MID-SEMESTER REPORT

on

"System Identification of MR Damper"

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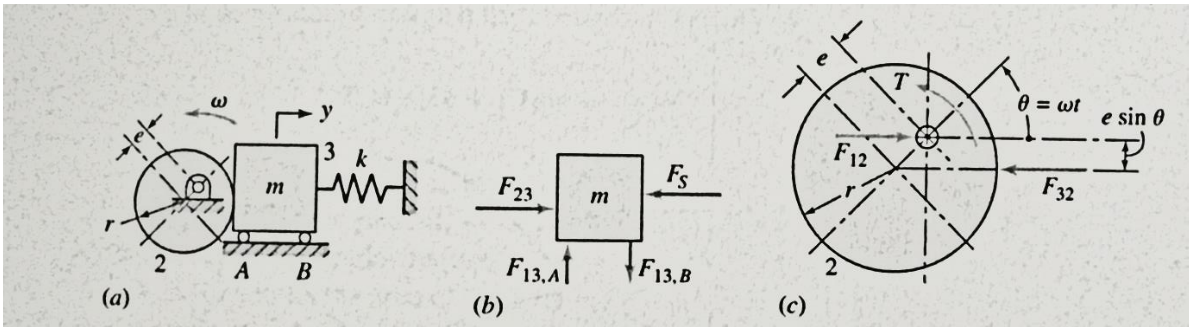
Design of a cam to generate a sinusoidal input for a seat vibration setup

In order to take our studies on human body vibration analysis and ergonomics, we proposed to design a CAM which would generate a sinusoidal input to a seat attached to a follower.

Model-



The CAM follower physical model

An eccentric CAM was used as elaborate analytical solutions for its dynamics were available in literature. Also, it would generate the desired sinusoidal oscillatory motion at the output. The CAM would be accompanied by a flat-face follower as this design would be mechanically stronger and less complicated to design and fabricate given the various mechanical elements that are present in a roller follower.

CAM kinematics:

$$y = e - e\cos\omega t \quad ; \quad \dot{y} = e\omega\sin\omega t \quad ; \quad \ddot{y} = e\omega^2\cos\omega t$$

For the dynamic model, we assume that there is no friction and there is a preload P=kδ where δ is the preload compression given to the follower spring during installation.

Summing forces on the follower mass in the y-direction gives:

$$\sum F^y = F_{23} - k(y+\delta) = m\,\ddot{y}$$

The force F_{23} is the contact force between the cam and the follower and hence can have only a positive value. Hence, substitution of the expression for y in the above equation of motion gives

$$F_{23} = (m\omega^2 - k)e\cos\omega t + (ke + P)$$

As the maximum probability of contact force becoming zero is at the top of the follower motion (ωt=180°), that value is substituted and F_{23} is made zero in order to find the value for k (minimum required value is obtained as this is the limiting case).

$$k = \frac{m\omega^2}{2e+\delta}$$

where

$$m = 100\ kg\ (say)$$
$$\omega = 2\pi\ \times 5 = 31.4\frac{rad}{s}$$

$$e = 0.01\ cm$$
$$\delta = 0.01\ cm$$

Thesis values are arbitrary but conservative. Hence, substitution of these values gives:

$$k = 3287\frac{kN}{m}$$

which is a very unrealistic value for a spring.

Let us assume that this spring is available and can be installed. However, we shall see in further calculations that the system parameters are far too unrealistic to be fabricated on the required scale.

Maximum value of F_{23} occurs at ωt=0, giving

$$F_{23(max)} \cong 132\ kN$$

Maximum Torque required

$$T_{max} \cong 480\ N.m$$

Maximum Power required

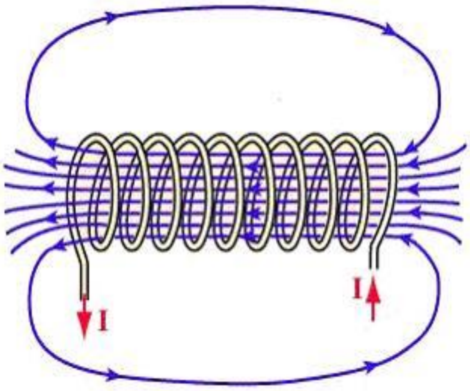
$$P \cong 15\ kW$$

These values are far too unrealistic to be implemented as anticipated and cannot be implemented with current constraints. As this is the most ideal model, we can safely assume that any other model would produce similar or worse results. The idea of using a cam for a human seat vibration setup is therefore terminated.

Conversion of Passive Damper to MR Damper

To convert passive damper into active damper we required two modifications in our passive damper.

- Firstly, to produce uniform magnetic field inside the cylinder of damper. This was achieved by using the basic principle of solenoid, electric current through the coil creates uniform magnetic field inside the coil. For this, we wound the outside of cylinder of damper with wire.



(Solenoid Magnetic Field)

Strength of magnetic field inside a solenoid is given by:

$$B = \frac{\mu N I}{L}$$

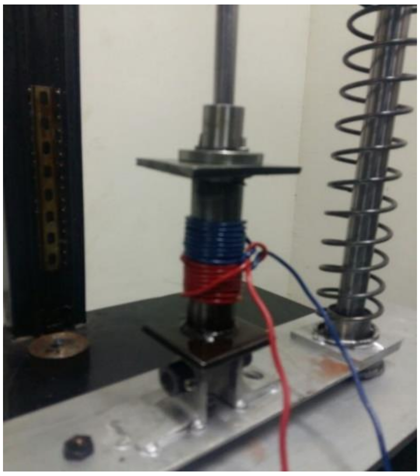
B: Magnetic field.

μ: Permeability.

N: Number of coil turns (16 number of coil turns for our damper).

I: Current flowing through coil.

L: Length of coil (6cm for our damper).



(Passive Damper converted to MR Damper)

- Secondly, the oil used inside the cylinder should be magnetized so that when it experiences magnetic field, there is change in viscosity of oil. For this purpose, Magnaflux spray used in

Magnetic particle inspection for cracks and creeps was mixed with SAE-40 oil which is used in our passive damper and different concentrations of magnetized oil were prepared.

(Magnaflux Spray)

This kind of MR damper can be reverted back to passive damper anytime whenever required.

Problem with this MR Damper

- There is a possibility that cylinder's thickness will shield the magnetic field produced inside the cylinder. We haven't been able to confirm that magnetic shielding exists and if it exists then what is the strength of magnetic field produced inside the cylinder.
- It cannot be assured that mixing SAE 40 oil with Magnaflux spray will result in magnetized oil.

Alternative approach

To encounter the problem that exists with this revertible MR damper this alternative approach is being considered.

- We need to manufacture another piston onto which the wire will be wound around as done in standard MR dampers this will eliminate shielding of magnetic field.
- SAE 40 oil can be mixed with Nano magnetic particles to get magnetized oil for MR damper.

Experiment: Attempt to convert passive damper to active damper by introduction of Magnetic Particles into damper oil.

MR dampers, like all magnetic materials, must possess a hysteresis curve. This curve can be represented between the current provided to the MR fluid, and its viscosity. Since the damping coefficient of a damper is directly proportional to the viscosity of the fluid inside it:

$$c = \mu \left[\frac{3\pi D^3 l}{4d^3} \left(1 + \frac{2d}{D} \right) \right]$$

C is the damping coefficient, μ is the viscosity
D, d and l are damper dimensions

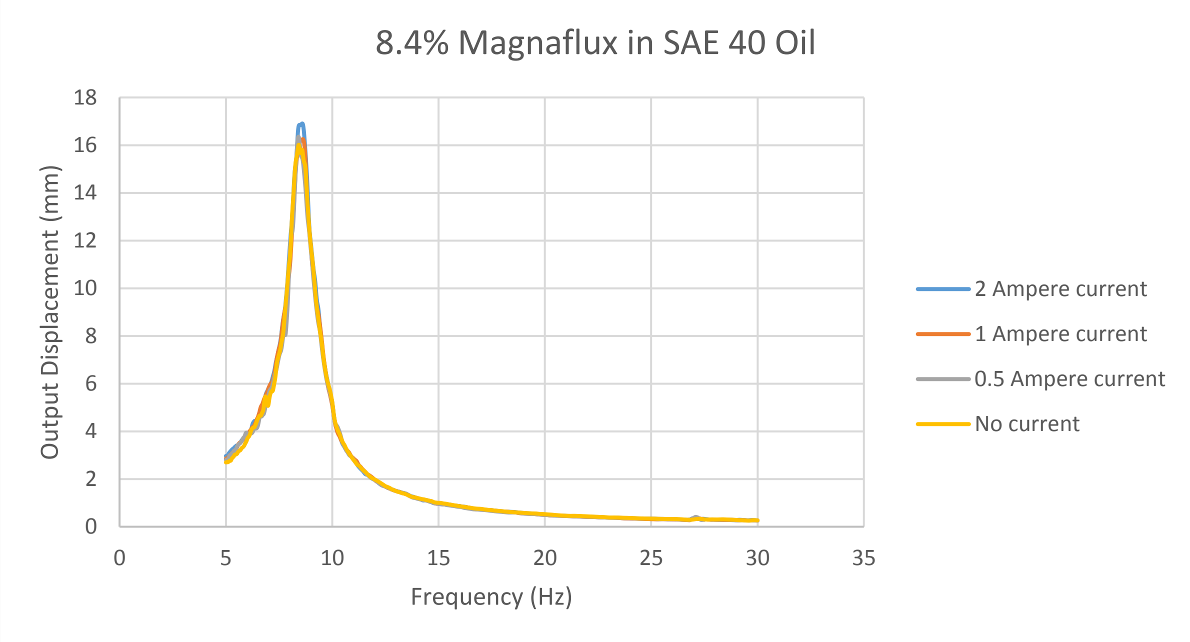
A change in the current must produce corresponding changes in the damping provided by the damper. This is taken as a sufficient condition for the success of the experiment.

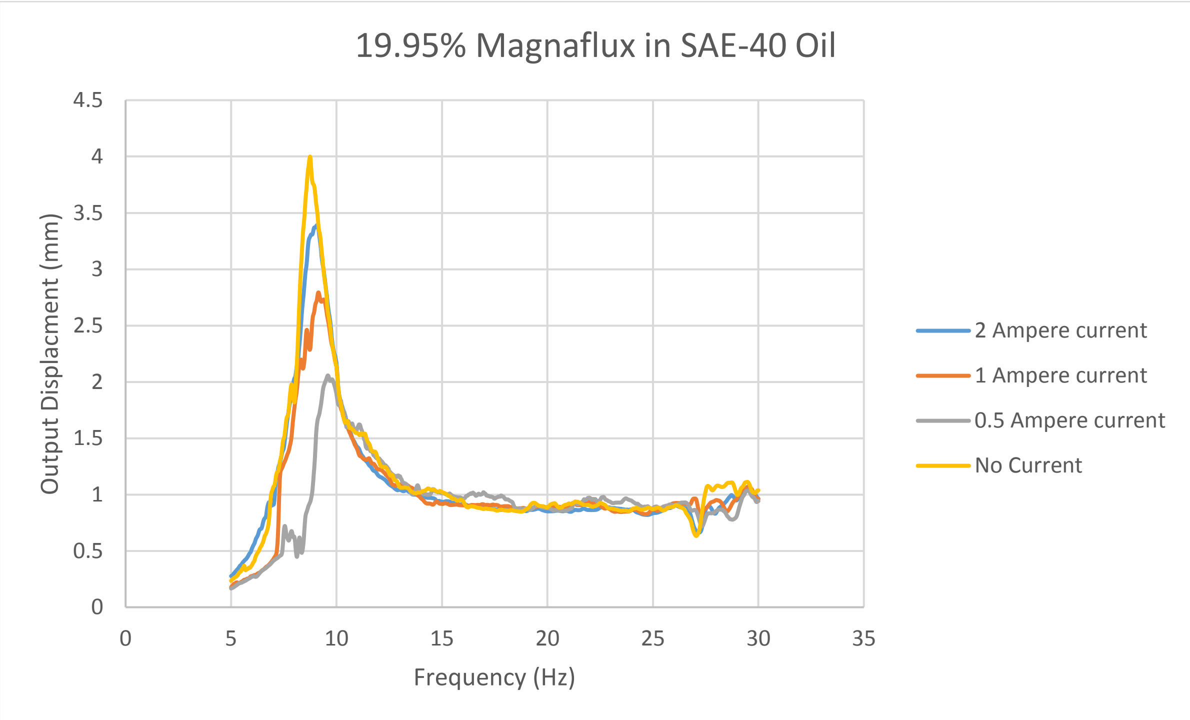
PROCEDURE

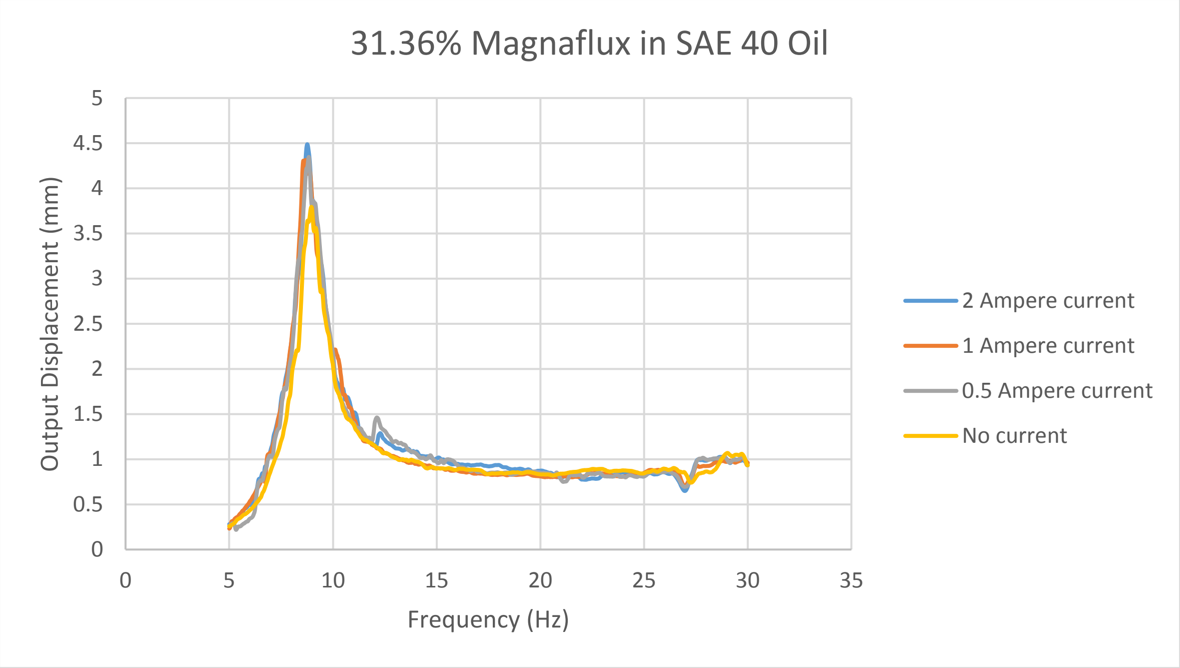
- Magnaflux-14 AM was added to SAE 40 Oil. All concentrations are measured as Wt./Wt. %
The standard weight of oil taken = 118.27 g.

- Three concentrations were prepared. The shaker test was carried out for each of these currents while passing different amounts of current through a coil wrapped around the damper cylinder.
- A *sine sweep test* was carried out from 5Hz to 30Hz using constant displacement input from the shaker = 2 mm.

RESULTS OBTAINED FROM EXPERIMENTS







INFERENCES

- No substantial change can be seen in the resonating frequencies of the system upon changing the current.
- Similarly, no change is observed in the resonating frequency upon change in concentration.
- There should have been a change in the resonating frequency if the damping of the system was changing due to varying currents. Therefore we can conclude that the damper, upon addition of Magnetic Inspection fluid, and with current passing around the cylinder, DOES NOT behave as an active MR Damper.
  There could have been two major reasons for this failure:

  - *Magnetic Shielding* occurs. Since the coil is wrapped outside the cylinder, the fluid (and therefore the magnetic particles) might be shielded by the effects of the solenoid by the cylinder material (Mild Steel).

  - The concentration of magnetic particles might be very low to have any significant effect on the damping. The Magnaflux-14 AM only has a 5% proportion of particles to petroleum suspension. Therefore, when we add a portion of Magnaflux-14 AM to the SAE 40 oil, the proportion of magnetic particles introduced into the oil is very low. Thus, the question arises if there is a particular ‘threshold’ concentration beyond which magnetic particles have a significant effect on the viscosity of the MR fluid.

FURTHER ITERATIONS

- Introduction of Fe^{3+} particles into the damper oil. As we are directly introducing particles instead of a suspension, the concentration will be sharper.
- Wrapping the current carrying coil inside the damper by wrapping it around the piston. This will help in eliminating magnetic shielding as a reason for no change in the response of the system.

Design of a piston around which current-carrying coil can be wrapped

By our current experimentation with the new mixture of oil and magnetic particles, there has been no change in the damping constant of the system for current varying between 0-2A. Therefore, there is a possibility that the magnetic field experienced by the fluid is not strong enough due to the shielding effect of steel.

Thus, a new design of the system in which the current-carrying coil will be wrapped around the piston will have to be designed.

Points to be taken care of for this design-

1. The groove made in the piston should be of appropriate dimensions so that the piston surface is kept as flat as possible
2. Since there will be wiring coming out of the inside of the cylinder, there should be appropriate arrangements in the sealing made for the same.
3. Overall sealing should be made tight as magnetic nanoparticles are expensive and leakage cannot be afforded

Proposed Piston Design

The project will proceed further with the design, fabrication and testing of the MR Damper equipped with such a piston. However, before we proceed, we will check whether our assumption of shielding is actually true or not by checking the magnetic field developed inside the cylinder with the current design configuration.