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Smart Material: Magneto Rheological Fluid

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ABSTRACT : *This paper presents basic properties of the magneto rheological fluids (MR) and their development in recent years. It is very clearly and well understood from the presented paper that replacement of the traditional devices with smart system. Many of them will include MR fluids as active component. A very useful material for the engineers engaged in the design of brakes, dampers, clutches and shock absorbers systems. A magneto-Rheological (MR) fluid brake is a device to transmit torque by the shear force of an MR Fluid. [1] An MR rotary brake has the property that its braking torque changes quickly in response to an external magnetic field strength. In this paper, the design method of the cylindrical MR fluid brake is presented theoretically. Vibration in today's increasingly high-speed vehicles including automobiles severely affects their ride comfort and safety. To improve the ride comfort, effective vibration control of suspension systems implement car suspension system with a MR fluid damper.*

Keywords - *Smart materials; Magneto rheological materials; Magnetic properties; Magneto rheological brakes, Magneto rheological suspension.*

I. INTRODUCTION

Science and technology have made amazing developments in the design of electronics and machinery using standard materials, which do not have particularly special properties. Imagine some materials have the ability to change shape or size simply by adding a little bit of heat, or to change from a liquid to a solid almost instantly when near a magnet; these materials called smart materials. Smart materials have one or more properties that can be dramatically altered.[1] Most everyday materials have physical properties, which cannot be significantly altered; for example if oil is heated it will become a little thinner, whereas a smart material with variable may turn from a liquid state which flows easily to a solid. Each individual type of smart material has a different property which can be significantly altered, such as viscosity, volume or conductivity.[3]

II. MAGNETO RHEOLOGICAL FLUID

Magneto rheological materials fluids (MR) are a class of smart materials whose rheological properties. Are rapidly varied by applying a magnetic field. This change in the material appears as a rapid increase in apparent viscosity or in the development of a semisolid state. [1]

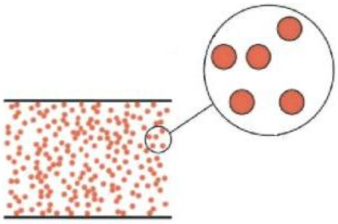

Fig.2.1 MR Fluid model without outer magnetic field

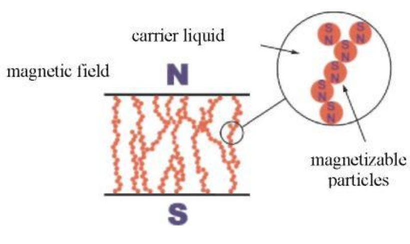

Fig.2.2 MR Fluid model in outer magnetic field

Typical magneto rheological fluids are the suspensions of micron sized, magnetizable particles (mainly iron) suspended in an appropriate carrier liquid such as mineral oil, synthetic oil, water or ethylene glycol. Typically, the diameter of the magnetizable particles range from 3 to 5 microns and materials can achieve yield strengths upto50–100kPaatmagnetic field strength of about 150–250 kA/m.[3] The MR effect is immediately reversible if the magnetic field is reduced or removed. Response times of 6.5 ms MR materials that have been already developed are stable in temperature ranges from -50 to 150°C. The power (50 W) and voltage (12-24V) requirements for MR materials activation are relatively small. The shear stress will increase with the magnetic field. [9]

The main performance parameters of MR Fluid are showed in the Table [9] -

Energy Consumption [J/cm^3]	0.1
Max Field Intensity [kA/m]	250
Max Shear Stress [kPa]	50~100
Apparent Viscosity [Pa·s]	0.2~1.0
Suitable Temperature [℃]	-50 ~ +150
Impurities Sensitivity	Insensitive
Density [g/cm^3]	3 ~ 4
Input Voltage [V]	2~25

MR Fluid devices have three basic work modes: Valve mode, shear mode and squeeze mode. In the valve mode, the MR Fluid is limited to the middle of the stillness magnetic poles, the pressure difference make the flow, the flow resistance is controlled by the magnetic field, the valve mode devices include, damper (shock absorber). In the shear mode, there is relative motion between the poles, this movement makes the MRF being the shear state, the shear stress could be changed by changing the magnetic field intensity, the shear mode devices include brake and clutch, etc. In the squeeze mode, the direction of the magnetic poles' movement is parallel to the magnetic induction line, the status of MRF is alternating stretches and compression, generally speaking, although the displacement of the magnetic poles is small, but that could produce big resistance, it is usually used as vibration damper. [7]

The principles of the three basic patterns are shown in figure –

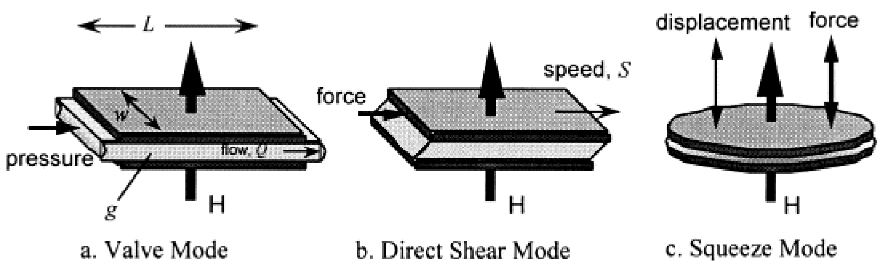

Fig.2.3 the three basic work modes of MR Fluid devices

III. MAGNETIC RHEOLOGICAL BRAKES

The automotive industry has a commitment to build safer, cheaper and better performing vehicles. For example, the recently introduced ''drive by wire" technology has been shown to improve the existing mechanical systems in automobiles. In other words, the traditional mechanical systems are being replaced by improved electromechanical systems that are able to do the same tasks faster, more reliably and more accurately. The proposed brake is a magneto rheological brake (MRB) that potentially has some performance advantages over conventional hydraulic brake (CHB) systems. A CHB system involves the brake pedal, hydraulic fluid; transfer lines and brake actuators (e.g. disk or drum brakes). When the driver presses on the brake pedal, the master cylinder provides the pressure in the brake actuators that squeeze the brake pads onto the rotors, generating the useful friction forces (thus the braking torque) to stop a vehicle. [2]However, the CHB has a number limitations, including, (i) delayed response time (200–300 ms) due to pressure build up in the hydraulic lines, (ii) bulky size and heavy weight due to its auxiliary hydraulic components such as the master cylinder, (iii) brake pad wear due to its frictional braking mechanism, and (iv) low braking performance in high speed and high temperature situations. [2]

The MR brake operates in a direct-shear mode, shearing the MR fluid filling the gap between the two surfaces (housing and rotor) moving with respect to one another. Rotor is fixed to the shaft, which is placed in bearings and can rotate in relation to housing. Resistance torque in the MR brake depends on viscosity of the MR fluid that can be changed by magnetic field. MR brake allows for continuous control of torque. When there is no magnetic field the torque is caused by viscosity of carrier liquid, bearings and seals. [10]

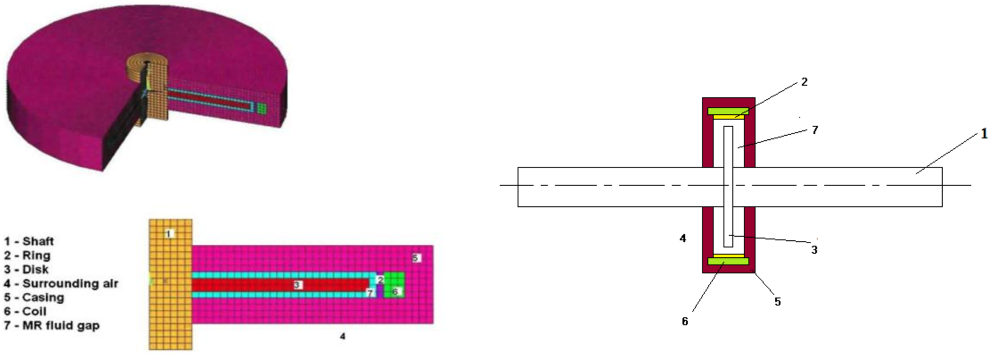

Fig.3.1 Basic configuration of the proposed MR brake

A basic configuration of a MRB was proposed for automotive applications. a rotating disk (3) is enclosed by a static casing (5), and the gap (7) between the disk and casing is filled with the MR fluid. A coil winding (6) is embedded on the perimeter of the casing and when electrical current is applied to it, magnetic fields are generated, and the MR fluid in the gap becomes solid-like instantaneously. The shear friction between the rotating disk and the solidified MR fluid provides the required braking torque. [3] In this paper, we propose a MR actuator for the brake in each wheel. The actuator consists of a rotating disk immersed in a MR fluid, enclosed in an electromagnet. In principle, the brake torque can be controlled by changing the DC current applied to the electromagnet. Magneto rheological fluid a compound containing fine iron particle in suspension - stiffens in the presence of a magnetic field. Two important characteristics of MR fluids are: (i) they exhibit linear response, i.e., the increase in stiffness is directly proportional to the strength of the applied magnetic field and (ii) they provide fast response, i.e., MR fluid changes from a fluid state to a near-solid state within mil-liseconds of exposing a magnetic field. [10]

IV. MAGNETIC RHEOLOGICAL SUSPENSION

Now day's people require high quality for everything. Certainly, the comfort in the moving vehicle is peoples concern, so it is desirable to have high performance suspension system for vehicles. In the environment of a moving vehicle, passengers often feel uncomfortable due to the vibration of the vehicle body. To improve the ride comfort, effective vibration control of vehicle suspension is very important. Shock absorbers in most vehicles rely on a hydraulic fluid, a sliding piston and other parts that suffer wear and tear. [8] In addition, the characteristics of a conventional shock absorber are either fixed, or else cannot be rapidly varied on demand. MR fluid is the enabling technology to design entirely new suspension systems that avoid these limitations, leading to improvements such as reduced wear and tear and more reliability through the life cycle. [11]

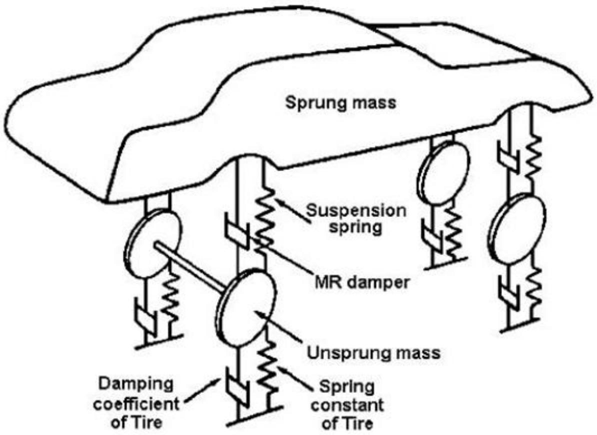

Fig.4.1 the Model of Vehicle

Magneto rheological dampers of various applications have been and continue to be developed. These dampers are mainly used in heavy industry with applications such as heavy motor damping, operator seat/cab damping in construction vehicles, and more. Seating equipped with MR dampers is the only product that offers both safety and health benefits for drivers. Unlike standard air suspended seats, which compromise shock and vibration control, the MR technology is the only solution that automatically adapts to both the drivers body weight and continually changing levels of shock and road vibration, improving driver responsiveness and control while reducing fatigue and risk of injury. MR-based suspension systems use the fluid in specially designed dampers, which take the place of standard dampers (shock absorbers). [11] If the shock absorbers of a vehicle's suspension are filled with magneto rheological fluid instead of plain oil, and the whole device surrounded with an electromagnet, the viscosity of the fluid, and hence the amount of damping provided by the shock absorber, can be varied depending on driver preference or the weight being carried by the vehicle - or it may be dynamically varied in order to provide stability control. One of the deliverables of the development for the Magneto rheological shock absorber was a direct comparison between the MR damper and a conventional hydraulic damper. This second shock absorber was also used to test the principal of replacing the conventional coil-spring with a gas-spring. A conventional shock absorber unit was designed with a conventional hydraulic damper unit. The unit flows all of the fluid through the damping valves which allows for much larger valves than is common in piston ported dampers. This in turn reduces fluid shear and improves damping response. The flow path was kept was long and very turbulent so the shock absorber is not sensitive to fluid viscosity temperature changes. [8]

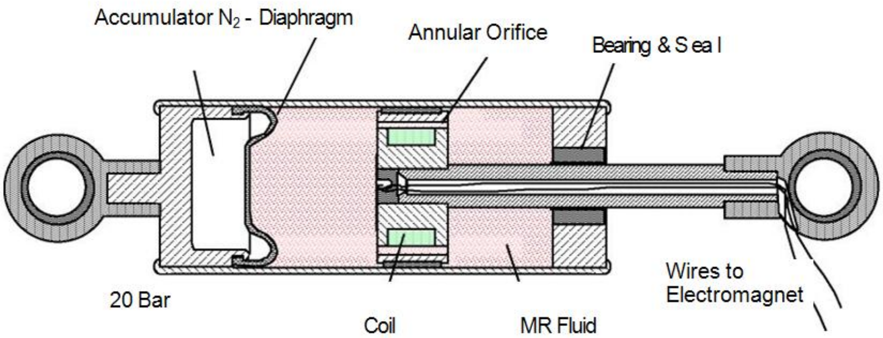

Fig.4.2 Commercial Linear MR Fluid-based Damper

The MR fluid damper contains MR fluid, bearing & seal, annular orifice, coil, diaphragm and accumulator. For accumulator, there is nitrogen gas with pressure 20-bar acting on the damper. The diaphragm is used to separate the nitrogen and the MR fluid. Also, the coil produces the electromagnetic field by the current passing through it. The annular orifice allows the MR fluid passing up and down. And also, the bearing & seal is used to prevent the friction. The MR fluid valves and associated magnetic circuit are fully contained within the piston. These magnetically controlled valves regulated the flow of MR fluid within the damper. Current is carried to the electromagnetic coil via the leads through the hollow shaft. When the current through the valves the MR fluid will change the state into solid. Then the damping force will increase. By changing the current, the damping force can be changed so that the damping can be controlled. [11]

V. CONCLUSION

The geometric design method of a cylindrical MR fluid brake is presented theoretically in this paper. Based on a commercially available magneto rheological fluid, a new automotive brake system was proposed. The model of the proposed MRB was presented, an optimum MRB design with two rotating disk was proposed. The proposed MRB is naturally a pure electronically controlled brake system that uses the use of ‘‘bytes and amperes instead of bars and compressed brake fluid.’’ This allows easy implementation of advanced braking control features with a smaller number of components, simplified wiring, improved braking response and generally optimized layout. Magneto rheological dampers of various applications have been and continue to be developed. The MR damper contains the fluid and an electric coil, which generates a magnetic field that controls fluid viscosity at any given moment. The overall MR suspension system also consists of a controller that manages the strength of the magnetic field applied to the fluid.

VI. Acknowledgements

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