Modeling Post-Process Indenting Using the Discrete Element Method for Particle Density Control in Additively Manufactured Dampers

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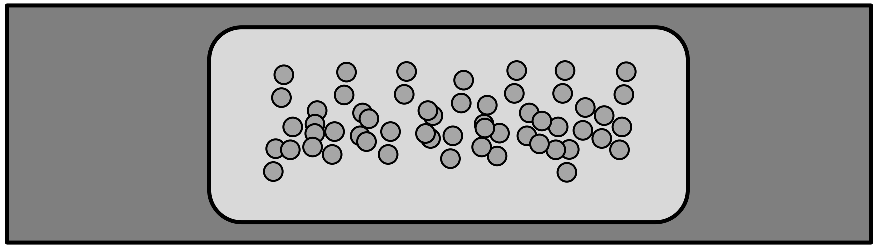
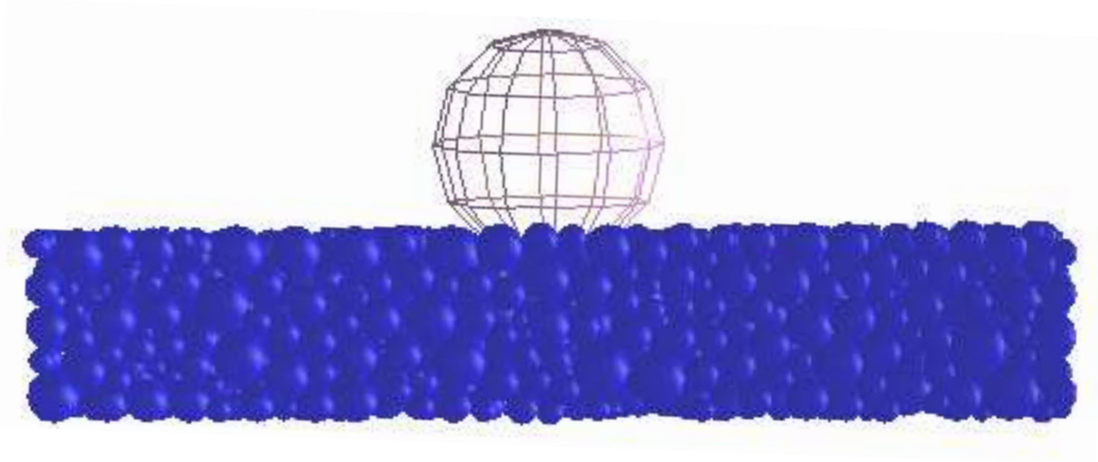


particle damper

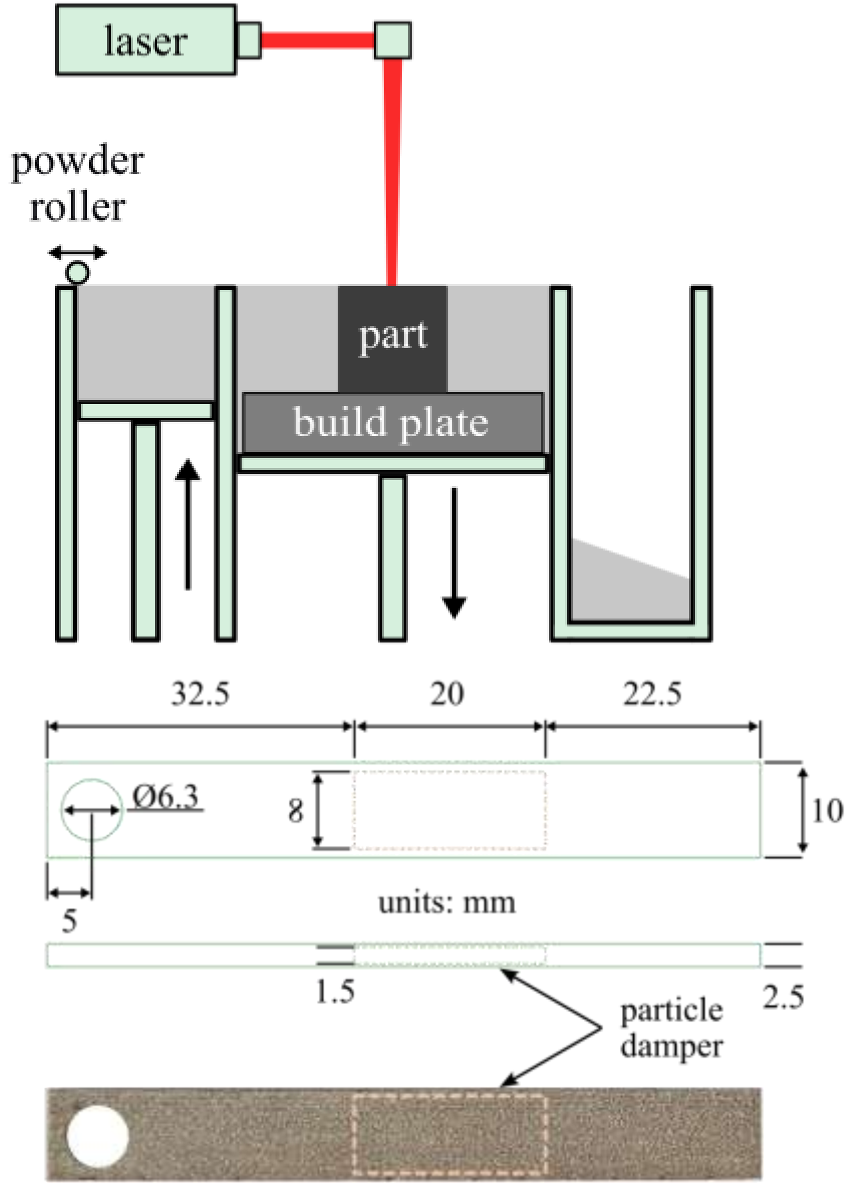


Discrete Element Method simulation

Laser Powder Bed Fusion

Laser Powder Bed Fusion

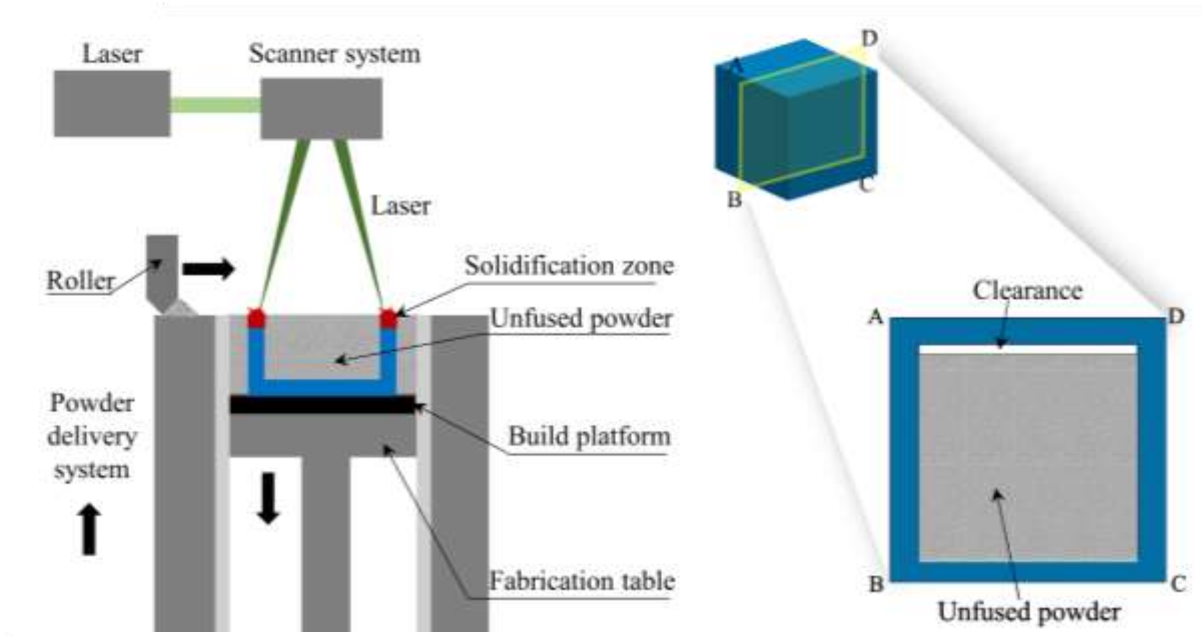
- Make complex parts
- High precision
- Material efficiency
- Wide material compatibility

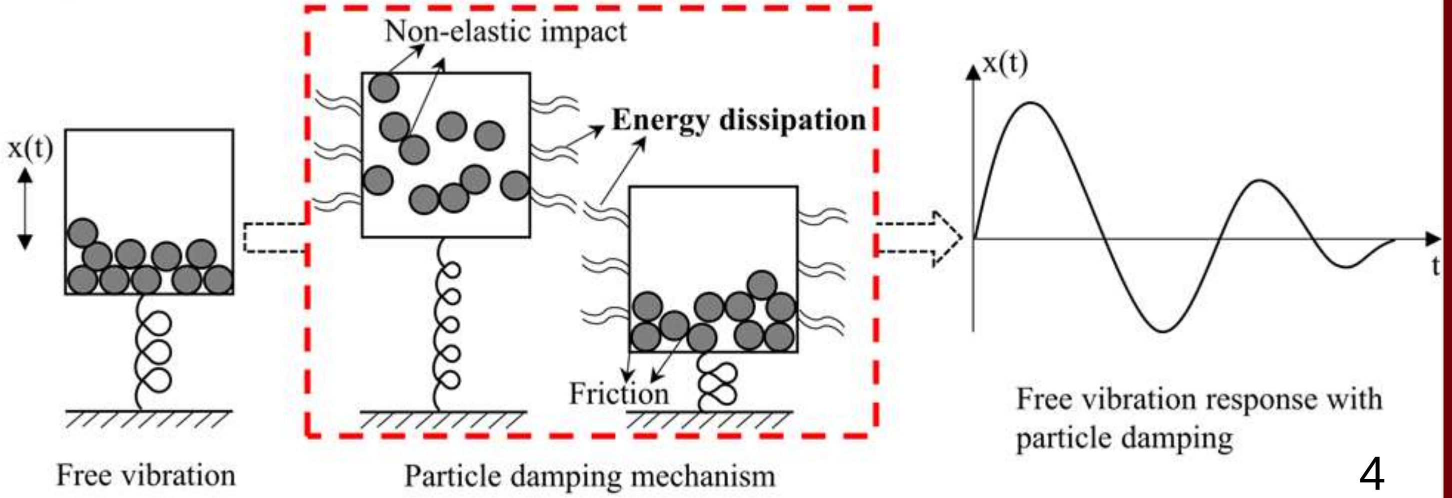


Particle Damper

Particle Damping in LPBF

- Dissipates energy via friction and collisions
- Simple, cost-effective, and robust damping mechanism
- LPBF allows for integrated dampers without adding extra mass



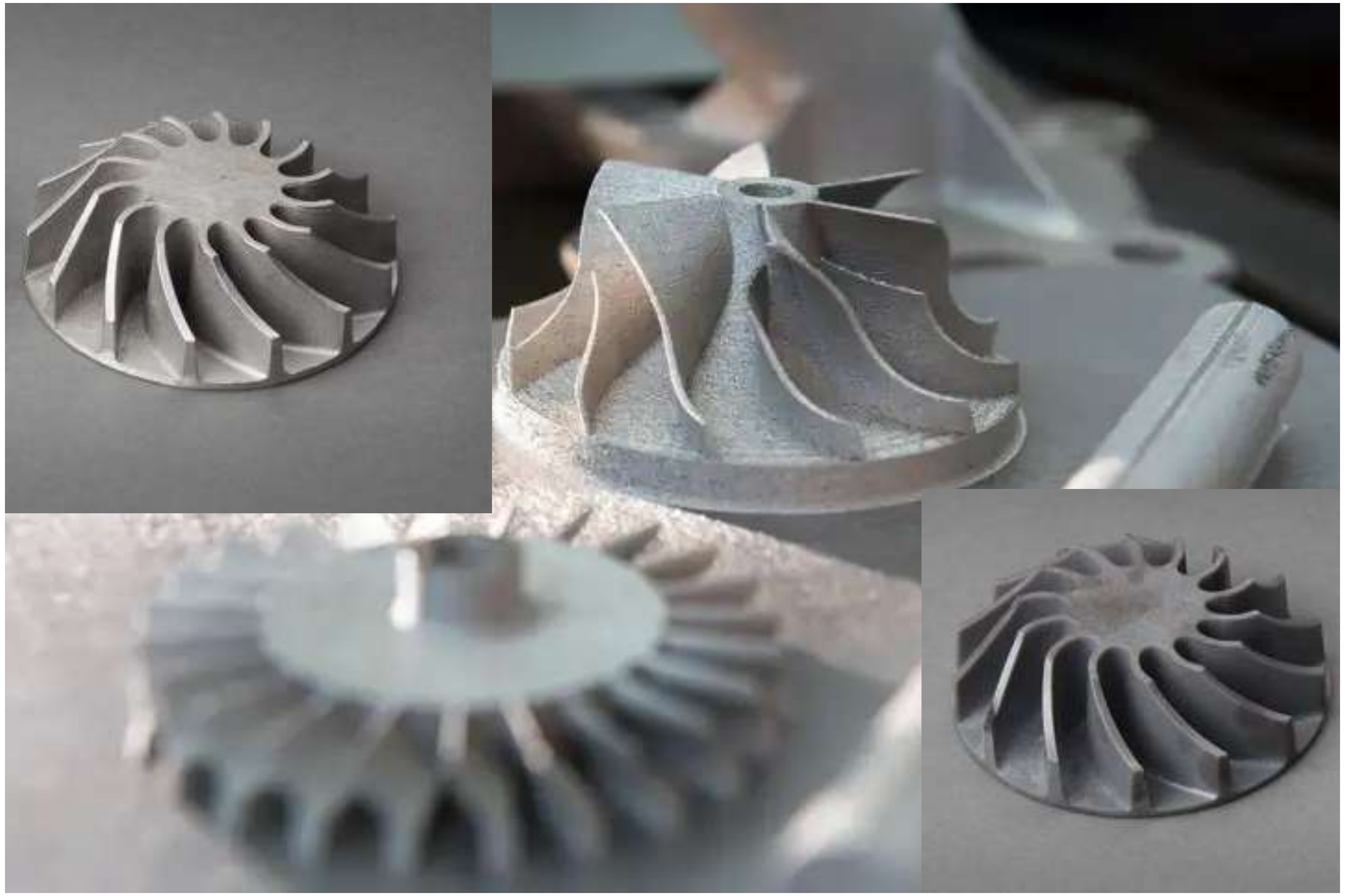


1. Guo H, Ichikawa K, Sakai H, et al. Numerical and experimental analysis in the energy dissipation of additively-manufactured particle dampers based on complex power method[J]. Computational Particle Mechanics, 2023: 1-15.

Particle Damper Application

Key applications

- Aerospace: Vibration mitigation in lightweight structures
- Mechanical systems: Damping for high-frequency oscillations
- Automotive: Enhancing durability of suspension components

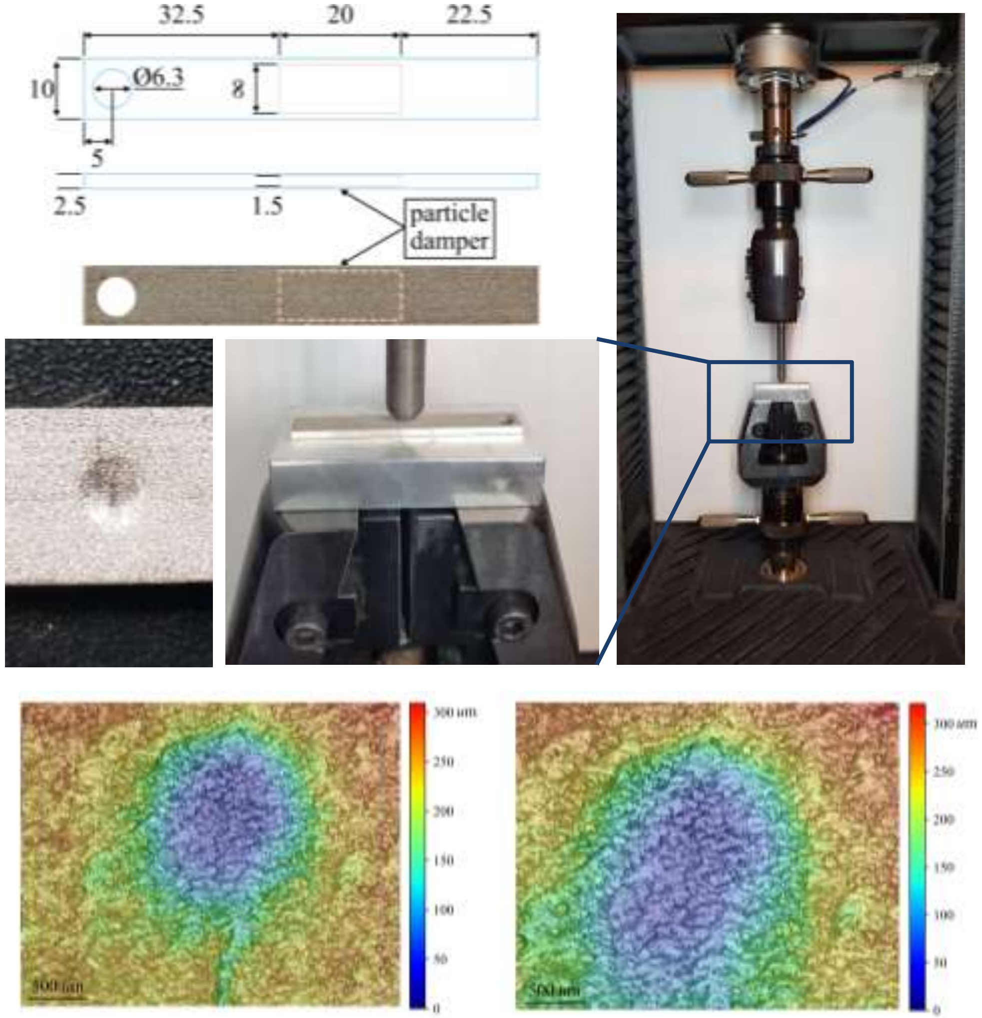


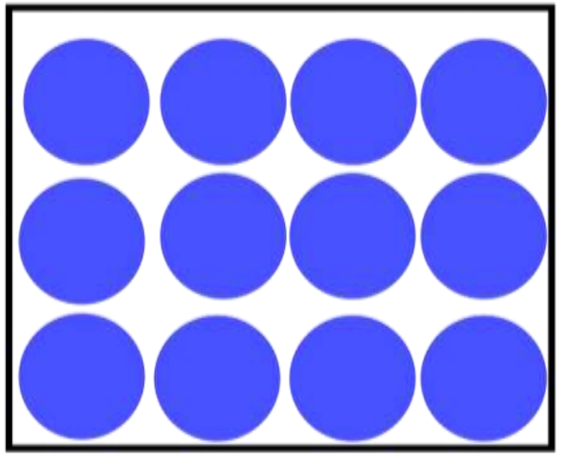
Packing Density Change

Changing Particle Packing Density

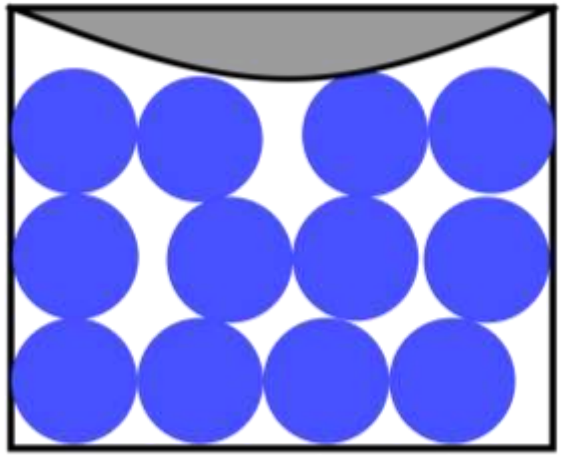
- Reduction in free space
- Changes damping capabilities
- Potential to target damping

for specific modes performance





regular

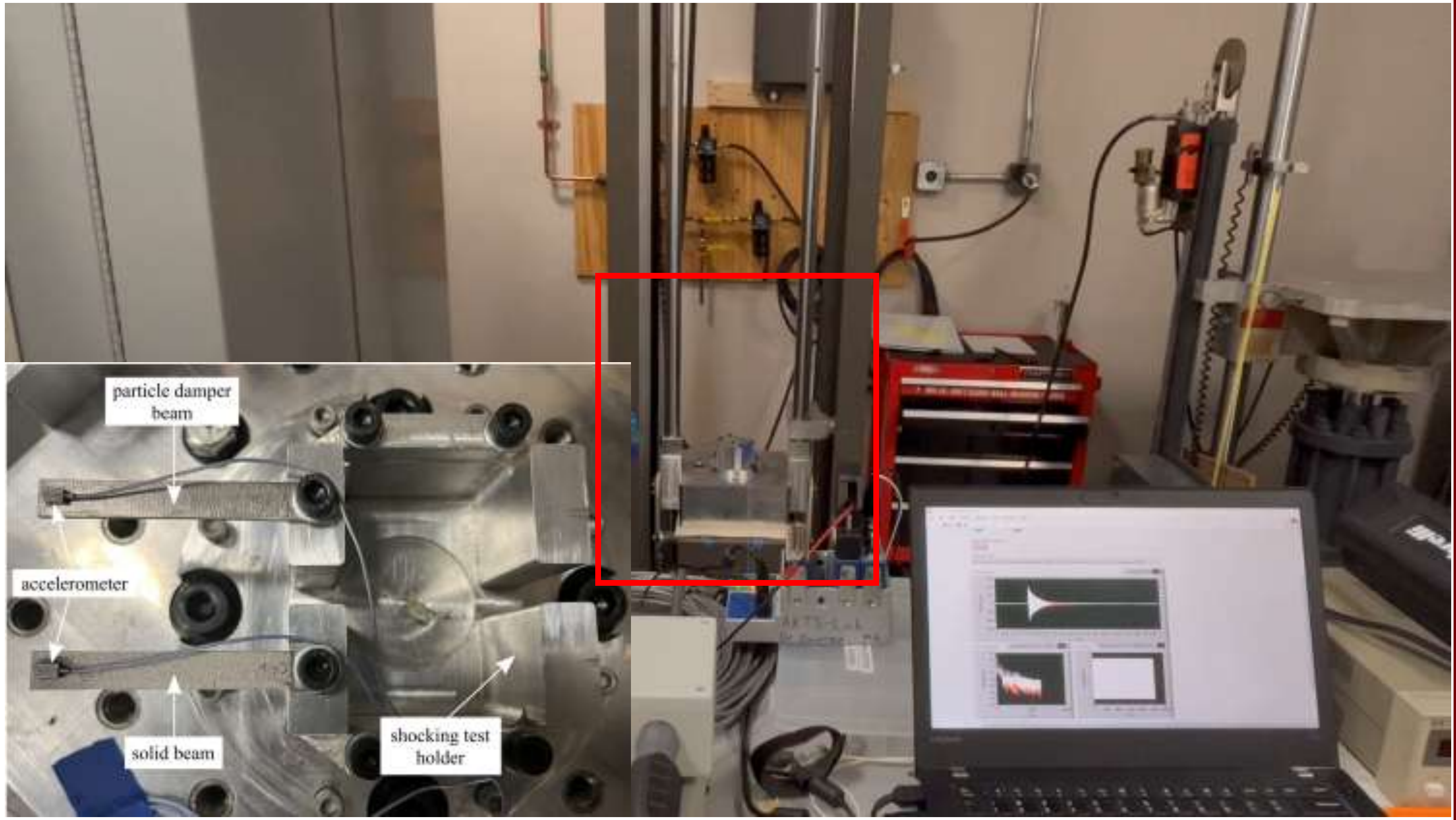


indented

Shocking Test

Shocking test setup

- cantilevered beam configuration
- test platform is dropped from a height of 76 mm to generate the impulse force
- Data collection: 50000 S/s

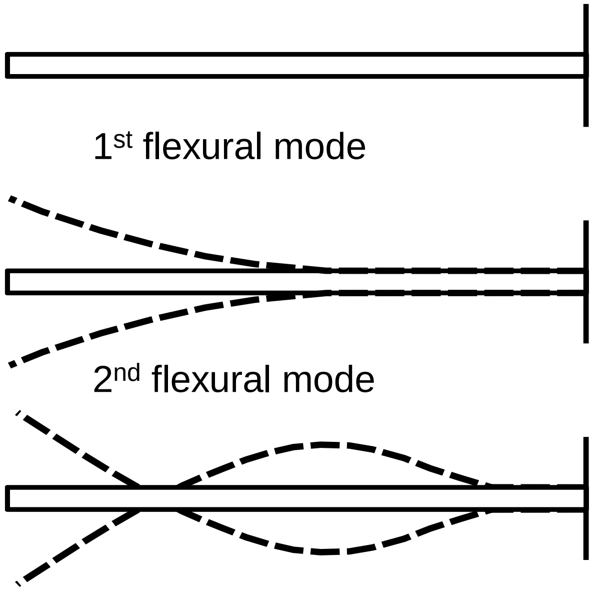


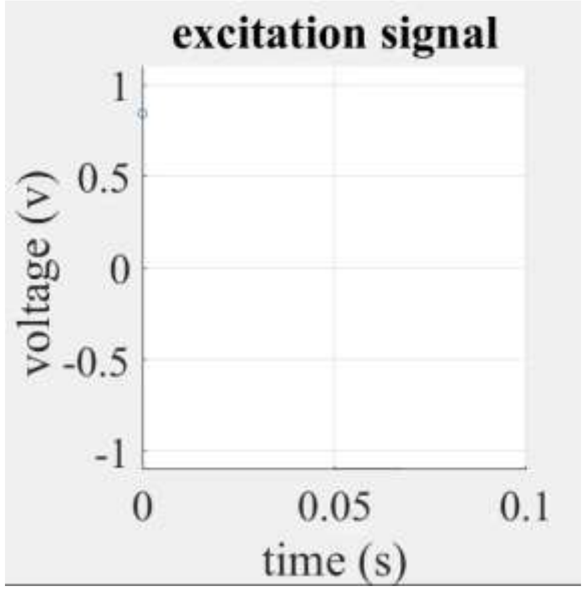
Shaking Test

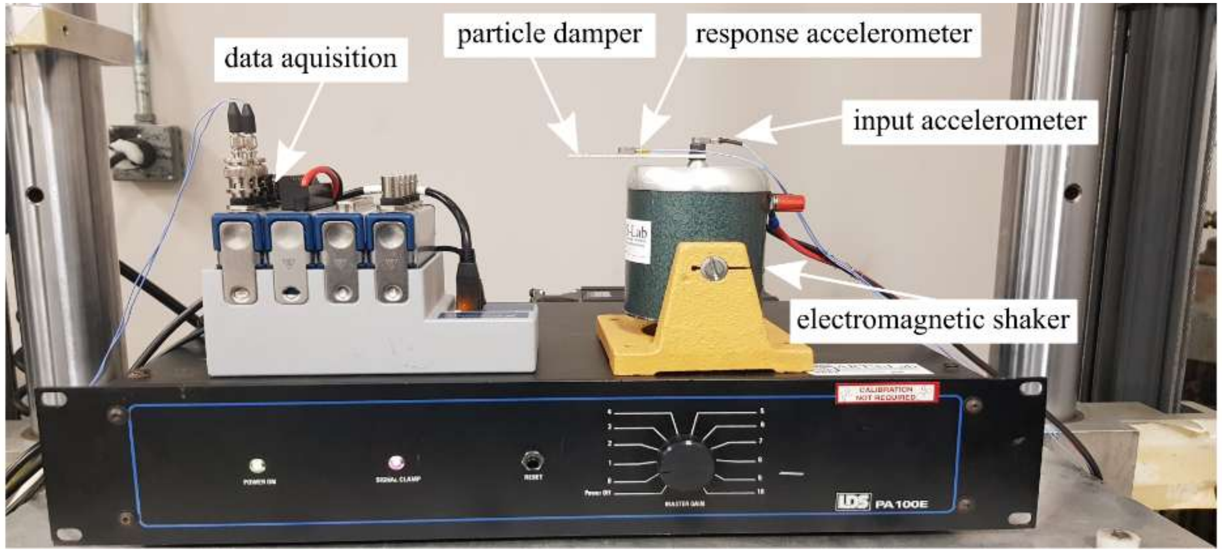
Frequency response of particle damper

- cantilevered beam configuration
- frequency sweep excitation
  - frequency range: 1-8 kHz
- second flexural mode
- acceleration frequency response observed

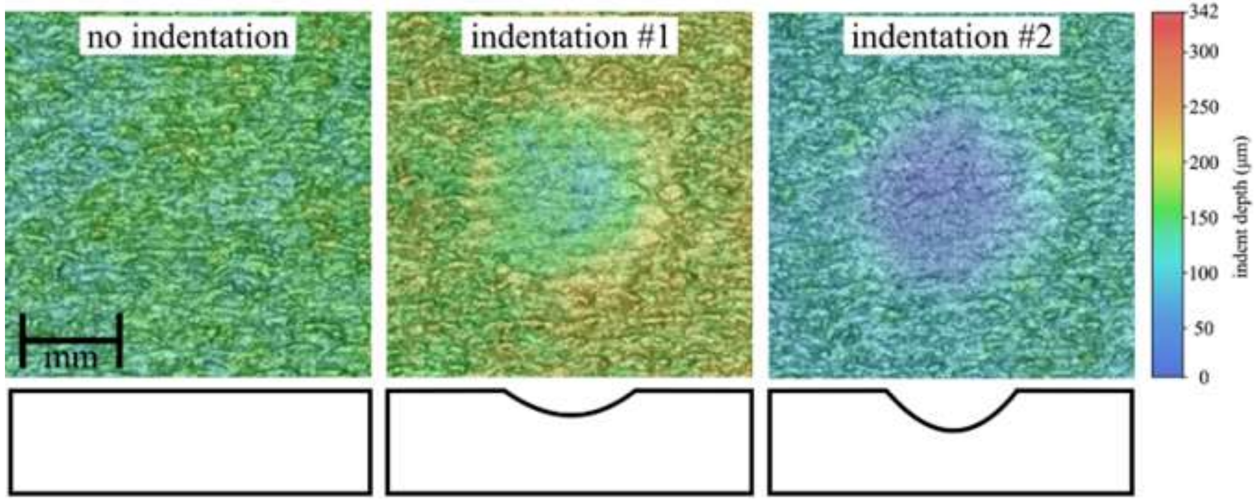
$$x(t) = \sin\left(2\pi\left(\frac{f_{\text{end}} - f_{\text{start}}}{2(\text{test time})}t^2 + f_{\text{start}}t\right)\right)$$







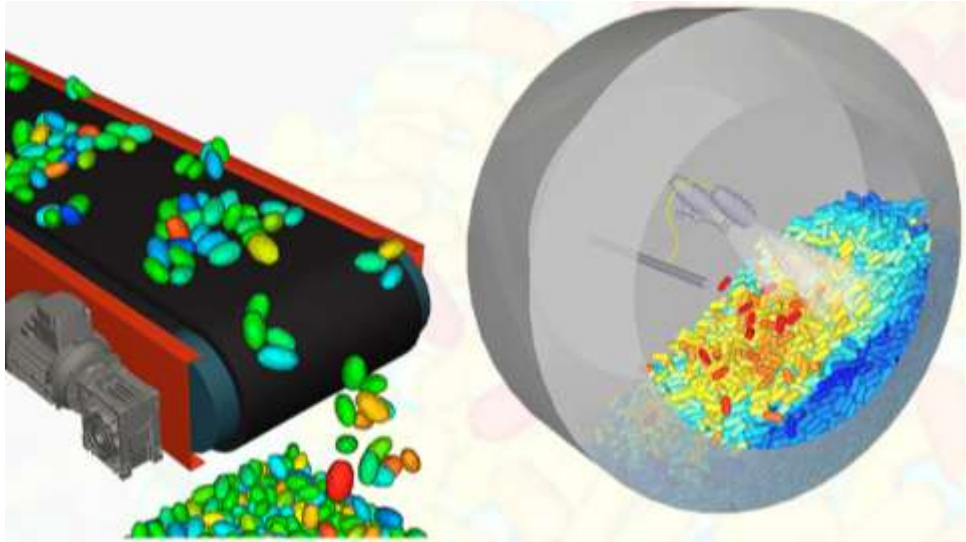
Limitation of Traditional Testing



Limitations of traditional testing

- Expensive equipment
- Time-consuming process
- Difficult to track all configurations experimentally

DEM and YADE



Discrete Element Method

- Simulates interactions between particles
- Well-suited for particle damper modeling
- Offers better insights compared to experimental testing

YADE

- Free and open-source
- Python-based, making it easy to work with

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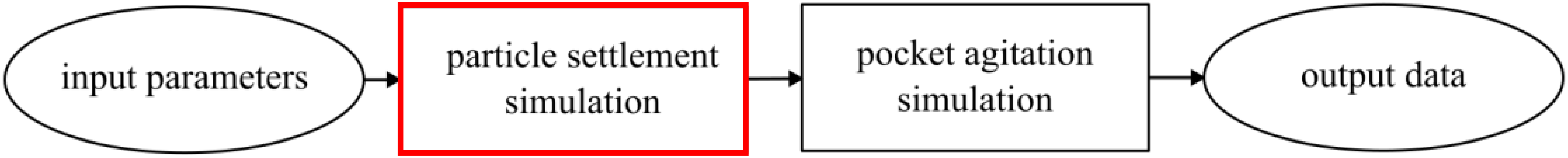
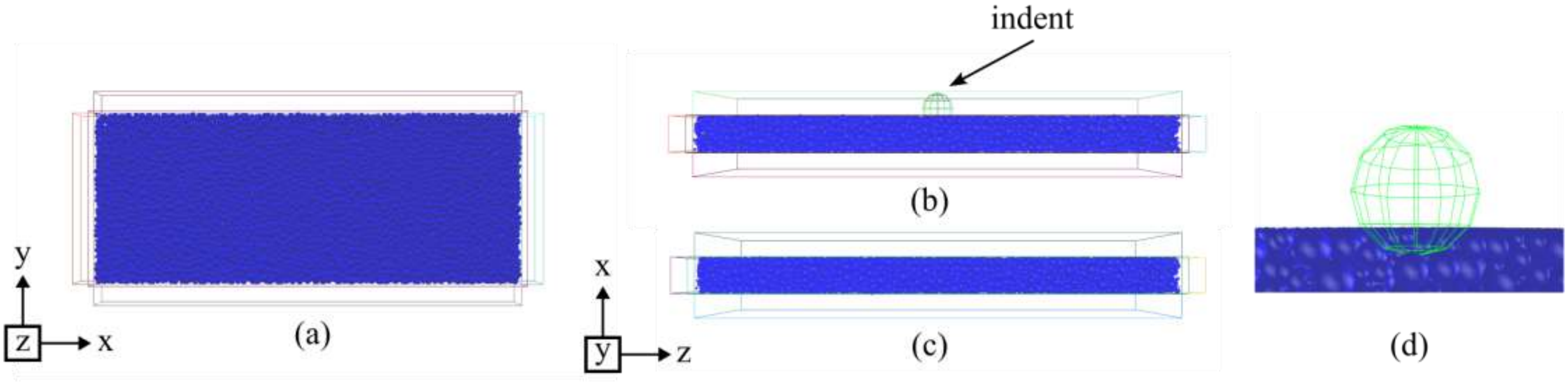
Simulation Process



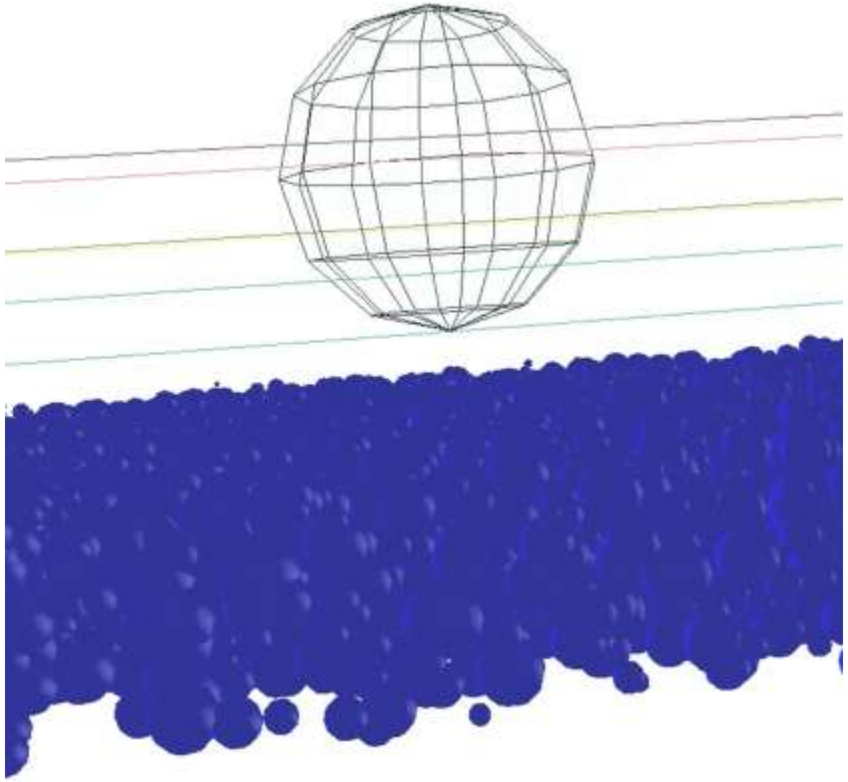


Simulation of a damper pocket, done in YADE, showing: (a) front view, (b) side view with simulated indent, (c) side view without indent; (d) cross-section of indent.

Particle Settlement and Indent

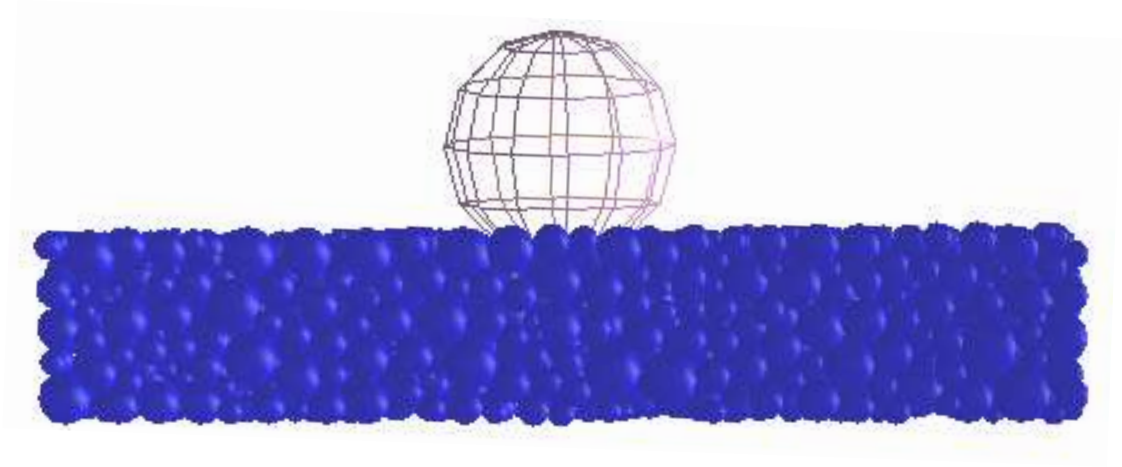
Simulation setup

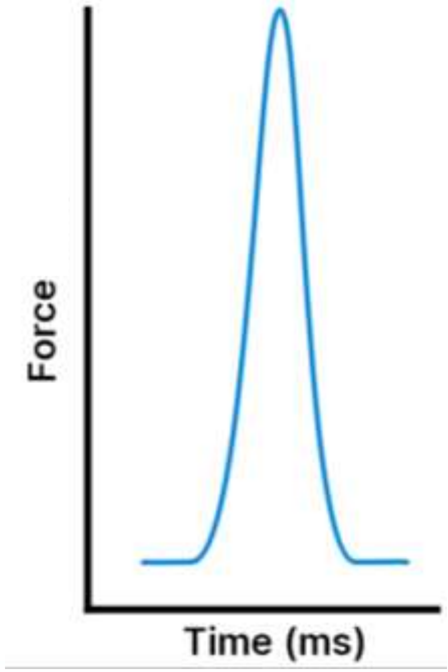
- YADE-based DEM model
- Three test cases: No indentation;
  Small indentation;
  and Large indentation



Simulated pocket being indented during particle settlement.

Indent and Impulse Force





Scaled down simulated pocket (~1300 particles) used for this study with indent applied.

An impulse force is applied to the pocket to collect the beam displacement.

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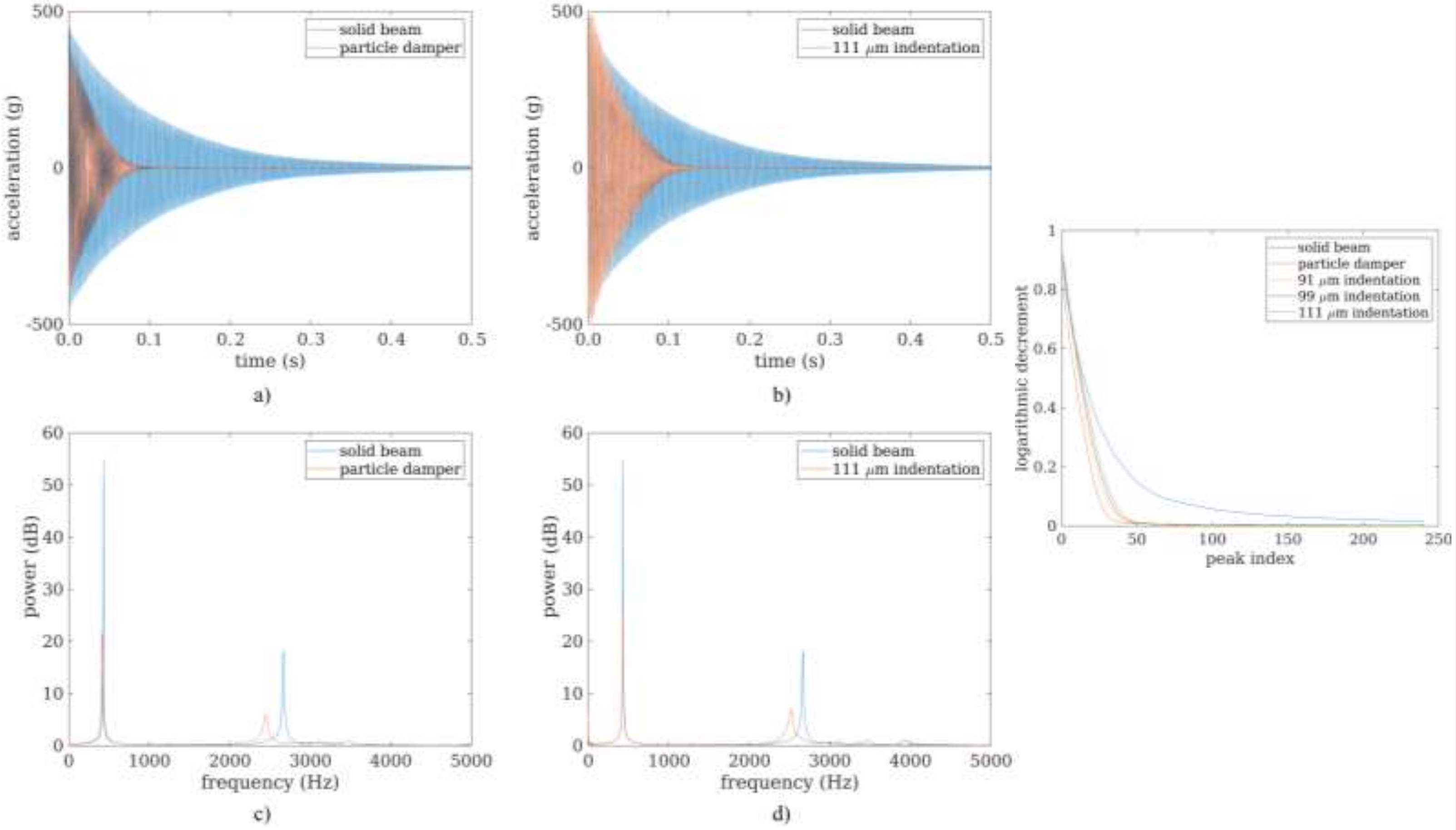
Shocking Experiment Result

Time and frequency domains:

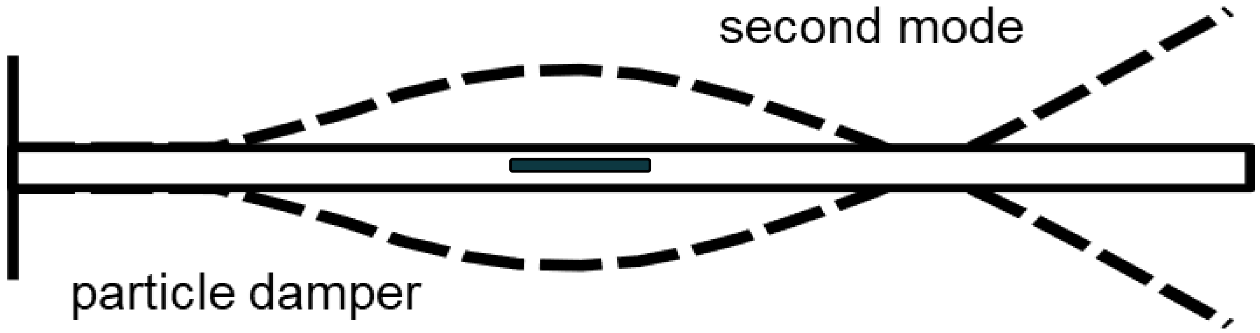
- solid beam vs. three damper cases
- particle damper inside of the beam can dramatically reduce the beam vibration
- high powder density cuts the beams damping performance down
- With the increasing indentation, the particle damper’s decay rate increases

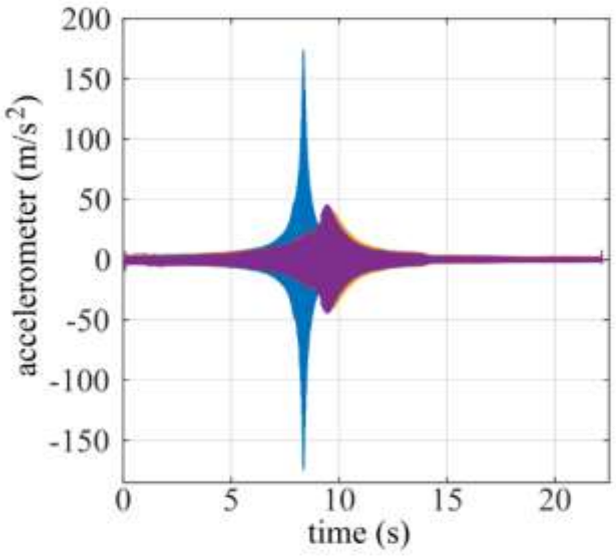


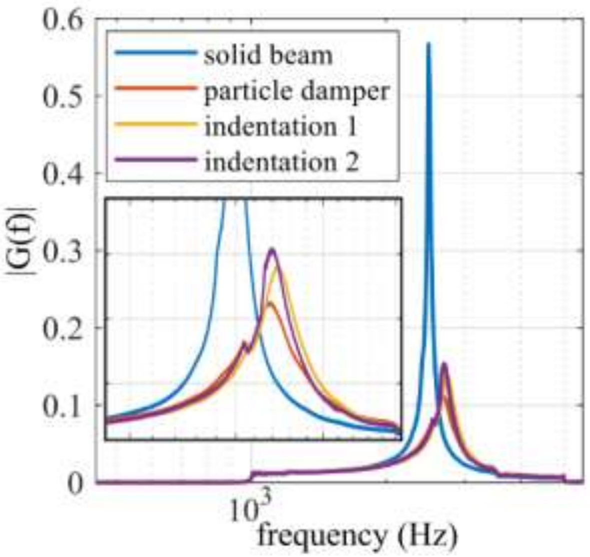
Shaking Experiment Result

Time and frequency domains:

- solid beam vs. three damper cases
- particle dampers can mitigate vibrations at targeted modes
- increasing packing density reduces damping magnitude
- shift in natural frequency observed
  - unfused powder reduces part mass

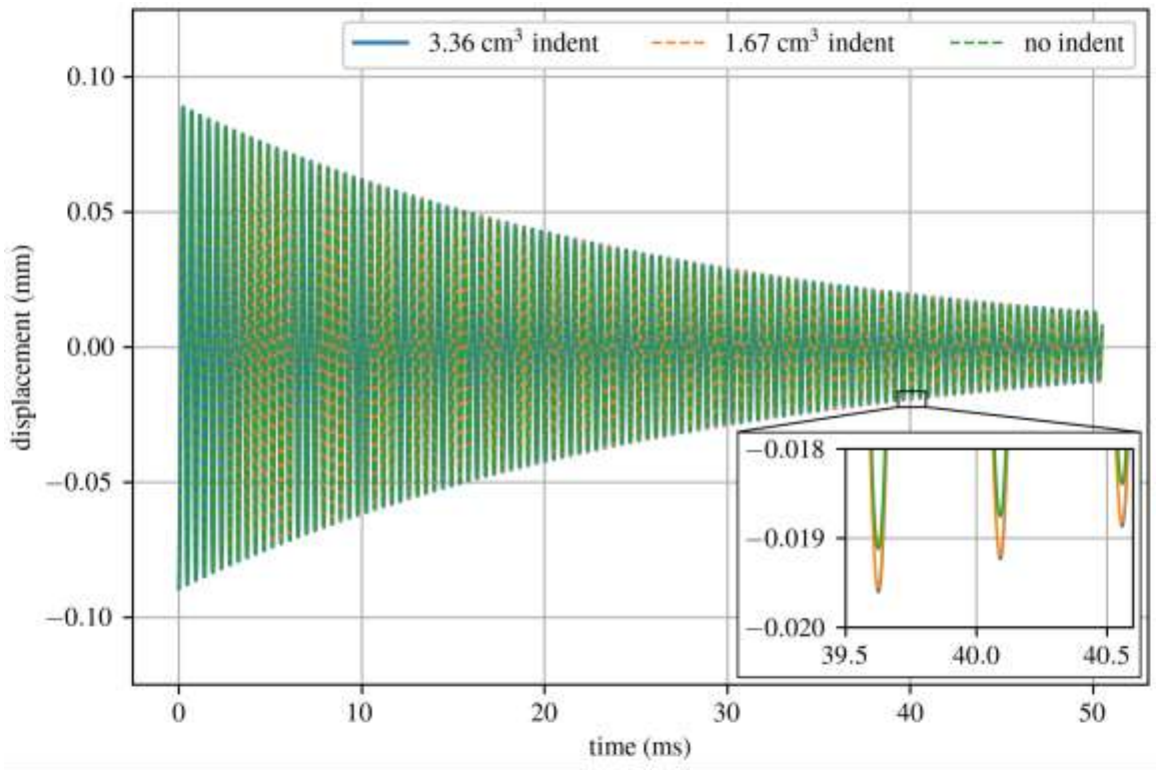






Simulation Displacement Result

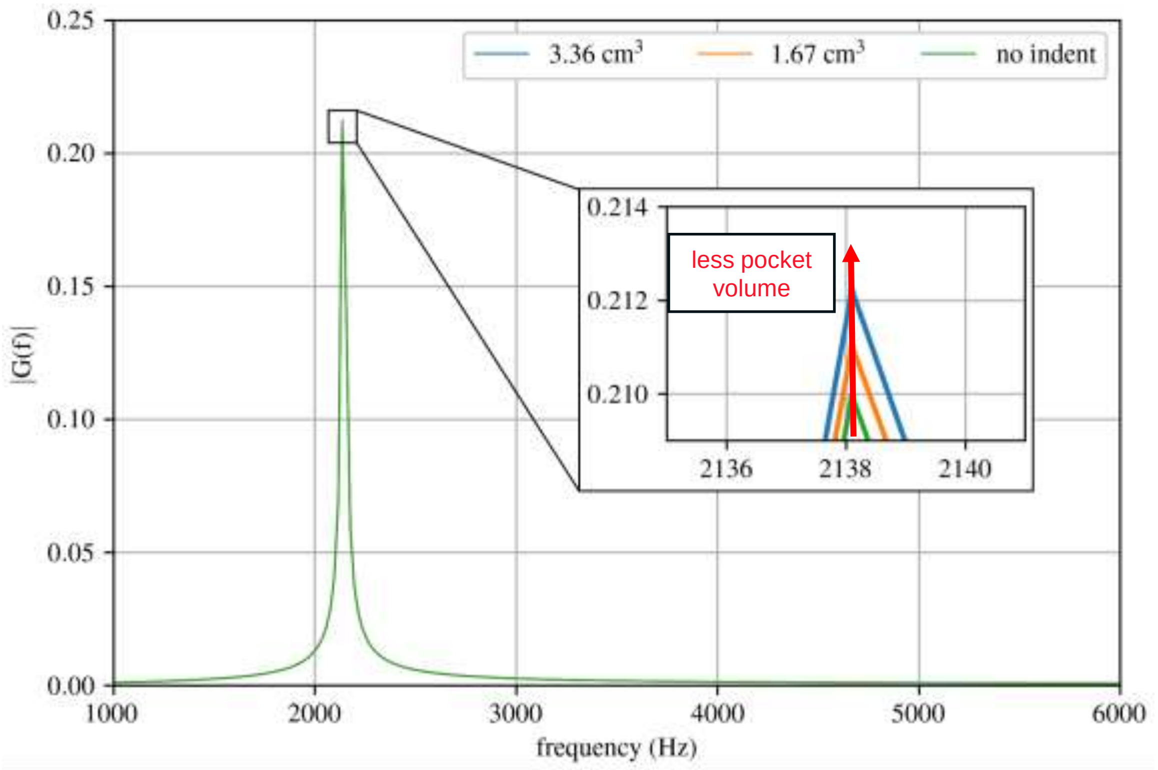
- simulation can observe changes on such a small scale without expensive equipment
- simulations showed that increasing the particle packing density reduced the damping ability
- as packing density increased via increasing indent volume, the amplitude of displacement increased



simulated damper displacement

Simulation FFT Result

- an increase in the modal resonance of the pocket as the packing factor increases
- simulations align with previous experiments using both shaker and shock testing
- we did not replicate the increase in resonant frequency associated with an increased particle packing density



displacement FFT

simulated damper displacement

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Conclusion and future work

1. This paper proposed using the discrete element method to simulate changes in particle packing density in indented LPBF particle dampers.
2. The approach aims to provide a more efficient alternative to experimental testing of indented LPBF dampers.
3. Results show that the DEM can predict trends observed in real-world experiments regarding particle packing density in particle dampers.
4. Results also demonstrated the DEM’s ability to observe said trends on scales that would require specialized equipment in experiments.
5. Future work will focus on improving the accuracy of DEM simulations on predicting properties of real-world experiments.

THANKS!

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