DESIGN AND DEVELOPMENT OF MAGNETO RHEOLOGICAL FLUID BRAKING 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 multiple 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.

*Keywords —**Magneto Rheological Fluid,Smart Material***

I. INTRODUCTION

Automotive industry is changing every day billions of dollars are invested in research and development for building safer, cheaper and better performing vehicles. One such investment is the "x by wire "topic which has been introduced to improve the existing mechanical systems on automobiles. This term means that the mechanical systems in the vehicles can be replaced by electromechanical systems that are able to do the same task in a faster, more reliable and accurate way than the pure mechanical systems. This thesis work is concerned with the topic of braking in the vehicles. Nowadays, conventional hydraulic brakes (chb) are being used in order to provide the required braking torque to stop a vehicle. This system involves the brake pedal, hydraulic fluid; transfer pipes and brake actuators (disk and drum brakes). When the driver presses on the brake pedal, the hydraulic brake fluid provides the pressure in the brake actuators that squeezes the brake pads onto the rotor. Pushes the pedal, there is a latency in building up the pressure necessary to actuate the brakes. Also, since chbs employ a highly pressurized brake fluid, there is the possibility of leakage of the brake fluid that would cause fatal accidents, and this fluid is harmful to the environment as well. Another problem seen in chbs is that this type of brake uses the friction between brake pads and the brake disk as its braking mechanism, leading to the brake pad wear. Due to both the material wear and the friction coefficient variation in high speeds, the brake performs less optimally in high speed region, as well as with the increased number of usage cycles. Thus, the brake pads must be changed periodically in order to get the optimum braking performance. Finally, another disadvantage of this type of brake system is that it is bulky in size, when both auxiliary components and brake actuators are considered. Nowadays in addition to the use of the CHB, pneumatically actuated drum brakes (i.e. air brakes) are being used for trucks and other heavy vehicles that need more braking torque. Similar to the CHB, in this type of brake, pneumatic pumps and pipes are used to transfer the air pressure to the brake actuators. However, with the introduction of"x by wire" technologies, electromechanical brakes (EMB) have appeared in the industry. In this configuration, some of the pure mechanical components of the conventional brakes are replaced by electromechanical components. A simple example of such brake system is the drum brakes used in trailers where less braking torque is required. These brakes are actuated by an electromagnet installed in the drum brake instead of a hydraulic mechanism that attracts magnetic rotating disks onto a stator. The friction generated between the stator and the rotor results in braking. Electric callipers developed by There are also eddy current retarders being used for trucks, buses, trains and garbage collectors. This type of brake basically works in conjunction with the main hydraulic brakes, in order to decrease the braking load

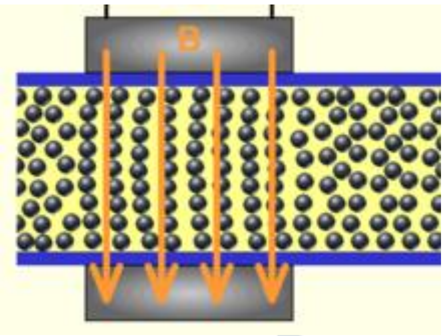

Fig. 1 structure of MR Fluid

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. Importantly, the yield stress of the fluid when in its active ("on") state can be controlled very accurately by varying the magnetic field intensity. The upshot is that the fluid's ability to transmit force can be controlled with an electromagnet, which gives rise to its many possible control-based applications. Extensive discussions of the physics and applications of MR fluids can be found in a recent book.

MR fluid is different from a Ferrofluid which has smaller particles. MR fluid particles are primarily on the micrometre-scale and are too dense for Brownian motion to keep them suspended (in the lower density carrier fluid). Ferro fluid particles are primarily nano particles that are suspended by Brownian motion and generally will not settle under normal conditions. As a result, these two fluids have very different applications.

The magnetic particles, which are typically micrometre or manometer scale spheres or ellipsoids, are suspended within the carrier oil are distributed randomly and in suspension under normal circumstances, as below.

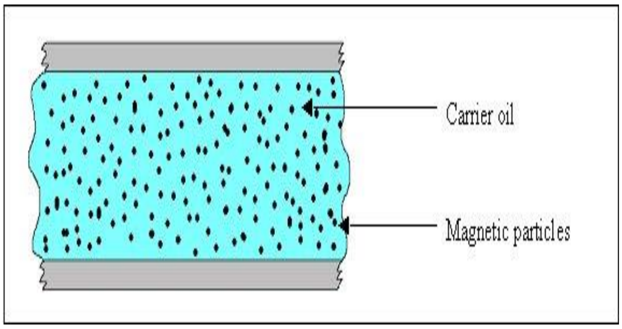

Fig. 2 structure of MR Fluid

When a magnetic field is applied, however, the microscopic particles (usually in the 0.1–10 μm range) align themselves along the lines of magnetic flux, see below.

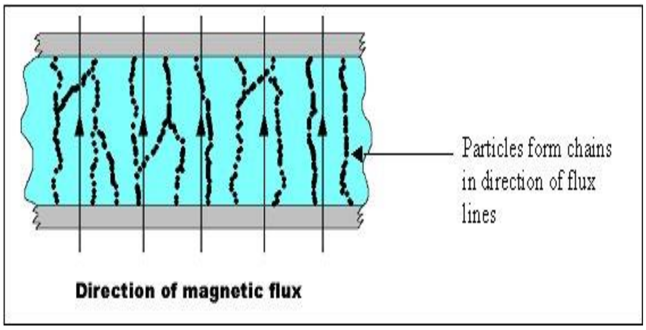

Fig. 3 structure of MR Fluid

II. LITERATURE REVIEW

"The Design of Eddy-Current Magnets Brakes"
Der-Ming Ma, Jaw-KuenShiau

The eddy-current is created by the relative motion between a magnet and a metal (or alloy) conductor. The current induces the reverse magnetic field and results in the deceleration of motion. The proposed mechanism implements this phenomenon in developing a braking system

"Intelligent Control For Brakes System"

William K. Lennon and Kevin M. Passino

There exist several problems in the control of brake systems including the development of control logic for antilock braking systems (ABS) and "base-braking." Here, we study the base-braking control problem where we seek to develop controller that can ensure that the braking torque commanded by the driver will be achieved.

"Design Of Magneto-Rheological Brake For Automotive Application"

Bhau K. Kumbhar*, Vikas R. Khalkar, Pravin N. Jadhav, Satyajit R. Patil

The Conventional Hydraulic Brakes (CHB) system is being used to provide the required braking torque to stop a vehicle. This system has number of drawbacks such as delayed response time to stop a vehicle, bulky size, brake pad wear etc. With the use of magneto-rheological (MR) brake, different limitations of CHB can be eliminated. MR brake is one of the possibilities to replace a CHB, which is the pure electronically controlled actuator and has a potential to further reduce the braking time. There lies a potential for investigation of MR brake for automotive application. Thus in this paper, the efforts have been taken to design the MR brake for E-bicycle

"Synthesis And Characterisation Of Magneto-Rheological (Mr)Fluid For Mr Brake Apllication"

Bhau K. Kumbhar ,Satyajit R. Patil , Suresh M. Sawant

Magneto rheological (MR) fluid technology has been proven for many industrial applications like shock absorbers, actuators, etc. MR fluid is a smart material whose rheological characteristics change rapidly and can be controlled easily in presence of an applied magnetics field.MR brake is a device to transmit torque by the shear stress of MR fluid. However,MR fluids exhibit yield stress of 50e90 kPa. In this research, an effort has been made to synthesize MR fluid sample/s which will typically meet the requirements of MR brake applications. In this study, various electrolytic and carbonyl iron powder based MR fluids have been synthesized by mixing grease as a stabilizer, oleic acid as an antifriction additive and gaur gum powder as a surface coating to reduce agglomeration of the MR fluid.MR fluid samples based on sunflower oil, which is bio-degradable, environmentally friendly and abundantly available have also been synthesized. These MR fluid samples are characterized for determination of magnetic, morphological and rheological properties. This study helps identify most suitable localized MR fluid meant for MR brake application. © 2015 Karabuk University.Production and hosting by Elsevier B.V. This is an open access article under

Magneto rheological Fluid Brake –Basic Performances TestingWith Magnetic Field Efficiency Improvement Proposal
A. Poznić1, A. Zelić1, L. Szabó2

The convectional friction brake (FB) is the most commonly used brake type in almost any mechanical system today. However, it is characterized by drawbacks such as periodic replacement due to wear, large mechanical time-delay, bulky size etc. partially altered. Electromechanical brakes (EMBs) have potential to overcome some of these drawbacks and are a suitable FB replacement. Today EMBs are applicable in almost any mechanical system. Application of intelligent materials is the next step in the development of EMB. Magneto rheological (MR) fluids belong to a class of intelligent materials that respond to applied magnetic field with fast, continuous, and reversible change in its rheological behaviour [3, 7, 28], partially altered. MR fluids are a type of suspensions, with carrier fluid usually mineral or synthetic oil, water, and kerosene and micro size magnetizable particles dispersed in it. When exposed to external magnetic field particles form a chain-like structures thus changing the viscosity of the fluid. In this study, authors used BASF's magneto rheologicalfluid,Basonetic 5030.MR fluids have attracted extensive research interest

A Study on Magneto Rheological Fluids and Their Applications

Suryawanshi Ravishankar[1], Rayappa Mahale[2]

Magneto rheological fluids commonly known as MR fluids are suspensions of solid in liquid whose properties changes drastically when exposed to magnetic field. It is this property which makes it desirable to use in different vibration controlling systems. Magneto-rheological fluids consist of micron sized polarizable particles in a liquid. Application of a magnetic field changes MR fluid from a liquid state to a semi-solid state, proportional to the strength of the field applied. Magneto-rheological fluid has the extremely widespread application prospect in many fields including aerospace, automotive industry, hydraulic transmission, biotechnology and medical because of its characteristics of continuous, reversible, rapid and easy control [6].

Preparation and Testing Of Magneto Rheological Fluid

Mr.Vaibhav R. Sawalkar, Mr.Chetan S. More, Prof. T. B. PatilA. Basics of MR fluid

The discovery of Magneto Rheological (MR) fluid is attributed to Jacob Rainbow in 1940's. Magneto rheological fluids are a class of controllable fluids which can be simply referred as a smart material. Nowadays they are stable exhibit many attractive properties such as high yield stress and low viscosity. Because of this magneto rheological fluids are recently used in suspension of high class vehicle. Magneto rheological fluids are mixture of micron sized ferromagnetic particle and grease in appropriate carrier oil. MR fluids manifest a change in rheological properties on the application of external magnetic field. Rheology is branch of science that deals with the study of deformation and flow of matter such as magneto rheological fluids, blood, paint etc. under the impact of a stress. The rheological property of controllable fluids turns on properties of the carrier oil, attention and density of particles, particle size and shape, external magnetic field and temperature etc.

III. METHODOLOGY

Fig. 4 Experimental Setup

Electric motor details
Power= 120 watt
Speed = 0-6000 rpm
Operating speed = 1000 rpm.
Now;

$$\text{Power (P)} = \frac{2\Pi NT}{60}$$

$$\Rightarrow 120 = \frac{2\pi \times 1000 \times T}{60\,\pi}$$

$$\Rightarrow T = \frac{60 \times 120}{2 \times \pi \times 1000}$$

T = 1.15 N.m
Considering 100% overload
Tdesign =2 T = 2.3N-m

DESIGN OF INPUT SHAFT

T_{Design} = 2.3 Nm.
= 2.3 x 10^3 N.mm
Selection of input shaft material
Ref :- PSG Design Data.
PgNo :- 1.10 & 1.12.1.17

Table No 1 Design of Input Shaft

Designation	Ultimate Tensile Strength N/mm^2	Yield strength N/mm^2
EN 24 (40 N; 2 cr 1 Mo 28)	720	600

Using ASME code of design ;
Allowable shear stress;
Fs_{all} is given stress ;
Fs_{all} = 0.30 syt = 0.30 x 600
=180 N/mm^2

Fs_{all} = 0.18 x Sult = 0.18 x 720
= 130 N/mm^2
Considering minimum of the above values;
fs_{all} = 130 N/mm^2
As we are providing dimples for locking on shaft;
Reducing above value by 25%.
$\Rightarrow fs_{all}$ = 0.75 x 130
= 97.5 N/mm^2

a) Considering pure torsional load;

$$T_{design} = \frac{\pi}{16} fs_{all}\, d^3$$

$$\Rightarrow d^3 = \frac{16 \times 2.3 \times 10^3}{\pi \times 97.5}$$

d = 4.7 mm

selecting minimum diameter of spindle = 16 mm from ease of construction because the standard pulley has a pilot bore of 12.5 mm in as cast condition, and a bore of minimum 16 mm for keyway slotting operation.

DESIGN OF MAIN SPINDLE.

T Design = 1.5234 Nm.
= 1.5234 x 10 3 N.mm
Selection of main spindle material
Ref:- PSG Design Data
Pg No.:- 1.10 & 1.12.1.17

Table No 2 Design of Main Spindle

Designation	Ultimate Tensile Strength N/mm2	Yield strength N/mm
EN 24(40 N; 2 cr 1 Mo28)	720	600

using ASME code of design
Allowable shear stress;
Fsall is given stress;
Fs all = 0.30 syt = 0.30 x 600, = 180N/mm^2
Fsall = 0.18 x Sult = 0.18 x72, = 130 N/mm^2
Considering minimum of the above values;
fs all =130 N/mm^2
Reducing above value by 25%
→fs all =0.75 x 130
= 97.5 N/ mm^2

a) Considering pure torsional load;

$$T\ design = \frac{\pi fs\ all\ d^3}{16}$$

$$\rightarrow d^3 = \frac{16 \times 3.68 \times 10^3}{\pi \times 97.5}$$

d = 5.77 mm

Selecting minimum diameter of spindle = 16 mm from ease of
Construction because the standard pulley has a pilot bore of 12.5 mmin as cast condition,
→ft x 119 = 3.68 x10^3
→ft = 30 .92 N

30 .9 N (T1 –T2) = 158.72N
A --------------------D
157 C 157 B60

FY =O
(T1 – T2) + F T = RA = RB
→(RA + RB) = 189.64
= 240.2 N
MA =O
RB x 314 =30.92 x 157 + 158.72 x 374.
→RB = 204.50 N
→RA = -14.86N
Max BM = 59.36 x 103 Nmm

Equivalent Torque;

Te = M2+ T2

Te = (59.36x103)2 + (3.68 x103) 2

Te =59.47 x 103Nm

Te= π ___________

16fsact x d3

→fs act = 16 x T _______

$\pi\ d^3$

→ $16 \times 59.47 \times 10^3$ $11(16)^3$

→fs act = 73.94 N/mm^2

→AS fs act <fs al

→Shaft is safe under torsional load

Check for bending failure of shaft

Max bending moment occurs at point 'A', the section diameter at point

DA = 20 MM

→ Me = ½ M + Te.

= ½ x 59.36 x 103 + 59.47 x 103

89.15 x 103 Nm

Me = $\pi fb\ act\ d^3$ 32

Fb act = 89.15 x10 3 x32

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$\pi \times 20^3$

113.5 N mm^2

As fb act <fb all

Shaft is safe under bending load

Selection of Bearing

Spindle bearing will be subjected to purely medium radial loads; hence we shall use ball bearings for our application.

Selecting; single Row deep groove ball bearing as follows;Series 62

Table No 3 Selection of Bearing

I S I No.	Bearing of Basic design No. (SKF)	D	D1	D	D2	B	Basic Capacity RPM	
20 BC02	6204	20	26	47	41	14	10000	6550

P = X F + Y F a

For our application F a = o

→ P = X F r

Where F r = 204.5 N

As ; F r < e → X = 1, → P = F r

Max radial load = F r = 204.5 N

→ P = 204.5 N

Calculation dynamic load capacity of bearing

L = (C) p where p =3 for ball bearingsP

When P for ball Bearing

For m/c used for eight hr of service per day;

L h = 12000- 20000 hr

But; L = 60 n L h ,

10L = 600 mrev

Now; 600 = $(C)^3$

$(204.5)^3$

→ C =1724.8 N

→ As the required dynamic capacity of bearing is less than the rated dynamic capacity of bearing;

→ Bearing is safe

IV. CONCLUSIONS

It is concluded that by using and experimenting MR fluids in the field of breaking system, it successfully reduced the weight ratio of existence breaking system and also reduce the heat generation rate of current braking systems.

Although the design criterions imposed challenging problems which, however were overcome by us due to availability of good reference books.The selection of choice raw materials helped us in machining of the various components to very close tolerance and thereby minimizing the level of wear and tear.

Needless to emphasis here that we had lift no stone unturned in our potential efforts during machining, fabrication and assembly work of the project model to our entire satisfaction.

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