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| **Title:** | Vibrational Properties of Additively Manufactured Materials Closeout |
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| **Intended for:** | Discussion of vibration with NASA engineers. |
| **Issued:** | 2024-05-23 |



# Vibrational Properties of Additively Manufactured Materials Closeout

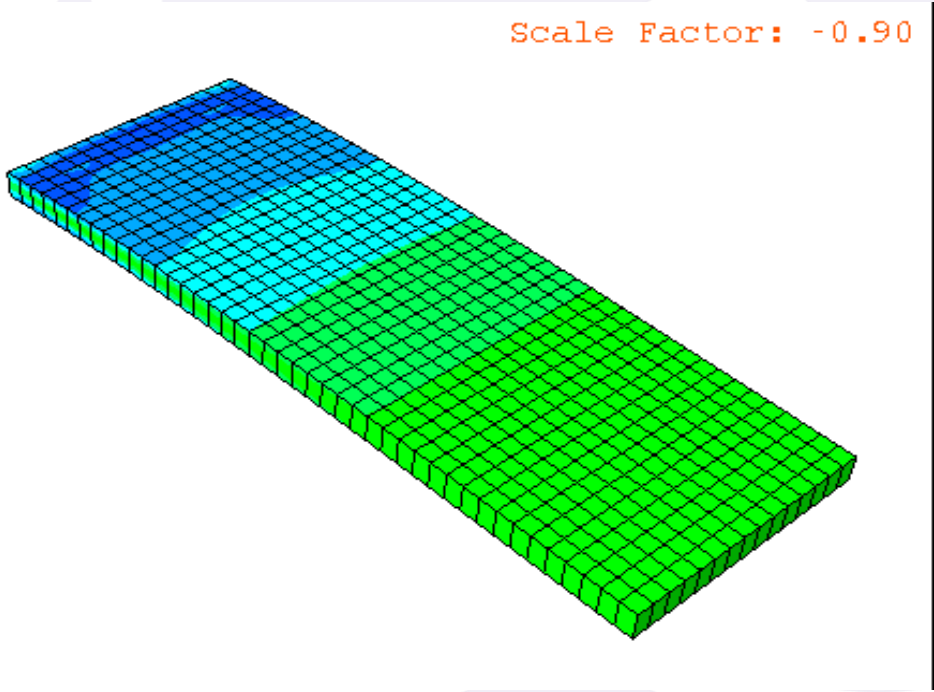
Troy Pacheco ISR-5

Background

- AM parts: complex, rapidly prototyped, unreliable?
- Resonance caused by vibration during launch can damage sensitive components
- The vibrational properties of AM parts are not well understood

Experiment

- Use the dynamics lab to test AM and conventional cantilever beams

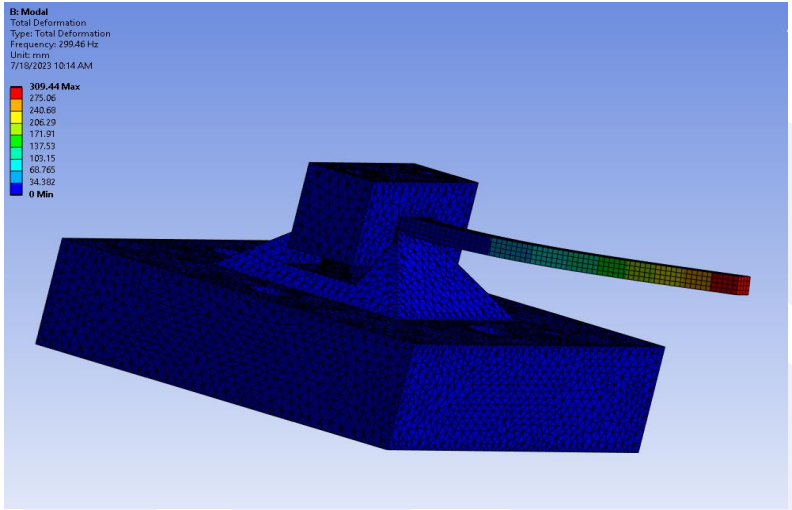


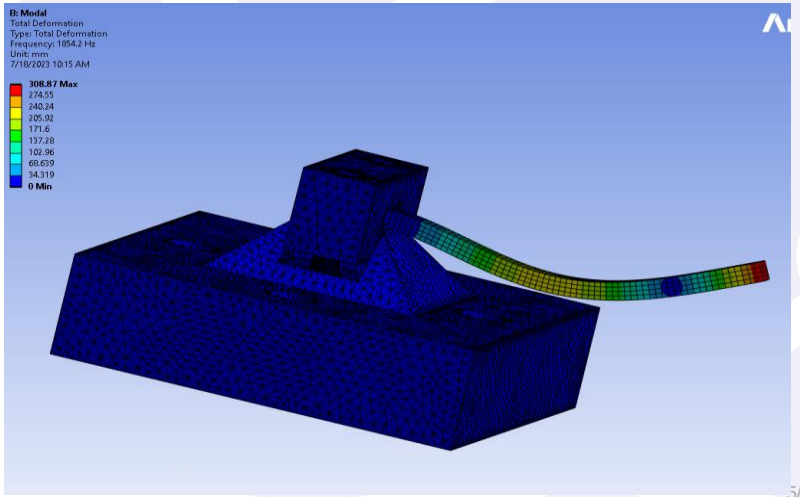
# Design and Modeling

Use an aluminum base and clamp to hold either an Additively Manufactured (AM) or Stainless Steel (SS) cantilever beam as it is tested on the vibe table

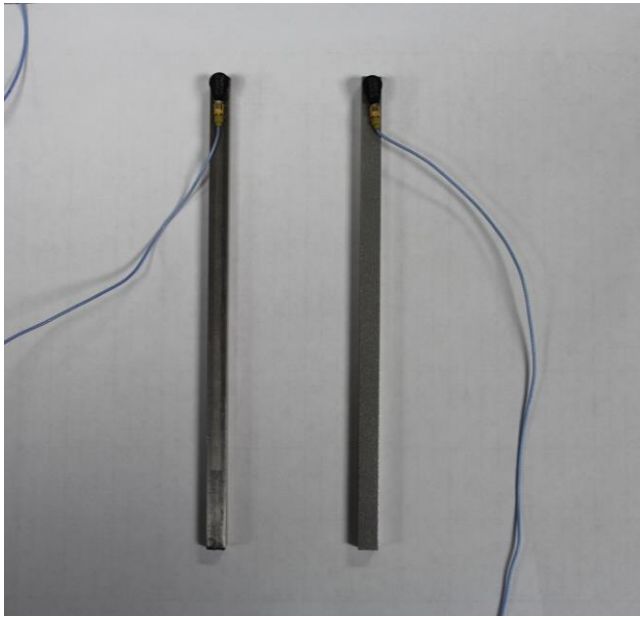
AM Density – 0.280 lb/in^3
SS Density – 0.282 lb/in^3

Mode 1: 290 Hz
Mode 2: 1850 Hz

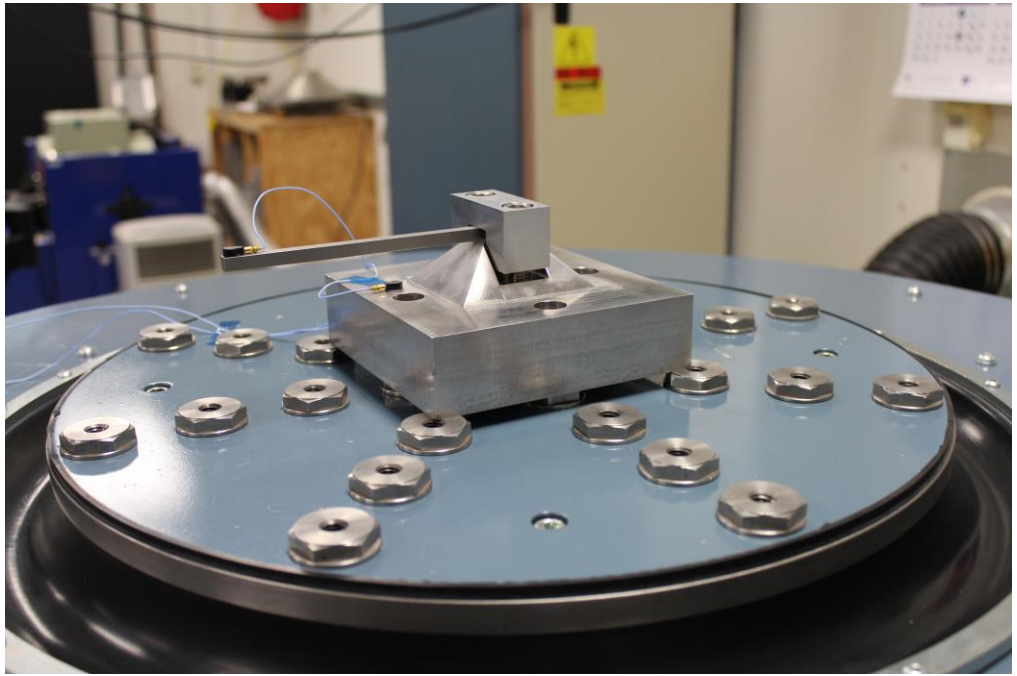


# Experimental Setup



Single axis accelerometers attached using super glue



The experimental setup mounted on the z axis of the shaker table. All mounts were torqued to 35ft-lbs

# Vibration Levels

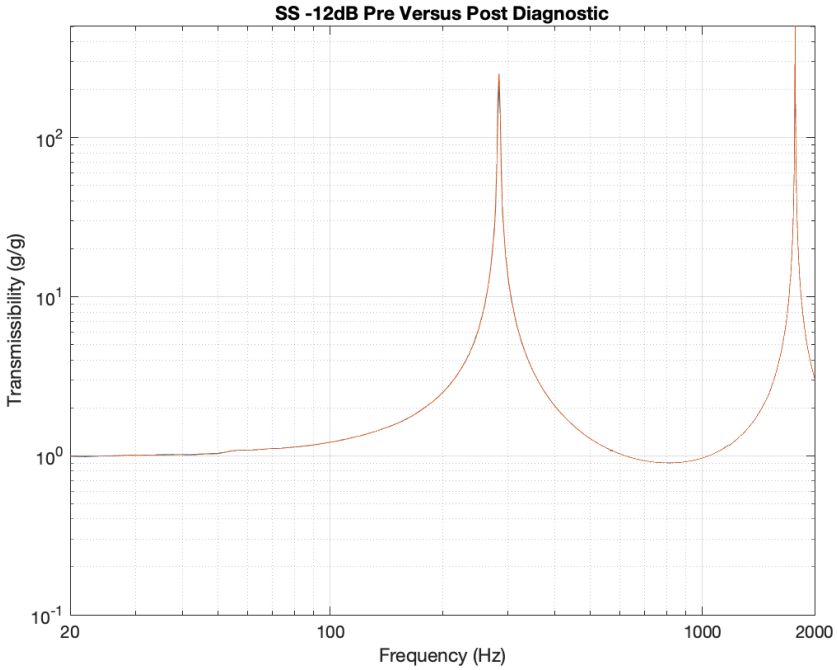
Random Vibration

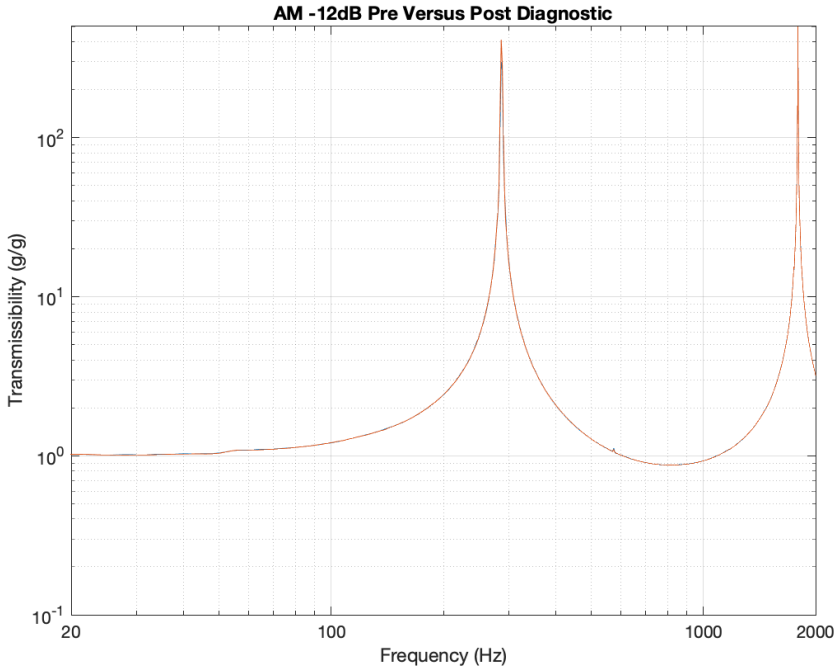
- 0.02g^2/Hz from 20-200Hz
- 6.293 gRMS

Sine

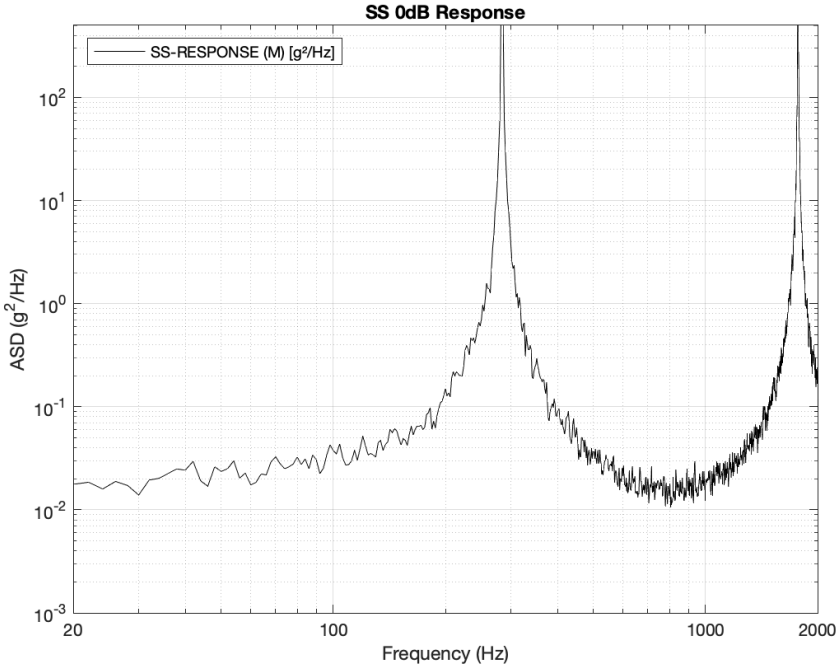
- 0.5g from 20-2000Hz

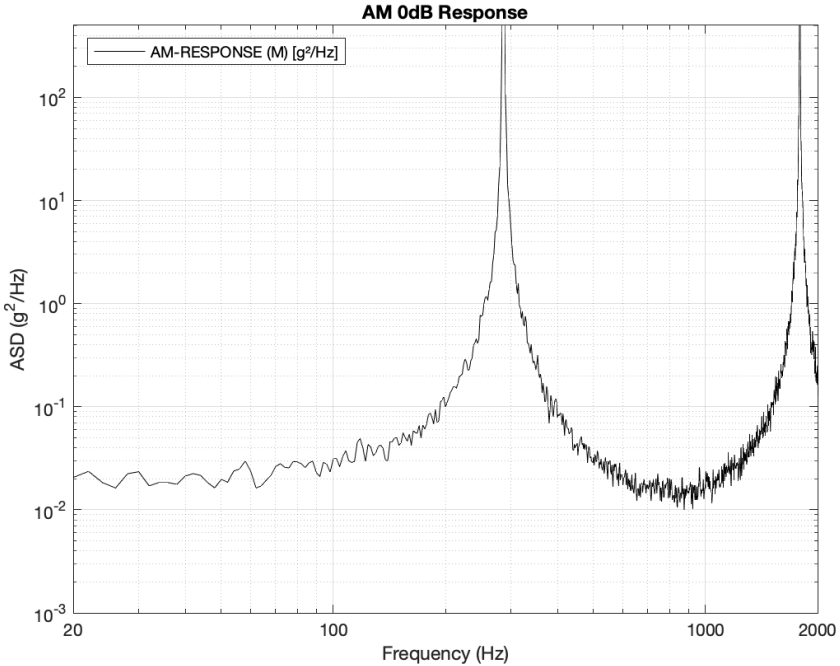
# Pre vs Post Transmissibility Comparison



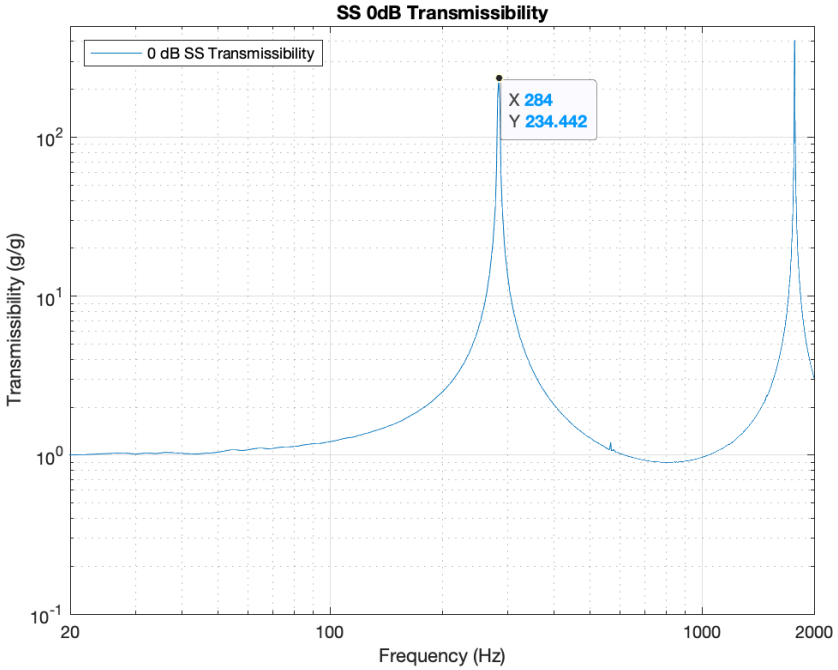



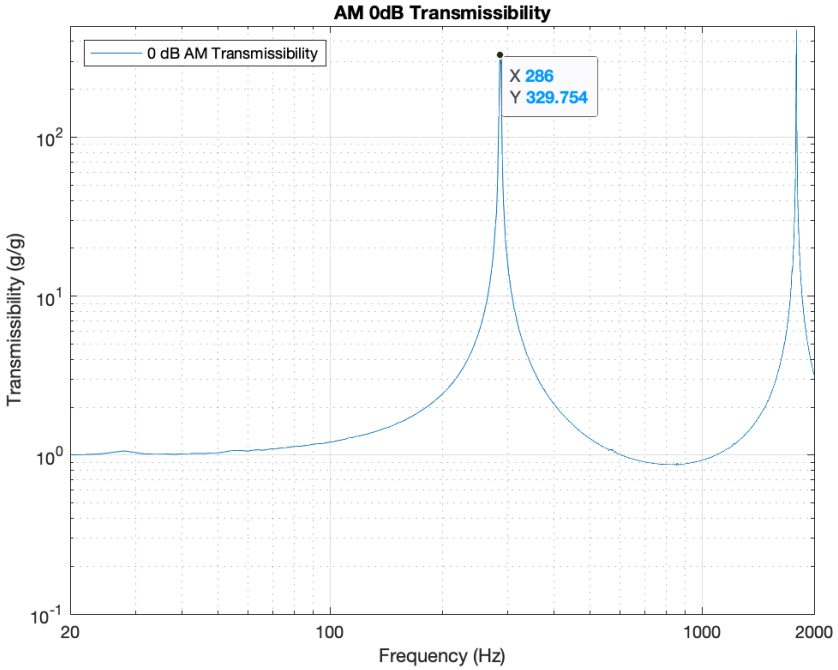
# Random Vibration Results, Input 0.02g^2/Hz 6.293 gRMS



# Transfer Functions



# Frequency Calculation

In addition to the modal analysis from the model, the theoretical modes were calculated using:

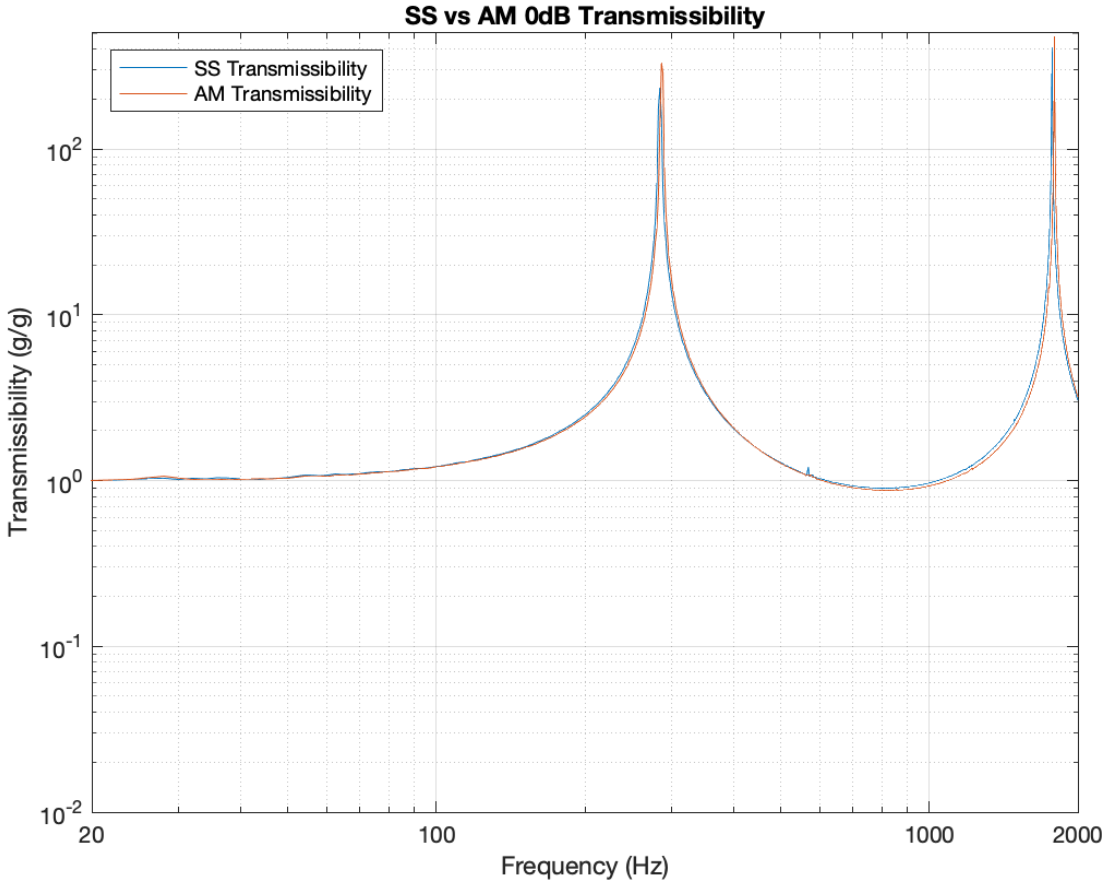
$$f_n = \frac{K_n}{2\pi}\sqrt{\frac{EIg}{wl^4}}$$

From Young, W. C., Budynas, R. G.(2002). Roark's Formula's for Stress and Strain, 7th edition. McGraw Hill, Chapter 16, pp767-768.

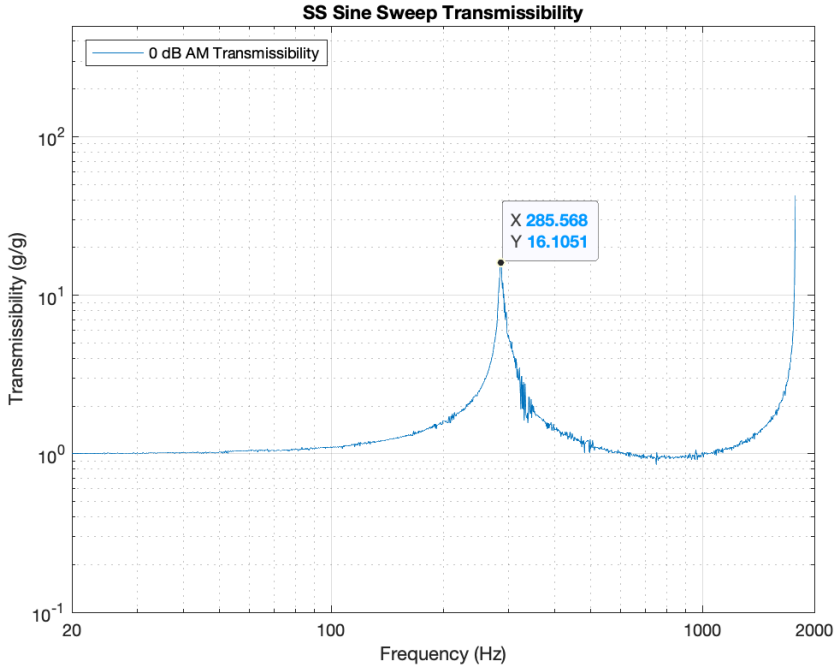
Where fn is the natural frequency, E is the elastic modulus, I is the moment of inertia, g is the gravitational constant, w is the uniform load (weight per unit length), l is the length, and Kn is a constant for each mode with K1=3.52, K2=22.0

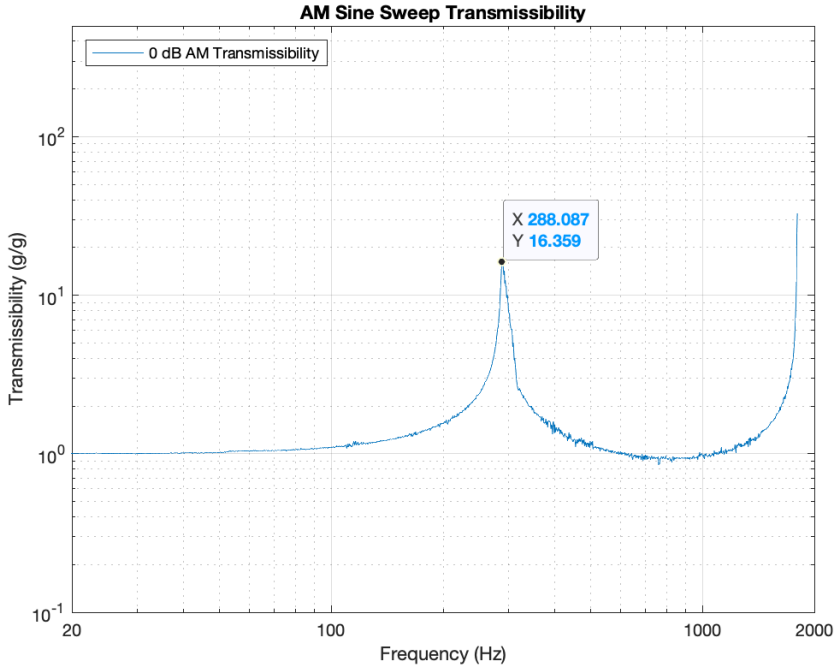
# Comparison

| | Theoretical | Model | SS | AM |
|---|---|---|---|---|
| 1 | 312 | 299 | 284 | 286 |
| 2 | 1950 | 1850 | 1772 | 1792 |



# Sine Sweep, 0.5g from 20-2000Hz

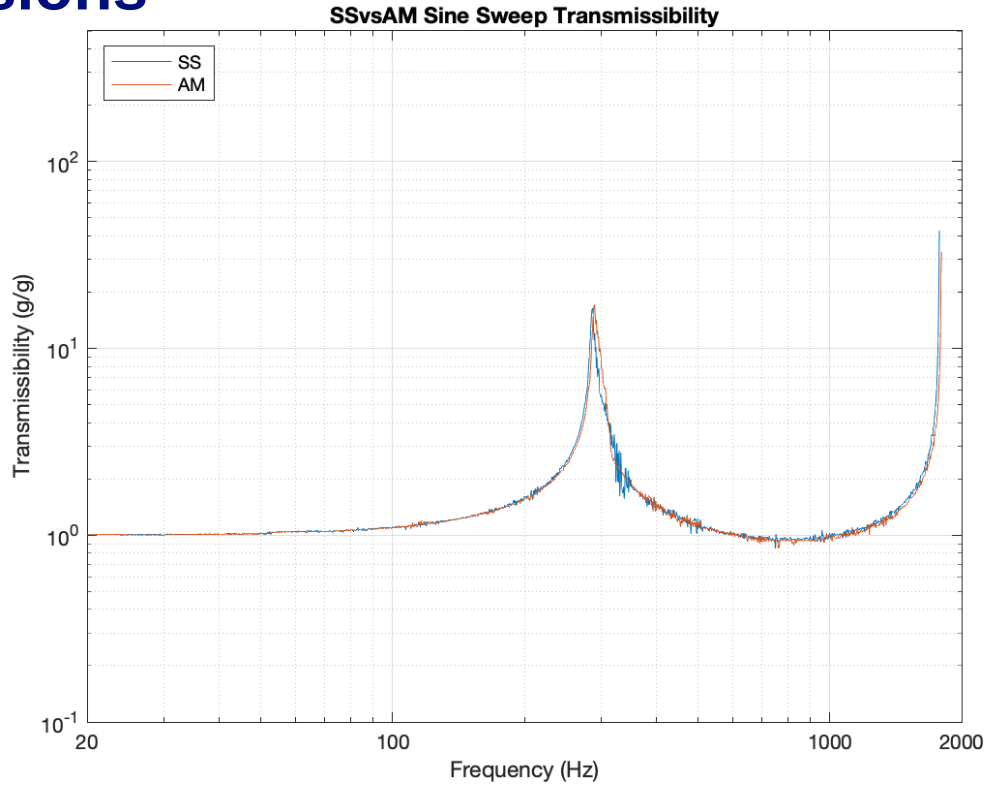


# Comparison and Conclusions

The results of the Sine Sweep are also nearly identical for both the SS and AM test bars.

We can be confident that our models are accurate for vibrational testing of AM parts in the future



# Future Research

- After discussions with the advanced manufacturing division, we determined that the effects of the AM process might not become evident until higher frequencies.
- The shaker table in ISR cannot test above 2000Hz, but the shock beam can.
- The next phase of research would be to repeat the experiment using the shock beam up to 10,000Hz.

# Works Cited


[1] J. J. Lewandowski and M. Seifi, "Metal Additive Manufacturing: A Review of Mechanical Properties," Annual Review of Materials Research, vol. 46, pp. 151-186, 2016.

[2] M. Albakri, L. Sturm, C. B. Williams and P. Tarazaga, "NON-DESTRUCTIVE EVALUATION OF ADDITIVELY MANUFACTURED PARTS VIA IMPEDANCE-BASED MONITORING," in International Solid Freeform Fabrication Symposium, 2015.

[3] E. R. Fotsing, A. Dubourg, A. Ross and J. Mardjono, "Acoustic properties of periodic micro-structures obtained by additive manufacturing," Applied Acoustics, vol. 148, pp. 322-331, 2019.

[4] D. Russel, "Vic Sparrow's Acoustics and Vibration Animations," Pennsylvania State University, 17 May 2018. [Online]. Available: https://www.acs.psu.edu/drussell/Demos/Sparrow/Sparrow.html. [Accessed 12 March 2023].