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Optimization of Friction Clutch for Various Friction Materials

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Abstract:

The very important machine component of an automobile is the friction clutch. Clutch is a mechanical link between engine and transmission system for conducting torque from engine to the transmission gears. In this present paper an attempt has made to analyze the single plate clutch for various frictional materials. The clutch behavior varies according to the friction material used, so the permissible thermal loading is considered in terms of maximum equivalent stress, deformation, and temperature induced at frictional surface.

The friction materials used here are representing the most important part of the each friction combination, which effectively consists of a counter frictional surface. To verify the strength of the clutch structural and thermal analysis has done on clutch. Design of single plate has done by using the CATIA-V5, and Finite Element Analysis has done by using ANSYS Workbench. Friction material which was selected here Asbestos, Kevlar 29, and Sintered iron.

Key Words: Single plate clutch, friction materials, Structural and thermal analysis.

INTRODUCTION

Clutch is a mechanism for transmitting rotation, where the engagement and disengagement process is common in the automotive vehicles. The clutch assembly takes place in between the two rotatingshafts. The foremost task of the clutch is to conduct torque and speed from engine to gear box via frictional engagement. Here the clutch enables to crank and start the engine disengaging the transmission and change the gear to alter the torque on the wheels. During the engagement process, a transient sliding contact occurs between the pair of clutch facings mounted on the friction disk and the counter faces of the flywheel and the pressure plate. Here the clutch permits the gradual taking up of the load, when properly operated. It avoids the jerky motion of the vehicle and thus prevents development of the undesired strain on the other parts of the transmission.

Clutch material selection criteria [3]:

The material selecting as a friction material should possess a following properties

- The frictional surface material should possess high co-efficient of friction.
- The frictional surface should have the constant co-efficient of friction over a range of pressures and temperatures.
- The frictional material should have the high thermal conductivity, and withstand to high temperatures.

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- The friction material in contact should be strong enough to resistwear effects like scoring, galling, and ablation.
- It should possess the high shear strength to transfer the frictional forces to structure.
- The materials should be safe to use, and acceptable to environment.

TABLE 1: PROPERTIES OF ASBESTOS

Friction material	Asbestos
Yield strength (MPa)	1400
Young's modulous (GPa)	160
Thermal conductivity (w/mk)	1.46
Specific heat (J/kg.k)	1907
Coefficient of friction (μ)	0.43
Poisson's ratio	0.28
Density (kg/m^3)	2500

TABLE 2: PROPERTIES OF KEVLAR 29

Friction material	Kevlar 29
Yield strength (MPa)	2800
Young's modulus (GPa)	61
Thermal conductivity (w/mk)	0.04
Specific heat (J/kg.k)	1.42
Coefficient of friction (μ)	0.35-0.37
Poisson's ratio	0.36
Max temperature	427-482 (^{0}C)
Density (kg/m^3)	1440

TABLE 3: PROPERTIES OF SINTERED IRON [4]

Friction material	Sintered iron
Yield strength (MPa)	570
Young's modulus (GPa)	275.8
Thermal conductivity (w/mk)	220
Specific heat (J/kg.k)	50
Coefficient of friction (μ)	0.15-0.45
Poisson's ratio	0.35
Max temperature	232-637(^{0}C)
Density (kg/m^3)	6200

Friction material properties:

Specifications:

To study the behavior of the clutch, we have taken the specifications of Light Commercial vehicle.

Vehicle model: TATA 407 SP TURBO

Max engine output: 75HP @2800 rpm.

Max Torque: 225 Nm @ (1500 to1800)rpm.

Capacity: 2956 cc

Emission norms: Euro-II.

The rated torque=225 Nm

The clutch wheel dimensions are

Inner radius r1=80mm

Outer radius r2=120mm

R=mean radius of the friction surface

Uniform Pressure theory [6]:

According to uniformly pressure theory the mean radius of friction clutch is

$$R=\frac{2}{3}\left[\frac{(r2)^3-(r1)^3}{(r2)^2-(r1)^2}\right]$$

$$R=\frac{2}{3}\left[\frac{(120)^3-(80)^3}{(120)^2-(80)^2}\right]$$

R = 101.33mm

When the pressure is uniformly distributed over the entire area of the friction surface, then the intensity of pressure

$$P=\frac{w}{\pi((r2)^2-(r1)^2)}$$

w = axial thrust for frictional surfaces are to be held together.

T = μ*w*R

225 = 0.3*w*0.10133

W = 7401.559N

$$P=\frac{7401.559}{\pi((120)^2-(80)^2)} = 0.2945 \text{ N/mm}^2$$

P = 0.2945 N/mm^2

Uniform wear theory:

Here $R = \frac{r1+r2}{2} = \frac{120+80}{2} = 100$

R = 100mm

In uniform wear theory we consider that P*R = C

T = μ*w*R

225 = 0.3*w*0.1

W = 7500 N

W = 2π* P*R*(r2-r1)

W = 2π*C*(r2-r1)

7500 = 2π* C*(120-80)

C=29.841

P*R = C

The intensity of pressure is maximum at inner radius r1

P_{max}*r1 = C

P_{max}*80 = 29.841

P_{max} = 0.373 N/mm^2

P_{min} *r2 = C

P_{min} *120 = 29.841

P_{min} = 0.248675 N/mm^2

Average pressure on friction surface = $\frac{w}{\pi((r2)^2-(r1)^2)} = \frac{7500}{\pi((120)^2-(80)^2)}$

P_{avg} = 0.2984 N/mm^2

To analyze the frictional surface of the clutch the axial pressure applied to the clutch is average pressure considered from uniform wear theory, i.e. P = 0.2984 MPa.

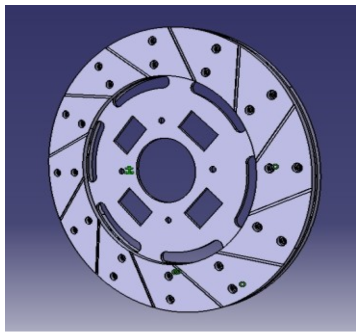


Fig 2: Assembly of single plate clutch

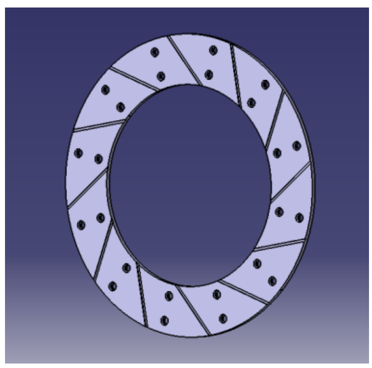


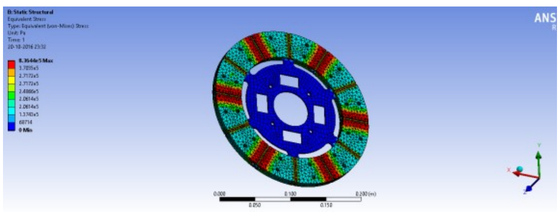
Fig 3: Friction plate lining

Structural analysis:

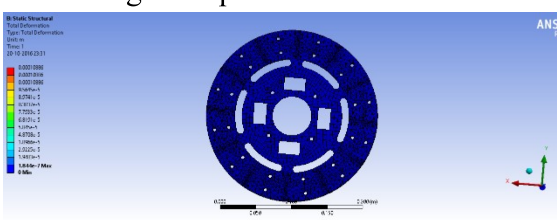
To study and predicts the behavior of the structure of the friction clutch we need to know the structural analysis, which comprises the set of physical laws and mathematical equations. The structural analysis is the judgment of ability to withstand the loads. From theoretical perspective the primary goal of structural analysis is the computation of deformations, internal forces, and stresses [2]. In practice, the structural analysis can be used more abstractly to find the ability of the friction clutch.

Structural analysis consist of the following methods [2],

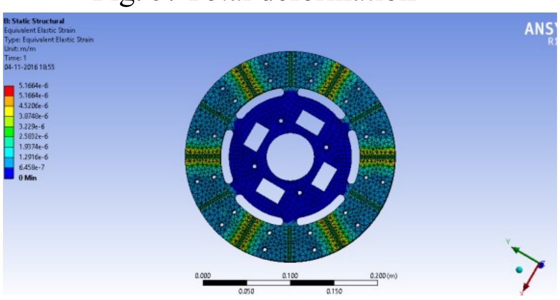
- Analytical methods
- Classical method (Strength of materials method)
- Finite element methods (FEM)
- **Case 1: Asbestos**



- Fig. 4: Equivalent stress

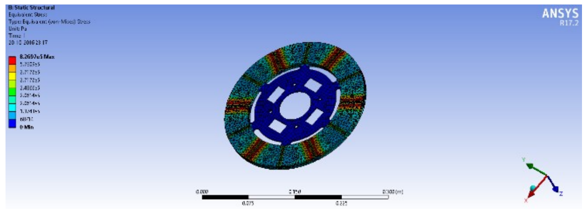


- Fig. 5: Total deformation

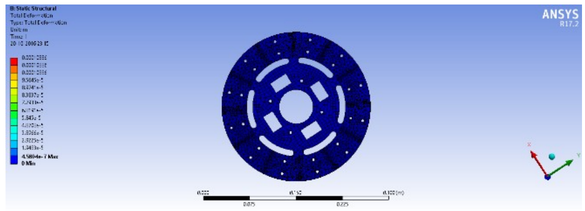


- Fig. 6: Equivalent strain

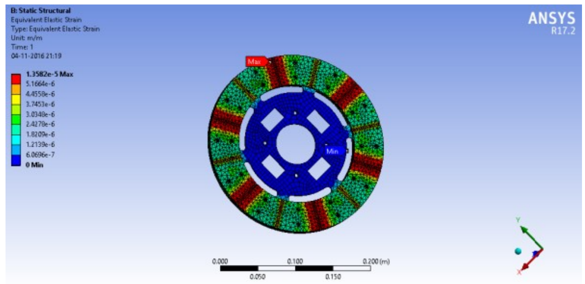
Case 2: Kevlar 29



- Fig. 7: Equivalent stress

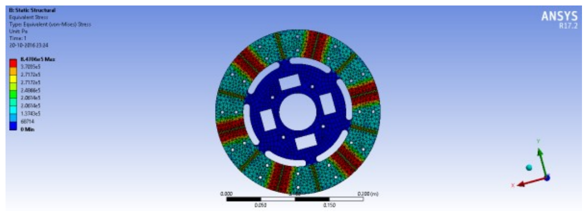


- Fig. 8: Total deformation

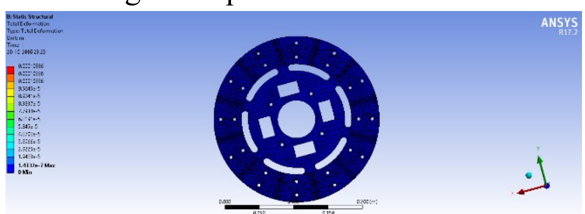


- Fig.9: Equivalent strain

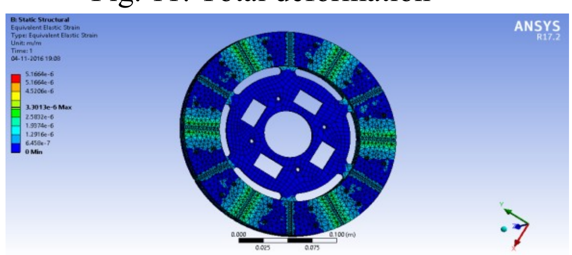
Case 3: Sintered iron



- Fig.10: Equivalent stress



- Fig. 11: Total deformation



- Fig. 12: Equivalent strain

Thermal analysis [5]:

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The thermal analysis is the judgment of the ability of the material to withstand the temperature induced at the interface of the clutch engagement. When the clutch plate is engaged with the flywheel there is africtional contact in between the frictional surface. There is a slip in between the frictional surface because of the rotational speed; the clutch is trying to engage with the flywheel. There is tremendous heat development occurred. This heat should be dissipating form the interfacing point. The dissipation of heat is depends on the material properties such as thermal conductivity, heat flux. Here thermal analysis has done to estimate the maximum temperature induced during engagement, which should not exceeds the material temperature properties.

Case 1: Asbestos

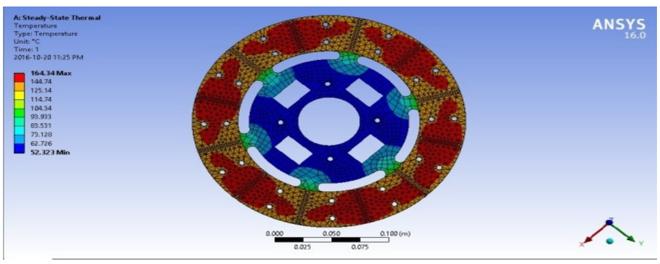

Fig.13: Max temperature of Asbestos

Case 2: Kevlar 29

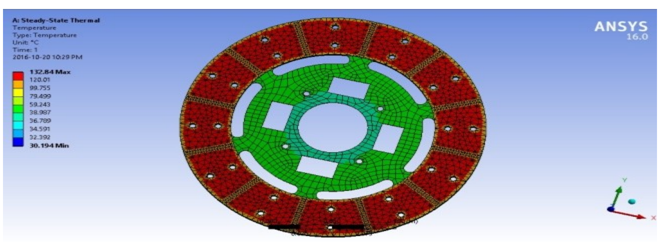

Fig. 14: Max Temperature of Kevlar 29

Case 3: Sintered iron

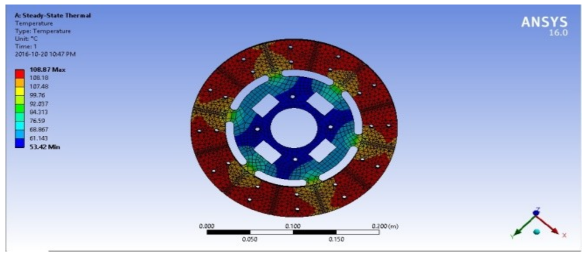

Fig. 15: Max Temperature of Sintered iron

RESULTS AND DISCUSSION

Results from structural & thermal analysis:

TABLE 5: RESULTS FROM STRUCTURAL AND THERMAL ANALYSIS

Parameters	**Asbestos**	**Kevlar 29**	**Sintered Iron**
Equivalent stress (MPa)	0.83644	0.82697	0.84706
Total deformation (µm)	0.1844	0.45804	0.14337
Equivalent strain (m/m)	5.166×10^{-6}	1.3582×10^{-5}	3.3013×10^{-6}
Maximum temperature (^{0}C)	164.34	132.84	108.87

The single plate clutch has modeled in CATIA V5. The model is analyzed in the ANSYS workbench for the axial pressure of 298.4KPa.

- The Equivalent stress is less for Kevlar 29 comparing with Asbestosand Sintered iron. This is due to high yield strength of the Kevlar 29.
- The total deformation is less for sintered iron comparing to asbestos and Kevlar 29. The Kevlar 29 has the highest deformation among the three i.e. 0.458 microns, which is due to less young's modulus value.

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- The sintered iron has the less deformation value of 0.14337 microns; this is due to high young's modulus value of sintered iron.
- The equivalent strain value of Kevlar 29 is more i.e. 1.3582 x 10^{-5}. The sintered iron has the less equivalent strain value compared to asbestos and Kevlar 29, due to its high young's modulus value.
- The thermal analysis has done for the friction clutch using various friction materials. The major requirement of the thermal analysis is to estimate the amount of temperature induced at the interface. The temperature induced is within the limits of all friction materials, but the sintered iron has 108.87 ^{0}C at the interface, which is less comparing with all the three friction surface material. This is due to the high thermal conductivity of the sintered iron.

Conclusion:

The single plate clutch model has analyzed in the ANSYS workbench. From the results it can be concluded that the equivalent stress is less for Kevlar 29. The sintered iron is showing the better results in terms of total deformation, equivalent strain, andmaximum temperature induced. For analyzing the any material we have to consider all the parameters in to the account i.e. from above results it can be concluded that the sintered iron is suggestible friction material for single plate clutch.

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