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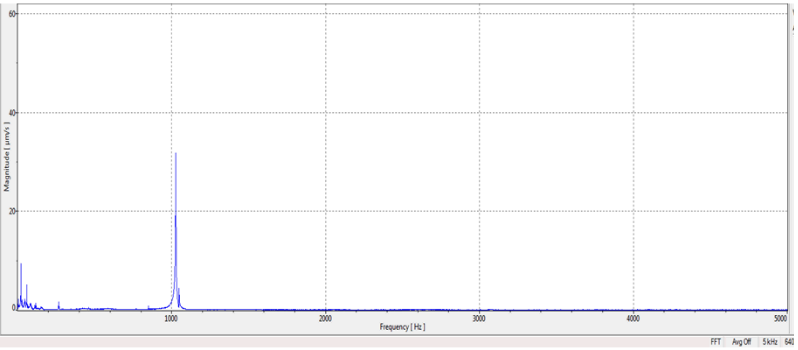

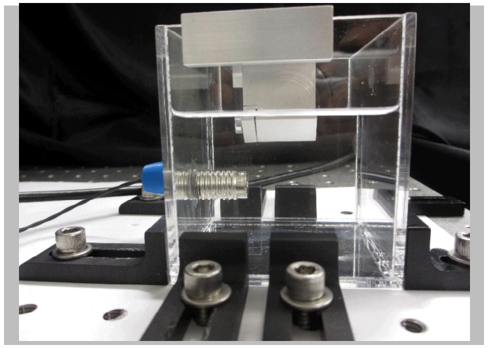

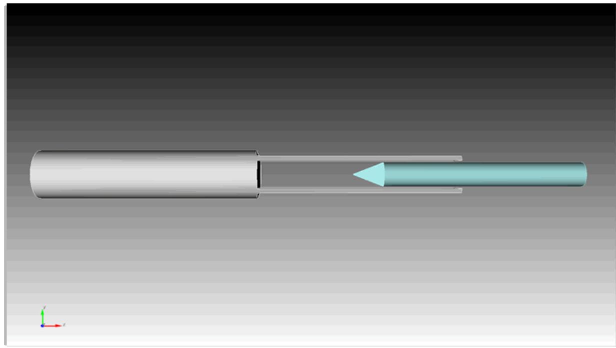

Model Validation of a Small Electrical Contact in a Viscous Fluid

Thesis Committee Update—Dec 8th, 2016

Kelsey Johnson

Structural Dynamics—Org 1522

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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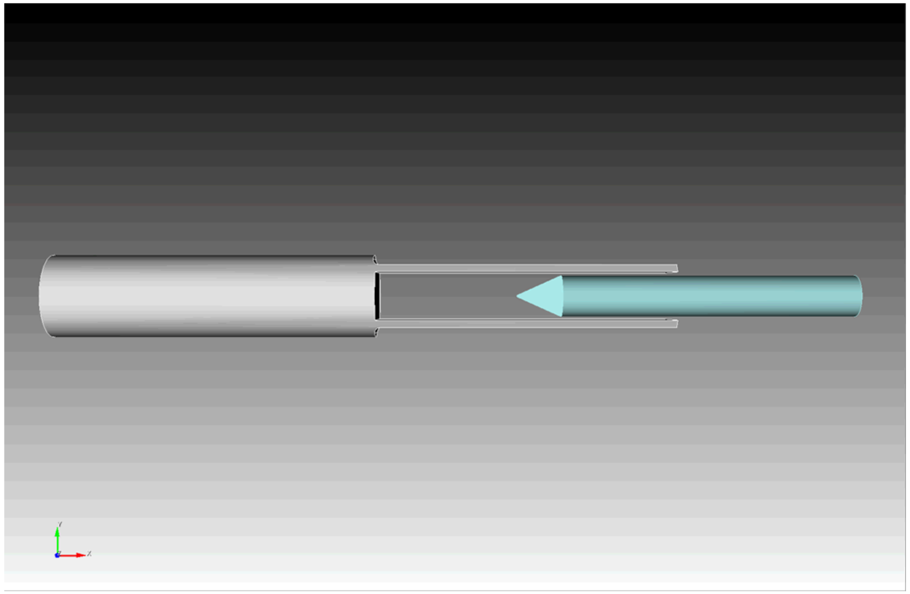
Outline

- Intro to problem
- Numerical Model
- Fluid Effects in other work
- Experimental Setup
- Results
- Conclusions and Path Forward

Objective and Overview

- Chatter Finite Element Model Exists
  - Considered a conservative model for meeting system requirements
  - Lacks experimental validation
  - Does not consider effect of a surrounding fluid
- Provide model validation data set
  - Dynamic ring-down testing in air and fluids
- Baseline comparison of ”air” data and model
- Comparison of “in-fluid” vs “out-of-fluid” data



Numerical Model

- Model created by Lacayo and Brake[1]
- Craig-Bampton reduction
  - Allows for many boundary conditions
  - Accounts for both mass and stiffness
- One node for each contact patch
  - Two total
- Reduction calculated in Sandia's Sierra structural dynamics code
- Model run in MATLAB code called ROMULUS
  - Fifth-order implicit-explicit integrator

Overview of Craig-Bampton Method

Original EOM broken into two parts—Interior and Boundary

$$x = \begin{Bmatrix} x_i \\ x_b \end{Bmatrix}$$

$$M = \begin{bmatrix} M_{ii} & M_{ib} \\ M_{bi} & M_{bb} \end{bmatrix}$$

$$K = \begin{bmatrix} K_{ii} & K_{ib} \\ K_{bi} & K_{bb} \end{bmatrix}$$

Craig-Bampton Transformation

$$x = \begin{Bmatrix} x_i \\ x_b \end{Bmatrix} = \begin{bmatrix} \phi_{ik} & \psi_{ib} \\ 0 & I_{bb} \end{bmatrix} \begin{Bmatrix} q_k \\ x_b \end{Bmatrix} = T_{cb} \begin{Bmatrix} q_k \\ x_b \end{Bmatrix}$$

Resulting reduced M and K matrices

$$M_{cb} = T_{cb}^T M T_{cb} = \begin{bmatrix} I & M_{kb} \\ M_{bk} & \widehat{M}_{bb} \end{bmatrix}$$

$$K_{cb} = T_{cb}^T K T_{cb} = \begin{bmatrix} \omega_k^2 & 0 \\ 0 & \widehat{K}_{bb} \end{bmatrix}$$

Fluid Effects

- Expected shift in frequency and damping
- Two parts of the fluid force to consider
  - Viscous damping
  - Added mass effect
- Several analytical and numerical attempts
  - All cantilevered beams surrounded by viscous fluids
  - All lack experimental validation

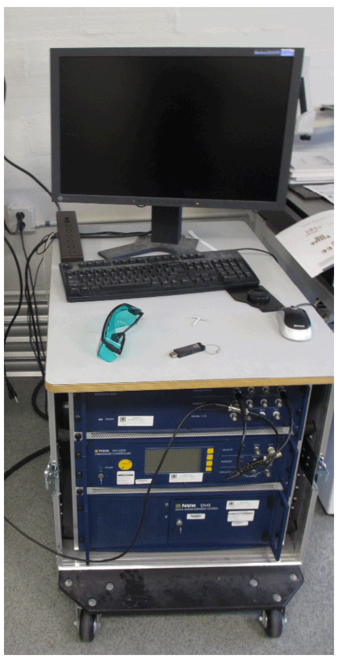
General beam equation

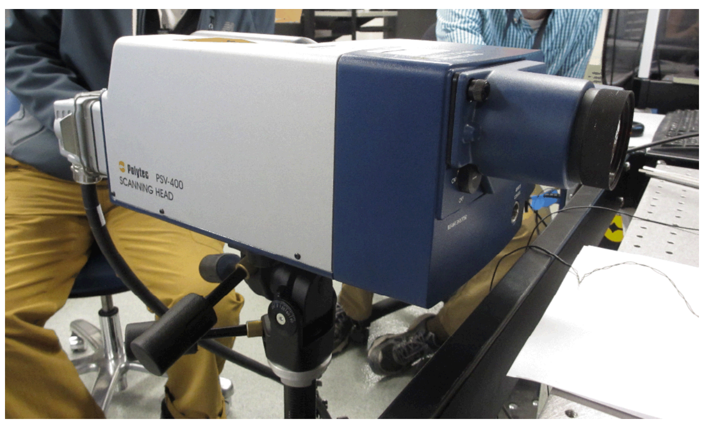
$$EI\frac{\partial^4 w(x,t)}{\partial x^4} + \mu\frac{\partial^2 w(x,t)}{\partial t^2} = F(x,t) \quad \text{where} \quad F(x,t) = \boxed{F_{Fluid}} + F_{NL\_contact} + F_{environment}$$

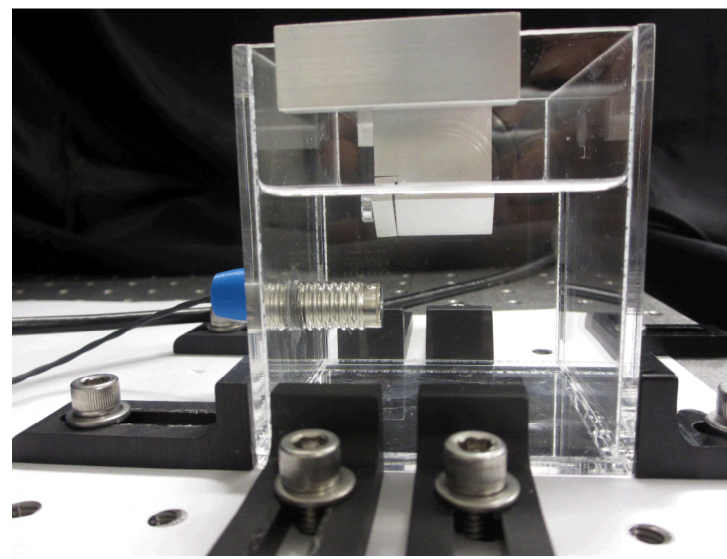
No model created at Sandia for this system has included the fluid effects on the pin-receptacle sub-assembly specifically

Experimental Setup

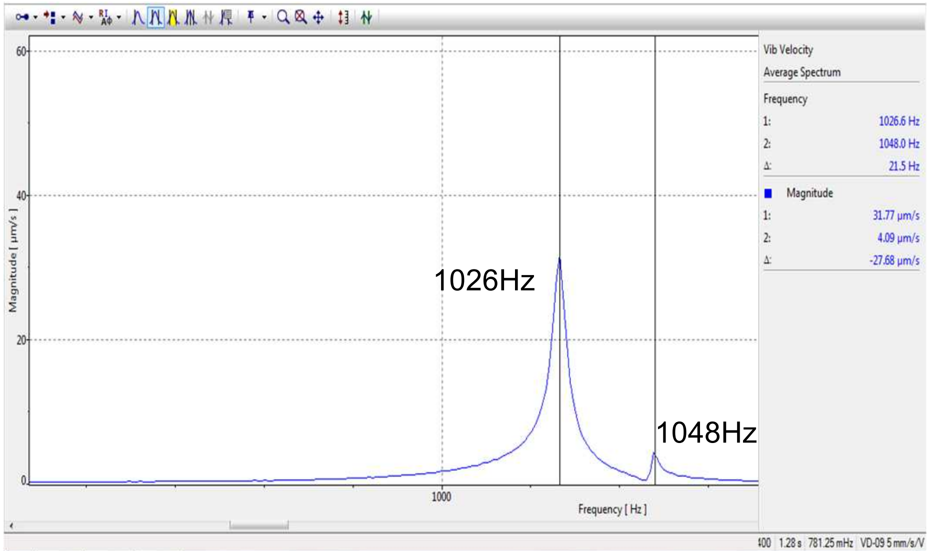
- Polytec PSV400 1D LDV
- High voltage amplifier
- Physik Instrumente PICMA® Encapsulated Stack Actuator
- Dow Corning XIAMETER PMX-200, 10cs and 20cs

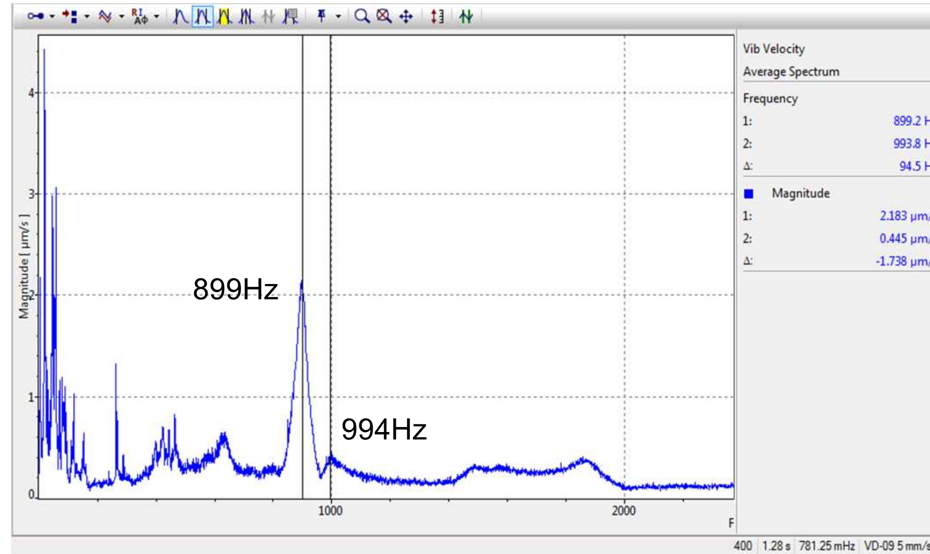


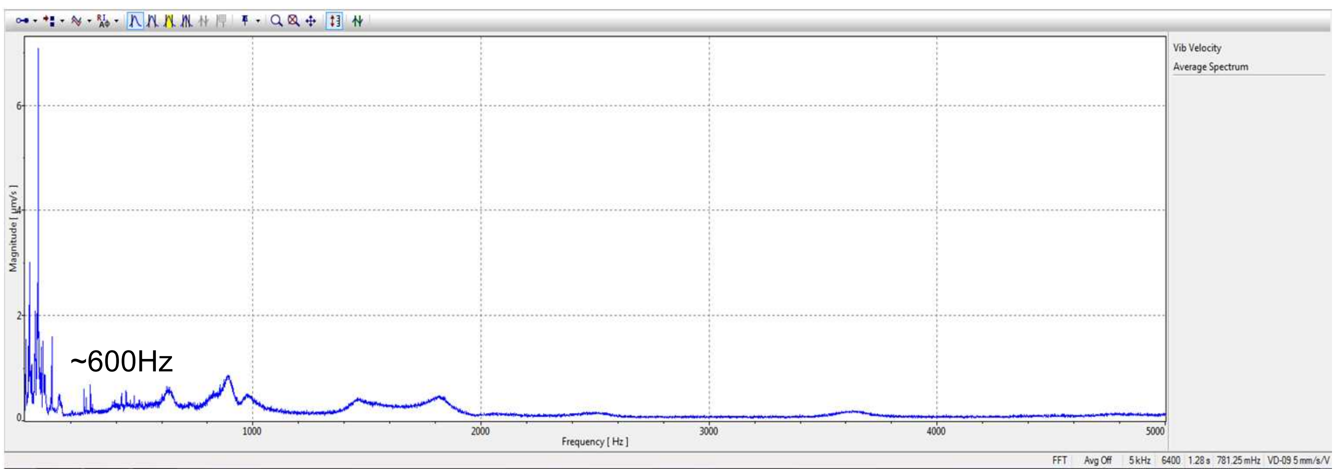




Results


Vib Velocity
Average Spectrum
Frequency
1: 1026.6 Hz
2: 1048.0 Hz
Δ: 21.5 Hz
Magnitude
1: 31.77 µm/s
2: 4.09 µm/s
Δ: -27.68 µm/s
Magnitude [µm/s]
Frequency [Hz]
1026Hz
1048Hz


Vib Velocity
Average Spectrum
Frequency
1: 899.2 Hz
2: 993.8 Hz
Δ: 94.5 Hz
Magnitude
1: 2.183 µm/s
2: 0.445 µm/s
Δ: -1.738 µm/s
Magnitude [µm/s]
899Hz
994Hz


Vib Velocity
Average Spectrum
Magnitude [µm/s]
Frequency [Hz]
~600Hz

Issues to be resolved

- Frequency content only out to 5000 Hz
- Cannot physically hit part with actuator
- Cannot see in-plane lateral modes

Path Forward

- Experiment
  - Hand calculate modes 1 and 2 in both normal and in-plane directions for cantilevered beam of same length
  - Re-do experiments, pushing the frequency content out to 20+kHz
  - Rotate pin and see if LDV can pick up modes in both directions
  - If all else fails—Base Excitation
- Discuss with modelers how to best add the data to the model
- Currently using a Short-Time Fourier Transform to obtain FFT from time history data
  - Use SMAC for closely spaced modes

Questions? Suggestions?