International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 16 (2018) pp. 12657-12662

Investigating Behaviour of Multi-Clutch Plate Frictional Materials using ANSYS

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Abstract

Clutch plays an essential part in automobile transmission in modern high-speed vehicle. Clutch are devices which are highly required as it used to control comfort, economy and sportiness Clutch are mainly use to engage and disengage the engine input shaft to output shaft, so that the vehicle shaft may be stopped or start without affecting the driving shaft. It can be used in any machine where power is being transmitted and subjected to variable loading like in automobile. In this study, an attempt is made to investigate the behaviour of clutch plate under different loading.

Currently used material of friction disc used in analysis are cork and kevlar fibre. During engagement and dis engagement of clutch plate deteriorate and get erode at every cycle. The aim of the research is to study the effect of axial force offered by the spring for engagement using theory's based on uniform pressure and uniform wear. Clutch plate of CT-100 was designed in solid works and for its finite element analysis has been performed.

Keywords: Clutch, cork and kevlar fibre, finite element analysis, uniform pressure and wear.

INTRODUCTION

Friction play's an important role in any automobile. Usually friction is an avoided likes in piston cylinder and gears, and in some case is necessary like in brakes tyres and frictional Clutch. Clutches are used to automobile for transferring torque produced by the engine to gear box. Its other advantage of clutch plate is to get disengage gear box with engine when required to stop the vehicle or to change the gear without effecting the engine speed. There are different kinds of clutch. Classified according to method of transmitting torque. 1) Positive clutch (jaw clutch) - It is used when positive drive is required. The use of jaw clutch is frequently used with sprocket wheels, gears and pulleys.2) Hydraulic clutch, this clutch use hydraulic fluid to transmit the torque. 3) Frictional clutch, as the name suggest friction force is used to transmit torque. There are commonly four type cone clutch, single plate clutch, multi plate clutch, diaphragm clutch. There is many other clutches on basis of different classification like, according to the method of engaging force, according to the method of control.

O.I. Abdullah et al. [1], describes three types of loading condition 1) thermal loading - when engine is at speed and engage with clutch it liberates lot of heat produced due to friction. 2)Pressure created by the axial force on contact of frictional material due to diaphragm spring. 3) centrifugal force caused when disk is rotating. When the rotating part engage with stationary part of clutch plate the slipping will occur between contact surfaces this time is called slipping time. Heat generated between frictional surface and disk dissipated by conduction and by convection to environment. In modelling two dimensional axisymmetric FEM is used for analysis as the design is symmetric. During investigation two mode of contact are available for analysis, node-to-surface and surface-to-surface, in which he used surface-to-surface because it offers large contact area. Abhijit Devaraj et al. [2], earlier asbestos were used as frictional material in clutch and now material with high coefficient of friction like Kevlar, ceramics, sintered iron etc are used. In this work Kevlar 29 material is used as it is very durable and resistant to hard use. Von-mises stress and total deformation were determined with ambient temperature of 400 C. The work was to optimize the design of single disk friction clutch made of Kevlar 29 and observed different parameters. Conclusion were made that the maximum Von Mises stress are at rivet hole regions and total maximum deformation and the maximum Von Mises stress can be decreased by increasing hub diameter in the clutch plate within limits. The research lead to optimize the design by enlarging hub diameter or enlarging rivet hole diameter (within certain limits) in order for the clutch to deliver maximum performance and last longer. Virendra kumar patel et al. [3] has discussed the effect of different material used to make clutch plate. Different material like A1-MMC (aluminium-metal matrix composite), carbon composites, Grey cast iron, composites made of ceramic were used to study wear resistant and failure in clutch. During power transmission a constant force keep the member together with a uniform pressure all over its contact area therefore investigation is based on uniform pressure theory. With increase in cycle of operation some wear take place, due to which contact pressure changes or vary a few micron and uniform pressure condition may no longer overrule. Now for analysis uniform wear condition will be used. Here Pin-On-Disk test method is used to calculate wear rate. Torque caring ability of sintered-iron frictional material is high and can bear excessive temperature. But grey cast iron was the best solution for frictional material. S. Jaya Kishore et al. [4], describes essential properties that frictional material should have. Contact material must be able to bear scoring, galling, and ablation.co-efficient of friction should not change over range of temperatures and pressures. The materials should have efficient thermal properties, good thermal conductivity, withstand high temperatures and high heat capacity. Good shear strength to transferred friction forces to structure. A comparison was made using simulation model between cork

and copper and found out that stress and strain observed in copper powder metal are less than cork. Rajesh Purohit et al. [5] works on dry clutch plate assembly and designed a model on Solid Works. For the research clutch plate made of Structural Steel, pressure plate of cast iron and diaphragm spring of spring steel with factor of safety 2.16 was used. Analysis were made on ANSYS Software in three steps Pre-processing followed by Solving and at last Post processing. Muhammad Mumtaz Jamil Akhtar et al. [6] investigated the thermal stresses generated during the engagement of clutch, as author which seems to be the main source of heat generation and failure. The investigated was made on temperature field and heat flux caused on the frictional surfaces and sliding speed on contact pressure distribution. When contact pressure is applied on the both side of clutch plate and pressure is uniformly distributed on both sides of the clutch disc the same stress are observed on both side of frictional plate. The magnitude of contact pressure increases with increase in time. when the slipping period almost approaches to an end the contact pressure approaches to maximum period. May Thin Gyan et al. [7] Analysed single plate Friction plate made of cast iron, alloy steel and copper. The design of the clutch plate was made in solid work and analysis was made in ANSYS software. The stress was calculated to understand the stress, strain and displacement after application of pressure on clutch disc during engagement. The results observed shows cast iron as friction material is advantageous than using alloy steel and copper as friction material. Cast iron is best suitable material among these three used as for single clutch plate.

Liping Li et al. [8] analysed the variable response characters of the clutch plate during starting of vehicle. Self-excited vibration characteristics of the clutch plate has been studied based on the developed 4 degrees of freedom non-linear multi-body dynamic model of the frictional clutch plate studying stick-slip characteristics and using Karnopp friction models. self-excited vibration is cause effect of negative damping which is induced due to negative friction gradient. When clamp forced vibrate with same function as clutch plate, then a condition of resonance take place causing misalignment in the driveline. They concluded that vehicle judder can be suppressed by improving of the machine frictional surface and alteration of the factors of driveline to cause the natural frequencies remaining away from the pressure fluctuation. Their observation to reduce judder vibration to some extent is by increasing moment of inertia, torsional stiffness viscous damping of the clutch plate or decreasing axial stiffness of the waveform.

M. Lia et al. [9] aimed his investigation to predict wear in friction plate lining during repetitive engagement of clutch plate. Degradation due to mechanical effect and thermal degradation wear both considered. Complete analysis was made from engagement to soaking, dwelling and stabilization duration. A mathematical model of wear was established for the studying paper-based friction material of a wet clutch, capable of analysing both thermomechanical wear and thermal degradation of the frictional plate material. Comparison made between the predictions wear results and test results shows a favourable validation with experimental results, which shows that wear rate increase with higher power input. Oday I. Abdullah[10] discussed the effect of high temperatures caused during the working results in accelerated wear rate, surface cracks and permanent distortions in some cases these disadvantage may results to permeant failure : earlier than actual life cycle. Numerical models of the frictional single-disc clutch plate was developed to predict the thermal field during the sliding single engagement period. when computes the thermal field of single based clutch disc using uniform pressure theory assumption, the heat flux growths linearly with increase in disc radius. They observed the temperature at the outer radius found to be maximum and minimum at inner radius at any time of sliding contact.

METHODOLOGY

Various studies are being carried out in analysis and increasing the torque carrying capacity of clutch in automobile. But when we use this clutch in any customise vehicle it dosed not transmit same efficiency as it was designed for. To analyse the bearing phenomena of clutch plate a single disk clutch plate of Bajaj CT-100 model is prepared in solid work with design specification [11][13]. For numerical calculation to find out the load carried out by the single clutch plate is done by using uniform pressure and uniform wear theory [12]. Maximum load obtain by two theories is applied to the clutch plate and stress is calculated by using ANSYS.

Engineering material Specification

The properties used in the analysis are mentioned in the Table1.

Table 1. Material properties

Mechanical Properties	Cork[11]	Kevlar[2]
Youngs Modulus (MPa)	32	59
Poisson's ratio	0.25	0.36
Density (kg/m3)	180	1440
Yield stress (MPa)	1.4	1240
Co-efficient of friction	0.3-0.5	0.51

Table 2. Design specification

Torque (T)	8.05×10^3 N-mm[13]
Rotational Speed (N)	4500 RPM
Inner radius of friction face(r_1)	55 mm
Outer radius of friction face(r_2)	47 mm
R_m, Average radius of cultch surface $= \frac{(r_1+r_2)}{2}$	51 mm
Number of discs mounted driving shaft (n_1)	5
Number of discs mounted driven shaft (n_2)	4
Number of pairs of contacting surfaces ($n = n_1 + n_2 - 1$)	8
Total operating force (W)	W = 65.767 N

Considering uniform pressure theory:

$R = \frac{2(r_1^3 - r_2^3)}{3(r_1^2 - r_2^2)}$ [12]

R = 61.478mm

In practice torque acting on the friction clutch surfaces can be expressed by

T = n × μ × W × R [12]

μ = co-efficient of friction

We know that,

T = 8.05 x 10^3 N mm

From above equation,

8.05 × 10^3 = W×61.47× 8× 0.3

Therefore, W = 54.5586 N

$P = \frac{W}{\pi(r_1^2 - r_2^2)}$ [12]

P =0.02128 N/mm^2

Applying uniform wear theory:

In this theory wear is considered to be constant during operation

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

R = 51 mm

In this wear theory, the magnitude of pressure is inversely proportional to the radius of friction plate.

P × r = C (where C is $constant$) [12]

Axial push required to engage the clutch,

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

Torque transmitted,

T = Active number of disk × μ × W × R [12]

8.05 x 10^3 = 8 x 0.3x W x51

W = 65.767 N

The Maximum axial force acting on friction clutch surface is given by,

$C = \frac{W}{2\pi(r_1 - r_2)}$ [12]

C = 1.308

It is found from the literature, that the effect of pressure is maximum at inner radius (r_2) of friction or contact surface.

Thus, for Uniform theory,the equation is expressed as,

$P_{max} \times r_2 = C$

$P_{max} = 0.0278$ MPa

The effect of pressure is minimum at outer radius (r_1) of friction or contact surface.

$P_{min} \times r_1 = C$

$P_{min} = 0.0237$ MPa

As we are using uniform theory p_{max} obtained by calculation will be applied for analysing design parameters of clutch plate.

DESIGN AND ANALYSIS WORK

The design of Multi plate clutch of Honda splender CT 100 was made on solid work. For analysis ANSYS software was used. Comparison is made between frictional material cork and Kevlar fabric.

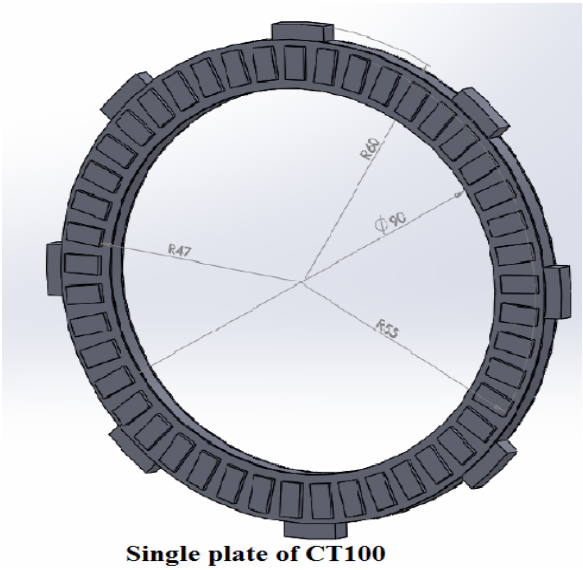

Figure 1. Model of single plate clutch of CT 100

Purpose of pressure plate is of engaging and disengaging the clutch disk. The pressure plate is riveted to the clutch. Clutch release mechanism is functioned using diaphragm spring. The pressure disk is mounted in such a manner that when the release bearing is forced inwards and pressure plate disengages and when release it come in contact with pressure plate. While transmitting torque one of the sides is fined and the pressure plate applies pressure on frictional clutch plate. As pressure is applied uniformly on all sides, frictional plate is truncated to a quarter part. Based on this logic boundary conditions were applied to the geometry.

RESULTS

For analysis modelling in explicit dynamics has been done. A comparative approach between frictional plate made of cork and kelvar is being applied. Sequence of computation has been directed using different loads from min to maximum to find the Von Mises Stress at each load. Figures 2-9 show the stress distribution of both sides of disc

Cork

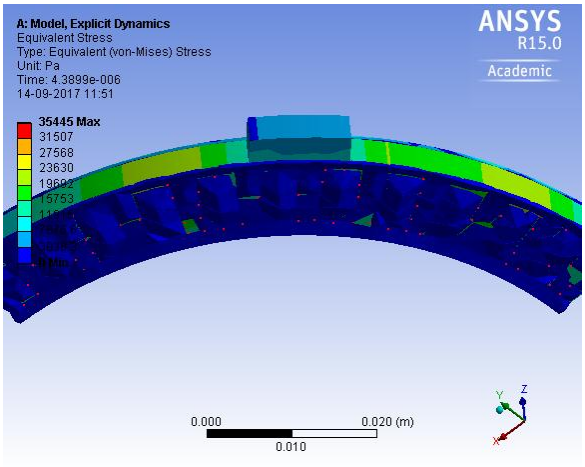

Figure 2 Von Mises Stress under 10 N force.

kevlar

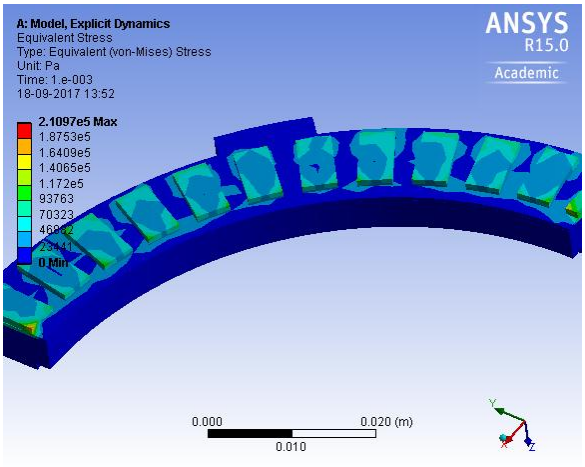

Figure 3 Von Mises Stress under 10 N force.

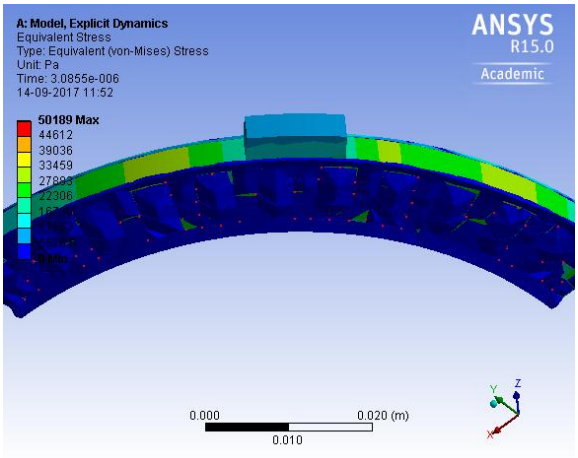

Figure 4 Von Mises Stress under 20 N force.

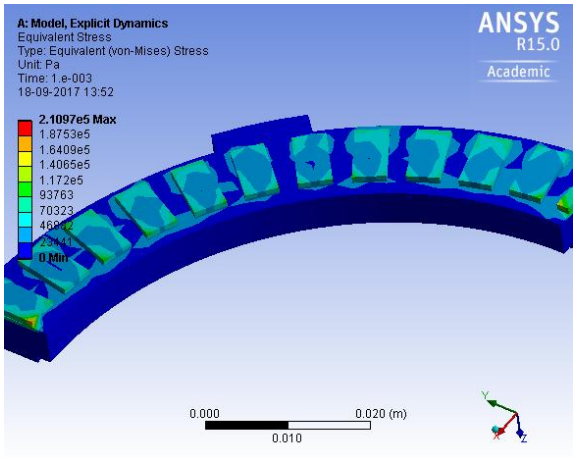

Figure 5 Von Mises Stress under 20 N force.

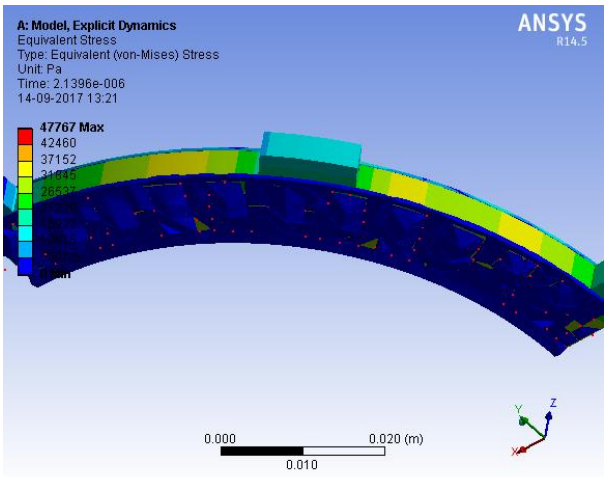

Figure 6 Von Mises Stress under 40 N force.

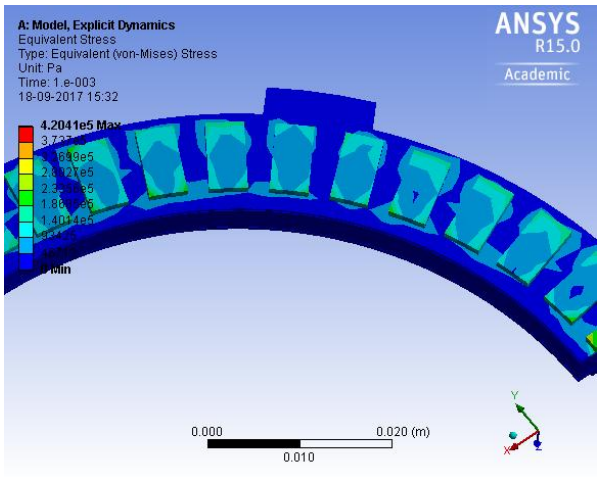

Figure 7 Von Mises Stress under 40 N force

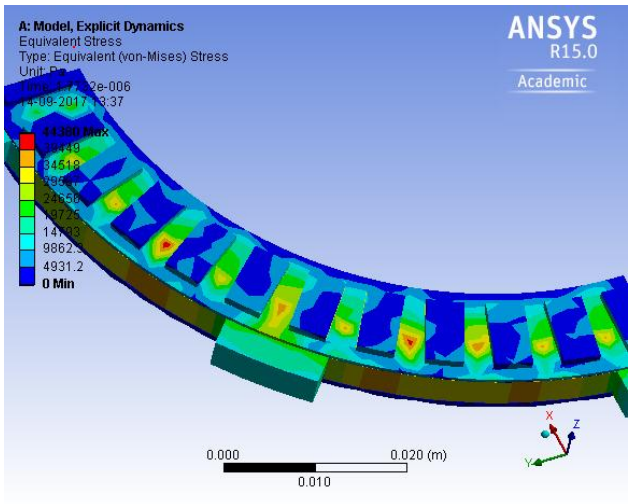

Figure 8 Von Mises Stress under 58 N force.

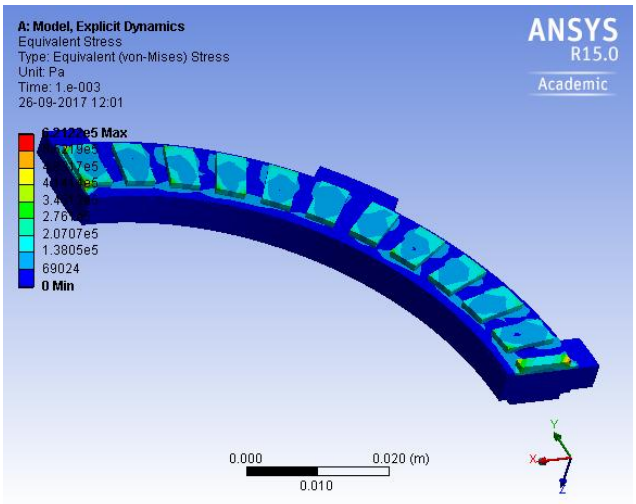

Figure 9 Von Mises Stress under 58 N force.

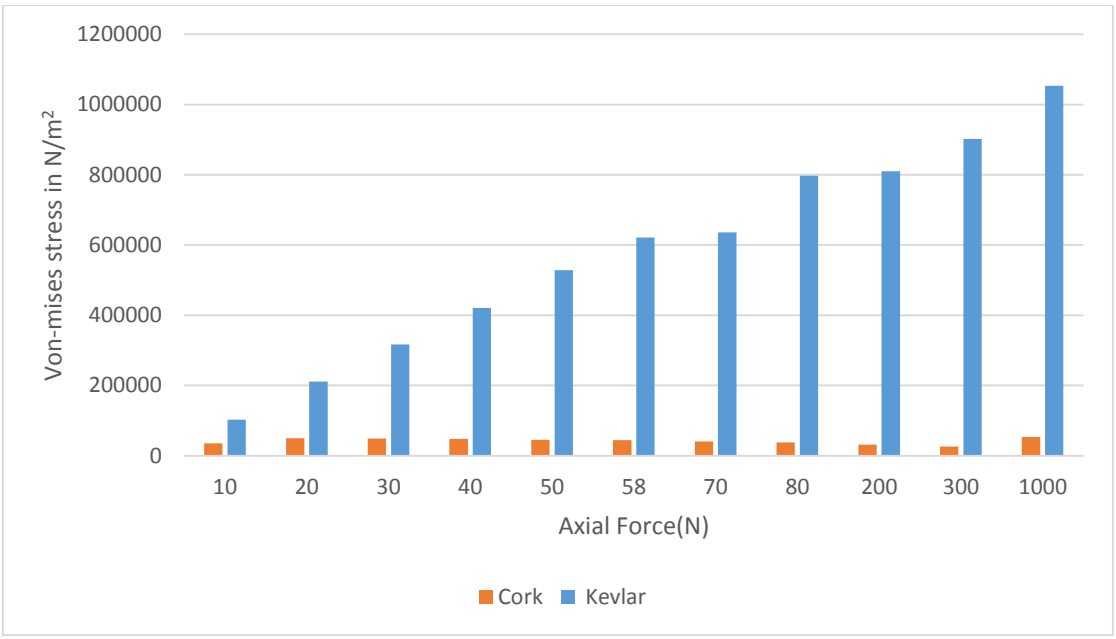

Figure 10 comparison between stress v/s axial force

Present results shows, the stresses developed in Kevlar fibers are more than the stress induced in cork. As kevlar can resist more stress than cork, it can be used in customize vehicle , which increases the cost of clutch plate . Clutch plate made of cork are mostly used to low capacity automobile as they are cheap and easily available .Present research show that cork suffers less stress under some loading as Kevlar , this is due to possion ratio of cork which deform in radial direction when axial load is applied.

CONCLUSIONS

In this study, a 3D model of frictional plate of multi plate clutch is designed and Structural analysis on clutch plate has been carried out using ANSYS workbench for cork and Kevlar as friction lining materials. Maximum Von-mises stress obtained an application of load are 44380 N/m^2 (cork under 58 N Load.) & 621220 N/m^2 (Kevlar fiber under 58 N Load). From this analysis, it can be concluded that, Kevlar can resist more than cork material. But due to its high cost makes it very inaccessible and expensive. Mostly used in expensive vehicle. As cork is easily accessible it used in most vehicle. Material degradation rate of cork is higher due to week toughness property and resistance to heat generated during frictional slip of clutch. Hence more research has to be carried on increasing the strength and toughness of cork. Present study can be used to choose the best material for your transmission on bases of your desired output The ANSYS simulated model can be used to test the transmission capacity of different composite suitable for use.

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