Static Structural Analysis of Multiplate Clutch with Different Friction Materials

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Abstract

This work depicts a solid modelling of multiplate clutch with PRO-E CAD package that is employed for varied automotive applications. The structural analysis of clutch plate is done over cork, copper and SA92 as friction lining materials. The analysis is carried out on ANSYS workbench to get the foremost appropriate friction material for clutch. From the analyzed results, stress, strain and total deformation values were compared for all the three materials and the best one was taken out. For study purpose, specifications of the clutch are obtained from the pulsar DTSi model.

Keywords — ANSYS, PRO-E, Copper, Cork, SA92, Stress, Strain.

1. Introduction

1.1. Clutch

A clutch is an automation that disconnects and reconnects the driving and driven members. It is aforesaid to be engaged when the shafts are coupled and disengaged when released. The main function of the clutch is to enable smooth transmission of a rotary motion of associate engine shaft to a stationary or slowly revolving output shaft. Rapid disengagement and re-engagement of the engine from transmission helps for gear dynamic and emergency stops. Slipping happens when two shafts are locked together however spin at completely different speeds [1]. The overwhelming majority of clutches ultimately rely on frictional forces for their operation.

The performance and life of the clutch is influenced by its working characteristics and structural features [2]. The actuating force, torque transmitted, energy loss and temperature rise can be considered for analyzing the clutch performance. The torque transmitted is related to actuating force, co-efficient of friction and geometry of the clutch [3]. Two theories are used to obtain the torque capacity of the clutch viz. uniform pressure theory and uniform wear theory. For, uniform pressure theory is used because the intensity of pressure is approximately uniform whereas for old clutches uniform wear theory is more approximate [4].

1.2. Types of clutches

- Positive contact clutches
- Friction clutches

Positive contact clutch transmit power from the driving shaft to the driven shaft by means of jaws or teeth, whereas friction clutches works on the principle of friction caused between the two rotating members viz. discs, plates or cones. Compared to positive contact clutches, friction clutches can be used for high speed engagement applications.

The aim of friction clutches is to attach a moving member to another that is moving different speed or stationary, typically to synchronize the speeds, or to transmit power. As friction clutches slip relative to each other, there is very little shock during engagement. Friction clutches are further classified as dry and wet sort friction clutches. Most of the vehicles rely on dry sort clutch instead of wet sort clutch as wet clutch has lower co-efficient of friction. Thus, different clutches are elite for use on the premise of speed, material and torque of the rotating members.

1.3. Clutch plate

Clutch plates are made of cast iron or high carbon steels with a splined hub and a round metal plate lined with friction lining material .Clutch plate of cast iron is ideally used as a result of its high compressive strength and low ductility [5]. The friction material used for the clutch plate embrace asbestos , in the past and modern clutches use copper, cork or SA92 as friction materials which consists of fibres, fillers, binders and friction modifiers. Cork and copper are generally used as friction materials for clutch plate but SA92 is a specific purpose friction material used for light medium duty. It is a fully cured material which is suitable for bonding and riveting.[6]

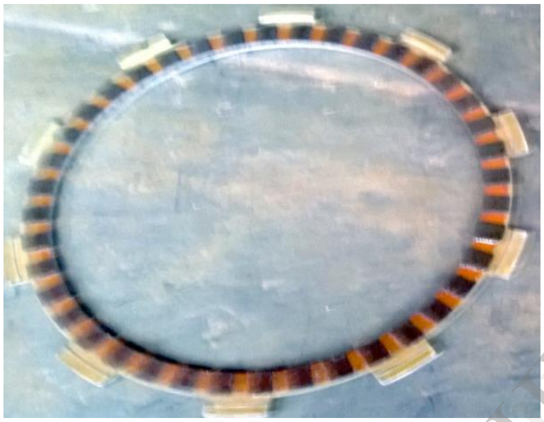

Figure. 1 Clutch plate

1.4. Desirable properties of friction lining material [7]

- The co-efficient of friction should be high for two materials in contact.
- The co-efficient of friction should be constant over a range of pressures and temperatures.
- The materials in contact should be strong enough to resist wear effects like scoring, galling, and ablation.
- The materials in contact should have sensible thermal conductivity, high heat capability and withstand high temperatures.
- Able to face up to high contact pressures
- Shear strength should be high enough to transfer the friction forces to structure.

2. Objectives

The main objective of this work is to carry out the structural analysis of the clutch plate with different friction linings and to select the most appropriate one.

- Solid modelling of multiplate clutch assembly.
- Determination of intensity of axial pressure as per rated torque.
- Determination of von mises stress.
- Determination of von mises strain.
- Determination of total deformation.
- Comparison of the design parameters viz. stress, strain and total deformation.

3. Methodology

In order to proceed with this study, the dimensions of the multiplate clutch were gathered from the pulsar DTSi model. The 3D model of the clutch assembly was designed in PRO-E.

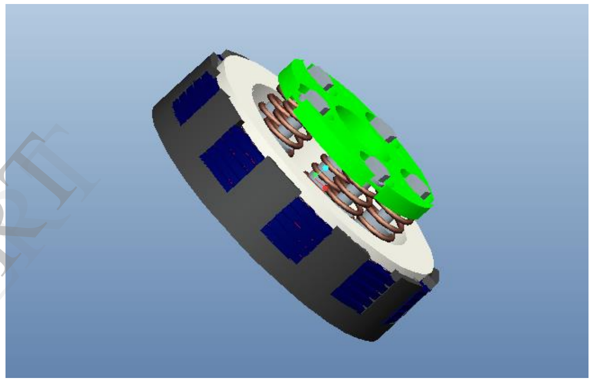

Figure 2. Assembly Of Multiplate Clutch

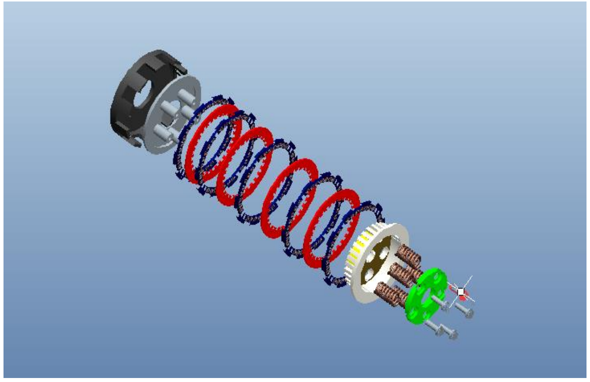

Figure 3. Exploded view of multiplate clutch

Figure 2 and 3 shows the assembly and exploded view of multiplate clutch which were designed with the help of PRO-E. In this study, steel (30Cr13) was used as a clutch plate material and copper, cork and SA92 were used as friction linings.

The intensity of axial pressure was calculated by using uniform pressure theory and uniform wear theory. As the structural behaviour of the friction lining of multiplate clutch can be studied by analyzing just a single clutch plate, hence in this study, structural analysis of a single clutch plate has been carried out in ANSYS workbench. The calculated axial pressure and the boundary conditions were applied on the clutch plate for copper, cork and SA92 as friction materials. The Von Mises Stress, Von Mises Strain and total deformation values for the three materials obtained from the analysis were compared and the best friction material was selected.

3.1. Engineering properties of material [5-8]:

The required properties to carry out the analysis are mentioned in the table 1.

Table 1. Properties of material

Mechanical Properties	Cork	Copper	SA92	Steel (30cr13)
Youngs modulus (MPa)	32	135000	3896	200000
Poisson's ratio	0.25	0.35	0.27	0.303
Density (kg/m^3)	180	8300	1800	7700
Yield stress (MPa)	1.4	510	14	550
Co-efficient of friction	0.3-0.5	0.28-0.3	0.3-0.4	0.27-0.3

3.2. Design Considerations

For a multiplate clutch, the number of pairs of contact surfaces is determined by the number of discs on driving and driven shafts. In this study the multiplate clutch employed has eight pairs of surfaces in contact (i.e n=8).

n = no of pairs of contact surfaces

$n = n_1 + n_2 - 1$

$n_1 = 5$ (no. of disc on driving shaft)

$n_2 = 4$ (of disc on driven shaft)

Hence n = 8;

Rated torque = 12.5 N-m = 12.5×10^3N-mm @ 6500rpm;

r_1 and r_2 are outer and inner radius of friction faces, where

r_1 =57.5mm and r_2 = 48.5 mm;

R = mean radius of friction surfaces

3.2.1. Considering uniform pressure theory:

For uniform pressure:

$$R = \frac{2(r_1^3 - r_2^3)}{3(r_1^2 - r_2^2)} = \frac{2(57.5^3 - 48.5^3)}{3(57.5^2 - 48.5^2)}$$

$$R = 53.12 \text{ mm}$$

When the pressure is uniformly distributed over the entire area of friction face then the intensity of pressure 'P',

$$P = \frac{W}{\pi(r_1^2 - r_2^2)}$$

W = Axial thrust with which friction surfaces are held together.

In general frictional torque acting on the friction surfaces or on the clutch is given by,

$$T = n \times \mu \times W \times R$$

μ = co-efficient of friction

We know that,

$T = 12.5\times10^3$N-mm

From above equation,

$12.5\times10^3 = 8\times0.3\times W\times53.12$

Therefore, W = 98.04N

$$P = \frac{W}{\pi(r_1^2 - r_2^2)} = \frac{98..04}{\pi(57.5^2 - 48.5^2)}$$

$$P = 0.03271 \text{ N/mm}^2$$

3.2.2. Considering uniform wear theory:

For uniform wear:

$$R = \frac{r_1 + r_2}{2} = \frac{57.5 + 48.5}{2}$$

$$R = 53 \text{ mm}$$

We know that, according to uniform wear theory, the intensity of the pressure is inversely proportional to the radius of friction plate.

$$P \times r = C \qquad (C = constant)$$

Axial force required to engage the clutch,

$$W = 2\pi C\,(r_1 - r_2)$$

Torque transmitted,

$$T = n \times \mu \times W \times R$$

$$12.5 \times 10^3 = 8 \times 0.3 \times W \times 53$$

Therefore, $W = 98.27$ N

The total force acting on friction surface is given by,

$$C = \frac{W}{2\pi(r_1 - r_2)} = \frac{98.27}{2\pi(57.5 - 48.5)}$$

$$C = 1.73779 \text{ N-mm}$$

We know that, the intensity of pressure is maximum at inner radius (r_2) of friction or contact surface.
Thus, the equation is written as,

$$P_{max} \times r_2 = C$$

That is, $P_{max} = 1.73779/48.5$

$$P_{max} = 0.03583 \text{ MPa}$$

Intensity of pressure is minimum at outer radius (r_1) of friction or contact surface.
Thus, the equation is written as,

$$P_{min} \times r_1 = C$$

That is, $P_{min} = 1.73779/57.5$

$$P_{min} = 0.03022 \text{ MPa}$$

The average pressure (P_{avg}) on the friction or contact surface is given by,

$$P_{avg} = \frac{\text{Total force on friction surface}}{\text{c/s area of frictional surface}}$$

$$P_{avg} = \frac{W}{\pi({r_1}^2 - {r_2}^2)} = \frac{98.27}{\pi(57.5^2 - 48.5^2)}$$

$P_{avg} = 0.032788 \text{ N/mm}^2$

In this study, maximum pressure calculated from uniform wear theory, is applied for analyzing design parameters of clutch plate.

4. Results and discussions

The design parameters (Von Mises stress, Von Mises strain and total deformation) obtained from the analysis were used to study the behavior of friction materials (copper, cork and SA92) on the clutch plate.

4.1. Analysis of clutch plate using copper as a friction material

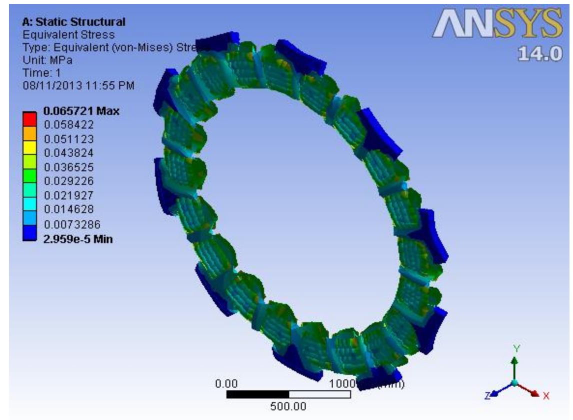

Figure 4. Maximum Von Mises Stresses

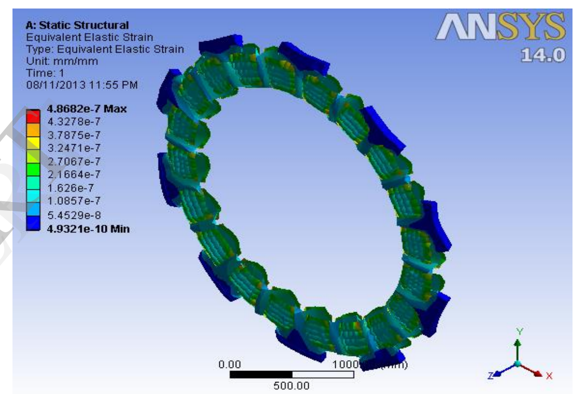

Figure 5. Maximum Von Mises Strain

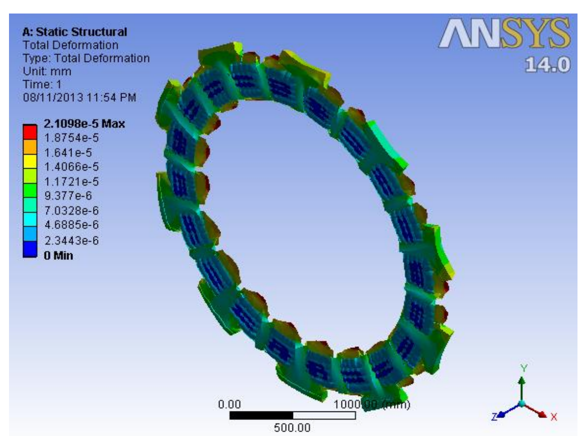

Figure 6. Total deformation

From the figure 4, it is observed that the maximum stress obtained from the analysis for overall component is 0.065752MPa which is less than the yield strength of material which is 550MPa. Thus the design is safe. Hence the stress developed in the clutch plate for rated torque is somewhat less than the yield strength of clutch plate. From figure 5 and 6, it is observed that the maximum von mises strain and maximum total deformation values of the clutch plate obtained are 4.8682e-7 and 2.1098e-5 mm respectively, which are very less than the deformation limit of material that is 1mm.

4.2. Analysis of clutch plate using cork as a friction material

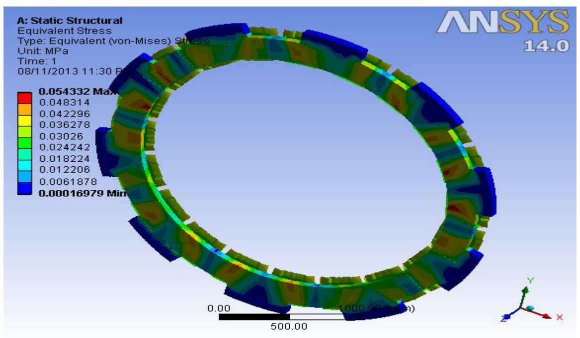

Figure 7. Maximum Von Mises Stresses

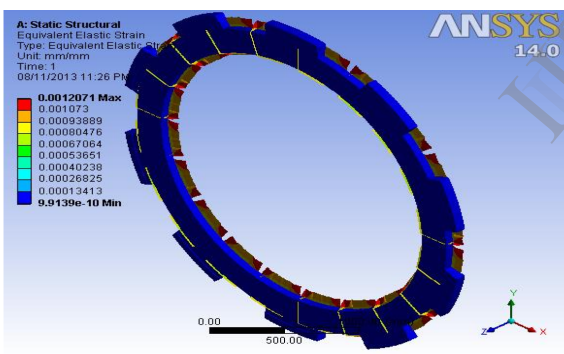

Figure 8. Maximum Von Mises Strain

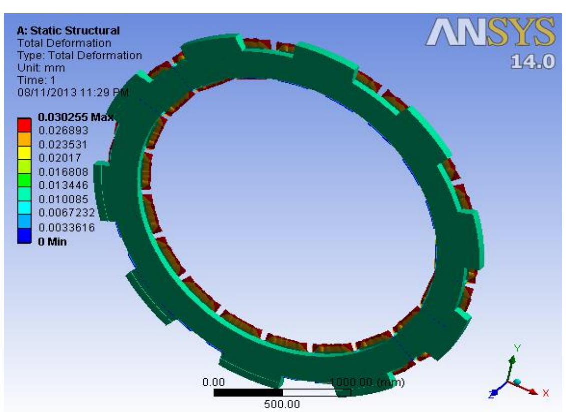

Figure 9. Total deformation

From the fig. 7, it is observed that for the overall component, the maximum stress obtained is 0.054332MPa which is less than the yield strength of material which is 550MPa. From fig. 8 and 9, the maximum von mises strain and maximum total deformation values obtained are 0.0012071 and 0.030255mm respectively, which are very less than the deformation limit of material (1mm).

4.3. Analysis of clutch plate using SA92 as friction Material

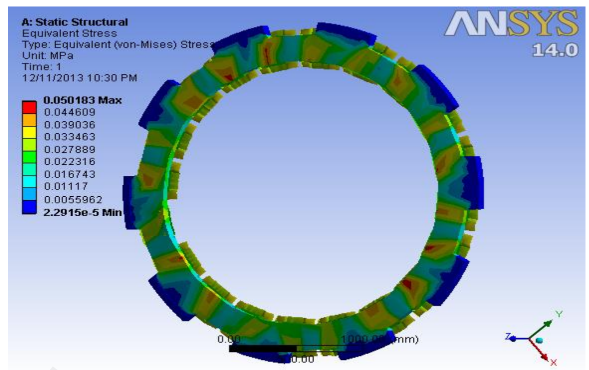

Figure10. Maximum Von Misses Stress

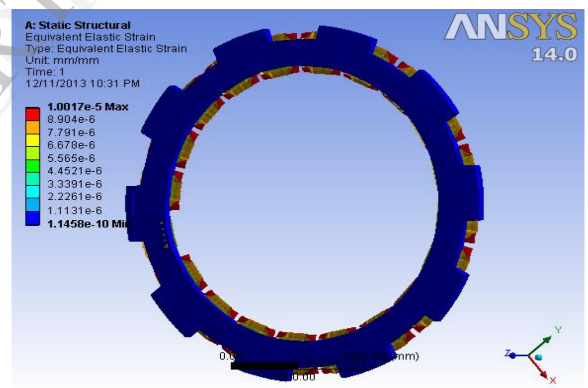

Figure 11. Maximum Von Misses Strain

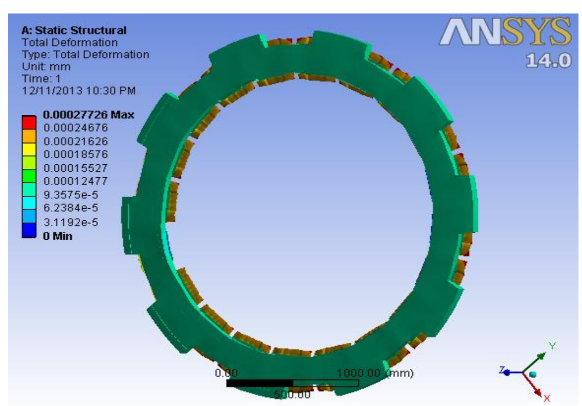

Figure12. Total Deformation

From the figure 10, the maximum stress value obtained for the overall component using SA92 friction material is 0.050183Mpa which is much less than the yield strength of material (550MPa). Also, the maximum strain and maximum total deformation values obtained from the analysis are 1.0017e-5 and 0.00027726mm which are very less than the deformation limit of material (1mm). In order to transmit the maximum torque from the engine to gearbox material should not get deformed beyond the safe limit. Ultimately, from the analysis, for all the friction materials, it is observed that for the rated torque the maximum stress developed in the clutch plate is very less than the yield strength of the material. Thus the factor of safety obtained for this design is found to be somewhat more.

Table 2. Analyzed results

Friction material	Von Mises Stress (MPa)	Von Mises Strain	Total Deformation (mm)
Copper	0.065752	$4.8682e^{-7}$	2.1098e-5
Cork	0.054332	0.0012071	0.030255
SA92	0.050183	1.0017e-5	0.00027726

Table 2 shows the variation in strength of all three materials. From the analyzed result it is observed that the maximum stress developed in SA92 is lesser than that of copper and which implies that SA92 has low wear rate and stable friction performance. The total deformation and strain developed in SA92 is lesser than that of cork and greater than that of copper.

5. Conclusion

In this project, a 3D model of multiplate clutch and its assembly has been done using Pro-E software packages. Structural analysis on clutch plate has been carried out using ANSYS workbench for copper, cork and SA92 as friction lining materials. Ultimately, from this analysis it can be concluded that, on the strength basis, SA92 is more suitable and quite better friction material than copper and cork for same rated torque.

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