Damping of metallic wool with embedded rigid body motion accelerators

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What is metallic wool

- Metal filaments
- Porous material
- Homogenous
- Temperature insensitive
Why to use steel wool as a vibration damper

- viscoelastic material
  - Damping varies with temperature

- porous metallic material
  - Tangled metal wire material
    - Difficult to fabricate
  - Metal swarf
    - Heavy weight and high additional volume
    - Inconsistent stiffness and damping
Use steel wool as a vibrational damper

- Investigation of damping from steel wool
  - Effect of mode shape/strain wave
  - Effect of amplitude dependent nonlinearity

- Investigation of effectiveness of RBMAs
  - Different quantities and distributions
  - Different compaction / pre-stress levels

- Semi-analytical model
  - Modal Strain Energy method
  - Multiple Tuned Mass damper model
How to use steel wool as a vibration damper
How to use steel wool as a vibration damper
Test Structure – background

Small difference

Strain energy change

normlised shape

location (mm)

m1, empty
m1, full
m2, empty
m2, full

Sample start
Sample end
Natural frequencies do not vary with excitation amplitudes.

Damping fluctuation due to imperfect constraint.
Natural frequencies do not vary with different compaction.

Damping for 1st mode ↓; for 2nd mode, 6-layer configuration.
Damping from steel wool
Effect of excitation amplitudes (4 layer)

- Insignificant effect on natural frequencies for both modes
- Damping for 1st mode ↓; for 2nd mode ↑ SLIDING
Damping from steel wool with RBMAs

Effect of excitation level

✧ Natural frequencies
  ✓ ↑ for 1st mode, ↓ for 2nd mode

✧ Damping
  ✓ 1st mode: ↑ up to 3g and then ↓ until 7g
  ✓ 2nd mode: ↓ up to 3g and then ↑ until 7g

✧ Sloshing mode for rigid spheres
Damping from Steel wool with RBMAs

Effect of RBMA quantities/distribution (1g excitation)

Mode 1

0.028 W

0.054 W

0.052 W
Damping from Steel wool with RBMAs

Effect of RBMA quantities/distribution (1g excitation)

Mode 2

Multiple peaks
– Dissipation power

0.017 W

0.036 W

0.05 W
Damping from steel wool with RBMAs

Overall performance of RBMAs

➢ Natural frequency
  ✓ steel wool ➔ additional mass
  ✓ locations of RBMAs

➢ Damping
  ✓ steel wool ➔ constant damping
  ✓ internal resonance of RBMAs

Mode 1
Damping from steel wool with RBMAs

Overall performance of RBMAs

- **Natural frequency**
  - ✔ steel wool ➔ structure stiffener
  - ✔ locations of RBMAs

- **Damping**
  - ✔ steel wool ➔ constant damping
  - ✔ internal resonance of RBMAs

**Mode 2**
Semi-analytical model

Strategy

✧ Identify strain wave ➜ Total strain energy for steel wool.
✧ Using multiple TMD model to identify energy dissipation from Steel wool and RBMAs. (modal strain energy method)
✧ Insert updated strain energy of steel wool back to harmonic analysis
Semi-analytical model

Analytical model — elastic properties

Different density for steel wools
Semi-analytical model

Strategy

- Identify strain wave ➔ Total strain energy for steel wool
- Using multiple TMD model to identify energy dissipation from Steel wool and RBMAs. (modal strain energy method)
- Insert updated strain energy of steel wool back to harmonic analysis
Semi-analytical model

Analytical model
Semi-analytical model

Assumptions

- RBMAs: Spherical and rigid; Move normal to steel wool
- Steel wool: isotropic and homogenous
- No interaction between neighboring RBMAs
Semi-analytical model

Analytical model

- Procedures
  - Initial displacement was estimated using harmonic analysis
  - Force acting on steel wool by RBMAs was then calculated and compared with inertia force.
  - Iterations were carried out to achieve convergence between inertia force and displacement and then calculate strain energy
Semi-analytical model

Strategy

- Identify strain wave → Total strain energy for whole system
- Using multiple TMD model to identify energy dissipation from Steel wool and RBMAs. (modal strain energy method)
- Insert updated strain energy of steel wool back to harmonic analysis
Conclusion

- Steel wool was shown to be a good metallic damping medium.
- RBMA showed a significant improvement on the energy dissipation of steel wool.
- Semi-analytical numerical model was established to predict the performance of steel wool with RMBAs.
Thanks for your attention. Any questions?