Analysis of Static Structure on Multi Plate Clutch with Different Friction Materials Using ANSYS 19.2

Author: Ishfaq Abdullah[1], Anil Kumar Bansal[2]

Affiliation: M. Tech scholar Student, Department of Mechanical Engineering, PPIMT, Hisar, Haryana, India1
Assistant Professor and Head of Department of Mechanical Engineering, PPIMT, Hisar, Haryana, India2

ABSTRACT

This work presents solid modeling of a multi-plate clutch with a UG-NX program that is used for various applications in the automotive industry. Clutch plate structural analysis is performed over the cork, copper, and SA92 as materials for friction lining. The assessment is conducted in ANSYS work-bench 19.2 to obtain the most suitable material for clutch friction. Stress, strain, and complete values of deformation were compared for all three components from the analyzed outcomes and the best one was carried out. Clutch requirements are acquired from the Yamaha SZ R model for research purposes.

Keywords — ANSYS, UG-NX, Cork, SA92, Copper, Strain, Stress, Total deformation **INTRODUCTION**

A clutch is a system used to convey rotary motion from shaft to shaft, the axis of which coincides with the first shaft. The clutch is placed between the engine and the gearbox.

When the clutch is mounted, the energy is transferred from the engine to the back wheels via the transmission system and the car begins to move

The energy is not transferred to the back wheel when the clutch is disengaged so that the car stops moving. Due to clutch it is possible to move the two shafts at different speeds. When clutch is engaged the two shafts spin at the same speed while during disengage condition the two shafts spin at different speeds.

Requirements of a clutch

Torque transmission
Gradual connection
Dissipation from heat
Dynamic equilibrium
Damping of vibrations
Easy operation
Lightness
Inertia
Size

Function of Clutch

The energy transmits from the engine to the wheels via the transmission system and the car moves when the clutch is engaged.

The energy will not be transferred to the wheels when the clutch is disengaged and the car will stop while the engine is still operating

The clutch also allows the load to be gradually assumed. It protects the car from jerky movement when correctly operated

The clutch is in disengaged position during:
Start of the engine
Gear change while car is moving
The car stoppage
The engine idle condition

Principle of Operation

The clutch is working on the friction principle

When 2 friction surfaces are brought into contact and pushed together, they are joined because of the friction between them

Types of Clutch

Positive Clutch

In case of positive clutch power is transmitted by the interlocking of jaws or teeth. Simplest form of positive clutch is jaw clutch which consists of two halves one permanently attached to driving shaft; other movable and fastened to driven shaft. Positive clutch has zero slip. This is because of presence of teeth or jaws which results in zero heat generation. These are rarely used clutches for practical purposes used in conditions where engagement and disengagement is not necessary under load.

Friction Clutch

It makes use of friction disk to transfer power from one rotating shaft to another shaft. Friction discs are alternately placed having smoothed surfaces on the two shafts, rotating and non-rotating shaft and allows power transmission. The size and number of friction surfaces used depends upon load requirements. The friction clutch will undergo into slip as soon as the torque capacity of the surface exceeds.

Multi plate Clutch

As the name indicates, multiple numbers of clutch plates are used to make frictional contact with the flywheel in order to transmit power generated by engine of the automobile to the transmission shaft, which results in movement of the vehicle.

Parts of clutch

Driving member
Driven member
Operating member

Materials used for surfaces of friction

It should have a strong and consistent friction coefficient.
Moisture and petroleum should not affect it.
It should be able to resist at elevated temperatures.
It must have higher conductivity to heat.
It should have a strong wear and scoring strength.

ANSYS History

John Swanson first conceived the idea for ANSYS while employed in the 1960's at the Westinghouse Astronuclear Laboratory. At the moment, (FEA) was performed by hand by the engineers. By developing general purpose engineering software, Westinghouse rejected Swanson's idea of automating FEA; in 1969 Swanson left the company to develop the software on his own. Swanson designed the original ANSYS program on punch- cards and used an hour-lent mainframe computer. As a consultant Swanson was employed in the westing house on certain conditions like any technology Swanson created for the company must be included in the ANSYS software as well. The first recipient of ANSYS also became Westinghouse. The ANSYS production credit goes to John Swanson and the ANSYS was finally ready for in 1970.

ANSYS Evolution

ANSYS came into existence first time in 1971 in the form of few punch card boxes this version of ANSYS is too much time consuming and takes days to get the result. With passage of time in 1975 few more features were added in the previous version viz non-linear and thermo electrical features. This version was mainly used in mainframe computers. At the end of 1979 version 3.0 was released with interface line command like DOS.

In 1980 Apple II launched upgraded version with new features like graphical user interface and simulated electromagnetism functions. Version 5.0 was released in 1993 with new more characteristics like shortened processing time from two to four than the previous one also provided a number of performance improvements in computing. Now ANSYS started combining products with CAD software. In 1996 multiprocessor parallel processing support was added.

Operation Process of ANSYS

Getting Started
Building the model
Applying Loads

LITERATURE REVIEW

Zagrodzki. P (2009) conducted this work for providing solution to thermo elastic instability (TEI) problems that arise because of frictional heating which is prevalent in almost all frictional clutches. Thermo elastic instability occurs when the sliding speed crosses the critical value. Thermo elastic instability leads to the development of hot spots on the circumference of contact surfaces which leads to reduction in the life of the component. The technique used in the research was model superposition. From the research it was concluded that the thermo elastic instability arises because of pressure variations induced by geometric imperfection or any other factors such as design features. It was also shown that comparatively little pressure variations, attributed to natural imperfection is significantly responsible for instability for short period of time.

Abdullah M. Al-Shabibi et al. (2014) from their research concluded that a large number of vital requirements should always be taken into consideration by friction clutch system developers during clutch design. Many scientists and researchers have thoroughly explored the transient thermo elastic issue of multidisc clutch using numerical techniques like finite element method. In this work the impact of the sliding velocity on the thermo elastic properties of clutch was carried during continuous heat generation conditions. An axisymmetric model of finite element was created and used in the paper simulation. ANSYS software was also used for numerical calculations.

Anil Jadhav et al. (2013) designed multi-plate clutch using uniform wear theory. PRO-E modeling software has been used for preparing the 3Dimentional model of multi plate clutch. Materials used for clutch plate lining are SAF001 and cork. The values of strain, stress, strain energy and deformation for the materials were obtained. ANSYS workbench 14.0 is used for structural analysis. From the derived observed results it is concluded that SAF001 is best material for friction lining compared to cork as the value of total deformation, strain energy and shear elastic strain is less for SAF001.

S. Prakash et al. (2013) tentatively examined, the finite element method used to study clutch system regarding stresses and deformations .The study also includes the impact of the contact stiffness factor (KFN) on the distribution of stress between deformations and contact surfaces. Augmented Lagrange algorithms were used to obtain the distribution of stresses between surfaces of contact. ANSYS 13 software was used for numerical calculation.

S.G. Seema Begum et al. (2015) The design and analysis of friction clutch plate was investigated using ANSYS and CATAI V5 R20 software. Structural analysis and numerical calculations were performed on ANSYS 14.5. The study was carried on materials, grey cast iron and Kevlar 49. During structural analysis, the equivalent (von misses) stress, total deformation and equivalent strain were evaluated after comparing it, is found that Kevlar 49 is more advantageous than grey cast iron.

Prof Jignesh et al. (2015) made study on friction lining substance in the clutch plate. Torque transmission ability and life span of the clutch were dependent on the clutch plate, so the primary objective of this study is to enhance the efficiency of the clutch by altering the friction lining of the clutch plate. The asbestos materials torque transmission capability is slightly greater than the sintered metal, but the asbestos materials lifespan is lower than the sintered metal because of the elevated heat dissipation rate. Lastly, according to the theoretical research of distinct clutch linear parts we end up in saying that the sintered metal is finest material in the automotive clutch system.

Sunny Narayan et al. (2018) analyzed automotive single plate clutch for stresses and deformation. Finite element method was used for performing structural analysis for vehicle clutch Toyota KUN 25. Input data for numerical analysis was first calculated. ANSYS workbench was used for numerical analysis. Two theories uniform wear theory and uniform pressure theories have been used for calculating pressure and wear. Materials used are asbestos, ceramic, sintered metal, and Kevlar. After comparison it was found ceramic friction lining material is suitable for friction lining. Also heat generated between the flywheel and disc can be reduced by choosing suitable friction lining material.

METHODOLOGY

Tools used

UG-NX:

Unigraphics NX (also known as Siemens nx) is an integrated CAD/CAM/CAE software program initially created by UGS Corporation, but since 2007 it has been owned by Siemens PLM Technology. It is used for Engineering Design analysis & finished design manufacturing for the purposes of development of parametric and surface/solid modeling

Technical analysis including dynamic, static, electromagnetic, thermal, linear, non linear using FEM method

ANSYS

ANSYS is software for computer simulation used to design components, products, semiconductors, and to create models to test the components lifespan, temperature control, electromagnetic properties and fluid motions. ANSYS develops and sells tools for study of finite elements used to model engineering problems. The program produces virtual digital models of structures, electronics or system parts to simulate resistance, resilience, temperature control, fluid flow, elasticity and electromagnetism. ANSYS used to assess how a system can work with dissimilar requirements, without the development of test products or crash tests. For example, ANSYS 19.2 software can model how a bridge can hold up after years of traffic, how to properly handle salmon in a cannery to minimize waste, or how to create a slide that uses less material without compromising protection. Most of ANSYS calculations are done using the ANSYS Work-bench software which is one of the major products of the company. ANSYS users usually break down heavy structures into small parts, which are modeled individually and checked independently. A user may first define an object's dimensions, and then add other physical properties like weight, pressure and temperature. The ANSYS program eventually simulates and analyzes over time movement, exhaustion, fracturing, temperature control, fluid flow electromagnetic performance and other effects. It also provides management of data and backup tools, as well as scientific research and teaching.

Initializing view of Ansys 19.2

FUNCTIONS PERFORMED BY ANSYS SIMULATION
DESIGN EXPLORATION AUTOMATION
AND CUSTOMIZATION GEOMETRY
MODELLING AND MESHING STRENGTH
ANALYSIS

Design Procedure

The sizes of the multi plate clutch have been acquired from the Yamaha SZ R model for the current work. Using UG-NX software 3D model has been constructed. The constructed 3D model which is in IGES format is then imported into ANSYS Work-bench 19.2 analysis software. The material properties were allocated to the geometry as shown in below table. After that static structural analysis were carried out to obtain equivalent strain, equivalent stress and total deformation.

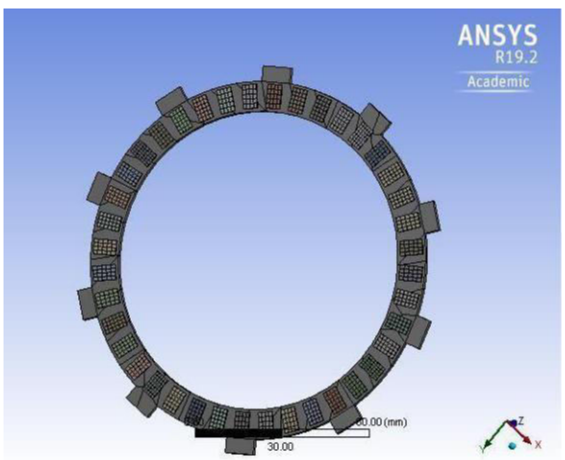
Modeling UG-NX software has completely designed the clutch assembly model. Then 3D clutch assembly model is generated by using the extrude and rotate commands.

Transformation of model

Then the model is transformed to the most appropriate and simple access IGES format for any other software. The clutch assembly model can be imported from UG-NX to ANSYS using the IGES format.

Meshing

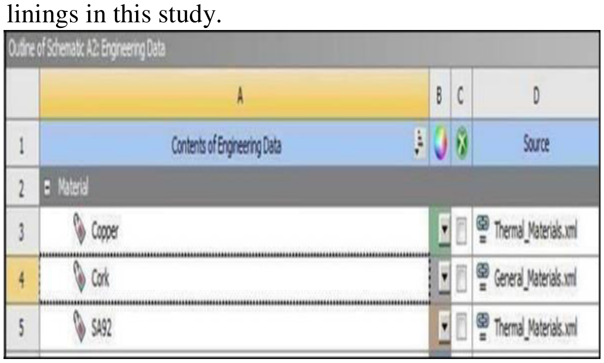
Following the modeling of the entire structure, the clutch assembly is meshed. Using ANSYS workbench 19.2 software, this was performed. The final stage to complete before meshing the model is to set the controls for meshing, That is, the shape of the component, the size, the amount of divisions, etc.



Mesh View

Materials for Clutch plate

Cork, Copper and SA92 have been used as friction linings in this study.



Outline of Schematic A2: Engineering Data

	A	B	C	D
1	Contents of Engineering Data			Source
2	Material			
3	Copper			Thermal_Materials.xml
4	Cork			General_Materials.xml
5	SA92			Thermal_Materials.xml

Schematic view of materials in workbench 19.2

Sr No	Mechanical Properties	Copper	Cork	SA92
1	Density(ρ) (Kg/m^3)	8300	180	1800
2	Young's modulus (MPa)	135000	32	3896
3	Poisson's ratio	0.35	0.25	0.27
4	Yield stress (MPa)	510	1.4	14
5	Coefficient of friction(μ)	0.28-0.3	0.3-0.5	0.3-0.4

Table 1 indicates values of different mechanical properties of materials used in research

PRESENT WORK

Following research has been carried out on Yamaha SZ-R model

The specifications of the model used are mentioned below as:

Torque = 12×10^3N-m at rpm N = 4500rpm r_1= inner radius of friction surface = 62mm r_2 = outer radius of friction surface = 50mm n = Contact surface pairs

n = n_1+n_2-1

n_1= discs on driving shaft n_2 = discs on driven shaft n_1 = 5

$n_2 = 4$

$$n = 8$$

R = mean radius of friction surfaces

μ = friction coefficient T

= Transmitting torque W

= Total operating force

P = Pressure intensity at radius r (N/mm²)

OBJECTIVES OF RESEARCH

The key purpose of this work is to conduct the structural examination of the clutch plate with different friction linings and to choose the most suitable one.

Multi plate clutch assembly modeling (Solid)
Determination of axial pressure intensity according to the measured torque
Determination of equivalent strain
Determination of equivalent stress
Determination of total deformation
Stain, stress and total deformation parameters for the above specified materials are compared
To prevent the loss of friction material used
To increase the overall performance of the vehicle To increase the life of the clutch

RESULTS AND DISCUSSION Calculation:-

The quantities of pairs of interacting surfaces are determined with the aid of the quantity of disks on riding and powered shafts for a multi plate clutch. The

h has eight pairs of

$$R = \frac{2}{3}\left\{\frac{(r_1)^3 - (r_2)^3}{(r_1)^2 - (r_2)^2}\right\}$$

4500rpm
of friction surfaces

$$R = \frac{2}{3}\left\{\frac{(62)^3 - (50)^3}{(62)^2 - (50)^2}\right\}$$

$$R = \frac{2}{3}\left\{\frac{(r_1)^3 - (r_2)^3}{(r_1)^2 - (r_2)^2}\right\}$$

$$R = \frac{2}{3}\left\{\frac{(62)^3 - (50)^3}{(62)^2 - (50)^2}\right\}$$

R = 56.21mm

Frictional torque

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

μ = friction coefficient= 0.3

On substitution in above equation we get

$$12\times1000 = 8\times0.3\times W\times56.21$$

Therefore, W = 88.95 N

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

$$P = \frac{88.89}{\pi\{(62)^2 - (50)^2\}}$$

$$P = 0.02107 N/mm^2$$

Uniform wear theory:

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

$$R = \frac{(62) + (50)}{2}$$

R = 56mm

Pressure intensity at a distance r from the axis of clutch

$$P \times r = C$$

C = Constant

Total force acting on the friction surface

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

Torque transmitted,

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

$$12\times1000 = 8\times0.3\times W\times56$$

$$W = 89.28\ N$$

The complete force acting on the surface of the friction

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

$$C = \frac{89.28}{2\pi\{(62) - (50)\}}$$

C = 1.18 N-mm

The pressure intensity is maximum at internal radius (r_2) of friction surface given as

$$P_{max} \times r_2 = C$$

$$P_{max} = 0.0236MPa$$

At the outer radius (r_1) of the friction or contact surface pressure intensity is minimum

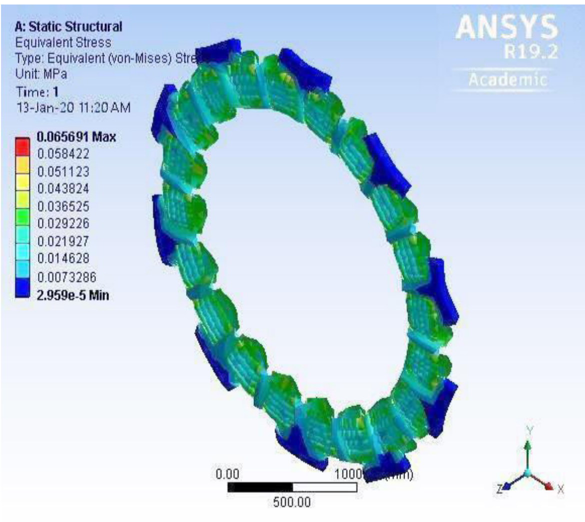
$$P_{min} \times r_1 = C$$

$$P_{min} = 0.01903MPa$$

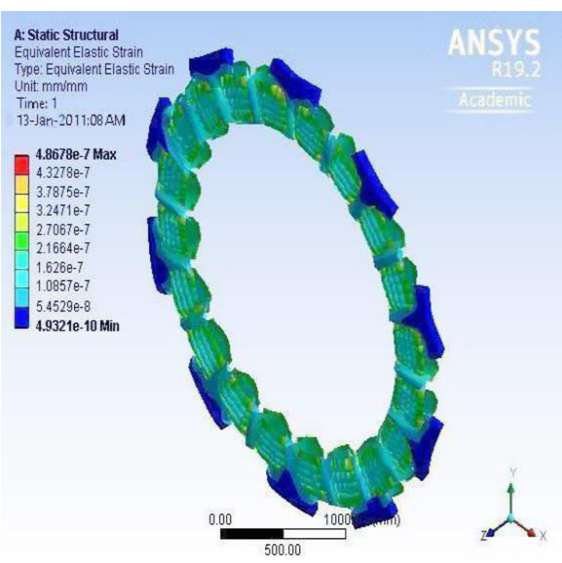
Maximum pressure calculated from standardized wear theory is used in this research to analyze clutch plate design parameters

Clutch plate analysis using copper as a material for friction

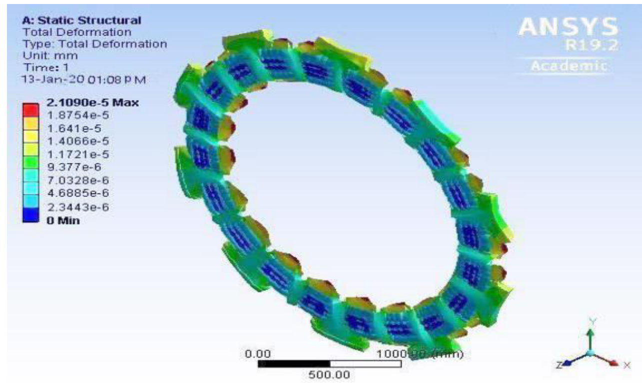
Copper (Cu) and its alloys play a crucial role as non-asbestos frictional additives. Increasing thermal conductivity, acting as a solid lubricant at elevated temperatures and influences overall tribological output are its primary functions. Copper is an important component in friction products used as friction lining for automotive clutches.



Equivalent Stress (copper)



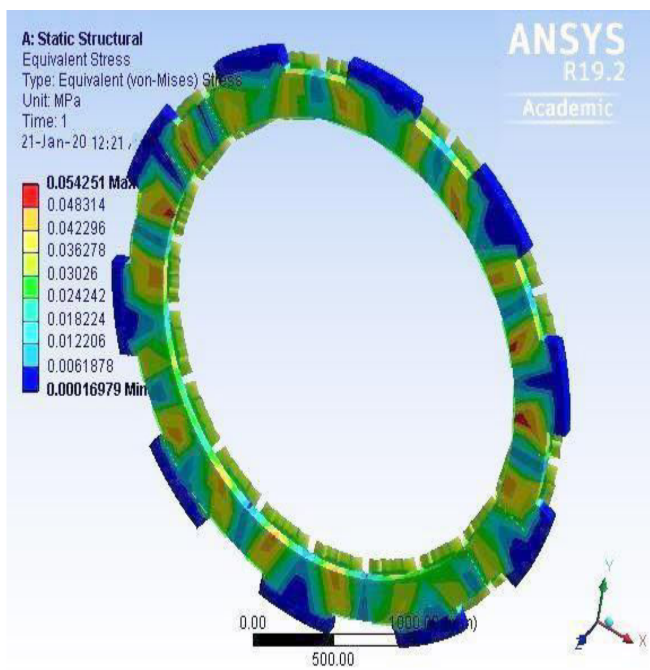
Equivalent strain (copper)



Total deformation (copper)

Clutch plate analysis using cork as a material for friction

Cork has a near zero Poisson ratio, which implies that when squeezed or pulled, the radius of a cork does not alter considerably. Cork is a very good material for the gasket. The composites produced by blending cork granules and cement have reduced thermal conductivity, reduced density and excellent absorption of energy. Cork products have a strong mechanical resistance and are capable of retaining mechanical characteristics between 80C^0 and 140C^0



Equivalent Stress (cork)

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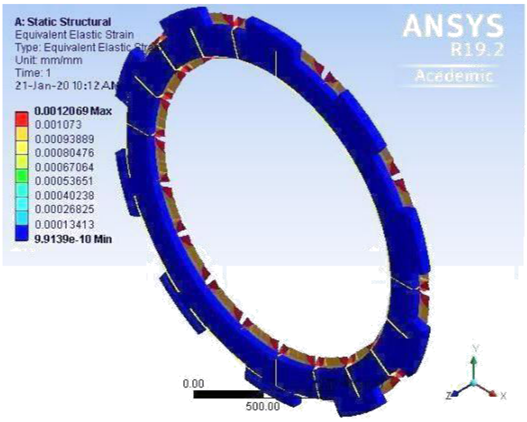
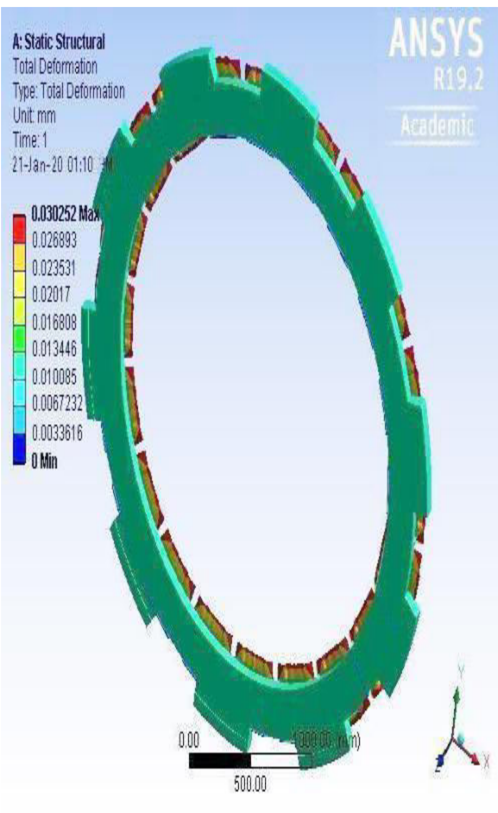


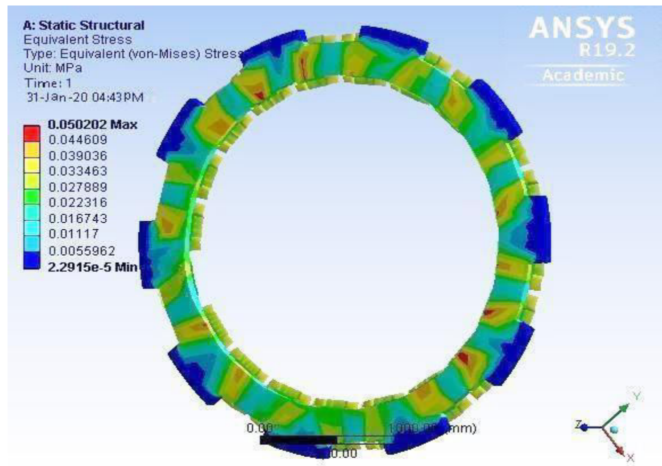
Equivalent strain (cork)



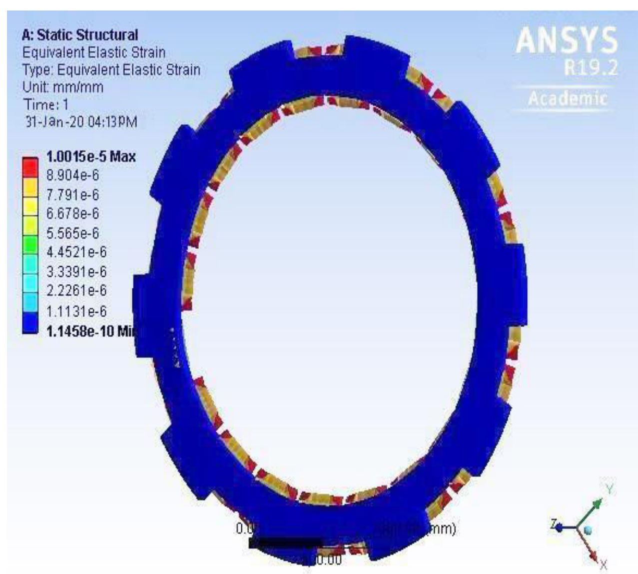
Total deformation (cork)

Clutch plate analysis using SA92 as a material for friction

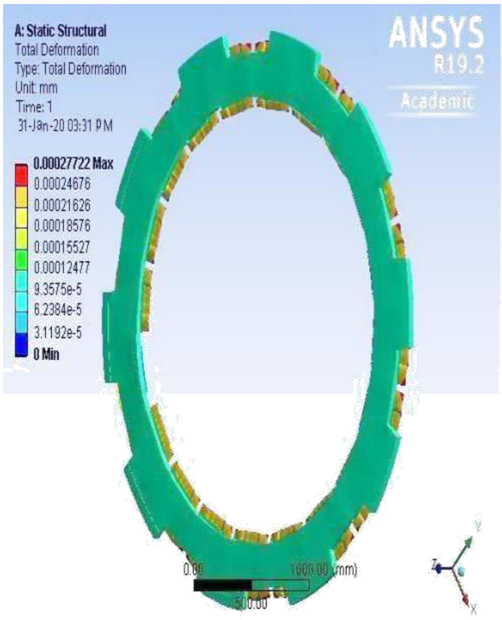
SA92 is a standard formulation suitable for light medium duty applications. It is a rigid composite material with low wear and very good friction, consists of phenol resins with NBR bonding system, thin fibers, friction modifiers and fillers ideal material for bonding and riveting.



Equivalent Stress (SA 92)



Equivalent Strain (SA 92)



Total Deformation (SA 92)

Friction material	Equivalent Stress (MPa)	Equivalent Strain	Total Deformation (mm)
Copper	0.065691	$4.8678e^{-7}$	$2.1090e^{-5}$
Cork	0.054251	0.0012069	0.030252
SA92	0.050202	$1.0015e^{-5}$	0.00027722

Table 2 shows Results of research

CONCLUSION

Following completion of the static structural analysis in ANSYS 19.2, under these loading conditions, none of the parts will yield, and therefore the design is safe. The results for what is expected are fairly nice.

In this project, a multi plate 3D model and setup clutch was carried out using UG-NX software packages. Structural clutch analysis was performed using ANSYS work-bench 19.2 for cork, copper and SA92 as materials for friction lining. Eventually, from this evaluation, it can be concluded that SA92 is the most appropriate and relatively better friction lining material than copper and cork for the same rated torque.

From the results it is concluded that SA92 has following desirable properties which make it better for clutch use lining material.

High transmission torque ability

High heat resistance

Good recovery from fade

Speed rubbing resistance is high

Pressure bearing resistance is high

FUTURE STUDY

The above research can be carried out for practical purposes with few specified conditions. The research is open in above field is on and it can be optimized by using new and improved versions of software's in which both design as well as analysis will be performed in single software. Using two different software's as above is little time consuming it must b done in single command.

REFERENCES

1) Zagrodzki P, "Thermoelastic instability in friction clutches and brakes - Transient modal analysis revealing mechanisms of excitation of unstable modes", International Journal of Solids and Structures (IJSS), Vol. 46, Issue 11-12, 1 June 2009, pp. 2463-2476.

2) Abdullah M. Al-Shabibi, Wassan Abd Al-Sahb, Oday I. Abdullah, "Thermoelastic Analysis of Multi-Disc Clutches Using Finite Element Method", Tribologia, Vol. 5 2014.

3) Anil Jadhav, Gauri Salvi, Santosh Ukamnal, Prof.p.Baskar, "Static Structural Analysis of Multi plate Clutch With Different Friction Materials", International Journal of Engineering Research and

Technology (IJERT), Vol. 2, Issue 11, November 2013.

4) S. Prakesh, T.C. Muralidharan, R. Suresh, "Analysi of Mf241Di Clutch Plate with Different Material (30Cr13 Steel and En15Steel)", International Conference on Advanced Nanomaterials and Emerging Engineering Techonologies (IEEE) , Date of Conference 24-26 July 2013.
5) S. Gouse Seema Begum, A. Balaraju, "Design and Analysis of Friction Clutch Plate Using ANSYS", International Journal of Advanced Engineering Research and Science (IJAERS), Vol. 2, Issue 5, May 2015.
6) Prof. Jignesh J, Patel, Mr. Kaushal R. Ajmera, Mr. Raghav K. Thanki, Mr. Rohit

7) Sunny Narayan, Ivan Grujic, Nadica Stojanovic, Kaisan Muhammad Usman, Abubakar Shitu, Faisal O. Mahroogi, "Design and Analysis of an Automotive Single Plate Clutch", Mobility and Vehicle Mechanics, 2 April 2018.