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# Preliminary Design of Carbon Composite Facing for Dry Clutch Disc of Mini Agricultural Tractor

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**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*

## Nomenclature

| | |
|---|---|
| $D_o$ | Outer diameter, m |
| $D_i$ | Inner diameter, m |
| $F_a$ | Axial force , Newton |
| $N$ | Number of friction surface |
| $P_{max}$ | Maximum pressure applied onto the clutch, Pascal |
| $T$ | Torque transmitted, Nm |
| $f$ | Coefficient of friction (material used) |
| $r_o$ | Outer radius, m |
| $r_i$ | Inner radius, m |

## I. Introduction

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. The component of a clutch disc can be represented in the Fig. 1. 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].

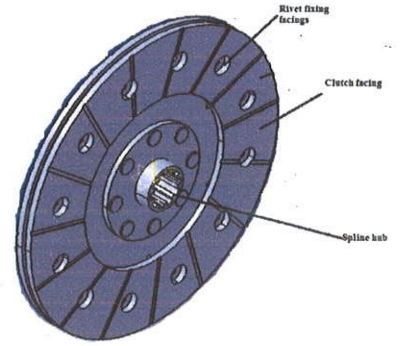


Fig. 1. Clutch disc components

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, 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]. Testing of clutch facing materials had been successfully by previous researchers [10].

## 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 [11]. 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:

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

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 [11]:

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

Carry out the calculation:

$F_a = \frac{1}{2} \pi P_{max} D_i (D_o - D_i)$
$F_a = \frac{1}{2}(3.142)(684\,000 \text{ Pa})(0.0890 \text{ m})(0.1536 \text{ m} - 0.0890 \text{ m})$
$F_a = 6178.0983$ N

Multiply with the factor of safety:

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

Therefore:

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

### *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

| Properties | Value |
|---|---|
| *Apparent Density* | 1.43 (g/cm³) |
| *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 using linear elastic material law.

Fig. 2 depicts the mesh generation of the clutch facing with its clutch hub.

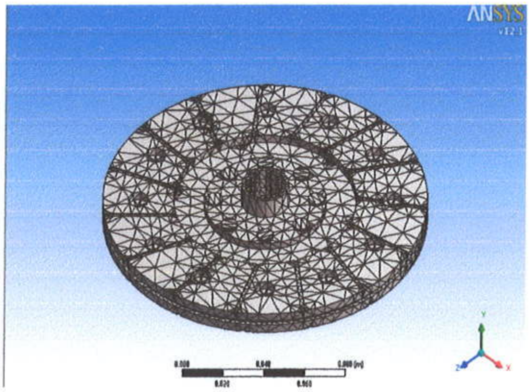

Fig. 2. Meshing of the clutch facing

By applying static force of 9267 N onto the surface of the clutch facing as shown in Fig. 3, the results of maximum displacement is obtained. In the analysis of the axial force is applied onto one side only due to symetrical property.

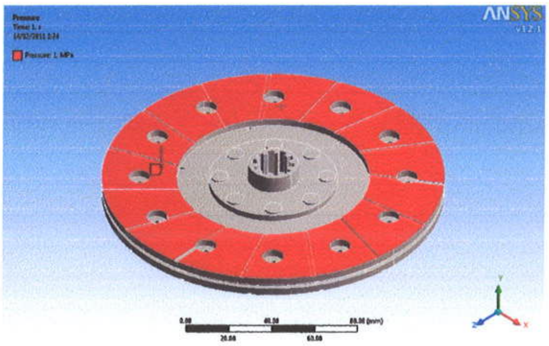

Fig. 3. Static force applied on clutch facing

The results in ANSYS maximum displacement is shown in Fig. 4. The maximum displacement obtained is 0.122 mm.

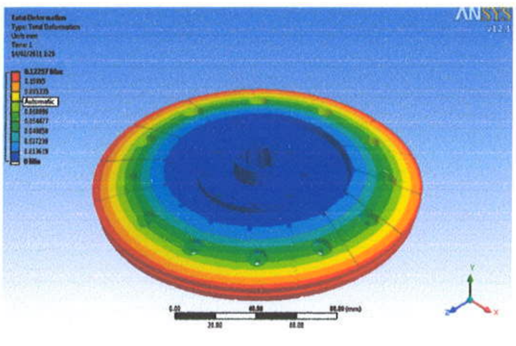

Fig. 4. Maximum displacement of the clutch facing

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.

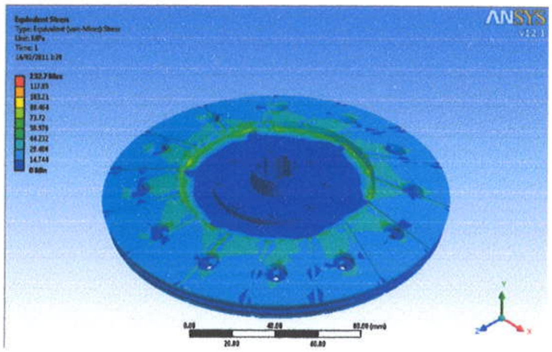

Fig. 5. Von Misses stress of the clutch facing

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. 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. 6. 5- Axis CNC milling machine

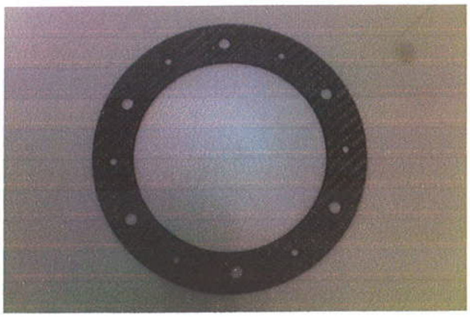

Fig. 7. Completed carbon composite clutch facing

Fig. 8. Carbon composite clutch facing is riveted to cushion 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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