THERMAL ANALYSIS OF LIGHWEIGHT CLUTCH DISC

MOHD ZUHAIR BIN ZULKARNAIN

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SUPERVISOR DECLARATION

"I admit that had read this thesis and in my opinion this thesis was satisfied from the aspect of scope and quality for the purpose to be awarded Bachelor of Mechanical Engineering (Automotive)"

Signature : ....

Name of Supervisor : FUDHAIL BIN ABDUL MUNIR

Date : 22-06-12

DECLARATION

"I verify that this report is my own work except for the citation and quotation that the source has been clarified for each one of them"

Signature : ....
Name of Author : MOHD ZUHAIR ZULKARNAIN
Date : 22 JUN 2012

To my father, Zulkarnain B Hj A. Bakar, my mother, Rozimah Bte Hj Mohd Yusof, my siblings, my friends and my supervisor, Encik Fudhail bin Abdul Munir, for supporting me throughout this project and for their understanding in the way I am

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ABSTRACT

Clutch system is among the main systems inside a vehicle. Clutch is a mechanical device located between a vehicle engine and its transmission and provides mechanical coupling between the engine and transmission input shaft. Clutch system comprise of flywheel, clutch disc and friction material, pressure plate, clutch cover, diaphragm spring and the linkage necessary to operate the clutch. The clutch engages the transmission gradually by allowing a certain amount of slippage between the flywheel and the transmission input shaft. However, the slipping mechanism of the clutch generates heat energy due to friction between the clutch disc and the flywheel. At high sliding velocity, excessive frictional heat is generated which lead to high temperature rise at clutch disc surface, and this causes thermo-mechanical problem such as thermal deformations and thermo-elastic instability which can lead to thermal cracking, wear and other mode of failure of the clutch disc component. In this project, the thermal characteristic of the lightweight clutch disc is studied using FE analysis method to identify the temperature distribution at the clutch disc in steady state phase. The thermal analysis is done using ANSYS finite element software. The results provide better understanding of the clutch disc thermal characteristics and helps in developing more efficient and effective clutch disc and the clutch system in general.

ABSTRAK

Sistem pencengkam adalah antara sistem yang penting di dalam sesebuah kenderaan. Pencengkam adalah peranti mekanikal yang terletak diantara enjin kenderaan dan transmisi dan membolehkan gandingan mekanikal antara enjin dan aci input transmisi. Sistem pencengkam terdiri daripada roda tenaga, cakera pencengkam dan bahan geseran, plat tekanan, penutup pencengkam, spring diafragma dan penyambungan yang sesuai untuk pencengkam itu beroperasi. Pencengkam bergabung dengan transmisi secara perlahana-lahan dengan membenarkan sedikit pergelinciran antara roda tenaga dan aci input transmisi. Walau bagaimanapun, mekanisma pergelinciran cakera pencengkam menghasilkan haba disebabkan geseran antara cakera pencengkam dan roda tenaga. Pada kelajuan yang tinggi, haba yang berlebihan terhasil dimana ia akan meningkatkan suhu pada permukaan cakera pencengkam, dan menyebabkan masalah termo-mekanikal seperti perubahan haba dan termo-elastik yang membawa kepada keretakan haba, haus dan masalah lain yang boleh timbul. Dalam projek ini, ciri-ciri termo cakera pencengkam dipelajari menggunakan analisis FE untuk mengenalpasti rata haba pada cakera pencengkam ketika fasa kukuh. Analisis termo dilakukan menggunakan perisian ANSYS. Hasilnya akan menyediakan pemahaman yang lebih terhadap ciri-ciri termo cakera pencengkam dan membantu dalam menghasilkan cakera pencengkam yang lebih efisyen dan efektif seterusnya di dalam sistem pencengkam itu sendiri.

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CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

A clutch is a mechanical device for quickly and easily connecting or disconnecting a pair of rotating coaxial shafts. It is usually placed between the driving motor and the input shaft to a machine, permitting the engine to be started in an unloaded stage. Single plate, dry clutch is among the popular type of clutches in use (Lee and Cho 2006). Mechanical clutches fall into two main categories which is positive engagement and progressive engagement (Garret et al. 2001).

1.2 OBJECTIVE

The objectives of this project are:

1. To study the thermal capacity of the clutch disc.
2. To determine the temperature distribution on the clutch countermate disc in steady state and transient condition.

1.3 SCOPE

The scopes of this proposed project are:

1. To generate 3-dimensional geometry model of the commercial clutch disc component.
2. To perform steady state thermal analysis on the model to determine the temperature distribution of the component under steady state component using ANSYS.
3. To compare thermal analysis between carbon-carbon composite and commercial (gray cast iron) material of clutch disc.

1.4 PROBLEM STATEMENT

Clutch failure and damage due to excessive frictional heat and heat fluctuations to the clutch countermate disc often happens to any type of automotive clutches. This situation contribute to thermal fatigue to the component which cause the clutch countermate disc to crack and deform. This later will create problems such as clutch slip, clutch drag or failure of clutch to disengage properly and clutch rattling as well as shortening the lifecycle of the component.

CHAPTER 2

LITERATURE REVIEW

2.1 HISTORY OF CLUTCH DEVELOPMENT

In 1885, it was reported that when Karl Friedrich Benz has invented the first commercial gas powered automobile, the famous Trip-Cycle, he also was the first person to invent and use the clutch system to the car .Exedy Corp., one of the major players for clutch technology, which manufactured clutches under the brand name of Exedy and Daikin, with the plate and spline hub secured by rivets (Daikin Clutch, 2011). Until now, clutch manufactures has come out with new and efficient technologies for clutch system to compensate higher torque produced by bigger engine created especially for heavy vehicles.

2.2 AUTOMOTIVE CLUTCH MECHANISM

Automotive clutches are located between the engine and the tranmission. It provides mechanical coupling between the engine and transmission input shaft. Manual tranmission cars need a clutch to enable engaging and disengaging the transmission. The clutch engages the transmission gradually by allowing a certain amount of slippage between the flywheel and the transmission input shaft (Erjavcc 2005). Clutch basically consists of six major parts: flywheel, clutch disc, pressure plate, diaphragm spring, clutch cover and the linkage necessary to operate the clutch (Lee and Cho 2006).

The flywheel and the pressure plate are the drive components of the clutch. The flywheel is connected to the engine crankshaft, while the clutch disc and the pressure plate are connected to the transmission input shaft. When a clutch is disengaged (clutch pedal release), the flywheel rotates independently as according to the engine rotation, and the engine (clutch pedal pressed), the pressure plate moves towards the flywheel and pushed the clutch disc towards the flywheel, causing both components rotating together at same speed and connecting the engine to the transmission shaft. This mechanism enables gear shifting and engine idling when the car stopped.

Component	Description
Flywheel	The flywheel is normally made from nodular or grey cast iron, which has a high graphite content to lubricate the clutch when is engaged. The rear surface of the flywheel is a friction surface and machined very flat to ensure smooth clutch engagement. The flywheel absorbed the torsional vibration cause by the crankshaft,

	and provides inertia to rotate the crankshaft.
Clutch Disc	The clutch disc receives the rotating motion from the flywheel and transfer the motion to the transmission input shaft. **A** clutch disc comprise of grey cast iron countermate disc, friction facing, and cushioning springs. The friction facing is the main component in contact with the flywheel, and provides the required friction force to maintain that contact. It is either riveted or bonded to the disc. The cushioning spring, or torsional springs, cause the contact pressure of the facings to rise gradually as the springs flatten out when the clutch is engage. It also eliminates chatter during engagement and avoiding the flywheel and pressure plate sticking to the clutch disc when disengaging the clutch.
Pressure Plate	Pressure plate acts to push the clutch disc onto the flywheel with sufficient force to transmit engine torque efficiently and move away from the clutch disc to stop rotating it. There are two type of pressure plate assembly, either using coil springs or diaphragm spring. Both types are usually have stamped steel cover and bolted to the flywheel, and also act as a housing holding the parts together. The assembly differs in the mechanism of pushing and drawing

	back the pressure plate from the clutch disc.
Clutch Release Bearing	The clutch release bearing or throw-out bearing is a sealed and prelubricated ball bearing. It smoothly and quietly moves the pressure plate release levers or diaphragm spring when the clutch is engage and disengage. The release bearing is mounted on a hub made from iron casting that slides on a hollow shaft at the front of the transmission housing.
Clutch Fork	The clutch fork function is to move the release bearing and hub back and forth during clutch engagement and disengagement. It is a forked lever that pivots on a ball stud at the opening in the bell housing. The fork end connects the clutch linkage and clutch pedal.
Clutch Linkage	Clutch linkage connects the clutch pedal to the clutch fork. It enables drivers to control the engage and disengage operation of a clutch system smoothly with minimum force. There are four types of clutch linkage available, which is the cable linkage, self adjusting clutch linkage, hydraulic clutch linkage and internal slave cylinders.

Table 1: Main components of a clutch disc (Erjavec, 2005)

2.3 CLUTCH DISC DESCRIPTION

The clutch countermate disc used in this project is a part of a diaphragm spring dry clutch dry disc system, which is normally used in commercial passenger vehicles. The clutch countermate disc is located between the clutch friction facing and the clutch cushioning plate. The clutch cushioning spring is a plate where is acts to absorb the vibration effect during clutch engagement as well as linking the clutch countermate disc and the clutch disc base together. In the overall clutch disc assembly, rivets and pins are normally used to attach all the components together. The clutch countermate disc functions as the base to firmly hold the clutch friction facing. A basic construction of the overall clutch disc assembly is shown in figure 1 below.

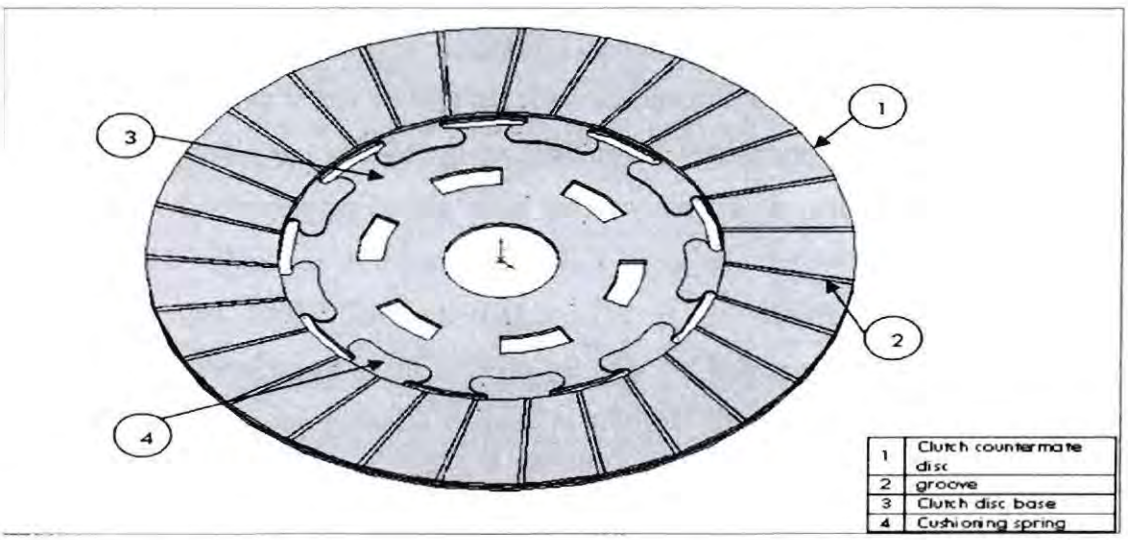

Figure 1: basic clutch disc assembly (Ridzuan Mansor, 2007)

2.4 THEORY OF HEAT TRANSFER

Heat transfer is the study of thermal energy transfer rate between material bodies as a result of temperature difference. There are three types of heat transfer method, which are through conduction, convection and radiation. A rough explanation of each heat transfer mode is stated below.

2.4.1 Conduction

Conduction is the transfer of thermal energy through a solid or fluid due to a temperature gradient (Huebner et al. 2001). The transfer of thermal energy occurs at the molecular and atomic levels without net mass motion of the material. Conduction takes place in solid, liquid and gases. In gases and liquids, conduction is due to collisions and diffusion of the molecules during their random motion. In solids, it it due to the combination of vibrations of the molecules in a lattice and the energy transport by free electrons (Cengel, 2003). Conduction also called as the transfer of energy from the more energetic particles of a substance to the adjacent less energetic one as a result of interactions between the particles (Yunus A. Cengel, 2011). This process can happen during solid, liquid or gases condition.

The rate equation describing conduction heat transfer mode is Fourier's law. For isotropic medium Fourier's law is (Huebner et al. 2001)

$$q = - k\frac{\partial T}{\partial n}$$

where q is the rate of heat flow per unit area in the ***n*** direction, k is the thermal conductivity that may be a function of the temperature T, and *n* indicates a normal direction. The minus sign appears because positive thermal energy transfer occurs from a warmer to a colder region; that is, the temperature gradient $\partial T/\partial n$ is negative in the direction of positive heat flow. Similarly, the Fourier's law for conduction can be simplified as (Cengel, 2003)

$$q_{cond} = kA\frac{T1-T2}{\Delta x} = -kA\frac{\Delta T}{\Delta x}$$

where ***A*** is the area, ΔT is the temperature difference and Δx is the thickness/length difference.

2.4.2 Convection

Convection is mode of energy transfer between a solid surface and the adjacent liquid or gas that is in the motion, and it involves the combined effects of conduction of fluid motion (Yunus A. Cengel, 2011). In other words, convection is the transfer of thermal energy through a fluid due to motion of the fluid and the energy transfer from one fluid particle to another occurs by conduction, but thermal energy is transported by the motion of the fluid. The transfer energy is called forced convection when the fluid motion is caused by external mechanical means. When the fluid motion is caused by density differences in fluid (buoyant effects), it is called free or natural. Several characteristic of non-dimensional convective of heat transfer such as Reynolds number, Prandtl number and Nusselt number.