Fabrication of a Semi-Active Friction Damping Device

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Introduction

Modern structures use lighter and are more malleable, which increases vibrations from wind and extreme events like earthquakes. Multi-hazard events can create issues when preparing for the next natural disaster, as they are hard to predict and appropriately design for. Tornados, earthquakes, hurricanes, and others have shown the absolute vulnerability of transportation structures and buildings [1]. Semi-active damping is one solution to overcome specific bandwidth tuning from passive systems and are shown to increase harmonic excitation mitigation [2].

The purpose of this research study is to create a new semi-active damper for mitigation of harmonic excitations called the Semi-Active Banded Rotary Friction Device (SABR-FD). Having simple mechanics, different friction materials available, an adjustable resonance setting, and low maintenance costs give this device positive outlook in more high capacity semi-active friction damping technology [3].

Instrumentation

Instruments in use during testing are a hydraulic MTS actuator, Transducer Techniques load cells, and the Tolomatic electronic actuators provided by PennAir. Software used to make CAD drawings and the simulations are Fusion 360 and SolidWorks.

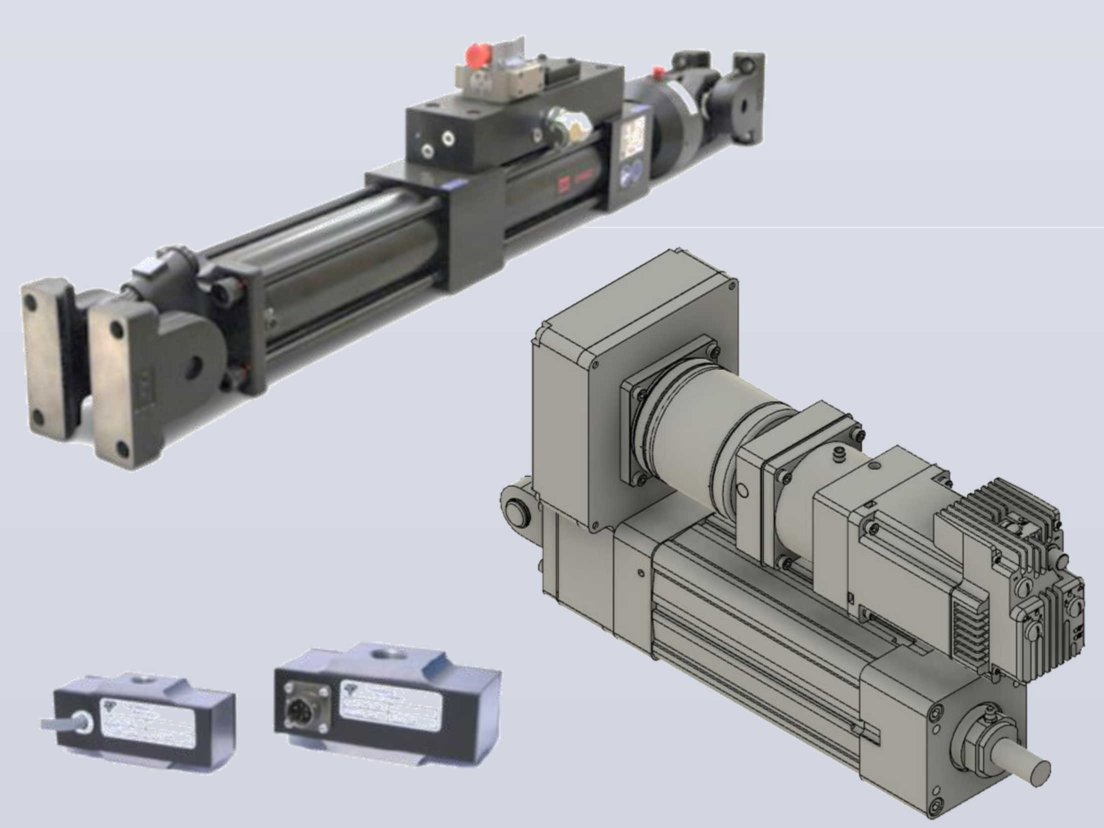


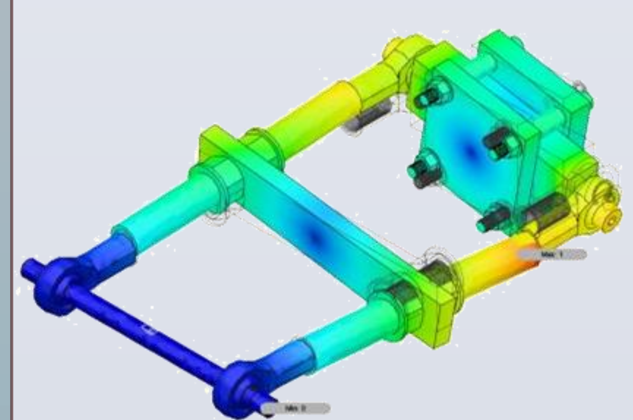
Figure 1: MTS DuraGlide™ 244.22 Hydraulic Actuator, TOLOMATIC Actuators, and Transducer Techniques load cells

Methodology

First, designing the new drum is done using CAD modeling in Fusion 360 and is drum is finished and fabricated. The original drum was completely hollow with plates on the outer edges while the new drum has three plates and allows for the use of ball bearings to help with stiffness.

Figure 2: New drum left, and original setup right

The next step was modeling the new connection from the MTS actuator to the drum. Original connection had slop and more moving parts than needed. Modal analysis gave different modes of vibration (shape) that corresponds to frequency.



Mode Number	Frequency (Hz)
1	60.64
2	71.9
3	275.6
4	285.6
5	367.6

Figure 3: Connection modal analysis

The damping mechanism for the drum is shown below. The band is anchored at one end, where an input force ($F_{applied}$) is applied to the center band, resulting in a reactionary force ($F_{reaction}$) at the opposite end. Once drum rotation occurs, a friction force ($F_{friction}$) is generated in the opposite direction of rotation. The force represented is simply

$F_{reaction} = F_{applied} + F_{friction}$ [1], [3].

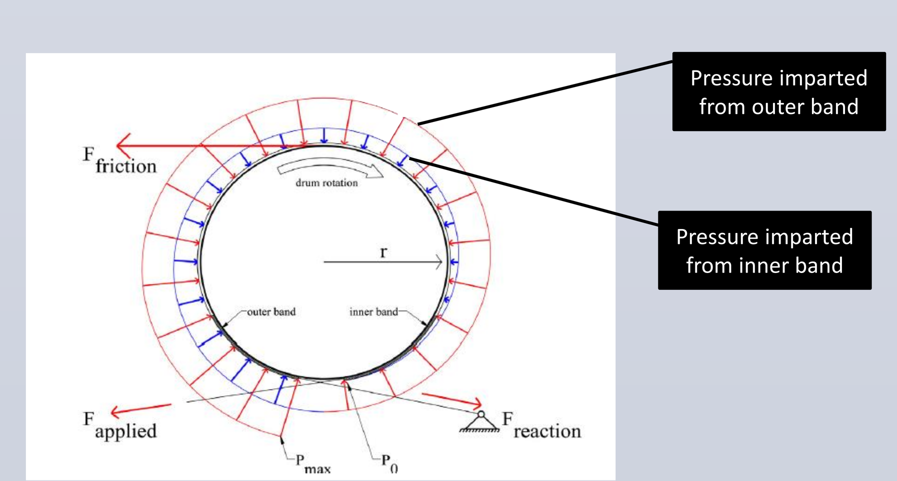
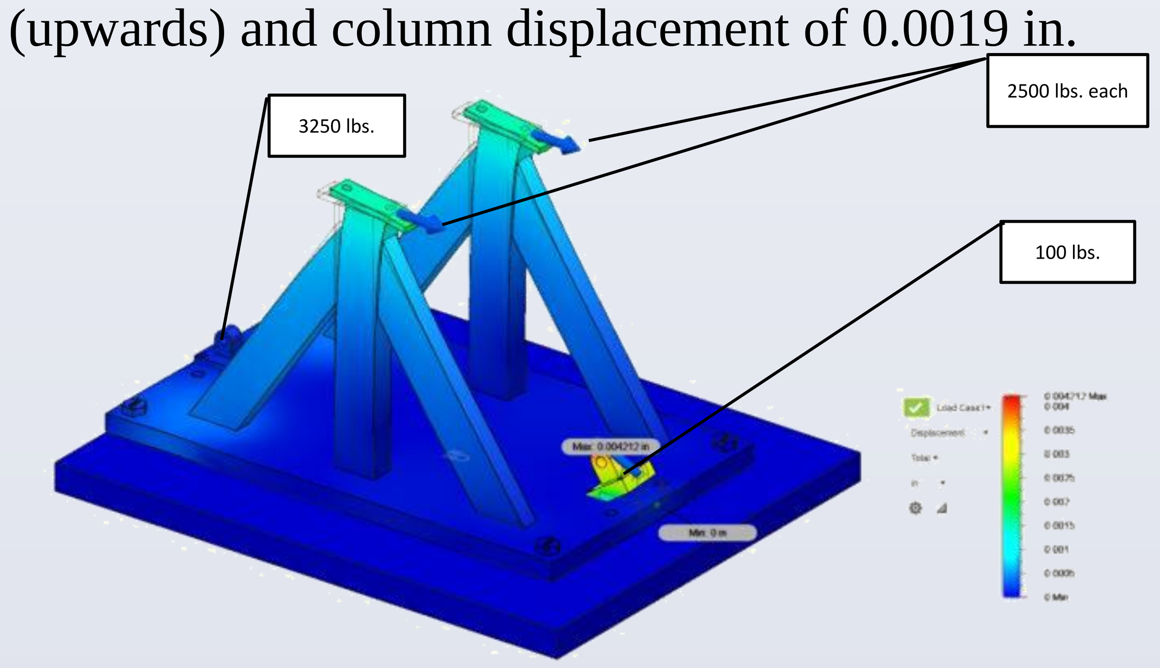


Figure 4: Forces acting on the SABR-FD

Preliminary Results

So far, preliminary results are based on successful simulations and fabrication of the device towards the semi-active control desired. The electric actuators are the reason this device can have semi-active capabilities. Figure 5 below shows static analysis of the base plate and support risers. The forces applied to the model are 2500 lbs. of pulling force with a reactionary force (3250 lbs.) and applied force (100 lbs.) generated at the base. An output of overall base plate displacement is given at 0.0002 in. (upwards) and column displacement of 0.0019 in.



Input Force	Displacement
2500 lbs. (right support)	0.00198 in.
2500 lbs. (left support)	0.00203 in.
100 lbs. (front clevis)	0.00421 in.
3250 lbs. (rear clevis)	0.05 in.

Figure 5: Static analysis of base plate and system

A test was ran to determine the damping capacity of the friction damper in passive mode, so a comparison can be made to the semi-active device. This test was carried out with different applied forces of 50, 60, and 70 lbs., which gave different damping forces of 0.5 kips, 2 kips, and 5 kips, respectively.

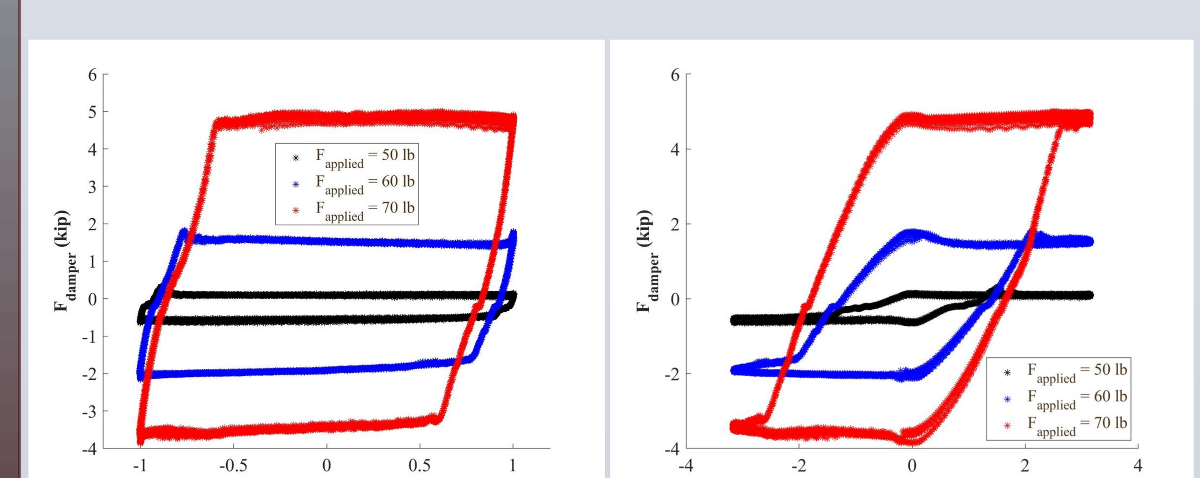


Figure 6: Force vs. displacement and force vs. displacement hysteresis

Finally, hybrid simulations are running for the current setup and a displacement model is explained next.

Discussion

The test conducted on the old drum was successful, and the new friction material works well with the surface of the drum. These are the boundary conditions the SABR-FD will be based off of. Hybrid simulations have been conducted and one of the tests of the RSN1176_KOCAELI_ YPT150, MCE EQ file is shown below. This graph shows displacement between the first two stories with dampers and without. Reduction = (peak floor displacement with the damper - peak floor displacement without the damper)*100/(peak floor displacement without the damper. The new damper can enable civil infrastructural systems to achieve a high level of performance, with minimal damage under severe earthquakes, and the high performance leads to resiliency being achieved.

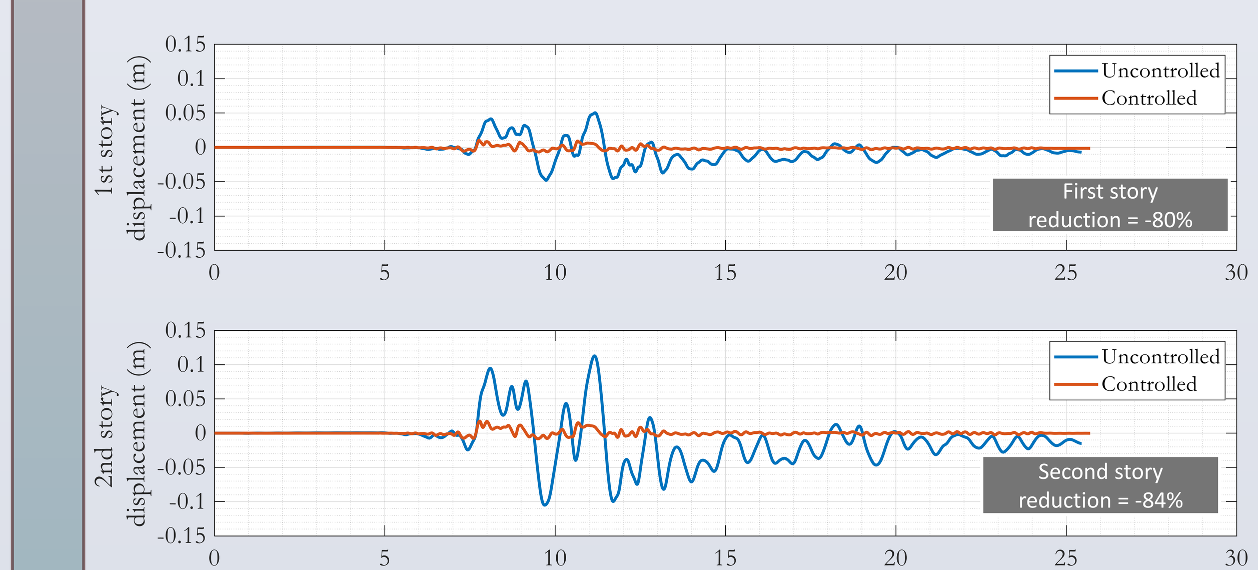


Figure 7: RSN1176_KOCAELI_ YPT150, MCE

The project will be continued after the summer between the University of South Carolina and Lehigh University, and tests on the SABER-FD will be conducted once the electronic actuators arrive.

References

[1] Downey, A., Cao, L., Laflamme, S., Taylor, D., and Ricles, J. (2016). “High capacity variable friction damper based on band brake technology.” Engineering Structures, 113, 287-298.

[2] Cao, L., Downey, A., Laflamme, S., Taylor, D., and Ricles, J. (2015). “Variable friction device for structural control based on duo-servo vehicle brake: Modeling and experimental validation.” Journal of Sound and Vibration, 348, 41–56.

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