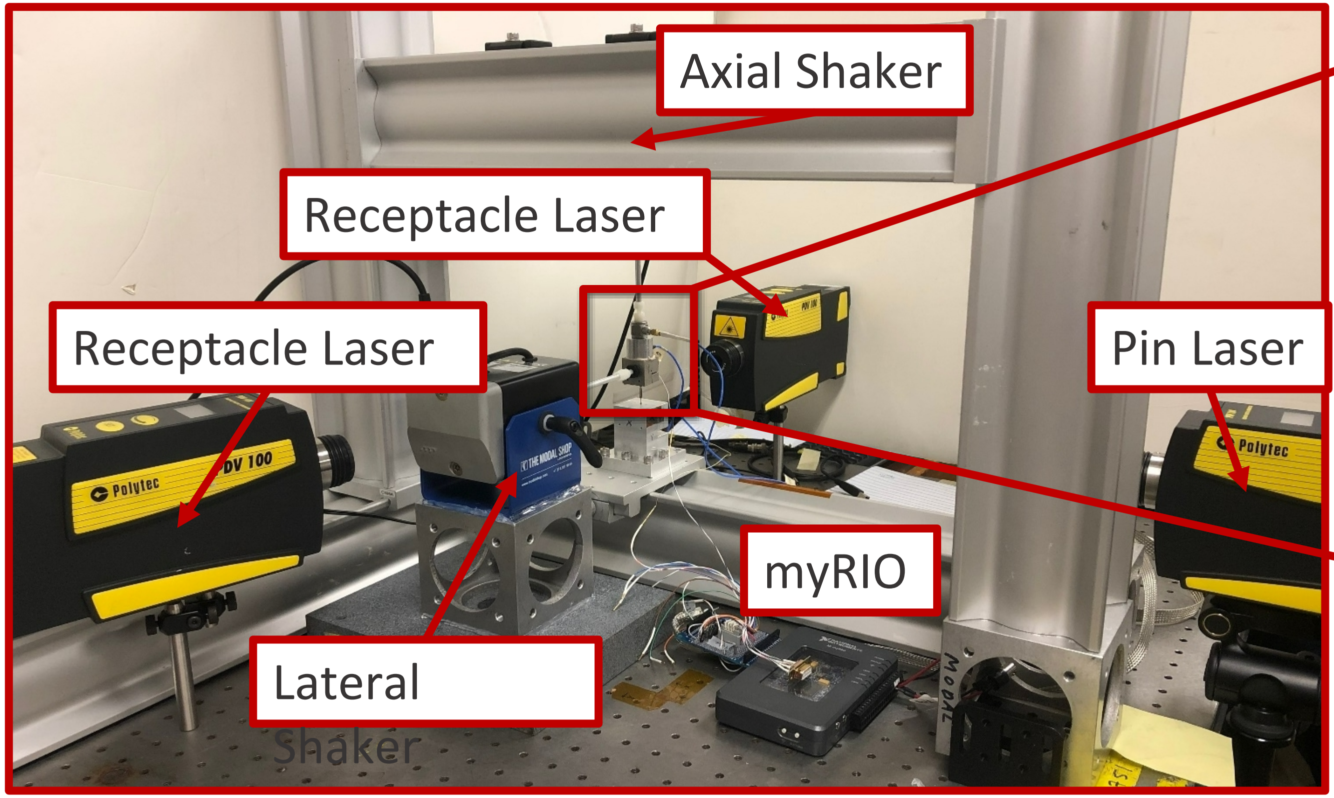
Testing performed during NOMAD Institute

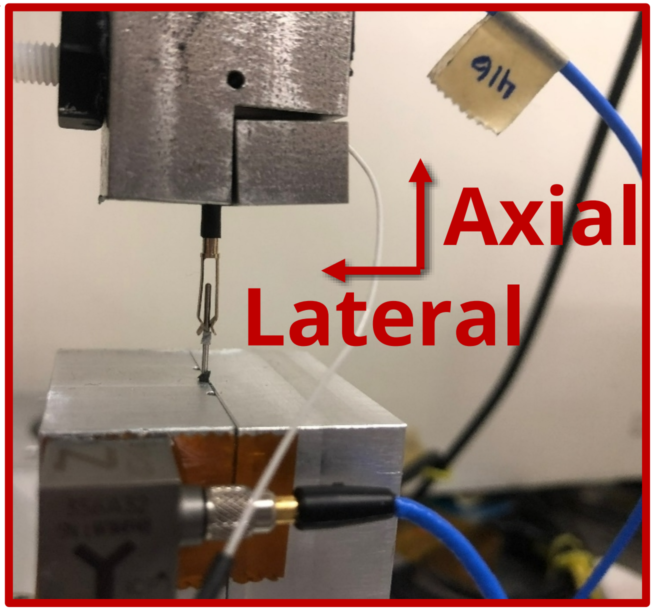
During the 2019 Nonlinear Mechanics and Dynamics Institute at Sandia National Laboratories, a bifurcated receptacle – pin contact pair was used to study chatter





Test setup





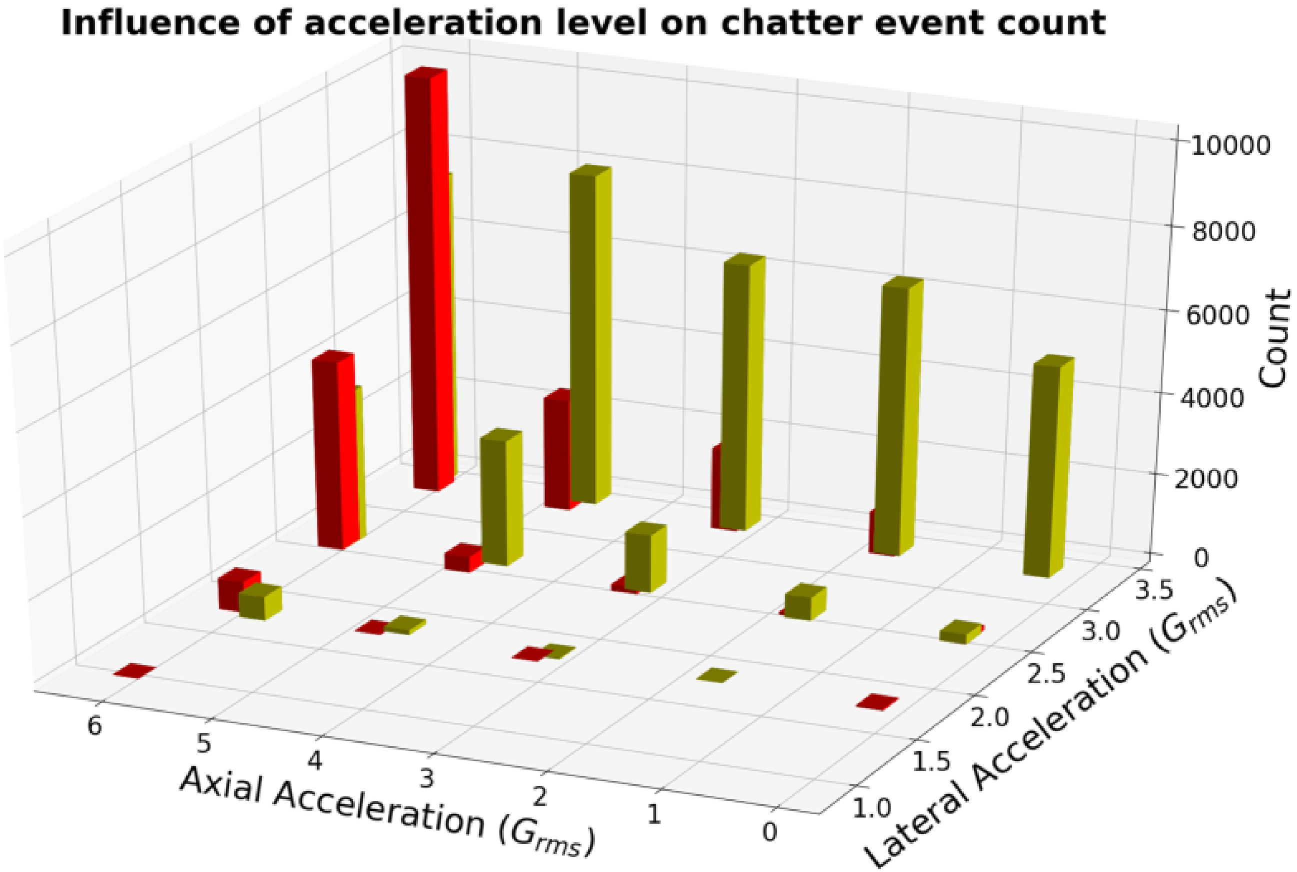
Scoping tests:

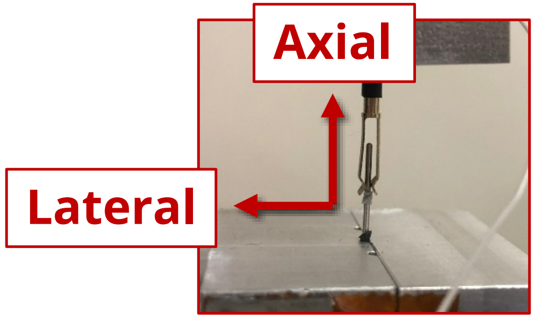
- Band-limited random vibration environments across frequencies from 100-1,500 Hz were used to determine the optimal environment for generating chatter
- 1100-1300 Hz environments were observed to generate the most chatter, and therefore all subsequent random vibration tests were performed in that frequency range

Relationship between excitation amplitude and chatter

Completed 72 random vibration tests (0-6 G_{rms} axially and 0-3 G_{rms} laterally)

Lateral excitation dictates the chatter behavior

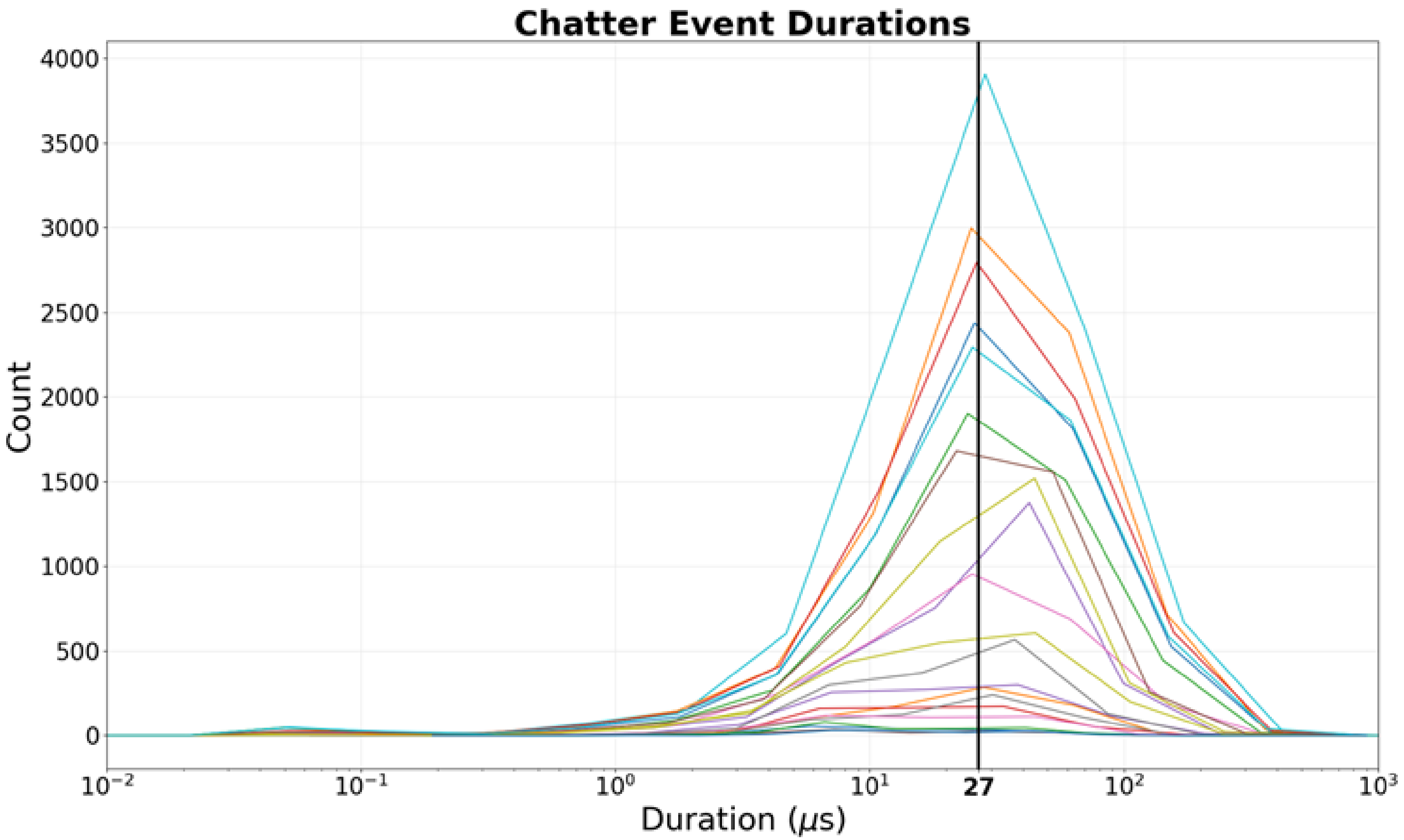




Statistical distribution of chatter event durations

Median chatter event duration is ~27μs

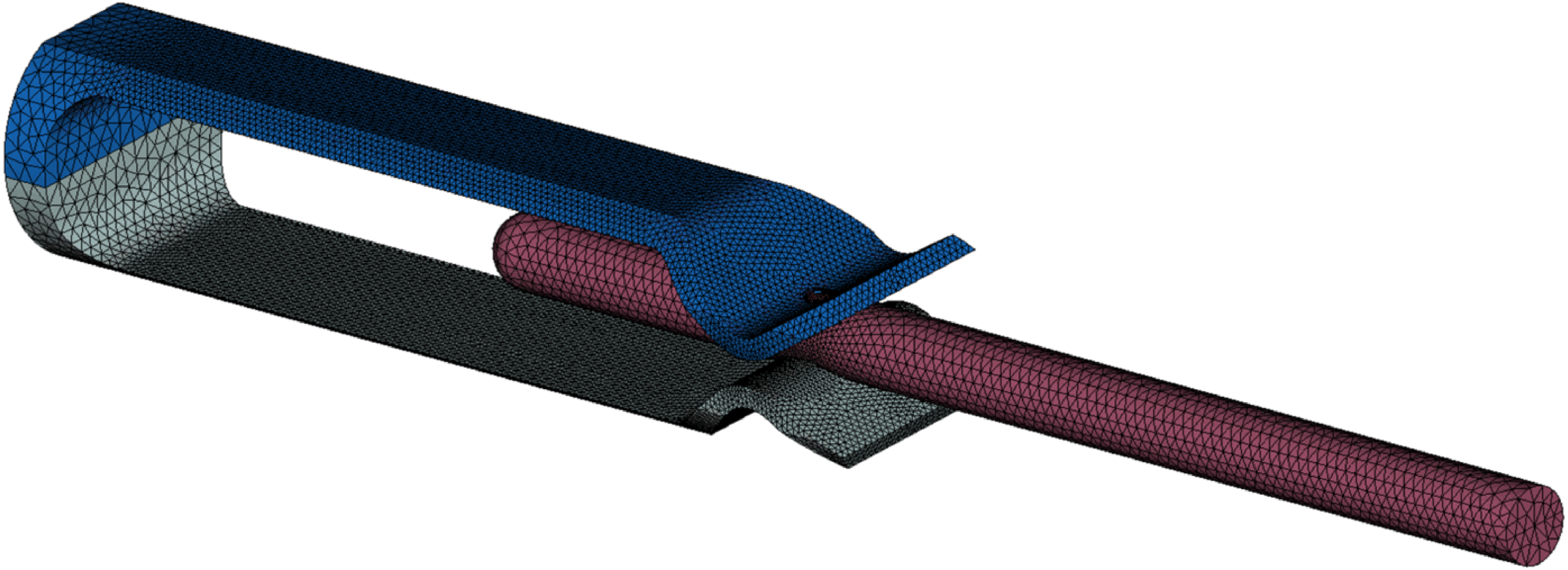
Chatter durations are log-normally distributed



Finite element model

210,000 elements

10-noded composite tetrahedral formulation

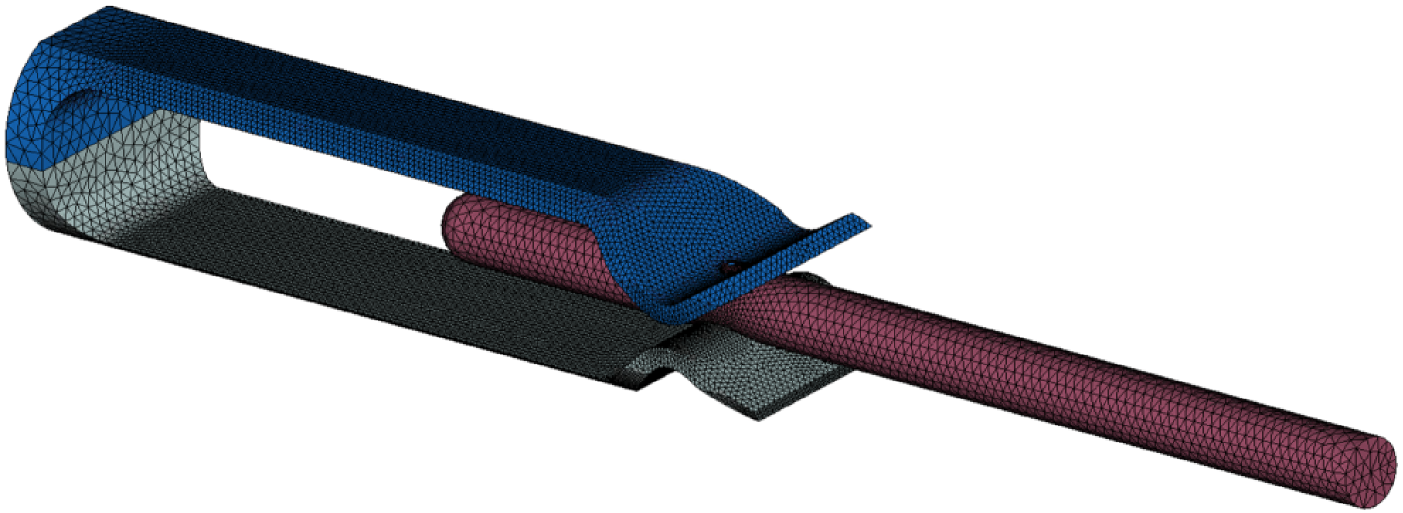


Choice of finite element solver

Structural dynamics models rely on rigorous linear assumptions

Explicit solid mechanics models tend to have small timesteps dictated by the size of their smallest element, often leading to prohibitive computational expense

Implicit solid mechanics models are capable of both representing strongly nonlinear behavior AND performing at reasonable computational expense

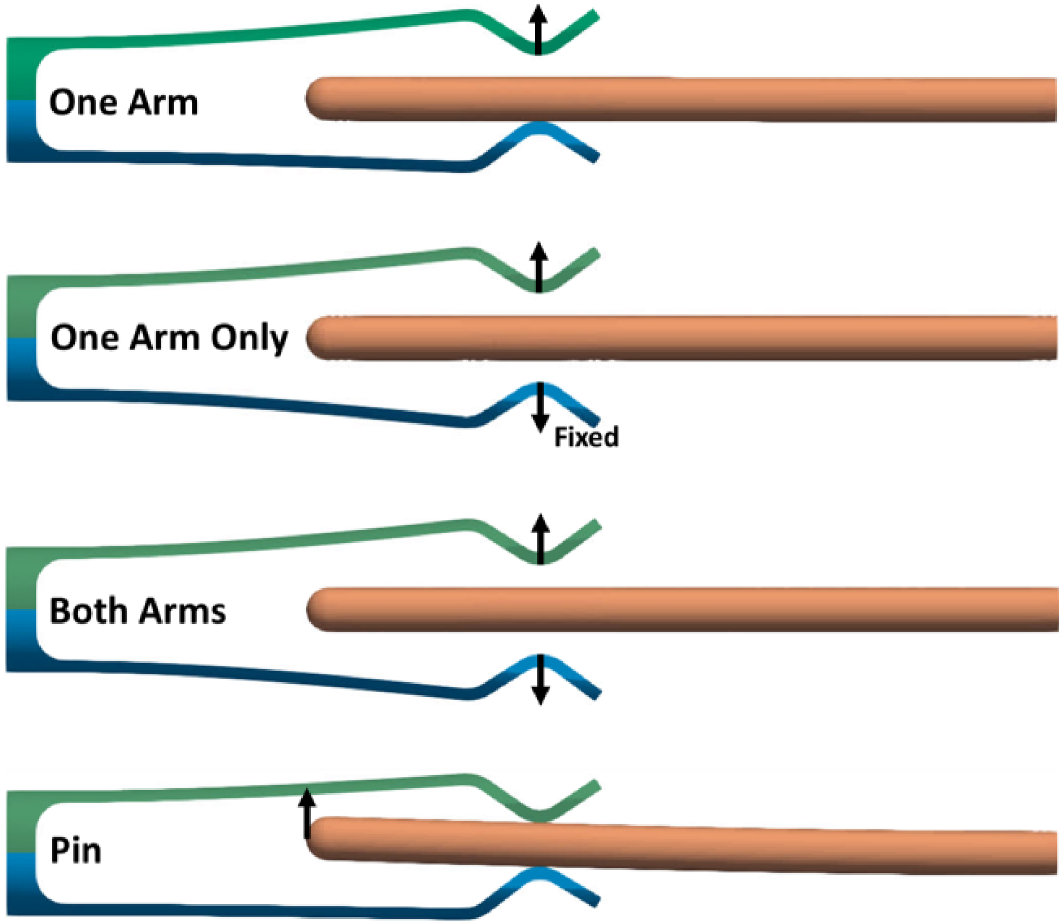


Perturbation types

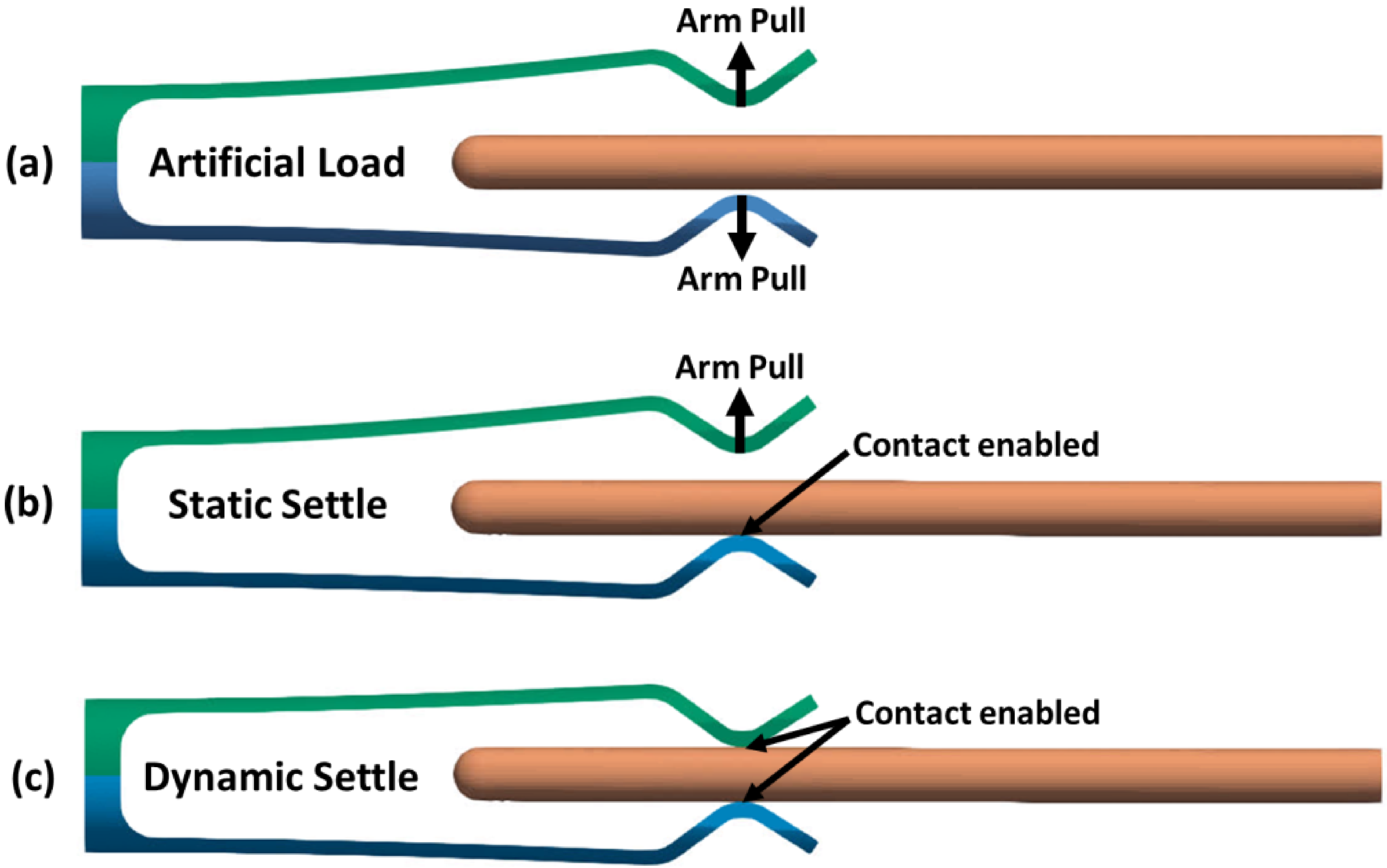
Four types of perturbation were investigated

Each perturbation represents a possible configuration of the pair during random vibration

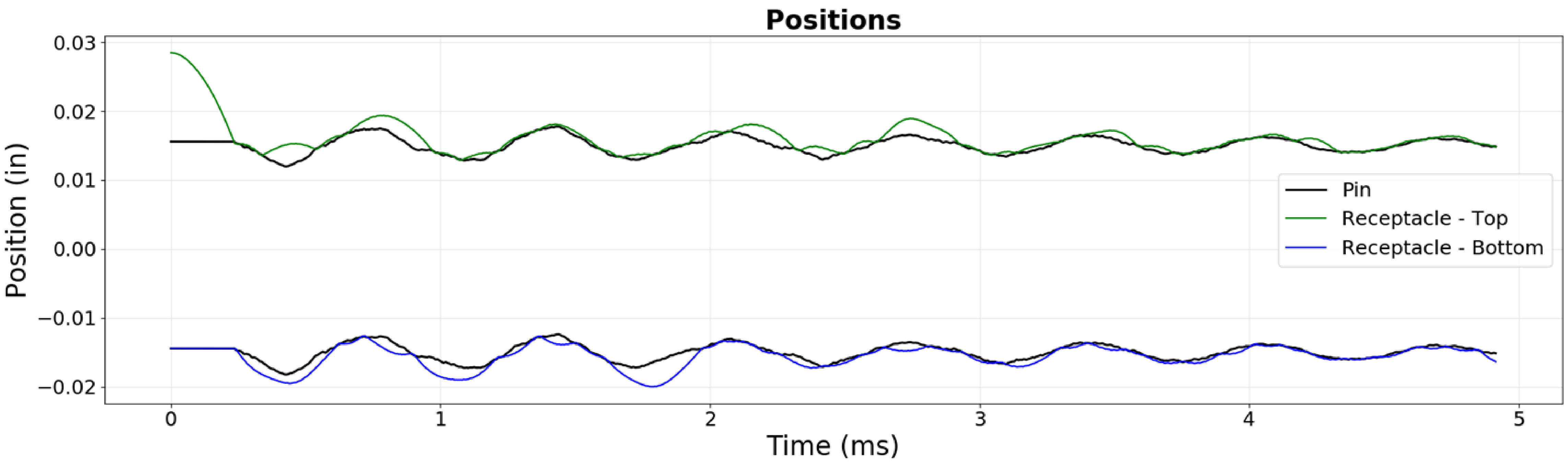
Note that this type of input is significantly different from a true random vibration environment



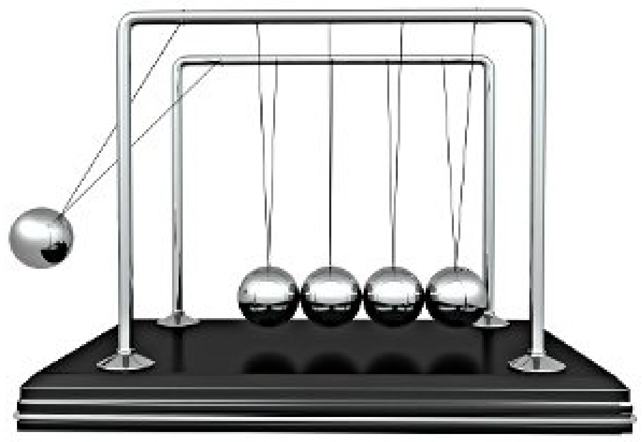
Simulation Procedure (Drop One Arm)



Displacement results replicate expected bouncing behavior



A "Newton's Cradle" style bouncing behavior is visible in the dynamic response of the pin-receptacle pair



Relationship between contact force and electrical resistance

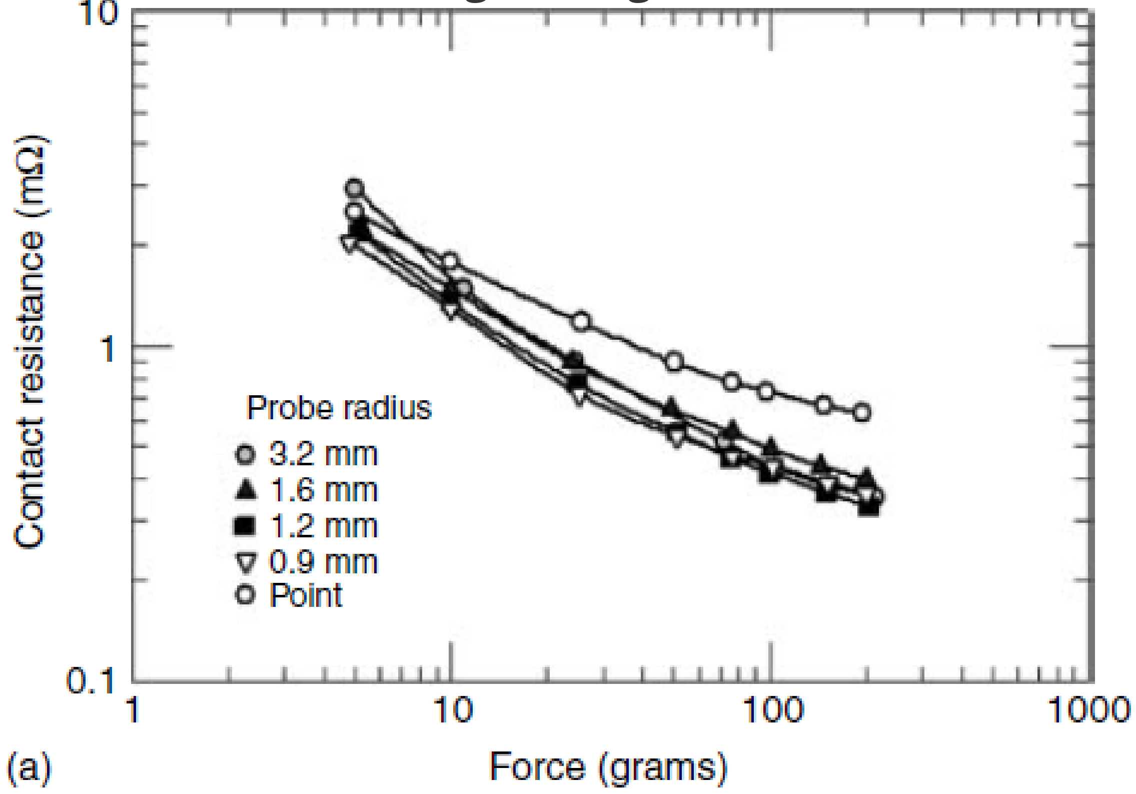
Literature suggests a relationship between contact force and electrical resistance

Loss of contact is our proxy for increased resistance, providing a conservative definition of chatter

Chatter:

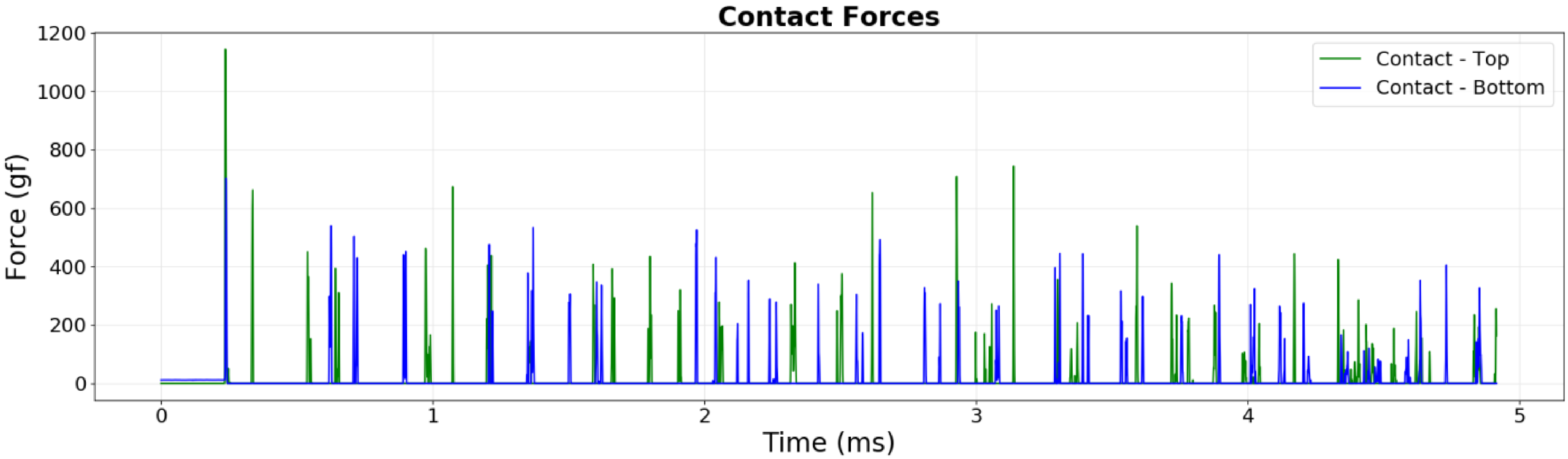
- Begins when both arm’s contact forces equal zero
- Ends when either arm’s contact force becomes nonzero

Contact resistances vs applied force
Clean gold-to-gold contact



M. Braunovic, V. V. Konchits, and N. K. Myshkin, Fundamentals of Electrical Contacts, Boca Raton, FL: Taylor and Francis Group, LLC, 2007.

Contact force results indicate the chaotic nature of chatter



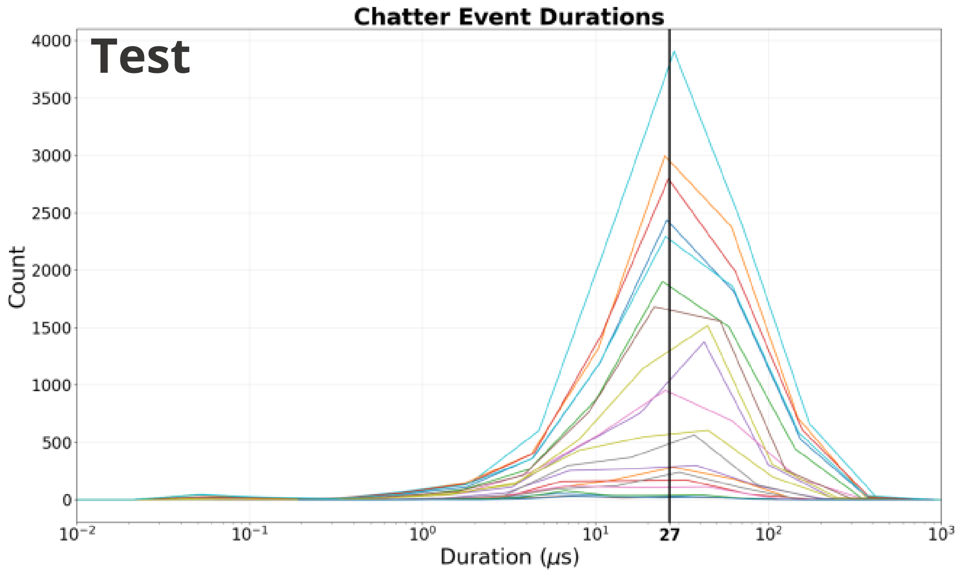
Chaotic contact behavior does not exhibit any clear trends

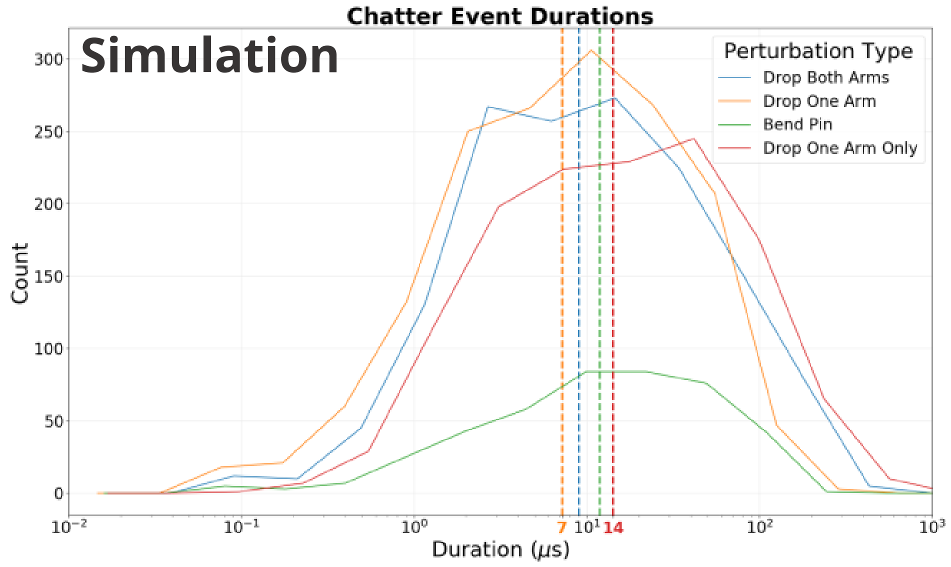
Comparison of chatter event durations

Median chatter event durations for test and simulation are within an order of magnitude of each other

- Test = 27 μs
- Simulation = 7 to 14 μs

This is surprising because the Test input is a random vibration environment, whereas the Simulation input is a single perturbation





Conclusion

Proposed a physical mechanism to explain electrical chatter – a "Newton's Cradle" style bouncing behavior

Random vibration testing

- Characterized the chatter behavior of a bifurcated receptacle – pin contact pair
- Identified a median chatter event duration of 27 µs

High-fidelity solid mechanics modeling

- Replicated the chatter behavior observed during random vibration testing
- Produced median chatter event durations of 7-14 µs for varying perturbation types (i.e. boundary conditions)

Further work

- Develop a reduced order model informed by the high-fidelity simulations
- This new model should be capable of efficiently simulating a full-duration (~1 minute) random vibration environment