FABRICATION OF MAGNETO-RHEOLOGICAL FLUID BRAKE SYSTEM

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Abstract— **Conventional hydraulic brake (CHB) systems used in automotive industry have several limitations and disadvantages such as the response delay, wear of braking pad, requirement for auxiliary components (e.g. hydraulic pump, transfer pipes and brake fluid reservoir) and increased overall weight due to the auxiliary components. In this thesis, the development of a novel electromechanical brake (EMB) for automotive applications is presented. Such brake employs mechanical components as well as electrical components, resulting in more reliable and faster braking actuation. The proposed electromagnetic brake is a magneto-rheological (MR) brake. The MR brake consists of rotating disks immersed into an MR fluid and an enclosed electromagnet. When current is applied to the electromagnet coil, the MR fluid solidifies as its yield stress varies as a function of the magnetic field applied by the electromagnet. This controllable yield stress produces shear friction on the rotating disks, generating the braking torque. This type of braking system has the following advantages: faster response, easy implementation of a new controller or existing controllers (e.g. ABS, VSC, EPB, etc.), less maintenance requirements since there is no material wear and lighter overall weight since it does not require the auxiliary components used in CHBs. The MRB design process included several critical design steps such as the magnetic circuit design and material selection as well as other practical considerations such as cooling and sealing. A basic MRB configuration was selected among possible candidates and a detailed design was obtained according to a set of design criteria. Then, In order to obtain an optimal MRB design with higher braking torque generation capacity and lower weight, the key design parameters were optimized, which was required to calculate the braking torque generation in each iteration. Next, the optimum MRB was prototyped. The braking performance of the prototype was tested and verified, and the experimental results were shown. Other possible sources of errors are also discussed. Since the prototype MRB generates much lower braking torque compared to that of a similar size CHB, possible design improvements are suggested to further increase the braking torque capacity. These include the relaxation of the optimization constraints, introduction of additional disks, and the change in the basic magnetic circuit configuration.**

Index Terms—**CHB,EMB,MRB.**

I. INTRODUCTION

A brake is a mechanical device by means of which artificial frictional resistance is applied to a moving machine member, in order to stop and retard the motion. Inhibit motion or preventing its motion Brakes are generally applied to rotating axles or wheels, but may also take other forms such as the surface of a moving fluid. Some vehicles use a combination of braking mechanisms, such as drag racing cars with both wheel brakes and a parachute, or airplanes with both wheel brakes and drag flaps raised into the air during landing. Generally mechanical brakes are used widely because of their simplicity.

Some materials have the ability to change shape or size simply by adding a little bit of heat, or to change it from a liquid to solid state instantly are called smart materials. Magneto-rheological (MR) fluid is one of the smart materials available. The conventional friction brake, is a device used to slow or stop a moving object by dissipating its kinetic energy as heat. In order to make collapsible fluid link to stop the motion of driving shaft, magneto-rheological fluid can be used as a medium. In this process magnetic field act as actuator and Magneto-rheological fluid operated brake. By this way we can use one of the smart fluids as a research application.

Magneto-Rheological (MR) fluids consist of stable suspensions of micro-sized, magnetized particles dispersed in a carrier medium such as silicon oil or water. When an external magnetic field is applied, the polarization induced in suspended particles results in the MR effect of the MR fluids. The MR effect directly influences the mechanical properties of the MR fluids. The suspended particles in the MR fluids become magnetized and align themselves, like chains, with the direction of the magnetic field. The formulation of these particle chains restricts the movement of the MR fluids, thereby increasing the yield stress of the fluids. The change israpid, reversible and controllable with the magnetic field strength The mechanical properties of the MR fluids can be used in the construction of magnetically controlled devices such as the MR fluid rotary brake, or clutch. To design the MR fluid brake for a given specification, one must establish the relationship between the torque developed by MR fluids and the parameters of the structure and the magnetic field strength. In this paper the fundamental design method of the cylindrical MR brake is investigated theoretically. A Bingham model is used to characterize the constitutive behavior of the MR fluids subject to an external magnetic field strength.

The theoretical method is developed to analyze the torque transmitted by the MR fluid within the brake. An engineering expression for the torque is derived to provide the theoretical foundation in the design of the brake. Based on this equation, after algebraic manipulation, the volume and thickness of the annular MR fluid within the brake is yielded.

- Mechanical braking system

Role of mechanical braking or frictional braking is very crucial in industries and automobile sectors. Mechanical braking system includes drum brakes, disc brakes, hydraulic brakes etc. In all the types the braking is dependent on the frictional force between mating surfaces. So they are called as friction brakes. Friction brakes convert the kinetic energy of a moving body into heat and dissipate it into the atmosphere. In general there are no coolants to absorb this heat so all hear is given out by natural or forced convection only. This is one of the reasons for degradation of the brakes and the brake fades effect.

- Role of brakes in automobile

A brake is the device used to reduce the speed or stop the moving body. The motion could be linear or rotary. In automobiles the wheels are the main components which give motion to the vehicle and then keep it in that state. So for stopping the vehicle the motion of the wheels is inhibited and the vehicle is made to stop. It is very essential to reduce the speed of vehicle during turning or when some object comes into the path of vehicle. The braking is required to be uniform not sudden in order to avoid skidding of the vehicle. The brakes have almost importance when safety of vehicle is considered. They are designed to stop the vehicle in a shortest possible distance without locking the wheels.

- Limitations of frictional brake

Many of the ordinary brakes, which are being used now days stop the vehicle by means of mechanical blocking This causes skidding and wear and tear of the vehicle. And if the speed of the vehicle is very high, the brake cannot provide that much high braking force and it will cause problems. These brakes also make use of brake oil which always have a risk of getting leaked during operations. And it will completely vanish the braking action in automobile and can cause a threat to lives of passengers.

- Aim of the Project

The main aim of this project is to prepare the magneto rheological fluid for the MR brake which may be used in vehicle braking system. This project also emphasis on the details of preparation of magneto rheological fluid and fabrication of the magneto rheological brake to calculate the braking torque.

- Objectives

1. No metal-with-metal friction.
2. No brake pad needed.
3. Simple design & construction.
4. Hydraulic free: no hydraulic line & need less space requirement.
5. Easy to control (potential to be used for brake-by-wire (BBW) system.

II. LITERATURE REVIEW

This literature review gives idea about MR fluid and its properties. Given reports gives brief information about limitations of existing brake and innovative applications of MR fluid explained in brief. MR fluid has wide applications due to less power consumption and very less response time (Milliseconds). Literature review also gives special focus on MR brake and its design issues. Some papers give information about the theoretical and practical analysis of MR brake and design of electromagnet.

Kerem Karakoc et al. have proposed MR brake consists of multiple rotating disks immersed in a MR fluid enclosed in electromagnet. The Current passing through electromagnet produces controllable yield stress which imparts shear friction on the rotating disks for the generation of the braking torque. In their work the practical design criteria's such as material selection, sealing, working surface area, viscous torque generation, applied current density, and MR fluid selection were considered to select a basic automotive MR brake configuration.[i]

Tran Hai NAM and Kyoung Kwan AHN in 2009 proposes a new approach to increase the resistance torque of an MR brake using a large-size magnetic particle which can be considered as the roller mentioned above (steel roller or rolling pin). Due to the cylindrical form of the roller and a line contact between the roller and the surface of the motion part, the steel roller can contribute to create a stronger magnetic field and larger resistance force than the conventional one. They concluded that proposed MR brake is having about 200% larger torque than the conventional one.[ii]

Ahmad Zaifazlin. Zainordin, MohdAzman ISSN 2320-4052. In 2013presents experimental evaluations on braking responses of MR Brake at various current and load.The experiments are performed using MR brake test rig to obtain three output responses namely the angular velocity response, torque response and load displacement response. The MR brake generates maximum torque at high current and causes fast decrement of shaft angular velocity. The effectiveness MR brake torque happens at minimum load with low stopping time. [iii]

Stuart W. Charles Department of Chemistry, University of Wales, Bangor, has given a lot of ideas regarding preparation of nano-sized particles and ferrous-fluids. Nano-sized ferrite particles can be formed by Wet grinding process which involves ball mill. This process usually takes a very long time (1000 hours) and it is mainly for this reason that the process has been superseded by a rapid and simple method involving the co-precipitation of metal salts in aqueous solution using a base. [iv]

Mukund A. Patil ISSN: 2249-5762 ISSN : 2249-5770 has proposed Magneto-Rheological (MR) fluid brake is a device to transmit torque by the shear force of an MR fluid. 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 investigated theoretically. The mechanical part is modeled using Bingham's equation, an approach to modeling the magnetic circuit is proposed in this work. [v]

Bhau K. Kumbhar and Satyajit R. Patil have given the various MRF component and its proper selection different properties are explained about MR fluid and their developments during recent years. Discussed possible candidates of carrier fluid, Magnetic Particles, additives and surfactants. [vi]

S. Elizabeth et al. have prepared different samples of MR fluids. They use silicone oil as a carrier fluid mixed with iron powder of average size 28 microns. In order to reduce sedimentation rate grease was used as stabilizer. Different samples were prepared with varying composition of stabilizer. Their study includes effect of percentage of additives on different properties of MR. [vii]

Roger I. Tanner has discussed concept of rheology. His research gives brief history about the development of rheological concept and experimental analysis. There is a lot of experimental work done on viscosity, but contrary to that very less on the normal stresses. [viii]

J. Wang and G.Meng have discussed about basic properties of MR fluid and its applications. Their study describe that MR fluids have yield strength of up to 50– 100 kPa, which is higher than ER fluids. [ix]

III. MATERIAL COMPOSITION

Preparation of MR fluid

- Composition
  1. Synthetic oil = 60%
  2. Grease = 10-12% of synthetic oil
  3. Metal Powder = 40% [with 3-5 microns dia.]
- Procedure
  1. First take Synthetic oil & Grease.
  2. Strictly stir it unidirectional only.
  3. Now, add metal powder simultaneously with stirring the mixture.
  4. We will get MR fluid.

Properties of Commercial MR Fluids

Table: Composition of MR fluids

MR Fluid	% Iron by volume	Carrier fluid	Density (g/ml)
X-336AG	36	Silicon Oil	3.47

- Magnetic Properties

Understanding the magnetic properties of MR fluids is important for designing MR fluid-based devices. In many such devices, the MR fluid represents the largest magnetic reluctance within the magnetic circuit. These magnetic properties may also prove useful in providing insight into the character and formation of particle structures within the fluid.

- Rheological Properties

The rheological properties of fluids depend on concentration and density of particles, particle size and shape distribution, properties of the carrier fluid, additional additives, applied field, temperature etc. The magneto rheological effect of the four MR fluids was measured on a custom rheometer using a 46mm diameter parallel plate geometry set at a 1mm gap. In the parallel plate geometry, shear rate occurring at the outer radius. The rheometer is capable of applying greater than 1 Tesla through the fluid sample. At low flux densities, the fluid stress can be seen to exhibit a power law behavior. As can be seen, the flux density at which this saturation occurs increases as magnetic, rheological, tribology and settling properties of commercial MR fluids.

- Other Important Properties of MR Fluid

Table: Properties of MR Fluid

1.	Viscosity	0.2 – 0.3 Pascal
2.	Density	1.3 – 4 g/cu.cm
3.	Magnetic field strength	150 – 250 KA/m at 1 amp
4.	Yield point pressure	50 -100 kpa
5.	Temp	-50 to 150℃

- Potting of Coil

1. Potting of coil is done for insulation purpose.
2. Designed for high voltage coils, this potting material is impervious to vibration and shock, and protects from moisture and other corrosive elements.

Types of Potting Compounds are as follows-

1. Polyster Resin

   Polyster resins are commonly used in electrical potting applications. The formulas' mechanical characteristics range from flexible to rigid and can be used in at temperatures up to 180°C. Chemical resistances of these materials are fair. Their adhesion to metals is good. Their applied cost is made more economical with the addition of inorganic fillers. The addition of fillers reduces shrinkage during cure.
2. Epoxy
3. Hot Melt
4. Urethanes
5. Silicone

6. UV Curing Materials

- Composition
  1. Hardener - 3 ml
  2. Polyester Resin- 150 ml
- Procedure
  1. First of all, take 50 ml Hardener (Araldite) and 150 ml polyester resin.
  2. Apply the polyester resin on the coil.
  3. Then slowly use hardener all over on the coil.
  4. Wait for half an hour.
  5. Potting will be ready.
- Precautions
  1. Take right proportion of both solutions.
  2. Wait until it gets solidified.
  3. By taking more hardener, it will get solidified rapidly and vice versa so use carefully.

IV. ASSEMBLY OF MR BRAKE

- Procedure for assembly of the MR brake
  1. Firstly, oil seals and bearings are mounted in the grooves provided on housing and housing cover properly by press fit.
  2. Now put housing on the floor and put tapered rollers in the groove provided on the housing.
  3. Put the rotor connected to the shaft in the housing vertically so that lower side of shaft should rest on the ground.
  4. Take MR fluid in conical flask (50 ml) and fill it slowly in the gap between rotor and housing.
  5. Fill it in the gap unless or until it creates 2 mm gap layer on the rotor.
  6. Assemble housing cover on housing by using M8 bolts.
  7. Now connect fly wheel to one end of shaft and other end is connected to motor by coupling.
  8. Mount this assembly on the frame.

- Set up Image

V. ASSEMBLY OF MR BRAKE

- Experimental Braking Torque Calculations

Firstly, one side of rope was fixed to the horizontal bar welded on frame, that belt was taken over Pulley through Flywheel and at the free end dead weights were attached.

It required 4 kg of dead weight to stop the Flywheel.

Therefore,

Torque = Force × Radius of Flywheel

$= F \times R$

$= m \times g \times R$

$= 4 \times 9.81 \times 94$

$= 3688.56$ N-mm

ADVANTAGES

1. Low power requirement.
2. Brake pad is not required.
3. Less wear and tear.
4. Long life when MR Fluid changed time to time.
5. Less space requirement as compared to pneumatic and hydraulic breaking system.

LIMITATIONS

1. High density, due to iron particles, makes the system heavy.
2. High-quality fluids are expensive.
3. Fluids are subject to thickening after prolonged use and need replacing.
4. Battery supply is essential.
5. Residual magnetism can affect other ferromagnetic components.

CONCLUSION

1. In this report, innovative idea to make Brake using Magneto rheological fluid is discussed and thereafter it is analysed by fabricating it.
2. Also in this system there is no metal to metal friction occurs so wear of components doesn't take place. So this mechanical device gives effective braking effect.
3. In this system, braking is done by collapsible fluid link andnot bythe friction pad therefore there is no wear and tear of the components.
4. There are no bulky hydraulic lines are used in the fabrication of the system so the design and construction of the system is simple and as the brake is applied with help of Brake By Wire (B-B-W).

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REFERENCES

i. K. Karakoc, E.J. Park, and A. Suleman, "Design considerations for an automotive magneto-rheological brake," Mechatronics, Vol. 18, 2008.

ii. T.H. Nam and K.K. Ahn, "A new structure of a magneto-rheological brake with the waveform boundary of a rotary disk," Smart Materials and Structures, Vol. 18, 2009.

iii. Ahmad Zaifazlin Zainordin, MohdAzman Abdullah, Khusbullah Hudha, “Experimental Evaluation of breaking response of MR brake ISSN 2320-4052 Vol-1 ,2013.

iv. Stuart W. Charles," The Preparation of Magnetic Fluids,” Vol-7,2002.

v. Mukund A. Patil, Ashutosh S. Zare, " Theoretical Studies on Magneto-rheological Fluid Brake,” Vol. 2, Issue 2, May - Oct 2012.

vi. Bhau K. Kumbhar and Satyajit R. Patil," A Study on Properties and Selection Criteria for Magneto-Rheological (MR) Fluid Components”,Vol.6, Aug-Sep 2014.

vii. S. Elizabeth et al, “Study and Preparation of MR Fluid and its selection”, Vol-4, 2005.

viii. Roger I. Tanner, “The changing face of Rheology”, Journal of Non-Newtonian Fluid Mechanics, Vol-1, 2009.

ix. J.Wang, G.Meng, "Magneto rheological fluid devices: principles, characteristics and applications in mechanical engineering", Vol-2, 2001.