MEASUREMENT OF STRESS AND STRAIN OF AN AUTOMOTIVE COMPONENT SUBJECTED TO STATIC LOADING

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DECLARATION

"I hereby declare that I have read this project and my opinion this project is sufficient in terms of scope and quality for the award of the degree of Bachelor Mechanical Engineering (Sturcture and Materials)"

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This report is submitted as partial fulfilment of the requirement for the degree of Bachelor of Mechanical Engineering (Structure and Materials)

Faculty of Mechanical Engineering

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DECLARATION

"I hereby declare that the work in this report is my own except the summaries and quotations that has been duly acknowledged"

Signature	:	……
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Date	:	…….

To my beloved family

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ABSTRACT

One of the important parts of the passenger vehicle is its braking system or specifically the brake pedal. This has been taken as the main research subject of this Final Year Projek (PSM). The measurement of stress and strain conditions of the brake pedal was determined by conducting a compression test to the brake pedal by controlling the travel distance of brake pedal. The study was done by designing and fabricating a special test fixture to hold the brake pedal while conducting the compression test by applying to static loading through the Instron universal testing machine. The compression load was applied to the brake pedal at three different areas and with three different travelling distance of 2 mm, 3mm and 4 mm respectively. And the areas of applying force is at the centre, left and right side of the brake pedal and is known as F1, F2 and F3 locations respectively. The strain gauges are installed at the critical part of the brake pedal and connected to the strain meter for the determination of strain readings at the specified locations. The load of every position of applying force and travelling distance of braking system has been recorded together with the strain gauge readings. Based on this study, the main achievement of determining the value of maximum stresses or strains at the critical locations of the brake pedal has been done though some influential factors have significantly affected the final results. Other than that, the determination of maximum load that the brake pedal can withstand at three different areas of applied force and three different travelling distance of brake pedal has also been carried out successfully.

ABSTRAK

Salah satu komponen yang penting di dalam kenderaan yang membawa penumpang adalah sistem brek atau lebih spesifik ialah pedal brek. Kajian ini telah diambil sebagai kajian subjek utama untuk Projek Sarjana Muda (PSM). Pengukuran tekanan dan tegangan di pedal brek dapat ditentukan dengan menjalankan uji kaji penekanan kepada pedal brek tersebut dengan menggunakan pedlbagai jarak sistem brek.Kajian ini telah dijalankan dengan mengfabrikasi 'jig' yang digunakan untuk memegang pedal brek tersebut semasa uji kaji dijalankan tertakluk kepada daya statik.Daya static dirujuk sebegai daya yang dikenakan dengan daya yang statik dengan struktur yang static tanpa mengubah posisi daya yang dikenakan. Uji kajii ini dijalankan dengan menggunakan tiga posisi keatas daya yang akan dikenakan di brek pad dan tiga jenis jarak sistem brek. Jarak sistem brek yang dikenakan ialah 2mm, 3mm dan 4 mm dan permukaan daya yang dikenakan di brek pad adalah di bahagian tengah, kiri dan kanan yang dikenali sebagai F1, F2 dan F3. . "Strain gauges" telah dipasang di tempat yang kritikal pedal brek dan telah disambungkan pada "strain meter" untuk mendapatkan bacaan nilai pemanjangan. Daya yang dikenakan pada setiap posisi daya dikenakan dan jarak sistem brek telah dicatat. Daripada pembelajaran ini, dapatlah dianalisis nilai pemanjangan pada pedal brek tersebut daripada sesetengah faktor berpengaruh yang menyebabkan kesan kepada bacaan akhir uji kaji. Selain itu, dapat mengenal pasti daya maksimum yang boleh brek pedal terbut bertahan dengan tiga jaak sistem brek dan tiga permukaan yang berbeza. Akhir sekali, daripada uji kaji ini dapatlah dikenal pasti bahagian yang kritikal yang terdapat pada pedal brek tersebut setelah daya penekanan diaplikasikan.

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ABBREVIATIONS

UTM	Universal Tensile Machine
AISI	American Iron and Steel Institute
ASTM	American Society for Testing and Materials

CHAPTER 1

INTRODUCTION

1.1Background

Brake pedal is an important automotive part for the vehicle that required high strength material in order to produce it. Typically mild or medium carbon steel is used for this part that meet the standard of AISI 1018. Carbon steels of various grades have very high value of tensile strength that involved a lot of heat treatment process in producing it such as normalizing, forging, tempering, annealing, stress relieving, case hardening, core refining and carburizing. With the presence of notches and areas of potential crack to initiate, it is necessary to know and determine the stress fields in the brake pedal completely to avoid its failure while under working condition. The failure process of such automotive component is not only controlled by the local stress amplitude, but also by the stress gradient.[26] (A. Nyoungue., 2016). The use of strain gauges for fracture studies was first suggested by Irwin in 1957. However, at that time researchers were hesitant in using strain gages because of large averaging errors produced due to finite size of these gages.

With the availability of extremely small gauges, it is now possible to effectively use them for fracture studies. Static fracture studies have been conducted recently using strain gauges.

In structural engineering, understanding the behavior of steel under extreme loading conditions is essential for accurate prediction of material response when subjected to combination of severe load scenarios. The overall stress-strain relationship, as well as the mechanical properties of pre-damaged steel is investigated previously at various temperatures and under static loading [2](Mirmomeni et al., 2015). In addition, application of high static load induces irreparable plastic deformation to the material which cannot be neglected when assessing the resistance of the material at room and elevated temperatures.

In order to investigate the mechanical behavior of the pedal brake that will cause the failures, the mechanical test must be conducted with the brake pedal is subjected to various loading conditions.

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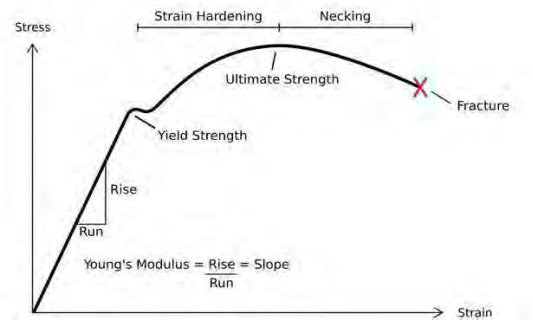

Figure 1.1 Stress-strain curve

For this study, it is crucial that the stress-strain curve of a material as shown in Figure 1.1 is known since it is one of the most important results that need to be determined and further investigated.The curve is normally used to measure a material's mechanical properties such as the yield and ultimate strengths, Young's modulus and ductility of the material. However, they are not without some subtlety, where in the case of ductile materials that can undergo substantial geometrical change during testing[4](Carlsson et al., 2006).

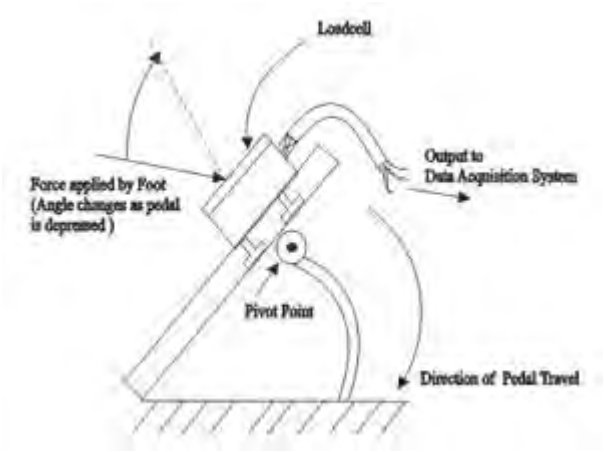

Figure 1.2 Brake Pedal

Figure 1.2 shows the brake pedal where the force is applied by foot of the driver with the angle varied. The maximum stress on the pedal brake is to be found under the various angle of applying load. There is a pivot point which can withstand the applied force or load.

1.2Problem Statement

The mechanical problems of the brake pedal will cause a brake failure such as poor braking performance which will cause it harder or difficult to control and stop the vehicle. Other than that, squealing or grinding noises will occur during braking. Excessive drag during acceleration can also happen if there is a failure on the brake pedal. The brake pedal will typically crack on its critical zone which caused by the excessive loading on the brake pedal or caused by the overloaded pressure subjected to the brake pedal. The present study is conducted to investigate the stress-strain distribution on the brake pedal when subjected to static and dynamic loadings in such a way the location and magnitude of critical stress may be determined and identified experimentally.For the brake pedal, the magnitude of the applied load will depends on the travelling distance of braking system of the respective vehicle. Different size of vehicle will have different design and size of the brake pedal and also its travelling distance to apply load to stop or control the vehicle. For the purpose of this study, a locally manufactured

brake pedal for a passenger car has been chosen. It is a brake pedal ofPeroduaKancilwill be taken as the research object of the current study.

1.3Objectives

For the current study, a few objectives will be investigated to complete the scope of this project successfully. The main objective is to investigate the stress-strain behavior occurred on the brake pedal when applying the static and dynamic loadings. This is followed with the objective to investigate the maximum value of stress and applied force for a certain travelling distance of braking system and compare the experimental result with its theoretical value.

1.4 Scope of Project

The scopes of the current project are listed below;

1. To investigate the stress-strain behaviour or distribution on the brake pedal subjected to static and dynamic loadings.
2. To determine the maximum value of applied force for a certain distance of braking system and compare the experimental value with the theoretical result.
3. Lastly, to investigate the effect of dynamic loading on the brake pedal when the force is applied at high rate or speed.

Furthermore, this project will be conducted with some limitations. The aerodynamic aspect of the car will not be included. In addition, the project will not be involved with test of other automotive part of the car.

In addition, this project will be focused only on the vehicles that are locally manufactured for passenger. The brake pedal that have been chosen for this study is one used for Perodua Kancil. Lastly, the specific weight of the driver that will push the brake pedal will not be included in this study because the research found that it is depends on the weight and type of person that apply the force on the brake pedal. It is also stated that the brake failure efficiency is at range of 60 to 85 percent of breaking efficiency[6](Segel, Dugoff, & Campbell, 1971).

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will explain the stress strain measurement of an automotive part which is brake pedal of a car subjected to static and dynamic loadings. In order to measure the value of stress and strain, the experiment needs to be conducted by installing strain gauges on the brake pedal at a number of locations. The strain gauges will measure the value of strain that will be generated on the brake pedal while compressing the brake pedal with a certain load. The applications and review of strain gauges in measuring strains will be discussed in this chapter. The stress and strain analyses will also be covered in order to get a better understanding on this project.

2.2 Brake Pedal

Brake pedal is one of the automotive part of a car that used to stop or slower down the vehicle or car from accelerating. The brake pedal is also the most important active safety means of a vehicle. Now a day, the braking system of many vehicles has been upgraded and supplemented with electronic system that are

helpful to users and will be much safe to use the vehicle with the latest design of braking system [7]. The cracking problems on a brake pedal was typically occurred due to the manufacturing defects of the brake pedal. The cracking also related to the higher stress-strain that exists on the critical section of the brake pedal [3].

The braking system in a car is normally made of mechanical, electronic and hydraulically activated components that used friction on the braking system as shown in Figure 2.1, either to stop the car or slower down the speed of the car. When the force is applied on the brake pedal as shown in Figure 2.2, it will produce a pressure that will moves a piston in the master cylinder. Next, the brake fluid from the master cylinder will force through the brake lines and flexible hoses to the calipers and wheel cylinders. As the driver push the brake pedal thus, the force will be applied. The applied force on the brake pedal is proportional on each of the pistons.

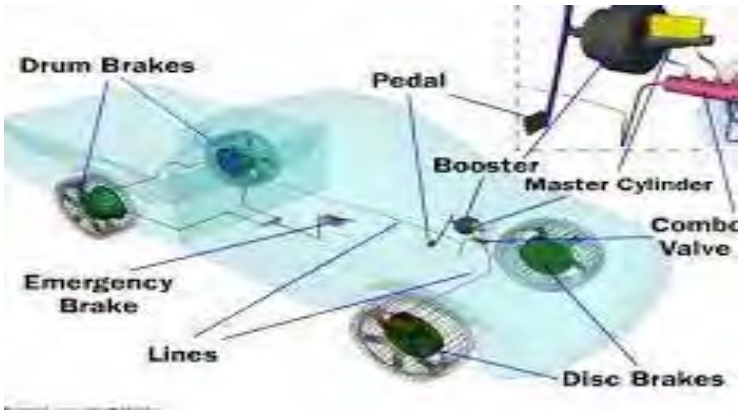

Figure 2.1 Braking system

According to Todorovic, Dubokaetat in 1995 and Park in 2005, the vehicle deceleration or stopping the car will produce the braking effectiveness. The driver will control itself the force that need to apply on the brake pedal by sensing the pedal force and the pedal travel. The brake effectiveness of a car is important as it has the relationship between stopping distance and perceived quality. The braking effectiveness can be determined by the types of the braking system and the system

parameters which include the brake pedal travel, brake pedal force and the relationship for the car to stop and certain distances with times. Thus, by improving the parameters of the braking system will improve the effectiveness of the brake pedal.

2.3 Material of Brake Pedal

The actual material of brake pedal used in this study initially was not known except it appears as steel without details information from the manufacturer or supplier. Thus it is necessary to determine the actual type of steel being used to produce the Perodua brake pedal. This may be done through a number of methods such as conducting the tensile test, metallurgical study as well as the hardness test. The first two options will involve the destruction of the brake pedal, thus is it decided that conducting hardness test is the most viable method for the current study. By conducting the Rockwell hardness test, the material of the brake pedal was determined. The Rockwell hardness results gave the information of tensile strength based on the conversion table. From the literatures, it is found that the brake pedal was made from the carbon steel which met the standards of AISI 1018 of mild or low carbon steel. This material has good weldability which considered as the best steel that can be case-hardened. With the great balance of toughness, strength and ductility, brake pedalsare most suitable be made from carbon mild steel. To deform a brake pedal during its production, the carbon steel need to have specific manufacturing controls such as chemical composition, rolling and heating process. To ensure the brake pedal has strong structure, the fabrication process will include the welding, forging, drilling, machining, cold drawing and heat treating process [15]. The properties of the low carbon steel are shown in Table 2.3.1[16]

Table 2.3.1 properties of low carbon steel

Property	Value
Density (kg/cm^3)	7870
Poisson's Ratio	0.29
Young's Modulus (GPa)	205
Thermal Conductivity (W/m^{o}C)	51.9
Specific Heat (J/kg/^{o}C)	486

Table 2.3.2 shows the chemical composition of the low carbon steel, AISI 1018:

Table 2.3.2 Chemical composition of carbon steel

Material	AISI 1018 steel
A(MPa)	520
B(MPa)	269
N	0.282
C	0.0476
M	0.053
T_{melt}(^{o}C)	1520

On the other hand, the mechanical properties of the low carbon steel is depicted in Table 2.3.3

Table 2.3.3 Mechanical propertiesof low carbon steel

Mechanical Properties	Metric
Hardness Rockwell	71
Tensile strength, Yield	370 MPa
Tensile strength, Ultimate	440 MPa
Modulus of Elasticity	205 GPa

2.4 Stress-Strain behaviour of a material

By using the well- known Bridgman equation, the correction of true stress can be determined [8]. The definition and correlation between stress-strain is derivedwhen there is changes of shape and size of the specimen as the external force is applied. On the other hand, strain is derivedwhen the external force is applied thus change the shape or size of the specimen while stress is defined as the internal force per unit area that associated with strain. From this definition, it refers to the Hooke's Law which is stress isdirectly proportional to strain for the linear part of the graph/curveshown in Figure 2.3. The stress-strain curve is virtually independent of specimen dimensions. Based on the Hooke's law,

$$Stress \propto Strain$$

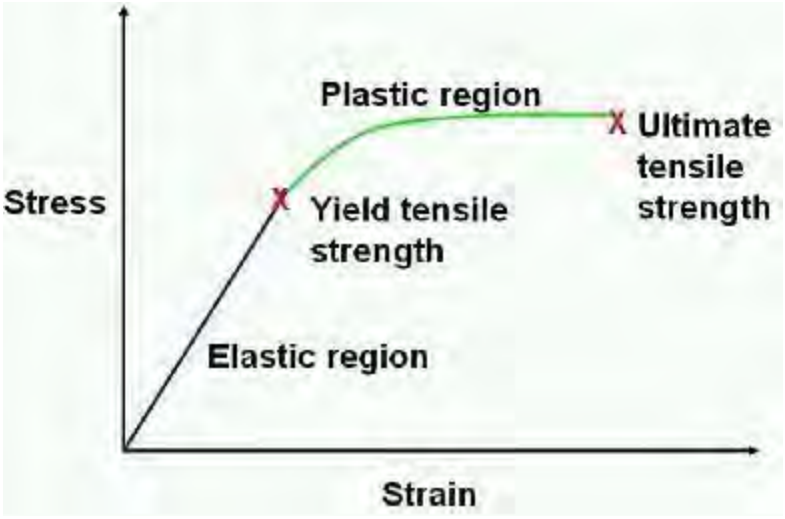

Figure 2.3 Hooke's Law

2.4.1 Bending Stress

For this project, the brake pedal was being compressed for a certain distanceof braking system. The compression of the brake pedal will cause bending stresses alongthe brake pedal. Bending stress is a specific type of normal stressgenerated longitudinally in the brake pedal material except on the neutral axis of the structure. The brake pedal will be subjected to compressive bending stress on the top side of itsneutral axis. While, the bottom side of the brake pedal experienced tensile bending stress. Generally, the bending stress vary linearly with distance from the neutral axis of the brake pedal. Equation (2.1) below shows that bending stress's equation that vary with the distance from the neutral axis.

$$\sigma_b = \frac{Mc}{I} \quad (2.1)$$

where,

σ_b= Bending stress

M = Bending moment

c= Vertical distance from neutral axis