International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 09 Issue: 08 | August 2022 www.irjet.net p-ISSN: 2395-0072

Comparative study of Structural Analysis of a Multi-plate Clutch

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Abstract- *A clutch is a mechanical device that transfers rotation from a shaft to the other. Contact clutches are widely utilized in the gearbox transmission system of automobiles. Clutches serve as a link between the driving and driven shafts. Multi-plate clutches are used in heavy weight vehicles as it is near to impossible to transmit torque with single friction plate. One of the most crucial assignments in friction clutches is the selection of the preferred friction lining material to attach to the clutch plates to transmit maximum amount of torque. We use the uniform wear hypothesis to design a multi plate clutch in this paper***.** *We have designed a 3D model using Solidworks 17.0 software for the clutch and Ansys Workbench 19.0 to study stress, strain, total deformation, Maximum Shear stress, Elastic strain for friction material made of Titanium carbide in comparison with Carbon Fiber.*

***Key Words*:** Ansys, Clutch, Titanium Carbide (Ti-C), Carbon Fiber, Solidworks, Friction plate.

1.INTRODUCTION

Clutches are engineered to transfer maximum torque while producing the least amount of heat. The sliding action between the two clutch discs occurs during both engagement and disengagement. Large amounts of heat will be produced during engagement and disengagement as an outcome of the two discs rubbing with one another. Unless the driver depresses the pedal to disengage it, the clutch is constantly in the engaged condition, meaning that the connection between the transmission and the engine is always "on". The engine rotates the input shaft of the transmission system when the clutch is engaged and the transmission is in neutral, but no power reaches the wheels. Positive clutches are capable of transmitting a significant amount of torque without slipping, but they have some drawbacks, including the failure to engage at high speeds. Any velocity of engagement results in shock. To engage when both the driving and the driven shafts are at equilibrium, require some relative motion. Friction clutches are the most popular choice in automotive applications since they can overcome these shortcomings.

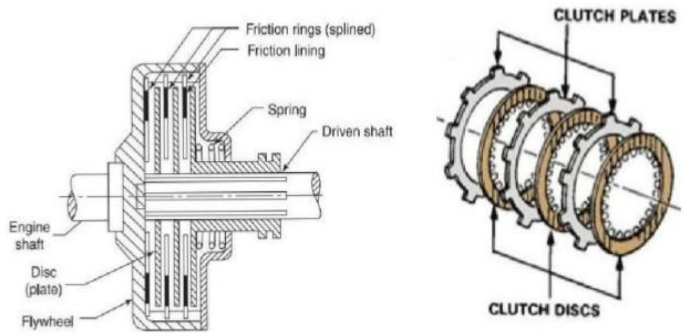

Fig -1: Multiplate Clutch and Friction lining material

2. Multiplate Clutch

In Fig 1, we see a simplified multi plate clutch involving more than one set of plate and friction plate. One set of plate slides in grooves on the flywheel and another set slides on splines on the pressure plate hub. So, alternate plates belong to each set. The pressure placed on the foot pedal is transmitted through the release finger, fork, and release bearing. After that, the springs compress and the pressure disc moves back, which releases the clutch plate.

The clutch is supposedly disengaged at this time. At this point, the clutch plate is immobile, allowing the pressure plate and flywheel to freely rotate. Similar to this, the clutch plate receives full spring pressure when the clutch pedal is removed. The plate rotates as a single unit while still being held between the pressure plate and flywheel. The following variables affect the friction clutch's torque capacity: friction coefficient, friction plate diameter and axial thrust imparted by the pressure plate the clutch's size imposes a limit on the friction plate's diameter. The following variables affect the friction clutch's torque capacity: friction coefficient, friction plate diameter and axial thrust imparted by the pressure plate the clutch's size imposes a limit on the friction plate's diameter. The amount of pressure an individual can exert on the clutch pedal to release the clutch limits the axial force. Therefore, friction lining materials must possess an optimum coefficient of friction to transfer the maximal torque.

2.1 Requirements of friction lining

1. Under working conditions, a relatively high coefficient of friction.
2. Reasonably good short-term energy absorption capacity.
3. Must be able to endure hot temperatures brought on by slipping
4. Should keep its frictional characteristics throughout its operating life.
5. Must endure a pressure plate's high compressive load.
6. Must be extremely resistant to wear effects such scoring, galling, and ablation.
7. Oil and moisture should have no effect on it.
8. The shear strength should be sufficient to transmit torque.
9. Good base metal compatibility across the working temperature range.
10. It should be able to dissipate heat well.

In this study, we compare two distinct friction lining materials, Ti-C and Carbon Fiber. Both these materials have high-performance metallic composite material made of carbon. It can endure high energy inputs and is suitable for both dry as well as oil-immersed application domains, making it an alternative to often used sintered metallic materials as friction lining. It isn't abrasive to the counter material, operates quietly, and can resist high stresses. Despite extreme temperatures, wear is minimal

3. Methodology

Power = 10.6KW @ 11000 rpm and Torque = 13.2 Nm @ 8500 rpm.

Table-1 Properties of friction lining materials

Property	Ti-C	Carbon Fiber
Density(g/cc)	4.92	1.60
Tensile Modulus (GPa)	400	70
Poisson coefficient	0.187	0.10
Yield Strength (MPa)	258	600
Coefficient of friction	0.35	0.32

Ti-C on steel was used as the material

R_1 and R_2 are the outer and inner friction face radiuses.

R_1 =0.056m and R_2 = 0.045m

k = no of pairs of contact surfaces

$k = k_1 + k_2 - 1$

Where k_1 and k_2 are no. of discs on driving and driven shaft

$k_1 = 6$ and $k_2 = 4$; $k = 9$

Taking into account the uniform wear hypothesis, wearing is dependent on the magnitude of the pressure "P" and the angular velocity of the friction plate, both of which are dependent on R,

As a result, having an even rate of wear (P)x(R) is continual.

For uniform wear $R = 0.5 * (R_1+R_2)$

Where R = average of the radius of friction material

R = (0.056+0.045)/2 = 0.0505m

Torque (T) = μ*W*R*k

Where, μ = friction coefficient and W = Clamping force or Load acting Axially.

13.2 = (0.35) *(W)*(0.0505) *(9)

W = 82.97 N

Now, from uniform wear hypothesis,

W = (2π) *(Pmax R2) *(R1 – R2)

Where, P_{max}= maximum pressure between the contacting surfaces

95.52 = (2π) *(P_{max} x 0.045) *(0.056 – 0.045)

P_{max}= 26,676.94 N/mm^2

The values of W and P_{max} are also calculated for another material Carbon Fiber (μ=0.32), using the method described above.

W = 90.75N

P_{max}= 29,181.32 N/mm2

4. Solid Modelling

The modelling is carried out in Solidworks 17.0. A same model of the Multi plate clutch is designed and assembled. The burst view of the multi plate clutch assembly is shown in the Fig 2.

Fig 3 shows the single plate of the multi plate clutch assembly on which the friction lining materials, Ti-C and Carbon fiber are present. The plate is made up of Structural stainless steel. The friction lining materials are attached to the clutch plate using different adhesives.

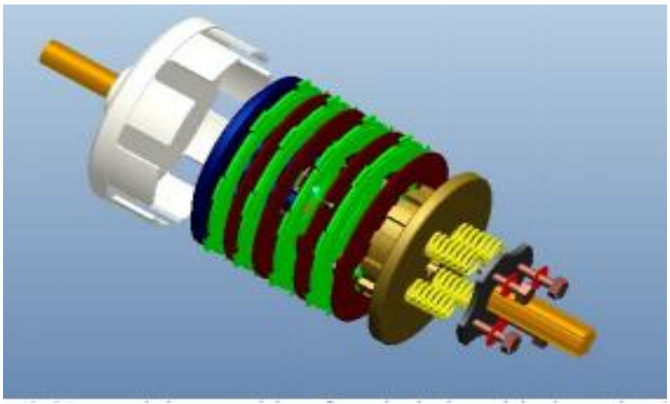

Fig -2 Assembly view of Multi Plate Clutch

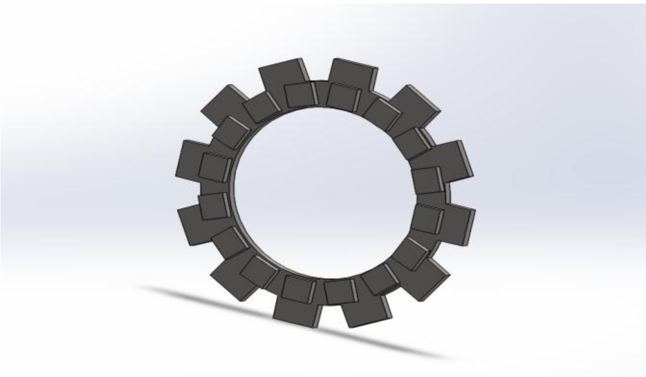

Fig -3: Singe clutch plate with friction lining

5. Analysis

Using computing methods, the maximum pressure is applied to the friction plate. Ansys is used to compute the results of Maximum shear stress, Total Deformation and Elastic strain are compared between two materials.

6. Results and Discussions

In ANSYS structural analysis is done for each node individually, after solving the results of each node it is compiled to give the result.

6.1 Total Deformation

Under dynamic conditions for structural analysis, figures 4 and 5 show the total deformations of clutch plate with Ti-C and Carbon Fiber respectively.

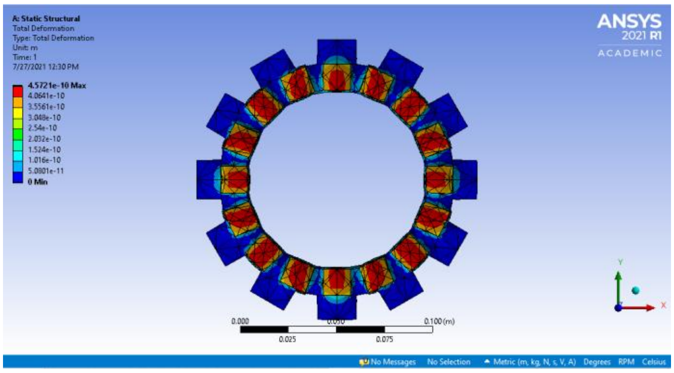

Fig-4: Total Deformation using Ti-C friction lining

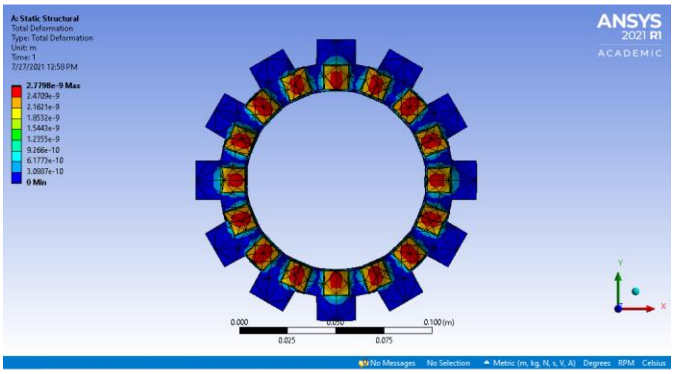

Fig-5: Total Deformation using Carbon Fiber friction lining

6.2 Maximum Shear Stress

Under dynamic conditions, figures 6 and 7 show the Maximum shear stress of clutch plate with Ti-C and Carbon Fiber respectively.

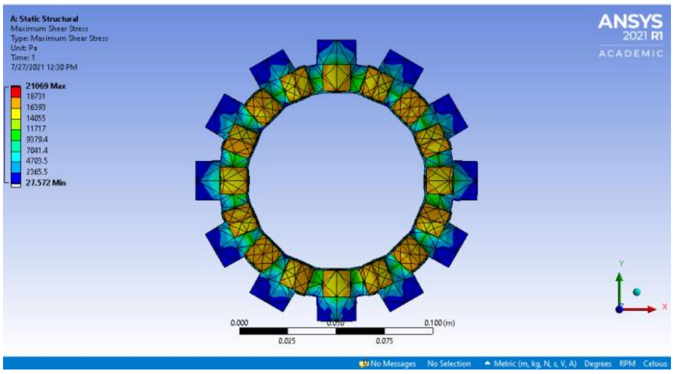

Fig-6: Maximum shear stress using Ti-C friction lining

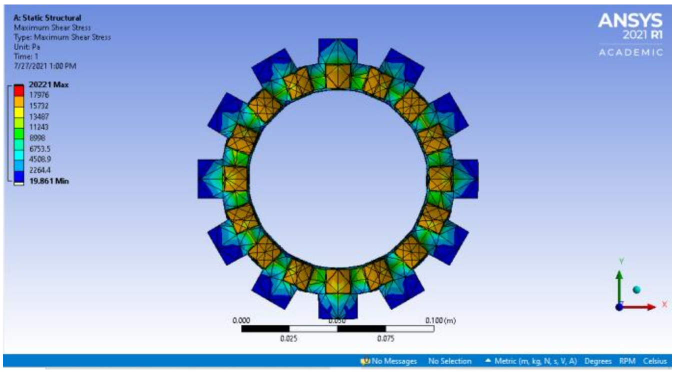

Fig-7: Maximum shear stress using Carbon Fiber friction lining

6.3 Maximum shear elastic strain

Under dynamic conditions, figures 8 and 9 show the Maximum shear elastic strain of clutch plate with Ti-C and Carbon Fiber respectively.

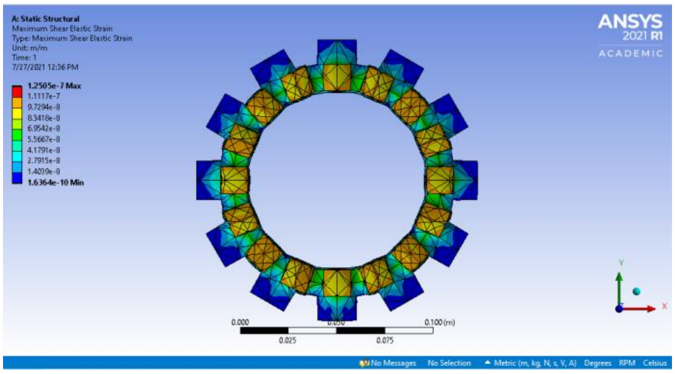

Fig-8: Maximum shear elastic strain using Ti-C friction lining

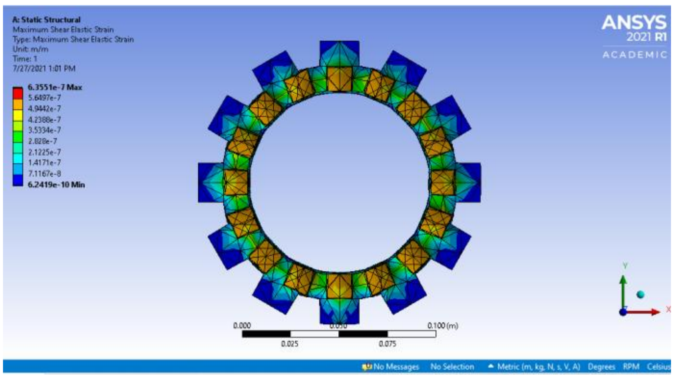

Fig-9: Maximum shear elastic strain using Carbon fiber friction lining

As shown in table 2, a comparison is made between the friction lining materials Ti-C and Carbon fiber for the dynamic structural analysis of the clutch plate.

Table 2- Comparison between Ti-C and Carbon fiber

Property	Ti-C	Carbon Fiber
Total Deformation(mm)	4.5721e-7	2.7798e-6
Maximum shear stress (MPa)	0.021069	0.020221
Maximum shear elastic strain	1.2505e-7	6.3551e-7

7. CONCLUSIONS

According to the findings in Table 2, it can be concluded that clutch plates built using fiber as the friction lining material exhibit less overall deformation and maximum elastic strain than clutch plates created with titanium carbide. Upon comparison to Titanium Carbide, the maximum stress that can be created in a clutch plate's friction material with Carbon Fiber is lower for the same amount of torque. Therefore, it is possible to conclude that clutch plates with carbon fiber friction material operate better than those with titanium carbide.

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