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MECHANISM DESIGN OF MR BRAKE FOR FORMULA VARSITY CAR

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"I declare this report is on my own work except for summary and quotes that I have mentioned its sources"

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To all that helped me:

Thank you very much

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ABSTRACT

Magnetorheological (MR) fluid is a smart fluid that can change its behavior in the presence of the magnetic field. This unique characteristic of the MR fluid make it suitable to use in automotive application such as braking system. This report presents the development of a new MR brake system to replace the current conventional hydraulic system on the Formula Varsity Car. The proposed brake system consist of multiple rotating disks immersed in a MR fluid and an enclosed electromagnet. When current is applied and magnetic field is created, the MR fluid solidifies as its yield stress varies as a function of the magnetic field applied. This controllable yield stress produces shear friction on the rotating disks, generating the braking torque.

In this project, practical design criteria such as material selection, working surface area, viscous torque generation, applied current density, and MR fluid selection are considered in order to design MR brake. Then, the multiple disks MR brake design will be analyzed using suitable software for it magnetic behavior. Simulation of vehicle in longitudinal direction will be built to observe the behavior of the MR brake while working.

ABSTRAK

Cairan ‘magnetorheological’ (MR) adalah cairan pintar yang mampu mengubah kelakuannya dengan kehadiran medan magnet. Perwatakan unik yang dimiliki oleh cairan MR ini membuatkan ia sesuai untuk digunakan di dalam aplikasi automotif seperti sistem brek. Kertas kerja ini mendedah tentang pembinaan sistem brek MR yang baru untuk menggantikan sistem brek hidraulik yang biasa di kereta Formula Varsity sekarang. Sistem brek cadangan mengandungi sebilangan cakera yang berputar yang ditenggelamkan di dalam cairan MR dan electromagnet yang tertutup. Apabila arus dibekalkan dan medan magnet dicipta, cairan MR mengeras sebagaimana hasil tekanan berbeza seperti fungsi medan magnet yang dibekalkan. Hasil tekanan yang boleh dikawal ini menghasilkan geresan merencat terhadap cakera-cakera yang berputar,menjanakan daya kilas membrek.

Dalam projek ini, kreteria merekabentuk yang praktikal seperti pilihan bahan, kawasan permukaan yang bekerja, penjanaan daya kilas kelikatan, ketumpatan arus yang dibekalkan dan pemilihan cairan MR adalah dalam pertimbangan untuk merekabentuk brek MR. Kemudian, brek MR cakera berganda yang direka akan dianalisiskn menggunakan perisian yang bersesuaian untuk kelakuan magnetiknya. Simulasi kenderaan dalan arah longitudinal akan dibina untuk memerhatikan perlakuan brek MR ketika berfungsi.

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SYMBOL	DESCRIPTION
A	Frontal area
B	Distance front axle from center of gravity
C	Distance rear axle from center of gravity
B_i	Pacejka model constant
C_i	Pacejka model constant
C_d	Aerodynamic drag coeffient
C_{fi}	Viscous friction coefficient
D	Pacejka model constant
E	Pacejka model constant
H	Distance center of gravity from ground
J_i	Polar moment of inertia
K	Electric constant
L	Wheel base
N	Number of contact surface
R_i	Wheel radius
μ_p	MR fluid viscosity
alpha	Propotional gain
T_H	Torque generated due to the viscosity of the fluid
T_μ	Torque generated due to the applied magnetic field
T_b	Total braking torque
F_d	Drag force
F_{X_i}	Force acting through the tyre
F_z	Tyre normal force
C_r	Rolling resistant coefficient
C_d	Aerodynamic drag coefficient
λ_i	wheel slip ratio
$\tau_{d\omega}$	Viscous friction torque
τ_r	Reaction torque due to tyre tractive force
τ_e	Torque delivered by engine
τ_{es}	Lag

μ_t	Throttle input
g	Gravity force
h	MR fluid gap
m	Vehicle mass
π	3.14
ρ	Air density
r_j	Rotated disk inner radius
r_z	Rotated disk outer radius
θ	Road gradient
η_f	Final gear ratio
η_1	1st gear ratio
η_2	2nd gear ratio
η_3	3rd gear ratio
η_4	4th gear ratio

NOMENCLATURE

ABS	Anti-lock braking system
ACC	Adaptive cruise control
CAD	Computer aided design
EPB	Electronic parking brake
kmph	Kilometers per hour
mph	Miles per hour
MR	Magnetorheological
UTeM	Universiti Teknikal Malaysia Melaka
VSC	Vehicle stability control

CHAPTER 1

INTRODUCTION

1.1. Background Study

Over the past few years, the topic of "x-by-wire" is a focus topic to automotive industry due to its potential to improve vehicle 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 with electrical components.

The magnetorheological brake (MRB) is the brake-by-wire technology. The MRB is a pure electronically controlled actuator and it has the potential to further reduce braking time as well as easier integration of existing and new advanced control features such as anti-lock braking system (ABS), vehicle stability control (VSC), electronic parking brake (EPB), adaptive cruise control (ACC), as well as on-board diagnostic features. With the MRB system, the brake components can be simplified by just doing wiring and automatically the weight can be reduces.

In performance vehicle such as racing car or sports car, reducing weight means that car can go faster without reducing the safety. Universiti Teknikal Malaysia Melaka (UTeM) also has its own racing car; Formula Varsity Car. This go-kart-like racing car is developed to compete in Inter-university Formula Varsity Racing. Other universities that had join this event have 1 or more this kind of car.

The aim of this project is to develop a MRB system that has performance advantages over conventional hydraulic brake system for UTeM's Formula Varsity

Car. The proposed brake system consists of rotating disks immersed in a MR fluid and enclosed in an electromagnet, which the yield stress of the fluid varies as a function of the magnetic field applied by the electromagnet. The controllable yield stress causes friction on the rotating disk surfaces, thus generating a retarding brake torque. The braking can be precisely controlled by changing the current applied to the electromagnet. This project also can be as a jumping stone to upgrade the formula varsity car.

1.2. Project Objective

1. To design multiple disks of MR brake for Formula Varsity Car.
2. To analyze the behavior of magnetic field in the MR brake.
3. To simulated the vehicle motion in the longitudinal direction for the vehicle performance.

1.3. Project Scope

The scope of this project is to change the UTeM's Formula Varsity Car brake system. The new system will be MR brake system. Exploration of MR brake mechanism and understand its working principle. MR brake will be design using manual sketching for concept design and CAD drawing for detail design. MR brake design will be analyzed for the magnetic behavior when current is applied. Then simulation of vehicle longitudinal dynamics will be built. In this simulation, the result of the vehicle performance will be observed.

1.4. Problem Statement

UTeM's Formula Varsity Car is currently using conventional hydraulic brake system. The system consist disk, caliper, hydraulic cables, brake fluid and reservoir. This conventional hydraulic brake system converts kinetic energy to thermal energy to provide the required braking torque in order to stop from moving or slow the vehicle down. There are some limitations and disadvantages about this system such as respond delay. Every delay happens in racing can cause losses the valuable time.

At the braking moment, the brake pads are squeezes onto rotating disk and producing braking torque results from the friction. The heat generated from the friction of the pad with the disk can decrease the friction capability of the brake pads compound. The brake pads can wear out due to friction. Brake pads are squeeze by hydraulic pressure in a hydraulic cable due to press on the brake pedal. If there is air bubble in the cable, it wills causing the drop the pressure on the brake fluid and makes the pads less friction with the disk. This might lead to an accident. Possibility of brake fluid leakage also can cause a fatal accident.

1.5. Outline Project

Chapter 1

In this chapter, the background study about MR brake project is concluded. Project objective, project scope and problem statement about current Formula Varsity Car braking system are also in this chapter.

Chapter 2

In this chapter, it shows literature review where the general information automotive braking system, magnetorheological fluid and magnetorheological brake is revealed.

Chapter 3

Chapter 3 is the methodology. The methods used for completing this project is discussed and elaborated. A flow chart will show the step taken doing this project. Every component in the flow chart will be elaborated in the subtopic.

Chapter 4

This chapter will be the result and discussion. The detail MR brake design will be present here. The simulation results such as vehicle velocity and braking time will be observed. The MR brake design also has the magnetic analysis the show the behavior of the magnetic flux in the MR brake.

Chapter 5

This chapter explains the entire chapter of the project. The objective of the project has been achieved or not. Then recommendations about this project for MR brake improvement for better result.

CHAPTER 2

2. LITERATURE REVIEW

2.1. Introduction

A brake is a device for applying a force against the friction of the road, slowing or stopping the motion of the vehicle. Brakes are fitted to the most wheeled vehicle such as cars, trucks, motorcycle and many more. Brakes were developed as early as the vehicle itself.

There are many types of brakes and for example is disk brake that is commonly used in automotive industry nowadays. Before the technology of the disk brake emerged, drum brakes were use as a brake system where the brake shoes pushed by cylinder toward the rotating drum.

Due to the respect for the environment, greater safety through integrated control systems and better performance, automotive industry worldwide actively researching and developing new technology for braking system. The 'Magnetorheological Braking System' is one of the new technologies for braking system. This braking-by-wire technology use Magnetorheological fluid, the fluid that change in viscosity when the present of the magnetic field.

2.2. History of Automotive Braking System

In 1902 at the road in New York City called Riverside drive, Ransom E. Olds had arranged to test a new brake system against the tire brake of a four-horse coach and the internal drum brake of a Victoria horseless carriage. His *Oldsmobile* sported a single flexible stainless-steel band, wrapped around a drum on the rear axle. When the brake pedal was applied, the band contracted to grip the drum. In the test, the Oldsmobile stopped in 21.5 ft. meanwhile its rival, Victoria that use expanding-shoe internal drum design and the coach's tire brake system, stopped in 37 ft. with the same speed of 14 mph. By 1903, most of other automotive manufacturer had adopted the car's braking system. And by 1904, practically all car maker manufactured cars with an external brake on each rear wheel and became all-dominant in the United State.

In Europe, during the '50s, particularly in Great Britain, the disk brake became more or less standard on the people cars. And only about 20 years, somewhere about year 1973, American car manufacturer adopted this kind of technology.

In 1902, a patent was issued to F. W. Lanchester for a nonelectric spot disk braking system that's similar in principle to what we have today but it use copper linings. Intense screech noise was produce when the linings make contact with the metal disk. By 1907, another Englishman named Herbert Frood, came up with the idea of lining pads with asbestos. With noise problem when braking is solved, car manufacturer quickly adapted this technology on both drum and disk brakes.

The application of hydraulic in braking emerged in 1918 from a young inventor named Malcolm Lougheed. This idea came because of the need of higher braking power due to fast driving behavior by community. He used cylinder and tubes to transmit fluid pressure against brake shoes, pushing the shoes against the drums. The Model A Duesenberg is the first passenger car to be equipped with four-wheel hydraulic brakes. Back in 1958, the new technology in braking system was developed by Road Research Laboratories in Great Britain called antiskid braking

system or as known as antilock braking system (ABS). The Jensen FF sports sedan was first applied with this ABS in 1966.

The braking technology still blooming and research are continuously made to achieve braking system that more reliable. Therefore, the braking-by-wire technology is now actively developed due to electric and hybrid cars that use electric power. After year 2010, there is probability that automotive industry in the world will start to change the usage of the conventional hydraulic brake system to brake-by-wire, according to research study by Frost & Sullivan. With brake-by-wire, drivers have advantage over the vehicle in controlling the vehicle particularly in case of sheer emergency.

2.3. Formula Varsity Car

In August 2008, Universiti Teknikal Malaysia Melaka (UTeM) became 1st runner up in the Formula Varsity Racing Competition that was hosted by UTeM itself. This competition was participated by Politeknik Shah Alam, Politeknik Kota Bharu, Nottingham University (Malaysia Branch) and Universiti Putra Malaysia. Car designed by Politeknik Shah Alam became the champion in that event. This event becomes popular among Malaysia Higher Education Institution. In July 25th , Universiti Industry Selangor (UNISEL) became champion in Formula Varsity Race 2009 that been held at Litar Dato' Sagor, Pasir Salak, Perak with their car named V-1.