Design and Analysis of a Single Plate Clutch Assembly

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Abstract – *The goal of this article is to design a single plate clutch for a specific pick-up vehicle that is ready to be manufactured. Auto Cad is used to create sketches using the calculations done in this paper. Complete material selection based on the various components of the assembly is done according to the requirements of the vehicle and the cost of components. Manufacturing procedures for each and every component in the assembly along with the type of fit are described, and finally pricing for all individual parts is covered in this paper.*

Key Words: **Clutch, Design, Auto Cad, Fly Wheel , Manufacturing**

1. INTRODUCTION

A clutch is essentially a mechanical device whose basic purpose is to connect and disconnect the power source from the remaining parts of the transmission system as per the will of the operator.

It is a vehicle component that joins two or more spinning shafts. The clutch in a manual transmission car manages the connection between the engine shaft and the shafts that turn the wheels. It is an important aspect of the car's functioning machinery because the engine creates power all of the time and has sections that rotate constantly, but the wheels do not. [2]

The connection between the wheels and the engine must be briefly interrupted to allow the car to alter the speed and come to a complete stop without turning off the engine. The clutch plate and the flywheel are the two major components of your clutch.[3] There are springs that keep a pressure plate pushed up against the clutch plate if your foot is not pressing down on the clutch pedal.

The clutch plate is pushed up against the flywheel by the spring pressure. This connects the engine to the shaft that transmits motion to the wheels, causing both to rotate at the same time. When you press down on the clutch pedal, your foot presses down on a release fork, which draws the pressure plate away from the clutch plate via a series of springs and pins.[2] This cuts the link between the rotating engine and the wheels, causing the wheels to spin on their own momentum rather than through the engine's power.

This design allows drivers to detach the wheels from the engine in order to change gear, giving them greater control over their vehicle's speed.

The main objective of this is project is to design a single plate frictional clutch assembly with theoretical analysis. This paper serves as a conduit of our work that we have done on our project.[4]

1.1) Specifications of engine

The single plate frictional clutch will be designed for a Pick-up -Truck named TATA YODHA 1700ar:[5]

Fig -1: TATA YODHA.

Engine and Clutch	
Engine Type	Tata 2.2L BS6 DI Engine
Max Engine Output	73.6 kW(100HP)@3750r/min
Max Engine Torque	250Nm @1000-2500 r/min
Fuel Tank Capacity	45L
Clutch	Single Plate Dry Friction Type 260 mm D

Table 1: Specifications

1.2) Specifications of engine[5]

- Clutch diameter (D): 260 mm.
- Torque (Engine) : 250 N-m (250,000N-mm).
- Power (Engine) : 100 HP (73.6 kW).
- Number of pairs of contacting surface (n) : 2.

- Number of springs = 8 .
- Service Factor ks = 1.5.
- Coefficient of friction (μ) = 0.32 (Sintered metal (dry) (0.33).)
- Intensity of pressure at radius r (p) = 0.689 N/mm2.

2. Material Selection

2.1) Fly Wheel

A fly wheel is subjected to heavy torque conditions with high temperatures. Hence, selecting Carbon steel AISI 1040 .

2.2) Clutch Friction Lining/Clutch Plate

While selecting the friction lining material higher coefficient of friction under lower pressure was considered. Also, the friction lining should withstand Higher temperatures .Below are some of the materials with their friction coefficient and maximum pressure required for their operations. As asbestos material being harmful for uses, we have decided to choose the material : Cermet (0.32).

Material	Friction Coefficient, f	Maximum Pressure, p_{max} [psi]
Cermet	0.32	150
Sintered metal (dry)	0.29-0.33	300-400
Sintered metal (wet)	0.06-0.08	500
Rigid molded asbestos (dry)	0.35-0.41	100
Rigid molded asbestos (wet)	0.06	300
Rigid molded asbestos pads	0.31-0.49	750
Rigid molded nonasbestos	0.33-0.63	100-150
Semirigid molded asbestos	0.37-0.41	100
Flexible molded asbestos	0.39-0.45	100
Wound asbestos yarn and wire	0.38	100
Wound asbestos yarn and wire	0.38	100
Woven cotton	0.47	100
Resilien paper (wet)	0.09-0.15	400

Table 2: Material Properties[1]

2.3) Pressure Plate

The pressure plate provides axial force for the clutch to remain in engaged position as well a complex design is required. Hence, Gray Cast Iron 20 (FS).

2.4) Springs in clutch

The springs in clutch provide axial force which essential for the engagement and the working of the clutch. They are also used for dampening the torque. Stainless Steel with UNS No. S030300 AISI No. 303[b] will be suitable for the application.

2.5) Rivets

Rivets are used to hold together the rotating component and the friction lining of the clutch. Hot Rolled Stainless Steel with UNS No. S030200 AISI No.302 will be suitable for the application.

3. Calculations

3.1) Nomenclature for mathematical calculations

- Outer diameter (friction lining) : R0.
- Inner diameter (friction lining) : Ri.
- Torque : T.
- Coefficient of friction : μ
- Intensity of pressure at radius r : p .
- Number of pairs of contacting surface : n
- Angular velocity rad/sec : ω.
- Speed of Engine in r.p.m : N.
- Clutch Outer diameter : R.
- Total operating force (N) = P.

To Calculate –

- Design Inner and outer diameter for the friction lining.
- Spring force (axial Force) required to keep the clutch engaged in its position.
- Torque transmitting capacity of the clutch (Tmax).
- Power transmitting capacity of the clutch (Pmax).
- Design of Spring for the pressure plate.
- Design of damper springs.
- Design of rivets in clutch.
- Design of pedal.

Here we need to manufacture a single plate frictional clutch with a service factor (K_s) of 1.5.

We know that

$(M_t)_{des} = K_s(M_t)$

Where,

K_s = Service factor

$(M_t)_{des}$ = Torque capacity of clutch for design = 1.5x250

$(M_t)_{des}$ = 375Nm.

M_t = Rated Torque

Hence torque capacity for design purpose will be 375N-m.

Service factor is necessary so as to avoid slippage of clutch during the start of engine.

3.2) Inner diameter of friction lining

The friction lining is provided on both sides of the friction disk. Hence, it has two pairs of contacting surfaces one between flywheel and one between the pressure plate.

Torque transmitting by one pair of contact surface – 375/2

187.5N-m (using uniform wear theory)

$M_t = \pi \mu p_a d(o^2-d^2)/8$ [1]

d = 235mm (choosing the higher positive value)

Hence , the inner diameter for the friction lining is 235mm.

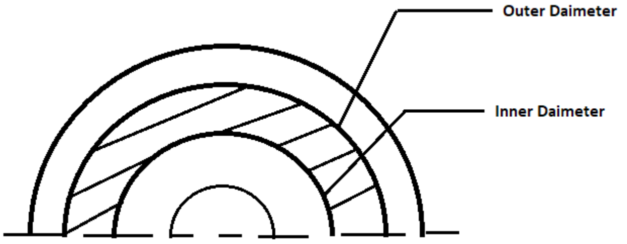


Fig -1: Friction Lining diameter.

3.3) Spring pressure plate design

Springs play the role of keeping the clutch in the engaged position by providing the axial force and it will slip when the spring force is no longer there.

Using uniform wear theory –

$M_t = \mu p(D+d)/4$[1]

187500 = Px0.32x(260+235)/4

P = 4734.84 N

Since there are 8 springs , the force per spring is -

P/8 = 591.85N

Hence if the force per spring is less than 591.85N , the clutch will begin slipping.

Now, taking a spring which gives 950N (P) of axial force when compressed 8mm(δ).

Compression of spring = -x (initial compression)

Stiffness of spring = 591.85/8-x (N/mm) ----(a)

Initially each spring is compressed by 8mm to provide the 950N force, hence stiffness = 950/8 ----(b)

From (a) & (b) , we get – x = 3.016mm ----(c)

Hence when the wear of friction lining is more than 3.016mm the spring force will be less than 591.85N and the clutch will slip.

Stiffness of the spring = 950/8 = 118.75 ----(d)

Taking,

Spring index(C) = 5

Youngs modulus (G) = 81370 N/mm^2

The permissible shear stress for the spring wire is 30% of the ultimate tensile strength.

$\tau_d = 0.2\ \sigma_{ut}$

P = 591.85N

Wahl's Factor

K = (4C-1/4C-4) + (0.615/C)[1]

K = 1.3105

$\tau = K(8PC/\pi d^2)$[1]

Now , solving by trial and error

$\tau = 8523.21/25 = 340.92$N/mm^2

$\tau_d = 0.3(1390) = 417$N/mm^2

Now , as $\tau_d > \tau$, the design is considered safe.

d=5mm.

Mean Coil Diameter

D = Cxd = 5x5 = 25

No of turns (n)

$n = Gxd/8c^2K_s$

n = 3.42

Total no of turns with squared and ground ends –

$n_t = n+2 = 5.42 \approx 6$

Free length = 6x5 + 4 + 591.5/118.75 ≈ 39mm.

Finally , to check if these 8 springs can be accommodated in the design-

Mean diameter of friction disk = (260+235)/2 = 247.5

Space available per spring = 247.5/8 = 31mm

Mean coil diameter = 25mm

Hence spring can be safely fitted.

3.4) Torque transmission after the wear

- We selected a spring which gives us 960N of axial force on compression of 8mm , and on calculation for the spring we obtained total free length to be 39mm.

- The spring has a sold length ≈ 28mm and to transmit the required torque the spring is compressed 8mm. Also the compressed length is 31mm for the required torque transmission.

- The force in compressed spring gets reduced due to wear.
- In our case the clutch begins to slip when a wear of 3.016mm on the friction lining occurs.
- Hence , the final compressed length of the spring will be 34.016mm (after the wear)
- The force in the compression spring is found by Hooke's law

  $F = k(L_{free}-L_{def})$ where k is the stiffness constant.

  F = 475N
- Hence the total axial force by 8 springs = 475x8=3800N
- Hence now the torque transmitting capacity by using the uniform wear theory

  $M_t = 0.32x3800x(260+235)/4$

  $M_t = 150480N$
- So the torque transmitted after the wear is 300.96Nm.
- Finally, Initial torque = 375Nm & Torque transmitted after wear = 300.96Nm.

3.5) Design for damper springs

In the design calculations of damper spring which is used to lock , the torsional force of the clutch plate is obtained by the equation –

$T_{damper} = F_sN_sR_s$ [1]

T_{damper} = lock torque of damper spring =375Nm

F_s = Force acting on the spring

N_s = no of springs =4

R_s = distance from axis of clutch to axis of damper = 600mm

F_s = (375x1000)/(4x200) = 468.75N ----(a)

Now to find the diameter of the damper spring, taking –

Spring Index C=5

G = 81370 N/mm

The permissible shear stress for the spring wire is 30% of the ultimate tensile strength. ($\tau_d = 0.3\ \sigma_{ut}$)

Wahl's factor

K = (4x5-1/4x5-4)+0.615/5 = 1.13015

$\tau = K(8PC/\ \pi\ d^2) = 6745.08/d^2$

On comparing with graphs for spring diameter with trial and error

d = 4mm , so $\tau = 421.56N/mm^2$

(Grade 2 patented cold drawn steel wire)

$\tau_{d\,=}\ 0.3x(1480) = 444N/mm^2$

Hence $\tau > \tau_{d}$, so it is a safe design.

Therefore – d =4mm

Mean coil diameter D =Cd = 5x4 = 20mm

To find the deflection of the damper spring –

$\delta = 8n_sFc^3/Gd = 5.760mm$

Stiffness of the damper spring – $K = F_s/\delta$ 81.37N/mm

3.6) Design for rivets in friction plate

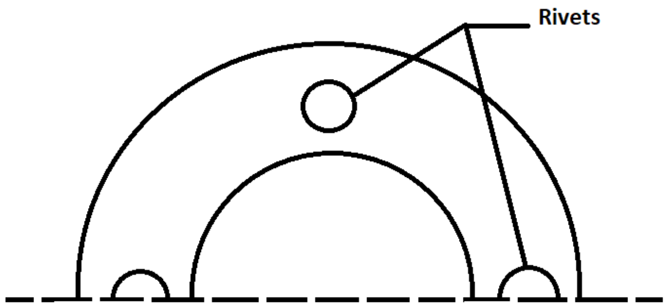


Fig -2: Rivets on a friction plate.

- Rivets do the job of holding the friction material lining in place with the respective rotating components in this case the clutch plate.
- As clutch plate being friction lined , its both sides forces acting on both sides are to be considered.
- Below is the cross sectional view of forces acting on the rivet.

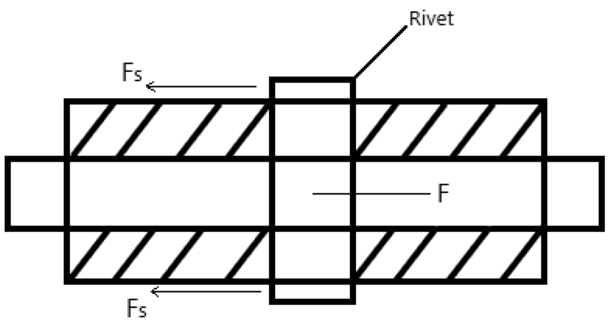


Fig -3: Cross sectional view of forces on rivet

- Here the force(Fs) is majorly due to the static friction.
- P is the axial force required for engagement of the clutch.
- On analyzing the above we can say that the rivet joint is subjected to double shear.
- For diameter of rivet(single riveted lap joint)

Taking rivets made of steel and sheat is 60N/mm2

$Fs = \mu_s x N$ (μ_s is coefficient of friction , N – normal force)

Fs = 1514.88N

$Ps = 2(\pi \text{ x } d^2 \text{ x } \tau \text{ x } n)/4$

d = 5.67mm ≈ 6mm.

Hence the diameter for the rivet is 6mm. Pitch of the rivet = width of the plate/n = 25/3.86 = 6.534 mm

Efficiency of the joint –

η = Pt/p(lowest) = 19900/26250 = 0.76 = 76%

3.7) Maximum Power Transmitting Capacity

By using uniform wear theory

$M_t = \mu$ p(235+260)/4

M_t = 193359.02N

$Kw = 2\pi n M_t/60x10^6$

Max Power Transmitting Capacity = 75.93KW

4. Final Features of the clutch assembly

Torque Capacity	375 N-m.
Power Capacity	75.93 Kw.
Diameter of the clutch.	270 mm.
Inner Diameter of the friction lining.	235 mm.
Outer Diameter of the friction lining.	260 mm.
Friction provided by lining.	0.33
Number of springs.	8.
Axial force provided by each spring.	591.85 N
Shaft diameter.	50 mm.
Service factor.	1.5

Table 3 : Rivets on a friction plate.

4.1) Fits included in design

Interference fit – As interference fit is ideal for heavy torque transmission, We have taken interference fit at two places. For both of them a heavy drive fit is selected(50H7-s6)

- Input shaft at engine and fly wheel.
- Clutch plate and output shaft

Clearance fit – At output shaft and pressure plate of the clutch. For easy running (50H6-e7) is used.

5. Manufacturing & Costing

5.1) Fly Wheel

As being subjected to heavy torque and friction .Fly wheel will be produced by casting method and holes in wheel must be made for riveting the friction lining by Drilling. Finishing must be done grinding and Heat treatment on required flat surface.

5.2) Clutch Plate

Precision is required in manufacturing of clutch plate . Hence Milling and holes in plate must be made for riveting the friction lining by Drilling.

5.3) Pressure Plate

A major responsibility being providing axial force for engagement of the clutch and having complex shapes . The pressure plate can be manufactured with help of Sand casting with the required mold and holes in plate must be made for riveting the friction lining by Drilling.

5.4) Springs

Spring provides axial force for engagement of the Clutch and also provide damping of torque for the clutch plate. Spring must be manufactured from cold-drawn steel wire of Grade 2.

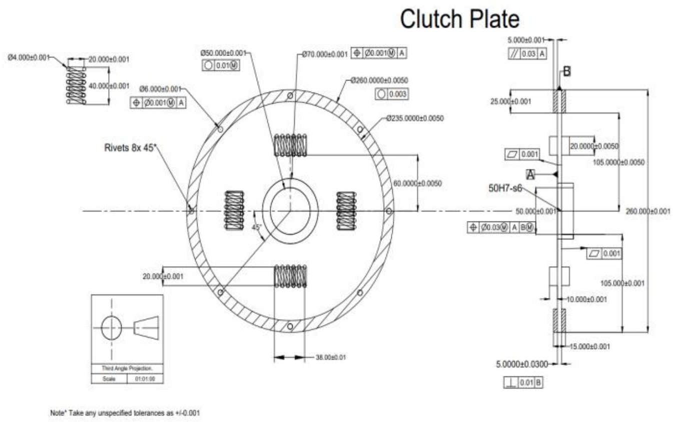
5.5) Costing

Component	Manufacturing cost
Fly Wheel	Rs. 500/-
Clutch Plate	Rs. 650/-
Pressure Plate	Rs. 500/-
Springs	Rs. 400/-
Total	Rs. 2050/-

Table 4 : Rivets on a friction plate.

6. Results and discussion

6.1) Clutch Plate



6.2) Clutch Assembly

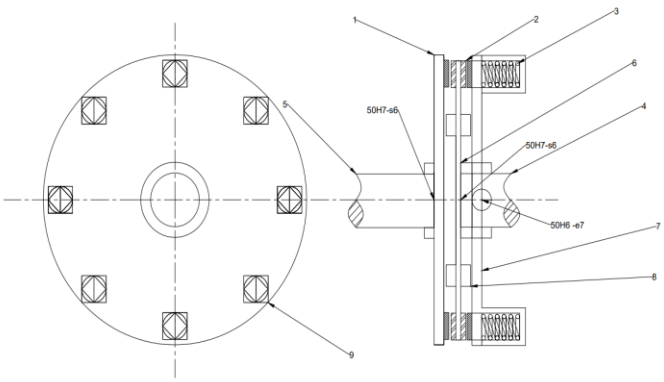


Fig -4: Cross section of clutch

6.3) Fly Wheel

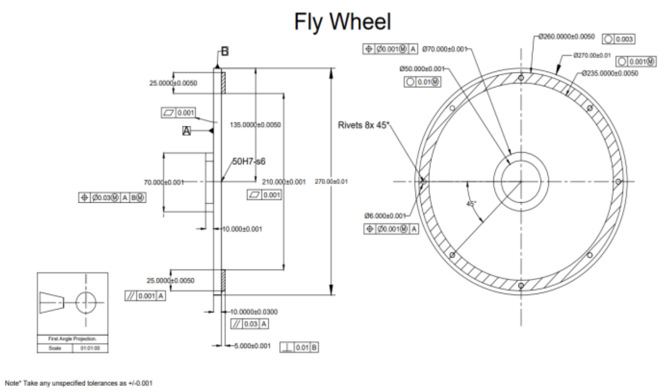


Fig -5: Flywheel CAD

6.4) Pressure Plate

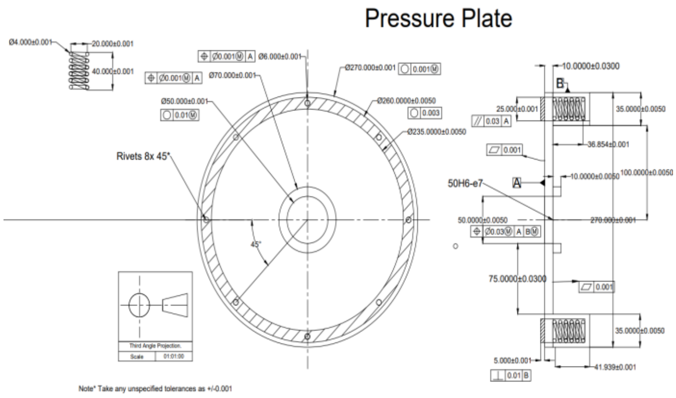


Fig -6: Pressure Plate CAD

7. Conclusion

In this paper complete design for manufacture of all the components of a single plate clutch was done along with the pricing for each individual component.

The sketches were made using AutoCad software with the help of the calculations shown in the paper.

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