Design and Fabrication of Quasi-Zero Stiffness Mount Prototypes

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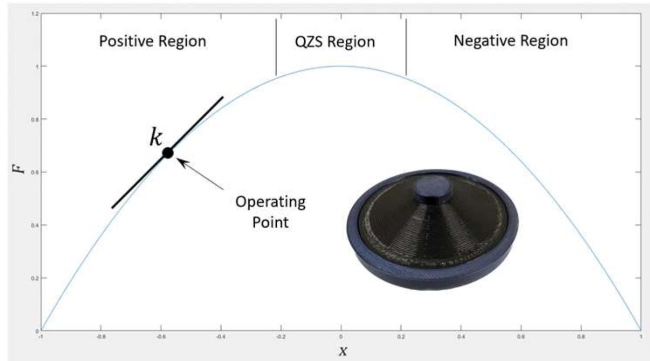
Abstract

In the mounting of mechanical systems, vibration isolation may be helpful to enhance the durability and/or comfort of nearby people. Isolation results from low-stiffness mounting, which may have the undesirable byproduct of large-amplitude motion. This project proposes physical prototyping of a nonlinear mount concept which obtains excellent vibration isolation through quasi-zero stiffness (QZS) mounts while maintaining resistance to large motion. The operating principle of these mounts involves large deflections, so candidate 3D printable rubber-like elastomers were selected. Material characterization tests were conducted to provide nonlinear material properties to the finite element (FE) models used in mount design and analysis which predict the desired multi-regime stiffness profile.

Physical mount prototypes were then printed and subjected to static and dynamic stiffness testing. Design success criteria include relatively high stiffness under no preload, very low stiffness under a specified preload value, and a smooth force-deflection behavior. Additional features such as an overload stopper were also considered. The prototype mount performance successfully achieved the desired stiffness profile, and additional issues were uncovered related to the effects of damping. More advanced designs and a more thorough investigation of damping are suggested for future work.

Quasi-Zero Stiffness (QZS) Concept



Material Testing

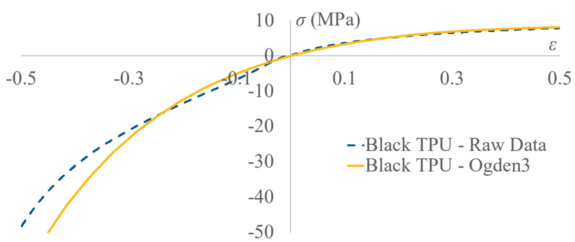
Tension Sample (ASTM D412)

Compression Sample (ASTM D575)

- Material property measurements
  - Tension
  - Compression
  - Volumetric compression
- Material Characteristics
  - Hyperelastic (nonlinear)
  - Viscoelastic (high damping)
  - Possibly anisotropic

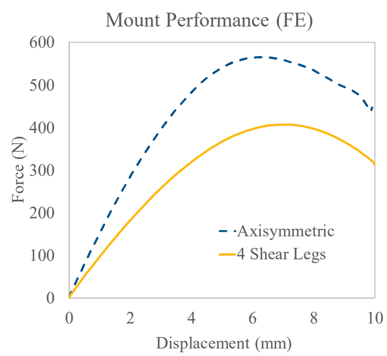
Several Materials

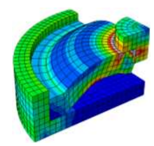
Nonlinear Material Modeling

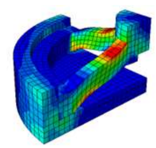


- Nonlinear elastomer
  - Properties vary with load
  - Interact with nonlinear geometry
- Ogden material model:
  - Curve-fit physical data
  - Captures elastic behavior for FE model

Finite Element Modeling

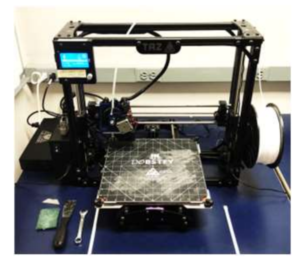


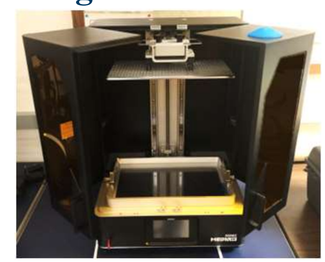




- Finite element models
  - Simulate physical performance
  - Capture complex geometry
- In simulation, mounts exhibit:
  - High initial stiffness
  - Tuned QZS region
  - Unstable negative-stiffness region

3D Printing





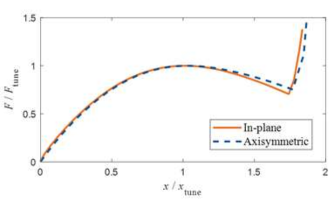
Fused Deposition Modeling (FDM)

- Lulzbot Taz 5
- Solid TPU filament
- Moderate geometric accuracy
- Easy manufacture process

LCD Liquid Resin Printer

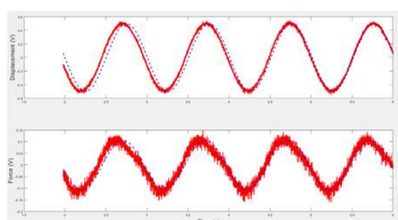
- Phrozen Sonic Mega 8K
- UV-cured liquid resins
- Outstanding geometric accuracy
- More involved process

Static Testing



- Slow "quasi-static" compression of mount
- Provides stiffness information
- Minimal damping effects due to slow speed
- QZS property achieved

Dynamic Testing



- Rapid, dynamic inputs (e.g. sinusoidal)
- Combined stiffness and damping property
- Damping contributes to force transmissibility
- QZS effectiveness impacted by dynamic forces

Future Work

- Develop next generation design concept
- Investigate effects of material damping
- Broaden range of materials to include cast elastomers

References

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