PREPARATION AND PERFORMANCE ANALYSIS OF MR FLUID IN DAMPERS

STALIN S.S

Assistant Professor, Sree Narayana Guru Institute of Science and Technology (India)

ABSTRACT

This project presents the preparation, synthesis, testing, design and implementation of magneto-rheological (MR) fluid in a conventional damper. In recent trends, the dampers are used with electro-rheological fluids, which have less yield stress and minimum operational temperature range. In this experiment, the conventional oil is substituted with magneto-rheological fluid. MR fluids are a class of smart materials, whose rheological properties changes, according to the magnetic field applied. Rheology is the study of flow and deformation of fluids (e.g. viscosity) may be rapidly varied by applying the magnetic field. Under the influence of magnetic field, the suspended magnetic particles interact to form a structure that resists shear deformation or flow. The formation of chain beads in columns produce the repulsion effect, thereby enhancing the cushioning effect in dampers. This change in the material appears as a rapid increase in apparent viscosity or in the development of a semisolid state. In the absence of an applied magnetic field, MR fluids behave as a normal fluid. MR dampers offer an attractive solution to energy absorption in mechanical systems and structures and can be considered as "fail-safe" devices.

Keywords (MR Damper, MR Fluid, FEMM V4)

I. INTRODUCTION

A suspension of a vehicle is the mechanism that physically separates the car body from the wheels of the car. The performance of the suspension system has been greatly increased due to increasing vehicle capabilities. In order to achieve a good suspension system, several performance characteristics have to be considered. These characteristics deal with the regulation of body movement, the regulation of suspension movement and the force distribution. Ideally the suspension should isolate the body from road disturbances and inertial disturbances associated with cornering and braking or acceleration. The suspension must also be able to minimize the vertical force transmitted to the passengers for their comfort. Suspension systems can be categorized as passive, semi-active, and full-active suspensions system. Passive system consists of conventional components with spring and damping (shock absorber) properties which are time-invariant. Passive element can only store energy for some portion of a suspension cycle (springs) or dissipate energy (shock absorbers). No external energy is directly supplied to this type of suspension. Semi-active suspensions contain spring and damping elements, the properties of which can be changed by an external control. A signal or external power is supplied to these systems for purpose of changing the properties. Full-active suspensions incorporate actuators to generate the desired forces in the suspension. The actuators are normally hydraulic cylinders. External power is required to operate the system.

II. PREPARATIONS OF MR FLUIDS

Ferro fluids are ultra-stable colloids of Nano-sized sub-domain magnetic dipolar particles inappropriate carrier liquids, actually an achievement of colloid science. Macroscopically, these fluids manifest themselves as magnetizable liquid media due to the “integration” in the structure of the carrier of sub-domain permanent magnetic dipolar particles. The size of magnetic particles in a Ferro fluid is in the nanometer range (3-15 nm), consequently, the magnetic moment of micron particles in MRFs is field induced and their Brownian motion is negligible, while in the case of Ferro fluids the magnetic Nano particles have permanent dipole moment and perform intense thermal motion. Particle aggregation processes are reversible and rather intense in MR fluids and are induced by the applied magnetic field, which is their key feature in developing field controlled flow behavior. Agglomerate formation in Ferro fluids is limited due to thermal motion of Nano particles and their strict or electrostatic stabilization in the carrier liquid; therefore the field induced changes in flow behavior usually are not significant. Ferro fluids have friction-reducing capabilities. If applied to the surface of a strong enough magnet, it can cause the magnet to glide across smooth surfaces with minimal resistance.

2.1 synthesis of Ferro fluid

At Nano scale, a specific difficulty associated with the preparation of magnetic fluids is that the Nano particles have large surface area-to-volume ratios and thus tend to aggregate to reduce their surface energy. In particular, magnetic metal oxide surfaces have extremely high surface energies (>100dyn/cm) that make the production of Nano particles very challenging. In addition, magnetic dipole-dipole attractions between particles enhance the difficulties experienced in the production of Ferro fluids. Long-range, attractive Vander Waals and magnetic forces are ubiquitous and therefore must be balanced by Columbic, satiric or other interactions to control the colloidal stability of dispersed Nano particle system, even in intense and strongly non-uniform magnetic field. Ferro Fluids are colloidal systems composed of isolated particles with nanometer-sized dimensions that are stabilized by surfactant molecules and dispersed in solvent media. In the ideal case, these non-interacting systems derive their unique magnetic properties mostly from the reduced size of the isolated Nano particles, and contributions from antiparticle interactions are negligible. The synthesis of Ferro fluids has two main steps: (a) the preparation of Nano-sized magnetic particles and (b) the subsequent stabilization/dispersion of the Nano particles in various non-polar and polar carrier liquids.

2.2 Materials required

The materials required for making Ferro fluid preparation are mentioned below.

1. Ferric chloride
2. Ferrous chlorides
3. Aqueous ammonia solution
4. Concentrated hydrochloric acid
5. Magnetite
6. Stirrer

2.3 Materials required

The materials required for making iron oxide preparation are mentioned below.

1. Iron nitrate
2. Citric acid
3. Distilled water
4. Ammonium hydroxide
5. Beaker
6. Stirrer
7. PH paper

III. EXPERIMENTAL APPARATUS

The scanning electron microscope (SEM) is a type of electron microscope that creates various images by focusing a high energy beam of electrons on to the surface of a sample and detecting signals from the interaction of the incident electrons with the sample surface. The type of signals gathered in a SEM varies and can include secondary electrons, characteristic x-rays, and back scattered electrons. In a SEM, these signals come not only from the primary beam impinging upon the sample, but from other interactions within the sample near the surface. The SEM is capable of producing high-resolution images of a sample surface in its primary use mode, secondary electron imaging. Due to the manner in which this image is created, SEM images have great depth of field yielding a characteristic three-dimensional appearance useful for understanding the surface structure of a sample. This great depth of field and the wide range of magnifications are the most familiar imaging mode for specimens in the SEM. Characteristic x-rays are emitted when the primary beam causes the ejection of inner shell electrons from the sample and are used to tell the elemental composition of the sample.

To improve resolution is by reducing the size of the electron beam that strikes the sample:

$D_{min} = 1.29C_s 1/4\lambda 3/4[7.92\ (it/J_c)\ x109+ 1]3/8$ J_c = current density of the source,

λ = electron wavelength C_s= spherical aberration, i = current,

T = temperature

The resolution is increased by the following factors:

- Increasing the strength of the condenser lens
- Decreasing the size of the objective aperture
- Decreasing the working distance

(WD = the distance the sample is from the objective lens)

The height over which a sample can be clearly focused is called the Depth of Field. The SEM has a large depth of field which produces the images that appear 3 dimensional in nature.

Depth of field is improved by:

- Longer working distance
- Smaller objective apertures
- Lower magnifications

Redwood viscometer is an instrument used to measure the viscosity of a fluid. Viscometers only measure less than one flow condition. This viscometer is used to measure the viscosity of the fluid at various ranges of temperatures. There are two cylinders in the viscometer. The inner cylinder is filled with MR fluid to the marker level and the outer cylinder is filled with water. The surrounding water is heated with an electrical heating coil. The heat is transferred to the inner cylinder by rotation of the blades of the agitator. The heat is uniformly

Fig 3.1 Redwood Apparatus Fig 3.2 Hall Effect Apparatus

The Hall co-efficient is defined as the ratio of the induced electric field to the product of the current density and the applied magnetic field. It is a characteristic of the material from which the conductor is made, since its value depends on the type, number, and properties of the charge carriers that constitute the current. The Hall Effect comes about due to the nature of the current in a conductor. Current consists of the movement of many small charge carriers, typically electrons, holes, ions or all three. When such a magnetic field is absent, the charges follow approximately straight, 'line of sight' paths between collisions with impurities, phonons, etc. However, when a perpendicular magnetic field is applied, their paths between collisions are curved so that moving charges accumulate on one face of the material. This leaves equal and opposite charges exposed on the other face, where there is a scarcity of mobile charges.

IV. MAGNETO-RHEOLOGICAL DAMPER

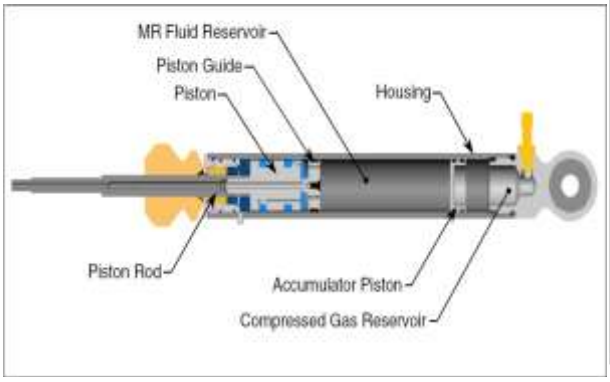
Magneto-rheological dampers are perhaps one of the most common applications for MR fluids. The fluid's adjustable apparent viscosity makes it ideal for use in dampers for vibration control. Real-time adjustable systems can be developed to change damping based on certain physical measurements, such as velocity or acceleration, in order to better counteract and control the system dynamics. Typically, MR damper applications use the pressure driven flow (valve) mode of the fluid or a combination of valve mode and direct-shear mode. Dampers that use only direct-shear mode tend to be used in applications that do not require much force from the damper. Linear MR dampers can be of three primary designs: mono tube, twin tube, or double-ended (also known as through-tube). The three design types reflect methods of adjusting the fluid volume to account for the volume of the damper shaft.

4.1 Types of Mr Damper

- Mono tube MR Damper
- Twin tube MR Damper
- Double Ended MR Damper

4.1.1 Mono Tube Mr Damper

A mono tube MR damper is one that has only one reservoir for the MR fluid and also has some way to allow for the change in volume that results from piston rod movement. In order to accommodate this change in reservoir volume, an accumulator piston is usually used. The accumulator piston provides a barrier between the MR fluid and a compressed gas (usually nitrogen) that is used to accommodate the necessary volume changes.



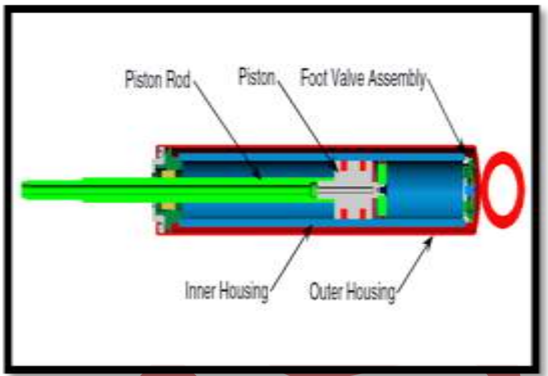
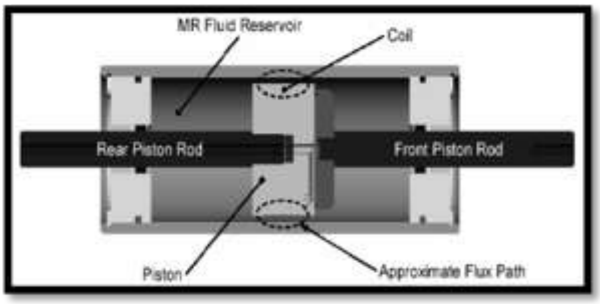


Fig.4.1 Mono-tube Mr Damper **Fig.4.2 Twin-tube Mr Damper**

4.1.2 Twin Tube Mr Damper

The twin tube MR damper is one that has two fluid reservoirs, one inside of the other. This configuration, which can be seen in, has an inner and an outer housing. The inner housing guides the piston rod assembly just as the housing of a mono tube damper does. This inner housing is filled with MR fluid so that no air pockets exist. To accommodate changes in volume due to piston rod movement, an outer housing that is partially filled with MR fluid occurs. In practice, a valve assembly called a “foot valve” is attached to the bottom of the inner housing to regulate the flow of fluid between the two reservoirs. As the piston rod enters the damper, MR fluid flows from the inner housing into the outer housing through the compression valve that is attached to the bottom of the inner housing. The amount of fluid that flows from the inner housing into the outer housing is equal to the volume displaced by the piston rod as it enters the inner housing. As the piston rod is withdrawn from the damper, MR fluid flows into the inner housing through the return valve.

4.1.3 Double Ended (Through-Tube) Mr Damper



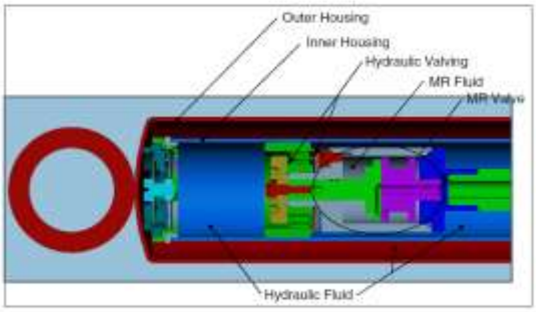


Fig.4.3 Double-Ended Mr Damper

Fig.4.4 Mr Piloted Hydraulic Damper

Double-ended (through-tube) dampers use a third method to account for the piston rod volume. Fully extended, the piston rod protrudes through both sides of the damper housing. This method of damper design retains a constant piston rod and fluid volume within the housing, thereby eliminating the need for a second housing or accumulator.

4.2 Mr Piloted Hydraulic Damper

MR piloted hydraulic dampers are hybrid dampers in which a small MR damper controls a valve that, in turn, is used to regulate the flow of hydraulic fluid.

4.3 Design Configuration

To use the concept of MR fluid damper we need to produce magnetic field in the flow path of the MR fluid. Hence the following configuration was used. As shown in figure, the MR fluid flows from the right chamber to the left chamber and vice versa when piston moves to and fro. The magnetic field is applied by using a copper coil wound around the piston body. The leads to the coil are taken out through the hollow piston rod. The configuration is simple and easy to manufacture. The design also based upon type of MR fluid used in the damper. The figure illustrates the conceptual design of the MR damper. Spool of magnet wire, Shown with the vertical hash marks, generate magnetic flux within the steel piston. The flux in the magnetic circuit flows axially through the piston core of diameter Dc, beneath the winding, radically through the piston poles of length Lp, through a gap of thickness tg, in which the MR fluid flows, and axially through the cylinder wall of thickness tW. Our MR damper design involves six different physically dimensioned parameters. They are the diameter of the cylinder bore, Db the diameter of the piston rod, Dp, the thickness of the casing wall, tw, the diameter of the piston core, Dc, the inside piston diameter, Dh, the pole length, Lp and the thickness of the gap, tg. Diameter of the piston rod (Db) =15 mm .Diameter of the actual piston core (Dc) = 30 mm.

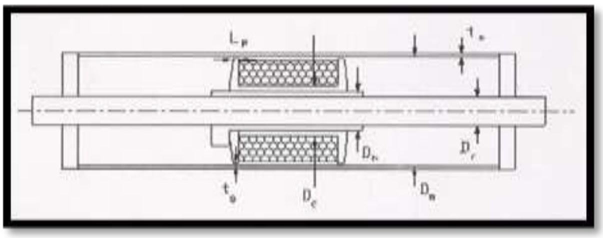


Fig.4.5 Design Configuration of Mr Damper

4.4 Re-modeling Of Damper

4.4.1 Drilling

Drilling is a cutting process that uses a drill bit to cut or enlarge a hole in solid materials. The drill bit is a multipoint, end cutting tool. It cuts by applying pressure and rotation to the work piece, which forms chips at the cutting edge. Drilling may affect the mechanical properties of the work piece by creating low residual stresses around the hole opening and a very thin layer of highly stressed and disturbed material on the newly formed surface. This causes the work piece to become more susceptible to corrosion at the stressed surface. The cutting edges produce more chips which continue the movement of the chips outwards from the hole. Cutting fluid is sometimes used to ease this problem and to prolong the tool's life by cooling and lubricating the tip and chip flow. Coolant may be introduced via holes through the drill shank.

4.4.2 Threading

Threading is the process of creating a screw thread. More screw threads are produced each year than any other machine element. There are many methods of generating threads, including subtractive methods; reformative or transformative methods; additive methods. In general, certain thread-generating processes tend to fall along certain portions of the spectrum from tool room-made parts to mass-produced parts, although there can be considerable overlap. The two types of threading are: Internal threading, where threads are produced in the internal diameter of the work piece by using the threading tool in the conventional lathe external threading, where threads are produced in the external diameter of the work piece by using the threading tool in the conventional lathe.

4.5 Magnetic Field Calculation:

Current (I) = V/R (Amps)
Circumference of the piston (L) = πD (m)

Magnetic field intensity (H) = NI/L (AT/m)

Magnetic Flux Density (B) = μ0μrH (Web/m2)

Area of the piston (A) = π/4 D2 (m2)

Magnetic Flux (Φ) = B * A (Web)

Where,

Permittivity of free space (μ0) =4π * 10-7

Relative permittivity (μr) = 250

N – Number of turns,

D – Diameter of the piston, m

H – Magnetic Field Intensity, AT/m

B – Magnetic Flux Density, Wb/m2

Φ - Magnetic Flux.

7.6.1MODELCALCULATION:

Circumference of the piston (L) = πD

L = π * 0.03 = 0.09424m

Magnetic Flux Density (B) = 0.6 T

=µ0µrH

0.6 =4∏*10-7*250*H

Magnetic Field Intensity= 1909.85AT/m.

Magnetic field intensity (H) = NI/L

1909.85 =(1.5*N)/0.9424

N= 90 Turns.

Area of the piston (A) = π/4 D2

= π/4* 0.032

A = 7.0685 * 10-4 m2

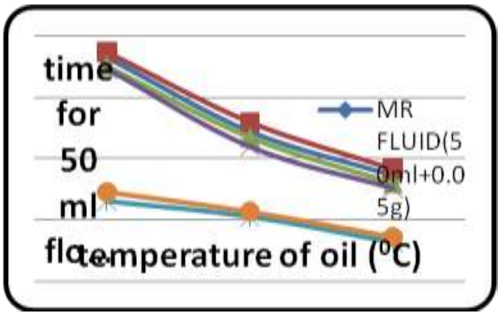
Magnetic Flux (Φ) = B * A

= 0.0833 * 7.0685 * 10-4

Φ= 5.88* 10-5Wb

V. RESULTS AND DISCUSSIONS

The redwood viscometer is used to measure the viscosity of the fluid at various ranges of temperatures. The readings for the flow of 50 cc oil are taken for different temperatures and the values are noted down. Kinematic viscosity and density of the oil are calculated by applying the formula for the readings taken.



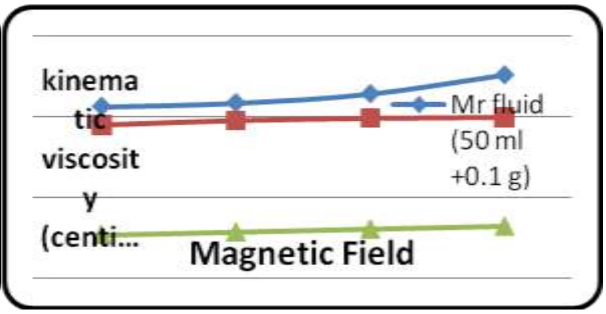
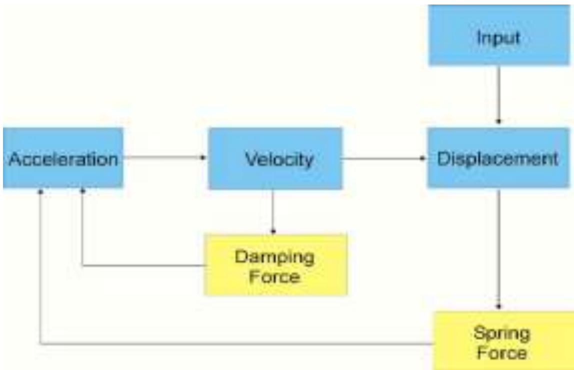


Fig. 5.1 Temperature of Oil vs. Time **Fig.5.2 Magnetic Field vs. Viscosity of The Fluid**

The above graphs (Fig.5.1) show that the time taken for the flow of various types of oil decreases with increase in temperature. Iron powder with silicon oil exhibits greater property than other fluids (i.e.) Ferro oxide and Ferro fluid mixed with silicon oil. The above graph (Fig.5.2) shows that in the presence of magnetic field the viscosity of the fluid increases. Also by increasing the field the viscosity increases continuously.

5.1 Flow Chart of Damper



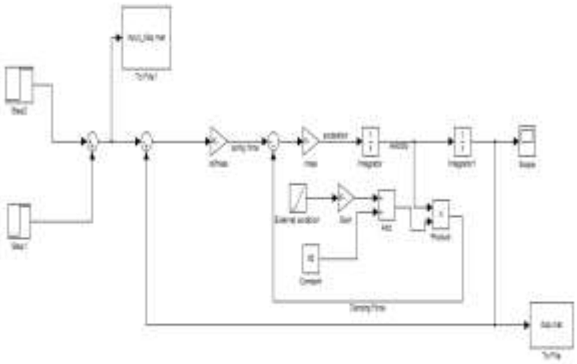


Fig.5.3 Flow Chart of the System Model **Fig 5.4.Simulink Model**

VI. CONCLUSION

The results presented in this project show the good efficiency of the MR fluid (50ml Silicon oil + 0.1g of Iron powder) in the presence of magnetic field. The capillary tube viscometer has been used to measure the viscosity of the magnetic fluid under the applied magnetic field. Through the experimental investigation, the effect of the magnetic particle concentration, the applied magnetic strength and the orientation on the viscosity of the magnetic fluid have been analyzed. The viscosity, thermal conductivity is improved by comparing with the conventional fluid. The damping properties are also improved. Thus the MR fluid is efficient than ordinary fluid used in damper. It also shows that the vibration damping within the full range of excitation frequencies occurring while driving a vehicle. The stimulant model will give the various results about the damping of MR shock absorber.

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