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SIMULATION EVALUATION OF MAGNETORHEOLOGICAL BRAKE BASED ON ANTI-LOCK BRAKING SYSTEM

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This report was submitted in accordance

with the partial requirement for the honor of

Bachelor of Mechanical Engineering (Automotive)

Faculty of Mechanical Engineering

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APRIL 2010

CONFESSION

"I admit that this report is from my own work and ideas except for the certain parts in few sections which were extracted from other resources as being mention".

Signature:……………………

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Date: 7/04/2010

“for my lovely family mama, bapak, abang, amal and arash…’

ACKNOWLEDGEMNET

Firstly I would like to appreciate Dr.khisbullah hudha for guiding me and giving me the opportunity to take this topic. The support and encouragement are truly appreciated during the entire project.

The guidance from the masters student, Ahmad Zaifazlin and Fauzi Ahmad for helping me and teaching me during the completion of the project. The used of MATLAB software and finite element software were also being taught and guide by him.

Lastly for all my friends for helping me throughout the project and encourage me to finish it. My lecturer for the support, guidance and knowledge throughout this entire project and helping me complete this report.

ABSTRAK

Projek ini adalah berkenaan simulasi pada magnetorheological brake (MR brake) pada system braking dengan dilengkapkan menggunakkan anti-lock braking system (ABS) untuk mengawal kelajuan pada motosikal. Ciri-ciri yang terdapat pada MR fluid ini adalah ia akan berubah bentuk daripada cecair kepada pepejal. Apabila arus dialirkan, MR fluid berkenaan akan mengeras dan hasil daripada kekerasan ini menyebabkan geseran yang menghasilkan daya kilas yang boleh memperlahankan kenderaan. Di bawah pengaruh arus elektrik, unsur-unsur iron besi didalam MR fluid akan meghasilkan sesuatu ikatan sesame unsure yang menyebabkan kelikatan pada cecair berkenaan. MR brake boleh dierjemahkan menggunakan Bingham plastic persamaan dimana persamaan ini adakah hampir sama. Persamaan Bingham's, daya kilas, ABS dan dinamika motosikal akan dimasukkan ke dalam persisian MATLab simulink. Alat pengawal seperti PID dan if-then mengawal arus yang dilalukan dan juga mengekallan kelinciran yang dikehendaki. Hubung kait antara daya kilas dengan arus elektrik untuk MR brake boleh dikenal pasti. Keberkesanaan MR brake untuk digunakkan bersama ABS juga akan dibahaskan. Simulasi motorsikal yang dilengkapi dengan MR brake dan juga ABS akan ditentukan. Kesahihan model juga akan dibahaskan.

ABSTRACT

This project is to simulate the magnetorheological brake (MR brake) with braking system. MR brake is equipped with anti-lock braking system (ABS) to control the braking system of the motorcycle. The behavior of the MR fluid is that it will change from liquid to solid. When a current is applied to the electromagnet, the MR fluid solidifies as its yield stress various as a function of the magnetic field applied. This controllable yield stress produces shear friction on the rotating plate and disc break generating the brake torque. Under the influence of magnetic field, the iron particles form chains that highly increase the viscosity of the fluid. The MR brake is represented by the Bingham's plastic model where it is simple and good approximation of the MR brake itself. The equation of Bingham's, torque brake, ABS and motorcycle dynamic is inserted in MATLab simulink software. A PID type controller and if-then controller were used to control the current supplied and maintains the desired slip. The relationship between the torque-current of MR brake can be determined. The effectiveness of MR brake to be used with ABS is also discussed. The simulation of motorcycle with MR brake and ABS are also been determined. Model verification is shown and discussed.

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τ	= Total shear stress
τ_y	= Dynamic yield stress
η	= Fluid viscosity
ω	= Angular velocity of the rotating disc/plate
h	= Thickness of the MR fluid gap
r	= Position of disc surface
N	= Number of disc
r_z	= Outer radii
r_w	= Inner radii
H	= Magnetic field intensity
k	= Electric constant, m/A
β	= Constant
μ_p	= Plastic viscosity, Pa s
α	= Proportional gain, m^{-1}
T_H	= Yield stress induced by applied magnetic field
T_μ	= Friction and viscosity of MR fluid
ǿ	= Rotational speed of disc/plate
Π	= 22/7

T_b	= Torque brake
F_t	= Rolling resistance
F_f	= Friction force
F_n	= Normal force
F_L	= Transfer of weight
I	= Total moment of inertia, kgm^2
$\ddot{\theta}$	= Angular acceleration
R_w	= Radius of wheel, m
x	= Distance travel, m
I_w	= Wheel inertia, kgm^2
I_e	= Engine inertia, kgm^2
Ψ	= Gear ratio
I_y	= Inertia of brake disc, kgm^2
M_t	= Mass of motorcycle, kg
M_v	= Mass of wheel, kg
M	= Total mass, kg
K_v	= Conversion factor
f_r	= basic coefficient
f_o	= speed coefficient
l_{base}	= Wheel base
h_{cg}	= Height of center of gravity
μ_f	= Friction coefficient

S_r = Slip ratio

Fxr = Longitudinal force rear tire

Fxf = Longitudinal force front tire

μ_f = Friction coefficient front tire

μ_r = Friction coefficient rear tire

Fxt = Total reaction force

$\dot{V}$ = Forward velocity, m/s

g = gravitational acceleration,m/s^2

(θ) = angle of gradient

Fd = Aerodynamics drag

Fzf = Front normal force

Fzr = Rear normal force

C = Distance between center of gravity and rear wheel,m

L = Wheelbase,m

H = Height of center of gravity,m

m = mass of the motorcycle,Kg

B = Distance between center of gravity and front wheel,m

ρ = Density of air

A = Frontal area, m^2

Cd = Aerodynamic drag coefficient

Cr = Rolling resistance coefficient

Λf = Front tire wheel slip ratio

Λr	= Rear tire wheel slip ratio
$\dot{w}f$	= Front wheel acceleration
$\dot{w}r$	= Rear wheel acceleration
Rf	= Radius of front tire, m
Rr	= Radius of rear tire, m
τef	= Throttle torque front,Nm
τrf	= Reaction torque front, Nm
τbf	= Braking torque front, Nm
τdf	= Viscous friction torque front
τer	= Throttle torque rear, Nm
τrr	= Reaction torque rear, Nm
τbr	= Braking torque rear, Nm
τdr	= Viscous friction torque rear
Jf	= Wheel moment of inertia front, kgm^2
Jr	= Wheel moment of inertia rear,kgm^2

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

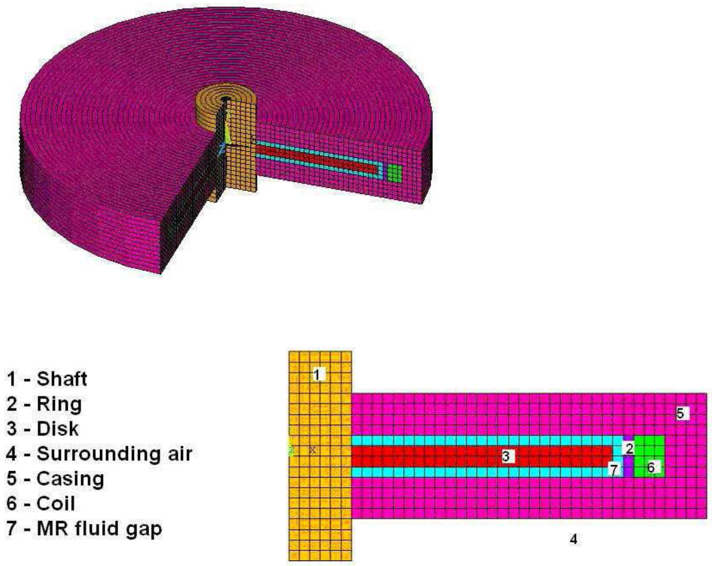

Figure 1.1: Cross section of MR brake

(Source: K.Karakoc, 2007)

In this paper, the prototype of brake-by-wire is being tested. The used of electromechanical brake (EMB) which is suitable for "brake-by-wire" application. The proposed brake is a magnetorheological brake (MR Brake) which has a potential over some conventional hydraulic brake system (CHB system). The CHB system has it disadvantages because it uses hydraulic fluid, transfer lines, brake pedal and brake actuators. This kind of system has been used in the automotive industry. The automotive industries are now committed to build a safer, cheaper and better performing vehicle in the near future.

The braking system makes the vehicle decelerate from the current speed to a standstill or to slow the vehicle. How the conventional braking system works on a vehicle is when the driver step on brake pedal it transfers the force from the pedal to the hydraulic fluid to the master pump and to the brake calipers or brake drum. The more forces applied to the brake pedal the more pressure given to the brake calipers or drum brake.

By using the “brake-by-wire” system because it electronically controlled is by running the current through to make the actuators trigger and make the vehicle to decelerate. Electronic braking makes the braking response much faster without any delay. The current technology allowed the vehicle to equip with electronic control system in case of emergency. The time for hydraulic will be pass down to a much faster, simpler and more effective electronic device aid.

The electronic device for this project controlled the viscosity of the magnetorheological fluid (MR fluid). The function of the MR fluid is to cause friction with the rotating steel plate and disc break. The shear friction cause by this movement will generate the braking torque. Brake torque is needed to stop or decelerate a moving vehicle. The rotation of the brake torque is the opposite direction of the wheel. For this project, a motorcycle will be used as it is simpler, easier and more manageable.

The placement of the MR fluid is in the rear hub of the motorcycle. Inside the hub contains the rotating steel plate, disc break and solenoid. The solenoid is placed inside the disc break to avoid contact with the MR fluid. There will be multiple disc breaks and three steel plates. The MR fluid filled the entire hub to create friction surface between the MR fluid, steel plate and disc break. For this project, the disc break is static and only the steel plate rotating. The steel plate is welded to the hub for easier to installed and checking.

The MR fluid is represented by the Bingham plastic model where it is good approximation of the fluid. The integration of the Bingham plastic model gave out the torque brake (T_b) equation and can be divided into two parts after integration to gave out T_H (torque generated due to the applied magnetic field) and T_μ (torque generated due to the viscosity of the fluid). From the design point of view, the parameter can be varied to increase the braking torque such as the no. of disc break and dimensions itself. By using MATLAB simulink software, all the equations involved to simulate the braking system is stored inside it. With this, it can simulate the real life situation of breaking the motorcycle. The result of this simulation is shown in a graph.

1.2 Problem Statement

The magnetorhoelogical fluid (MR fluid) is a “magic” fluid when a current is applied the MR fluid change its properties from liquid to semi-solid. The amount of current plays a major role in determining the level of solidifies needed from the MR fluid. The more current gives the harder the MR fluid the higher the braking torque produce. The control current is measure in ampere (A) and only certain amount of ampere needed to change the properties of the MR fluid. The mathematical equation of the motorcycle dynamic in longitudinal direction has to be determined. Motorcycle equations are needed for simulation of the braking system. The equation of the brake torque also required to achieve the highest brake torque. The effectiveness of MR brake for anti-lock braking system (ABS) has to be determine. From the simulation, the parameters can be varied to achieve the required result. With all the equation, the simulation has to be perfect by connecting the entire block on the simulink according to the equation.

1.3 Objective

- To show the torque-current relationships of magnetorheological brake (MR brake).
- To develop a vehicle model in longitudinal direction.
- To study the effectiveness of magnetorheological brake (MR brake) to be used for anti-lock braking system (ABS).

1.4 Scope

Simulation study of an anti-lock braking system (ABS) using magnetorhoelogical brake (MR brake) for motorcycle. The simulation is done by using MATLAB simulink software to study the effectiveness of MR brake to be used with ABS. The development of vehicle model in this case motorcycle model in longitudinal direction. To determined the relationship of braking torque and current.

1.5 Outline

Chapter 1

For this chapter is an introduction to the project. This chapter consists on the project background, problem statement, objectives and scope.

Chapter 2

This chapter 2 is a literature review. Inside this chapter consists of explanation about the magnetorheological brake (MR brake), mathematical model, and the control current and existing model.

Chapter 3