ATTENUATION OF CRYOCOOLER INDUCED VIBRATION USING MULTIMODAL TUNED DYNAMIC ABSORBER

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OUTLINE

- Introduction
- Tuned Dynamic Absorber – HOW STUFF WORKS?
- Multimodal Tuned Dynamic Absorber - simulation
- Multimodal Tuned Dynamic Absorber - experimentation
- Conclusions and future work
Novel HOT IR detectors are operative at >150K

SWaP&C split Stirling cryocoolers: low Size, Weight and Power & Cost

Side-by-side packed compressor and expander \(\Rightarrow\) tonal force couple \(\Rightarrow\) tonal translational and angular vibration \(\Rightarrow\) angular line of sight jitter and translational defocusing

Regular SDOF Tuned Dynamic Absorber – not sufficient for complex vibration control

Multimodal Tuned Dynamic Absorber - simultaneous attenuation of translational and angular vibration
TUNED DYNAMIC ABSORBER – HOW STUFF WORKS?

TDA

COMPRESSOR

DEWAR-DETECTOR ASSEMBLY
FREQUENCY TUNING

\[
\frac{\text{Mass Dynamic Absorber}}{\text{Total Mass}} = 5\%
\]

\[
\text{Damping Ratio} = 0.014\%
\]
350 mg rms @ 72 Hz $\Rightarrow$ 6.9 N rms @ 72 Hz
17 $\mu$m rms @ 72 Hz

3.4 mg rms @ 72 Hz $\Rightarrow$ 0.066 N rms @ 72 Hz
0.16 $\mu$m rms @ 72 Hz
Multimodal mechanical resonator with “useful” dynamic modes matched to the driving frequency.

Dynamic reactions: forces and moments counterbalance cooler induced vibration export.
FINITE ELEMENTS DESIGN FOR 105HZ
SIDE-BY-SIDE INPLANE PACKED CRYOMODULE
TRANSLATIONAL AND ANGULAR FREQUENCY RESPONSES

- Compressor: 8N@100-110Hz
- Expander 3N@100-110Hz
TRANSLATIONAL AND ANGULAR FREQUENCY RESPONSES

Without MTDA

With MTDA
EXPERIMENTAL SETUP
EXPERIMENTAL SETUP

Mechanical design

Testing setup
EXPERIMENTAL SETUP
VIBRATION SPECTRA WITH AND WITHOUT MTDA

33-fold attenuation

[Graph showing vibration spectra with and without MTDA.]

52-fold attenuation

[Graph showing vibration spectra with and without MTDA.]

Acceleration, g

Angular acceleration, rad/s²

Frequency, Hz
CONCLUSIONS AND FUTURE WORK

- Multimodal Tuned Dynamic Absorber - attenuation of angular and translational components of cryocooler induced vibration
- Experimental testing supports experimental predictions