Investigating Magneto-Rheological (MR) Fluids for Integration Into Automotive Systems

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**Introduction/Motivation:**

Magneto-rheological (MR) fluid is a technology that has vast potential in many fields of engineering. MR fluid is a specially engineered fluid consisting of magnetic particles one to ten micrometers in diameter suspended in an aqueous base fluid, usually a hydrocarbon based oil. In addition, it contains proprietary additives that resist particle settlement and prevent corrosion. When a magnetic field is induced across the fluid, the particles within the fluid stiffen causing the metal particles contained within the liquid to become attracted to one another and align as seen below:

Currently, MR fluid is used commercially in vibration control in the form of dampers and also in torque transfer. For example, in vibration control, they are used in car suspension systems, where it has been integrated into shock design (see below), and for torque transfer they have been implemented into exercise equipment as a small rotary brake supplying variable resistance.

With this in mind, it is possible to implement this fluid into an automotive braking system with the intent of making that system more reliable or self-sustaining. The goal is to design a braking system that integrates MR fluid technology, and is capable of meeting and or outdoing the performance output of today’s conventional automotive brake system. Analysis of the feasibility of incorporating this fluid into a vehicle will be addressed following evaluation of the properties of the fluid. In addition, optimal integration of this fluid into a braking unit will be investigated following construction of an MR brake prototype. This will be accomplished by attaching the prototype to a custom-built, small-scale braking assembly able to record resistance to motion.

**Why MR Fluid?: Interesting and Important MR Fluid Properties**

- Liquid to near-solid response in milliseconds to an applied magnetic field;
  - Apparent viscosity can increase on order of $10^5 \rightarrow 10^6$ from magnetic field
  - Liquid to near-solid transformation involves no change in volume and it is completely reversible

- Operable temperature range of -40°C to 130°C

- Increasing magnetic field increases shear strength, and thus resistance to flow up to a critical shear strength based on the fluid’s magnetic saturation point

- Two resistive modes: plug and shear

**Materials & Methods:**

**Characterization of DC Motor:**

In order to determine the resistive capabilities of a MR fluid braking device, a DC motor had to be characterized in terms of output torque, power, and RPM’s derived from the output current to an applied voltage. This was done by first connecting a pulley to the end of the motor with thin, wound fishing line whereby the time traveled by various weights for a predetermined distance were timed using a stopwatch. The output torques at varying RPMs seen below can then be compared to the output values when using our device.

**Construction of Brake Testing Apparatus/Brake Assembly:**

First, a preliminary small-scale braking unit was created that essentially represented our full scale prototype (seen in bottom corner). It contains plastic discs with the bottom one containing inserted baffles used to further resist the flow of the MR fluid through a magnetic field, firmly set inside of a 3” piece of PVC pipe. The characterized DC motor was then attached through a threaded rod with couplings to the rotating brake unit. Next, above and below the brake unit were wire-wrapped solenoids to create a uniform magnetic field on each side of the fluid. The electromagnets were set at the highest voltage possible to create a 0.1T field at a 1.7 cm gap. A clear overall trend in applied voltage to torque was not discerned because of error in the testing apparatus.

**Recommendations/Conclusions:**

- After initial evaluation of the brake unit, it can be seen that concrete results cannot be reached at this point because the testing apparatus needs fine tuning.
- In order to increase effectiveness of testing apparatus:
  - Must take steps to minimize gap distance between electromagnets (currently 1 inch gap) and must minimize material between fluid and electromagnet
  - Must use stronger electromagnet (acquired one from the Physics Dept.)
  - More stable shaft needed to obtain more reliable yield of output current; shaft could rub against solenoids since it wobbled slightly, especially at higher speeds
  - Easier and more repeatable set-up of apparatus needed to ensure reliable output

**Future Work:**

- Will work with partner Brent Blythe to:
  - Finalize testing apparatus
  - Finalize prototype design
  - Construct larger-scale testing apparatus after success with smaller apparatus that includes a large, >4x stronger electromagnet, a 1 hp electric motor, and an advanced, aluminum incased MR braking unit

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**Source**