AN INVESTIGATION OF MOTORCYCLE DISC BRAKE ROTOR USING FINITE ELEMENT METHOD

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"I hereby to declare that the work is my own except for summaries and quotations which have been duly acknowledge"

Signature : ………………………………….

Author : KAMAL RUZUAN BIN MAT HUSSIN

Date : OCTOBER 8TH 2009

DEDICATION

To him who is our source of grace, our source of commitment, and our source of knowledge,
And,
To her, whose love is a source of joy.

ACKNOWLEDGMENT

First of all I thank god for the blessing upon me to finish up this report. I would like to express my gratitude and appreciation to my supervisor, Mr. Ridzuan b. Mansor for his valuable suggestion and advice throughout this project.

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ABSTRACT

This project will study briefly to investigate current motorcycle disc brake rotor model in term of thermal performance. This project covers the determination of disc brake rotor performance in terms of heat transfer during brake fade test for motorcycle. So, for thermal analysis, the approach of finite element method is used to study the effect of heats to geometric dimension of rotor. By using ABAQUS CAE V6.7.1, the temperature distribution on rotor surface is calculated. From that point, the effect of disc coning is observed from the result of thermal deflection.

ABSTRAK

Projek ini akan melakukan kajian secara terperinci terhadap rekaan terbaru terkini brek cakera motosikal. Walaubagaimanapun projek ini hanya akan merangkumi kajian terhadap prestasi cakera dari segi pemindahan tenaga haba untuk ujian kegagalan brek motorsikal. Terdapat beberapa pendekatan yang digunakan untuk mengenalpasti asas pemindahan haba yang mempengaruhi struktur bahan cakera. Pendekatan elemen terhingga digunakan di dalam kajian ini menggunakan program analisis elemen terhingga (FEA) iaitu perisian ABAQUS CAE V6.7.1. Suhu pada permukaan cakera brek diperoleh daripada analisis pemindahan haba dan melaluinya kesan bengkok yang diakibatkan oleh haba dikaji.

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WT	=	Weight transfer to front axle (N)
m_{total}	=	Total mass of motorcycle (kg)
a	=	Deceleration of motorcycle (ms^{-2})
CGH	=	Center of gravity's height of motorcycle (m)
WB	=	Wheelbase of motorcycle (m)
m_{moto}	=	Mass of motorcycle (kg)
W_{moto}	=	Weight of motorcycle (N)
W_{total}	=	Total weight of motorcycle (N)
$\% WT$	=	The percentage of weight transfer to front axle
KE	=	Kinetics energy of motorcycle (J)
u	=	Speed of motorcycle (ms^{-1})
t_{brake}	=	Time taken for braking process (s)
P_{brake}	=	Total braking power for motorcycle (W)
$P_{brakefront}$	=	Braking power at front axle (W)
A_{brake}	=	Total brake surface area on rotor (m^2)
Re	=	Reynold's number
ω_{rotor}	=	Rotational speed of rotor (rad s^{-1})
r_{outer}	=	Outer radius of brake rotor (m)
v_{air}	=	Kinematics viscosity of air (m^2 s^{-1})
Nu	=	Nusselt's number
h	=	Convective heat transfer coefficient (Wm^{-1} $^{\circ}C^{1}$)
k_{air}	=	Thermal conductivity of air (Wm^{-1} $^{\circ}C^{-1}$)
D_{outer}	=	Outer diameter of brake rotor (m)
Pr	=	Prandtl's number
ρ_{air}	=	Air's density (kgm^{-3})

u_{avg}	=	Average speed of motorcycle (ms^{-1})
μ_{air}	=	Dynamics viscosity of air ($kgm^{-1} s^{-1}$)
d_h	=	Diameter of cross-drilled holes on rotor braking surface (m)
l	=	Depth of cross-drilled holes (m)

LIST OF APPENDIX

CHAPTER 1

INTRODUCTION

1.1 Introduction

The invention of vehicle is basically to fulfill the human need's to travel from one place to another. Based on that point vehicle must move for a certain distance which means that there will be start and stop point. When moving, vehicle is characterized by speed and acceleration at particular position or for overall measure. Because of movement, vehicle complies with kinematics and dynamics of motion. Dynamics of motion describes every moving object has magnitude and direction of unit vectors relative to the body. Actually, driver has fully access to the motion of vehicle by regulating this magnitude, direction or both components. For example when vehicle about to reach bend of the road, the driver first will slow down and take the corner; means magnitude of velocity vector is reduced and then their direction is changed to negotiate the corner. By acting this way the vehicle can be kept moving on track and as a safety figure he does so. Performance of vehicle relies on several elements; motive power that propels vehicle and its load, steering system, suspension system, braking system and so on. So, for propelling the vehicle many kinds of thrust system were and have been used. The current power of a vehicle comes from internal combustion engine which converts chemical energy of hydrocarbon fuel into thermally expansion gas energy due to combustion of air fuel mixture inside confined cylinder chamber in engine. Later, that beneficial energy delivered by mechanical linkage to the wheels thus making vehicle moves. However, propulsion system along is incomplete without handling instrument such as steering system and braking system. Because the travel courses are not always straight and vehicle need to be maneuvered properly to prevent from going off the track. Braking system is not only provides the means to slowing down and stop a vehicle. It also ensures stationary position of vehicle can be maintained especially when standing on steep road. In spite of brake system is as crucial as it concerns to safety of passengers onboard, malfunction of even one component should be avoided as it tends to defect overall braking operation. Catastrophic disaster can be prevented from happening if precautions are taken. The counter measures like servicing critical components regularly and make sure that those components used are genuine part whose approved its quality thus reduce chance of brake fail.

1.2 Overview of Disc Brake System

The purpose of braking system can be simplified into three objectives. First, to make the vehicle stop at certain instance when desired or to avoid collision. Second, to keep the vehicle sped at controllable velocity especially when downhill. And last one is to keep the stationary vehicle stand still under acceptable condition such as on low grade. Brake system operates by actuating the force from muscle through mechanical, electrical, hydraulic or combination of two or more media transmit the power to end components. Friction brakes do the job by converting kinetic energy of moving vehicle into frictional heat energy due to forced contact between rotating drum or brake disc with fixed pads or brake shoes. Substantial portion of heat generated during braking will be absorbed by rotating part (brake drum or rotor), and the remaining will be dissipated to ambient.

Whole brake system can be broken into several discrete systems. The first system which located close to operator is the apply system. This system consists of levers, pedals or mechanical linkage that introduces the muscle force from either hand or foot and activates a brake force. The second system is boost system, worked by providing the operator with supplementary power to assist braking force. In other way, boost system multiply the brake pedal force. This is available only on weighty vehicle. The third one is hydraulic system; the system supplies braking force alternatively connects a system to other. Function of this system is to direct the braking force induced by the pressure of confined fluid through tubes and hoses to wheel brakes. The last system in braking structure which links by brake fluid is wheel brake cylinder or brake calliper. This component actuate as the braking force applied to pedal thus manipulate frictional part (brake pad or brake shoe) to press against rotating drum or rotor.

Generally the foundation of brake system can be short listed to several components. The combination of two or more components forms small subsystems which integrate together working as overall brake system. Brake system is distinguished by the two common things; disc brake and drum brake. Disc brake simply consists of disc brake rotor, brake pad and brake calliper. While drum brake contains pan-like drum, brake shoe and brake wheel cylinder.

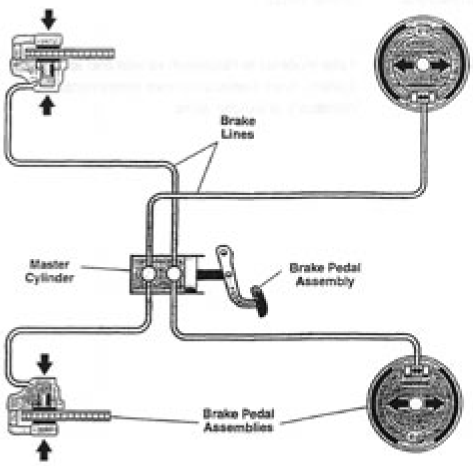

Figure 1.1: Simple diagram of braking system (source: courses.gmtraining.com)

Braking process begins when the driver pushed brake pedal. Normally, the brake pedal is arranged in second class lever to produce reaction force in same direction as applied force. In the arrangement, the magnitude of reaction force also can be multiplied to achieve necessary braking load. Later, force from lever will be transfer to pushrod directly connecting to piston of brake master cylinder. As long as the pushrod is pressed piston will move along. The contraction of volume in the brake master cylinder by the piston movement will develop pressure in brake fluid thus transmit braking force through fluid medium. Finally, fluid pressure will reach the brake caliper and actuate caliper piston inside. By attaching brake pad to the caliper piston, pressure will act the brake pad against rotating disc brake rotor and clamping both sides of disc brake rotor's swept areas. As the pad linings touch rotor surface, frictional drag gradually increase to slow down the rotational speed of rotor thus decrease vehicle's speed. In the end of braking operation driver will release brake pedal, hence the pressure inside brake hydraulic lines will relax. Here the self-adjustment regulates the position of brake pad back into release state by compensating slight wear of pad lining and the retraction of piston seal holding down caliper's piston.

1.3 History of Disc Brake Rotor

The history of disc brake rotor was begun in 1890's, as it firstly introduced by Frederick William Lanchester in England. He patented the early design of disc brake in his Birmingham factory in 1902. For the next half of the century the design of disc brake got nowhere until 1949 when it emerged on Crosley Hotshot. However, a year later product encountered problem regarding to their design. Between 1949 and 1953, Chrysler's company had implemented kind of disc brake into their Imperial model. The design combined double internal expanding, fully-circle pressure plate that represents nowadays brake pad. In short while, the evolution of disc brake system had became breakthrough component when Dunlop developed new generation of disc brake and the system was mounted to Jaguar C-Type racing car. The wave of disc brake technology then reached European continent as continental vehicle manufacturer aggressively started equipped their new vehicle model with disc brake. After several year of achieving the trust from vehicle manufacturer, the disc brake type has been evolved for the better.

1.4 Rotor

In friction brake, the rotor serves by implementing braking mechanism of contact friction between two surfaces. So, the requirement of platform for contact interaction idealizes a structure called disc brake rotor. A simple construction of rotor has frictional surfaces and centre section. Solid rotor can be identified by the solid plane of frictional surface, sometimes with cross-drilled holes on it.

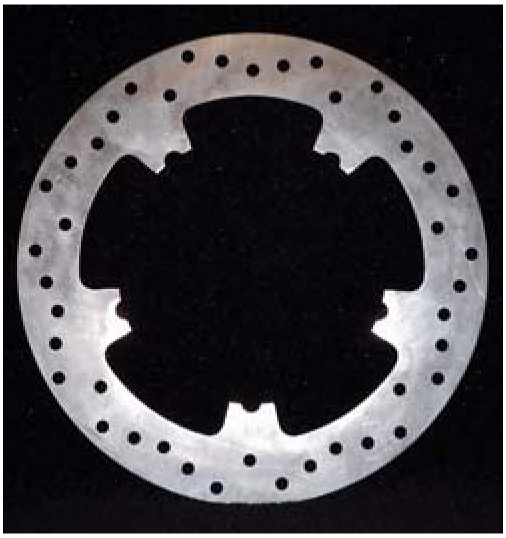

Figure 1.2: Solid rotor (Source: www.ebcbrakes.com)

Another design called ventilated rotor differs by additional ventilation vanes located at centre between inboard and outboard sides of rotor.

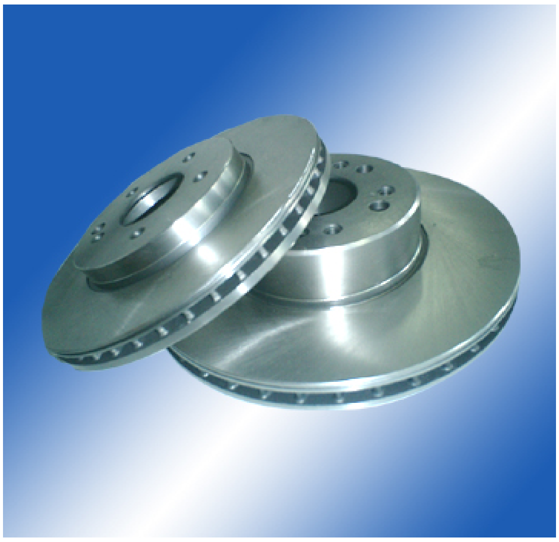

Figure 1.3: Ventilated rotor (source: www.bestyre.com)