THERMAL STRESS ANALYSIS ON DISC BRAKE ROTOR FOR NGV VEHICLE BY USING FINITE ELEMENT ANALYSIS (ANSYS)

MUHAMMAD SYAFIQ B ABDUL MUNIR

A report submitted

in fulfillment of the requirements for the degree of

Bachelor of Mechanical Engineering (Plant & Maintenance)

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2017

DECLARATION

I declare that this project entitled "Thermal Stress Analysis On Disc Brake Rotor For NGV Vehicle By Using Finite Element Analysis (ANSYS)" is the result of my own work except as cited as reference

Signature : .....

Name : MUHAMMAD SYAFIQ BIN ABDUL MUNIR

Date : .....

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Plant & Maintenance).

Signature :.....

Name of Supervisor :.....

Date :.....

ABSTRACT

In modern vehicle, braking system is one of the most important systems in order to prevent accidents. Braking system is used to slow or stop the vehicle. When braking, the friction between pads and disc rotor will generate heat and will result on temperature rise. The rise in temperature usually will contribute to disc brake problem such as thermal crack and brake fade. Therefore, controlling the thermal stress of disc brake is a must in order to prevent these problems. This research will focused on thermal stress analysis on gray cast iron disc brake rotor for NGV vehicle for steady state and transient condition. The gray cast iron disc brake for NGV vehicle is designed and modeled by using SolidWorks. Heat flux and convectional heat transfer coefficient was calculated to determine the temperature distribution of disc brake. Thermal stress of disc brake was predicted by using finite element analysis technique in ANSYS and the effect of NGV to thermal stress distribution of disc brake rotor was analyzed to determine whether the disc brake is safe to use. As a result, the highest temperature distribution recorded for NGV vehicle gray cast iron disc brake is still below the maximum service temperature of gray cast iron disc brake and the value of equivalent (von-Mises) stress also below maximum tensile strength.

ABSTRAK

Di dalam kenderaan, sistem brek merupakan salah satu sistem yang paling penting untuk mengelakkan kemalangan. Sistem brek digunakan untuk melambatkan atau menghentikan kenderaan. Apabila brek ditekan, geseran antara pad dan rotor akan menjana haba dan akan mengakibatkan kenaikan suhu. Kenaikan suhu biasanya akan menyumbang kepada masalah cakera brek seperti retakan haba dan brek pudar. Oleh itu, mengawal tekanan haba brek cakera adalah satu keperluan untuk mengelakkan masalah ini. Kajian ini akan memberi tumpuan kepada analisa tekanan haba pada cakera brek besi tuang kelabu untuk kenderaan NGV dalam keadaan statik dan mengikut masa. Cakera brek besi tuang kelabu untuk kenderaan NGV telah direka dan dimodelkan menggunakan SolidWorks. Fluks haba dan pekali pemindahan haba telah dikira untuk menentukan taburan suhu cakera brek. Tekanan haba brek cakera di jangka dengan menggunakan teknik analisa unsur terhingga dalam ANSYS dan kesan-kesan NGV terhadap agihan tekanan haba cakera brek rotor telah dianalisa untuk menentukan sama ada brek cakera selamat untuk digunakan. Sebagai hasil kajian, haba agihan maksimum yang direkodkan oleh kenderaan NGV brek cakera tuangan kelabu masih di bawah suhu servis maksimum brek cakera besi tuangan kelabu dan nilai setara (von-Mises) tekanan juga di bawah kekuatan tegangan maksimum.

ACKNOWLEDGEMENT

First and foremost, the author would like to take this opportunity to praise to ALLAH for the blessing that allow the author to finish this research. The author also wishes to express his sincere acknowledgement to DR. MOHD ZAID AKOP for his supervision, encouragement and support towards completion of this research. Author also would like to thank to the members of BMCL students whom are willingly to share the knowledge, experience and also not forgotten, the amount of encouragement that had been given to me to complete this research. Also, author would like thank my loved one, which is my family, who have supporting me throughout the entire research. Last but not least, author wants to thank to everyone who had been to the crucial parts of realization this project.

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LIST OF ABBEREVATIONS & SYMBOLS

NGV	Natural Gas Vehicle
FEA	Finite Element Analysis
CFD	Computational Fluid Dynamic
CNG	Compressed Natural Gas
LNG	Liquefied Natural Gas
Q	Rate of Heat Transfer
h	Convection Heat Transfer Coefficiant
As	Surface Area of Rotor
Ts	Surface Temperature
$T\infty$	Ambient Temperature
ε	Emissivity
σ	Stefan Boltzmann's Constant
[K]	Heat Conduction Matrix
{u}	Vector of Unknown Temperature
[R]	Radiation Exchange Matrix
{P}	Vector of Constant Applied of Heat Flow
{N}	Vector of Temperature Dependent Heat Flow
K	Kelvin
$\{\dot{u}\}$	du/dt
MPa	Mega Pascal
°C	Degree Celsius

CHAPTER 1

INTRODUCTION

1.1 Background of Research

The brake disc rotor is the rotating part of a disc brake assembly normally located on the front axle which is one of the most important part in NGV vehicles. The function of the disc brake is to slow or stop the rotation of wheel. To stop the wheel, the brake pad mounted on brake caliper is forced mechanically or pneumatically against both part of the disc. The friction between the brake pad and disc rotor of the NGV vehicle will create heat flux generation that will effect brake performance because the heat is mainly be absorbed by rotor and brake pad. Due to the generation of frictional heat on the interface of the brake pad and disc rotor, there is rise in temperature. The rise in temperature must be effectively dissipated through convection, conduction and radiation to improve braking performance. It is because, when this temperature exceeds the critical value, it leads to catastrophic events such as brake fail, failure of bearing, premature wear, thermal crack or vaporisation of brake fluid. The rate of heat generate during the braking process are depends on the certain criteria such as vehicle mass, velocity and rate of deceleration. Since this research is about a NGV vehicle, the mass of vehicle might be different from the actual vehicle mass and the rate of heat generation also will differ. In this research, finite element analysis using ANSYS will be used to predict the thermal distribution inside the rotor in steady and transient condition.

1.2 Problem Statement

This project concerns about thermal stress on disc brake rotor of a NGV vehicle. Most of the vehicles today have disc brake rotors that are made of cast iron and stainless steel. Both are chosen for its relatively high thermal conductivity, high thermal diffusivity and low cost. But, the disc brake rotor is designed to suit a regular vehicle. Are a NGV vehicle that has much higher mass than a regular vehicle suitable or safe to use the same disc brake as regular vehicles? In this project, analysis on the thermal issues of a NGV vehicle on disc brake rotor are to be done, and to determine the temperature behaviour of the disc brake rotor due to severe braking condition by using Finite Element Analysis (FEA) and effect of NGV in thermal stress distribution to disc brake rotor. Braking performance of a NGV vehicle can be significantly affected by the temperature rise in the brake components as the disc brake of a NGV vehicle require more power for disc brake to stop compared to a regular vehicle. High temperature during braking will caused to: Brake fade, thermal judder, Brake fluid vaporization, Bearing failure, Thermal cracks, Thermally-excited vibration. Therefore, it is important to study and predict the temperature rise of a disc brake rotor of a NGV vehicle and assess its thermal performance in the early design stage. Finite element analysis (FEA) has been preferred and chosen method to analyse the in thermal stress distribution to disc brake rotor during braking operation and compare it with regular vehicles.

1.3 Objective

This research is focus on thermal stress analysis on brake disc rotor during solid state condition and transient condition and to show temperature distribution of disk brake on NGV vehicle. The main objectives of this study are:

1. To study thermal stress distribution in disc brake rotor on NGV vehicle caused by temperature distribution during braking operation
2. To analyze the effect of NGV in thermal stress distribution to disc brake rotor during severe braking operation and compare it with regular vehicles

1.4 Scope Of Project

The scopes of this project are:

1. Literature review on working principle, components and theories
2. Design of 2D and 3D model of disc brake rotor
3. FE model (Meshing of geometry model)
4. Finite element analysis(ANSYS) on steady state and transient state
5. Justification of thermal stress analysis on disc brake rotor for NGV vehicle

1.5 General Methodology

The actions that need to be carried out to achieve the objectives in this project are listed below.

1. Literature review

   Journals, articles, or any materials regarding the project will be reviewed.

2. Calculation

   The calculation related to load analysis and heat transfer.

4. Simulation

   Simulation of disc brake rotor on steady state and transient state for NGV vehicle.

5. Analysis and discussion

   Analysis will be presented on how the thermal stress distribution to disc brake rotor during braking operation. Thermal stress of disc brake will be discuss based on the analysis.

6. Report writing

   A report on this study will be written at the end of the project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction to Braking System

In a vehicle, one of the most important systems is the braking system. Braking system is used to control the speed of a moving vehicle. During braking process, braking system enable vehicle to stop within a distance. Thus, it provides safety to the passenger during emergency as it prevent vehicle to collide. To ensure the safety of vehicle, the braking system must be efficient in term of braking performance and proper heat dissipation. Braking performance involve the necessary braking torque to be applied to the wheel while heat dissipation involve dissipation of heat at brake components due to the friction between brake pads and rotor.

In this research, disc brake system is being used to analyse the temperature distribution of disc rotor. The temperature of disc brake rotor will increase as the heat generated due to the friction is high. The increasing temperature of disc rotor usually is depends on mass of the vehicle, duration of braking event and rate of retardation. This increasing temperature need to be reduced to ensure the brake efficiency is at it best.

2.2 History of braking system

In the 19th century, the first mechanisms in automotive industry to slow a vehicles momentum and prevent motion were designed and tested. Today, over 200 years later, the design of braking system has evolved into a complex device to adapt to different working conditions. From the simple design such as wooden block brake to modern day discs, braking system has improved safety and reduced the risk of car crashes worldwide. With so many types of brakes that have existed over the century, it is hard to pinpoint the inventor of the original brake system. However, those who are designed these braking systems had a common goal which is to control the speed of vehicle and to stop it. With the goal of creating safer conditions, the designers have come up with new technologies to the braking system and improve the original idea. In all new developments of braking system, the number one priority is to improve efficiency and safety of vehicles. Since the earliest type of automobiles, several methods of braking have been used such as drum. As the vehicle is keep improving, the braking systems also improve in order to catch up with the modern vehicles. There are a few type of braking system that has been used over the years as:

- Wooden block brake - The earliest braking system that applied the physical principles to design brakes today. However, this system consisted of only wooden blocks and a single lever used by the driver to apply the brake. This form was used on vehicles with steel-rimmed wheels, including horse-drawn vehicles and steam-driven automobiles.

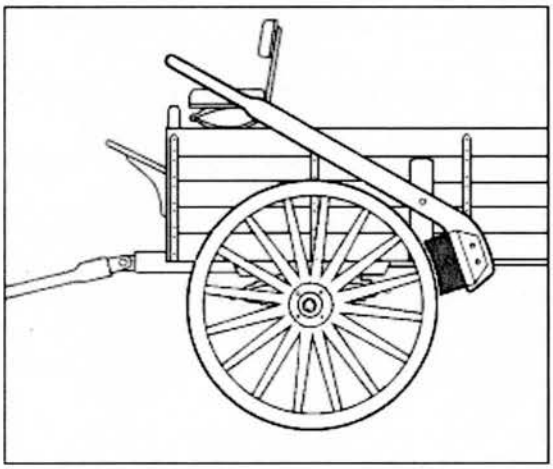

Figure 2.1 Wooden block brake (Source: www.dbrake.com)

- Mechanical drum brakes – This brake is considered to be the foundation of the modern braking system. The mechanical drum brake was first developed in 1902 by French manufacturer Louis Renault, but it had been invented earlier by Gottlieb Daimler. Daimler had theorized that anchoring a cable-wrapped drum to the vehicles chassis could be used to stop momentum, thus creating the first concept of the drum brake.

Figure 2.2 Mechanical drum brakes (Source: Knott Brake)

- Expanding internal shoe brakes - Before the expanding internal shoe brake was invented, all the braking systems had been fastened outside of the vehicle. Those systems were vulnerable to the environment such as collecting dust and water, and being affected by surrounding temperature. All of it made the brake less effective. The internal shoe brake was the first brake to be fixed inside the vehicles frame. Thus, it is an important innovation in the history of braking systems.

- Hydraulic brakes - In 1918, Malcolm Loughead proposed the concept of a four-wheel brake system using hydraulics. This system used fluids to transfer force to the brake shoe when pedal was pressed. This braking system then was adopted in majority of vehicle by the late 1920's.

- Disc brakes - This disc brake system was invented long before it become popular. The design of disc brake was patented by Frederick William Lanchester at Birmingham factory in 1902. The system was not really popular until the automotive industry began to boom in the mid-20th century. The rise of disc brakes popularity is due to the increasing weight and speed capabilities of vehicles, which caused hydraulic brakes to become less efficient in distributing heat. The heat produced when braking is dissipated directly from the surface of disc and it is more efficient than hydraulic drum brake. The first system to use disc brakes integrated both disc and hydraulic functions and was introduced in the Chrysler Imperial. Later, in the modern vehicle, most of the braking system is using disc brake.

2.3 Disc Brake

2.3.1 Introduction

Brake disc is an important component in vehicle system. A brake disc consists of a disc component bolted to the wheel hub and a stationary housing called caliper. The caliper is used to press the pads against a disc. This caliper is located at some stationary part of the vehicle like the axle casing or the stub axle as is cast in two parts each part containing a piston. In between each piston and the disc, there is a brake pad held in position by retaining pins, spring plates. As the brake is applied, pressurised hydraulic pressed fluid is constrained in the chamber pushing the contradicting cylinders and the caliper will squeezes the pad against the disc rotor. The sandwiched disc brake will results in friction. That friction slows the rotation of a shaft to hold it stationary or slow its rotational speed. Also, the friction between brake pad and disc rotor will produce kinetic energy and potential energy and it is transferred into heat which is mainly absorbed by rotor and brake pad. Due to the generation of frictional heat on the interface of the brake pad and disc rotor, there is rise in temperature. The rise of the temperature can affect the braking performance and increase brake fade. Thus, good heat dissipation is needed in order to overcome this problem.