

# LA-UR-24-25116

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**Title:** Vibrational Properties of Additively Manufactured Materials Closeout

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**Intended for:** Discussion of vibration with NASA engineers.

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# Vibrational Properties of Additively Manufactured Materials Closeout

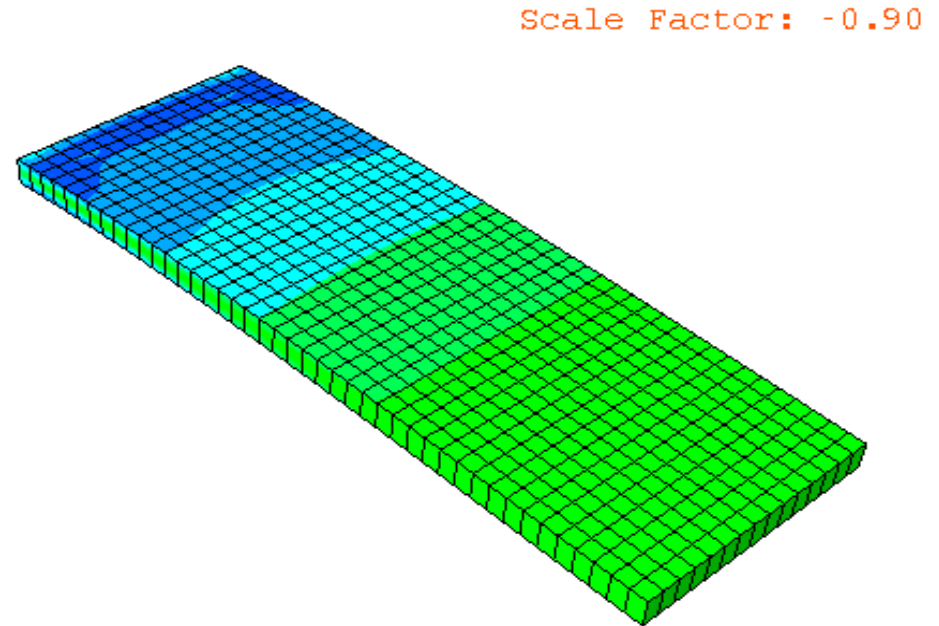
Troy Pacheco ISR-5

## 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

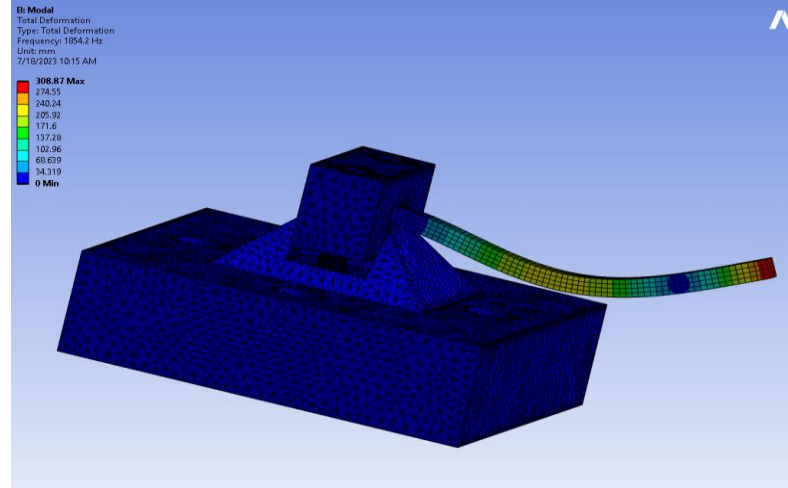
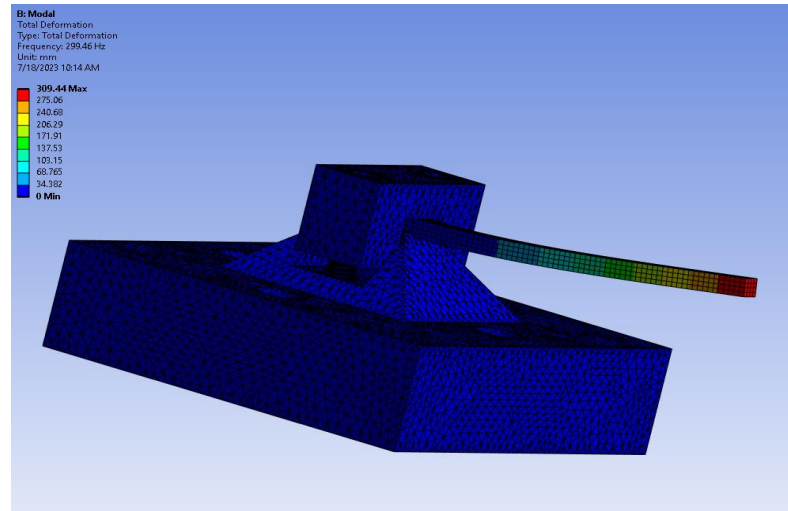
Use an aluminum base and clamp to hold either an Additively Manufactured (AM) or Stainless Steel (SS) cantilever beam as it is tested on the vibe table

AM Density –  $0.280 \text{ lb/in}^3$

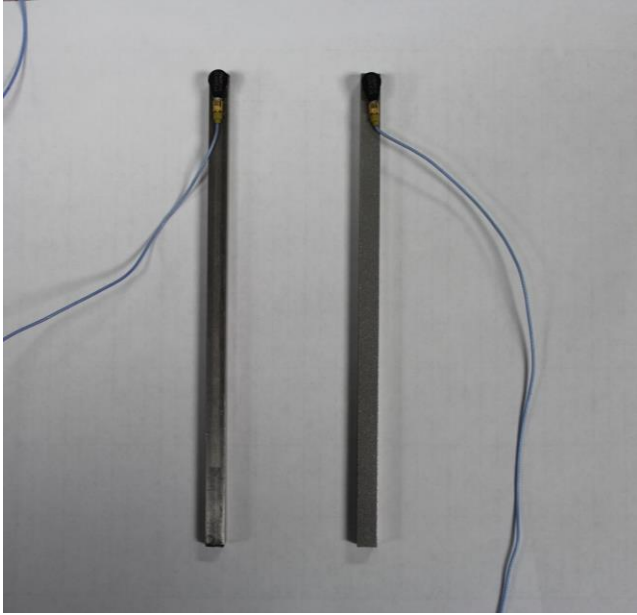
SS Density –  $0.282 \text{ lb/in}^3$

Mode 1: 290 Hz

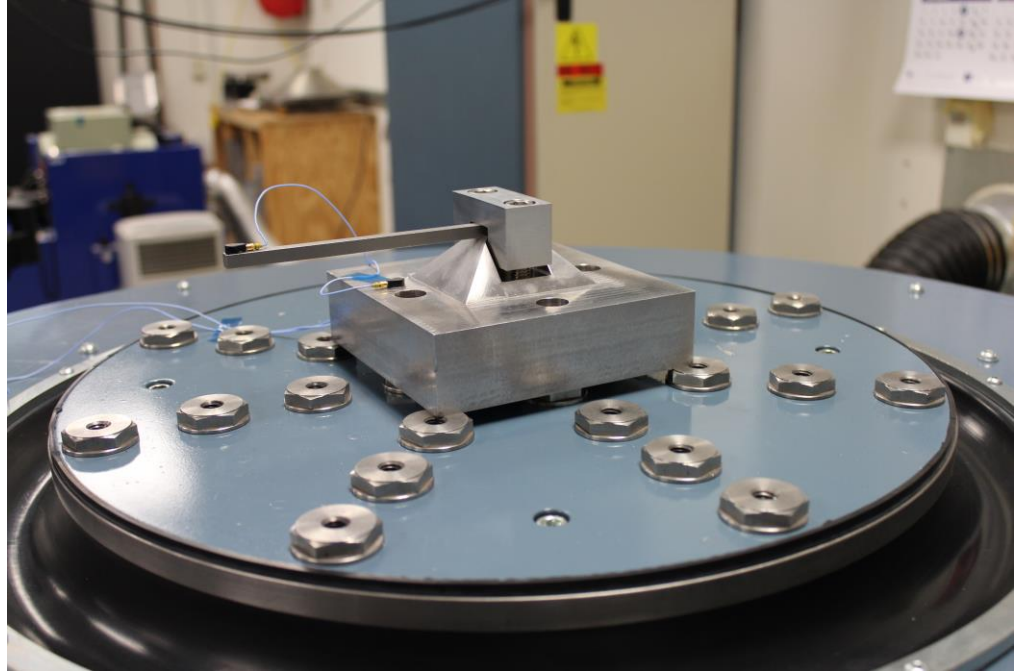
Mode 2: 1850 Hz



# 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

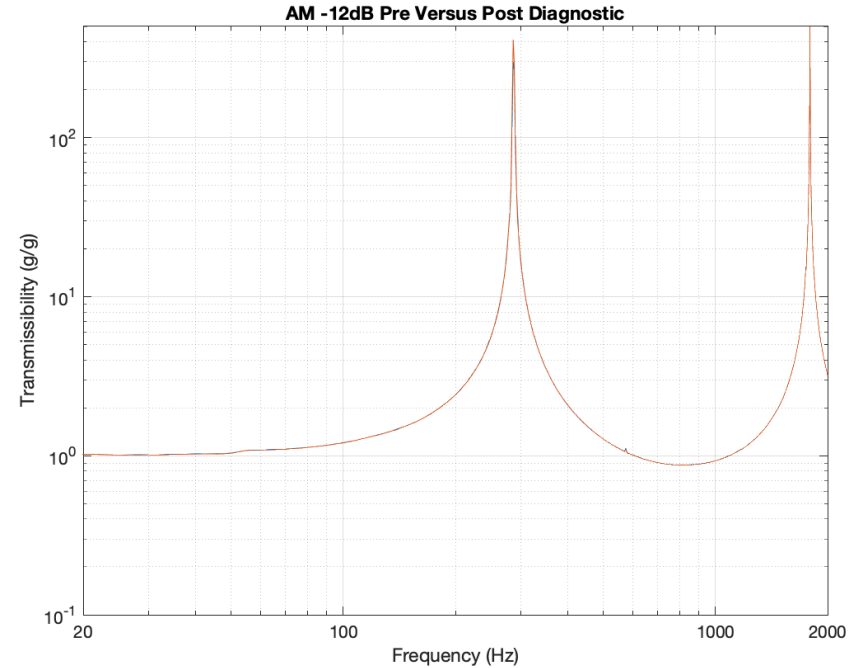
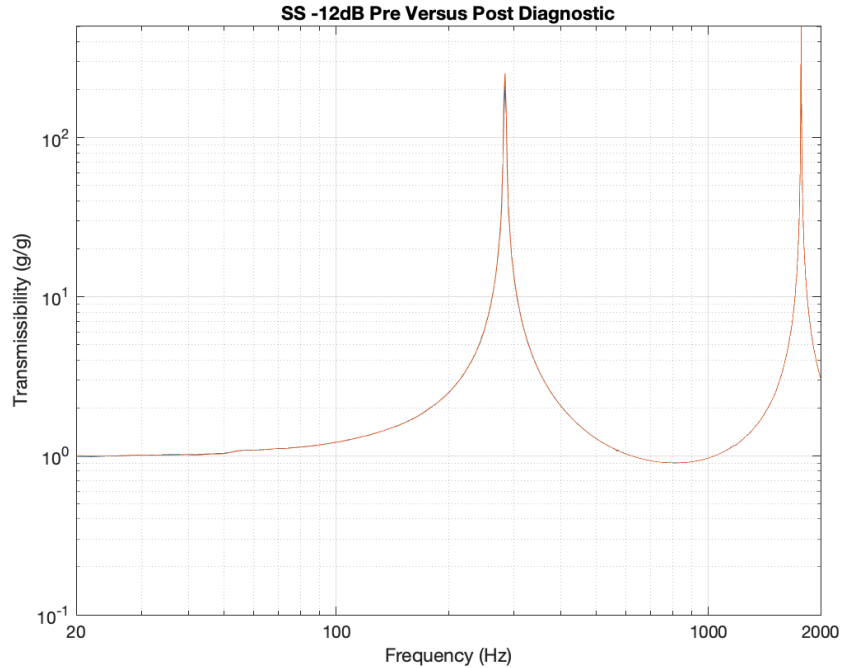
## Random Vibration

- $0.02\text{g}^2/\text{Hz}$  from 20-200Hz
- 6.293 gRMS

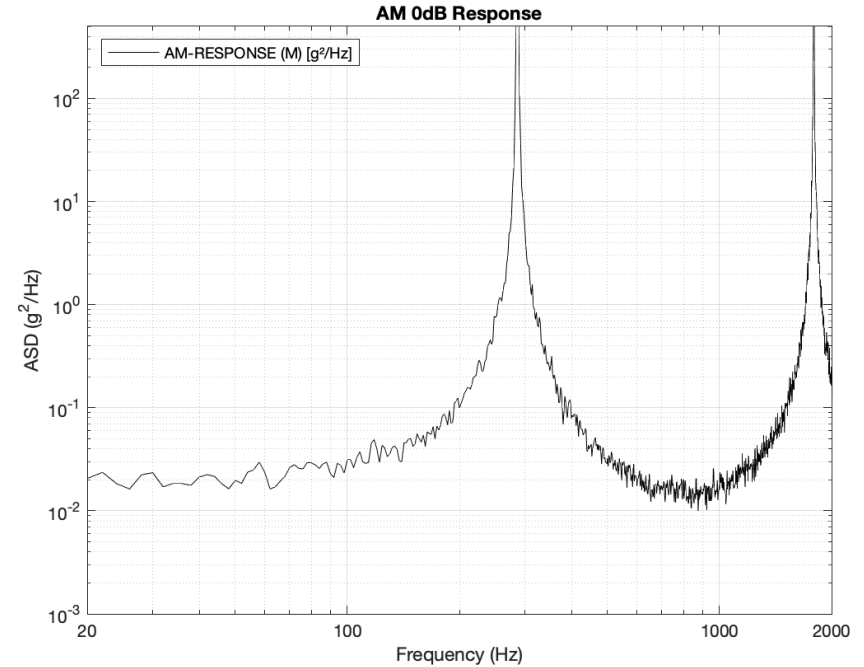
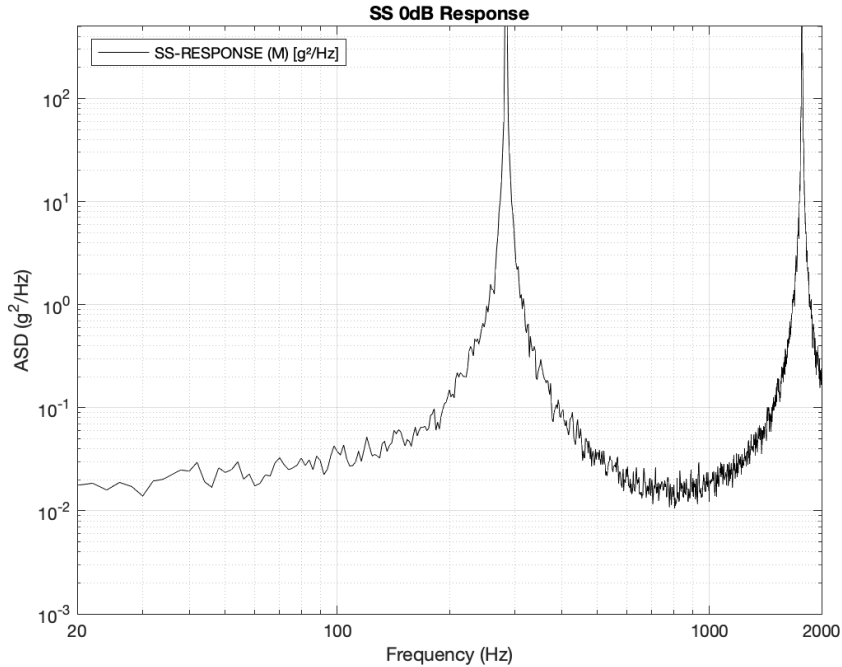
## Sine

- 0.5g from 20-2000Hz

# Pre vs Post Transmissibility Comparison

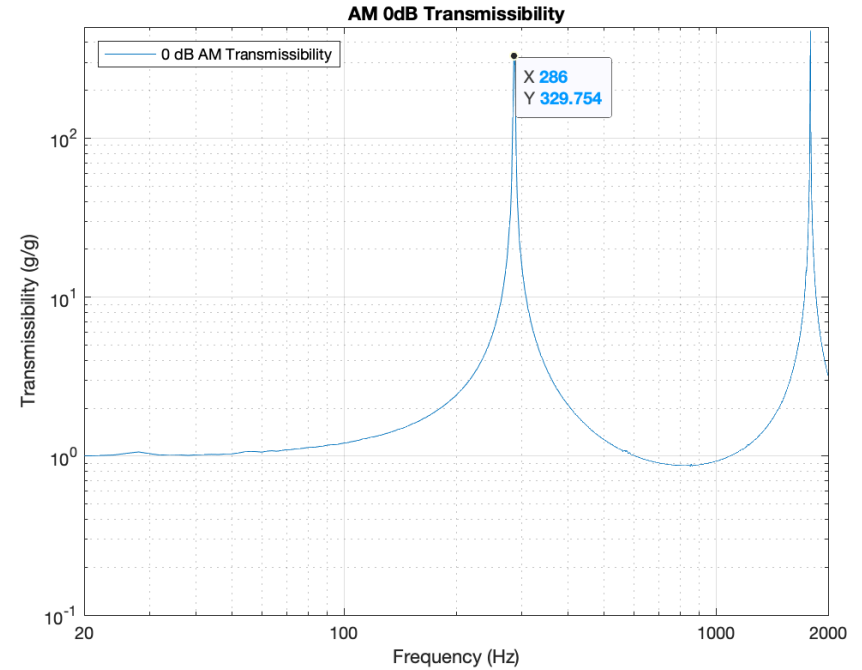
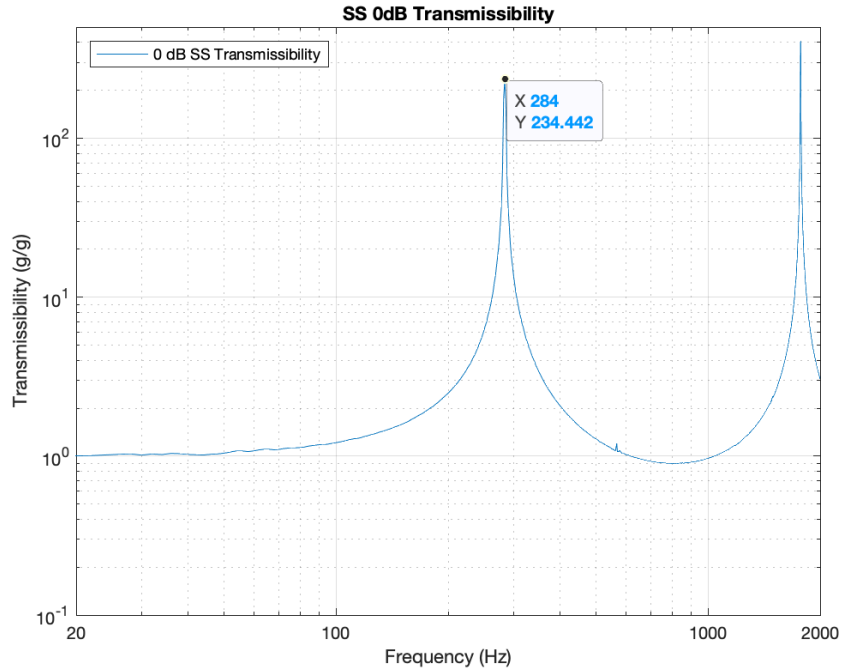


# Random Vibration Results, Input $0.02\text{g}^2/\text{Hz}$ 6.293 gRMS





# Transfer Functions



# Frequency Calculation

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

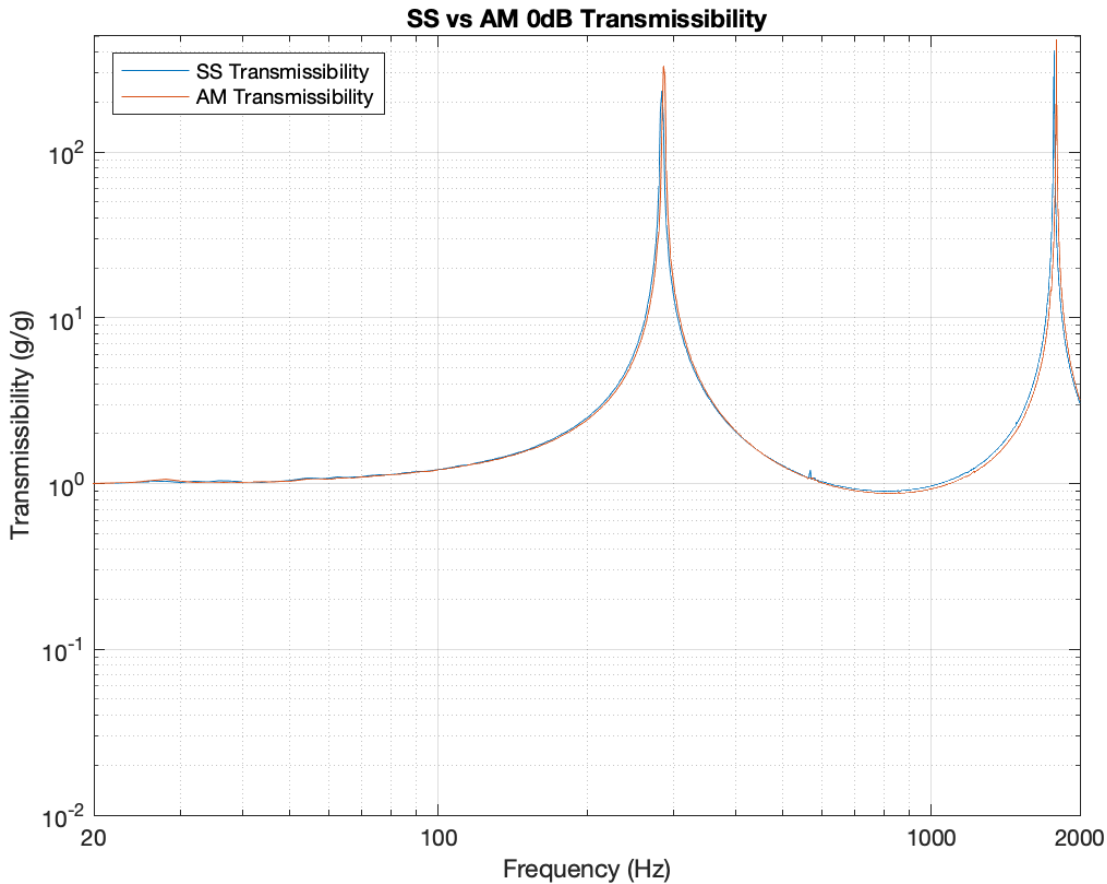
$$f_n = \frac{K_n}{2\pi} \sqrt{\frac{EIg}{wl^4}}$$

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

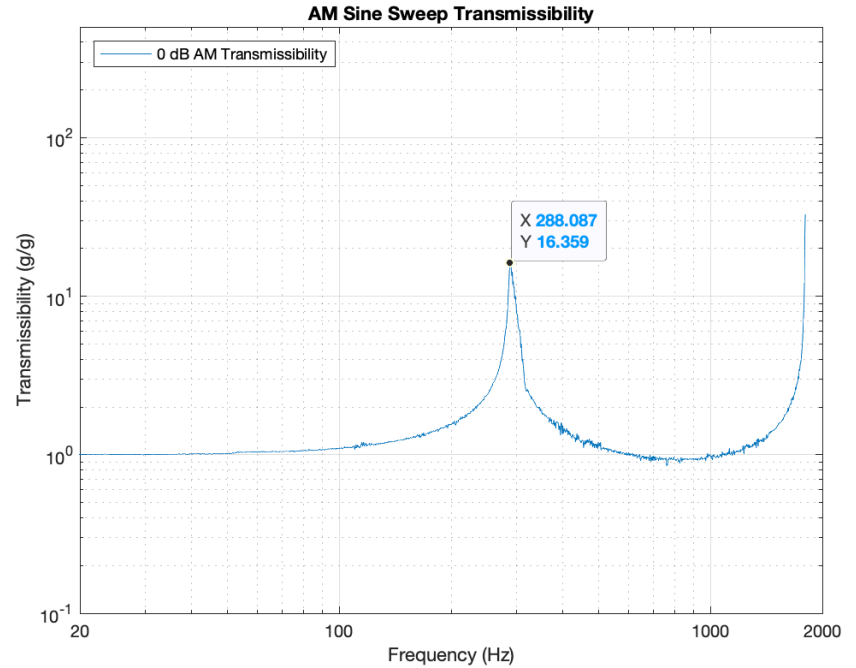
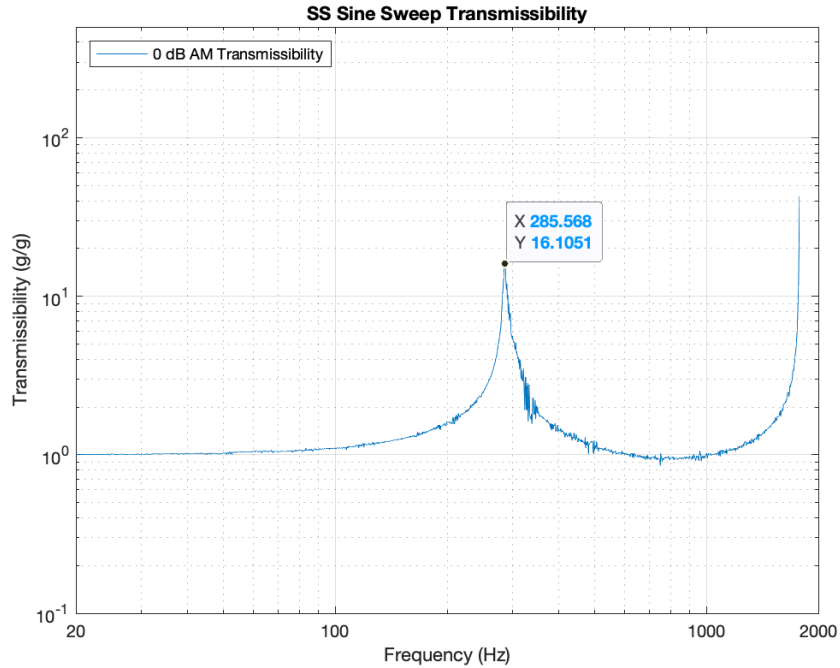
Where  $f_n$  is the natural frequency,  $E$  is the elastic modulus,  $I$  is the moment of inertia,  $g$  is the gravitational constant,  $w$  is the uniform load (weight per unit length),  $l$  is the length, and  $K_n$  is a constant for each mode with  $K_1=3.52$ ,  $K_2=22.0$

# Comparison

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



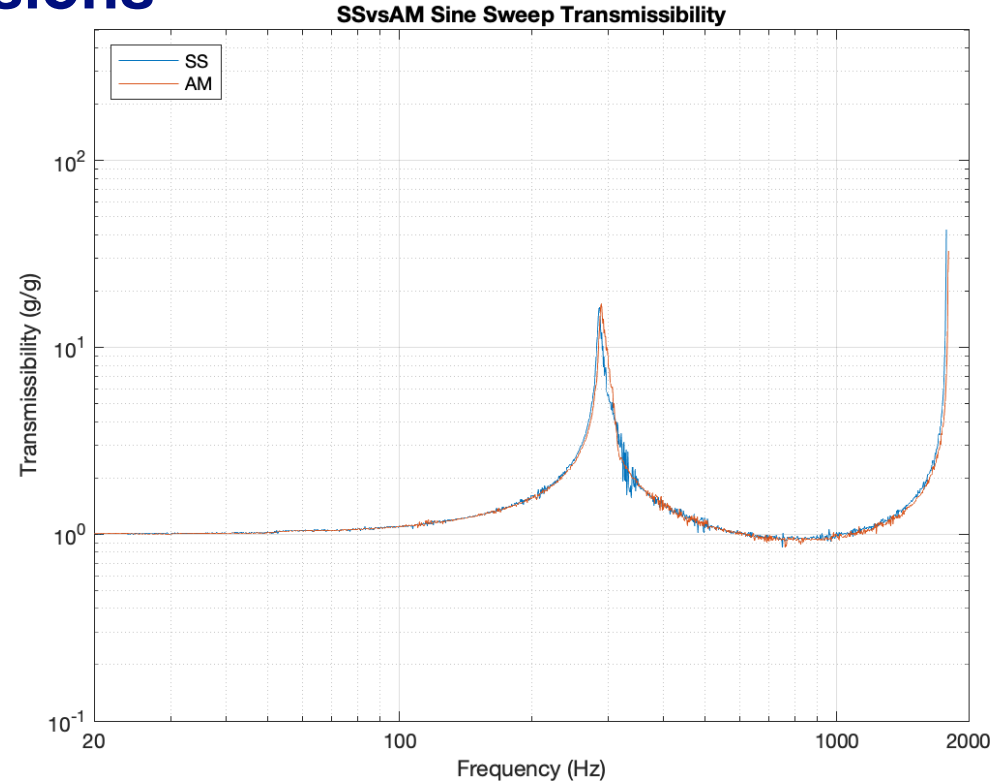
# Sine Sweep, 0.5g from 20-2000Hz



# 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.
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