UNIVERSITI TEKNIKAL MALAYSIA MELAKA

PREDICTIVE TOOLS FOR THE FV RACING CAR DISC BRAKE SQUEAL

This report is submitted in accordance with the requirement of Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Mechanical Engineering Technology (Automotive) with Honours

by

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2015

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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TAJUK: **PREDICTIVE TOOLS FOR THE FV RACING CAR DISC BRAKE SQUEAL**

SESI PENGAJIAN: **2015 / 2016 SEMESTER 1**

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Engineering Technology (Automotive Technology) (Hons.). The member of the supervisory is as follow:

…….

(Project Supervisor)

ABSTRACT

Brake squeal is widely accepted by scientists and engineers as a noise which is caused by friction-induced vibrations and it frequently occurs at frequency above 1 kHz. It is one of the most difficult problems and is a big issue in the automobile industry. In recent years, squeal noise prediction methodologies using finite element analysis (FEA) have widely been investigated. Extensive research effort has been undertaken on understanding of brake squeal generation. This thesis is concerned with the FEA on FV racing car disc brake rotor. The goal is to predict squeal noise at early stage of design development using modal analysis method. Firstly, the FE model of the disc brake was developed using a ABAQUS. Type of mode shape and natural frequency that leads to classification brake squeal generation is discussed.

ABSTRAK

Brek pekik diterima secara meluas oleh ahli sains dan jurutera sebagai bunyi yang disebabkan oleh getaran dan geseran dan ia kerap berlaku pada frekuensi melebihi 1kHz. Ia merupakan salah satu masalah yang paling sukar dan merupakan isu besar dalam industry pasaran kereta. Usaha kajian menyeluruh telah dijalankan untuk menyiasat kejadian brek pekik. Kertas kerja ini adalah berkenaan dengan "FEA" dan ujian yang dijalankan terhadap cakera brek kereta lumba FV. Matlamatnya adalah untuk mengkaji ramalan bunyi pekik pada peringkat awal menggunakan model FE. Permulaannya, "FE model" dibentuk menggunakan ABAQUS. Jenis bentuk mod dan frekuensi semulajadi yang membawa kepada terjadinya brek pekik dikenalpasti dan dibincangkan.

DEDICATIONS

To my beloved parents

ACKNOWLEDGMENTS

I express my gratitude to my supervisor and co-supervisor Dr Muhammad Zahir Bin Hassan and Madam Najiyah Safwa Binti Khashi`ie for their time, efforts, and invaluable contributions to my academic growth during my time at the Universiti Teknikal Malaysia Melaka (UTeM).I also thanks to every members of the Universiti Teknikal Malaysia Melaka (UTeM) for their invaluable support.

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LIST OF SYMBOLS AND ABBREVIATIONS

FEA	=	*Finite Element Analysis*
FE	=	*Finite Element*
EMA	=	*Experimental Modal Analysis*
Hz	=	*Hertz*
Al	=	*Aluminium*
SiC	=	*Silicon Carbide*
FRF	=	*Frequency Response function*
CES	=	*Cambridge Element Selector*

CHAPTER 1
INTRODUCTION

1.0 Overview

Disc-style brakes development and use start at England in the 1890's which is the first ever automobile disc brakes were patented by Lanchester, 1890 (Gladwell and Vijay, 1975). It was patented at Birmingham factory in 1902, though it took another half century for the innovation to be widely adopted. The first designs resembling modern-style disc brakes began to appear in Britain in the late 1940 and early 1950. The first appeared on the low-volume Crosley Hotshot in 1949, although it had to be discontinued in 1950 due to design problems. Modern-style disc brakes offered much greater stopping performance than comparable drum brakes, including much greater resistance to "brake fade" which is caused by the overheating of brake components. Meanwhile, from the late 1990 to present, North American automotive industry accelerated the pace on brake research and application to catch up with Japanese quality performance. It has been more tailored towards American vehicle brake designs which often have more challenges to balance between brake performance and quality. Disc brakes were most popular on sports cars when they were first introduced, since these vehicles are more demanding about brake performance. Discs have now become the more common form in most passenger vehicles.

From theoretical point of view, the disc brake squeal noise can be classified as friction due to the vibration. Understanding of this this problem is very complicated by the fact that the system is only temporary phenomenon. The brake disc rotor which acting like a speaker is a moving component and the assembly brake component is the combination of many components of brake parts.

The brake squeal noise needed to be eliminate because the problem cause discomfort towards the vehicle occupant as well as surrounding. Continuity from the problem may cause the car manufacturer loses its future because of the customer

dissatisfaction on the quality of noise produced from the brake (Crolla and lang, 1991). Customer might file a warranty claim despite that the brake disc is still functioning very well.

Modal analysis is one of the methods used by many researchers to understand the brake squeal phenomenon. Modal analysis work will represent the mode shape and natural frequencies of the brake disc.

There are three general categories of noise associated with automotive disc brakes. These categories are classified according to the frequency range in which the noise occurs. Low frequency disc brake noise typically occurs in the frequency range between 100 and 1000 Hz (Kinkaid et al., 2003). The noise types in this category are known as grunt, groan, grind and moan (Papinniemi et al., 2002). These are caused by friction material excitation at the brake rotor and lining interface where the energy is transmitted as a vibration within the wheel corner which couples with other chassis components (Dunlap et al., 1999). For the frequency bandwidth 1000 Hz to 5 kHz, the noise generated is classified as low frequency squeal (Dunlap et al., 1999). High frequency squeal is classified as squeal occurring above 5 kHz (Crolla and Lang, 1991). Squeal noise is produced by friction induced excitation, causing coupled resonance between the rotor and other brake components (North, 1972).

1.1 Problem statement

This project is about to investigate the brake squeal phenomenon using finite element analysis (FEA). By understanding the vibration characteristics and mode classification of the solid disc brake type, it will be a useful tool to assist brake disc designers for necessary modifications of existing disc brake structure to enhanced brake disc behaviour to avoid brake squeal.

The FEA software is used to analyse the behaviour of the brake disc rotor. Modal properties, natural frequencies and mode shape of disc rotor can be obtained through FE model prediction using ABAQUS. From existing geometry of FV racing car brake disc rotor, The 3D model is also can be created using ABAQUS software. The study on five different types of material properties is carried out to shows the effect

of vibration mode and natural frequency as the cause of brake squeal happened. The second part of this project is to classify the frequencies obtained from free – free modal analysis into three categories low frequency brake noise, high frequency brake squeal, and low frequency brake squeal.

1.2 Aim and Objective of Research

1.2.1 Aim

The overall aim of this research is to investigate the brake squeal phenomenon at early stage prediction that happened since the past decades. To achieve the mentioned objectives, a Formula Varsity disc brake rotor will be used in this project to be carried out modeling simulation. Selection of disc brake materials based on its properties will be used to investigate in order to determine the effect of vibration that causing the brake squeal. Finite Element Analysis approach will be performed to identify the squeal noise problem. This will verify on how the brake squeal phenomenon occurs.

1.2.2 Objective

Based on the problem statement, the objectives have been drawn:

I. To study on brake squeal phenomenon on five different types of material.
II. To analyse the effect of vibration in term of brake disc rotor behaviour.
III. To classify the natural frequencies in 3 different categories.

1.3 Scope and Limitation of The Project

The scope and limitation of the present project are as follows:

I. Undertaking a study on material properties that include the following item ; grey cast iron BS Grade 220, grey cast iron BS Grade 100, steel, aluminium silicon carbide (Al-SiC), carbon ceramic that causing squeal.

II. Analyzing the vibration pattern using free- free modal analysis

III. Classification of frequency and vibration pattern in 3 different categories.

CHAPTER 2
LITERATURE REVIEW

This chapter presents the studies and research paper related to this project. The literature review was a process continues until the end of this project. Regarding the research and study, some knowledge and information from the paper that can be use and apply to complete this project was conduct carefully. The sources for literature review are from thesis, journal, reference books and source from internet.

2.0 Introduction

Subject brake squeal has generated a large amount of literature that has been told in a number of theories have been formulated to explain the mechanisms of brake squeal. Studies on the disc brake squeal involves two major areas of study: interaction of disc-pad and vibration caused by friction.

In this chapter, automotive disc brake system has been introduced to provide an overview of the disc brake components and their functions. Automotive brake noise has been categorized by frequency range in which they occur. A review of the literature brake squeal is then presented which explains the phenomenon of disc brake squeal. The results of scientific studies are categorized into theory, finite element (FE) and experimental approach to conducting and analyzing the problem of brake squeal. In the section FE, studies of natural frequencies and mode shapes of deformation of shape of rotor disc, which is characteristic of the brake squeal study are presented. Natural frequencies and mode shapes of the disc rotor are depending on the model geometry and material properties. The next section discusses the experimental investigations that have been used to identify the noise problem. Finally, a summary of existing approaches is provided along with them had to deal with issues of real brake noise. The structure of the chapter is shown in **Figure 2.1**.

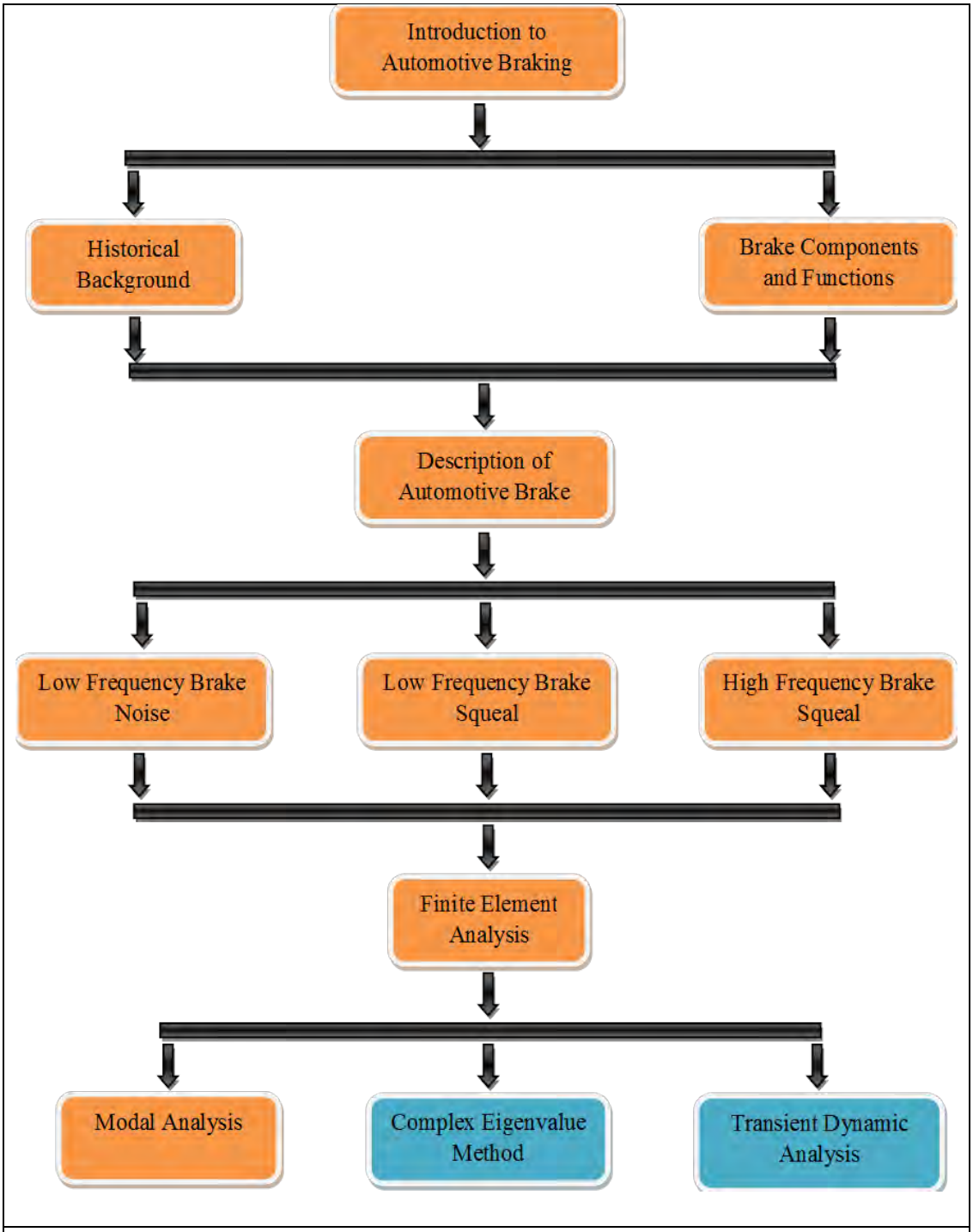

Figure 2.1: Overview of Literature Review

2.1 Automotive Disc Brake System

2.1.1 Historical Background

Elmer Ambrose Sperry has been leading the development of this type of clutch disc brakes in 1898, as quoted in Hughes (1971). The design features the electromagnetic disc brake actuated by the brake torque generated when the magnetic disc is pressed into contact with other disc known as a disc brake.

The first model of the brake discs has been registered by Frederick William Lanchester in 1902 (Newcomb and Spurr, 1967). A sheet metal rotor that connected to the rear wheels of the vehicle is pinched in order to slow down the vehicles. This invention comes before the sports car design disc brake system in the early 1950s that traces its developments to Dunlop, Girling and Lockheed Corporation (Newcomb and Spurr, 1967). The design of sports-type brake disc are similar with the type of disc brakes available on most road vehicles (Harper, 1998). The biggest problem faced by Lanchester is the noise that occurs when metal on metal contact between the layers of copper and metal disc causing the screech that sends chills through anyone within earshot. Since then, the materials and actuation methods used in earlier invention of brake has been modified and improved.

Rules and regulations that have enhanced security around the world about the widespread use of disc brake. The safety regulations have contributed most important in the automotive industry. for example, the Federal Motor Vehicle Safety Standards (FMVSS) 105 regulations have set all cars must be equipped with front disc brake to require all cars to meet the standard stopping distance and brake fade requirements (Oppenheimer, 1977). This is because the brake disc can meet the specifications of the brake power with superior water resistance and fading performance compared to drum brakes.

2.1.2 Brake Components and Functions

Disc brake system consists of a disc brake rotor, two brake pads and a calliper (SAE International, 2007). The combination of these components allows the rotating wheel to experience hard braking in the shortest stopping distance. Braking surface is an area where braking action of the friction material happened (Limpert, 1999).

Figure 2.2 shows the components of the disc brake system used on passenger vehicles. Central part of the disc brake has a circular gap, which locates in the wheel hub (SAE International, 2007). It is surrounded by some of the holes to bolt the wheel. The rotor rotates along with the wheel. Normal load will produced when the brake is pressed, results of friction force happened at the interface of dics-pad. This in turn produces a braking torque on the wheel as shown in **Figure 2.3**. The reaction of brake force will slows the vehicle.

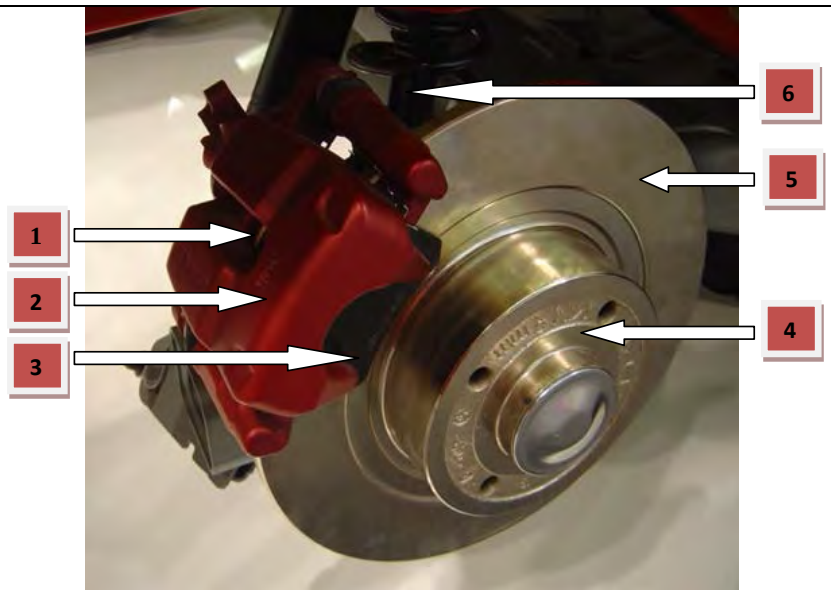

Figure 2.2: Brake System Components: 1) Piston 2) Calliper 3) Pad 4) Brake Disc Retainer 5) Rotor Disc 6) Wheel Hub (Talati and Jalalifar, 2009)

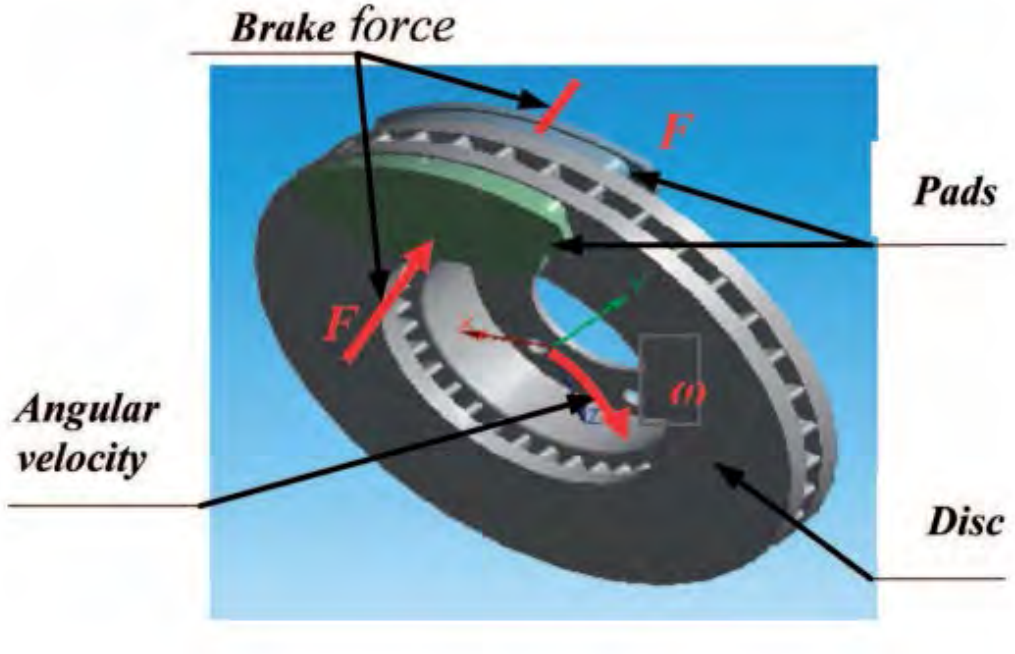

Figure 2.3: Schematic Diagram of Forces Acting on Wheel (Belhocine and Bouchetara, 2014)

There are two major types of car brake disc which is solid and ventilated. The ventilated disc gives increased cooling ability without increasing in weight, but it is more complex in its design and is not always necessary. In the case of high performance cars where a ventilated disc is required for the desired heat transfer, the disc is commonly constructed of a cast iron hub and two circular braking faces, separated by vanes (Gerrard, 1993). Air is able to flow through the air passages between the vanes to carry heat away from the brake disc components(Hwang and Wu, 2010). A solid disc has no such air passages and has poorer cooling performance. **Figure 2.4** shows a ventilated brake disc. This thesis is concerned with the design of a solid disc.

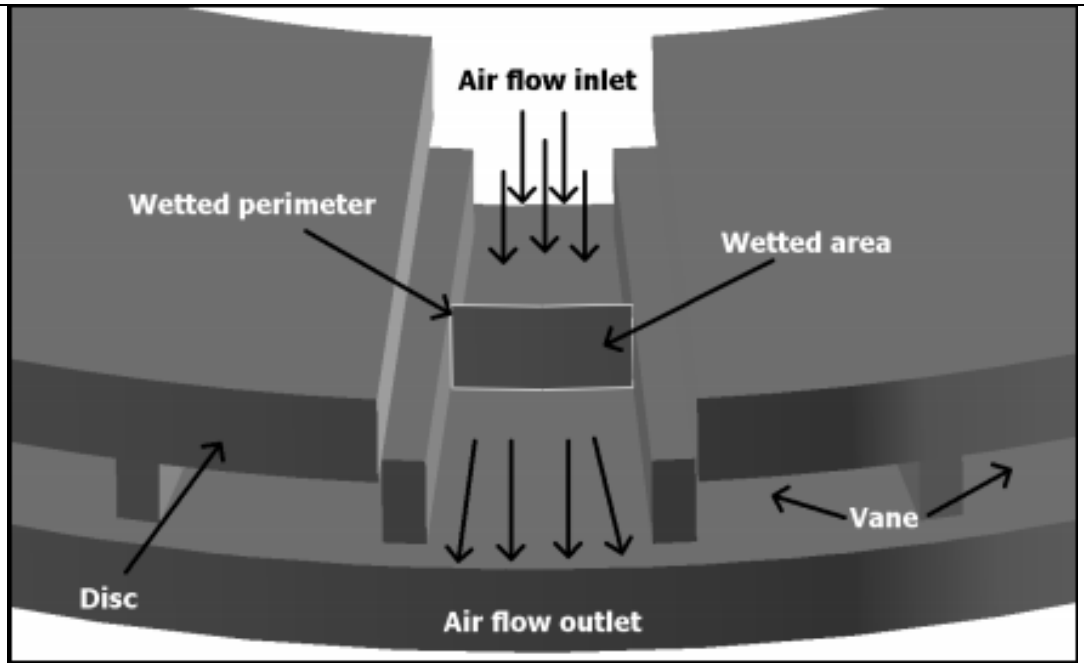

Figure 2.4: Air flow in The Vanes of Ventilated Brake Disc (Hwang and Wu, 2010)