APPROVAL

"I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in term of scope and quality for the award of degree of Bachelor Mechanical Engineering (Automotive)"

Signature : ....

Supervisor's Name : ....HILMI..........

Date : ......12/05/08............

DISC BRAKE PERFORMANCE: FEA

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fulfillment of the requirements for the award of the
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DECLARATION

"I hereby declared that this thesis is result of my own research except as cited in the references"

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Date : 13 - 05 - 2008

DEDICATION

Special dedicate to my beloved parent, family, supervisor, friends and all that me to finish my thesis.

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ABSTRAK

Brek cakera atau rotor menyediakan permukaan membrek atau dikenali sebagai permukaan geseran bagi brek pad untuk mengosok padanya apabila brek dikenakan. Fungsi utama brek cakera adalah untuk memindahkan daya mekanikal dan menyebarkan tenaga haba yang dihasilkan akibat geseran semasa membrek dan keadaan suhu tinggi. Haba yang terlalu tinggi disebabkan oleh suhu tinggi semasa membrek akan menyebabkan 'brake fade', kehausan brek cakera, pengewapan cecair brek, kegagalan galas, brek cakera retak dan getaran akibat panas pada sistem brek cakera. Tujuan utama projek ini adalah untuk menentukan kontur suhu dan sifat tegasan brek cakera pada 'DTDP ventilated disc brake' dengan menggunakan perisian analisis unsur terhingga (FEA). Dalam projek ini, perisian analisis unsur terhingga MSC Nastran Patran 2005 digunakan untuk menganalisis suhu dan sifat tegasan pada brek cakera dalam tempoh masa membrek yang tertentu. 'Ventilated disc brake' model yang sedia ada akan dimodelkan dalam perisian CATIA V5R10 dan diimport kedalam perisian MSC Nastran Patran untuk kegunaan menganalisis. Sebelum memulakan kerja-kerja analisis, parameter penting seperti tenaga haba yang dikenakan pada permukaan membrek, pemalar bagi pemindahan haba perolakan pada permukaan membrek dan lubang pengudaraan akan ditentukan dengan kaedah matematik. Keputusan-keputusan kontur suhu, sudut anjakan yang disebabkan olen pengembangan brek cakera akibat panas akan dikaji pada akhir simulasi proses. Keputusan daripada analisis ini menunjukkan keberkesanan lubang pengudaraan pada brek cakera dalam kapasiti penyejukan jika dibandingkan dengan brek cakera biasa.

ABSTRACT

The disc or rotor provides braking surface or friction surface for brake pads to rub against when braking is applied. The main function of brake rotor disc is for transmission of mechanical force and dissipation of heat produced implies to be functioning at both medium and high temperature. The excessive heat cause by high temperatures during braking may causes brake fade, premature wear, brake fluid vaporization, bearing failure, thermal cracks and thermally-excited vibration on disc brake systems. This project aims to determine the DTDP ventilated disc brake transient temperature and examine the disc thermal stress behaviour by using finite element analysis (FEA) software. In this project, the FEA software MSC NASTRAN 2005 is used to analyse the temperature and thermal stress behaviour of the disc under some periodic braking operation. An existing ventilated disc brake rotor model is then created in CATIA V5R10 program and is exported into MSC NASTRAN for analytical purposes. Before starting the analysis, an important parameter such as heat flux applied on the braking surface and convective heat transfer coefficient for braking surface and vane hole of disc is calculated via mathematical calculation. The results of temperature contours, coning angle cause by thermal expansion of disc are analyzed at the end of the simulation process. The result of analysis indicates that the vent holes show effectiveness for cooling capacity if compared to solid disc brake.

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NOMENCLATURES

CAD	=	Computer-Aided Design
DTDP	=	Diamond and Tear Drop Pillars
DTV	=	Disc Thickness Variation
FEA	=	Finite Element Analysis
FEM	=	Finite Element Method
SRV	=	Straight Radial Vane
SRV-R	=	Straight Radial Vane with Rounded vane

LIST OF SYMBOLS

a	=	Deceleration, m/s^2
d_h	=	Rotor Passage Hydraulic Diameter, m
h_R	=	Convection Coefficient, W/m^2k
k_a	=	Air Thermal Conductivity, W/mk
L	=	Braking Work/ Energy
l	=	Cooling Vane Length, m
m	=	Vehicle Mass, kg
N_{disc}	=	Disc Rotational Speed, rpm
P_r	=	Prandtl Number = 0.72
Q	=	Heat Transfer, W
q	=	Thermal Flow, J/s
$q_{specific}$	=	Heat Flux, W/m^2
R_D	=	Disc Outer Radius, m
Re	=	Reynolds Number
$R_{i\text{-}hub}$	=	Disc Inner Radius of Rubbing Surface, m
r_{tyre}	=	Tyre Radius, m
s	=	Second
S_{flux}	=	Braking Surface, m^2
S_{in}	=	Chords Length, m
μ_a	=	Air Absolute Viscosity at $30^0c = 1.86 \times 10^{-5}$ Ns/m^2
V	=	Vehicle Velocity, m/s
v	=	Air Kinematic Viscocity at $30^0c = 1.60 \times 10^{-5}$ m^2/s

ω_{tyre}	=	Vehicle Angular Velocity, s^{-1}
ΔE	=	Kinetic Energy, J
Δt	=	Braking time, s
Δx	=	Stopping Distance, m

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CHAPTER 1.0

INTRODUCTION

1.1 Disc Brake Overview

The disc brake is a device for slowing or stopping the rotation of a wheel and to keep it from starting to move again. Disc brakes are widely used for reducing velocity for their characteristics of braking stability, controllability and the ability to provide a wide-ranging brake torque. Typical passenger vehicle, disc brake assembly consists of several major components namely disc or rotor, brake pad or friction material and caliper as shown in Figure 1.1. The disc or rotor is a flat round disc and usually made of cast iron or ceramic is attached to the wheel hub. Brake pad is positioned on opposite sides of the disc which is mounted on the brake caliper. Currently, there are two types of calipers which is fixed and floating or sliding caliper. Once the brake is applied, the brake pads are pushed by the hydraulic piston and squeezed against the disc surface and generates a friction force between the disc and pads in order to slow down or stop the vehicle (Owen, 2004).

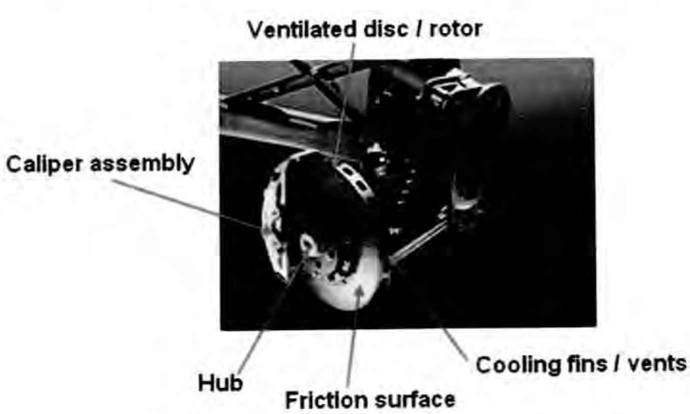

Figure 1.1: Disc Brake Component (Source: Adapted from Howstuffworks "How the Mercedes SLR Works")

1.2 Introduction

An automotive brake is utilized to convert kinetic energy of motion into thermal energy through the friction between stationary brake pads and a rotating surface. Commonly this is done by the using a cast iron rotating brakes disc or rotor with stationary friction surfaces mounted in a caliper. The brake discs or rotors may be a solid discs or ventilated disc with two disc separated by a vane air flow passage. In bringing a vehicle to stop, the brake rotor must be able to store a significant amount of thermal energy since braking occurs in a relatively short period of time. Subsequently, the brake rotor must then dissipate the stored thermal energy quickly in order to be ready for the next application of the brake or friction contact. The ventilated brake rotors using an internal air passages for increase the level of forced convection and indirectly improve the rate of heat transfer. Cooling air is to be conveyed by the vanes enters the channels on the hub side at the inner circumference of the brake ring and exits at the outer circumference. The convective heat transfer coefficient of a vented disk brake rotor is approximately twice that of a solid disk (Limpert, 1972).

Most of the heat energy (99%) is dissipated through brake disc during the braking process. This major heat energy diffuses through conduction within the disc and through the hub and is dissipated by convection and radiation from the outer surface of disc and hub flanges. The temperature within the disc is transient in nature and is difficult to log correctly and fastly through convection method (Hwang *et al.* 2007).

The frictional heat generated on the interface of the rotor and the pad during braking can cause high temperature at the rotor surface which may deteriorate the material properties of the pad and causing the brake fade phenomena. The high temperature gradient at the surface may cause an excessive thermal stresses and causing in the surface crack after a long period of usage. Besides that, the uneven distribution of the temperature near the intersection of the hat and the rotor will result in thermal distortion of the frictional surface, which is know as coning and found to be a main cause of judder (Limpert, 1972). Therefore it is important to predict the temperature rise and thermal deflection in the early design stage and for modification and improvement stage.

1.3 Problem Statement

Braking performance of a vehicle can be significantly affected by the temperature rise in the brake components. There are two main problem of disc brake which is related to the thermal, and is classified as excessive heat and severe thermal distortion. The excessive heat cause by high temperatures during braking may causes brake fade, premature wear, brake fluid vaporization, bearing failure, thermal cracks and thermally-excited vibration on disc brake system (Valvano and Lee 2000). For instance, the severe thermal distortion of a rotor can affect the important characteristics of brake such as reduce the system response and brake judder propensity. The above problems occur is mainly cause by the lacks of information about disc brake passenger vehicle performance and this is indirectly makes the disc brake designers fail to improve the existing disc construction.

1.4 Objective

- To determine the ventilated disc brake transient temperature contour and thermal stress behavior using FEA software (MSC NASTRAN PATRAN).
- By understanding the temperature transient behavior and contour of disc brake, it will become very helpful information for disc brake designer to improve the current disc brake problem and avoid disc brake from warp due to the excessive heat.

1.5 Scope

- The disc brake or rotor used in this analysis is DTDP passenger car ventilated disc brake.
- The brake periodic operation of braking sequence for total 320 seconds.

1.6 Organization of Report

The report is divided into several chapter/sections, corresponding to the following consideration. In Chapter 1, the introduction of project, problem statement, objective and scope of project is discussed. The complete temperature analysis is presented in Chapter 2, which states the literature of previous researches, types of discs or rotors, disc rotor properties and others.

The methodology to conduct this project is discussed in Chapter 3 whereby the method, modeling and mathematical calculations and simulations are presented. While in Chapter 4, the results of findings and discussions of results are presented. A brief summary and concluding remarks with recommendations are presented in Chapter 5.

CHAPTER 2.0

LITERATURE REVIEW

2.1 Introduction

The first patented model of disc brake was registered by Frederick William Lanchester in 1902. He described that a disc brake consists of a sheet of metal connected to one of the rear wheels of vehicle which is pinched at the wheel edge in order to slow down the vehicle. His invention leads towards the early sport type brake system design in the early 1950s which can be traced as development by Dunlop and the disc brake appeared in 1953 on the Jaguar C-Type racing car (Limpert, 1999). The sport-type design of disc brake is similar to the present type of disc brake which it can be found on any vehicle. However the materials used and actuation method used in the early period have been modified and improved.

Disc brakes offer better stopping performance than comparable drum brakes, including the resistance to "brake fade" caused by the overheating of brake components. Unlike a drum brake, the disc brake has no self-servo effect and the braking force is always proportional to the pressure placed on the braking pedal or lever. The most important contribution toward the widespread used of disc brake is due to the safety regulation throughout the world.

Disc brakes were most popular on sports cars when they were first introduced, since these vehicles are more demanding on brake performance. Discs brake now have become the more common form in most passenger vehicles, although drum brakes are many use on the rear wheels to keep costs and weight down as well as to simplify the provisions for a parking brake.