A STUDY ON VARIOUS TYPE OF ROTOR DISC BRAKE USING FAE ANALYSIS

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for award of the degree of
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EXAMINERS APPROVAL DOCUMENT

UNIVERSITI MALAYSIA PAHANG
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I certify that the thesis entitled ‘A Study On Various Type of Rotor Disc Brake’is written by MohdAffendi bin Ibrahim. I have examined the final copy of this report and in my opinion, it is fully adequate in terms of language standard, and report formatting requirement for the award of the degreeof Bachelor of Mechanical Engineering with Automotive Engineering. I herewith recommend that it be accepted in fulfillment of the requirements for the degree of Bachelor of Engineering.

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I hereby declare that the work in this report is my own, except for quotations and summaries which have been duly acknowledged. The report has not been accepted for any other degree and is not concurrently submitted for award of other degree.

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Specially dedicated to

My beloved parent
Who always give me courage to finish this thesis.

Also, to those people who have guided and inspired me throughout my journey.

Thank you for the supports and advices that have been given.

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Alhamdulilillah, the highest thanks to God because with His Willingness I can finish as well as completing the final year project in time without any delayed.

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ABSTRACT

This thesis deals experiences on finding stress distribution on the various brake discs. The test is done in simulation. The disc brake is modeled using SOLIDWORK 2012 software and simulation analysis is done FAE analysis using ALGOR software. The result for distribution stress on various disc brakes is compared. In this thesis normal, drilled, grooved and combination disc brakes are used. The result of simulation for every type of disc brake is compared. The maximum stress von mises is simulated using ALGOR. The difference in the results between each type of disc brake is discussed. The final selected maximum stress von mises for simulation is based on mesh 100%. Force selected applied on brake pad in this simulation is 62.5 N, 125 N and 187.5 N. Simulation result maximum stress for normal disc brake is 7.544067 kN/m^2 at 62.5 N, 15.08802 kN/m^2 at 125 N and 22.63209 kN/m^2 at 187.5 N. Simulation result maximum stress for drilled disc brake is 14.22672 kN/m^2 at 62.5 N, 27.03406 kN/m^2 at 125 N and 40.551 kN/m^2 at187.5 N. For simulation result maximum stress for grooved disc brake is 9.968343 kN/m^2 at 62.5 N, 19.93669 kN/m^2 at 125 N and 29.90503 kN/m^2 at 187.5 kN/m^2. Simulation result maximum stress for combination disc brake is 15.87852 kN/m^2 at 62.5 N, 31.75681 kN/m^2 at 125 N and 47.63511 kN/m^2 at 187.5 N. The different value of maximum stress at various type of disc brake are discussed and analyzed.

ABSTRAK

Tesis ini membincangkan pengalaman dalam mencari taburan tekanan pada cakera brek pelbagai. Ujian ini dilakukan dalam simulasi. Brek cakera dimodelkan menggunakan SOLIDWORK 2012 perisian dan analisis simulasi dilakukan analisis FAE menggunakan perisian ALGOR. Keputusan untuk tekanan pengedaran di pelbagai cakera brek dibandingkan. Dalam tesis ini normal, digerudi, brek cakera beralur dan gabungan digunakan. Hasil simulasi untuk setiap jenis cakera brek dibandingkan. Tekanan maksimum von Mises adalah simulasi menggunakan ALGOR. Perbezaan dalam keputusan antara setiap jenis cakera brek dibincangkan. Akhir dipilih maksimum tekanan von Mises bagi simulasi adalah berdasarkan jaringan 100%. Pasukan dipilih digunakan pada pad brek dalam simulasi ini adalah 62.5 N, 125 N dan 187.5 N. Simulasi akibat tekanan maksimum bagi brek cakera biasa adalah 7.544067 kN/m2 di 62.5 N, 15.08802 kN/m2 di 125 N dan 22,63209 kN/m2 pada 187.5 N. Simulasi akibat tegasan maksimum untuk cakera digerudi brek 14.22672 kN/m2 di 62.5 N, 27.03406 kN/m2 di 125 N dan 40.551 kN/m2 at187.5 N. Untuk hasil simulasi tekanan maksimum bagi brek cakera beralur adalah 9.968343 kN/m2 di 62.5 N, 19.93669 kN/m2 di 125 N dan 29.90503 kN/m2 di 187.5 kN/m2. Simulasi akibat tekanan maksimum untuk gabungan brek cakera adalah 15.87852 kN/m2 di 62.5 N, 31.75681 kN/m2 di 125 N dan 47.63511 kN/m2 di 187.5 N. Nilai jenis tekanan maksimum pada pelbagai jenis cakera brek dibincangkan dan dianalisis.

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CHAPTER 1

INTRODUCTION

1.1: INTRODUCTION

Brakes are by far the most important mechanism on any vehicle because the safety and lives of those riding in the vehicle depend on proper operation of the braking system. It has been estimated that the brakes on the average vehicle are applied 50,000 times a year. Brakes are an energy-absorbing mechanism that convert vehicle movement into heat while stopping the rotation of the wheels. All braking systems are designed to reduce the speed and stop a moving vehicle and to keep it from if the vehicle is stationary.

Typically, there are two types of brake that were implement in today's car, drum brakes and disc brakes. Drum brakes are used on the rear of many rear-wheel- drive, front-wheel-drive, and four-wheel-drive vehicles. Disc brakes are used on the front of the most vehicles built since the early 1970s and on the rear wheels of many vehicles. A disc brake operates by squeezing brake pads on both sides of rotor disc that is attached to the wheel.

1.2 PROJECT BACKGROUND

Brakes are one the most important safety and performance components in automobiles. Appropriately, ever since the advent of the automobile, development of brakes has focused on increasing braking performance and readability. Brake deals with many design variables and components in a complex brake system. The design of the disc is important to determine the rate of stress and uniform wear of disc brake pad and thus affecting braking efficiency.

This project will focus on the simulation or comparison analysis on various type disc brakes during operation when forces and is applied during the static. The stress distribution of disc from simulation can be analyzed.

1.3 PROBLEM STATEMENTS

The disc brake is a device for slowing or stopping the rotation of wheel of vehicles. To stop the wheel, friction material in the form of brake pads is forced mechanically, hydraulically, pneumatic, or electromagnetically against both sides of the disc and cause the wheel to slow or stop. When brakes were used rapidly, the discs and brake pads will become stress. The brake cannot brake with better because disc brake become crack. Now, there are different types of disc brake design which is normal disc brake, drilled disc brake, grooved disc brake and combination drilled and grooved brake disc. Normally every different type of design disc brake produces different brake performance and stress. This happens because during the brake process the formation of gas between brake pads and rotors. The design of the disc is important to determine the rate of stress and uniform wear of disc and brake pad and thus affecting braking efficiency.

This project will focus on the simulation analysis of various disc brake during operation when forces and moments generate from braking is applied during the static. The stress distribution of disc from simulation result can be analyzed.

1.4 PROJECT OBJECTIVES

To investigate and analyze the stress distribution for various disc brakes using FEA analysis.

1.5 PROJECT SCOPES

To achieve the mentioned objectives, a disc brake from Proton Wira 1.5L will be used as reference. The project scope includes:

a) Selection of disc brake that will be used in this project
b) Determination mechanical properties and dimension of the selected disc brake.
c) Modeling the disc brake in Solid works 2012 software.
d) Performing Finite Element Analysis using Algor software.
e) Comparison stress analysis between each types of disc brake.

1.6 FLOW CHART

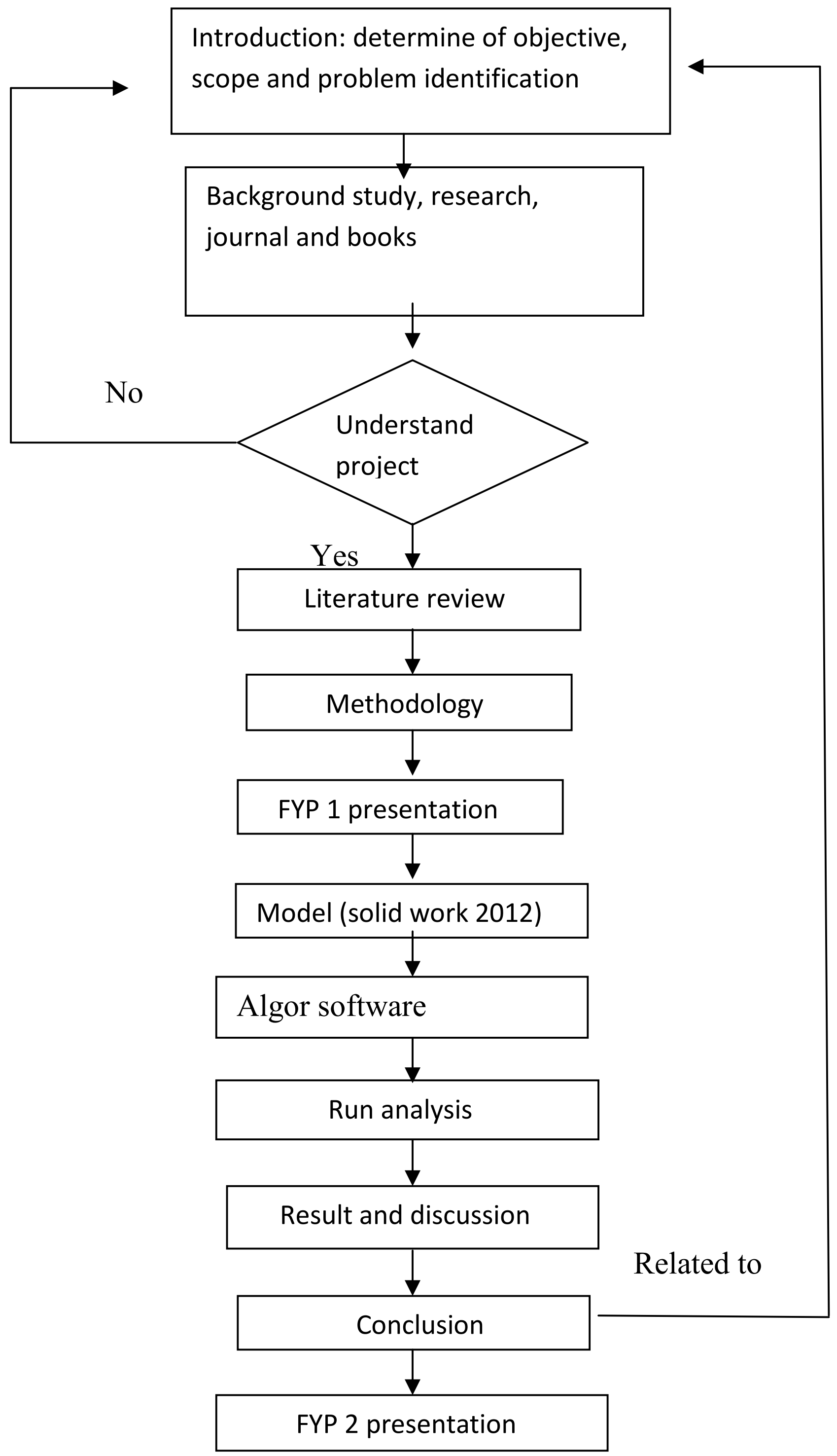

Figure 1.1: Project Flow Chart

CHAPTER 2

LITERATURE REVIEW

2.1 BRAKE SYSTEM

The braking system provides the means to stop a car. The braking system is considered by many people to be the most important system involved in the operation of a vehicle. The ideal braking systems is one that will allow the driver to bring a vehicle to a stop in the shortest possible distance (Thomas W. Birch, 2004).

The modern automotive brake system has been refined for over 100 years and has become extremely dependable and efficient. The typical brake system consists of disk brakes in front and either disk or drum brakes in the rear connected by a system of tubes and hoses that link the brake at each wheel to the master cylinder. Vehicle brake system operation begins with the driver and the application of the brake pedal. Brakes slow and stop a vehicle by transforming vehicle motion into heat energy. The amount of heat produced is proportional to the vehicle speed and driver foot pressure on the brake pedal. Fast vehicle speeds and quick stops produce more heat. The brake system is comprised of many sub-systems. Stopping a vehicle requires that all brake sub-systems work together. Other systems that are connected with the brake system include the parking brakes, power brake booster and the anti-lock system.

To stop a wheel, the driver exerts a force on brake pedal. The force on the brake pedal pressurizes brake fluid in a master cylinder. This hydraulic force is transferred through steel lines and flexible brake lines to a wheel cylinder caliper at each wheel.

Hydraulic pressure to each wheel cylinder or caliper is used to force friction material against the brake drum or disc and causes the rotating part to slow and eventually stop .

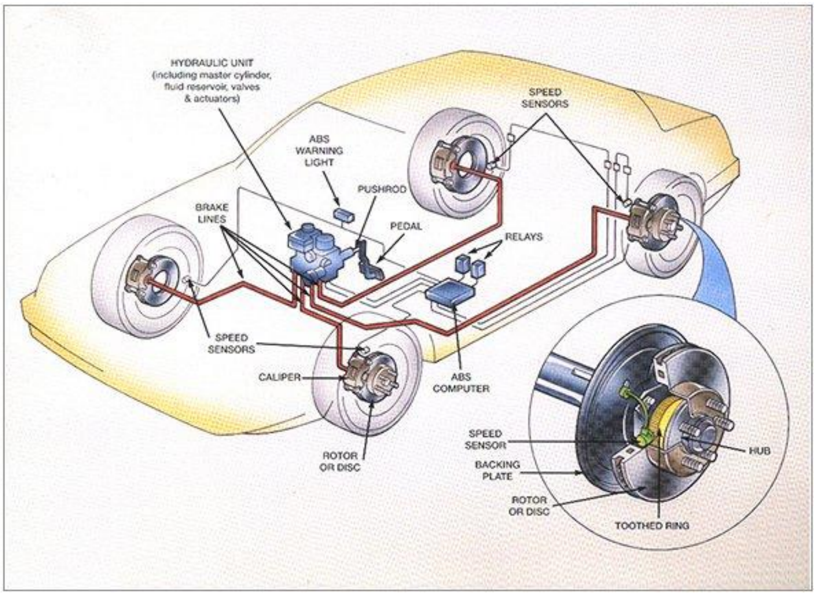

Figure 2.1: Modern automotive brake system

Source: James D. Halderman, 2010

2.1.1 Brake System Categories

Brake system components can be classified and placed into six subsystem categories depending on their function (James D. Halderman, 2010).

i) Apply system. The driver starts the operation of the braking system by pressing on the brake pedal. The apply system includes all the levers, pedals or linkage needed to active a braking force.

ii) Boost system. The boost (power brake) system is used on most vehicles to reduce the force that the driver must exert on the brake pedal.

iii) Hydraulic system. Force from pedal force transferred to the hydraulic system, where the force is directed through pipes and hoses to the wheel brakes.

iv) Wheel brakes. Hydraulic pressure from the hydraulic system moves the piston, which uses friction to press material against a rotating drum or disc. The resulting friction slows the rotation of the wheels.

v) Brake balance control system. Mechanical, electrical, and hydraulic components are used to ensure that brakes are applied quickly and with balanced pressure for safe operation. Components include metering and portioning valves, and antilock braking system components.

vi) Braking warning lights. The red braking warning lamp (RBWL) lights whenever a hydraulic system failure occurs and the amber ABS warning lamp or dim red brake light indicates an ABS self-test a possible problem in the ABS system.

2.2 DISC BRAKE

A disc brake system usually consists of break disc rotor, two brake pads and a caliper. The combination of these components allows the rotating wheel to experience severe braking in a short stopping distance.

The centre part of the brake disc has a circular aperture, which is locates on the wheel hub. It is surrounded by a number of holes for the wheel bolts. The

brake disc rotates along with the wheel. The normal load, produced when the brake is actuated result in the generation of an in-plane friction force at the disc-pad interface. This in turn produces a brake torque about the centre of rotation of the wheel. The reaction to the brake torque is seen in the brake force, between the tire and ground, which slow the vehicle.

Disc brakes work by applying pressure to two brake pads on opposite sides of a spinning rotor attached the hub of a wheel. Disc brake pad are mounted in a caliper that sits above the spinning disc. All friction components of disc brake are exposed to the air, which helps to cool the brake parts and braking effectiveness during repeated hard stops from higher speeds. A disc brake requires higher hydraulic pressure and greater force to achieve the same stopping power as a comparable drum brake (Jack ERjavec, 2004).

Disc brakes are widely used for reducing velocity by the friction caused by pushing brake pad against a brake disc with a set of calipers. The brake disc normally made by cast iron, but may in some cases made by composites (C.H.Gao, 2012).

The contacts conditions between the disk and pads correspond to heat flux which is function of the time and space variables. The thermal boundary conditions outside the contact region correspond to convection, radiation and the known temperature. The sliding speed and the frictional heat flux are time dependent and there are intensity related with pressure increasing model (Ali Belhocine, 2011).

Figure 2.2: Disc brakes \

Currently, there are two types of disc brake rotor used in passenger car which is solid disc and ventilated disc. A solid rotor is simply a solid piece of metal with friction surface on each side and this of rotor is light, simple, cheap and easy to manufacture. A ventilated disc is a rotor with various opening profiles likes holes and grooves which provide better cooling performance. Therefore, it widely used compared to solid disc.

Solid disc brake are often used on smaller in width, lighter, and less expensive compare with vented disc brake more using in heavier brake. Solid disc also have various opening profile likes drilled, grooves and combination both of them.

For this project, solid disc with opening various profile was selected which is normal disc brake, drilled disc brake, grooves disc brake and combination drilled and grooves disc brake.

2.2.1 Normal Disc Brake

Normal disc brakes have more surface area touching the pads when the brakes are applied so initially have better braking power. But normal brake have some problem is that when brakes in progress get a buildup of gas between the pad and disc which causes brake fade and pad glazing. The extra heat cal also warp the discs if this brakes are poorly made or have been paired inappropriate pads (Evilution, 2012).

Figure 2.3: Example normal disc brake

Source: Evilution, 2012

2.2.2 Drilled Disc Brake

The face for these disc brakes is drilled through all mainly to increase surface area which it can rid them of heat quicker. Function the holes on the surface this brake is the way to stopping the gas build up that cause brake fade. But, the problem with drilled discs is that the holes can have a tendency to start cracking and collect dust (Evilution, 2012).

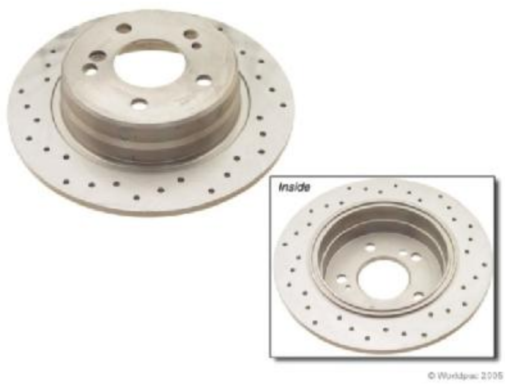

Figure 2.4: Example of drilled disc brake

Source: Evilution, 2012

2.2.3 Grooved Disc Brake

The faces of these discs have diagonal lines cut. The function of that line is to allow the venting of brake pad gasses thus eliminating brake fade. It also ejects brake pad dust to stop glazing of the pad. It keeps the pad face fresh allowing better braking. But, the problem this disc is tendency to be noise when the brakes are applied due to scrubbing of the pads (Evilution, 2012).

Figure 2.5: Example of grooved disc brake

Source: Evilution, 2012

2.2.4 Combination Disc Brake

A very common combination disc brake is drilled and grooves disc brake. This disc gives better performance during brakes process. This disc normally used for sport car or racing car (Evilution, 2012).

Figure 2.6: Example of combination disc brake

Source: Evilution, 2012

2.3 DISC MATERIAL

The disc brake rotor is made from gray cast iron material which provides good wear resistance with high thermal conductivity and the production cost is low compared to other high performance disc brake rotor material such as carbon composities and ceramic based composities (H.Jang, 2003).

Cast iron a material that has been commonly used to create components of varying complexity for a long time. This is because it is relatively inexpensive and easily formed into complex shapes. Normally, cast iron consists of two substances: graphite (carbon) flakes and matrix ferrous metal. Both of these constituents have a significant influence on the stress-strain response of the material. This is because of the weak bonding between the graphite flakes and metal matrix which causing gaps or voids to open in the material under tension.

Measured the specific heat and thermal conductivity at room and elevated temperatures of various cast iron materials used in brake disc. That carbon had a large influence on these properties. In addition, the longer the graphite flakes, the greater the thermal diffusivity (Hecht, 1996).

Classifications of cast irons are determined by the eutectic graphite/carbide form present in the iron microstructure. Classifications are controlled by alloying, solidification rates and heat treatment. White irons, malleable irons, gray irons, ductile irons and compacted graphite irons (Mark Ihm, 2009).

Cast irons are indicated to produce brake disc because have excellent thermal conductivity besides the low costs of the production, which eases the dissipation of heat generated by the friction of the pads during a stop, and the capacity of damping vibrations (Omar Maluf, 1999).

For this project material gray cast irons are selected. The gray cast iron classifications and mechanical properties like table below:

Table 2.1: Classifications and Mechanical Properties Gray Cast Iron

Source: Mark Ihm, 2009

Casting Grade SAE J431	**Class per ASTM A48M**	**Typical Carbon Content (%)**	**Theoretical Minimum Tensile Strength (MPa)**	**Typical Brinnel Hardness Range (BHN)**
G7	20	3.50 – 3.70	124	163 – 223
G9	25	3.45 – 3.65	170	170 – 229
G10	30	3.35 – 3.60	198	187 – 241
G11	35	3.30 – 3.55	217	207 – 255
G12	40	3.25 – 3.50	272	217 – 259
G13	40	3.15 – 3.40	268	217 - 259

2.4: MANUFACTURING OF DISC BRAKE

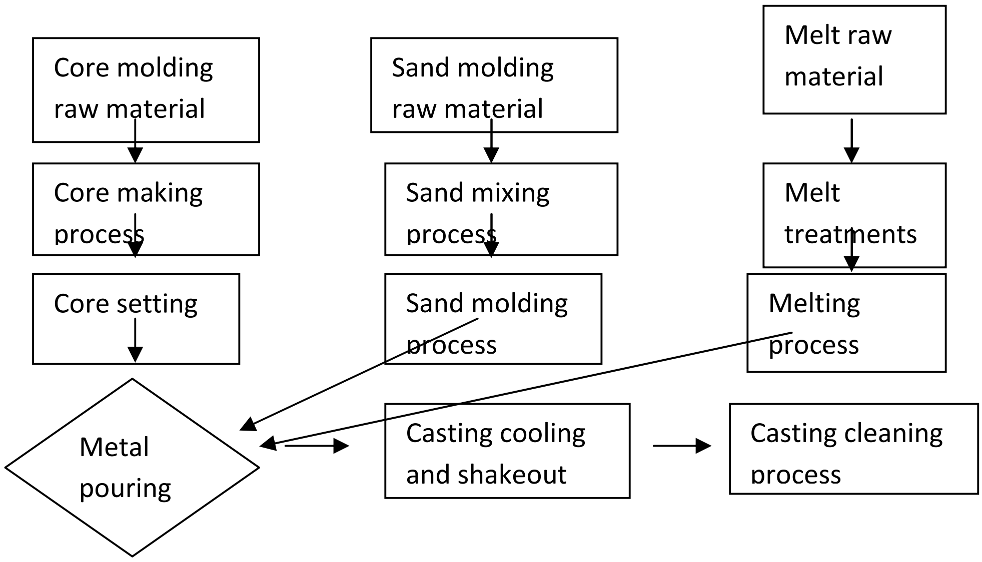

Figure 2.7: Flow chart for manufacturing brake disc process

Source: Mechanical engineering, 2000

i) To begin this process following ingredients, short carbon fibers, carbon powder and heat molded resin must be mixed together.

ii) Then using an automated machine this mixture is poured into a permanent aluminum mold cavity which is in shape of a brake disc (disc ring), until it is half full. After permanent aluminum mold half full, the mold is removed and workers have to insert aluminum cores into a belt with gaps around the mold that allows the cores to be inserted into the mold. These cores will form a ventilation cavity in the disc ring (brake disc) to prevent the disc from overheating.

Figure 2.8: Permanent aluminum mold

Source: Mechanical Engineering, 2000

Figure 2.9: Mold setting process

Source: Mechanical Engineering, 2000

iii) The mold again moves back into the automated machine to fill the other half of the mold cavity with the rest of the mixture that was poured into first half of the cavity. Once the cavity is full it is leveled using a roller and then using the cover or the other half of the permanent mold, it is covered and is pressed lightly to compact the contact inside.

Figure 2.10: Press process

Source: Mechanical engineering, 2000

iv) Then the fully covered mold is sent to a large press which applies 20 tons of pressure and heating to almost of 400 F. This heat and pressure compact the carbon fiber and resin into plastic and makes it stronger.

v) Once the mold is cooled down to be handled, submerge it in cold water for 5-8 minutes which cools the disc ring completely, enabling them to pull out the cores that were inserted for the ventilation purposes.

vi) Once all the cores have been removed, remove the cover of the mold and pull out the disc ring from the mold as shown in Fig 2.11. Then using the computer guided machines smooth out all the rough edges on the disc ring and drill tiny ventilation holes.

vii) Then, put the disc ring into an oven and on over two days it gradually heats it to 1800 F.

Figure 2.11: Core removed process

Source: Mechanical Engineering, 2000

viii) Then take a crucible which is a high heat resistant container and place five mounts inside so that it can hold the disc ring on them without having the disc ring to touch the base of the crucible. Once the disc is mounted on the crucible, place a funnel at the center of the disc ring and fill it with a fine silicon powder.

Figure 2.12: The crucible and the five mounts

Source: Mechanical Engineering, 2000

ix) Then loaded the crucible into a furnace for 24hours and allow it to gradually heat the disc ring to temperature of 3000oF until the silicon is melted completely. This liquid silicon is then drawn into the disc ring by the pores of the framework of the disc ring and forms a completely new material called silicon carbide which makes the disc ring exceptionally hard.

x) Once after it is removed from the furnace, a drill machine bores the mounting holes on the disc ring. And then the disc ring goes to a chamber to receive a coat of protective paint. This paint is used to shield the carbon and disc ring from oxygen and this process is very critical since at high temperatures, oxygen burns carbon. Hence this anti oxidation process increases the lifetime of the disc ring.

xi) Once the protective player is applied, with the help of a computer guided robot arm, moves the disc and polishes the entire disc surface.

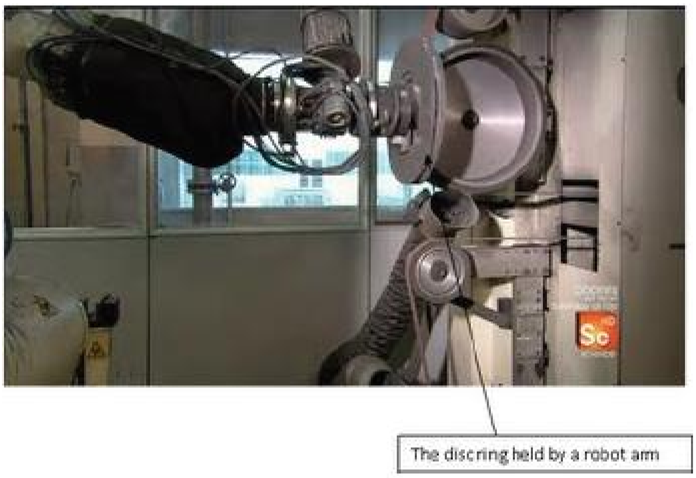

Figure 2.13: Computer guided robot arm

Source: Mechanical Engineering, 2000

xii) After when all the polishing has been completed, a computer guided machine thoroughly inspects the disc ring surface by taking high definition photographs to further examine the molecular and crystal structures to detect any defects.

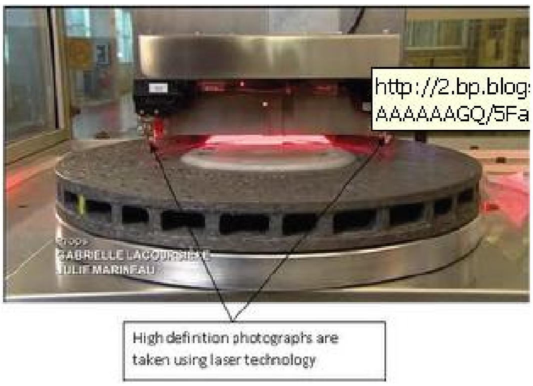

Figure 2.14: Photographs process is taken using the laser technology

Source: Mechanical Engineering, 2000

2.5 INTRODUCTION TO STRESS

Thermal analysis is a stage in the study of the brake systems, because the temperature determines thermo-mechanical behavior of the structure. In the braking process, temperatures and thermal gradients are very high. This generates stress and deformation whose consequences are manifested by the appearance and the accentuation of racks. It is then important to determine with precision the temperature field of the brake disc. The temperature distribution in a part can cause thermal stress effects which the stresses caused by thermal expansion or contraction of the material.

The thermal analysis is a primordial stage in the study of the brake systems, because the temperature determines thermo mechanical behavior of the structure. In the braking phase, temperatures and thermal gradients are very high. This generates stress and deformations whose consequences are manifested by the appearance and the accentuation of cracks (Ali Belhocine, 2011).

Thermal stresses in the disc appear because the temperatures rise. Beside the thermal stress, the centrifugal load and the holding force of the brake caliper is also considered. The goal of this analysis is to determine the influence of the centrifugal load in comparison with the thermal load. The comparison stress is given on von Mises stress (Oder, 2009).

The heating on a surface of friction leads to temperature shock that generates surface cracks. However, most often temperatures and stresses are obtained from a solution of a one-dimensional contact problem with transient frictional heat generation (Evilution, 2012).

2.5.1 Von Mises Stress Yield Criterion

Although formulated by Maxwell in 1865, it is generally attributed to Richard Edler von Mises (1913). Tytus Maksymilian Huber (1904), in a paper in Polish, anticipated to some extent this criterion. This criterion is also referred to as the Maxwell–Huber–Hencky–von Mises theory.

In materials science and engineering the von Mises yield criterion can be also formulated in terms of the von Mises stress orequivalent tensile stress, σ_v, a scalar stress value that can be computed from the stress tensr. In this case, a material is said to start yielding when its von Mises stress reaches a critical value known as the yield strength, σ_y. The von Mises stress is used to predict yielding of materials under any loading condition from results of simple uniaxial tensile tests. The von Mises stress satisfies the property that two stress states with equal distortion energy have equal von Mises stress.

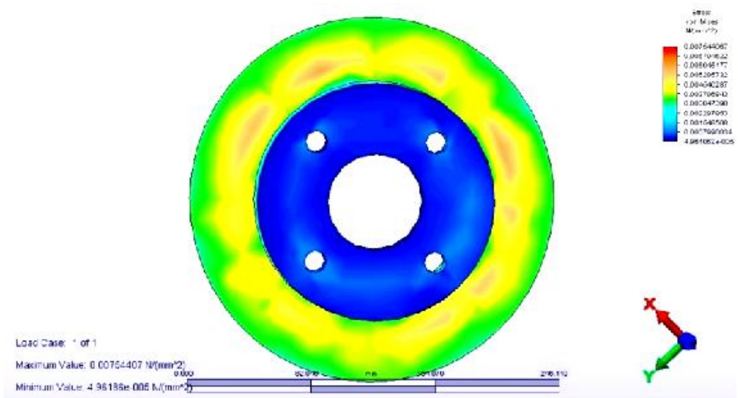

Figure 2.15: Example von-mises stress for disc brake

2.6 INTRODUCTION TO SOLIDWORKS

Solidworks is a 3D mechanical CAD program that run on Microsoft Windows and was developed by SolidWorks Corporation. Building a model in SolidWorks usually starts with a 2D sketch. The sketch consists geometry such as points, lines, arcs, conics, and splines. Dimensions are added to the sketch to define the size and location of the geometry. Relations are used to define attributes such as tangency, parallelism, perpendicularity and concentricity. The dimensions in the sketch can be controlled independently, or by relationship to other parameter inside or outside of the sketch.

2.7 INTRODUCTION TO ALGOR

The finite element method is a powerful tool to obtain the numerical solution of wide range of engineering problem. The method is general enough to handle any complex shape or geometry, for any material under different boundary and loading conditions. The generality of the finite element method fits the analysis requirement of today‟s complex engineering systems and designs where closed form solutions of governing equilibrium equations are usually not available. In addition, it is an efficient design tool by which designers can perform parametric design studies by considering various design cases, and analyze them to choose the optimum design.(coupled). Algor is the software in finite element.

ALGOR is a general-purpose multiphysics finite element analysis software package developed by ALGOR Incorporated for use on the Microsoft windows and Linux computer operating systems. It is distributed in a number of different core packages to cater to specifies applications, such as mechanical event simulation and computational fluid dynamics. ALGOR typically used for bending, stress strain, mechanical contact, thermal, fluid dynamics and coupled and uncoupled multiphysics.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter mostly describes all about the method and process used for simulation. The project starts with preparation of sample that is use in finite element analysis. Then project continue with determining material properties of model.

In the design modeling, Solidworks 2012 software is used to develop the 3-dimensional disc brake model that will use in the simulation analysis. For this project normal disc brake, drilled disc brake, grooved disc brake and combination disc brake are used. The model that had drawn in SolidWork 2012 is transferred into ALGOR. ALGOR software is used to simulation and analyze the stress distribution of the disc brake model.

Methodology is the work flow to achieve the objective this project. For this project the methodology like chart below:

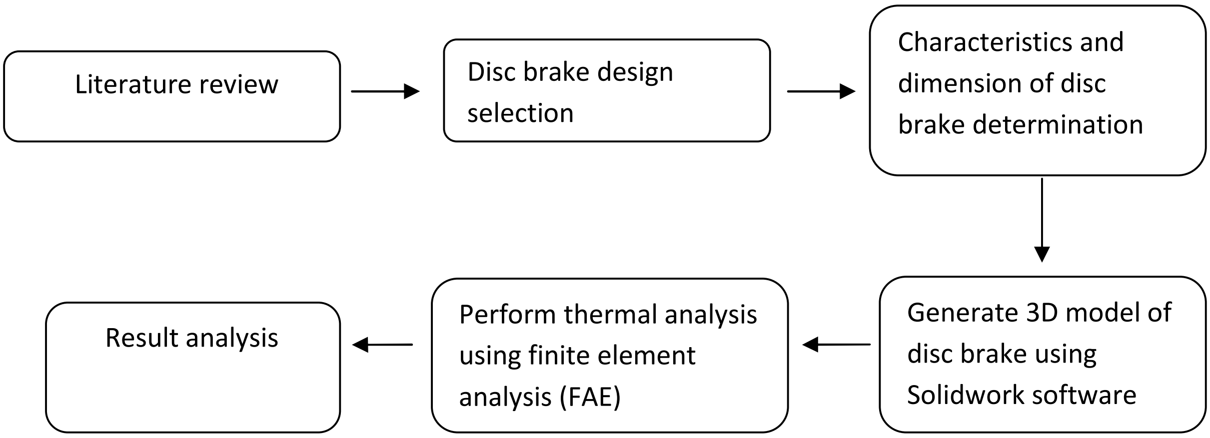

Figure 3.1: Methodology flow

3.2 MODEL

The model for this project consists of normal disc brake, drilled disc brake, grooved disc brake, and combination disc brake. The shape and properties of the disc brake was taken from the actual disc brake implemented in the proton Wira. Start with sketching in 2-dimensional model until it generate the model into 3-dimensional model by using SolidWork 2012 and save into IGES format in order to be opened in Algor software lately. The all dimension about disc brake are list in table below, this dimension refer to AUDIO TECH Catalogue's.

Table 3.1: Dimension for Disc Brake

Part of disc brake	**Dimension (mm)**
Thickness	18
Center hole diameter	64
Height	45
Number bolt hole	4
Outer diameter	236

3.2.1 3D Model

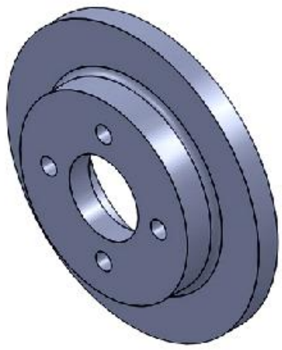

Figure 3.2: Normal disc brake

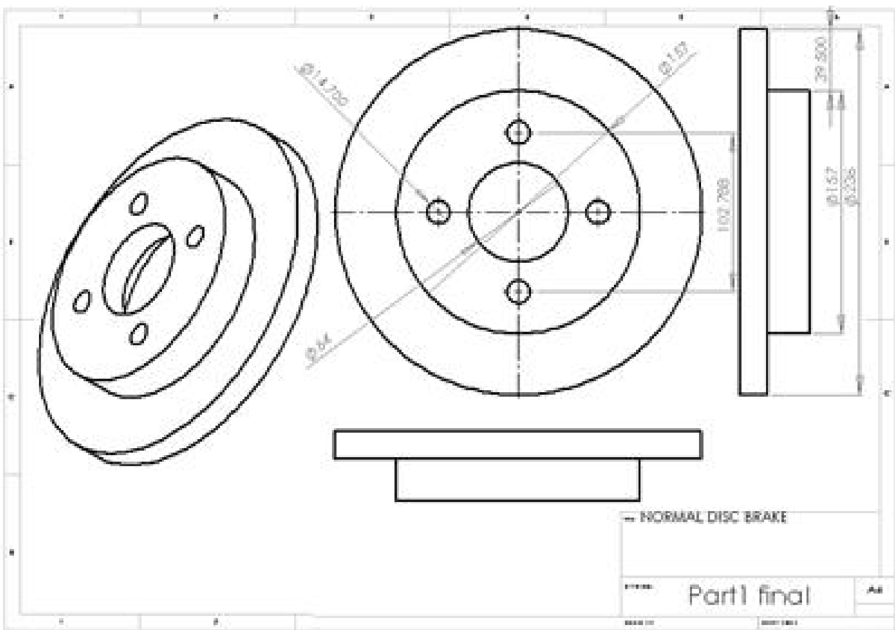

Figure 3.3: Dimension drawing for normal disc brake

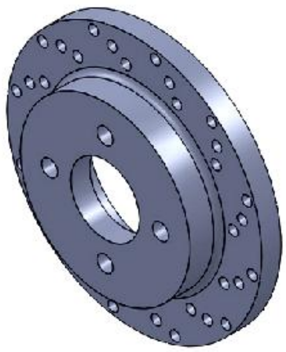

Figure 3.4: Drilled disc brake

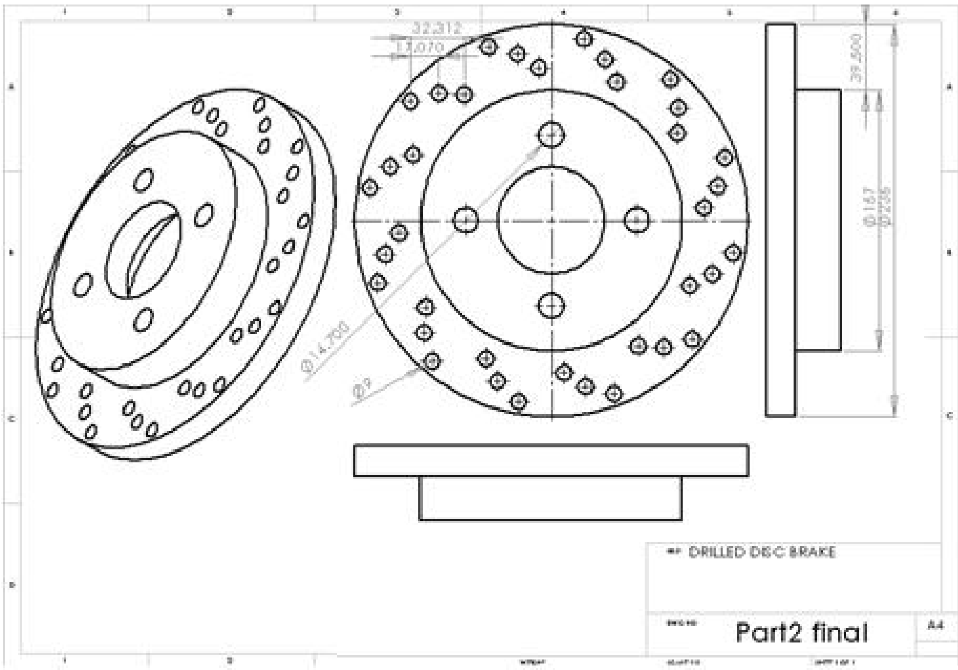

Figure 3.5: Dimension drawing for drilled disc brake

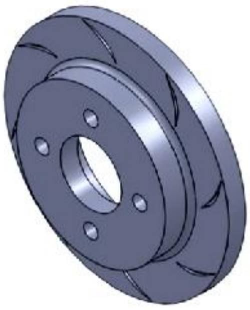

Figure 3.6: Grooved disc brake

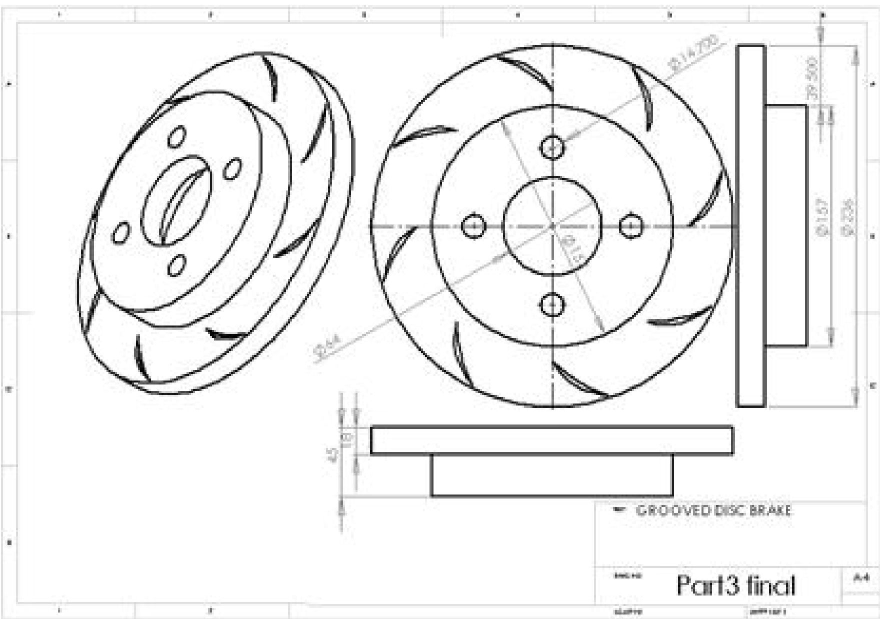

Figure 3.7: Dimension drawing for Grooved disc brake

Figure 3.8: Combination disc brake

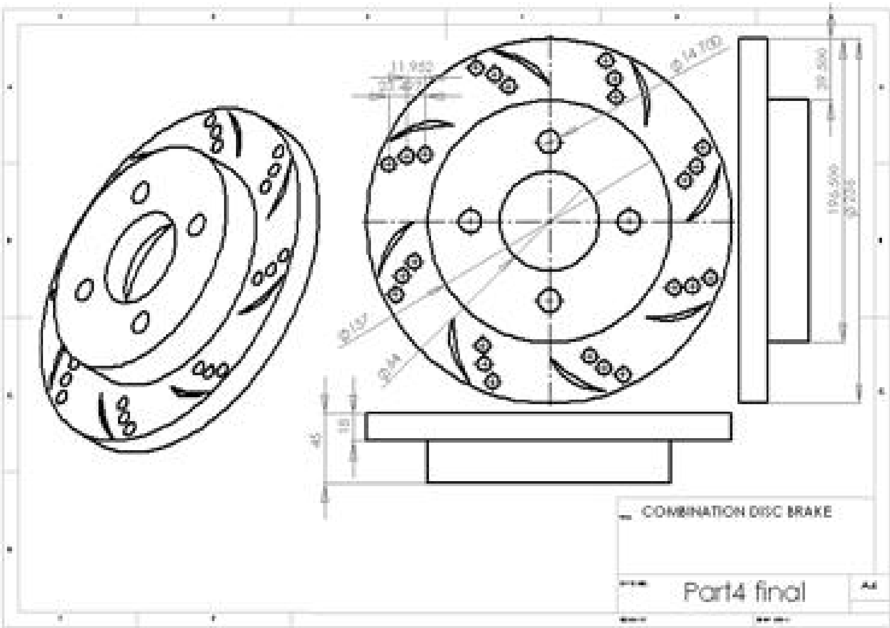

Figure 3.9: Dimension drawing for combination disc brake

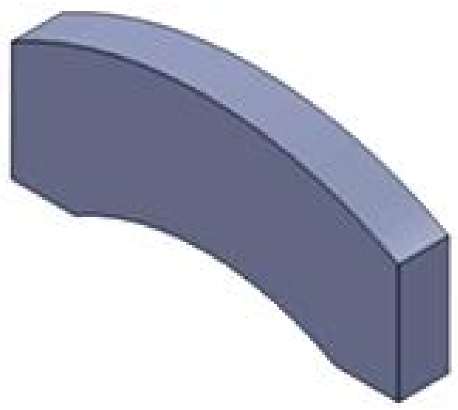

Figure 3.10 Brake pad

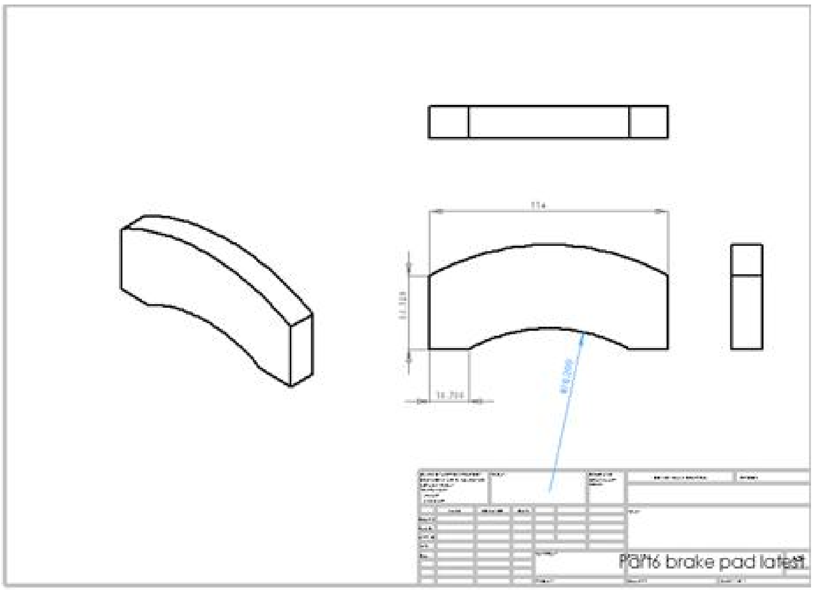

Figure 3.11 Brake pad drawing

Figure 3.12: Disc brake assembly

3.3 ANALYSIS

Algor Fempro version 16 was used for finite element analysis of the disc brake. 3D analysis was done to examine the stress distribution on the surface of disc. 3D model was imported from SolidWork 2012 to Algor Fempro analysis. Analysis type is static stress with linear material model.

In this analyses, 62.5N, 125N and 187.5 N force was applied on each of the disc brake. Material for disc rotor is high carbon, grey iron composition (SAE J431 GRADE G10 (G3000), ASTM A48M Class 30).

Table 3.2: Parameter of Analysis

PARAMETER	**ANALYSIS**
Force apply	62.5N, 125N,187.5N
Coefficient of friction	0.6
Material	Disc: iron, gray cast class 30
	Brake pad: Dupon Kevlar 49 aramid Fibre
Analysis type	Static stress with linear material model.

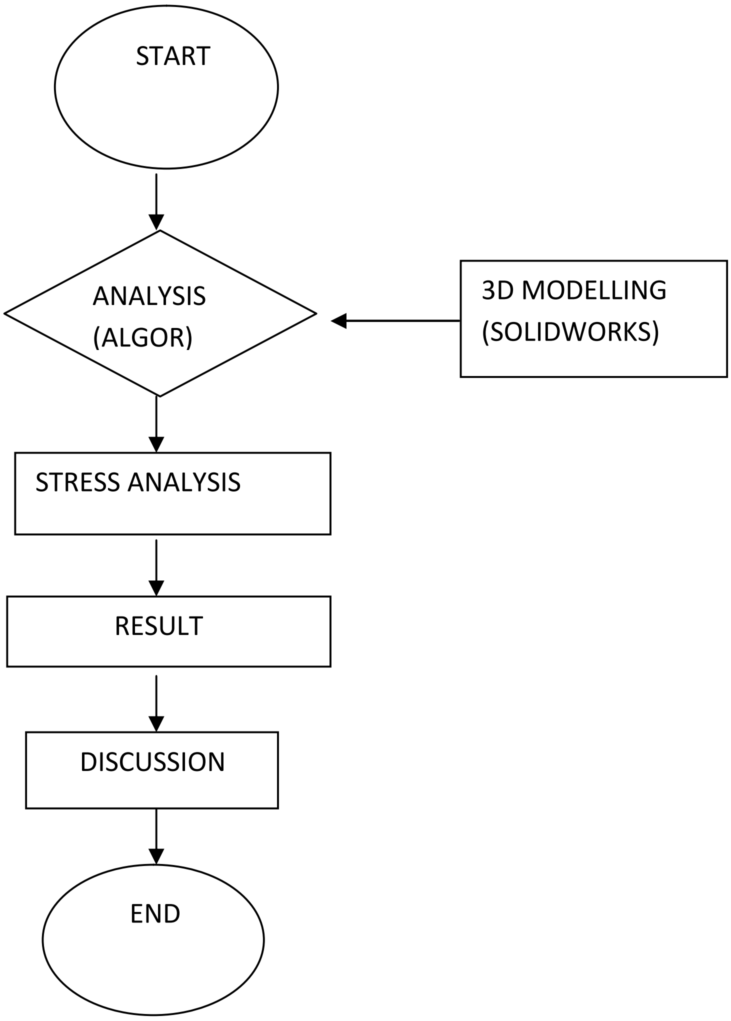

Figure 3.13: Work flow

3.3.1 Mesh Size

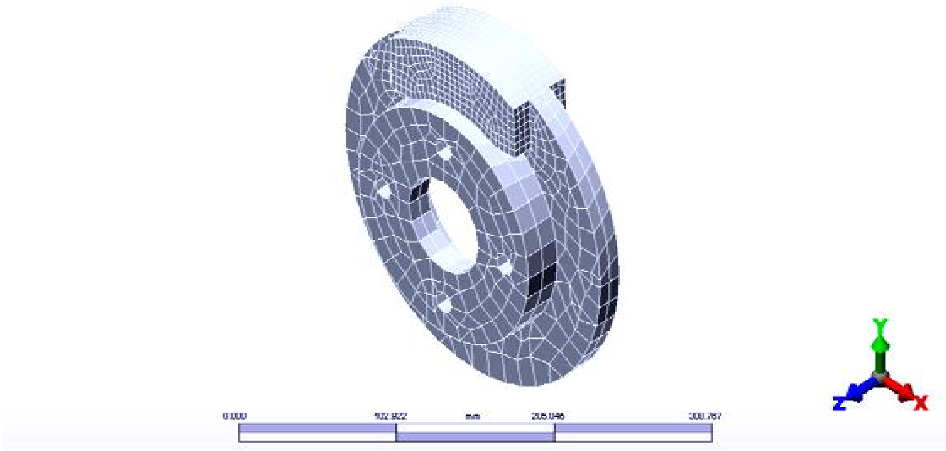

Figure 3.14: 100% mesh size

Theoretically, the smaller the mesh size the result is more accurate but constraint by the computer time to analysis to run. This factor is more obvious when complex model is used. So 100 % is the best selected mesh size.

3.3.2 3D Analysis

The applied pressure on the brake pad is in Newton and the resultant stress taken from analysis is N/mm^2. For easy to build graph the resultant stress taken changed to KN/m^2. Colour gradient start with red and continue with orange, yellow and green until dark blue on top left of the analysis result the stress location. Red spot is the highest von mises stress location.

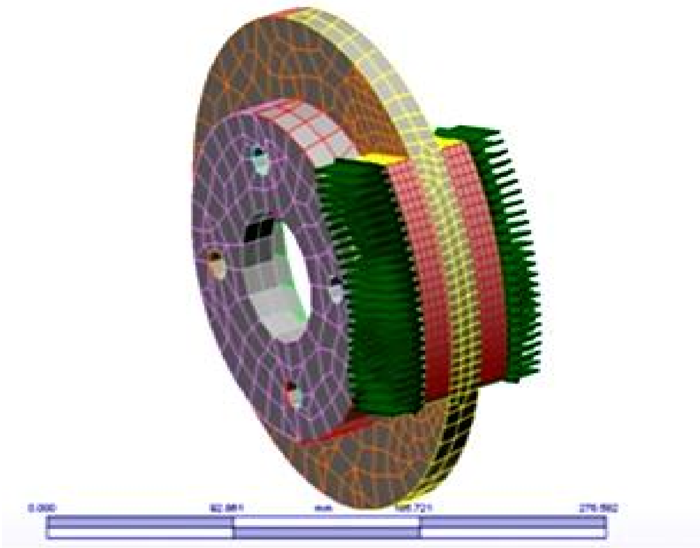

Figure 3.15: Apply force condition

From figure 3.15 the force applied on brake pad. For this project 62.5 N, 125 N and 187.5 N are selected.

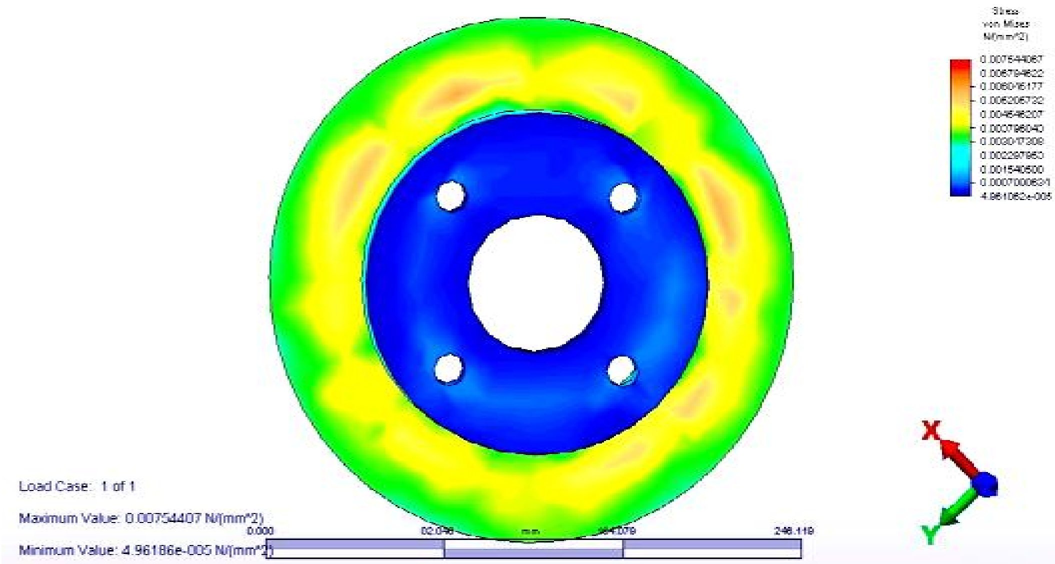

Figure 3.16: Normal disc brake at 62.5N force

From figure 3.15 shows the result and region of the analysis for normal disc brake at 62.5 N force applied. The maximum stress value is

0.00754407 N/mm^2. The stress more concentrated at the middle of disc brake. It illustrate maximum stress happen at the middle on disc brake because have red region at that part.

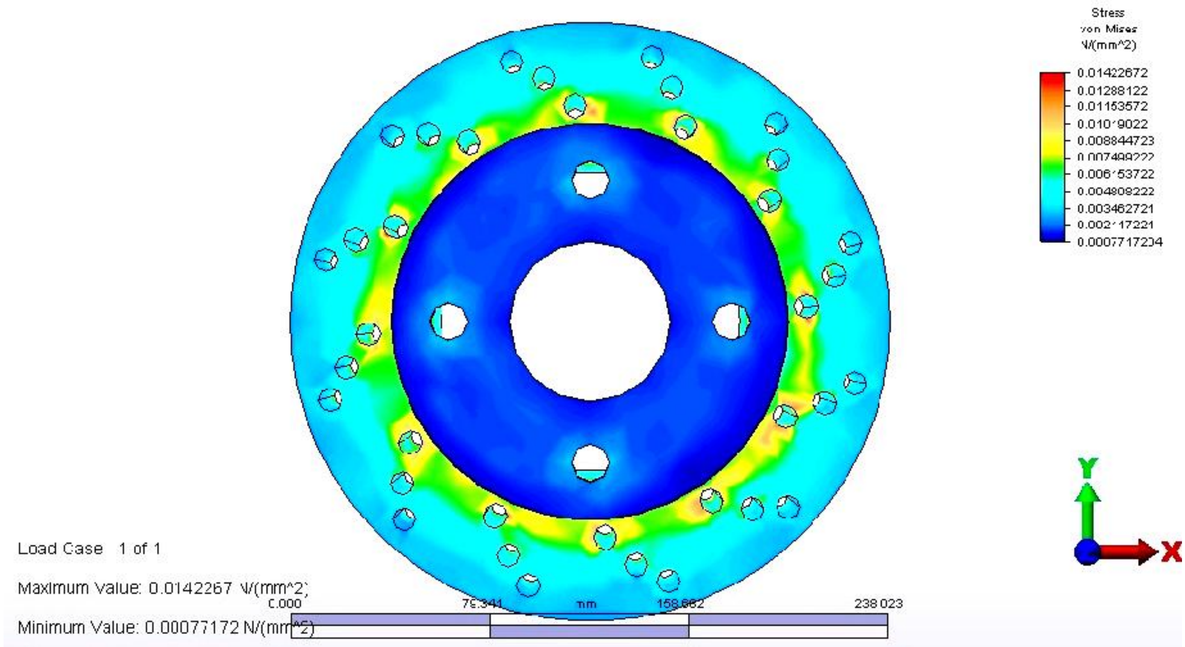

Figure 3.17: Drilled disc brake at 62.5N force

From figure 3.16 show result and region stress happen on the drilled disc brake when 62.5 N force applied on it. From the figure more stress happen at the holes part. The maximum stress is 0.0142267 N/mm^2. From the result drilled disc brake more high stress compare with normal disc brake because the holes at this disc brake contribute more stress compare flat disc like normal disc brake. Red colour concreted more at holes area that show high stress at that part and the holes can caused cracking.

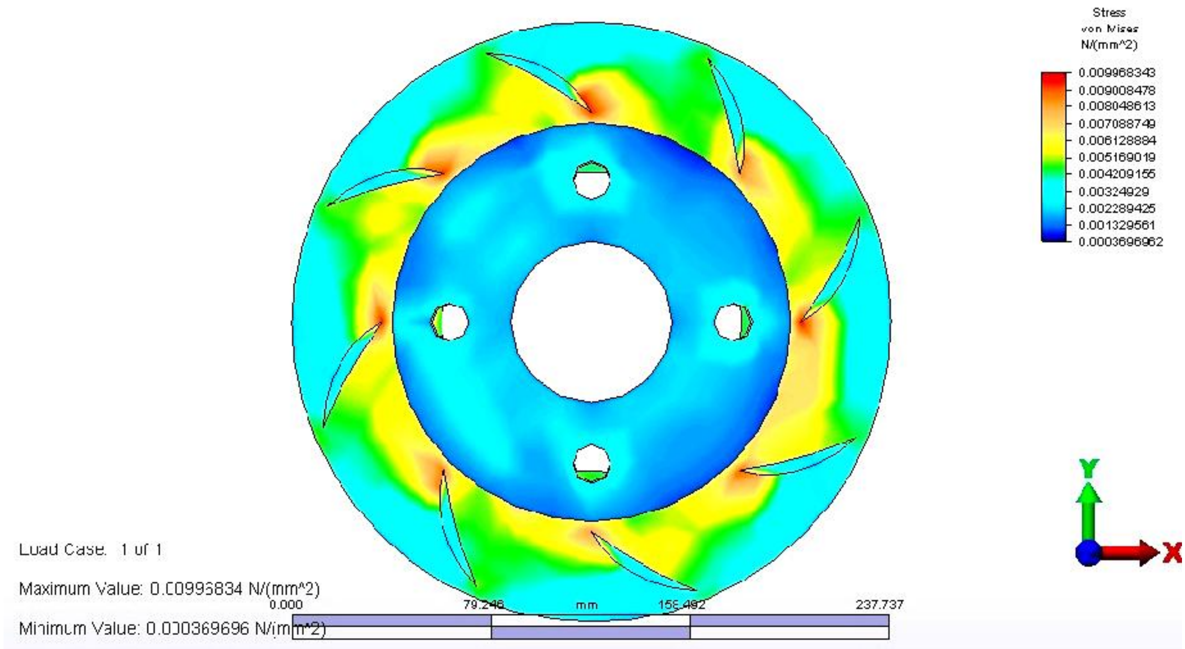

Figure 3.18: Grooved disc brake at 62.5N force

From figure 3.17 show the result and region stress happen on grooved disc brake at 62.5 N. For the grooved disc brake more stress concentrated at diagonal line cut because more red colour at that area. But, the diagonal line cuts not contribute high stress compare with holes at drilled disc brake. That why the values max stress of grooved disc brake low compare value max stress of drilled disc brake.

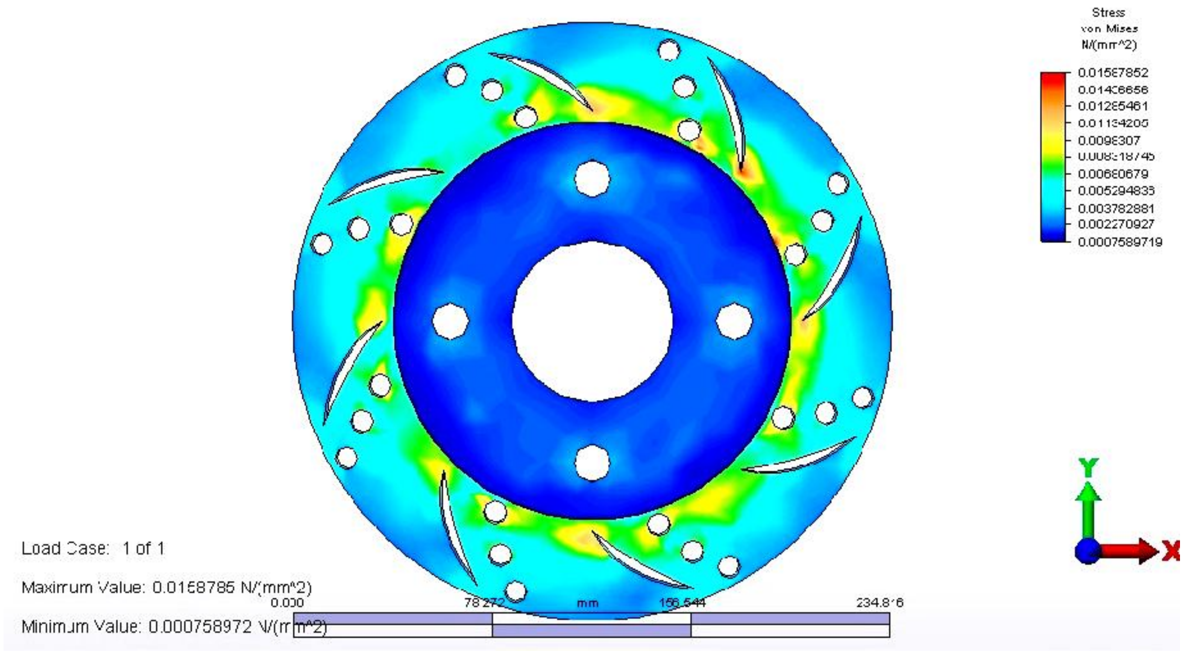

Figure 3.19: Combination disc brake at 62.5 N

Figure 3.19 show the result of the analysis based on stress von mises. It is illustrate the max value of the combination disc brake if applied force at 62.5N. The maximum stress for 62.5 N force is 0.01587585 N/mm^2. From the figure, more stress happen at holes and diagonal line cut on this disc brake. It represent with red colour for the max stress. The holes and diagonal line cut contribute high stress for this disc brake. That why combination disc brake have highest maximum stress compare with other type disc brake.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 SIMULATION RESULT

Table 4.1: Result for 62.5N Force

Types disc brake	**Max stress von mises (kN/m^2)**
Normal disc brake	7.544067
Drilled disc brake	14.22672
Grooved disc brake	9.968343
Combination disc brake	15.87852

Table 4.2: Result for 125N Force

Types disc brake	**Max stress von mises (kN/m^2)**
Normal disc brake	15.08802
Drilled disc brake	27.03406
Grooved disc brake	19.93669
Combination disc brake	31.75681

Table 4.3: Result for 187.5N force

Types disc brake	Max stress vom mises (kN/m^2)
Normal disc brake	22.63209
Drilled disc brake	40.551
Grooved disc brake	29.90503
Combination disc brake	47.63511

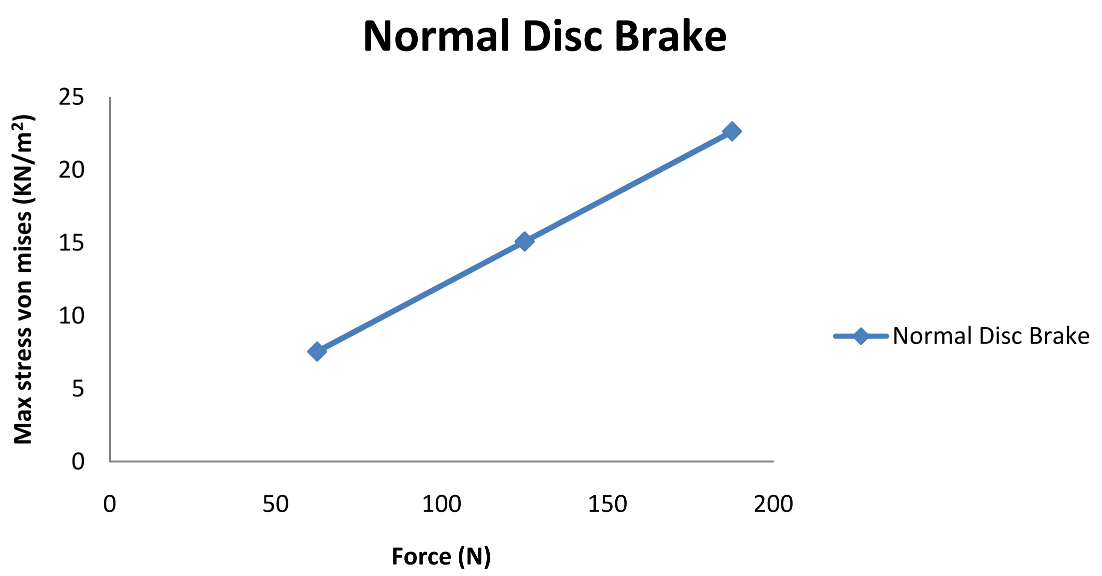

Figure 4.1: Graph max stress von mises vs force for normal disc brake

From figure 4.1 show Max von mises stress vs force for the normal disc brake. Max stress represent y axis and the force represent on the x axis.

When the force applied at 62.5 N the max stress is 7.544067 kN/m^2. When the force increased the max stress also increased, it can see from the graph above. The result for 125 N and 287.5 N applied force is 15.08802 kN/m^2 and 22.63209 kN/m^2. Gradient of this graph is 0.120. The percentage of increasing max stress is 50% from 62.5 N force applied to 125 N force and 187.5 N force.

The normal disc brake have better braking power and it no easy to crack, that why the value of max stress for this brake lower compare with another type disc brake.

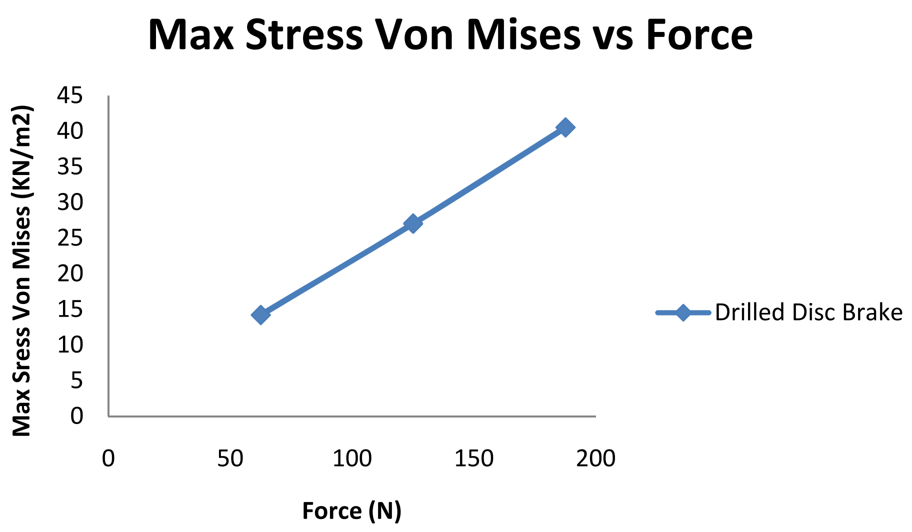

Figure 4.2: Graph max stress von mises vs force for drilled disc brake

Figure 4.2 show Max von mises stress vs force for the drilled disc brake. Max stress represent y axis and the force applied on the disc brake at x axis. The value for force applied is 62.5 N, 125 N and 187.5 N.

From figure 4.2 when the force applied at 62.5 N the max stress are 14.22672 kN/m^2. The drilled disc brake more highest max stress at 62.5 N compare with normal disc brake. The difference value max stress at 62.5 N between disc brake is 6.682653 kN/m^2. When force applied increased to 125 N value for max stress also increased to 27.03406 kN/m^2, same also force 187.5 N applied the values of max stress is 40.551 kN/m^2. Gradient of this graph is 0.121. The percentage of increasing max stress is 50%.

This drilled disc brake highest max stress value compare with normal disc brake because max stress easily happen at the holes part of drilled on this brake. The holes have tendency to cracking during braking process, that why that part contribute more stress for drilled disc brake.

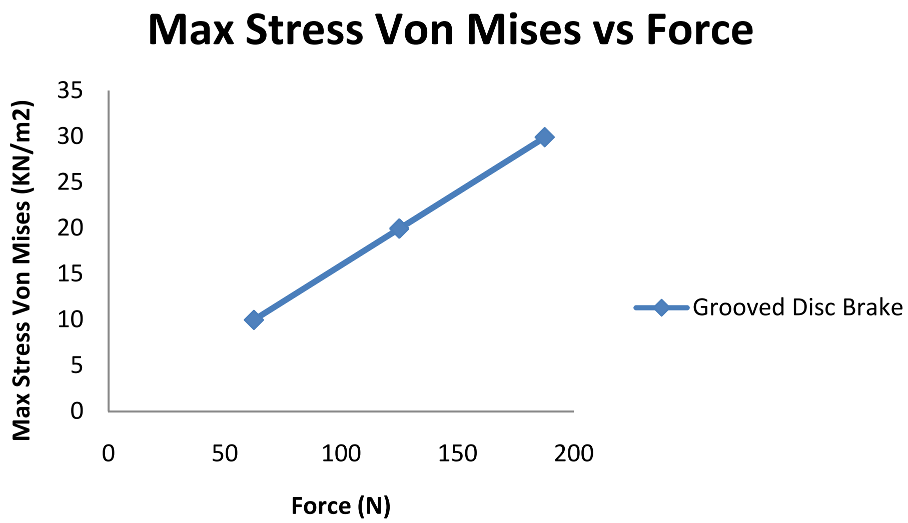

Figure 4.3: Graph max stress von mises vs force for grooved disc brake

Figure 4.3 show Max von mises stress vs force for the grooved disc brake. Max stress represent y axis and the force applied at x axis. 62.5 N, 125 N and 187.5N selected.

When the force applied at 62.5 N the max stress value is 9.968343 kN/m^2. Increased the force to 125 N also caused increased max stress to 19.93669 kN/m^2. Same like force applied at 187.5 Nthe max stress is 29.90503 kN/m ^{2}. The value at force 62.5 N for drilled disc brake low compare with drilled disc brake, about 4.258377 kN/m^2. The percentage that the difference is 29.9%. The gradient of this graph is 0.159. The increased max stress for drilled disc brake is 50%.

This drilled disc brake have low value max stress at 62.5 N compare with drilled disc brake because diagonal line cut exist on this brake disc not more contribute formation stress on this brake. The diagonal line cut have tendency to be noised compare with stress.

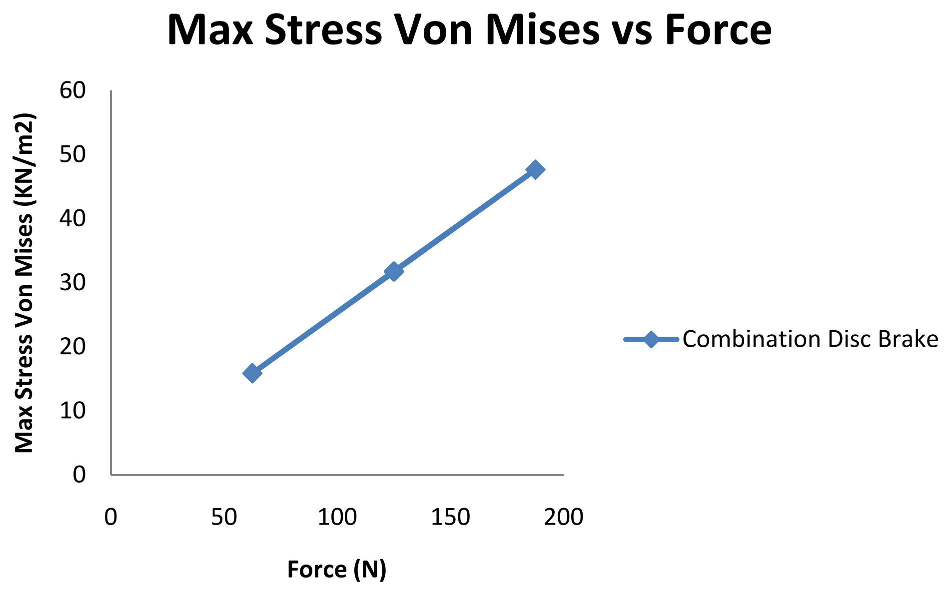

Figure 4.4: Graph max stress von mises vs force for combination disc brake

Figure 4.4 show Max von mises stress vs force for combination disc brake. max stress represent y axis and force represent x axis. Normally combination disc brake combination drilled and grooved disc brake. the force applied to do this stimulation is 62.5 N, 125 N and 187.5 N.

From figure 4.4 15.87852 kN/m^2 max stress was resulted when 62.5 N force applied. At 125 N the value max stress is 31.75681 kN/m^2 and at 187.5 N the max stress values is 47.63511 kN/m^2. At the 62.5 N this disc brake has highest value compare another types disc brake. The different value max stress between combination disc brake and grooved disc brake is 5.910177 kN/m^2. The percentage difference that value is 37.22 %. The gradient of this graph is 0.254.

The gradient value of combination disc brake highest because it produce more stress during braking compare with another types of disc brake. Normally stress deformation occur more at holes at this brake.

4.2 RESULT COMPARISON

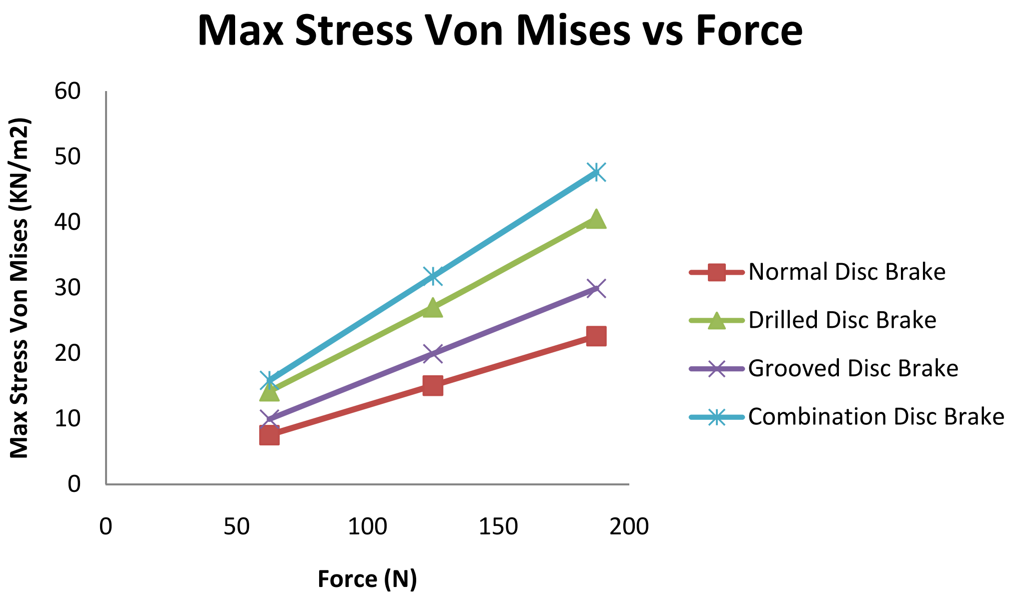

Figure 4.5: Comparison max stress von mises vs force graph between each type disc brake

Figure 4.5 represent comparison scatter graph between each type disc brake. The type disc brake is normal disc brake, drilled disc brake, grooved disc brake and combination disc brake. This graph show max stress von mises versus force which y axis represent max stress value and x axis represent force applied.

At force 62.5 N the highest value max stress is combination disc type 15.87852 kN/m^2 and the lowest value of max stress is Normal disc brake 7.544067 kN/m^2. The difference between highest and lowest value is 8.33445 kN/m^2 and the percentage of this difference is 52.49%. Percentage between combination disc brake with drilled disc brake is 10.40%. Percentage between drilled disc brake with grooved disc brake is 29.93%. Percentage between grooved disc brake with normal disc brake is 24.32%.

At force 125N the highest value max stress is also combination disc brake 31.75681 kN/m^2 and the lowest also normal disc brake 15.08802 kN/m^2. The difference between highest and lowest values is 16.66879 kN/m^2. Percentage between combination disc brake with drilled disc brake is 14.87%. Percentage between drilled disc brake with grooved disc brake is 26.25%. Percentage between grooved disc brake with normal disc brake is 24.32%.

At for 187.5 N the highest value max stress is combination disc brake 47.63511 kN/m^2 and the lowest normal disc brake 22.63209 kN/m^2. The difference between highest and lowest values is 25.00302 kN/m^2. Percentage between combination and drilled disc brake is 14.87%. Percentage between drilled disc brake with grooved disc brake is 26.25%. Percentage between grooved disc brake with normal disc brake is 24.32%.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

From the result of analysis, when the applied force on the brake pad the type combination disc brake have highest value of max stress von mises and type of normal disc brake have lowest value of max stress von mises. The percentage of max stress distribution like table below:

Table 5.1: Percentage max stress distribution for 65N force

Type disc brake (F)	**Max stress von mises (kN/m^2)**	**Percentages of max stress distribution (%)**
Normal disc brake	7.544067	15.84
Drilled disc brake	14.22672	29.88
Grooved disc brake	9.968343	20.93
Combination disc brake	15.87852	33.35

From the table the percentages max stress von mises highest is type combination disc brake is 33.35% and the lowest is type of normal disc brake 15.84%. Combination disc brake have highest value of stress distribution because the holes contribute more stress and easy to crack. This show the normal disc brake more suitable for braking system because have lowest stress compare other type disc brake.

From the graph result, the gradient of normal disc brake lowest compare with each other type disc brake. This show normal disc brake experience low stress during braking process.

5.2 RECOMMENDATION

In this part there are following area have been noted as being worthy for further research

a) Study should be using different software other than solidworks and Finite Element Software
b) Study should running on disc brake in mesh situation more small because result more accurate.

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APPENDICES A1

GANTT CHART FOR FINAL YEAR PROJECT 1

TASK	W 1	W 2	W 3	W 4	W 5	W 6	W 7	W 8	W 9	W 10	W 11	W 12	W 13	W 14
Background study														
Project understanding														
Work planning														
Problem identification														
Chapter 1														
Chapter 2														
Chapter 3														
Project proposal preparation														
Project proposal approval														
Presentation 1 preparation														
Project presentation 1														

APPENDICES A2

GANTT CHART FOR FINAL YEAR PROJECT 2

TASK	W 1	W 2	W 3	W 4	W 5	W 6	W 7	W 8	W 9	W 10	W 11	W 12	W 13	W 14	W 15	W 16
CAD Disc and other modeling																
Analysis																
Progress Presentation																
Chapter 4: Result & Discussion																
Chapter 5: Conclusion & Recommendation																
Preparation For Presentation																
Project Presentation 2																
Final Report Preparation																
Final Report Approval																
Final Report Submission																