A NOVEL VARIABLE FRICTION DEVICE FOR NATURAL HAZARD MITIGATION

Liang Cao[1], Austin Downey[1], Simon Laflamme[1,2] , Douglas Taylor[3] and James Ricles[4]

[1] Dept. of Civil, Construction, and Environmental Engineering, Iowa State University
[2] Dept. of Electrical and Computer Engineering, Iowa State University
[3] Taylor Devices, North Tonawanda, NY
[4] Dept. of Civil and Environmental Engineering, Lehigh University

Motivation

- Passive are generally only applicable to limited bandwidths of excitation and do not perform well against near-field earthquakes due to the nature of the impact that comes in the form of a shock rather than an energy build-up.
- Active systems are not widely used in structural engineering due to high power requirements, controller robustness, and possible actuator saturation .
- Semi-active damping systems can have considerable economic benefits over passive energy dissipation systems, in addition to enhanced earthquake and wind mitigation. However, limited research work has been conducted.

Experimental Investigation

Phase I : The MFD was prototyped from the duo servo drum brake of a car, due to the readily availability of the components.

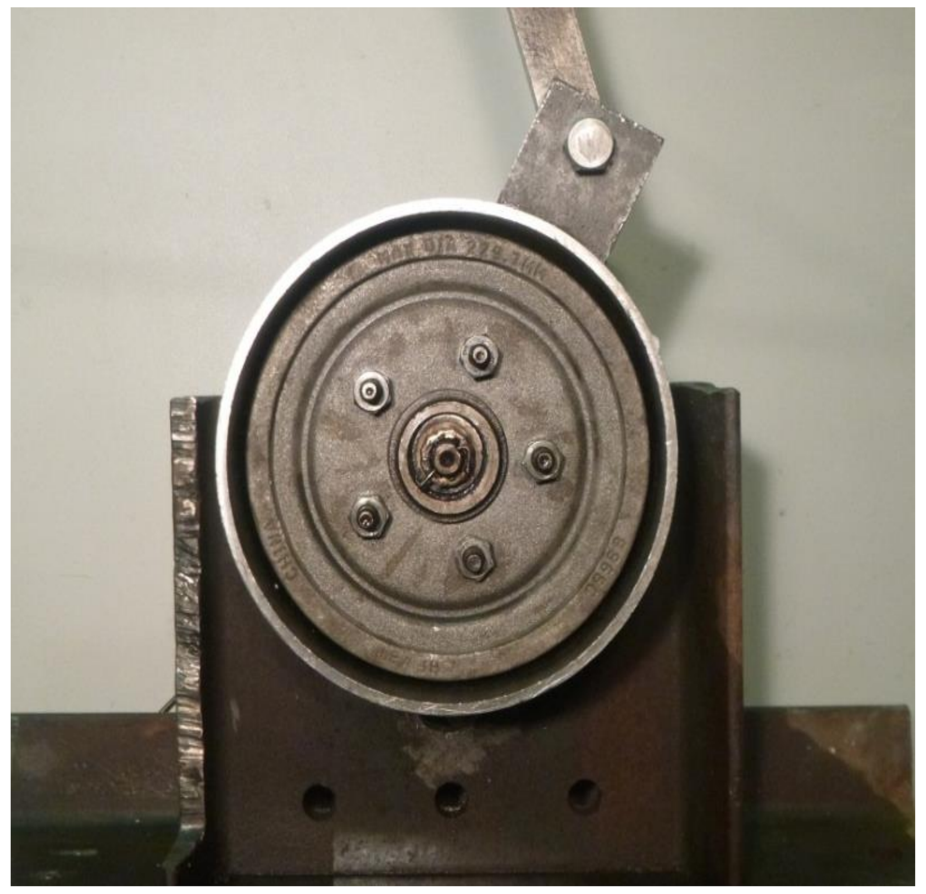

Figure 1: Prototype of the MFD

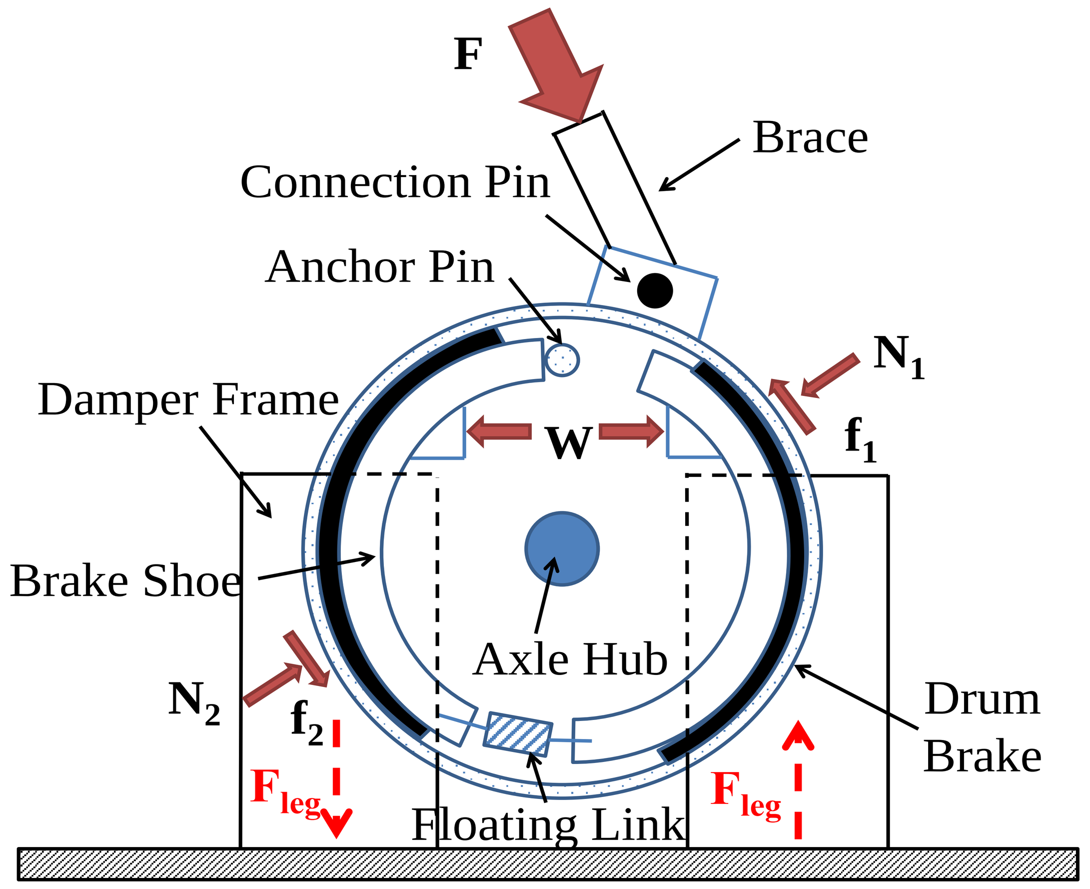

Figure 2: Schematic of the braking mechanism in the MFD

Phase II : A single and repeated harmonic test has been conducted at a frequency of 0.5 Hz, amplitude of +/- 1 inch, 1500 psi hydraulic pressure corresponding to approximately 50% of the braking capacity, over 20 cycles per test.

Figure 3: Experimental Set-up for the MFD Dynamic Tests

Experimental Results

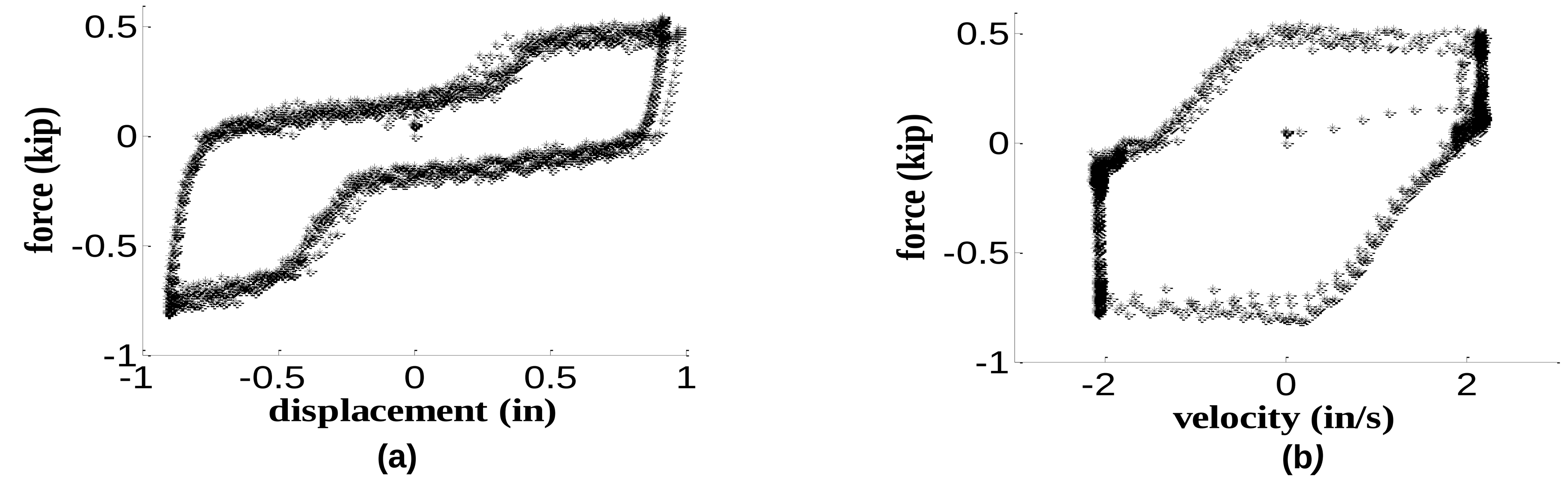

Figure 4: Dynamic of the MFD under hydraulic pressure of 1500 psi: (a) force-displacement plot; and (b) force-velocity plot.

Numerical Analysis

In order to simulate experimental results from dynamic tests in Phase II, LuGre model with stiffness region is selected for numerical simulation.

Procedures:

- Dividing the hysteresis loop into two regions : a pure stiffness zone and a friction zone;
- For pure stiffness zone : $F_{stiffness} = kx + \alpha$;

  For friction zone : $F_{friction} = \sigma_0 z + \sigma_1 \dot{z} + \sigma_2 \dot{x}$; where $\dot{z} = \dot{x} - \sigma_0 \frac{|\dot{x}|}{g(\dot{x})} z$
- Model parameters are determined using MATLAB by minimizing the performance function

  $J = (\hat{f}_k - f_k)^2$ where $\hat{f}_k$ is numerical result and f_k is experimental data

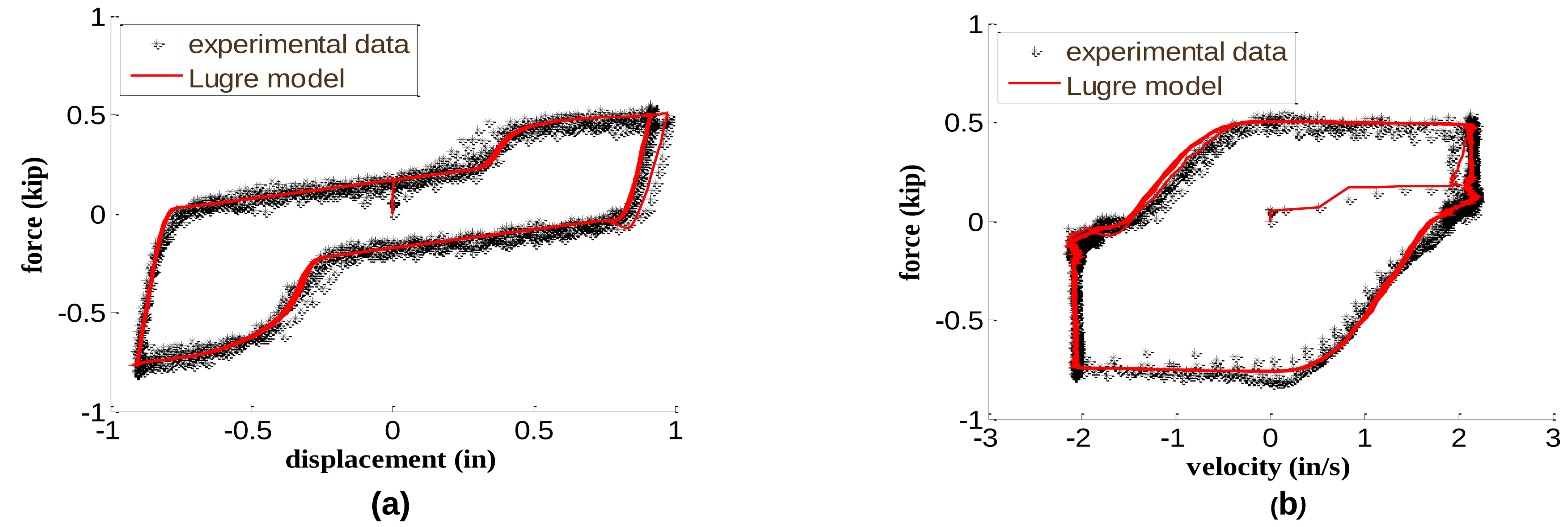

Figure 6: Model fitting of the MFD: (a) force-displacement loop; and (b) force-velocity loop

Conclusions

- Experimental results showed that the mechanism of the car brake led to a sudden drop of force when velocity switches sign, because the rotation of the braking shoes is causing a temporary loss of contact with the drum.
- The dynamics of the MFD outside the loss-of-contact zone has been modeled using the LuGre model due to the high hysteresis found in the device.
- Optimal model parameters have been determined by fitting experimental data. Results show that it was possible to use the dynamic model to characterize the friction behavior.

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