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Variable magnetic damper for semi-active suspension system

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ABSTRACT

Magnetorheological damper is modeled to provide semi active suspension system in vehicles .The stiffness of suspension system can be varied by using MR fluid. The project aims at fabrication of MR damper and preparation of magneto-rheological fluid, which can vary its viscosity inside the damper in presence of magnetic field. The damper design is analyzed using FEMM software and magnetic field strength is analyzed at various points. Finally, the damper is tested using fatigue testing machine to test its performance.MR fluid varies its stiffness under magnetic field, this principle is used to control the damping action of shock absorber. The iron particles in the MR fluid opposes the carrier fluid passing through piston head holes .This resistance builds strong opposition for shock absorber oscillation.

Keywords: MR FLUID, damper, suspension, carrier fluid

1. INTRODUCTION

Suspension system mainly comprises of shock absorber .A shock absorber is a hydraulic device that absorbs damp shocks. The key role of shock absorber is to keep the vehicle's tires to remain in contact with road surface all the time, this ensures balance and braking response of vehicle. Shock absorber avoids the vehicle imbalance during turnings. Hydraulic shock absorbers has orifices to regulate the flow through them. This develops internal pressure over fluid in passing through. This pressure or resistance can control the oscillation of suspension system due to damping force.MR damper uses magnetizable iron particles inside the carrier fluid. The viscosity of MR fluid can be altered by increasing or decreasing magnetic field at orifices.

Semi-active suspension system: If the suspension is externally controlled then it is a semi-active or active suspension- the suspension is reacting to signals. As electronics have become more sophisticated, the opportunities in this area have expanded. For example, a hydro pneumatic Citroën car will "know" how far the car ground clearance must supposed to be and constantly reset to achieve that level according to mode selected, regardless of load. Regardless of load, the suspension system arranges its stroke length using electrically operated hydraulic motion. Semi-active suspensions include devices such as air springs and switchable shock absorbers, various self-leveling solutions, as well as systems like Hydro pneumatic and Hydrolastic suspensions. Mitsubishi developed the world's first production semi-active electronically controlled suspension system in passenger cars; the system was first incorporated in the 1987. Delphi and Lord's currently sells shock absorbers filled with a magneto-rheological fluid, whose viscosity can be changed electromagnetically, thereby giving variable control without switching valves, which is faster and thus more effective. The regulating of the damping force can be achieved by adjusting the orifice area and electromagnetic field strength in the damper, thus changing the resistance of fluid flow. Most recently the possible application of electro-rheological and magneto-rheological fluids to the development of controllable dampers has also attracted considerable interest. The below figure shows semi-active suspension.

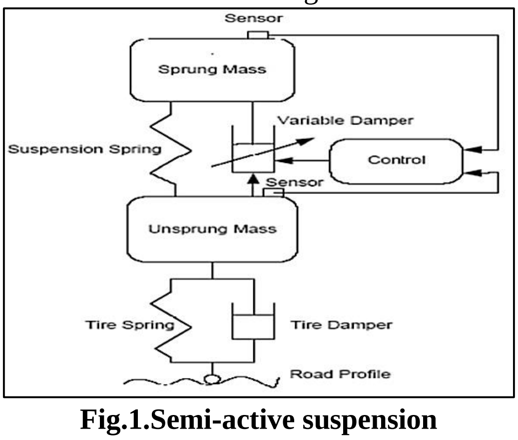

Fig.1.Semi-active suspension

Types of dampers:

Monotube: The cylinder is divided into two sections in mono tube. It has one reservoir for fluid and one reservoir for pressurized fluid. It has an accumulator piston to act as a barrier between fluid and gas chamber .The compressed gas usually used is nitrogen. The piston has a valve to allow the change in fluid volume, which results due to piston rod movement.

Twin tube: It has two fluid reservoirs. One is inner tube and other is outer tube. The inner housing is called working tube and the outer housing is called reserved tube. The inner housing guides the piston assembly just as mono tube damper does .There is no separate reservoir for pressurized gas. The piston head has a foot valve assembly to regulate the flow between two reservoirs. A piston oscillates in the damper due to load, the fluid flows from inner housing to outer housing through compression valve that is attached at bottom of working tube. The amount of fluid flowing to outer tube is equal to volume of fluid displaced by piston rod.

MR Fluid: A magneto-rheological fluid (MR fluid) is a type of smart fluid in a carrier fluid, usually a type of oil. When subjected to a magnetic field, the fluid greatly increases its apparent viscosity, to the point of becoming a viscoelastic solid. It has huge applications in suspension systems and brake applications etc. "MR fluid" is the short form of magneto-rheological fluid, which is used in the MR damper. These fluids are novel materials, which are suspensions of micron-sized, magnetizable particles in oil. Normally, MR fluids are free flowing liquids having a consistency similar to that of motor oil. However, when a magnetic field is applied, particle chains form, and the fluid becomes a semi-solid. The below figures show the MR fluid at normal stage and in the presence of magnetic field.

2. METHODOLOGY

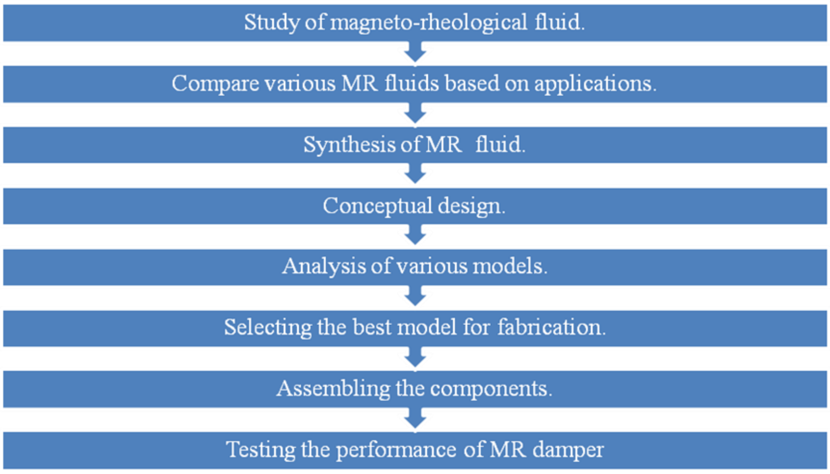

Figure.2.Flow chart of Methodology

MR Fluid: A magneto-rheological fluid (MR fluid) is a type of smart fluid in a carrier fluid, usually a type of oil. When subjected to a magnetic field, the fluid greatly increases its apparent viscosity, to the point of becoming a viscoelastic solid. It has huge applications in suspension systems and brake applications etc. "MR fluid" is the short form of magneto-rheological fluid, which is used in the MR damper. These fluids are novel materials, which are suspensions of micron-sized, magnetizable particles in oil. Normally, MR fluids are free flowing liquids having a consistency similar to that of motor oil. However, when a magnetic field is applied, particle chains form, and the fluid becomes a semi-solid.

Synthesis of MR Fluid:

Carrier fluid: It is the major constituent of the magneto-rheological fluid and it is generally 50 to 80 % by volume. Silicon oil is most commonly used carrier fluid for the synthesis of magneto-rheological fluid however it can also be prepared using water, mineral oil and synthetic oils. A good carrier fluid should have low viscosity and its value should be nearly independent of temperature. The carrier fluid we used for our work is mahua oil which is extracted from *Madhuca longifolia* which is an Indian tropical tree. The below table shows the property values of mahua oil.

Table.1.Properties of mahua oil

Fuel	Specific gravity	Calorific value (MJ/kg)	Carbon content (%)	Pour point (˚C)	Flash point (˚C)	Kinematic viscosity (eSt at 40˚C)
Mahua oil	0.904	38.863	0.4215	15	238	37.18

Magnetic particles: They are the key constituent of the MR fluid as their influence to the magnetic field determines various MR fluid properties. The magnetic particles should have size between 1µm to 10µm, the lesser the size the greater is the settling stability. The carbonyl or electrolytic iron particles are generally can be used.

Surfactants: Surfactants are used as additives mainly to avoid gravitational settling of iron particles due to their density in the MR fluid. They also reduce the surface tension of a liquid in which it is dissolved. They help the iron particles to get suspended throughout the MR fluid and hence they improve the settling stability. The most commonly used surfactants are oleic acid, citric acid and tetra methyl ammonium hydroxide etc.

Anti-friction additives: It is used to reduce friction between iron particles hence the iron particles are coated with these additives .Magnesium stearate, lithium stearate, gaur gum powder can be used as anti-friction additives.

MR Fluid preparation: Iron powder of particle size 1-10µm obtained from ball milling is kept in a furnace to make it dry .The mixing proportions to prepare MR fluid are 22% iron powder by weight, 68% mahua oil by weight as carrier fluid and 8% oleic acid and 3% magnesium stearate all by weight are used. Here oleic acid is used as a surfactant and magnesium stearate as anti-friction additive .The weights of all the constituents are measured and kept ready. Initially the iron powder is coated with magnesium stearate and then the coated iron particles are added to a beaker along with 8% oleic acid and stirred for about half an hour at 400rpm.Now this mixture is added with 10% carrier fluid and stirred again with same rpm for half an hour .The carrier fluid is added in intervals of 10% by weight each time and stirred for same time.

Figure.3.The synthesized MR fluid

3. ANALYSIS USING FEMM SOFTWARE

FEMM means finite element magnetic methods. It is used to check the magnetic field strength around the surroundings of a permanent or an electromagnet .This software allows to solve magnetic problems in two dimensional plane .For any kind of design problem, boundary conditions should be clearly defined in order to get unique solution. The inputs it takes are surrounding design geometry and surrounding media around a magnet with properly defined boundary condition. Any magnetic problem is solved and analyzed in 2 stages namely preprocessor stage and post processor stage. The preprocessor stage deals about the geometry of the design and after successful completion of first stage post processor stage deals about mathematical calculations and gives the output which can be seen by selecting any random point within the boundary condition.

Preprocessor stage: Firstly the geometry should be clearly defined. The geometry of design should be only two dimensional so the vertical cross-section of a damper is selected as the required plane. Firstly the origin is defined in the plane and then the corner points of the geometry are defined. After this these coordinates are joined using lines or arcs according to the geometry by selecting their respective tools .Once this is completed ,the whole geometrical design is enclosed in a circle and this circle is selected as the boundary .Now the materials and surrounding media should be defined. The material of the damper is mild steel and external medium is air. In the design the piston head has internal housing where electromagnet is kept. The defined electromagnet has 300 turns and current supply given is 1 ampere. Now, the magnetic problem is ready for post processor stage.

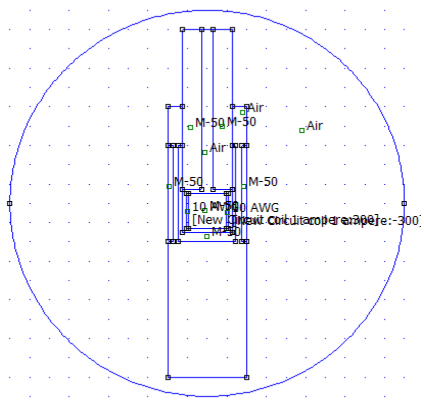

Fig.4.Preprocessor stage in FEMM

Post processor stage: After the first stage the magnetic problem is analyzed to check errors in preprocessor stage and if found any they are indicated. After this verification, it can be simulated to get the output. The main role of this stage is to do complex mathematical calculations involving magnetic equations. The output we get are magnetic field strength, magnetic induction and magnetic flux etc. at various points. It also shows magnetic field lines in and around the magnet.

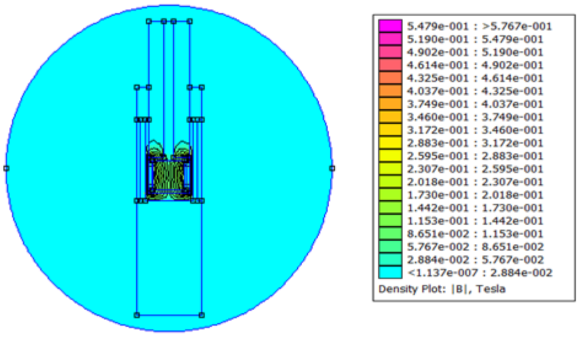

Fig.5.Post processor stage in FEMM

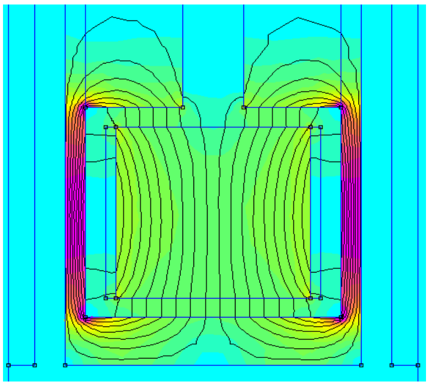

Fig.6.Zoomed view of piston head

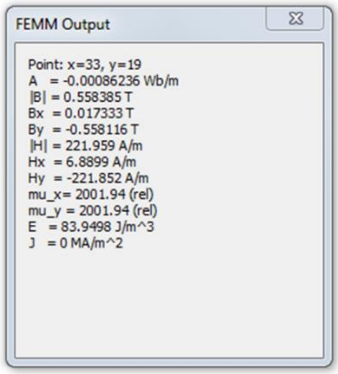

Fig.7.Output at a random point

Fabrication of MR Damper: A mono tube without accumulator is chosen to model MR damper .Mono tube reduces gravitational settling and avoid clogging of valves. The performance of damper is efficient by using mono tube, due to proper regulation of fluid between two sections. The piston head of mono tube damper must be modified to acquire variable damping. The piston head must be fitted with variable electromagnet or solenoid to produce magnetic field inside the damper. The electromagnet is fitted exactly in the piston head to produce magnetic field over fluid throughout its entire length of displacement. The electromagnet housing must be adjacent to the holes of piston head for attaining maximum field strength over fluid.

Based on CAD and FEMM analysis, a similar MR damper designed with slight change in position of electro magnet housing, without degrading its performance. As showed in fig 5.1 a 4cm inner diameter tube made of mild steel is chosen as working tube. A piston rod of outer diameter 2.4cm and 16cm length is chosen and was drilled at its center throughout its length with an orifice of 6mm diameter using special drill bit tool. A piston head of 39cm diameter and 4 holes of size 3mm to regulate fluid flow is used. The head is centre drilled to 2.4cm diameter to accommodate electromagnet.

Fig.8.The machined parts

Performance test of the damper: The performance test of the MR damper is done by fatigue testing machine which applies cyclic load on it .A sine vibration of frequency 0.5Hz is applied on it. The load 250N is applied. Firstly the MR damper is tested at 0 ampere and later it was tested at 0.5 and 1 ampere .An electromagnet with 300 turns of copper wire winded over mild steel is used. The experimental electrical circuit consists of a resistance, ammeter and 12V battery .The resistance is varied manually to change the value of current being supplied. Before the experiment we should ensure that the magneto-rheological damper is clamped tight and we should also check the vertical alignment.

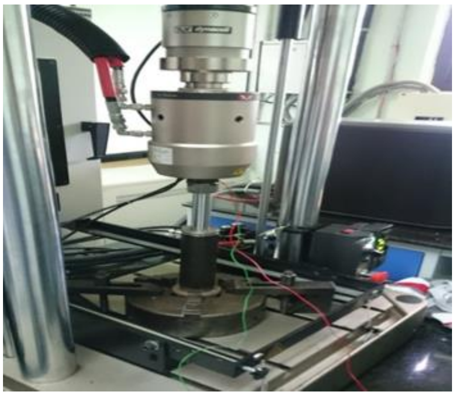

Figure.9.The fatigue testing machine

The force-displacement curve is obtained from the software for 0, 0.5 and 1 ampere. It is observed that when current is set to 1 ampere the displacement is reduced for the same load applied implying that the MR fluid has become stiffer and it is not easy for piston to displace unlike the former case. On supplying electric current the electromagnet is activated producing magnetic field around it in the piston head which makes the iron particles to align in magnetic field direction resulting in an increase in the viscosity of the MR fluid.

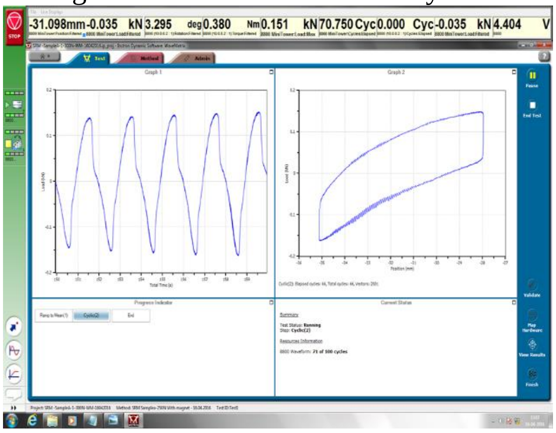

Figure.10.Damping force-displacement curve at 0A

The above curve shows the force-deflection curve at 0 ampere. At 0 ampere it works similar to a normal shock absorber as there will be no magnetic field present inside the damper. The applied load-time graph is sinusoidal and both graphs are for 100 cycles.

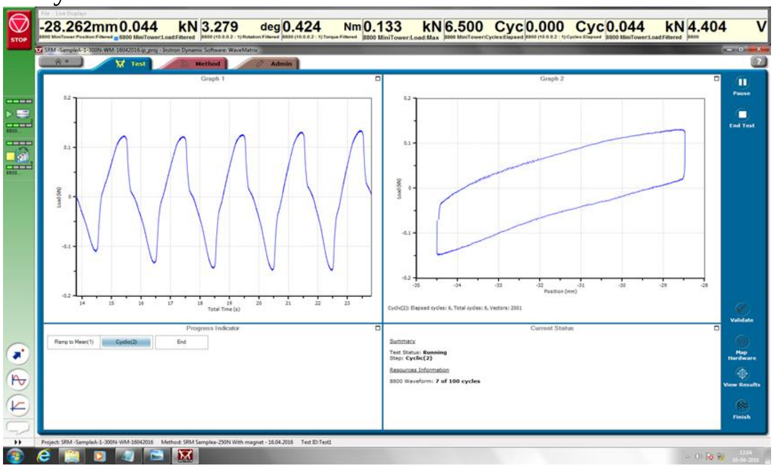

Figure.11.Damping force-deflection curve at 1A

4. CONCLUSION

The fabricated MR damper is successfully tested. The synthesized MR fluid shows increased stiffness with increase in current .With increase in current the deflection is reduced from 7mm to 5mm from 0A to 1A this is due to increase in viscosity .The use of MR fluid in the damper aids and semi active control and good road holding ability.

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