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DESIGN AND FABRICATION OF A LIGHTWEIGHT DRY CLUTCH DISC FOR A MINI FARMING TRACTOR

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ABSTRACT

DESIGN AND FABRICATION OF A LIGHTWEIGHT DRY CLUTCH DISC FOR A MINI FARMING TRACTOR

(Keywords: carbon clutch disc, finite element analysis).

In this research, the design of carbon composite clutch facing for the use of mini agricultural tractor dry clutch disc is presented. The main factor that needs to be considered in order to design a clutch disc facing is the torque produced by the engine. An optimum clutch facing disc should have minimum in weight, simple to manufacture and high reliability. Finite element analysis is conducted to determine the maximum stress the designed clutch disc facing before the fabrication take place. The design carbon facing is then fabricated by using Computer Numerical Controlled (CNC) 5-axis milling machine. The completed design will then used for experimental analysis to determine its reliability and durability.

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INTRODUCTION

1.1 Background

In this research, a clutch friction disc material for dry clutch of a mini farming tractor will be designed and fabricated.

A clutch is a mechanical device, by convention understood to be rotating, which provides driving force to another mechanism when required, typically by connecting the driven mechanism to the driving mechanism. The name of clucth has become established due to its meaning of grasp or grip tight.

Clutches are useful in devices that have two rotating shafts. In these devices, one shaft is typically attached to a motor or other power unit (the driving member), and the other shaft (the driven member) provides output power for work to be done. The clutch connects the two shafts so that they can either be locked together and spin at the same speed (engaged), or be decoupled and spin at different speeds (disengaged).

Dry clutch are widely used on large trucks and heavy industrial units. The main advantages of dry clutch is its large contact area and the main components of a dry disc clutch are pressure plate and the disc.

CHAPTER 1

INTRODUCTION

1.1 Background

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Dry clutch are widely used on large trucks and heavy industrial units. The main advantages of dry clutch is its large contact area and the main components of a dry disc clutch are pressure plate and the disc.

1.2 Objectives

The objectives of this project are:

1. To design a lightweight dry clutch disc for a mini farming tractor by using CAD software (CATIA).
2. To do finite element analysis of the design by using FEA software (ANSYS VERSION 12.1).
3. To fabricate the completed designed of the lightweight clutch disc friction material.

1.3 Scopes

The scopes of study for this project are:

1. Design the clutch disc for a mini farming tractor.
2. Analysis (static and linear) on the designed clutch disc.
3. Produce engineering drawing of the clutch disc.
4. Fabricate the lightweight clutch disc friction material

1.4 Problem Statement

Agriculture is the third largest economy in Malaysia. Hence, tractors have been used extensively like in paddy field, and palm oil estates to work like plugging, seeding and harvesting.

A lightweight disc clutch is an essential part for a mini farming tractor. The lighter the overall weight, the higher the fuel efficiency will be. Apart from that, the light clutch enables the manoeuvre without the feel of high contact pressure, it is driver friendly. In addition, by reducing weight can enable the reduction of fuel consumption and can enhance the performance of the tractor.

There are not many references that can be obtained pertaining to methods need to be employed in order to design a proper tractor clutch disc. The resources are very limited. Therefore, a reverse engineering process need to be undergone in order to acquire know how knowledge of designing clutch disc. In this project, benchmarking will be made against a real model of clutch disc that is available in market. Therefore, by embarking into this project, the methods to design a clutch disc can be acquired. The drawings of the clutch disc will be done by using CATIA V5 software. Once the designed have been completed, the engineering analysis will be conducted. Finite Element Analysis (ANSYS V12.1) software that is available in the faculty will be fully utilized for this project. After the analysis is accomplished, the next step of the research will be embarked. The fabrication of the design clutch disc friction material will be done by using Computer Numerically Control (CNC) machine.

CHAPTER 2

LITERATURE REVIEW

2.1 History of Tractor

The first known tractor was introduced in 1868. The tractor used steam as it power. The most popular steam tractor was the Garrett 4CD. It was Charter Gasoline Engine Company that had introduced gasoline powered tractor back in as early as 1887. The company adapted its engine to a Rumley steam-traction-engine chassis, and in 1889 produced six of the machine to become one of the first working gasoline traction engines (Ralph W. Sanders, 1999).

Apart from Charter's tractor, there were few other gasoline powered tractor were introduced in 1880s. For an instance, a tresher named John Froelich used gasoline powered tractor for threshing work. Froelich used the machine succesfully to power a threshing machine by belt during his 52 days harvest season of 1892 in South Dakota. The Froelich tractor, forerunner of the later Waterloo Boy tractor, is considered by many to be the first succesful gasoline tractor known. Froelich's machine fathered a long line of stationary gasoline engines and, eventually, the famous John Deere two cylinder tractors.

The famous automotive industrialist, Sir Henry Ford produced his first emperimental gasoline tractor in 1907. The command to produce the tractor came under the direction of chief engineer Joseph Galamb. It was referred to as an "automobile plow". After 1910 and onward, petrol powered tractos were used entensively in farming (Dean Stanley, 2001).

2.1.1 General Idea on Farming Tractor

A tractor is a device intended for drawing, towing or pulling something which cannot propel itself and, often, powering it too. The word is commonly used to describe a vehicle intended for such a task on some other vehicle. Generally, tractor is used as a replacement for animal in farming industry. The classic farm tractor is a simple open vehicle with to very large driving wheels on an axle below and slightly behind a single seat and the engines in front of the driver with two steerable wheels below the engine compartment. This basic design has remain unchanged for a number of years, but now enclosed cabs are available for many models of farm tactor. Modern farm tractors range in size from 18 to 500 horsepower (15 to 400 kW). Tractors can be generally classified as two wheel drive, two wheel drive with front wheel assist, or four wheel drive (with articulated steering). In western region, most farmers change from horse to tractor by the end of the World War II.

Modern farm tractors are classed in three groups: general-purpose (land utility) tractors, universal-row-crop (row-crop utility) tractors, and special purpose tractors. *Land utility tractors* are used for major farm operations common to the cultivation of most crops, such as tillage, discing, general cultivation, harrowing, sowing and harvesting. The tractors are also characterized by a low ground clearance, increased engine power and good traction. *Universal-row-crop tractors* are intended for row-crop work, as well as for many other fields task. Some row-crop utility tractors are provided with replaceable driving wheels of different tread widths-wide for general farm and narrow for row-crop work. In order not to damage plants, the tractors have a high ground clearance a wide wheel track that can be adjusted to suit the particular inter-row distance. *Special-purpose tractors* are modification of standard land or row-crop utility tractor models and are used for definite jobs, for example in cotton fields or for various jobs under certain condition, for example on marshy soils or hillsides.

2.1.2 Importance of Farm Tractor

The farm tractor is used for pulling agricultural machinery or trailers, for ploughing, harrowing and similar tasks. Farmers found that tractor can save time and can be used for a combination of operation rather than a single task in a complex chain of process. In Malaysia, tractor mostly used in paddy and palm oil farm to do works like plugging, seeding and harvesting. However, the used of tractor are widening to land clearing, slashing grass and collecting grass clippings, leave and twig. Farming tractor generally used diesel engine to propel the wheels. The main reason is although the initial cost of diesel engine is higher, but it is often offset by the amount of fuel cost that can be saved. In short, usage of diesel tractors is more cost effective than gasoline engine tractor. This is due to the higher effeciency of diesel engine which results in lowering fuel consumption. Moreover, diesel engine always operates at lean fuel mixture. It also have better in term of torque capacity which is good for rough work and uneven terrain.

2.2 CLUTCH

Clutches are useful in devices that have two rotating shafts. In these devices, one shaft is typically attached to a motor or other power unit (the driving member), and the other shaft (the driven member) provides output power for work to be done. The clutch connects the two shafts so that they can either be locked together and spin at the same speed (engaged), or be decoupled and spin at different speeds (disengaged). A clutch can be defined as a mechanical device, by convention understood to be rotating, which provides driving force to another mechanism when required, typically by connecting the driven mechanism to the driving mechanism. The name of clutch has become established due to its meaning of grasp or grip tight.

Clutch disc can be either dry or wet. Dry here means the clutch operates in dry condition. The clutch facing of dry running clutches are the force closure couplings (Czel et al.,2009). On the other hand, wet here means, the clutch operates in oil bath or spray. Dry clutch are widely used on large trucks and heavy industrial units. The main advantages of dry clutch are its large contact area and the main components of a dry disc clutch are pressure plate and the disc (Hillier & Coobes, 2004).

According to Sfarni et al. (2009), an optimum clutch system is a system where it gives more power transmission, high comfort, highly effective, and low cost in design

2.2.1 Disc Clutch

Disc clutch can be either dry or wet. Dry here means the clutch operates in dry condition. On the other hand, wet here means, the clutch operates in oil bath or spray. Dry clutch are widely used on large trucks and heavy industrial units. The main advantage is it large contact area. However, dry clutch are not recommended to be used in condition where frequent disengaging or slipping is required due to the heat build up (Donald et al. 1974). Wet clutch are actuated either mechanically or hydraulically. Operation in oil reduces wear and provides cooler operation. The major difference between the dry and the wet clutch is that the disc facing material. In a wet clutch, this material must grip when soaked in oil. The two main components of the dry clutch are pressure plate and the disc clutch.

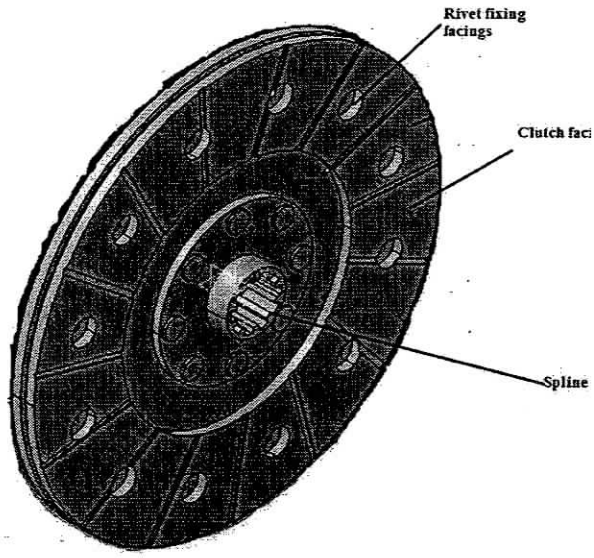

Figure 2.1 Clutch disc components

The clutch disc may be rigid or flexible. A rigid clutch disc is a solid circular disc fastened directly to the center hub. On the other hand, flexible disc has torsion dampener springs around the hub. When the clutch is engaged, the dampener springs flex and allow the clutch disc to twist slightly in its shaft. Twisting absorbs some of the sudden power impulses from the engine when the clutch is engaged and reduces shocks loads on the transmission. The facing of the clutch disc is usually made of asbestos woven wire material.

Asbestos is nearly an ideal friction material for brake lining and clutch facing because it has a very good coefficient of friction, exellent heat characteristics, and low cost (Thomas Birch, 1999). However, it has the possibility to cause cancer from inhaling its fibers. Due to this, the use of asbestos has been decreased significantly. Asbestos has been replaced with fiberglass and aramid nonmetallic compounds and metallic friction facings using various mixtures of powdered iron, copper, graphite, and ceramics to obtain the desired friction and wear characteristics.

Some clutches use a ceramic material of clay and metal. Frequently a composite metallic friction material or a cellular paper material is used. These materials have good durability and friction capacity in oil. However, ceramics have several disadvantages. Firstly, it is difficult to be manufactured and secondly is ceramics can cause the mated pairs to wear excessively.

The pressure plate provides the means of engaging the clutch disc. A typical pressure plate assembly has a clutch plate, bracket, release levers, and working springs (Donald etc al. 1974). The heavy plate engages the clutch by pressing the disc against the flywheel surface. The bracket is bolted directly to the flywheel and support the release levers and springs. The levers pivot in bosses on the plate. When the levers are depressed by the release bearing, the plate is pulled away from the clutch disc. When the clutch pedal is released, the compressed clutch springs force the pressure plate holds the facing of the clutch disc against the machined surfaces of the flywheel. Because the clutch disc is splined to the transmission input shaft, power is transmitted to the transmission.

2.3 THERMAL BEHAVIOR OF AUTOMOTIVE FRICTION CLUTCH

Numerous researched on friction clutch especially regarding thermal capacity of the system have been studied for years now by researches in multiple fields. The automotive clutches generate heat from the rubbed surface due to power dissipation by frictional slip between flywheel and clutch disc and between the clutch disc and pressure plate (Lee & Cho, 2006). When the member of a machine are initially at rest are brought up to speed, slipping must occur in the clutch until the driven members have the same speed as the driver. Kinetic energy is absorbed during slippage of a clutch, and this energy appears as heat. Temperature rise occurs when heat is generated faster than it is dissipated (Shingley, 2003). The generated heat has a considerable influence on the efficiency of the clutch and it is important to keep the clutch under some critical temperature ranges. Otherwise, the overheated clutch could fail or work at very low efficiency. Therefore, assessment of the clutch thermal capacity is essential especially in the early stage of its design (Lee & Cho, 2006).

However, due to the rush towards higher performances has increased sliding operative speeds of clutches and other sliding system (Afferante et al., 2003). Increase of sliding speed resulted in the increse of frictional heat generated during clutch engagement. Excessive frictional heat may create thermal distortion and deformation on the clutch disc contact surface. Thermal distortions of friction disc caused by frictional heating modify pressure distribution on friction surface. Pressure distributions, in turn, determine distribution of generated frictional heat. These interdependencies create a complex thermoelastic system that, under some condition, may become unstable and may lead to severe pressure concentrations with very high local temperature and stress. This phenomenon is responsible for many common thermal failure modes of friction elements and is known as frictionally excited thermoelastic instability (Zagrodzki & Fams, 1998).

CHAPTER 3

RESEARCH APPROACH

3.1 DESIGNING THE CLUTCH DISC

In designing the clutch disc, the following criteria need to be considered:

i. Sizing
ii. Material selection
iii. Configuration
iv. Overall sizing
v. Disc plate

The first two criteria are very important parameters needed in order to design a clutch disc. Apart from that, assumption that need to be undertaken are:

i. Complete contact of the clutch disc
ii. The pressure due to the contact is uniform.

According to Shingley, Mischeke, Budynas (2003), the factors that determine the amount of the torque a clutch can transmit are: friction area, nature of the friction surace, diameter of friction surface, and amount of pressure which holds the surfaces together. Generally, the greater the friction area and diameter of the surfaces, the greater the torque capacity of the clutch.

Apart from that, an increase or decrease in the pressure which holds the friction surfaces together results in an increase or decrease in torque capacity of clutch. Besides that, the type and condition of friction surfaces also affect the clutch torque capacity. As an example, a glazed, smooth facing will be reduces the amount of torque that a clutch can transmit. Figure 3.1 shows the clutch geometry.

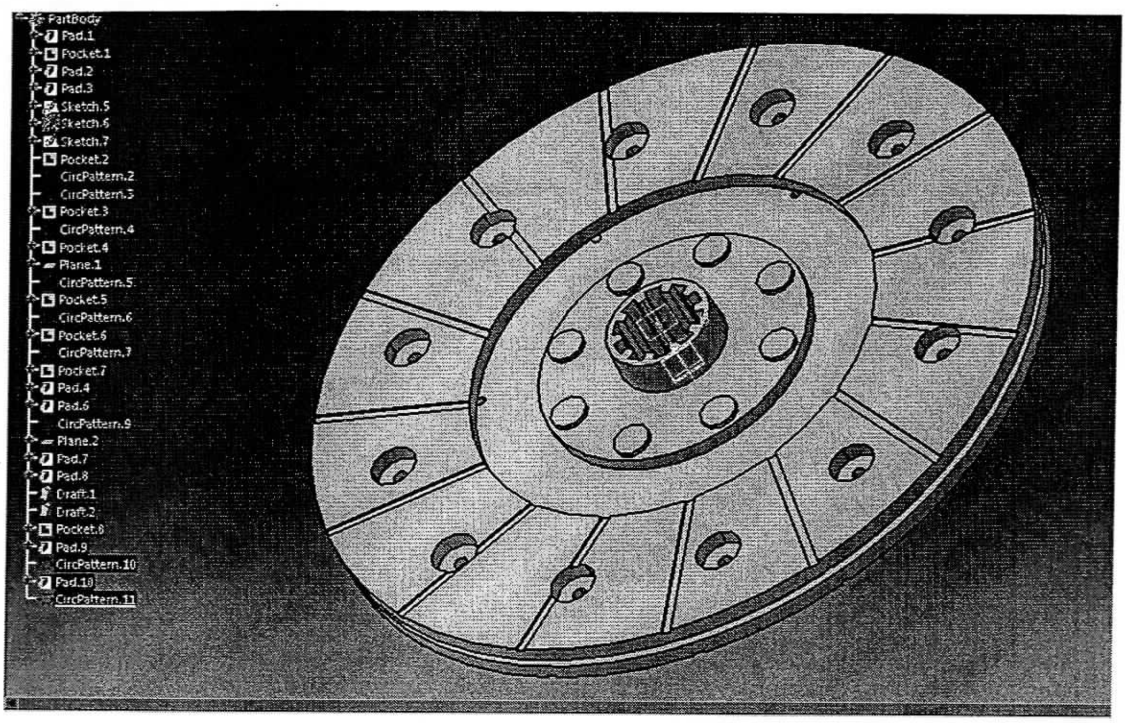

Figure 3.1: Clutch Design Geometry

3.1.1 Determining the Clucth Disc Diameter and the Value of Axial Force

To calculate for torque that the clutch can transmit, the formula below is used:

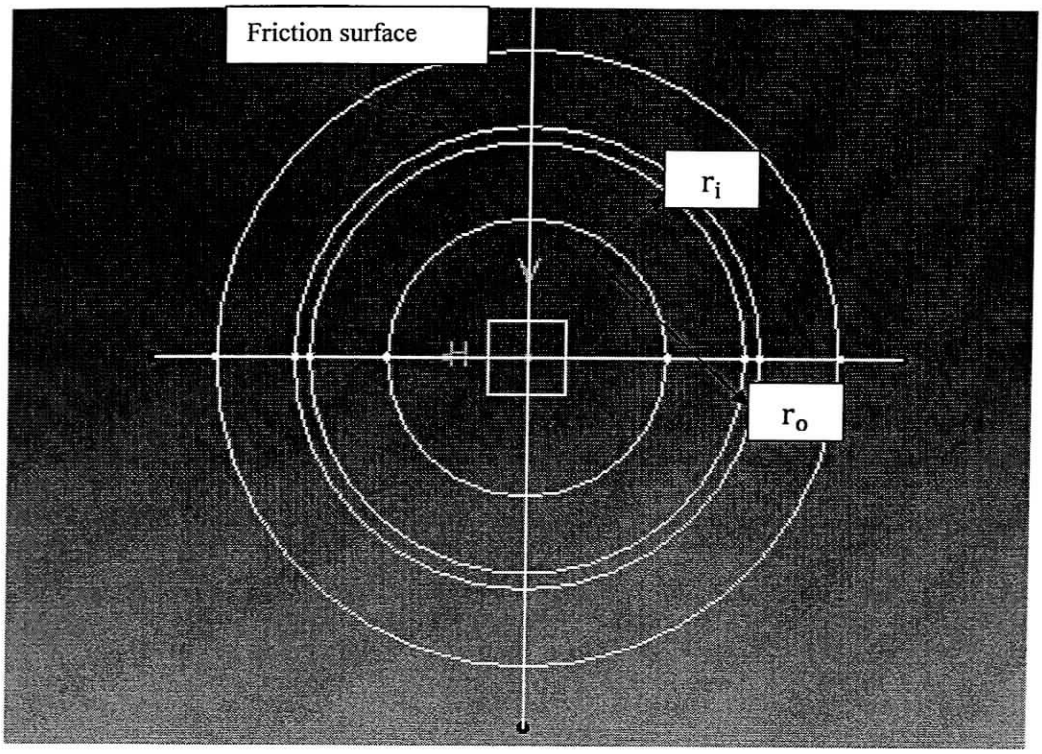

Figure 3.2 Radius of the Clutch

$$T = \pi P_{max} r_i f(r_o^2 - r_i^2)N$$

Where:

T	= torque transmitted, Nm
P_{max}	= maximum pressure applied onto the clutch, Pa
f	= coefficient of friction (depends on material used)
r_o	= outer radius, m
r_i	= inner radius, m
N	= number of friction surface

To calculate for the axial force, the formula below is used:

$$F_a = \frac{1}{2}\pi P_{max} D_i (D_o - D_i)$$

Where:

D_i = inner diameter of the clutch, m

D_o = outer diameter of the clutch, m

3.2 MATERIAL SELECTION

The availability of asbestos in automobile components like clutches, brakes and gasket may bring potential health risk to the automotive mechanics (Kakooei & Marioryad, 2008). Therefore, there is a need to replace the material used in the present automotive clutches to alternative material which has no potential threat to human health.

3.2.1 Carbon-carbon Composite

Carbon composite clutch disc is one of the alternatives to asbestos woven clutch. Carbon composite materials are used extensively in high performance racing cars especially in Formula 1 (Savage, 2010). It was first used in aircraft industries back in 1970s. (Stadler,2008). Apart from light in weight, carbon-composite materials have high melting temperature, low density, high thermal conductivity and shock resistance, low thermal expansion, and high elastic moduli. These criteria is suitable for structural application in extreme temperature surroundings (Zhao,2008). Testing of clutch facing materials had been successfully by previous researchers (Angulo et al., 2008).

3.2.2 Properties of Carbon-carbon Composite

Carbon-carbon composites have the capability of stuctural integrity at temperature above 1000 °C. Compared to the other composite materials, carbon-carbon composite has a very high thermal and elecrical conductivity which are 12-15 times higher in the fiber direction than perpendicular to the fiber (John & Dan, 1993). The mechanical properties are much superior to those conventional graphite. In particular three-dimensional, carbon-carbon composite can be tailored to withstand damage and minimum delamination crack growth under inter laminar shearing.

Table 3.1: Properties of Carbon-carbon Composite

Density	1.70 x 10^3 kg/m^{-3}
Young's Modulus	95 Gpa
Poisson's Ratio	0.32
Tensile Strength	83 Mpa
Thermal Conductivity	31 W/mK

3.3 FINITE ELEMENT ANALYSIS

The finite element analysis (FEA) is a numerical technique for finding approximate solutions of partial differential equations (PDE) as well as of integral equations. The solution approach is based either on eliminating the differential equation completely (steady state problems), or rendering the PDE into an approximating system of ordinary differential equations, which are then numerically integrated using standard techniques.

Finite Element Analysis (FEA) consists of a computer model of a material or design that is stressed and analyzed for specific results. It is used in new product design, and existing product refinement. It's a powerful engineering tool that can solve many kinds of engineering problems to as high a degree of precision as necessary.

A variety of specializations under the umbrella of the mechanical engineering discipline such as aeronautical, biomechanical, and automotive industries commonly use integrated FEA in design and development of their products. Several modern FEA packages include specific components such as thermal, electromagnetic, fluid, and structural working environments. In a structural simulation, FEA helps tremendously in producing stiffness and strength visualizations and also in minimizing weight, materials, and costs.

FEA allows detailed visualization of where structures bend or twist, and indicates the distribution of stresses and displacements. FEA software provides a wide range of simulation options for controlling the complexity of both modeling and analysis of a system. Similarly, the desired level of accuracy required and associated computational time requirements can be managed simultaneously to address most engineering applications. FEA allows entire designs to be constructed, refined, and optimized before the design is manufactured.

This powerful design tool has significantly improved both the standard of engineering designs and the methodology of the design process in many industrial applications. The introduction of FEA has substantially decreased the time to take products from concept to the production line. It is primarily through improved initial prototype designs using FEA that testing and development have been accelerated. In summary, benefits of FEA include increased accuracy, enhanced design and better insight into critical design parameters, virtual prototyping, fewer hardware prototypes, a faster and less expensive design cycle, increased productivity, and increased revenue.

3.4 SOFTWARE OF FINITE ELEMENT ANALYSIS

ANSYS is an engineering simulation software computer-aided engineering (CAE). Once the design has been finalized, Finite Element Analysis was conducted by using ANSYS. The Static Structural was used in the analysis.

The core product of Ansys is its ANSYS multiphysics or structure mechanics module. This code is based on the finite element analysis and is capable of performing static stress analysis, thermal analysis, modal analysis, frequency response analysis, transient simulation and also coupled field analysis. The Ansys multiphysics can couple various physical domains such as structural, thermal and electromagnetics.

3.5.1 Static Structural Analysis

Structural analysis comprises the set of physical laws and mathematics required to study and predict the behavior of structures. The structural analysis are engineering artifacts whose integrity is judged largely based upon their ability to withstand loads, they commonly include buildings, bridges, aircraft, ships and cars. Structural analysis incorporates the fields of mechanics and dynamics as well as the many failure theories. From a theoretical perspective the primary goal of structural analysis is the computation of deformations, internal forces, and stresses. In practice, structural analysis can be viewed more abstractly as a method to drive the engineering design process.

To perform an accurate analysis a structural, it must determine such information as structural loads, geometry, support conditions, and materials properties. The results of such an analysis typically include support reactions, stresses and displacements. This information is then compared to criteria that indicate the conditions of failure. Advanced structural analysis may examine dynamic response, stability and non-linear behavior.

3.5 MESHING IN ANSYS

Meshing consists of semi-permeable barrier made of connected strands of metal, fiber, or other flexible or ductile material. Mesh is similar to web or net in that it has many attached or woven strands. Subdivision surface, in the field of 3D computer graphics, is a method of representing a smooth surface via the specification of a coarser piecewise linear polygon mesh. The smooth surface can be calculated from the coarse mesh as the limit of a recursive process of subdividing each polygonal face into smaller faces that better approximate the smooth surface. Figure 3.3 depict the meshing of the designed clutch disc.

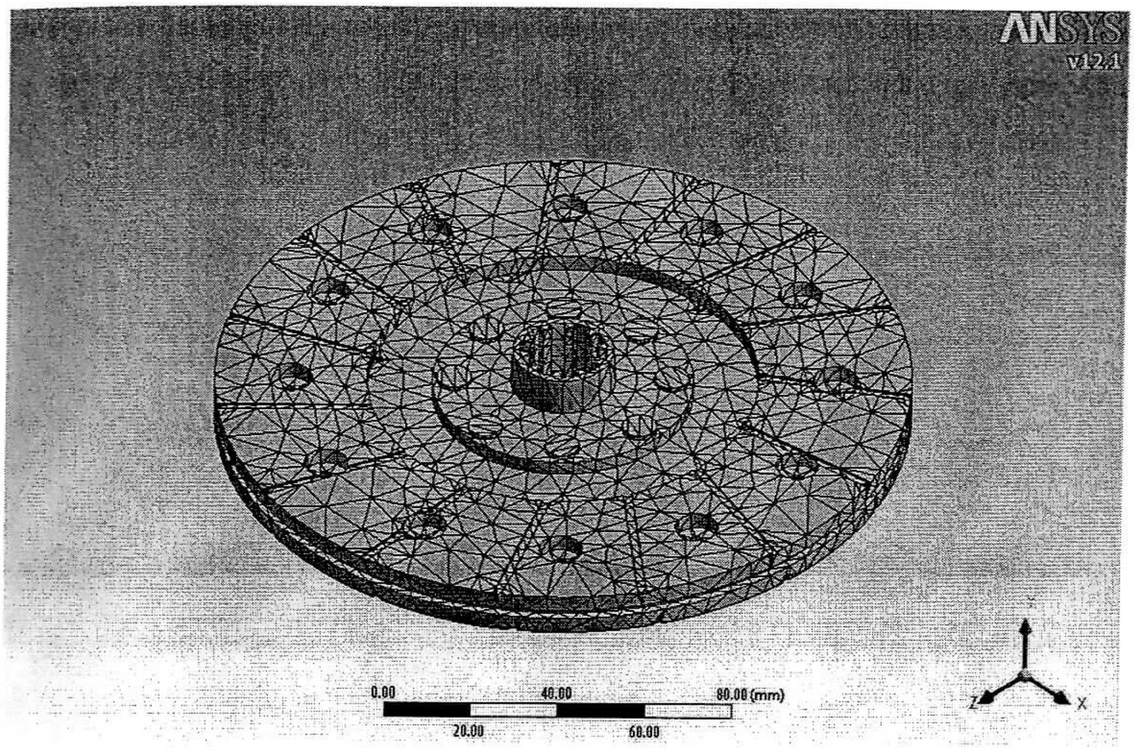

Figure 3.3: Meshing of the clutch disc

In this analysis, coarse meshing type is used. Coarse meshing is a default meshing in ANSYS. The function of meshing is to calculate the critical area of the part or surface when the load is applied. It will calculate the every meshing area with details information about the stress, strain and deformation and will notify if the part is failure when the load is applied.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 DESIGNING THE CLUTCH DISC FRICTION MATERIAL

4.1.1 Calculating the Clutch Diameter, D

Formula used:

$$T = \pi P_{max} r_i f(r_o^2 - r_i^2)N$$

Assumption:

i. $r_i = 0.58r_o$
ii. Pressure applied onto the clutch uniform.
iii. The factor of safety, F.O.S = 1.5 (Automotive application F.O.S = 1.38 - 1.5).
iv. The material for the friction material is woven asbestos applied on steel.

Given that:

i. The maximum torque required for the clutch to transmit is 150 Nm

ii. $T = 1.5 \times 150$ Nm = 225 Nm

iii. $N = 2$

iv. $f = 0.3$ (Obtained from table in Appendix)

v. $P_{max} = 684\ 000$ Pa (Obtained from table in Appendix)

Carry out the calculation:

$$T = \pi P_{max} r_i f(r_o^2 - r_i^2)N$$

$$T = \pi P_{max}\, 0.58 r_o\, f(r_o^2 - 0.58 r_o^2)N$$

$$T = \pi P_{max}(0.3849 r_o^3)N$$

$$225 \text{ Nm} = (3.142)(684\ 000 \text{ Pa})(0.3)(0.3849 r_o^3)(2)$$

$$r_o^3 = 4.5334 \times 10^{-4} \text{ m}$$

$$r_o = 0.0768 \text{ m}$$

$$r_i = 0.58 r_o$$

$$= 0.58(0.0768 \text{ m})$$

$$= 0.0445 \text{ m}$$

Therefore:

$$D_o = 0.1536 \text{ m}$$

$$D_i = 0.0890 \text{ m}$$

These values are the minimum values that should be used to accommodate the maximum torque of the tractor engine.

4.1.2 Calculating the Axial Force, F_a

Formula used:

$$F_a = \frac{1}{2}\pi P_{max} D_i (D_o - D_i)$$

Carry out the calculation:

$$F_a = \frac{1}{2}\pi P_{max} D_i (D_o - D_i)$$

$$F_a = \frac{1}{2}(3.142)(684\ 000\ \text{Pa})(0.0890\ \text{m})(0.1536\ \text{m} - 0.0890\ \text{m})$$

$$F_a = 6178.0983\ \text{N}$$

Multiply with the factor of safety;

$$F_a = 1.5(6178.0983\ \text{N})$$

Therefore,

$$F_a = 9267.1474\ \text{N}$$

4.2 RESULTS OF FINITE ELEMENT ANALYSIS

4.2.1 Force Applied On The Friction Surface

Structural loads are forces applied to a component of a structure. In structural design, assumed loads are specified in national and local design codes for types of structures, geographic locations, and usage. In addition to the load magnitude, its frequency of occurrence, distribution, and nature of static or dynamic are important factors in design. Loads cause stresses, deformations and displacements in structures. Assessment of their effects is carried out by the methods of structural analysis. Excess load or overloading may cause structural failure, and hence such possibility should be either considered in the design or strictly controlled

Figure 4.1 depicts the structural load applied onto the disc clutch.

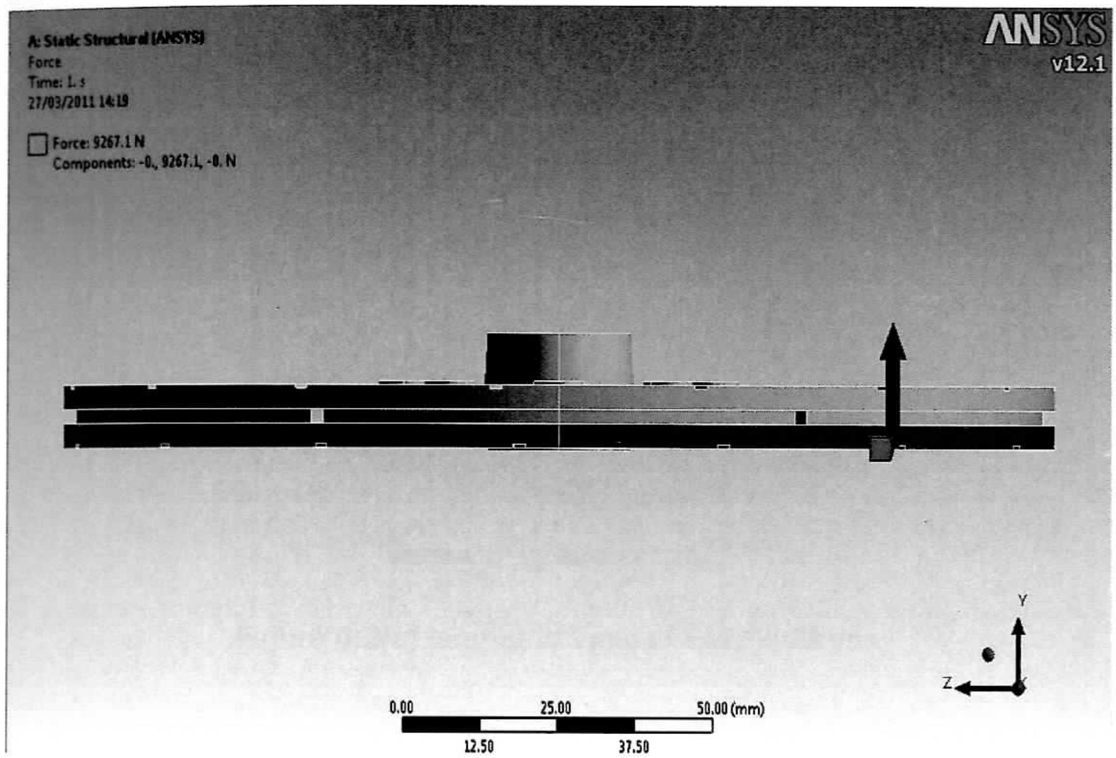

Figure 4.1: Force Applied on the Clutch Facing

In this analysis, the distribution load will be applied just one side on the facing of the clutch disc, the other side of the clutch disc facing will engage to the flywheel that will support the distribution force from the pressure plate.

4.2.2 Equivalent Elastic Strain

Figure 4.2(a) to (b) shows the results of the strain due to the static force applied.

Elastic stress-strain relations:

$$\sigma = E\,\varepsilon$$

where;

E = modulus of elasticity (Young's Modulus)

ε = strain

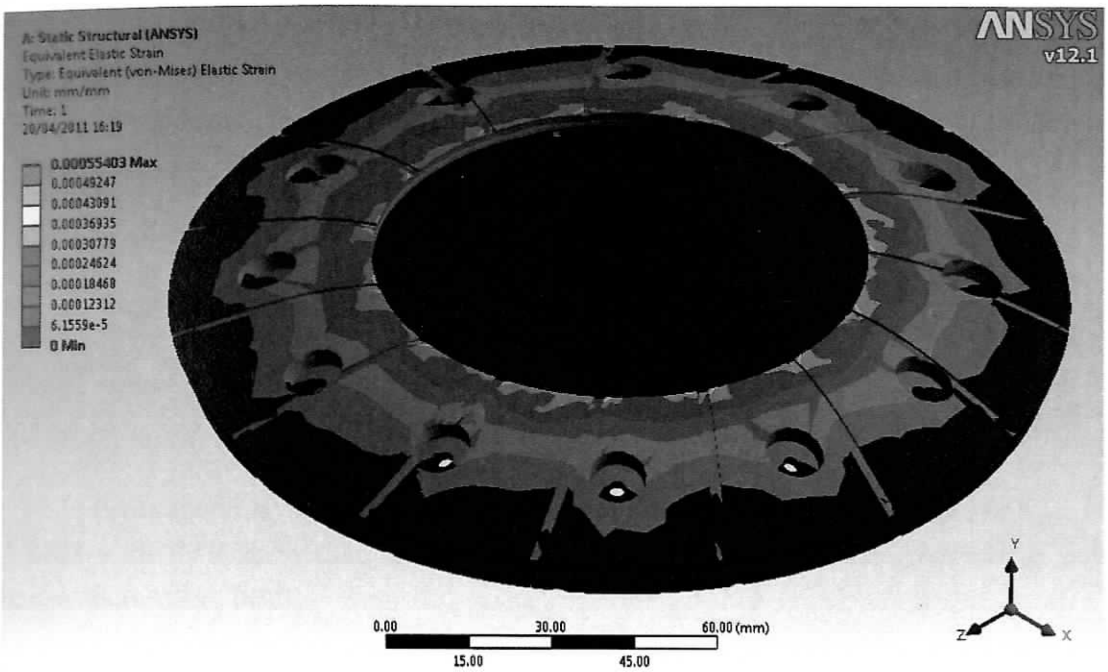

Figure 4.2(a) Isometric View of Elastic Strain

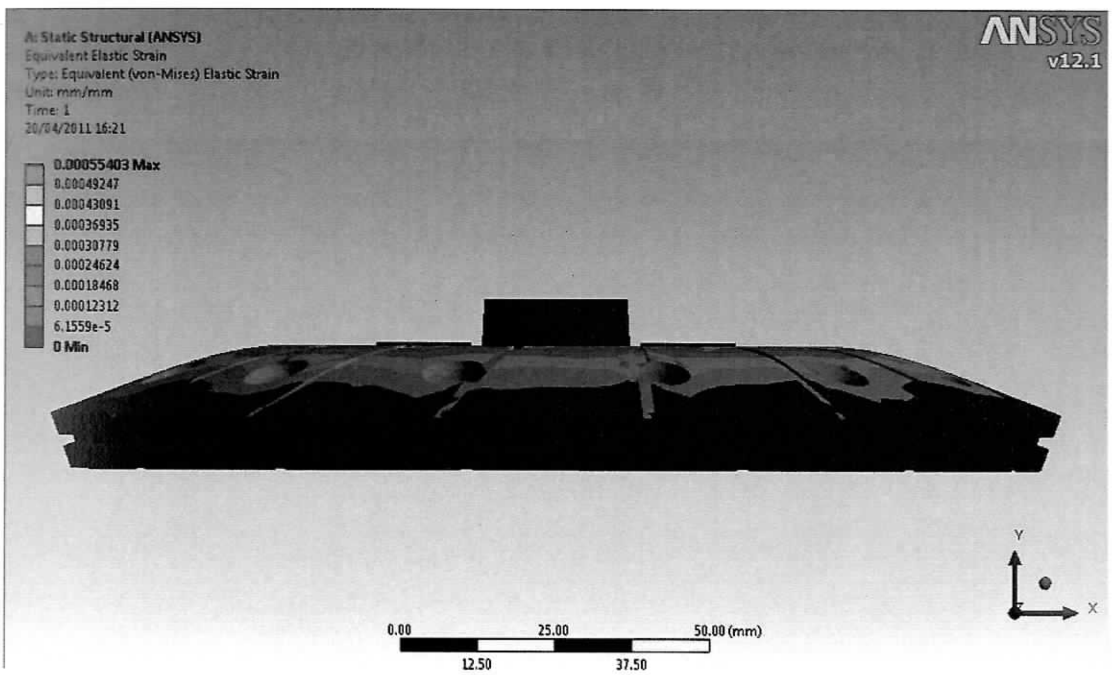

Figure 4.2(b): Front View of Elastic Strain

where:

σ = stress (Yield Strength)

From the table of mechanical properties of carbon composite, we know the value of stress (Yield strength), σ is 83 Mpa and modulus of elasticity (Young's modulus), E is 95 Gpa. So, by using the formula of elastic stress-strain relation, we can calculate the value of maximum strain, ε_{max} by theoretical:

$$\varepsilon_{max} = \frac{\sigma}{E}$$

$$= \frac{83 \text{ Mpa}}{95 \text{ Gpa}}$$

$$= 8.737 \times 10^{-4}$$

From the analysis using ANSYS, we get the value of maximum strain, ε_{max} is 5.5403×10^{-4}. It show that, the value from analysis is smaller than theoretical and below than safety limit.

4.2.3 Stress Analysis

The stress analysis obtained in the Finite Element Analysis is shown in Fig.4.3(a) to (b) below.

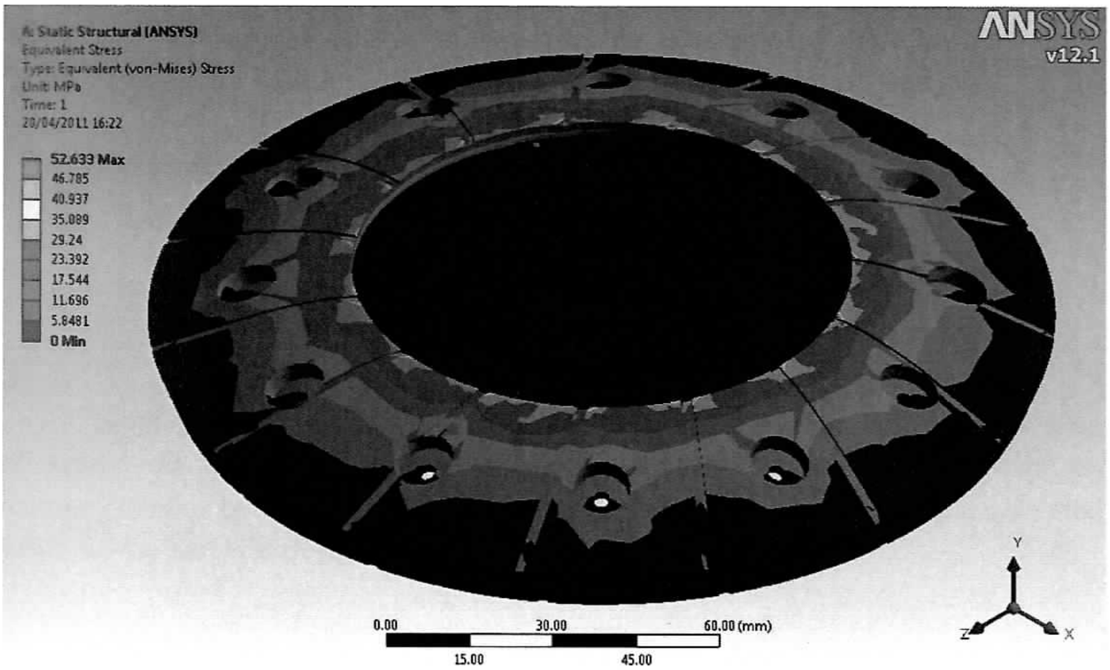

Figure 4.3a: Isometric View of Stress Analysis

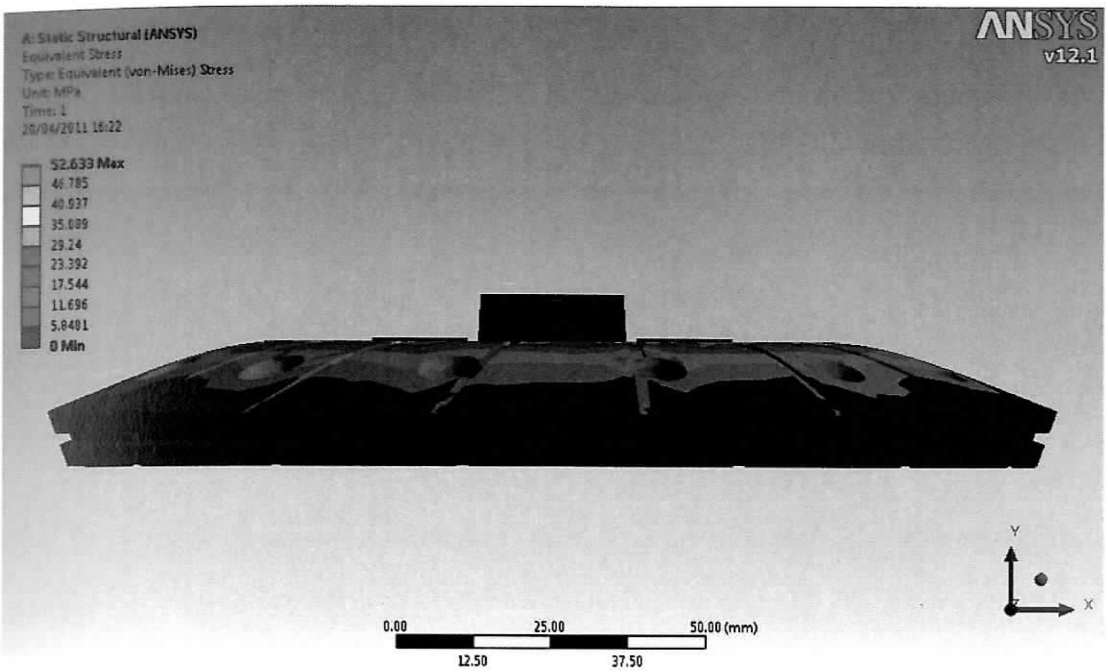

Figure 4.3b: Front View of Stress Analysis

From the table of mechanical properties of carbon composite, we know that that the value of yield strength, σ is 83 Mpa. From analysis using ANSYS, we get the maximum stress, σ_{max} that occur for clutch disc when force is applied is 52.633 Mpa. So, from this two value, we can calculate the value of factor of safety (FOS).

Factor of safety for the structural is a ratio of the allowable stress (yield strength) per working stress (maximum stress from structural analysis).

$$\text{Factor of safety (FOS)} = \frac{\text{yield strength},\sigma}{\text{maximum stress},\sigma}$$

$$= \frac{83 \text{ Mpa}}{52.633 \text{ Mpa}}$$

$$= 1.6$$

From the value of factor of safety, we know that the part is safe to use in term of safety. In automotive engineering, the value for factor of safety (FOS) recommended is between 1.5-3.0. The value that we get is in range of recommended value, so the part was design is safe.

4.2.4 Displacement Analysis

Next, the diplacement of the clutch disc for the designed material is shown in Fig. 4.4 (a) to (b).

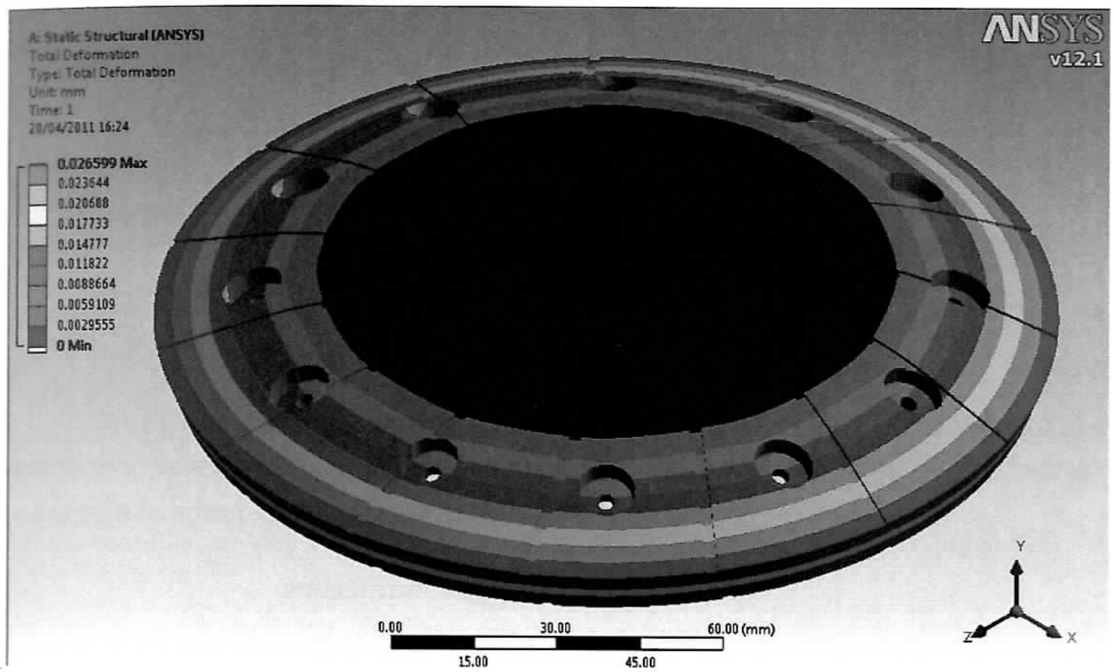

Figure 4.4a: Isometric View of Total Deformation

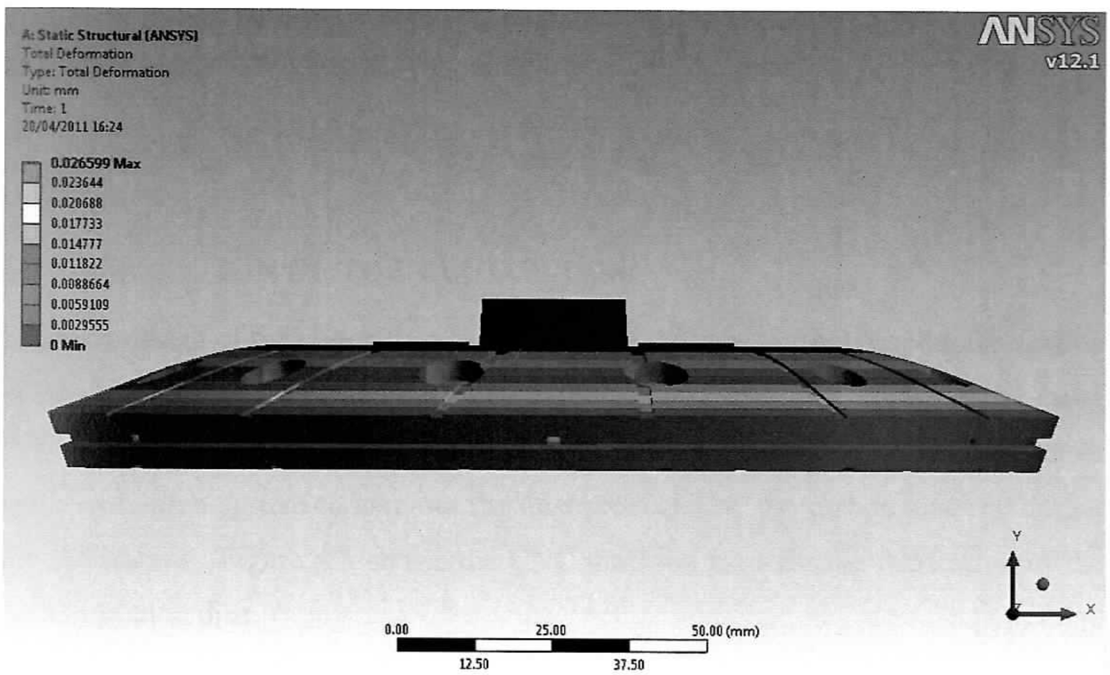

Figure 4.4b: Front View of Total Deformation

Deformation is a change from the normal size or shape of an anatomic structure due to mechanical forces that distort an otherwise normal structure. By using the formula of average linear strain, ε is the ratio of change in length to the original length.

$$\varepsilon = \frac{d}{L}$$

where:

d = change in length (deformation)

L = original length (thickness of clutch disc)

From this formula, we can calculate the value of total deformation of the clutch disc when load is applied. The thickness of the clutch disc is 17 mm and the value of maximum strain, ε_{max} is 8.737×10^{-4}.

$$maximum\ displacement, d = \varepsilon L$$

$$d = (8.737 \times 10^{-4})(17)$$

$$d = 0.01485 \text{ mm}$$

So, by theoretical value of total deformation is 0.014856 mm and the value of total deformation by using ANSYS is 0.026599 mm. It show that, this part is safe to use and failure will not occur.

4.3 FABRICATION OF THE CLUTCH DISC

After the design of the clutch disc passed the Finite Element Analysis, the fabrication of the clutch disc was carried out. The carbon friction disc was fabricated by using 5-Axis Computer Numerical Control (CNC) milling machine. The machine must have ventilation system to take out the dust produced by the carbon material during the fabrication. Figure 4.5 shows the CNC machine used for the fabrication of the carbon friction disc.

Figure 4.5 CNC 5 Axis Milling Machine

Once, the fabrication is finished, the friction material obtained is shown as in Figure 4.6.

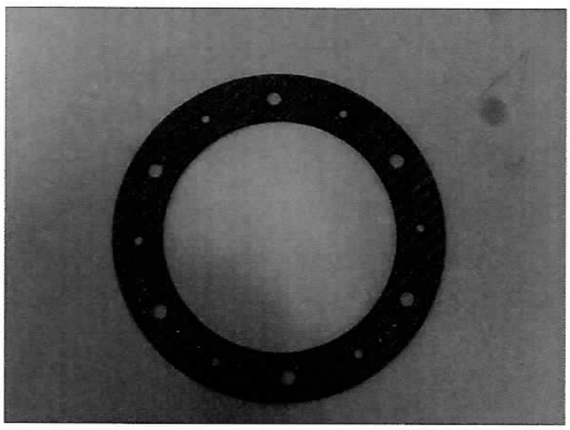

Figure 4.6 Completed Clutch Carbon Composite

Next, the 2 pairs of the clutch carbon composite was riveted to the clutch spline hub as shown in Figure 4.7

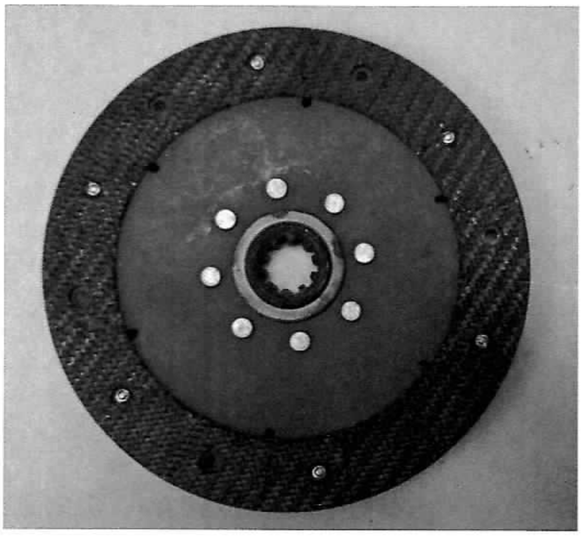

Figure 4.7 Clutch Carbon Composite Riveted to Clutch Spline Hub

The 3 Dimensional view of the completed clutch disc is shown as in Figure 4.8 below.

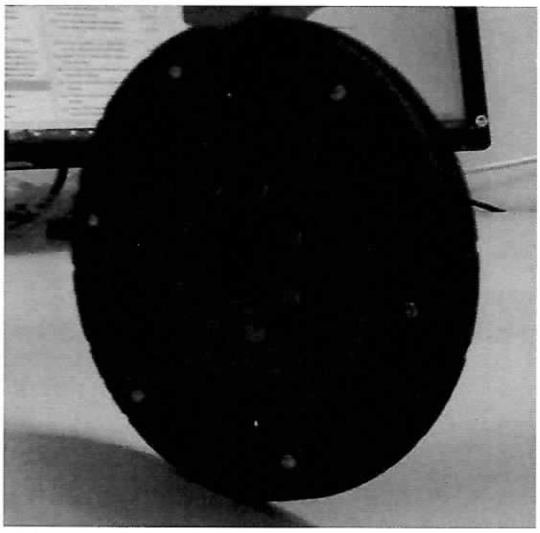

Figure 4.8 3D View of Completed

The completed clutch disc should undergo reliability and performance test. However, since rigs to perform the test can be built due to budget constraint, the test will be conducted in next phase of research.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

The final parameters of the friction clutch disc are as follow:

i. Material used for the friction facing is a carbon-carbon composite.
ii. Type of clutch plate used is a rigid hub.
iii. Outer diameter, D_o= 160 mm
iv. Inner diameter, D_i= 90 mm

The type of clutch plate used is a rigid hub because is due to its simplicity and cheaper cost of production. Moreover, for a mini tractor which is has a low maximum speed and low engine rpm, the rattling effect is at minimum. Therefore, rigid hub is more suitable.

Formula that used to determine the clutch outer and inner diameter and axial force are as follow:

i. $T = \pi P_{max} r_i f(r_o^2 - r_i^2)N$
ii. $F_a = \frac{1}{2}\pi P_{max} D_i(D_o - D_i)$

The values from this formula is depends on the maximum torque produced by the engine. From this value, the lightweight dry clutch disc for a mini farming tractor is designed and the engineering drawing of the clutch disc is produced by using CATIA software.

After that, ANSYS software was used to do the finite element analysis (static structural analysis) on the design of the clutch disc. From the analysis, the value of equivalent elastic strain, maximum stress and total deformation when the force is applied was obtained as shown in Figure 5.1 belows.

Model (A4) > Static Structural (A5) > Solution (A6) > Results

Object Name	*Equivalent Elastic Strain*	*Equivalent Stress*	*Total Deformation*
State	Solved		
Scope			
Scoping Method	Geometry Selection		
Geometry	All Bodies		
Definition			
Type	Equivalent (von-Mises) Elastic Strain	Equivalent (von-Mises) Stress	Total Deformation
By	Time		
Display Time	Last		
Calculate Time History	Yes		
Identifier			
Integration Point Results			
Display Option	Averaged		
Results			
Minimum	0. mm/mm	0. MPa	0. mm
Maximum	5.5403e-004 mm/mm	52.633 MPa	2.6599e-002 mm
Information			
Time	1. s		
Load Step	1		
Substep	1		
Iteration Number	1		

Figure 5.1: Results of Static Structural Analysis

All the parameter of the stresses, strain and deformation that we get from the analysis is below than theoretical. So, the clutch disc that we designed is safe to use in the industrial application in term of safety. The clutch disc also can fabricated in future to use in automotive industrial. So, all the objective of the project is achieved.

Last but not least, after the Finite Element Analysis was conducted, the clutch friction disc was fabricated by using Computer Numerical Control machine.

5.2 RECOMMENDATIONS

After fabrication of the clutch friction disc is completed, it should undergo feasibility and reliability test. A special design test rigs should be fabricated for the tests. However, due to constraint in budget, the rigs were not able to be materialised. However, further research grant can be applied to build up the test rigs. The fabricated lightweight clutch friction disc will be tested by using the rig to validate th FEA results.

Apart from that, dynamic analysis should be imposed to the designed clutch disc to obtain much accurate results. Last but not least, we recommend that the torsional spring should be introduced in the design to reduce gear rattling (vibration of the clutch) . It will be lead to incerase of the life span of the clutch disc. It also can do the dynamic analysis in finite element analysis (FEA).

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APPENDICES

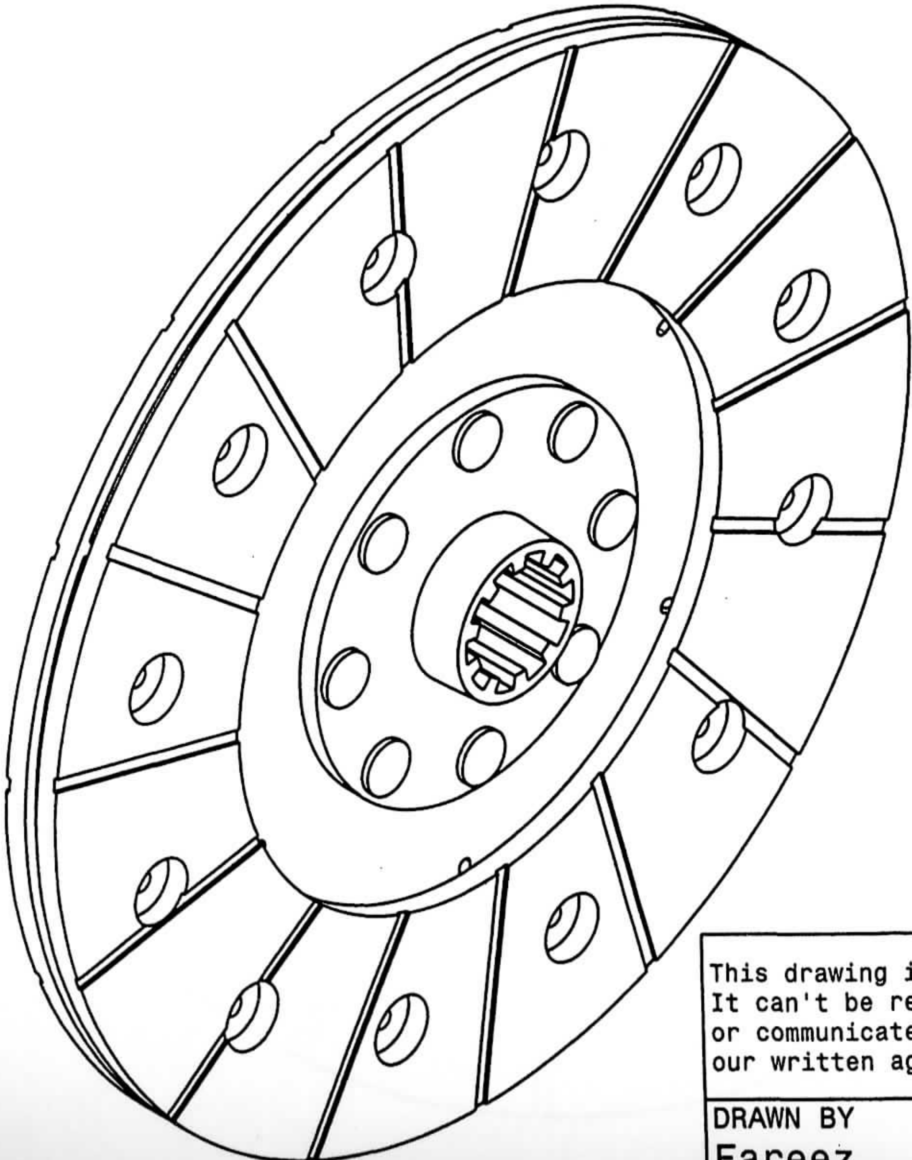
Appendix A – Engineering Drawing of Completed Lightweight Clutch Disc

Appendix B - Gantt Chart of Research

Appendix C – List of Publications

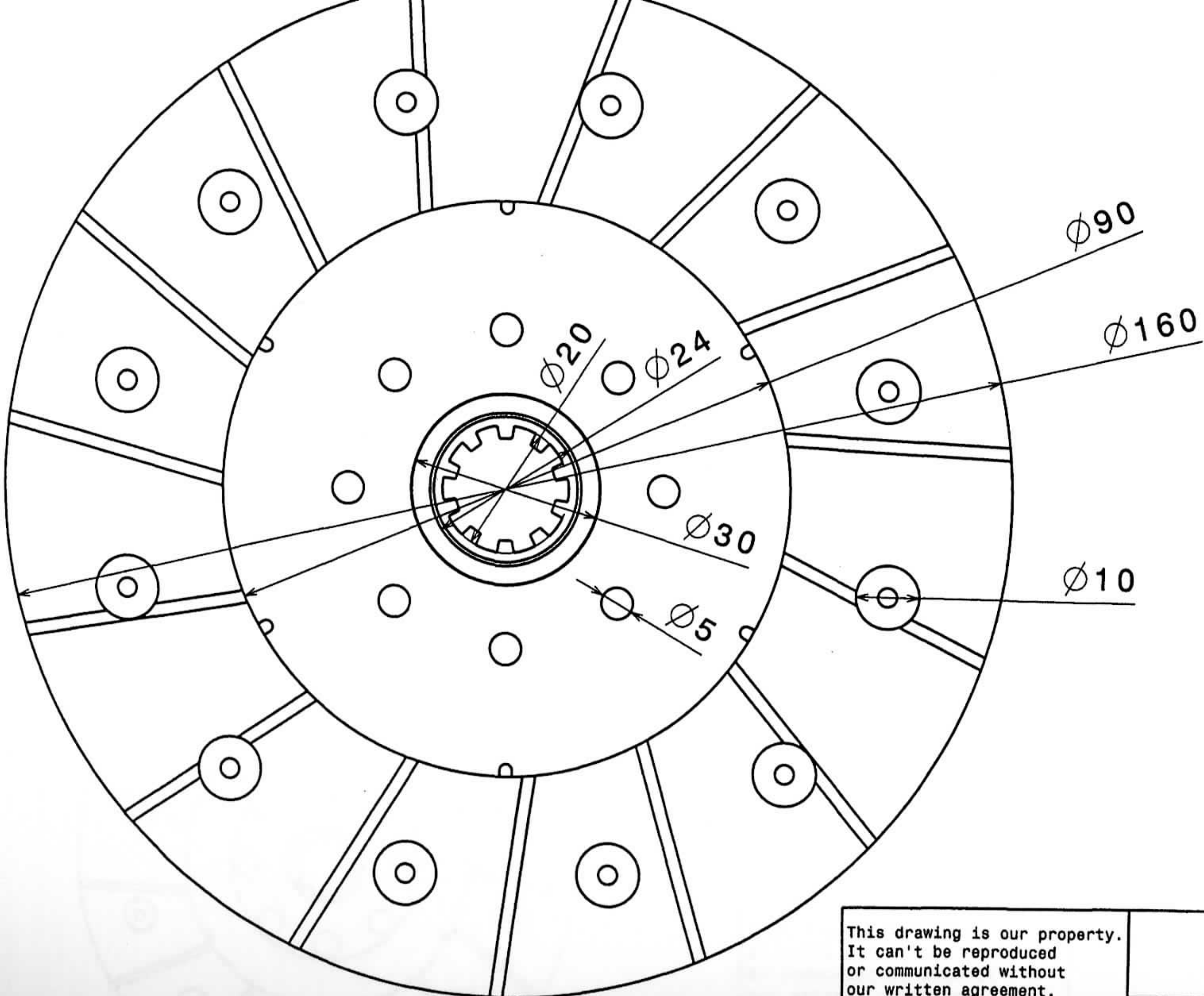
APPENDIX A

Engineering Drawing of Completed Lightweight Clutch

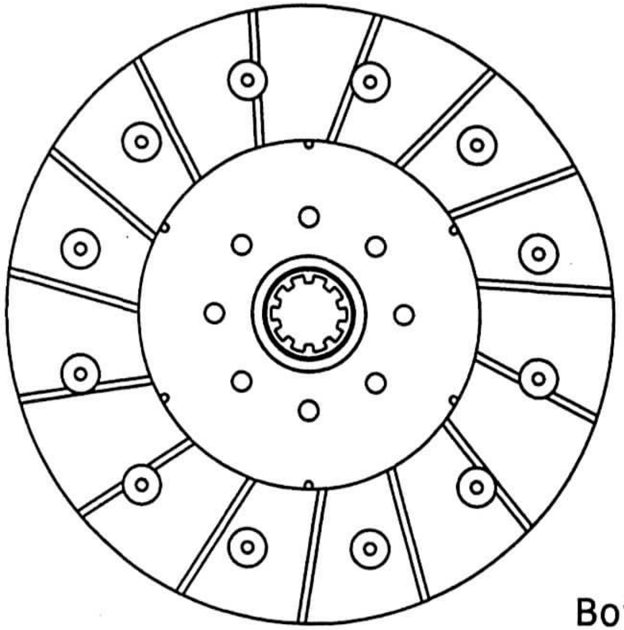


Isometric view

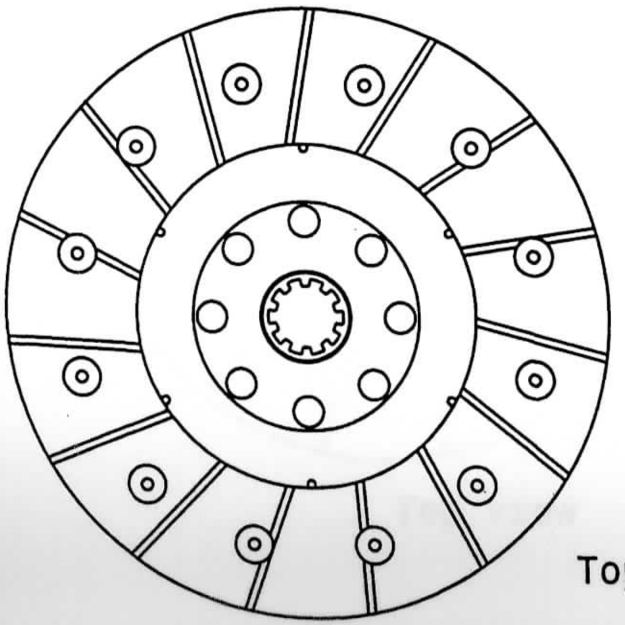
This drawing is our property. It can't be reproduced or communicated without our written agreement.		UTeM	
DRAWN BY Fareez	DATE 10/10/2010	DRAWING TITLE Clutch Disc	
CHECKED BY En. Fudhail		SIZE A4	DRAWING NUMBER 1
DESIGNED BY			



This drawing is our property. It can't be reproduced or communicated without our written agreement.		UTeM	
DRAWN BY Fareez	DATE 10/10/2010	DRAWING TITLE clutch disc	
CHECKED BY En. Fudhail		SIZE A4	DRAWING NUMBER 2



Bottom view



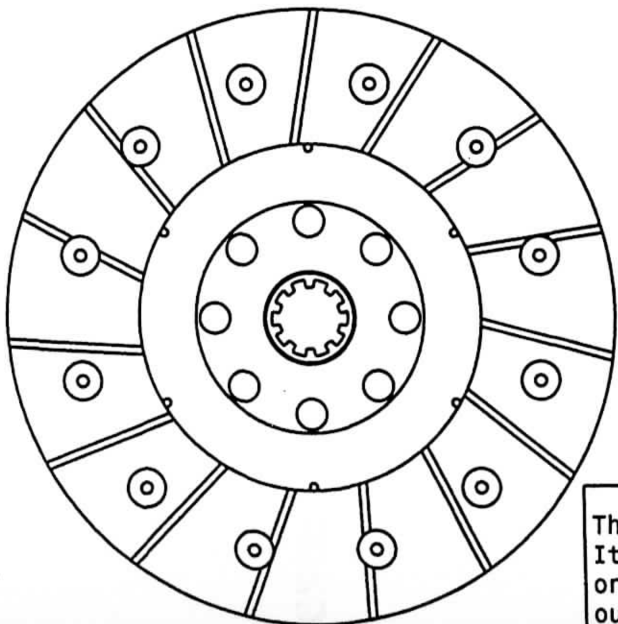
Top view

Right view

This drawing is our property. It can't be reproduced or communicated without our written agreement.		UTeM
DRAWN BY Fareez	DATE 10/10/2010	DRAWING TITLE Clutch Disc
CHECKED BY En. Fudhail		SIZE / DRAWING NUMBER

Front view

Left view



Top view

This drawing is our property. It can't be reproduced or communicated without our written agreement.		UTeM	
DRAWN BY Fareez	DATE 10/10/2010	DRAWING TITLE Clutch Disc	
CHECKED BY En. Fudhail		SIZE A4	DRAWING NUMBER

APPENDIX B

Research Gantt Chart and Milestones

Items	2010						2011					
	7	8	9	10	11	12	1	2	3	4	5	6
1. Literature review of tractor clutch system	■	■										
2. Literature review of lightweight clutch disc	■	■	■									
3. Design of the lightweight clutch disc				■	■	■						
4. Analysis of the designed clutch disc using CAE software.							■					
5. Fabrication of the clutch disc								■	■			
6. Performance evaluation (experiments)										■		
7. Report Writings.											■	■

Milestones

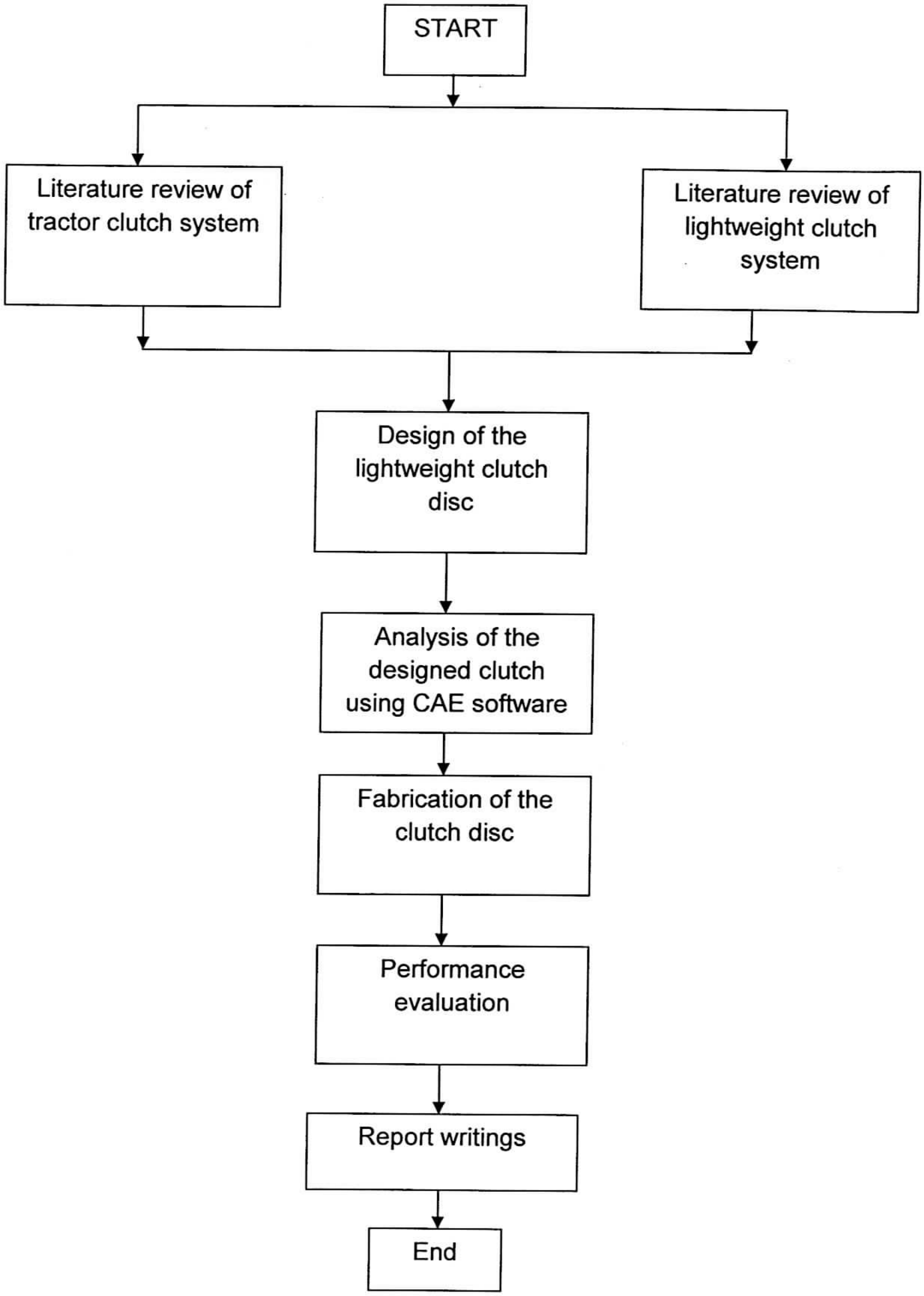
30 September 2010 - Literature review on tractor clutch and lightweight clutch disc is accomplished

31 December 2010 - Design of the lightweight clutch disc is accomplished

31 March 2011 - A lightweight clutch disc is produced.

30 June 2011 - Results are submitted to conference and journals.

Flow Chart of Research Activities



APPENDIX C

List of Publications

1. International Conference on Mechanical , Automotive and Aerospace Engineering 2011.17-19 May 2011.Kuala Lumpur.
2. International Review of Mechanical Engineering. In Press (Indexed By Scopus)

asic Design of Dry Clutch Disc For a Mini Farming Tractor

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Department of Automotive

— In this paper, the method to design dry clutch disc for arming tractor is presented. The main factor that needs nsidered in order to design a clutch disc is the torque d by the engine. An optimum clutch disc should have n in weight, simple to manufacture and high reliability. lement analysis is also conducted to determine the m stress the designed clutch disc.

ords-component; dry clutch dic, farming tractor,finite nalysis

I. INTRODUCTION

tch is a mechanical device, by convention understood otating, which provides driving force to another sm when required, typically by connecting the driven sm to the driving mechanism. The name of clutch has established due to its meaning of grasp or grip tight.

hes are useful in devices that have two rotating shafts. devices, one shaft is typically attached to a motor or ver unit (the driving member), and the other shaft (the ember) provides output power for work to be done. h connects the two shafts so that they can either be gether and spin at the same speed (engaged), or be d and spin at different speeds (disengaged).

disc can be either dry or wet. Dry here means the erates in dry condition. The clutch facing of dry lutches are the force closure couplings [1]. On the d, wet here means, the clutch operates in oil bath or y clutch are widely used on large trucks and heavy units. The main advantages of dry clutch are its large ea and the main components of a dry disc clutch are late and the disc [2]. Clutch system basically consists or parts which are flywheel, diaphragm spring, clutch ure plate, clutch cover and linkage that is necessary the clutch [3].

An optimum clutch system is a system where it gives more power transmission, high comfort, highly effective, and low cost in design [3].

A good clutch disc must have the following criteria:[1]

(i) High torque transmission which depends on the friction co-efficient.
(ii) High comfort
(iii) Low wear criteria

II. FARMING TRACTOR CLUTCH DISC

A tractor is a device intended for drawing, towing or pulling something which cannot propel by itself. Generally tractor is used to describe a vehicle intented for such task on some other vehicle or object [4]. In Malaysia, tractor mostly used in paddy and palm oil farm to do works likes plugging, seeding, and harvesting. However, the used of tractor are widening to land clearing, slashing grass and collecting grass clippings leave and twig.

Basically, in agricultural machinery, there are three main clutched that are normally used. These clutches are disc clutch, overrunning clutch and cone clutch. All these types of clutch come under axial friction clutches [5]. Clutch facing thermal properties lead to a large extent temperature rise and this would lead to tribological performances at the contact interfaces [6].

III. DESIGNING THE CLUTCH DISC

In designing the clutch disc, we have to consider the following criteria:

i. Sizing
ii. Material selection
iii. Configuration
iv. Overall sizing
v. Disc plate

The first two criteria are very important parameters needed order to design a clutch disc. Apart from that, we also have make assumption of the following:

i. Complete contact of the clutch disc
ii. The pressure due to the contact is uniform.

According to [7], the factors that determine the amount of e torque a clutch can transmit are: friction area, nature of the iction surface, diameter of friction surface, and amount of essure which holds the surfaces together. Generally, the eater the friction area and diameter of the surfaces, the eater the torque capacity of the clutch.

Determining Clucth Disc Diameter

To calculate for torque that the clutch can transmit, the rmula below is used.

$$T = \pi P_{\max} r_i f (r_o^2 - r_i^2) N \quad (1)$$

T = torque transmitted, Nm
P_{max} = maximum pressure applied onto the clutch in Pascal
f = coefficient of friction (depends on material used)
r_o = outer radius, m
r_i = inner radius, m
N = number of friction surface

ssumptions made:
i. $r_i = 0.58 r_o$
ii. Pressure applied onto the clutch is uniform.
ii. The factor of safety, F.O.S = 1.5 (Automotive application F.O.S = 1.38 - 1.5).
v. The material for the friction material is woven asbestos

nowing that:
i. The maximum torque required for the clutch to transmit is 150 Nm
ii. T = 225 Nm
ii. N = 2
v. f = 0.3
v. $P_{max} = 684\ kPa$

om these values and also the formula used, we obtained:
= 0.1536 m
= 0.0890 m

erefore, the outer diameter of the clutch will be set to 53m. From the calculation and theory, it can be concluded t the clutch diameter is depends on two parameters which torque produced by the engine and also clutch facing used the design.

B. Determining The Axial Force

Formula used are as follows:

$$F_a = \frac{1}{2}\pi P_{max} D_i (D_o - D_i)\ (Shigley) \quad (2)$$

Carry out the calculation:

$F_a = \frac{1}{2}\pi P_{max} D_i (D_o - D_i)$

$F_a = \frac{1}{2}$ (3.142)(684 000 Pa)(0.0890 m)(0.1536 m – 0.0890 m)

F_a = 6178.0983 N

Multiply with the factor of safety;

F_a = 1.5(6178.0983 N)

Therefore,

$\boldsymbol{F_a}$ **= 9267.1474 N**

III. FINITE ELEMENT ANALYSIS

In automotive engineering, the rotational motion is difficult to be modeled in Finite Element because it involves a lot of complex phenomenon such as friction, thermal effects, shocks between mechanical parts, vibrations and other factors [3].

Basic finite element analysis was conducted to determine the displacement and the maximum stress the disc can sustain for the calculated axial force. The disc is meshed with shell elements (Shell 181in ANSYS) and computed by using linear elastic material law. Fig. 1 depicts the mesh generation of the clutch disc.

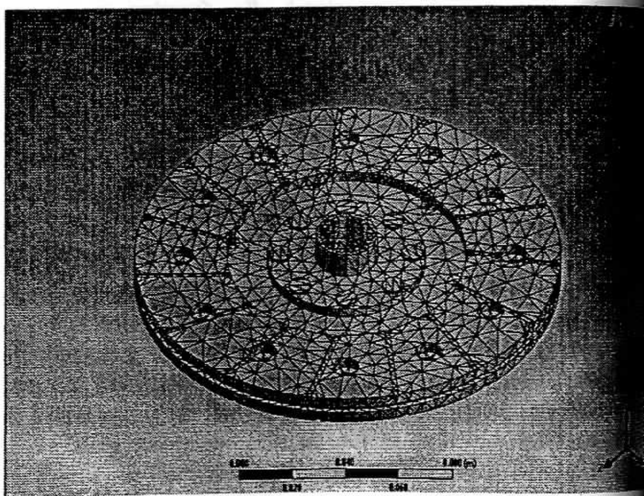

Figure 1. Mesh generation of the clutch disc

By applying static force of 9267 N onto the surface of the clutch disc as shown in Fig. 2, the results of maximum displacement is obtained. The results are shown as in Fig. 3 The maximum displacement obtained is 0.122 mm which is considerable low. On the other hand, the maximum stress yield from the analysis is 132.7 Mpa which is shown in Fig. 4 This maximum stress is way below the allowable limit for the designed clutch disc.

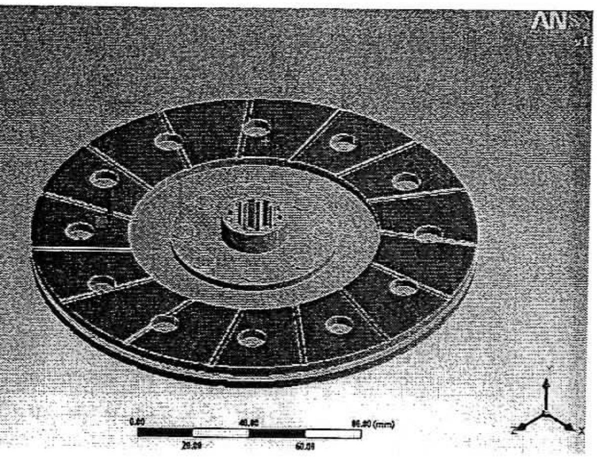

Figure 2. Static force applied onto the clutch disc

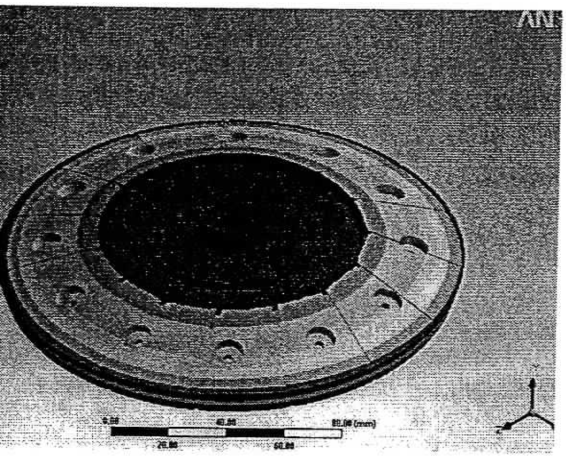

Figure 3. Results of displacement of clutch discc

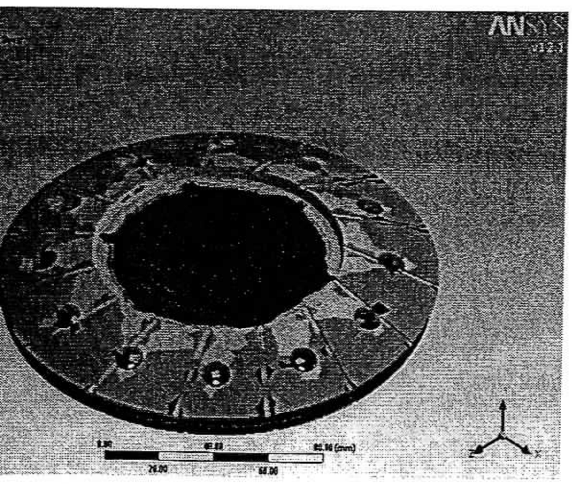

Figure 4. Von Misses stress

IV. CONCLUSION

In conclusion, the design method of clutch disc has been successfully demonstrated. The following steps are the guidance to design a clutch dry disc:

(i) Determine the clutch diameter (inner and outer)
(ii) Determine the clutch hub length and diameter
(iii) Determine the diameter of working spring (if any)

ACKNOWLEDGMENT

The authors would like to thank the Universiti Teknikal Malaysia Melaka (UTeM) and government of Malaysia for supporting this research activity.

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PUSAT PENGURUSAN PENYELIDIKAN DAN INOVASI, CANSELORI

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ujukan Tuan (Your Ref) :

20 April 2011

ncik Fudhail bin Abdul Munir
Melalui dan salinan
Dekan Fakulti Kejuruteraan Mekanikal

ıan/Puan,

ELULUSAN MENGHADIRI DAN MEMBENTANGKAN KERTAS KERJA DI "INTERNATIONAL ONFERENCE ON MECHANICAL, AUTOMOTIVE AND AEROSPACE ENGINEERING 2011 (ICMAAE 11)"

lalah saya dengan segala hormatnya di arah merujuk kepada perkara di atas.

Sukacita dimaklumkan bahawa Universiti telah **meluluskan** permohonan tuan untuk menghadiri rsidangan dan membentangkan kertas kerja bertajuk ***"Basic Design of Dry Clutch Disc For a Mini rming Tractor"*** seperti butiran berikut :-

2.1	Tarikh	:	17 hingga 19 Mei 2011
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ʾreliminary Design of Carbon Composite Facing for Dry Clutch Disc of Mini Agricultural Tractor

Fudhail Abdul Munir[1], Mohd Irwan Mohd Azmi[1], Mohd Adrinata Shaharuzaman[1], Mohd Rody Mohd Zin[1], Muhammad Zahir Hassan[1]

Abstract – *In this paper, the preliminary design of carbon composite clutch facing for the use of mini agricultural tractor dry clutch disc is presented. The main factor that needs to be considered in order to design a clutch disc facing is the torque produced by the engine. An optimum clutch facing disc should have minimum in weight, simple to manufacture and high reliability. Finite element analysis is conducted to determine the maximum stress the designed clutch disc facing before the fabrication take place. The design carbon facing is then fabricated by using Computer Numerical Controlled (CNC) 5-axis milling machine. The completed design will then used for experimental analysis to determine its reliability and durability.*

***Keywords:** carbon clutch disc, finite element analysis.*

I. Introduction

utches are useful in devices that have two rotating s. In these devices, one shaft is typically attached to ıtor or other power unit (the driving member), and ɔther shaft (the driven member) provides output r for work to be done. The clutch connects the two s so that they can either be locked together and spin same speed (engaged), or be decoupled and spin at ent speeds (disengaged).

clutch can be defined as a mechanical device, by ention understood to be rotating, which provides ıg force to another mechanism when required, ılly by connecting the driven mechanism to the g mechanism. The name of clutch has become ished due to its meaning of grasp or grip tight. The ɔnent of a clutch disc can be represented in the Fig. ıw.

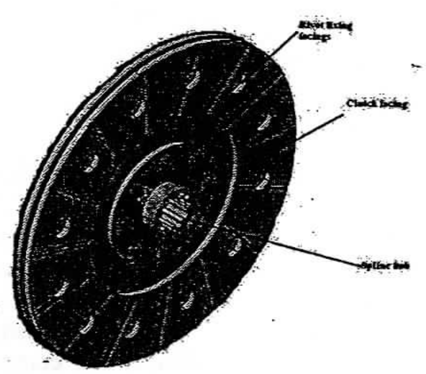

Fig 1. Clutch disc components

Clutch disc can be either dry or wet. Dry here means the clutch operates in dry condition. The clutch facing of dry running clutches are the force closure couplings [1]. On the other hand, wet here means, the clutch operates in oil bath or spray. Dry clutch are widely used on large trucks and heavy industrial units. The main advantages of dry clutch are its large contact area and the main components of a dry disc clutch are pressure plate and the disc [2].

An optimum clutch system is a system where it gives more power transmission, high comfort, highly effective, and low cost in design [3].

A good clutch disc must have the following criteria: [1]

(i) High torque transmission which depends on the friction co-efficient.
(ii) High comfort
(iii) Low wear criteria

The availability of asbestos in automobile components like clutches, brakes and gasket may bring potential health risk to the automotive mechanics [4], [5] and [6]. Therefore, there is a need to replace the material used in the present automotive clutches to alternative material which has no potential threat to human health.

Carbon composite clutch disc is one of the alternatives to asbestos woven clutch. Carbon composite materials are used extensively in high performance racing cars especially in Formula 1 [7]. It was first used in aircraft industries back in 1970s. [8]. Apart from light in weight,

ɪpt received January 2007, revised January 2007

carbon-composite materials have high melting temperature, low density, high thermal conductivity and shock resistance, low thermal expansion, and high elastic moduli. These criteria is suitable for structural application in extreme temperature surroundings [9].

II. Design process

In designing the clutch disc, the following consideration needs to be adhered:

i. Sizing
ii. Material selection
iii. Configuration
iv. Overall sizing
v. Disc plate

The first two criteria are very important parameters needed in order to design a clutch disc. Apart from that, we also have to make assumption of the following:

i. Complete contact of the clutch disc
ii. The pressure due to the contact is uniform.

The factors that determine the amount of the torque a clutch can transmit are: friction area, nature of the friction surface, diameter of friction surface, and amount of pressure which holds the surfaces together [10]. Generally, the greater the friction area and diameter of the surfaces, the greater the torque capacity of the clutch.

II.1. Determining Clutch Disc Diameter

To calculate for torque that the clutch can transmit, the formula below is used.

$$T = \pi P_{max}\, r_i\, f\, (r_o^{\,2} - r_i^{\,2}) N \quad (1)$$

Where:

T = torque transmitted, Nm
P_{max} = maximum pressure applied onto the clutch in Pascal
f = coefficient of friction (depends on material used)
r_o = outer radius, m
r_i = inner radius, m
N = number of friction surface

Assumptions made:

i. $r_i = 0.58 r_o$
ii. Pressure applied onto the clutch is uniform.
iii. The factor of safety, F.O.S = 1.5 (Automotive application F.O.S = 1.38 - 1.5).
iv. The material for the friction material is woven asbestos

Knowing that:

i. The maximum torque required for the clutch to transmit is 150 Nm
ii. T = 225 Nm
iii. N = 2
iv. f = 0.3 (carbon composite)
v. $P_{max} = 684\ kPa$

From these values and also the formula used, it was obtained that:
$D_o = 0.1536$ m
$D_i = 0.0890$ m
Hence, the outer diameter of the clutch will be set to 0.153m. From the calculation and theory, it can be concluded that the clutch diameter is depends on two parameters which are torque produced by the engine and also clutch facing used in the design.

II.2. Determining the axial force

Formula used are as follows [10]:

$$F_a = \frac{1}{2}\pi P_{max} D_i (D_o - D_i) \quad (2)$$

Carry out the calculation:
$F_a = \frac{1}{2}\pi P_{max} D_i (D_o - D_i)$
$F_a = \frac{1}{2}$(3.142)(684 000 Pa)(0.0890 m)(0.1536 m – 0.0890 m)
F_a = 6178.0983 N
Multiply with the factor of safety;
F_a = 1.5(6178.0983 N)
Therefore,
F_a = 9267.1474 N

II.3. Finite Element Analysis

In automotive engineering, the rotational motion is difficult to be modeled in Finite Element because it involves a lot of complex phenomenon such as friction, thermal effects, shocks between mechanical parts, vibrations and other factors. Therefore, since we only need to design a specimen to be used for experiment, static structural analysis was conducted.

The property of the carbon friction disc is shown in table I below:

Table I
Properties of carbon friction clutch disc

Reynolds Number	Grid Size
Apparent Density	1.43 (g/cm^3)
Flexural Strength	107 Mpa
Tensile Strength	83 MPa
Thermal Conductivity	31 W/mK

Basic finite element analysis was conducted to determine the displacement and the maximum stress the disc can sustain for the calculated axial force. The software used is ANSYS 12. The disc is meshed with shell elements (Shell 181in ANSYS) and computed by ng linear elastic material law. Fig. 2 depicts the mesh ıeration of the clutch facing with its clutch hub.

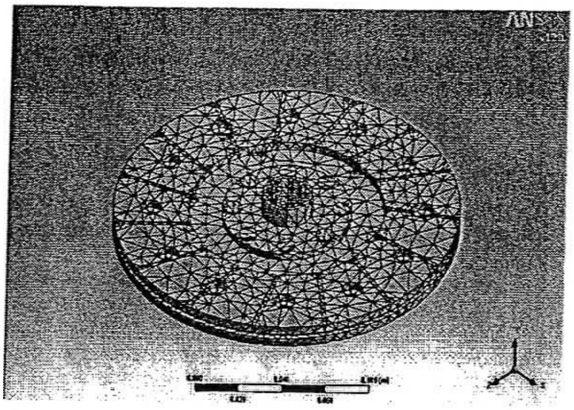

Fig. 2 Meshing of the clutch facing

pplying static force of 9267 N onto the surface of the :h facing as shown in Fig. 3, the results of maximum lacement is obtained. In the analysis of the axial : is applied onto one side only due to symetrical erty.

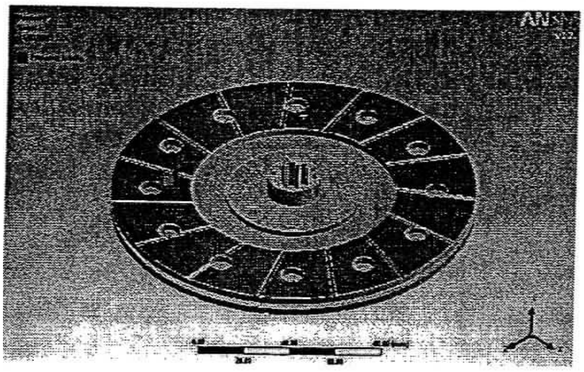

Fig. 3 Static force applied on clutch facing

esults in ANSYS maximum displacement is shown . 4. The maximum displacement obtained is 0.122

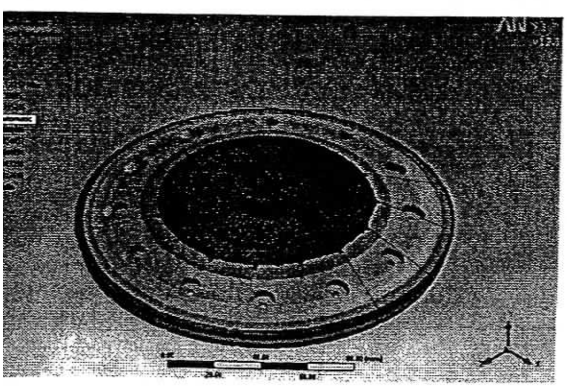

Fig. 4 Maximum displacement of the clutch facing

The maximum displacement obtained is 0.122 mm. From theoritical value of strain the carbon composite used for the clutch facing is $8.737 \, x \, 10^{-4}$. The results obtained from ANSYS is $5.5403 \, x \, 10^{-4}$ which is lower than the theoritical value. Hence it is acceptable.

On the other hand, the maximum stress yield from the analysis is 132.7 Mpa which is shown in Fig. 5. This maximum stress is way below the allowable limit for the designed clutch facing.

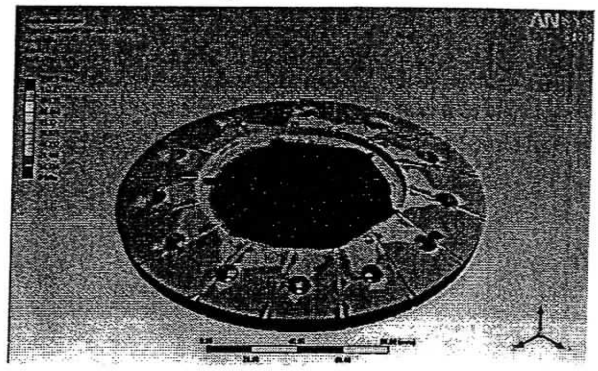

Fig. 5 Von Misses stress of the clutch facing

From the table of mechanical properties of carbon composite, we know that that the value of yield strength, σ is 83 Mpa. From analysis using ANSYS, the maximum stress obtained is 52.633 Mpa. Thus, the maximum stress of the designed clutch facing is below than the tensile strength.

III. Fabrication of the carbon facing disc

After the design of the clutch disc passed the Finite Element Analysis, the fabrication of the clutch disc was carried out. The carbon friction disc was fabricated by using 5-Axis Computer Numerical Control (CNC) milling machine. The machine must have ventilation system to take out the dust produced by the carbon material during the fabrication. Fig. 6 shows the CNC machine used for the fabrication of the carbon friction disc.

Fig. 6 5- Axis CNC milling machine

On the other hand, Fig.7 depicts the completed carbon friction disc. There are two carbon friction disc was made. These clutch facing was then riveted to the cushion disc together with the spline hub as shown in Fig 8.

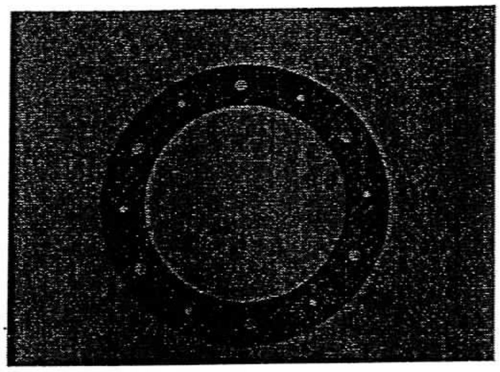

Fig. 7 Completed carbon composite clutch facing

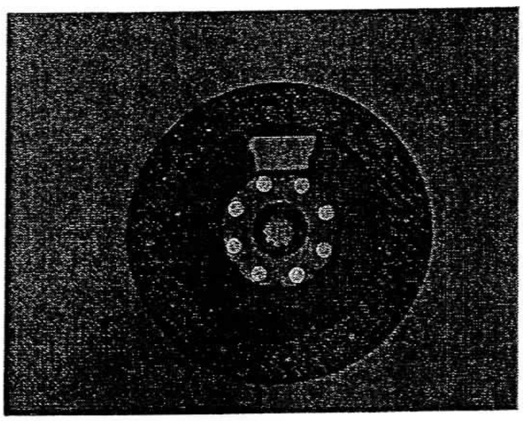

Fig. 8 Carbon composite clutch facing is riveted to cushin disc and spline hub

IV. Conclusion

In this paper the method of designing carbon composite facing for clutch disc is properly demonstrated. The designed clutch disc will then be used for experimental analysis to determine its reliability in term of usage and durability. The investigation will be done by using experimental rig specialized built to study clutch system for automotive applications.

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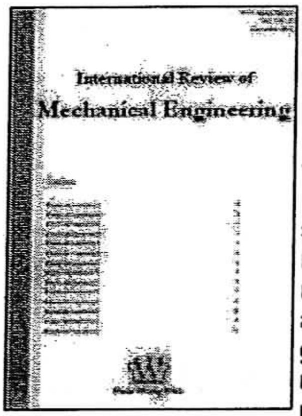

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