Design optimization of a Kevlar 29 single disk friction clutch plate based on static analysis using Ansys

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Abstract: A clutch plate is a significant component used in all motor vehicles nowadays, which is used to transmit power produced by the engine to the gear box. A pressure plate which is used for engaging and disengaging the clutch applies pressure on the clutch plate, which results in small deformation and stress concentration in the clutch plate. The aim of this work was to design a single disk friction clutch plate made of Kevlar 29 and optimize the design, based on static analysis performed on the clutch using Ansys workbench software. This work sheds light upon how to optimize the design of the clutch plate, so as to deliver maximum performance and last longer.

Keywords: dry friction single disk clutch plate, Kevlar 29, NX-CADD, Ansys Workbench, total deformation, Von mises stress distribution, design optimization.

I – INTRODUCTION

A clutch is a device used in the transmission system which engages or disengages power from the engine crankshaft to transmission [1] [7]. It is a device, which enables one rotary drive shaft (the driving part) to be coupled to another shaft (the driven part), either when both the shafts are stationary or when there is a relative motion between them. [3][8] Clutches allow a high inertia load to be started with a small power. All of the clutch components are enclosed in the bell housing of the transmission, between the rear of the engine and the front of the gearbox [5]. Internal combustion engines, unlike the steam engine, do not produce high power at low speed. So the engine must be rotating at a speed at which sufficient power is developed [6]. The need for the clutch seems mainly from the characteristics of the turning-effort developed by the engine over its lower speed range. [4] The motion of the crankshaft is transmitted through the clutch to the gear box or transmission, which consists of a set of gears to change the speed [7]. An automotive clutch can permit the engine to run without driving the car. This is desirable when the engine is to be started or stopped, or when the gears need to be shifted. When the vehicle is started from standstill, clutch is engaged to transfer torque to the transmission; and when vehicle is in motion, clutch is first disengaged of the drive to allow for gear selection and then again engaged smoothly to power the vehicle. Depending on the orientation, speeds, material, torque produced and finally the use of the whole device, different kinds of clutches are used. [2] [4]. There are three types of friction clutches, namely disc or plate clutch (single or multiple- clutch), cone clutch and centrifugal clutch [6]. When the friction clutch begins to engage, slipping occurs between the contact surfaces (pressure plate, clutch disc and flywheel) and due to this slipping, heat energy will be generated in the interfaces friction surfaces. At high relative sliding velocity, high quantity of frictional heat is generated which leads to high

temperature rise on the clutch disc surfaces resulting in problems such as deformation and stress concentration [8]. In
The past asbestos was used as the friction material for clutches, but it was found to be carcinogenic. Hence now mostly materials like Kevlar, ceramics, sintered iron etc which have a high coefficient of friction are used. Kevlar 29 is highly durable material and is more resistant to hard use. It has a high operating temperature range, although care should be taken that it doesn't overheat due to slipping. Kevlar clutch plates can be used for street driven cars up to 500hp, for auto-x and heavy track use. The aim of this work was to design a single disk friction clutch plate made of Kevlar 29 and optimize the design by changing the hub diameter and rivet diameter in the clutch, based on static analysis performed on the clutch using Ansys workbench analysis software. The total deformation and Von mises stress concentration in the clutch were determined when the ambient temperature was maintained at 40 C. In this work, Von mises stress theory was preferred over other theories such maximum principle stress theory etc. as the factor of safety assumed in this theory is high which facilitates a safer design.

II – IMPLEMENTATION

A - Design Calculations

A single disk Kevlar 29 friction clutch plate was designed to transmit a power of 20KW. Uniform wear theory was assumed to perform the calculations. A pressure 'p' of 1MPa was applied on the clutch plate. Both the surfaces of the friction plate were assumed to be effective (i.e. $i = 2$)
Power to be transmitted = N = 20 KW

Outer Diameter = D_1 = 185mm

Inner Diameter = D_2 = 145mm

Friction Coefficient = μ = 0.51

Pressure = p = 1 MPa = 1 N/mm^2

Axial Force = $F_a = 0.5*\pi*p*D_1(D_2-D_1) = 9.11$ KN [10]

Torque transmitted= $M_t = 0.5*\mu*F_a*D_m*i = 766.65$ KNmm

$M_t = 9550*1000*N/n$ [10]

Speed = n = 250 rpm

Kevlar 29 was chosen as the material for the clutch which has the following physical and thermal properties:
Table 1: Properties of Kevlar 29. [9]

Sl. No	Property	Value
1	Density	1440 Kg/m^3
2	Elastic Modulus	59 GPa
3	Poisson's Ratio	0.36
4	Friction coefficient	0.51
5	Tensile strength	3600 MPa
6	Tensile Modulus	83000 MPa
7	Specific Heat @ 25 C	1.42 J/KgK
8	Thermal Conductivity	0.04 W/mK

B – Designing/ Drafting

A sketch of the clutch plate to be designed was made by drafting using NX-CADD software according to the dimensions and specifications as shown in figure 1.

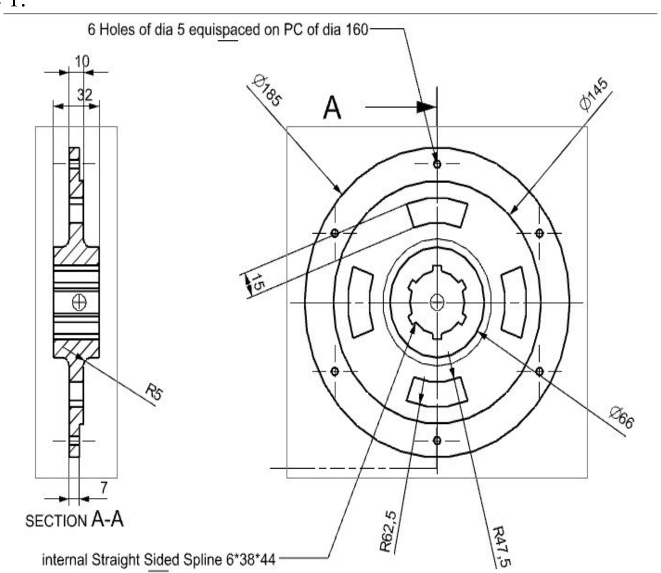

Figure 1: 2D sketch of clutch plate

The clutch design features 4 windows which can house springs which damper shatter to achieve an easy operation and to reduce the impact to the gear box at the engagement. The design also consists of a hole for the Hub to pass through at the centre and 6 rivet holes. Clutch plates were designed with the same dimensions but different hub diameter and different rivet hole diameter respectively.

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C - Modelling

A 3D model of the clutch plate was prepared based on the sketch shown in figure 1 using NX-CADD modelling software as shown in figure 2.

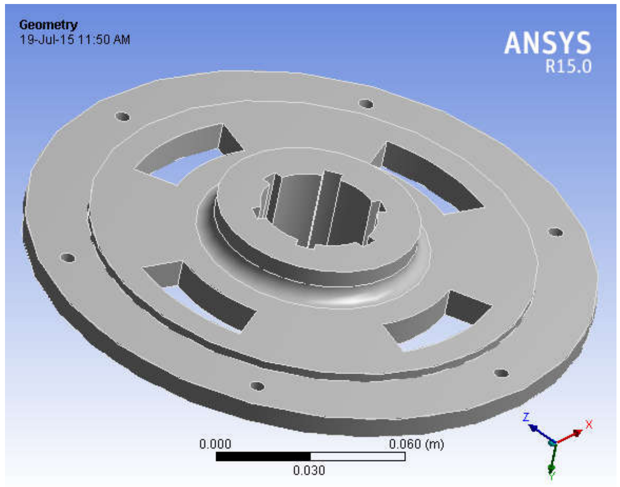

Figure 2: 3D model of clutch plate

The 3D part model was then imported into Ansys Workbench analysis software. The material properties were assigned to the geometry as shown in table 1. The model was then meshed /divided into a finite number of elements using fine mesh option as shown in figure 3.

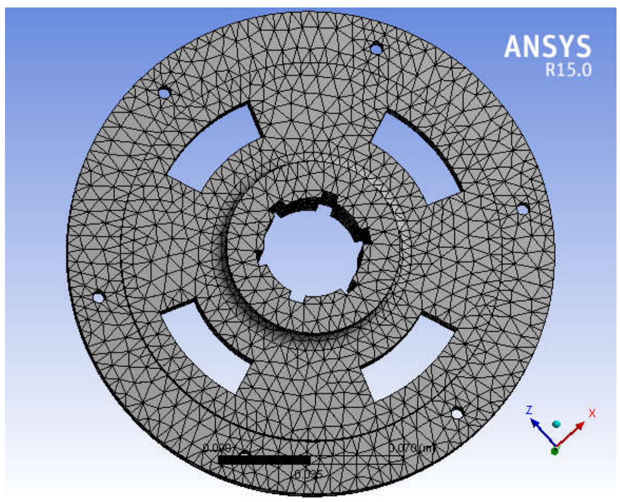

Figure 3: Meshed view of the clutch plate

A pressure plate is needed for engaging and disengaging the clutch disk. The pressure plate is riveted to the clutch. A clutch release bearing is positioned in front of a diaphragm spring. The pressure disk is mounted in a flexible manner such that when the release bearing is pushed inwards the pressure plate disengages and when release bearing is released the clutch comes in contact again with the pressure plate. Based on this logic boundary conditions were applied to the geometry. Fixed Constraints were applied to the 6 rivet holes and a pressure a 1MPa was applied to friction surface of the clutch plate as shown in figure 4.

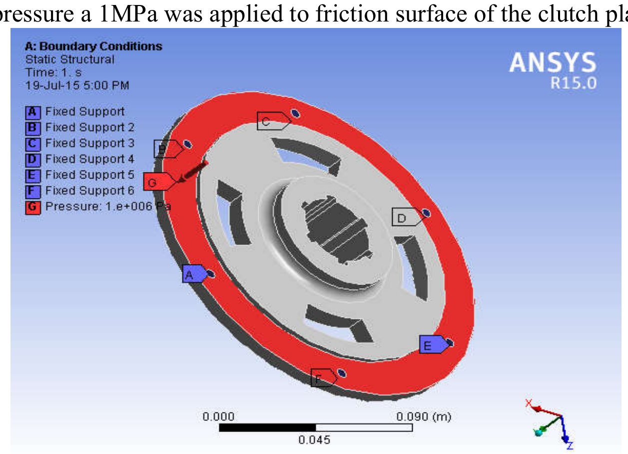

Figure 4: Boundary conditions applied to the clutch plate

The problem was then solved using the software and the results were plotted. The experiment was repeated for different hub diameter and also different rivet hole size.

III – RESULTS AND DISCUSSION

A – Total Deformation

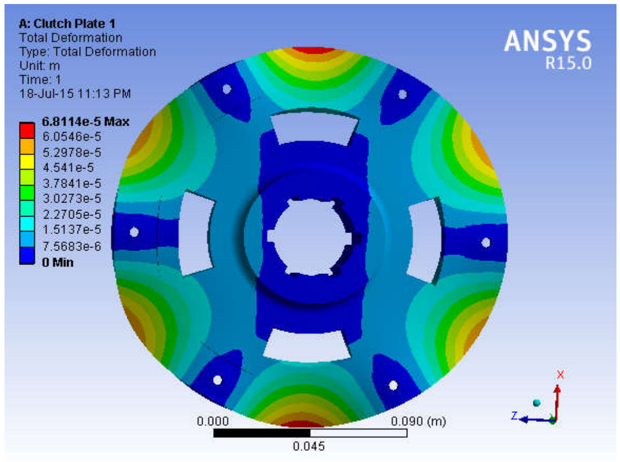

Figure 5: Total deformation in Clutch Plate 1

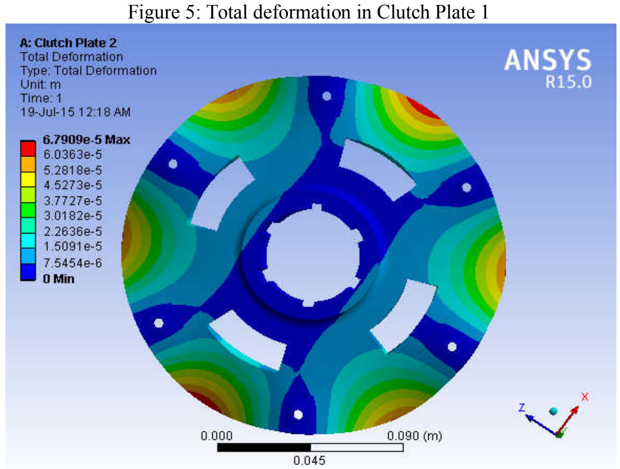

Figure 6: Total Deformation in Clutch Plate 2

The plots of total deformation in clutch plate 1 with smaller hub diameter and clutch plate 2 with bigger hub diameter are as shown in figure 5 and 6.

B – Von Mises stress distribution

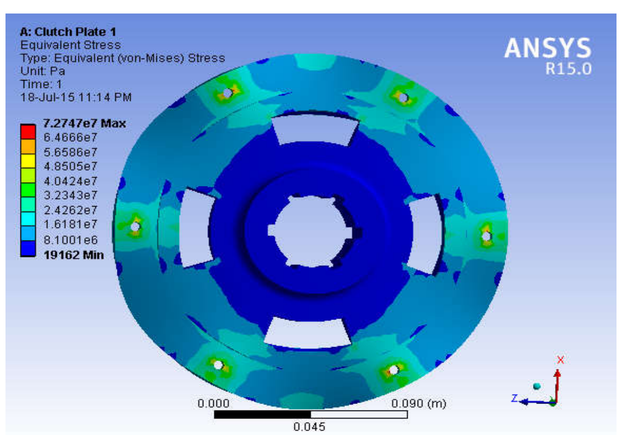

Figure 7: Von Mises stress distribution in Clutch Plate 1

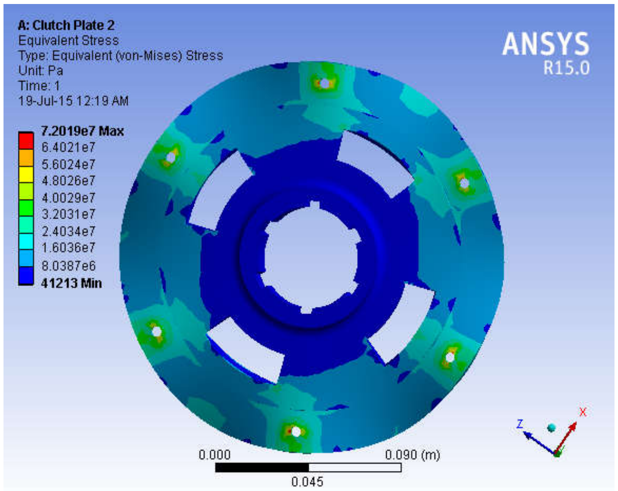

Figure 8: Von Mises stress distribution in Clutch Plate 2

The Von Mises stress distribution in clutch plate 1 with smaller hub diameter and clutch plate 2 with bigger hub diameter are as shown in figure 7 and 8.

C – Total deformation and Von Mises stress distribution in clutch plate with different rivet size

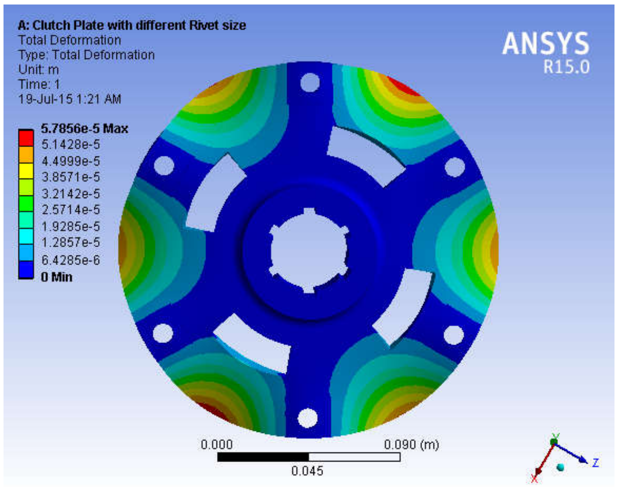

Figure 9: Total deformation in clutch plate with bigger rivet hole size.

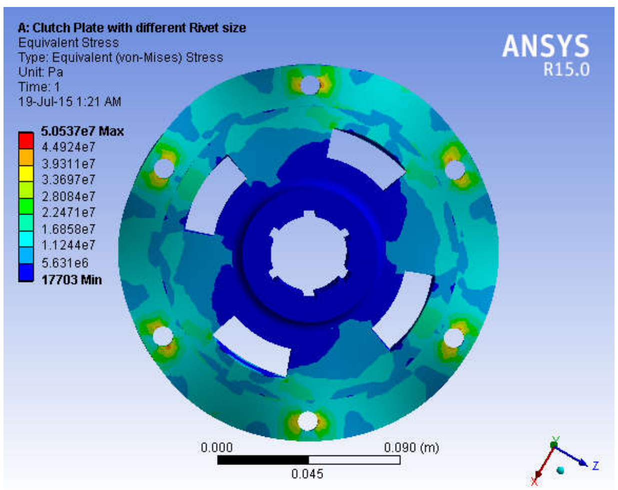

Figure 10: Von Mises stress distribution in clutch plate with bigger rivet hole size.

The plots of total deformation and Von Mises stress distribution in the clutch plate with a bigger rivet hole size are as shown in figure 9 and 10.

IV – CONCLUSIONS

The maximum Von Mises stress was found in the rivet hole regions. Also minimum deformation was found in rivet hole regions which were constrained as fixed.

From figure 5, 6, 7 and 8 it was observed that by increasing the hub diameter in the clutch plate within certain limits the maximum total deformation and the maximum Von Mises stress can be decreased. From figure 9 and 10 it was found that by increasing the rivet hole size (within certain limits) when the hub diameter was kept constant, the maximum total deformation and the maximum Von Mises stress can be decreased.

Therefore a clutch plate design can be optimized by increasing the hub diameter or increasing the rivet hole diameter (within certain limits) in order for the clutch to deliver maximum performance and last longer.

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