Semi-active Inerters Using Magnetorheological Fluid

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Introduction

The inerter is a device capable of delivering similar vibration control to tuned mass dampers, making use of inertia instead of mass. Most current inerter designs only deliver passive vibration control; semi-active elements will allow for retunable devices and better vibration control under a larger range of conditions.

Design

The semi-active inerter considered here is a helical fluid inerter, as shown in figure 2. Piston motion causes a working fluid to flow through the helix, creating inertance as well as a parasitic damping force. Normally the working fluid is oil or water, however here denser magnetorheological (MR) fluid is used.

The MR fluid contains magnetisable particles which, when subject to a magnetic field, align to increase the yield stress of the fluid (see figure 1), leading to an increased resistive force in the valve. Using an appropriate control scheme to adjust set the magnetic field strength, the damping force of the device can be set to any desired value within the region shown in figure 3.

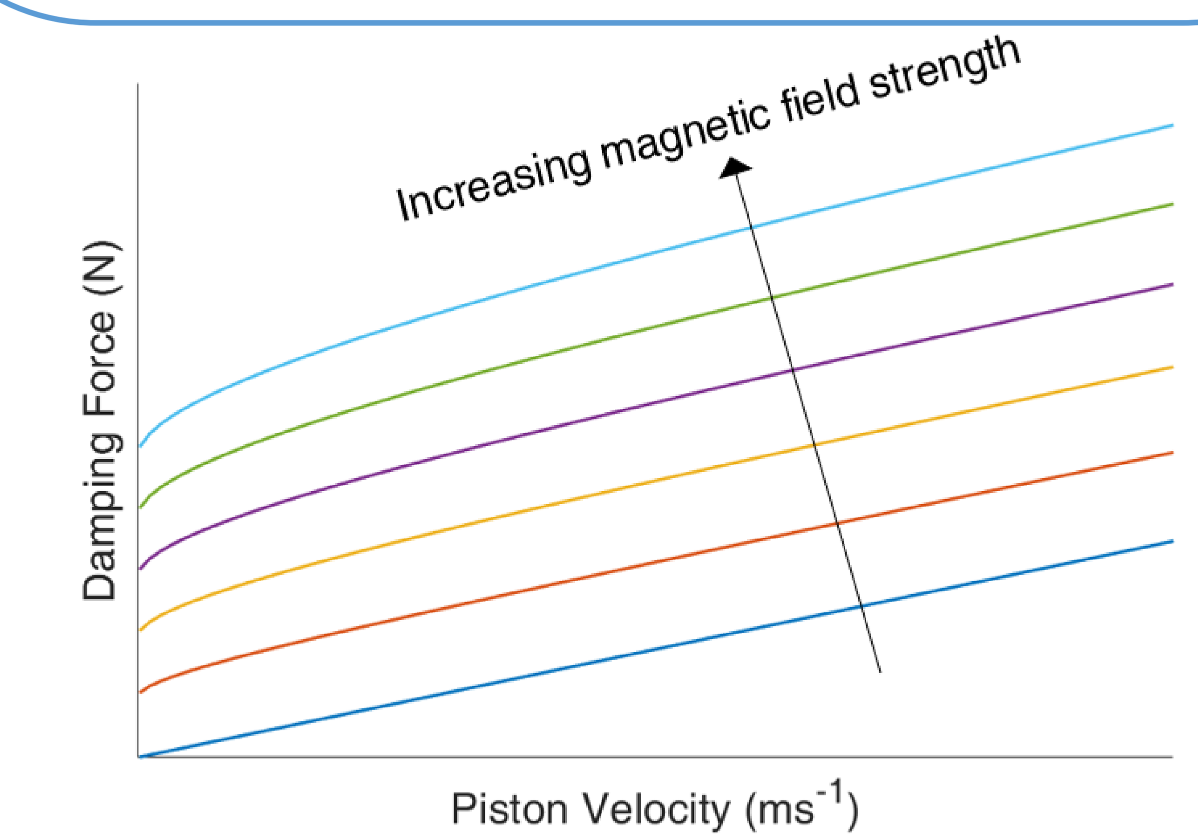


Figure 1: Increasing the magnetic field strength in the valve increases the amount of force required to cause the MR fluid to flow but doesn't significantly affect the gradient: this is known as Bingham flow.

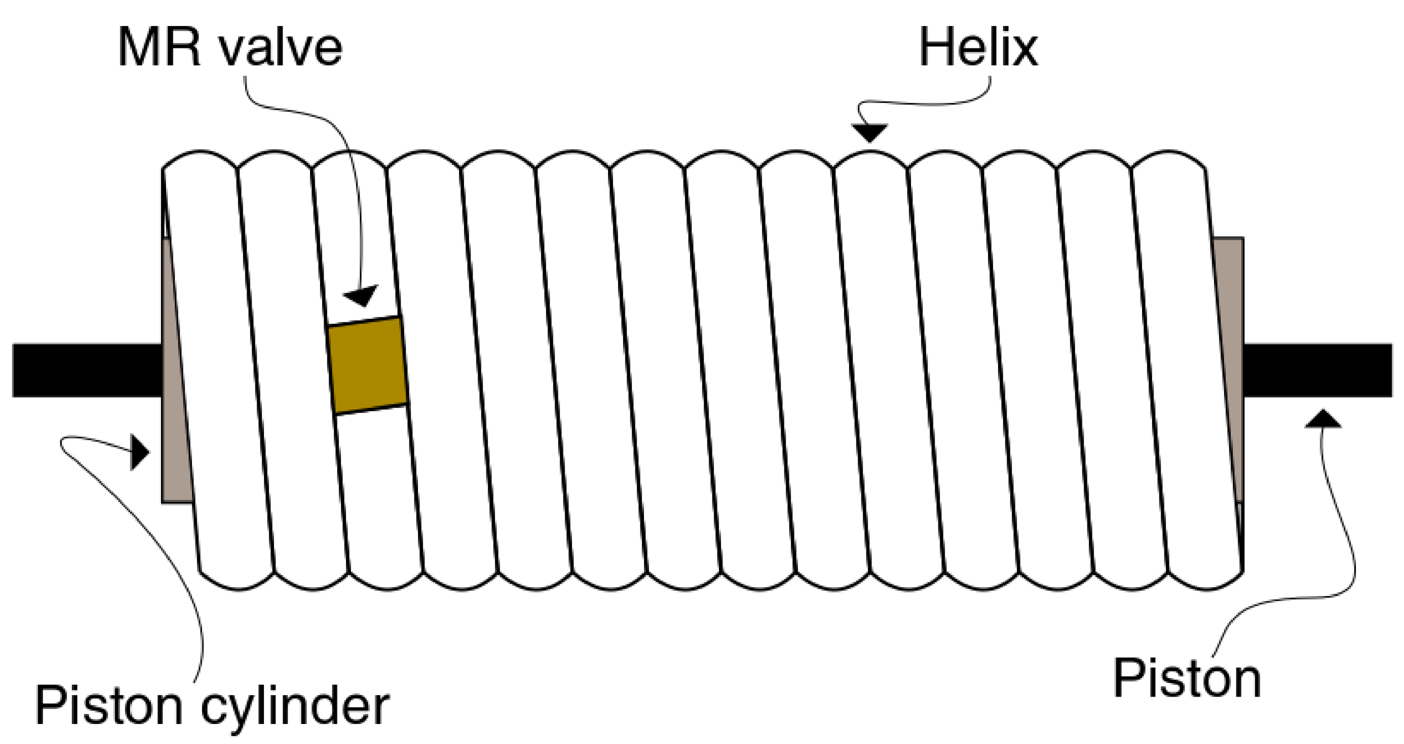
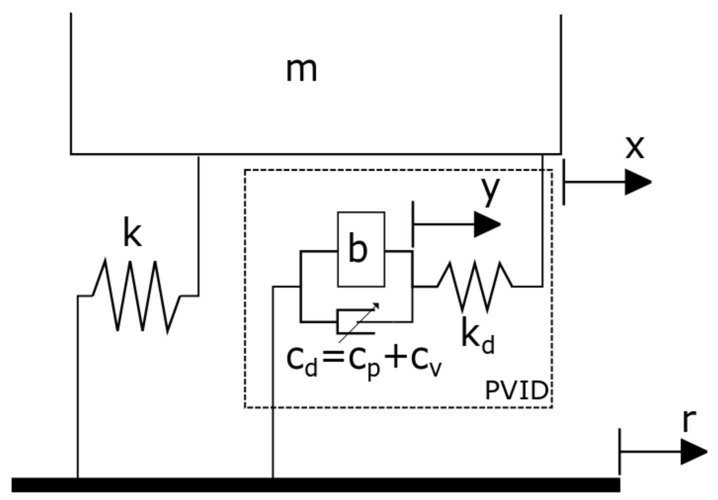


Figure 2: Motion of the piston causes fluid to flow through the helix, creating inertance and parasitic damping. The MR valve makes the damping force controllable by adjusting the fluid's viscosity.



$$b\ddot{z} + c_q\dot{z}^2 + (c_l + c_v)\dot{z} = 0$$

$$z = y - r$$

Figure 3: The device is shown here as part of a parallel viscous inerter damper (PVID). The equation of motion of the isolated device under free vibration is as shown, with the damping consisting of quadratic and linear parasitic terms, c_q and c_l, and the valve term, c_v.

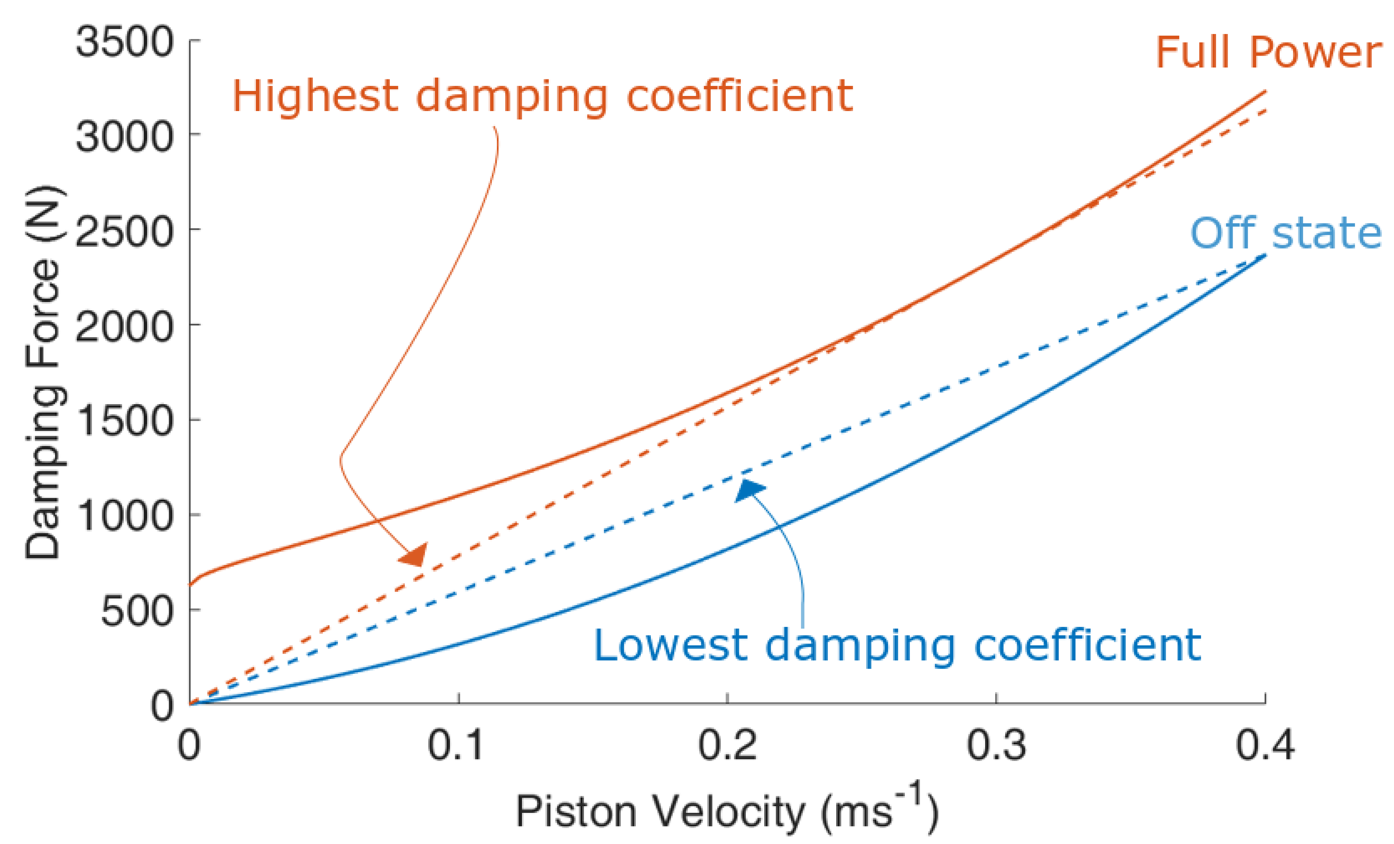


Figure 4: Although the damping force can be any value encompassed by the upper and lower bounds, for the case study linear damping coefficients are assumed; this simplifies comparison with existing, passive devices.

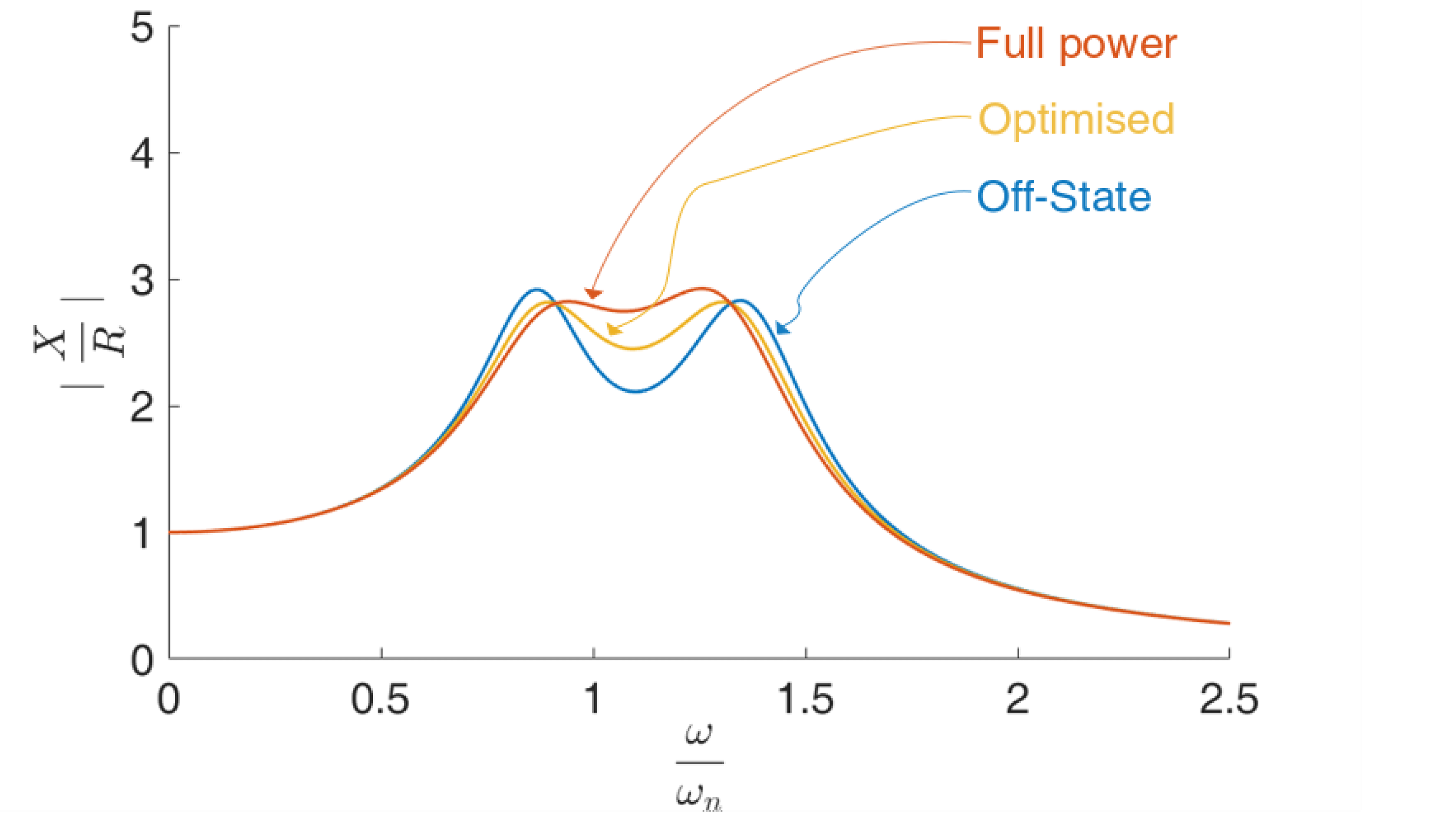


Figure 5: The device is underdamped when turned off. Increasing the damping ratio tunes the transfer function through a range which includes the 'traditional' optimum.

Case Study

The semi-active inerter was considered as part of the parallel viscous inerter damper (PVID) shown in figure 2, which can be used to isolate buildings from earthquakes. The damping forces were linearised to create the best damping possible coefficients and the device was designed so that the structure was underdamped when there was no magnetic field.

It can be seen that increasing the damping ratio decreases the vibration experienced at certain frequencies. The passive optimum damping of the structure is achievable in this range, meaning the device could be retuned to account for changes in the structure's mass or stiffness.

Conclusions and further work

The semi-active inerter as designed allows for damping force control in a suitable range to be useful. A way of optimising the design would increase this range. Control methods also need to be developed to take full advantage of the device and may require a more complete, dynamic model.