GS-13 Seismometer Alternative Flexure Design

Stanford University – Advanced LIGO Seismic Isolation Team

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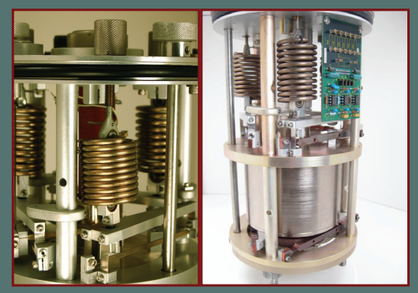
LIGO LASER INTERFEROMETER GRAVITATIONAL-WAVE OBSERVATORY

Background

The GS-13 is a single axis seismometer that is used as a feedback sensor for both the HAM and BSC chamber seismic isolation systems. The current installation of the GS-13 seismometer requires the addition of an internal, remote-controlled, proof mass locking motor. This motor is required because the existing "delta-rod" flexures that currently constrain the proof mass have a maximum of 3.4g of loading before they go into Euler buckling.

It would be advantageous to design a new flexure that would sustain up to a 20g acceleration load without failing but that would:

- Keep the instruments' natural frequency the same as original flexures
- Maintain same performance / noise floor
- Not have a significantly higher cost than the remote locking motors
- Be easy to manufacture / implement



GS-13 Seismometer

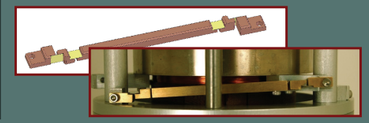
Design and Calculations

Failure Modes:
- Euler buckling
- Stress

Round / Elliptical Notch Flexures:
- Provide better buckling protection
- Unknown closed form buckling load equation
- Use equation for stiffness and stress (Flexures, S. Smith)

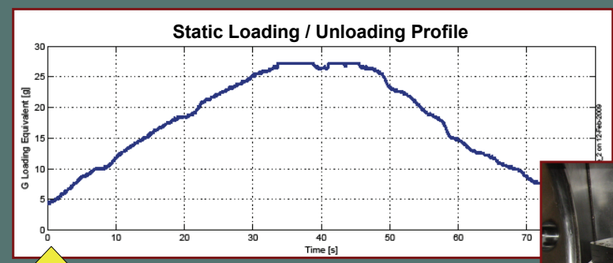
Maraging Steel Flexure:
- Round notch flexure design
- 45g max static equivalent loading
- High material cost
- Moderate machining difficulty
- Extensive hardening procedure
- Can be magnetized – holds proof mass

Brass / BeCu Strip Flexure:
- Flat crossed strip design
- 18g max static equivalent loading
- Inexpensive
- Difficult assembly

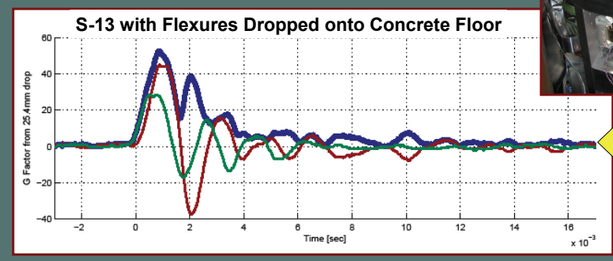


Solid BeCu Flexure:
- Large (r = 0.250 in.) notch design
- 33g max static equivalent loading
- Easier to machine and harden
- Non-magnetic

Testing / Validation

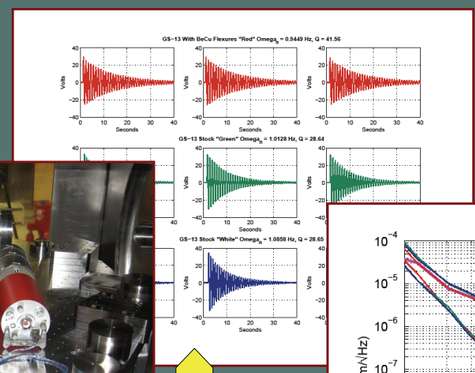


Static loading of the BeCu flexure at maximum deflection up to load cell saturation verifies failure point is greater than 27g (33g calculated load limit)



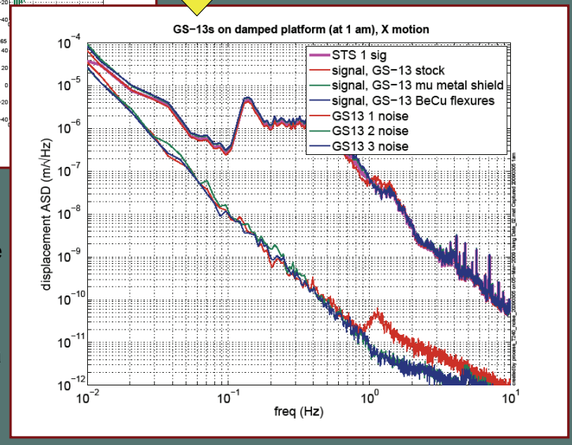
Drop of an instrument with flexures onto a concrete floor from a height of 1 in. creates g loading in excess of 50g, no detectable effect on flexures

Testing of the modified GS-13 against other instruments on the Stanford ETF



Multiple weight lift tests demonstrate the new flexures (in red) provide a lower natural frequency and a higher Q factor than stock flexures

Comparison of the GS-13 equipped with the new flexures to 2 stock GS-13 witness, 2 Streckeisen STS-2, a Trillium T-240, and 6 stock feedback GS-13 seismometers on the Stanford ETF Demonstrates acceptable signal and noise levels



Acknowledgements

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Conclusions

The final design of a solid BeCu flexure is a promising alternative to the stock flexure and remote locking motors. The new flexures, through prototype testing, were demonstrated to meet or exceed the stated design requirements.