DESIGN EVALUATION OF A MULTI PLATE CLUTCH

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***Abstract*:** A clutch is a mechanical device which provides for the transmission of power (and therefore usually motion) from one component (the driving member) to another (the driven member). A multi plate clutch may be used when a large torque is to be transmitted. The inside discs are fastened to the driven shaft to permit axial motion. The outside discs are held by bolts and are fastened to the housing which is keyed to the driving shaft. The inside discs are usually made of steel and outside discs are usually made of bronze. The materials used for lining of friction surfaces are Asbestos, Cork, Rubber, Cast iron, Powder metal. The aim of the project is to design a multi plate clutch by using empirical formulas. A 2D drawing is drafted for multi plate clutch from the calculations and a 3D model is created in the 3D modeling software Pro/Engineer. By conducting structural and fatigue analysis by varying the friction surface of material for above design for validating design. By extracting the result we are going to find out which material is best for the lining of friction surfaces. Structural and fatigue analysis is done for multi plate clutch using the properties of the two materials. Materials used for liner is Cork and Powder metal AL-7075-T651. Comparison is done for above both materials to validate better lining material for multi plate clutch under the different load conditions while changing the gears. Analysis is done in ANSYS software.

Index Terms – Steel, Bronze, Copper Metal Powder, AL-7075-T651 Powder Matrix.

1. **DESIGN CALCULATIONS**

1.1 Specifications -

Power = 13.8 BHP @ 8500 rpm

Torque = 13.4 N-m = $13.4 \times 10^3\ n - mm$

Material used is pressed asbestos on cast iron or steel μ = 0.3

Maximum operating temperature = 150 – 250^0 c

Maximum Pressure = 0.4 N/mm^2

r_1 & r_2 outer and inner radius of friction faces r_1 =109 mm and r_2 = 90 mm

n = no of pairs of contact surfaces

$n = n_1 + n_2 – 1$

$n_1 = 5$ & $n_2 = 4$; n = 4

For uniform Pressure $R = \frac{2}{3}\left[\frac{{r_1}^3 - {r_2}^3}{{r_1}^3 - {r_2}^3}\right] = \frac{2}{3}\left[\frac{109^3 - 90^3}{109^3 - 90^3}\right] = 99.80mm$ …. Eq.1

For uniform wear $R = \frac{r_1 + r_2}{2} = \frac{109+90}{2} = 99.5mm$ … Eq.2

2. CONSIDERING UNIFORM PRESSURE

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

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

$T = 13.4\times 10^3 = 8 \times 0.3 \times W \times 99.80 = 55.94$ …. Eq.3

$P = \frac{W}{\pi({r_1}^2 - {r_2}^2)} = P = \frac{55.94}{\pi(109^2 - 90^2)} = 0.00047$ ….. Eq.4

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

$T = \mu WR$

$T = 13.4\times 10^3\ N - mm,\ R = 99.80,\ \mu = 0.3$ …… Eq.5

By substituting all these values in the above equation we get W

$13.4\times 10^3 = 0.3 \times W \times 99.80 = 447.561$ …. Eq.6

$P = \frac{W}{\pi({r_1}^2 - {r_2}^2)} = \frac{447.561}{\pi(109^2 - 90^2)} = 0.0376\ N/mm^2$ …… Eq.7

3. CONSIDERING UNIFORM AXIAL WEAR

For uniform wear $P\times r = C$ …. Eq.8

Axial force required to engage the clutch $W = 2\pi C\ (r_1 - r_2)$ ….Eq.9

Mean radius of the friction surfaces $R = \frac{109+90}{2} = 99.5$

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

$13.4\times 10^3 = 8 \times 0.3 \times W \times 99.5 = 56.11$ ….Eq.10

The intensity of pressure is maximum at the inner radius (r_2) of the friction or contact surface

Equation may be written as $P_{max} \times r_2 = C$ … Eq.11

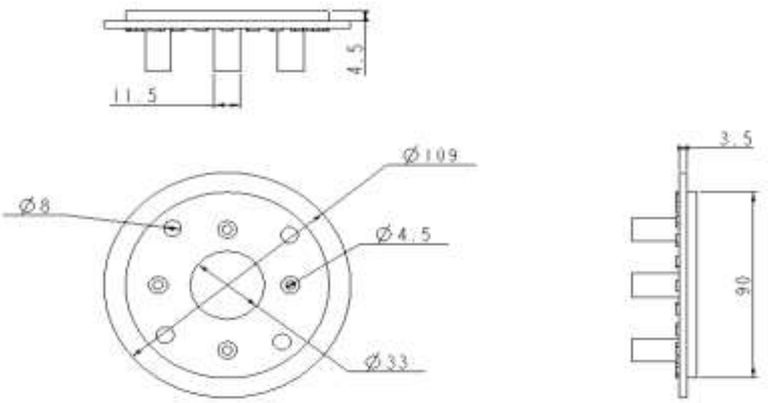
WKT total force acting on the friction surface C = $\frac{W}{2\pi(r_1 - r_2)} = \frac{56.11}{2\pi(109-90)} = 0.470$ …Eq.12

$$P_{max} = \frac{C}{r_2} = \frac{0.470}{90} = 0.00522 \text{ …..Eq.13}$$

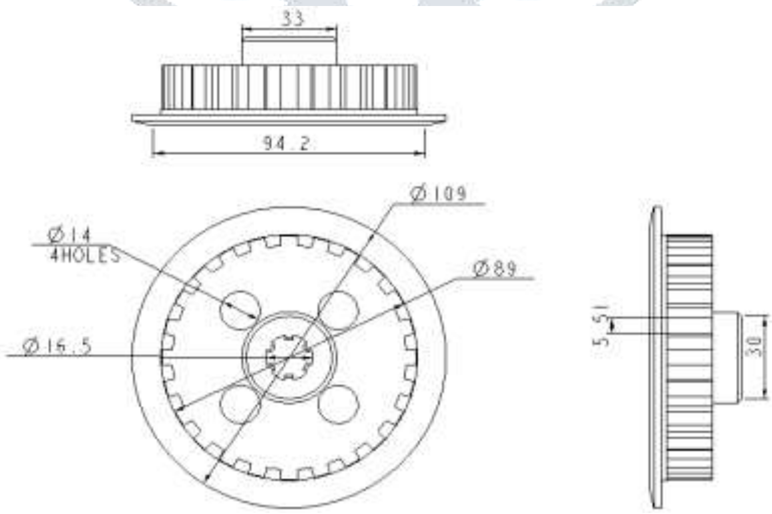
The intensity of pressure is minimum at the outer radius (r_1) of the friction or contact surface
Equation may be written as $P_{min} \times r_1 = C$

$$P_{min} = \frac{C}{r_1} = \frac{0.470}{109} = 0.00431 \text{ …..Eq.14}$$

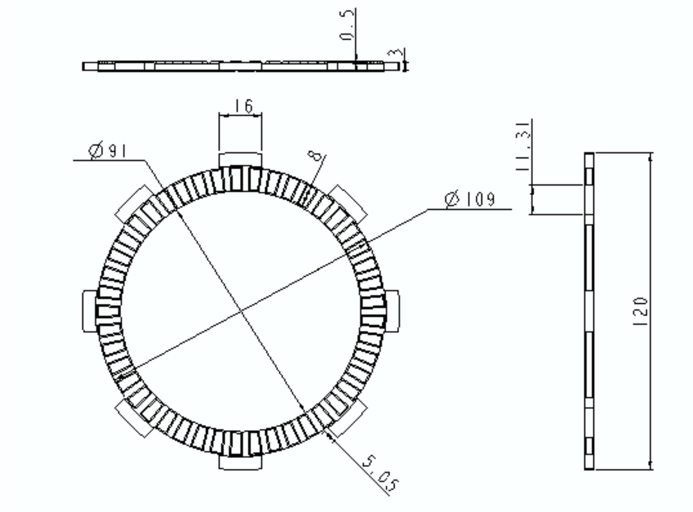
4. 2D DRAWINGS



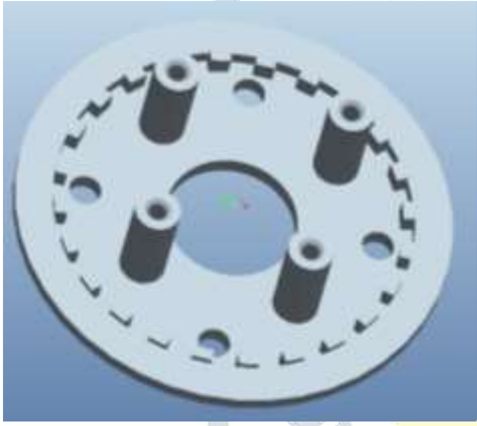
Base Part



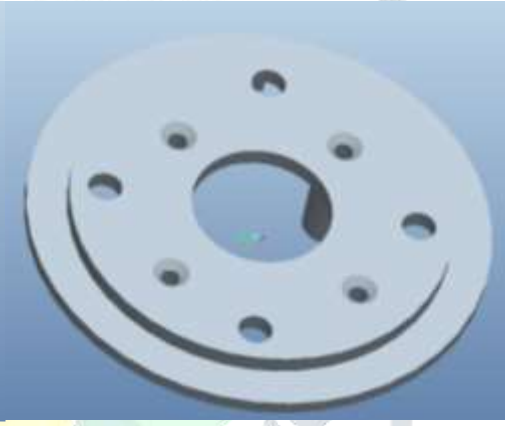
Double Disc Part



Friction Plate



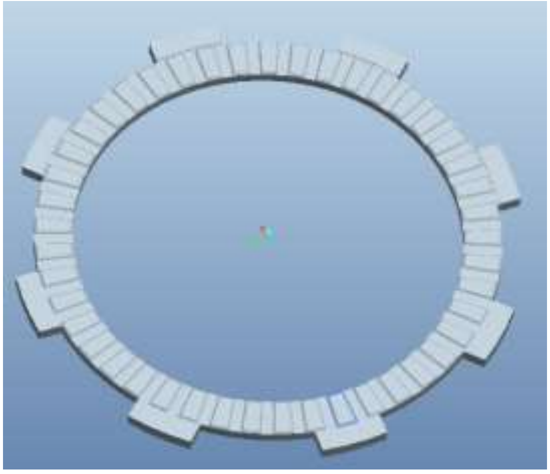
Base Plate



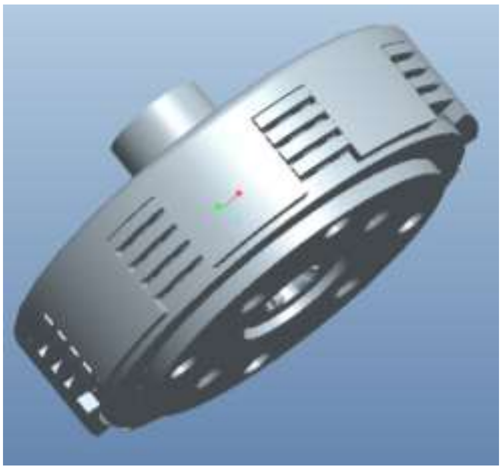
Base Plate Top

Double Plate Bottom

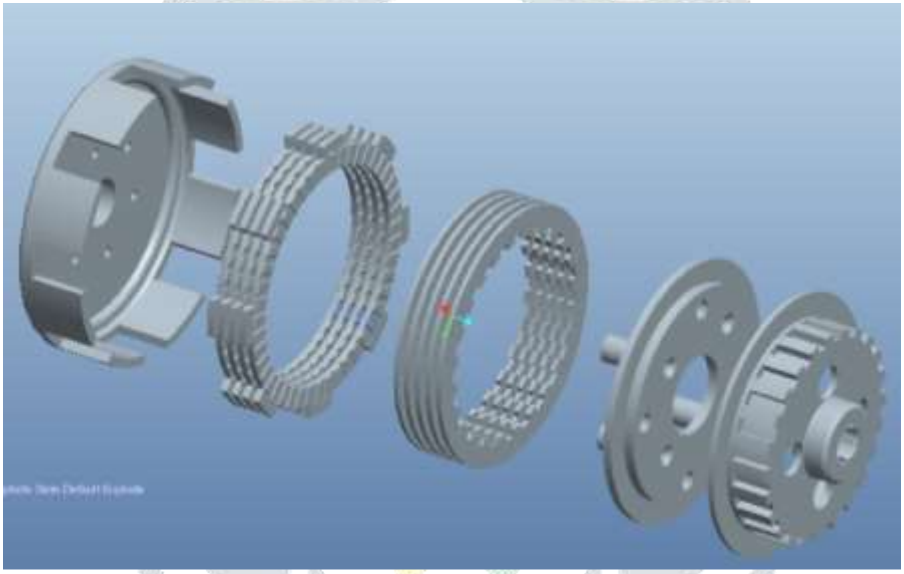
Double Plate Top



Friction Plate

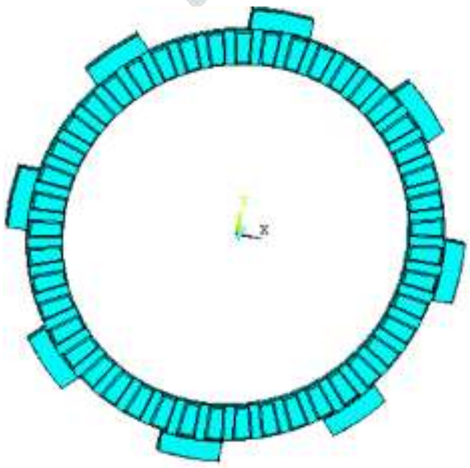


Assembly of Multi Plate Clutch



Exploded View of Multi Plate clutch

5. STRUCTURAL ANALYSIS ON MULTI PLATE CLUTCH



Meshed model for analysis

5.1 Cork as friction material

1. Inner Disc - Steel

Element Type: Solid 20 node 95

Material Properties: Young's Modulus (EX) : 205000N/mm^2

Poisson's Ratio (PRXY) : 0.29

Density : 0.00000785kg/mm^3

2. Outer disc – Bronze

Element Type: Solid 20 node 95

Material Properties:

Young's Modulus (EX) : 137000N/mm^2

Poisson's Ratio (PRXY) : 0.346

Density: 0.00000925kg/mm^3

3.Friction Material – Cork

Element Type: Solid 20 node 95

Material Properties:

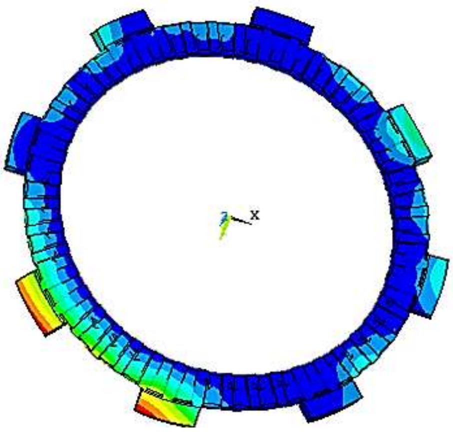
Young's Modulus (EX) : 20N/mm^2

Poisson's Ratio (PRXY) : 0.064

Density: 0.0000024kg/mm^3

Loads

Pressure – 0.00522N/mm^2



Nodal solution for cork as friction material

5.2 FATIGUE ANALYSIS

Four load cases are applied:

a. 0.00522 The time at the end of the load step is 10 seconds.
b 0.01044 The time at the end of the load step is 20 seconds.
c. 0.01566 The time at the end of the load step is 30 seconds.
d. 0.02088 The time at the end of the load step is 40 seconds.

The events to be used in the analysis are

Event No.	Load No.	Loading	Number of Repetitions
1	1	0.00522	500,000
1	2	0.01044	500,000
2	1	0.01566	5,000
2	2	0.02088	5,000

6. STRUCTURAL ANALYSIS USING POWDER METAL AL-7075-T651 AS FRICTION MATERIAL

1. Inner Disc - Steel

Element Type: Solid 20 node 95

Material Properties: Young's Modulus (EX) : 205000N/mm^2

Poisson's Ratio (PRXY) : 0.29

Density: 0.00000785kg/mm^3

2. Outer disc – Bronze

Element Type: Solid 20 node 95

Material Properties: Young's Modulus (EX) : 137000N/mm^2

Poisson's Ratio (PRXY) : 0.346

Density: 0.00000925kg/mm^3

3. Friction Material – AL-7075-T651

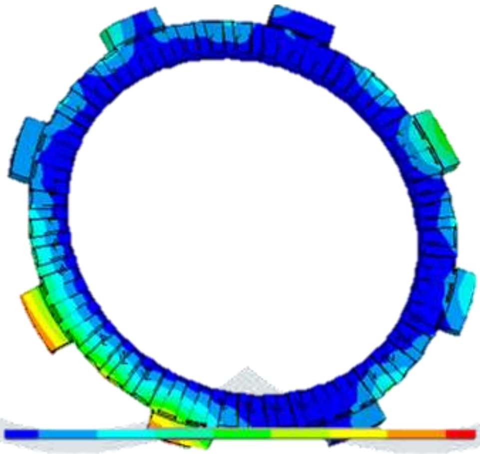
Element Type: Solid 20 node 95

Material Properties: Young's Modulus (EX) : 70000N/mm^2

Poisson's Ratio (PRXY) : 0.3

Density: 2800 kg/mm^3 .

Pressure – 0.00522N/mm^2



Nodal solution for powder metal matrix AL-7075-T651 as a friction material

7. RESULTS TABLE

	Displacement (mm)	**Von Mises Stress (N/mm^2)**	**Yield Stress (N/mm^2)**
Cork as Friction Material	0.010513	0.022904	1.38
Powder MetalAL-7075-T651 as Friction Material	0.181e^{-5}	0.017917	345

Structural analysis

	Cork as Friction Material	**Powder MetalAL-7075-T651 as Friction Material**
Constrained area **Event 1 Load1, Event 1 Load 2** **Event 2 Load1, Event 2 Load 2**	0.681 E^{-02} 0.278 E^{-01}	0.638E^{-02} 0.527E^{-01}
Pressure area **Event 1 Load1, Event 1 Load 2** **Event 2 Load1, Event 2 Load 2**	0.323 E^{-02} 0.461 E^{-02}	0.546 E^{-03} 0.552E^{-03}

Open area **Event 1 Load1,** **Event 1 Load 2** **Event 2 Load1,** **Event 2 Load2**	0.63449 0.63634	$0.269E^{-01}$ $0.385E^{-01}$

Fatigue analysis

9. CONCLUSION

Structural analysis is done on the friction plates to verify the strength. Friction materials used are Cork and Powder Metal. Material used for inner disc is steel and outer disc is bronze. By observing the analysis results, the stress values for cork and powder metal AL-7075-T651 are less than their respective values. So our design is safe. The displacement and stress values are less using Powder Metal than using cork. Fatigue analysis is also done for cyclic loading. The loads applied on the multi plate clutch are increased for every 10secs. The results are considered for nodes at constrained area, open area and pressure area. By observing the results of fatigue analysis, the stress values are less of powder metal. So we conclude that for multi plate clutches using powder metal AL-7075-T651 as friction material is advantageous than using cork as friction material.

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