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Shear Plus Squeeze Mode Based Magneto-Rheological Fluid Brake

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***Abstract* - Nowadays, magneto rheological fluid technology is growing rapidly to satisfy the different application demands. However, yield stress produced by the MR fluid limits its use option only several applications. Yield stress produced by a typical MR fluid is only 70 -90 kPa. Hence, while exploring the possibility of this fluid to be used in MR brake, it cannot attain required braking torque. Thus, if a conventional shear mode of this MR brake is combined with the simultaneous compression mode, then the typical MR fluid can attain a yield stress of about 800-900 kPa which will satisfy the braking torque requirements. During this review, the theoretical research has been carried out about the shear plus squeeze mode based MR brake to satisfy automotive brake application requirements.**
***Keywords:* Magneto rheological fluid, yield stress, shear mode, compression mode.**

I.INTRODUCTION

The research about Magneto rheological fluid (MRF) was initially started by Rabinow in 1948.MRF is fluid with variable viscosity. If there is no magnetic field applied, then MR fluid act as low-viscous oily fluid. After applying a magnetic field, the solid permanence particles will chain together in line along the N-S magnetic flux, and chains produce the force to normal and against normal or shear stress [1]. The quick change in MR fluids' behavior (5–10 ms) when a magnetic field is applied makes this material interesting for tunable or even adaptive damping and dissipative applications [2]. MRF is successfully applied in many engineering fields such as shock absorbers, damper, clutch, brake, metering valve and so on.

Operational modes of MRF

The modes of operation of MR fluid devices are flow mode (fixed plate mode, valve mode), shear mode (clutch mode), squeeze mode (compression mode) and any combination of these three.

Valve mode:

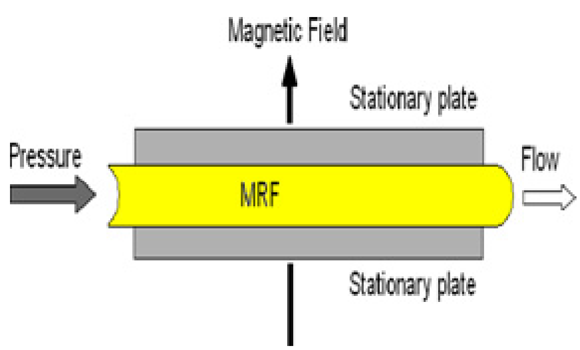

Fig. 1 Valve mode [3]

In the flow mode, MR fluid is made to flow between static plates by a pressure drop, and the flow resistance can be controlled by the magnetic field which runs normal to the flow direction. Examples of the flow mode include servo valves, dampers, shock absorbers and actuators [4].

Shear mode:

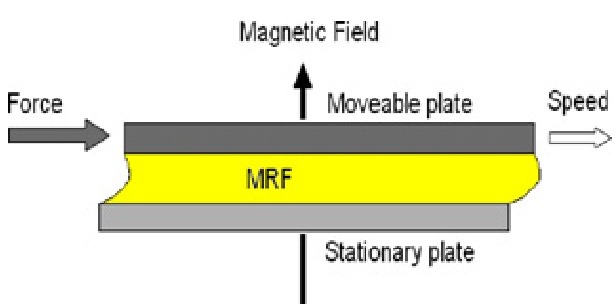

Fig.2 Shear mode [3]

In the shear mode, the MR fluid is located between surfaces moving (sliding or rotating) in relation to each other with the magnetic field flowing perpendicularly to the direction of motion of these shear surfaces. The characteristic of shear stress versus shear rate can be controlled by the magnetic field. Examples of the shear mode include clutches, brakes, chucking and locking devices, dampers and structural composites [4].

Squeeze Mode

In the squeeze mode, the distance between the parallel pole plates changes, which causes a squeeze flow. In this mode relatively high forces can be achieved; this mode is especially suitable for the damping of vibrations with low amplitudes (up to a few millimetres) and high dynamic forces. The squeeze mode has been used in some small-amplitude vibration dampers[4].

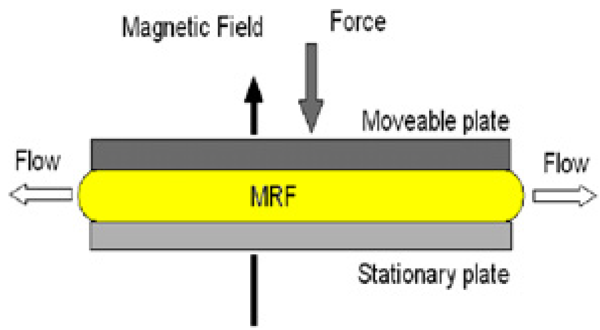

Fig. 3 Squeeze mode [3]

There are some considerations that should be made while designing MR fluid devices, such as the minimum volume of active MR fluid and electrical power requirement. The rheological properties of MR fluids, the working mode and the design of the magnetic circuit all considerably influence the properties of the MR fluid device [4].

Most of MR brake devices used shear mode in their design. A rotating disk is enclosed by a static casing, and the gap between the disk and the casing is filled with the MR fluid. A coil winding [5,6] is provided 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. Magneto rheological brake (MRB) potentially has some performance advantages over conventional hydraulic brake. A Conventional hydraulic brake (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. 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 (CHB) systems.

For the applications in brake, brake torque for most of MRF brake is still not enough. Thus increasing the brake torque efficiency is the most important research issue of MRF brake. Different ways are used to increase torque of MRF brake.

II. LITERATURE SURVEY

Hirani and Sarkar [7] had designed multimode brake comprising of compression and tension zones. The torque characteristics of magneto rheological brakes, consisting of rotating disks immersed in a MR fluid and enclosed in an electromagnetic casing, are controlled by regulating the yield stress of the MR fluid. An increase in yield stress increases the braking torque, which means that the higher the yield strength of the MR fluid, the better the performance of the MR brake will be. The required compressive force on MR fluid of the proposed brake has been applied using an electromagnetic actuator. The torque results have been plotted and compared with theoretical study. Experimental results as well as theoretical calculations indicate that the braking torque of the proposed MR brake is higher than that of the MR brake operating only under shear.

Hong-Yun Wang et al [8] has conducted experiment on the performance on MRF brake.

Magnetic fields being generated by two coils carrying different magnitudes of DC electrical current were applied on the MR fluids when shearing after compression were carried out on a self-constructed test system. For stress was recorded.MRF without compression process has a yield stress about 53kPa at most even if increasing the applied current. But after compression, the yield stress increase with the increasing compressive stress under the different applied currents. And some promising results are obtained, for example, when the applied current is 2.5A and the compressive stress is 2.0MPa, the yield stress exceeds 1100kPa. It showed that the yield stress of MR fluids after compression was much stronger than that of uncompressed MR fluids under the same applied current.

Andrea Spaggiari and Eugenio Dragoni [9] have also conducted experiment on MRF brake. The system is designed to apply both the magnetic field and the pressure following a design of experiment method. The experimental apparatus comprises a cylinder in which a piston applies both pressure and a prescribed rotation. The magnetic circuit is designed to provide a tunable, nearly constant magnetic induction field inside the fluid. A statistical analysis of the results finds a positive interaction between the magnetic field and the pressure, which enhances the magneto rheological fluid performances, measured in terms of yield stress, up to more than two times the value reached with no pressure.

L H Hamdan et al [10] presented a magneto rheological brake design with additional squeeze working mode to the conventional rotation shear. The MR brake was designed with consideration given to new concept of braking mechanism with the help of magnetic simulation. Simulation results showed that magnetic field strength was at best by having magnetic coil beside non-magnetic material, which was located at end of the outer diameter. The value of magnetic field was greater than when a small squeeze gap was applied and thus increase yield strength with two running modes.

Yao Jung Shiao and Cheng Yan Chang [11] designed the innovative MRF brake which features with multiple electromagnetic poles to significantly increase the active chaining areas of MRF and then increase brake torque. Because of special arrangement of pole numbers and directions of magnetic flux of these poles, the active chaining area of MRF and brake force are maximized. Performance comparison shows that the innovative MRF brake has 118% more torque output than commercial MRF brake

Shear plus squeeze mode based MR brake

The conventional MR brake operates in a direct-shear mode, shearing the MR fluid filling the gap between the two surfaces [6]. The MR fluid brake is a device to transmit torque by the shear stress of MR fluid. MR rotary brake has the property that its braking torque changes quickly in response to an external magnetic field strength. As shown in figure 4, MR brake consists of a rotating disk immersed in a MR fluid, enclosed in an electromagnet.

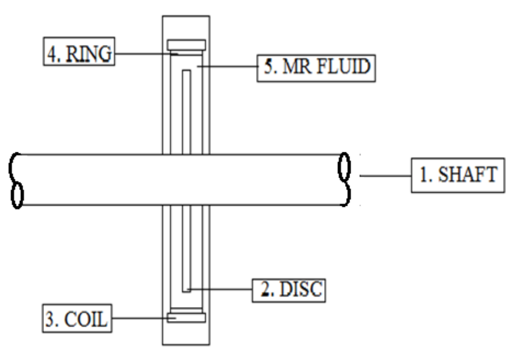

Fig. 4 Schematic of Shear Mode Based MR Brake

The yield stress of a fluid varies as a function of magnetic field applied by electromagnet[8]. However, overall braking torque produced by this shear mode based MR brake cannot exceed a typical value of around 25 Nm to 50 Nm. Thus, to explore the possiblity of this MR brake device to be used in automotive application, the shear mode is combined with compression mode.

A schematic of the proposed shear plus squeeze mode based MR brake is shown in figure 5. The proposed MR brake is of a single-disk type with rotating rotor plate and stationary armature housing plates (covering the central electromagnet).

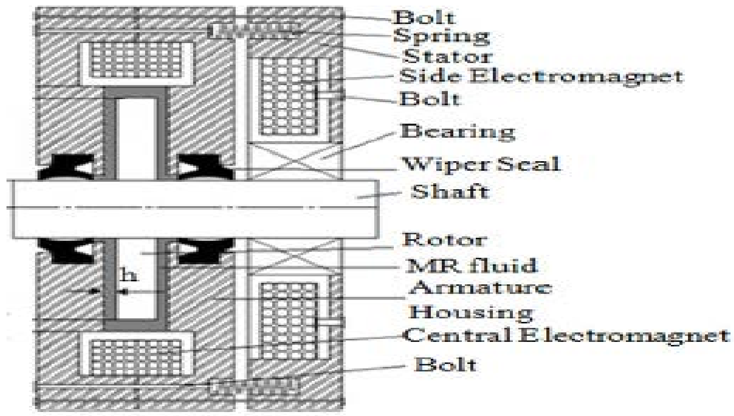

Fig. 5 Shear Plus Squeeze Mode based Magnetorheological Brake

MR fluid is placed in the annular space along the periphery as well as at both sides of the MS rotor which is mounted on the SS shaft. The wiper seals are used to seal the MR fluid and allow sliding in the direction of attractive force by the stator when magnetic field is applied in the side electromagnet. Six compression springs are used to provide restraint against the electromagnetic force generated by the side electromagnet.

III. CONCLUSION

The MR brake based on compression plus shear mode will show much better performance as compared to the brake operating under only shear mode. Based on the present research work it can be said that all MR brakes should be designed based on compression plus shear mode mechanisms. The braking torque produced by this proposed brake would be nearly 10 to 12 times than that of the conventional shear mode based MR brake. This will help to explore the possibilty of MR brake to be used in automotive braking applications.

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