Double-Thread Mechanical Inerter

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I. Introduction

A mechanical inerter is a two terminal device where the force generated is proportional to the relative acceleration between its terminals. This constant of proportionality is called inertance. The dynamic model of a mechanical inerter system is shown in Figure 1, where b represents the damping coefficient of the inerter. Inerters are used to damp output frequency by converting linear motion to rotational energy of a flywheel. A double threaded inerter allows for the two terminals of the inerter to move in opposite directions, causing flywheel rotation. We aim to prove that a double-thread mechanical inerter is capable of reducing the effects of vibrations from experimental testing and data collection.

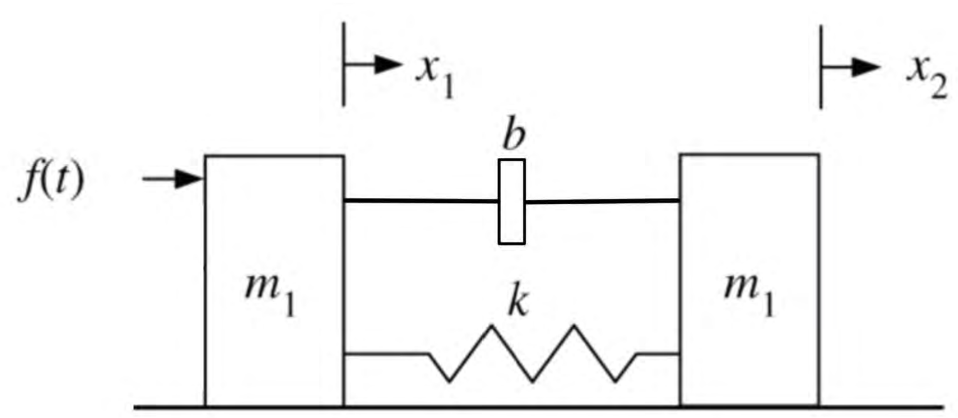

Figure 1: Dynamic model of a mechanical inerter.

II. Problem

Our primary user was the Utah Waves & Architect Materials Lab. Their goal was to write an experimental research paper to prove that a double-screw mechanical inerter is capable of reducing the effects of vibrations. Our job was to design a double screw inerter and obtain experimental data though testing that can be used in their research paper to support their thesis. The design requirements are listed in Table 1.

Table 1: Design Requirements

Design Objective	Specification
Returns to Initial Position	< 2.5mm Variation
Maximum Design Volume	$1000\ cm^3$
Cost	< $70
Operating Frequency	1-5 Hz
No Self-Locking	Friction Angle < Pitch Angle
Connection to Shake Table	Acrylic Plate
Reduction in Acceleration	$a_1 < a_2$
Experimental Natural Frequency Matches Theory	3.7 Hz

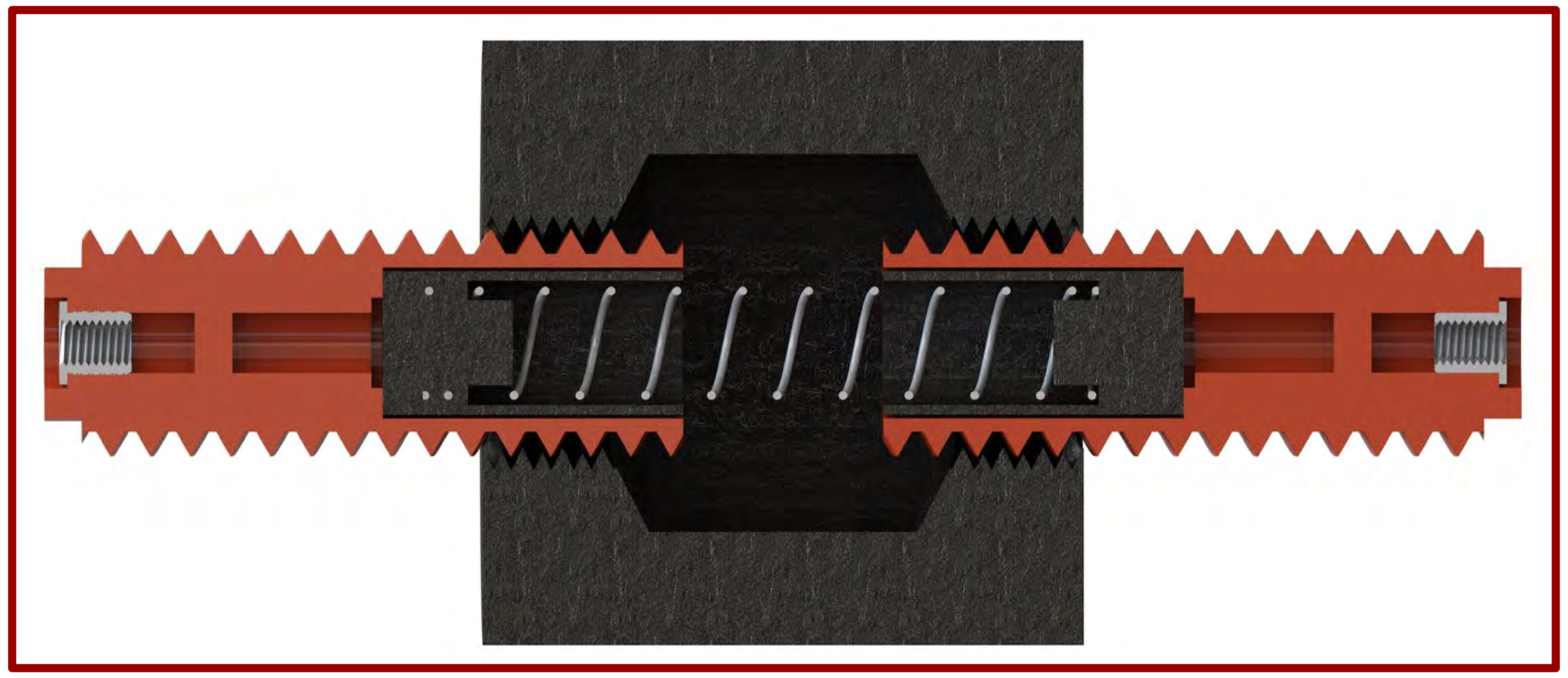

Figure 2: Rendering of the double-thread mechanical inerter. Studs (indicated in red) have left and right handed thread, respectively. The flywheel (black) is internally double threaded.

III. Methods

To test the mechanical inerter we attached the terminals to a linear rail system. The input (terminal 1) was connected directly to the shake table via an acrylic plate. The output (terminal 2) was free to move along the rail system. An accelerometer was connected to the shake table to measure the input acceleration. An additional accelerometer was connected to the free terminal to measure the output acceleration. This test set up can be seen in Figure 3.

Our testing procedure consisted of running tests at a range of frequencies from 1 Hz to 5 Hz. Each test consisted of allowing the shake table to run for 10 seconds for the inerter to reach steady state and then recording the accelerations of the free terminal and the shake table output. This was done for three different amplitudes: 0.5 cm, 1.0 cm, 1.5 cm. The data was then plotted to show the ratio of accelerations between the free terminal and the shake table.

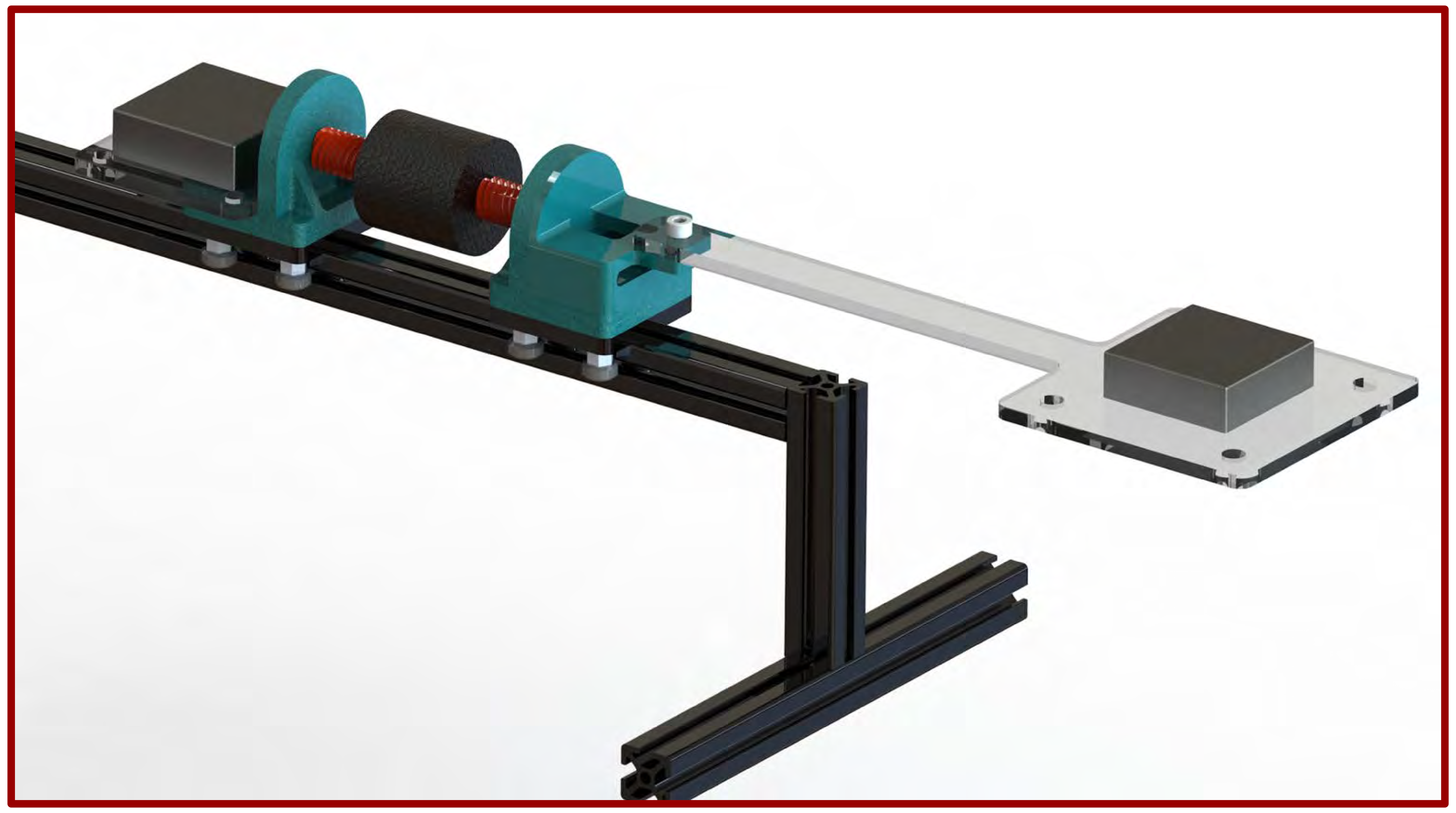

Figure 3: Rendering of the testing set up. Includes the rail system and accelerometer connection points.

IV. Results

After the data was collected, we plotted the acceleration of the shake table against the acceleration of terminal 2 (Figure 4). From the plots we saw a reduction in acceleration at terminal 2 in all frequencies and amplitudes. When comparing the ratio of acceleration amplitudes at all frequencies test, we observed peak inertance at 3.6 Hz with a reduction in amplitude of 52.2%. However, no peak was observed at the theoretical natural frequency as seen in Figure 4.

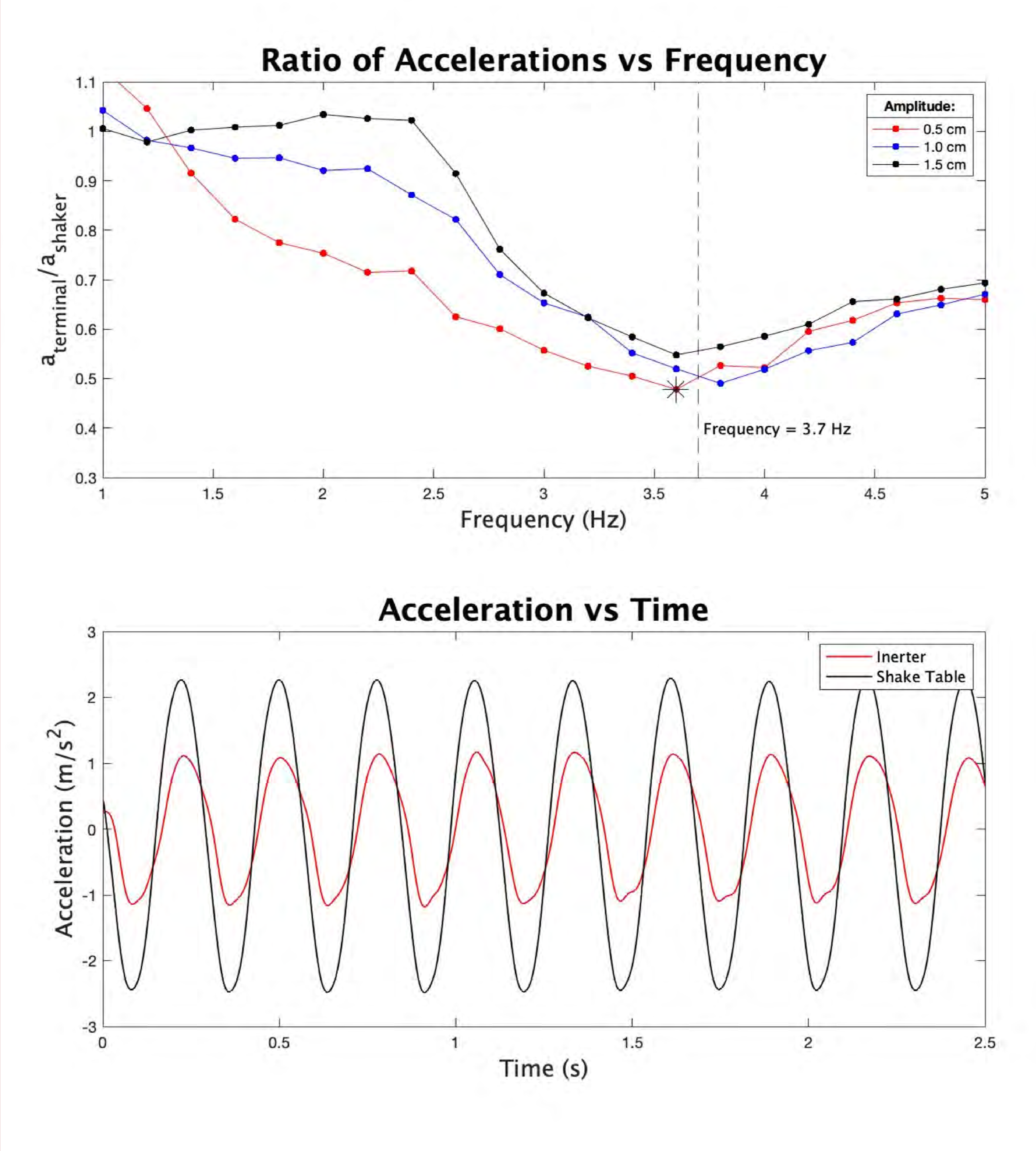

Figure 4: Ratio of terminal accelerations to input accelerations versus frequency (top plot). Acceleration versus time for the shake table and inerter at 3.6 Hz with an amplitude of 0.5 cm (bottom plot).

V. Conclusions

We concluded that the double thread design of the inerter functioned as intended by reducing the amplitude of vibrations, as seen in Figure 4. From the data collected, we found limitations with the predictability of the inerter since the natural frequency did not match the theoretical calculations. Further research will need to be done to include a larger range of frequencies and experimentally determine the natural frequency. If this design of inerter functions at a larger scale, a double-screw inerter could have applications in commercial use such as wind turbines and structural vibration mitigation.