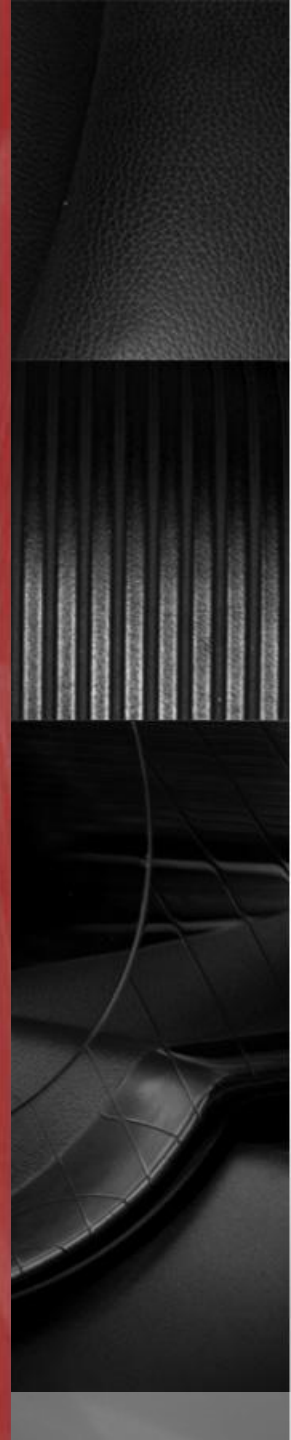
P11566: ITT Magnetic Damper

Ben Hensel, Tiffany Heyd, Jake Norris, Tom Sciotto

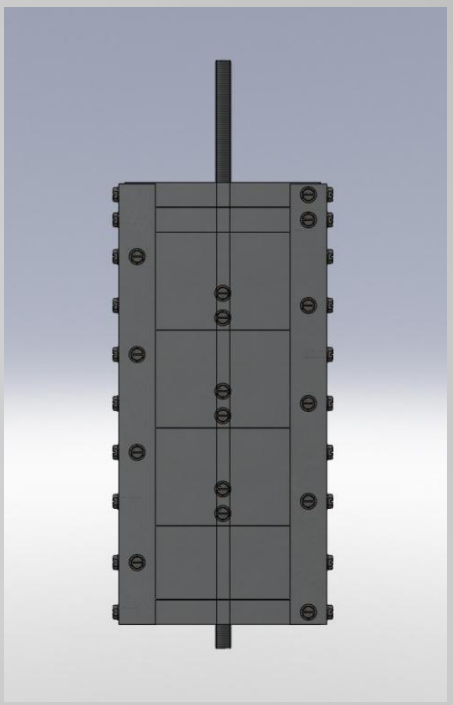
2/18/2011

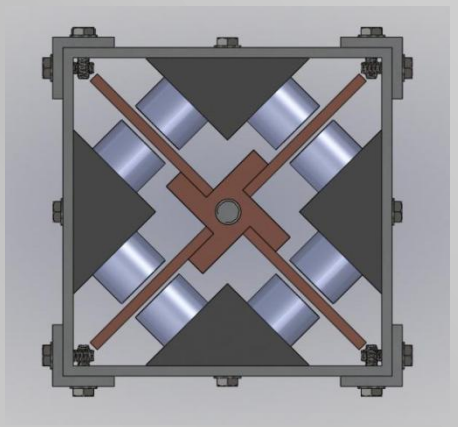


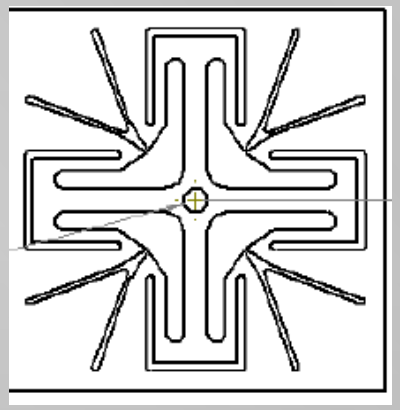
Project Background

- Approached by ITT to develop eddy current damper for space applications.
  - Mounts between satellite payload and bus as part of a Stewart Platform.
- Needed to be designed with space applications in mind, but cheaper analogous material could be used.
- Needed to deliver an appropriate model of the prototype.
  - Critical: This is where ITT had trouble.

Design







Fabrication Overview

Design

Assembly

Fabrication

- casing
- copper fixture
- flexures
- iron magnet fixtures

Assembly

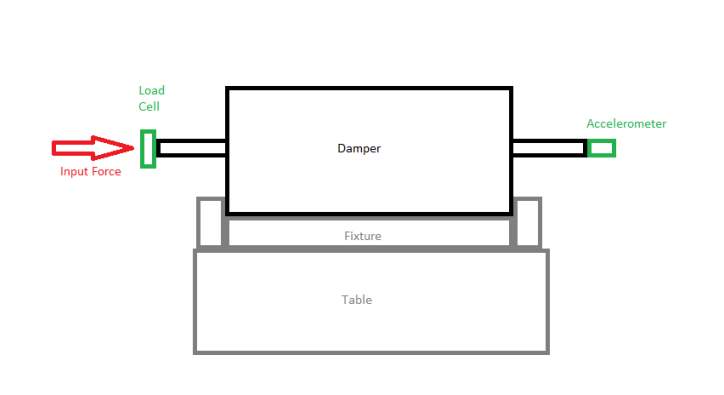
- casing
- copper assembly
- magnet assembly
- whole thing

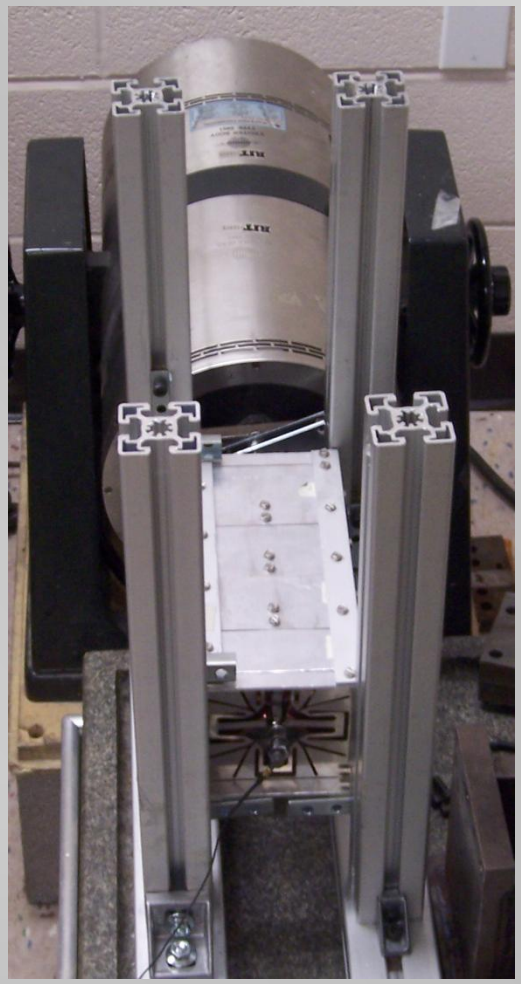
Fabrication Changes

- Solder to epoxy on copper conductor
- 1/4”-20 to 5/16”-24 threaded rod
  - Thanks Tom
- Epoxy magnets
  - No, friction and magnetic field will be fine
  - OK, let’s use epoxy

Shaker Testing Overview

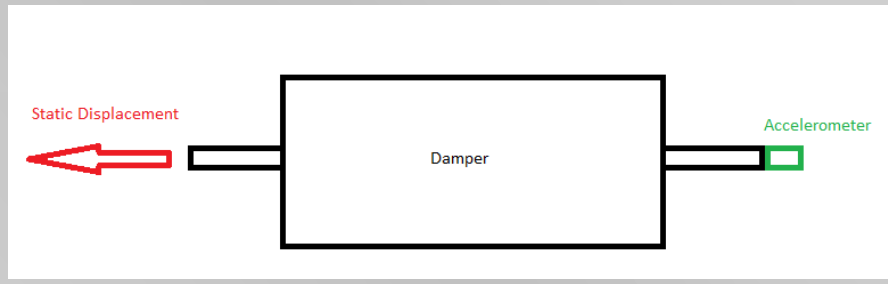
- Successfully damped shaker vibration.
- Damped too well.





Displacement Testing Overview

- Second option after shaker table issues.
- Simplification of test conditions.
- Rubbing of parts persisted.



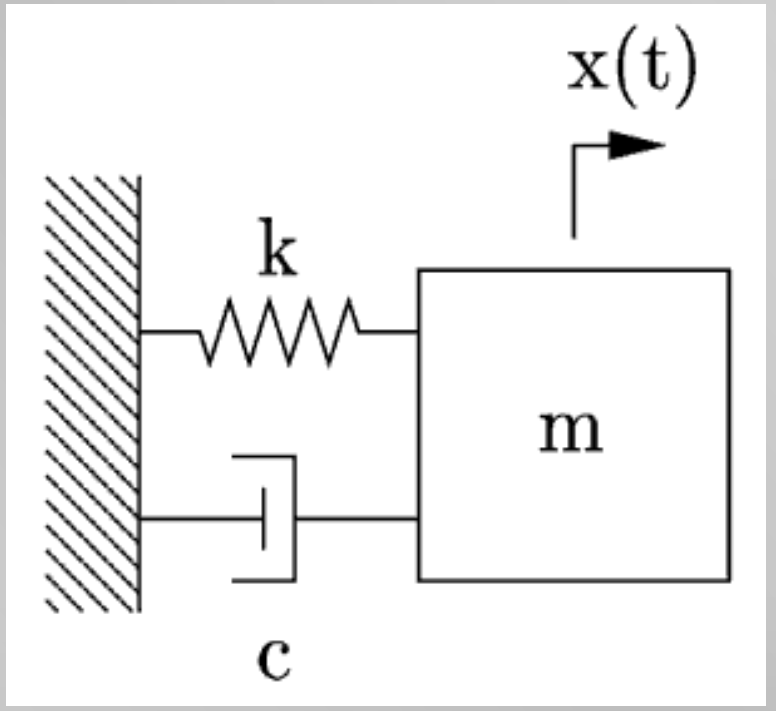
Available Results

- Friction experienced between moving parts.
  - Mitigation of this continuously delayed testing.
  - Friction not severe, did not cause destruction of components during vibration.
- Overdamped system.
  - Initially hid friction.
- Withstood all loads applied to system.
- Small gap existed between flexure and casing
  - Design flaw.

Governing Equation

- $F=mx+cx+kx$
- in the frequency domain

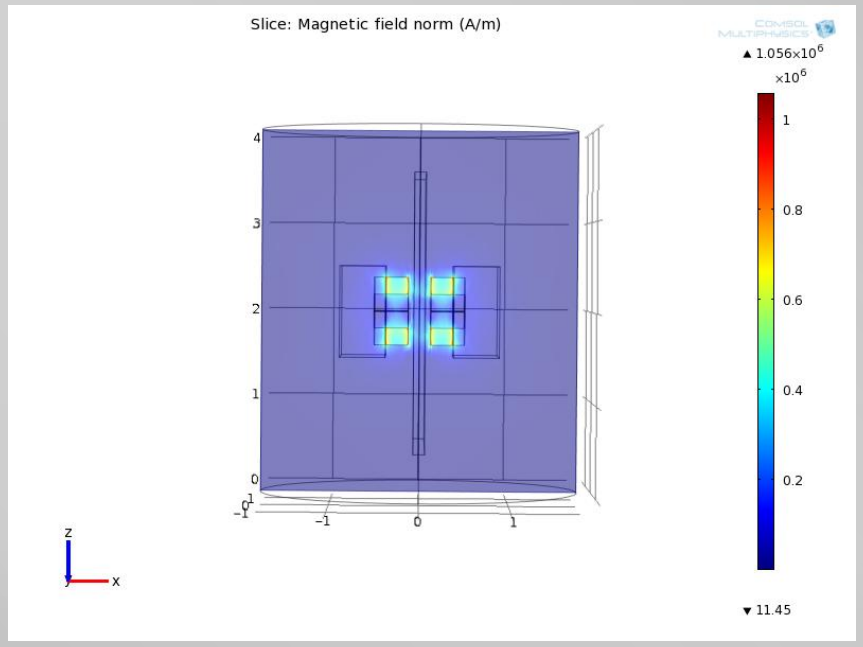
  $F= x+2\zeta\omega nx+\omega n2x$
- where $\omega_n=km$ and $\zeta= c/2\ \sqrt{k/m}$



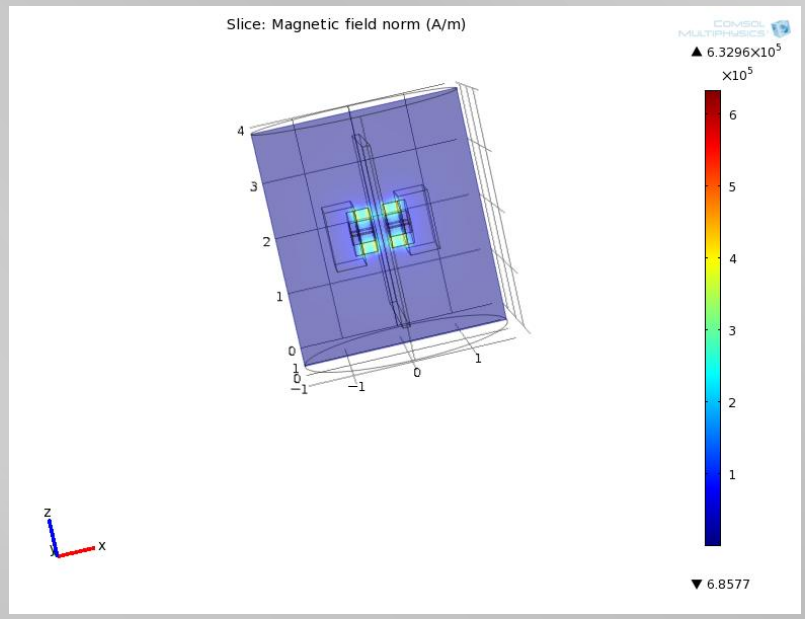
Source: blinkdagger Blog

Magnetic Field Strength

THEORETICAL

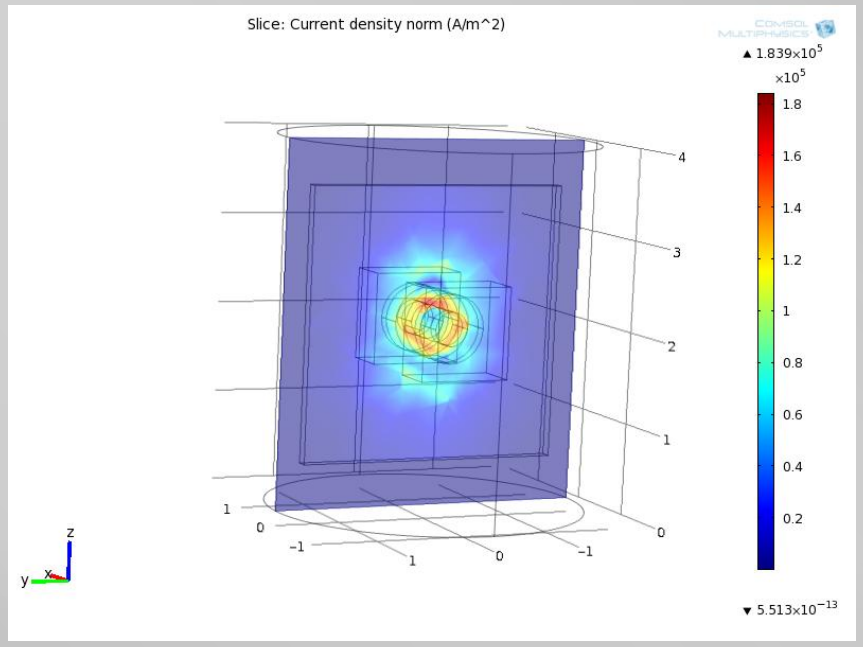


WITH EXPERIMENTAL VALUES

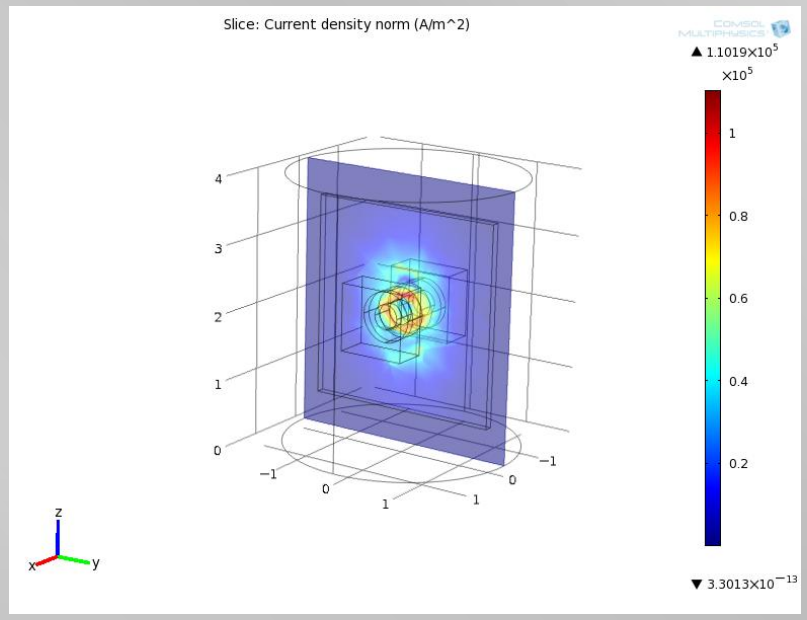


Eddy Current

THEORETICAL

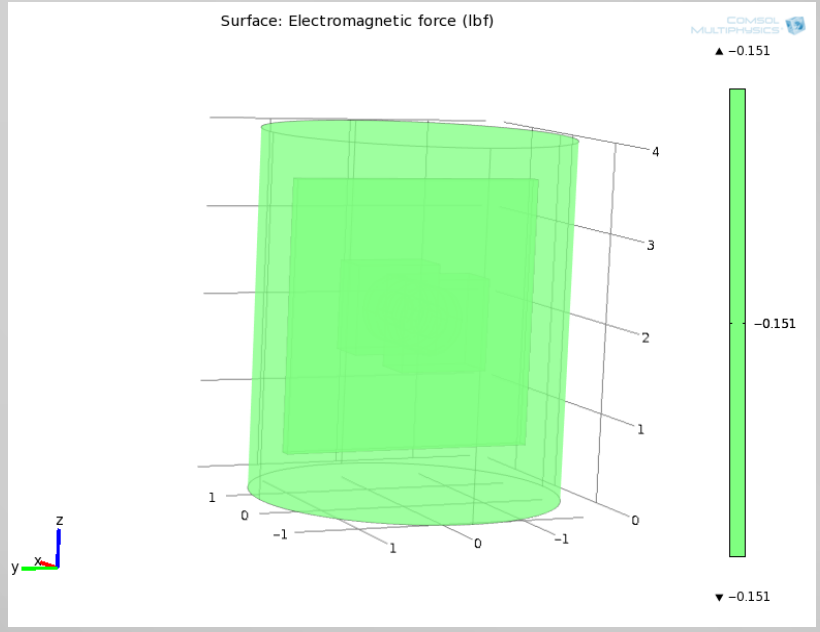


WITH EXPERIMENTAL VALUES

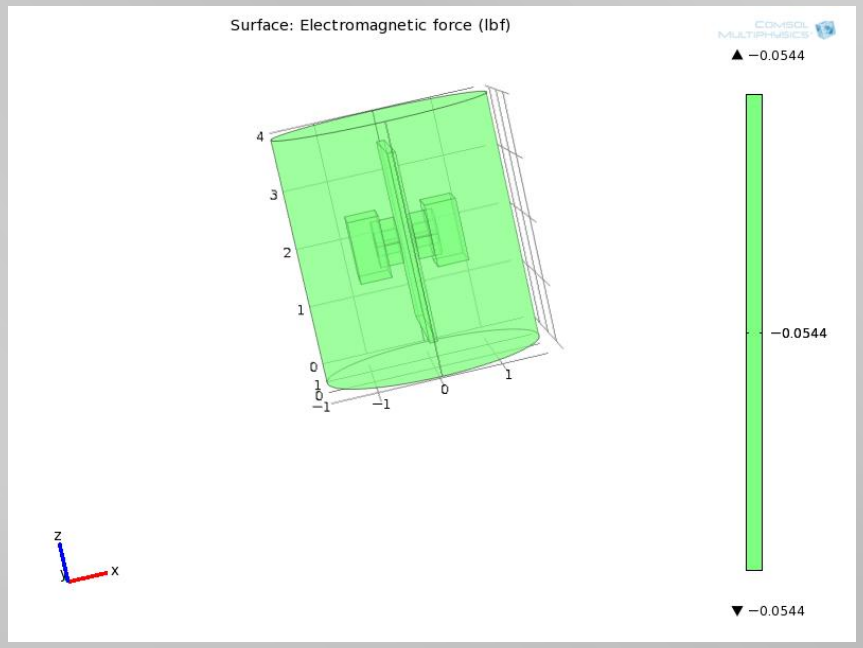


Induced Damping Force

THEORETICAL



WITH EXPERIMENTAL VALUES



Modeling Roadblocks

- Error occurred when trying to solve. Cause found due to “0” value input for electric conductivity of air surrounding model. Fixed by changing to extremely small value (1E-7 S/m)
- Opposing force unable to calculate. Fixed by downloading COMSOL update.
- Eddy current saturation. This was found only to occur at larger velocities, which should not be seen in the damper’s environment.

Results

	Magnetic Field Strength (T)	Damping Force (lbf)	Mass of Payload, m (kg)	Spring Constant, k (lbf/in)	Damping Coefficient, c (lbf-s/in)	Zeta (%)
Theoretical	1.48	1.812	10	20.87	3.624	13.83
Experimental	0.8867	0.6528	1.19	82.87	1.306	7.25

Conclusions

- Layered approach too complicated.
  - Caused alignment issues
- Cast iron brackets could be replaced with aluminum to create simpler magnetic circuits.
- Using aluminum for the conductive vane.
  - Aluminum reduces weight.
  - Aluminum has similar conductivity.

Questions?

Special Thanks to:
Dr. Alan Raisanen
Phil Vallone of ITT
Rob Kraynik and the entire ME shop staff
Dr. Linda Barton
Dr. Marca Lam
Dr. Mark Kempski
Dr. P. Venkataraman