Mechanical Inerter for Vibration Mitigation in Seismic Events

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Introduction

Modern day vibration mitigation systems are often made up of springs and dampers. These two components help control the velocity and displacement of a system. However, there are very few systems that incorporate any mechanical elements that control the acceleration of a system. Mechanical components that control the acceleration go by the name of “Inerter”. The fundamental concept of the ball screw inerter is to convert linear motion to rotational motion, and store that energy in a flywheel. The storage of this energy can be used to effectively dampen vibrations. The inerter acts as a “simulated mass”, which increases the effective mass of a system.

Objective

One of the primary focuses was to create an inerter that is small scale while maintaining a high effective mass. The purpose of this is to implement these mechanical components into small spaces while still providing a high effective mass. Another focus of the team was to determine how to implement the inerter into a vibration mitigation system to dampen vibrations targeting 3 Hz or less. Additionally, the team focus was set on creating an inerter that requires little to no maintenance, is cost effective, scalable, tunable, quiet, and is easily manufactured and assembled. With all of these characteristics, the inerter can become a more viable option to improve vibration mitigation systems.

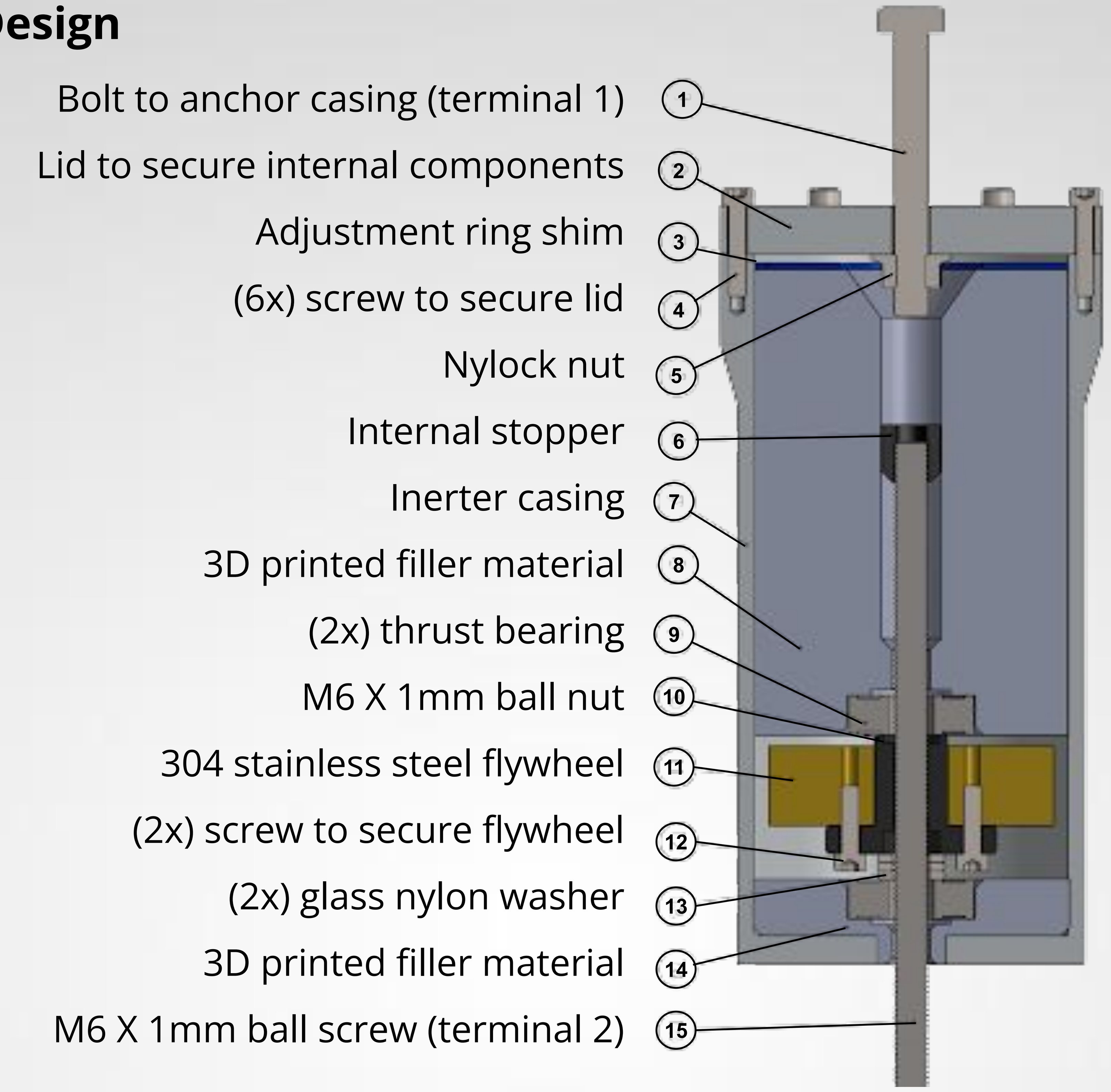
Metrics

Design Requirement	Specification
Small Scale	Inerter Volume ≤ 400 cm^3
Target Frequency	Target Frequency ≤ 3 hz
Amplitude Reduction	Amplitude Reduction ≥ 20%
Sound Intensity	Sound Intensity ≤ 60 dB
High Inertance	Inertance Value ≥ 250 kg

Key Equations

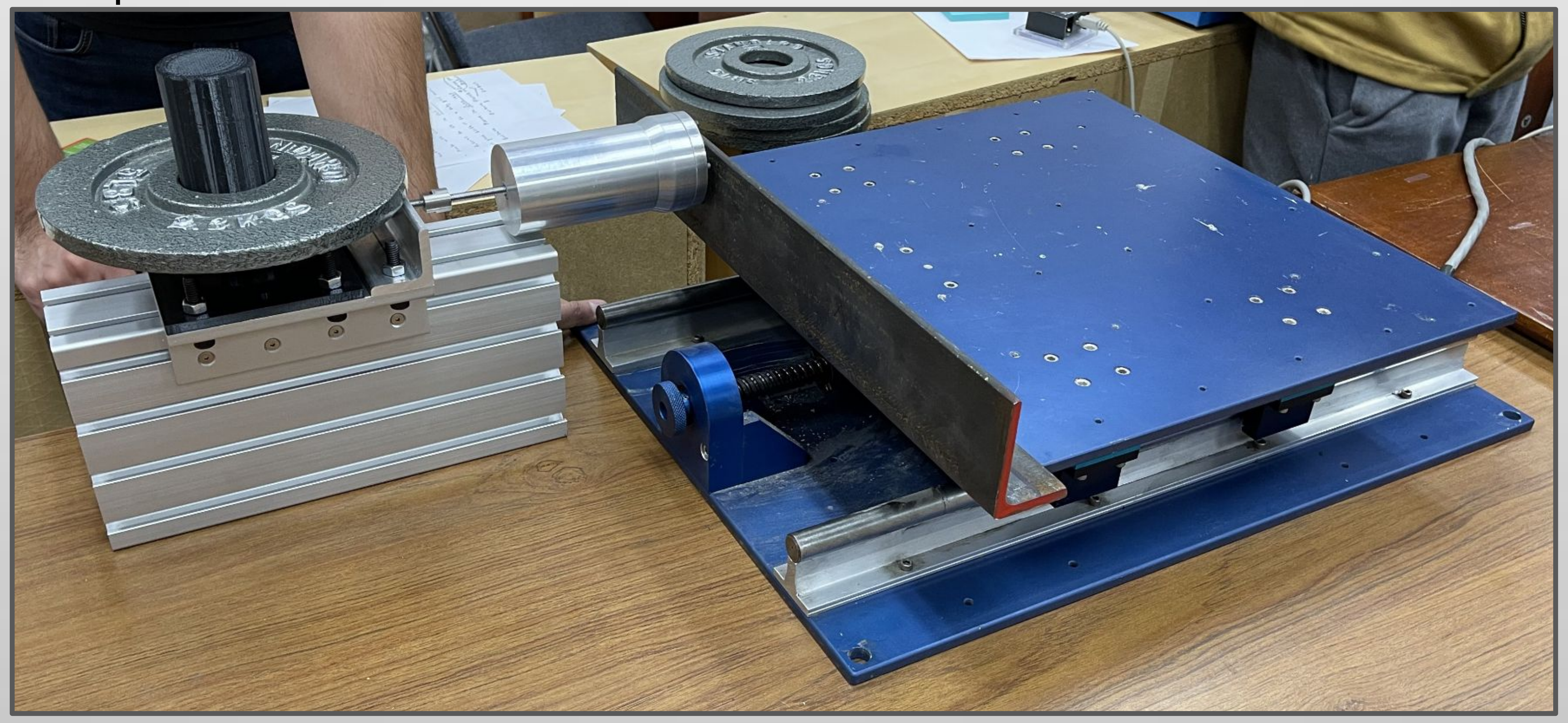
Description	Equation
Theoretical Inertance	$F = b(a_2 - a_1)$
Ball Screw Inerter Inertance	$b = \left(\frac{2\pi}{L}\right)^2(\Sigma I) + m_s$

Design



Test Setup

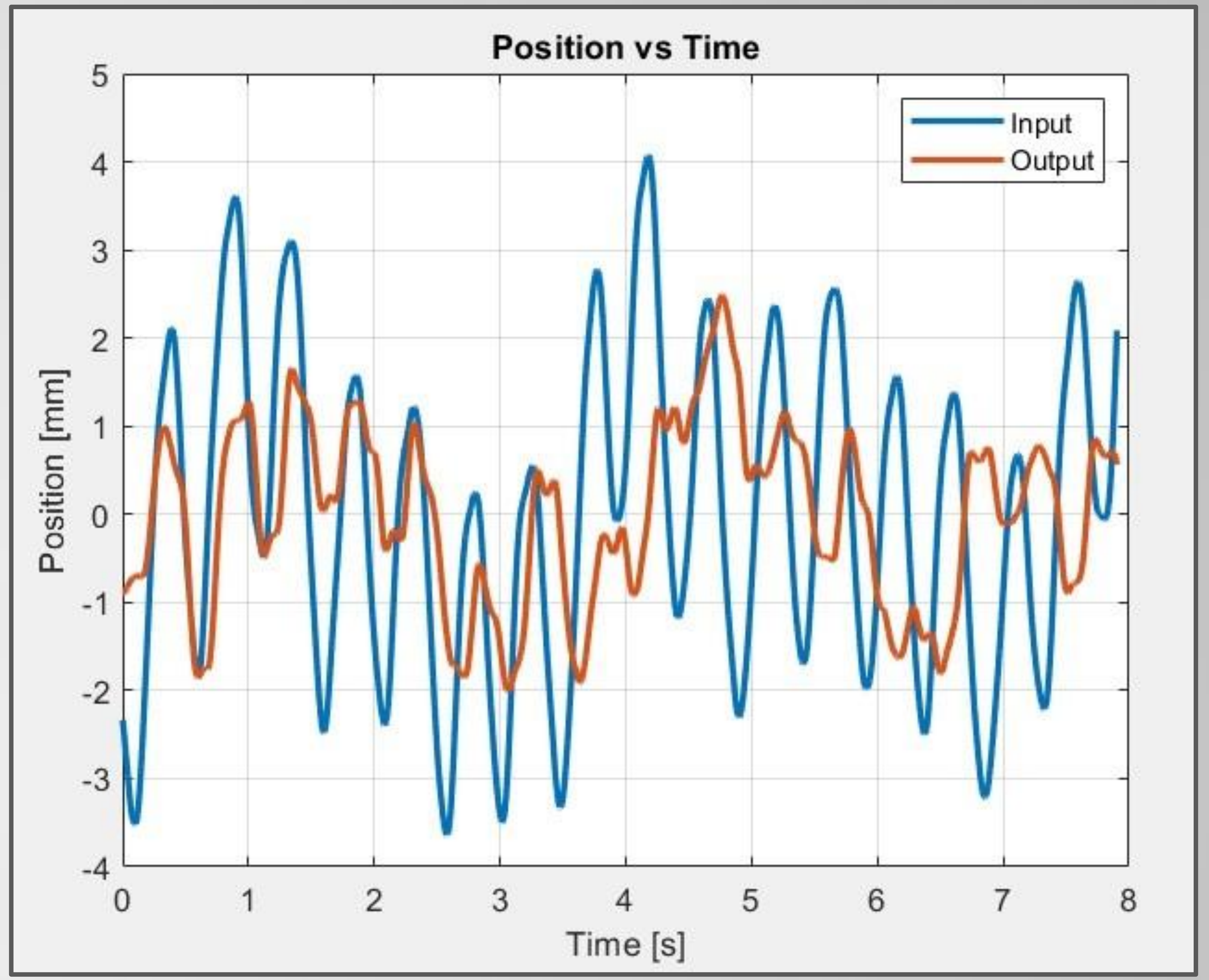
To test the efficacy of the inerter, the inerter was integrated between a weighted cart and a Quanser Shake Table II. At the time of testing, the shake table was broken and had to be moved by hand. A oscillating displacement was applied to the shake table with an approximate amplitude of 2.5 mm and a frequency of 2 Hz as the input signal. The input was applied to one terminal of the inerter. The other terminal of the inerter was connected to the weighted cart and output the damped vibration signal. The test setup can be seen below.



Test setup showing the linear bearing, weighted cart, inerter, and shake table

Results and Conclusions

The results of the vibration testing are shown in the graph below. The output signal had an average amplitude of 1.5 mm, whereas the input signal had an average amplitude of 2.5 mm. Thus, the average percent reduction of the amplitude was 40% at 2 Hz.



Specification	Achieved
Inerter Volume ≤ 400 cm^3	392 cm^3
Target Frequency ≤ 3 hz	2 Hz
Amplitude Reduction ≥ 20%	40%
Sound Intensity ≤ 60 dB	53.2 dB
Inertance Value ≥ 250 kg	2028 kg

Future work

The inerter should be tested in a mechanical system similar to the one below. A system such as this will target a specific frequency, and yield an amplitude reduction of nearly 100%. The bode plot would yield a notch filter 180 degrees out of phase.