

DESIGN OF MR FLUID BASE
BRAKE SYSTEM FOR MOTORCYCLE

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FOR MOTORCYCLE

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I/We admit that have read this report and in my/our opinion, this report is enough in
terms of scope and quality to bestowal Bachelor of Mechanical Engineering
(Automotive)

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DECLARATION

I hereby declare that this project report entitled

**DESIGN OF MR FLUID
BASE BRAKE SYSTEM FOR MOTORCYCLE**

Is written by me and is my own effort and that no part has been plagiarized without citations.

SIGNATURE:

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DATE: 7th April 2010

DEDICATION

Special appreciation dedicated to my parents, Mr. Mat Zain bin Hamid and Mrs. Mariam binti Ahamad for all their support throughout this semester. Also, thousands of thanks to my supervisor, Mr. Faizul Akmar Abdul Kadir for giving me support and motivation while implementing this project. All the support and encouragement given has become one of the roots for me in achieving my success.

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ABSTRAK

Sistem-sistem brek hidraulik konvensional (CHB) yang digunakan dalam industri automotif mempunyai beberapa batasan dan keburukan-keburukan seperti tindak balas membrek yang lambat, pelapik brek menjadi haus, keperluan untuk komponen-komponen tambahan (seperti pam hidraulik, paip pindah dan takungan bendalir brek) dan berat keseluruhan bertambah disebabkan komponen-komponen tambahan. Di dalam projek ini, perkembangan brek elektromekanik yang baru digunakan untuk aplikasi automotif. Brek seperti ini menggunakan komponen-komponen mekanikal dan komponen-komponen elektrik, supaya ianya lebih berkesan dan lebih cepat masa yang diambil untuk membrek. Brek electromagnet yang dicadangkan ialah *magnetorheological*(*MR*) brek. Brek *MR* ini mengandungi beberapa cakera yang berputar di dalam bendalir *MR* yang disertakan dengan satu electromagnet yang tertutup. Apabila dikenakan arus elektrik ke lilitan electromagnet, sebagai satu fungsi medan magnet yang digunakan oleh electromagnet bendalir *MR* mengeras seperti tegasan alahnya. Tegasan alah yang terkawal menghasilkan geseran ricih terhadap cakera-cakera yang berputar dan menghasilkan daya kilasan brek. Terdapat beberapa kelebihan menggunakan sistem brek *MR* ini seperti tindak balas membrek yang lebih cepat, pengawalan baru yang mudah dilaksanakan atau kawalan yang sedia ada seperti *ABS*, *VSC*, *EPB* dan sebagainya, kurang penyenggaraan selagi tiada bahan yang haus dan berat keseluruhan lebih ringan selagi ianya tidak memerlukan komponen-komponen tambahan yang digunakan di dalam sistem brek hidraulik konvensional. Rekebentuk terhadap brek *MR* bermula dengan analisis model brek *MR* yang dicadangkan. Brek *MR* direka dengan tumpuan terhadap konsep mengemudi basikal *BMX* pada bahagian brek hadapan dan brek belakang, tambahan kepilan cakera, keluasan permukaan yang terlibat, pilihan terhadap bendalir *MR* dan kekuatan aruhan elektrik yang digunakan.

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 project, 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 magnetorheological (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 design process was started with an analytical model of the proposed MRB. Then, the MRB was designed with a focus on concept of BMX bicycle steering front and rear system, additional disc attachment, working surface area, MR fluid selection and applied current. Disadvantage of MR brake is the brake torque of MR brake produced is not enough to generate the brake torque of motorcycle. Therefore, an improved MR brake will be designed with an increased number of discs and value of current applied and modified the outer and inner radius of disc.

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LIST OF SYMBOLS

τ	=	Shear Stress (Pa)
τ_y	=	Yield Stress (Pa)
$\tau_y(H)$	=	Dynamic yield stress (Pa)
λ	=	Dynamic Range
H	=	Magnetic Field Intensity
η	=	Newtonian Viscosity
$\frac{dv}{dz}$	=	Velocity gradient in the z-direction
ω	=	Angular velocity (rad/sec)
h	=	Fluid gap thickness
r	=	Radius of rotary disc (m)
T	=	Resistance torque (Nm)
R_o	=	Outer radius (m)
R_i	=	Inner Radius (m)
d	=	diameter for rotary disc (m)
W_m	=	Maximum work (Watt)
g	=	gap between casing and disc (mm)
L	=	Length (m)

V	=	Fluid volume (m^3)
S	=	Relative pole velocity
A	=	Shear (pole) area (m^2)
r_z	=	Outer radius of disc(m)
r_w	=	Inner radius of disc(m)
k	=	Constant parameter of magnetic field for MR fluid (Pa-m/A)
β	=	Constant parameter of yield stress for MR fluid
α	=	Proportional gain
i	=	Current (Amp)
n	=	Number of surfaces of brake disk in contact with MR fluid
$\eta\dot{\gamma}$	=	Shear strain rate with the η , the constant plastic viscosity which is considered equal to the no-field viscosity of the fluid
T_{mr} / T_b	=	Torque of MR brake or brake (Nm)
$\mu = f(s)$	=	Coefficient of friction in function of longitudinal slip
μ	=	Coefficient of friction
S	=	Longitudinal slip
α_w	=	Wheel angular acceleration (rad/sec^2)
I_w	=	Wheel moment of inertia (kgm^2)
T_w	=	Wheel torque (Nm)
T_b	=	Brake torque (Nm)
T_t	=	Tractive torque (Nm)

R	=	Tire radius (m)
M_v	=	Vehicle mass (kg)
a_v	=	Longitudinal acceleration (m/s^2)
V_w	=	Longitudinal wheel speed (m/s)
V_v	=	Longitudinal vehicle speed (m/s)
W_w	=	Wheel angular speed (rad/sec)
F_f	=	Road resistance (N)
T_μ	=	Viscous torque (Nm)
T_H	=	Torque generate due to applied field (Nm)

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CHAPTER 1

INTRODUCTION

1.1 Project background

The topic of ‘x-by-wire’ is focus to motorcycle industries due to its potential to improve automotive performance, safety and cost. The ‘x’ in x-by-wire is a technological wildcard for automotive systems such as steering and braking, and means replacing conventional mechanical components by electrical ones. The project is to develop brake-by-wire system using an electromechanical brake (EMB) that employs magnetorheological(MR) fluid.

A magnetorheological fluid (MR fluid) is a type of smart fluid. It is a suspension of micrometer-sized magnetic particles in a carrier fluid, usually a type of oil. In chemistry, a suspension is a heterogeneous fluid containing solid particles that are sufficiently large for sedimentation. Usually they must be larger than 1 micrometer. 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 of which 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.

MR fluids have attracted considerable interest in both academic and industrial fields. A variety of valuable outcomes have been used in various products, which

contribute tremendously to industry developments and to human daily lives. The most successful applications of MR devices are dampers or shock absorbers for vehicles and other applications requiring vibration control. For example, damper suspension equipment is used in a vehicle seat control system to compromise shock vibration control in response to the levels of shock and road vibration. Another innovative commercial application for an MR fluid is in the polishing of optical lenses. Compared to conventional polishing, MR fluid works as a compliant polishing lap, with which the shape and stiffness of the polisher can be magnetically manipulated and controlled in real time.

MR brake system	Hydraulic brake system
Low power requirement (several ampere)	High energy consumptions
Simple design and construction	Bulky design
Hydraulic free: no hydraulic line and need less space requirement	Problem with leakage in hydraulic line
No metal-with metal friction	Brake noise due to metal-with-metal friction
No brake pad needed	Brake pad need to be replaced periodically
Fast response (0.02second)	Response delay due to pressure build up
Easy to control (used for brake-by-wire system)	Require auxiliary components such as hydraulic pump, brake valve and fluid reservoir

Table 1.1: Comparison in between MR brake system and conventional hydraulic brake system

While, disc brake is a device for slowing or stopping the rotating wheel. A brake disc (or *rotor* in U.S. English), usually made of cast iron or ceramic composites (including carbon, kevlar and silica), is connected to the wheel and/or the axle. To stop the wheel, friction material in the form of brake pads (mounted on a device called a brake caliper) is forced mechanically, hydraulically, pneumatically or electromagnetically against both sides of the disc. Friction causes the disc and attached wheel to slow or stop.

There are many advantages of using pure electronically controlled brake systems. The properties and behavior of the brake will be easy to adapt by simply changing the parameters and electrical outputs instead of adjusting mechanical components. So, this project is actually study base on MR fluid brake system (brake by wire) which has the potential to improve the braking time required to stop the motorcycle with using only small amount of input current.

1.2 Objective

Design of MR fluid base brake module to be used on motorcycle

1.3 Problem statement

Brake-by-wire is state of the art brake design. Research done shows that MR fluid base brake system has the potential to improve braking time required to stop the vehicle with using only small amount of input current. The brake system is currently tested on rig and this study is intended to incorporate the brake to a motorcycle.

1.4 Scope

There is a few scope which need complied in undertaking the project this namely;

- Study MR brake system
- Design/suggest MR brake module for motorcycle
- Identify the size of motorcycle engine
- Identify how to improve the brake torque of motorcycle