FEM ANALYSIS OF WET MULTI PLATE CLUTCH BY VARYING FRICTION SURFACE MATERIAL

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Abstract - ***The important component of any automotive machine is the friction clutch. Clutch is a mechanism for transmitting rotation which can be engaged and disengaged. It is a link between engine and transmission system which conducts power in the form of torque from engine to the gear assembly. When vehicle is in motion clutch is first disengaged for the drive to allow for gear selection and then again engaged smoothly to power the vehicle to transfer torque to the driving wheels. In the present work, an attempt is made on wet multi plate clutch with varying friction material. The behavior of the clutch or brake is influenced by the friction combination when being engaged and disengaged, the permissible thermal loading and the behavior in terms of wear and tear should be considered.***

The friction materials which is used here represent the most important part of each friction combination, which effectively consist of the counter frictional surface and in the case of wet-running. Structural and Thermal analysis is done on the wet friction plates to verify the strength. Design of wet multiple plate clutch is carried out by using CATIA design software and Finite Element Analysis is carried out by using ANSYS v11 software. Friction materials used are Cork and Copper Powder Metal. Material used for inner disc is steel and outer disc is bronze. By observing the analysis results it indicates that the design is safe and considerable.

Key Words: *Wet multi plate clutch, Friction materials, Thermal analysis, Cork material, Copper powder metal.*

1. INTRODUCTION

Clutch is a mechanism for transmitting rotation which can be engaged and disengaged. Devices where we can use clutch is those which have two rotating shafts. In these devices, one shaft is typically driven by a pulley or motor and the other shaft drives another device. Now let us consider an example where one shaft is driven by a motor and the other drives a drill chuck. The clutch connects the two shafts so that they can either be locked together and spin at the same speed, this is called engaged, or be decoupled and spin at different speeds, this is called disengaged. Different kinds of clutches are used depending on the speeds, orientation, material, torque produced and finally the use of the whole device. The clutch itself is a mechanism, which employs different principles and different configurations in various models available.

1.1 Classification of Friction Clutches

Based on the application of the friction clutches in any automotive or machine they can be divided in different categories. The classification of friction clutches is done according to the design, working mechanism and shape of the mating surfaces.

- Flat Plate Friction Clutch
- Conical Friction Clutch

1.2 Desirable Properties for friction materials/ linings for clutches

- The materials in contact must have a high coefficient of friction.
- The materials in contact must resist wear effects, such as galling, scoring and ablation.
- Over a range of temperatures and pressures the friction value should be constant.
- The materials should possess good thermal properties, good thermal conductivity, high heat capacity, withstand high temperatures.
- The materials Should be safe to use and acceptable for the environment

2. LITERATURE SURVEY

- The Friction plate used in this Project is part of a Wet Multi-Plate clutch System which is normally used in commercial Motor vehicles. The clutch Friction plate is located between the Clutch Center and the Pressure plate. The clutch cushioning spring is a plate where is acts to absorb the vibration effect during clutch engagement as well as linking the clutch counter mate disc and the clutch disc base together.

- Gorin and Shilyaev (1976)[1] studied the analytical solutions between two rotating annular disks having small gaps. Since the analytical solutions were derived from the Navier-Stokes equations using an integral approach, i.e. the Slezkin-Targ method, the inertial terms were not considered. The study was limited to laminar flow between a rotating and a stationary disk, and computed exactly the radial, axial and tangential velocity components.

- Li and Tao[2] (1994) compared three types of outflow boundary conditions for recirculating flows with experiment data for convective heat transfer of a two-dimensional jet impinging on a rectangular cavity. They tried a local mass conservation method, a local one-way method and a fully-developed flow assumption. They concluded that, if possible, the area of the outflow boundary should be located far enough from the re circulating area in order to obtain a realistic numerical solution and avoid significant errors. Of the three methods that Li and Tao studied, the mass conservation method for the outflow boundary model having are circulating flow at the boundaries had the best agreement with the experimental data.

- Natsumeda and Miyoshi[3] (1994) developed a numerical solution for the clutch 15 engagement process including the permeability of the friction plate, the compressive strain and the asperity contact of the friction material. In addition, they solved the equations of heat conduction to model the heat generated by the asperity contact. Furthermore, the conducted experiments with multi-friction plates to measure the torque and temperature variation in the system. They found that during engagement the temperature at the centerline of the separator plates begins to rise from its initial state. Also, it was observed that during the engagement process the temperature at the end of clutch pack was much lower than that between the friction plates although the temperature at the both locations was almost identical prior to engagement. Since the friction material insulates the separator area surrounded by the friction plates, it achieves a higher temperature than that of the separator area, whose one side is in contact with the piston.

- Berger et al.[4] (1996) developed a Finite-Element Model (FEM) model to simultate the engagement of rough, grooved, paper-based permeable wet clutches. A modified 16 Reynolds equation was adopted from the Patir and Cheng flow model using average flow factors to include surface roughness effects. The Reynolds equation and force balance equations were discretized using the Galerkin approach. The simulation results indicate that increasing the applied force increases the torque peak and decreases the engagement time. Furthermore, the permeability of the friction material affects the magnitude of the increase in torque peak and the corresponding decrease in engagement time. The FEM model radial grooves on the friction material and the computational results showed that an increase in groove width results in a decrease of the torque peak while groove depth only slightly affects the torque. Furthermore, the film thickness decay was shown to be related to increasing the torque peak. However, no comparison between the simulation and available experimental measurements were made.

- In 1997, to obtain a more efficient solution to the problem, the modified Reynolds equation of Berger et al.[5] (1997) was simplified assuming axisymmetric flow, and neglecting the compressive strain of the friction material. The system of Reynolds and force balance equations was reduced to a single, first-order differential equation that resulted in a fast executing model.

- Yuan et al. [6](2007) proposed an improved hydrodynamic model for open, wet-clutch behavior. This theoretical model includes not only the effects of trapped air bubbles, but also surface tension and wall adhesion. The surface tension between fluid and air at outer interface is assumed and the relation between the surface tension and the pressure jump is formulated. With the formulation, an equivalent radius assumption was made. The drag torque for the equivalent radius was validated with experiment results and the computed drag torque from this model was proven to be more accurate than previous models at high rpm. The analytical solution of Yan et al. agreed well with the experimental results, however the need for adjustment of the oil viscosity was rather problematic. Also, since the model corresponded to a non-grooved open wet clutch, there were limitations to any potential applications to a realistic wet clutch having a grooved friction plate and undergoing dynamic engagement.

3. MULTI-PLATE CLUTCH MODELING

In this section the modeling of Multiple Plate clutch is done by CATIA v5 R21 modeling software. CATIA part enables to design models as solids in progressive 3D solids modeling environment. Solid models are geometric models that offer mass properties such as volume, surface area and inertia.

Fig -1: 3D Model of Inner Base-part

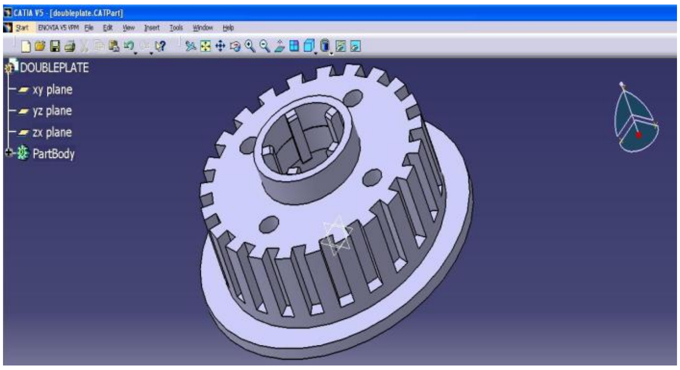

Fig -1: Double-Plate Modeled in CATIA

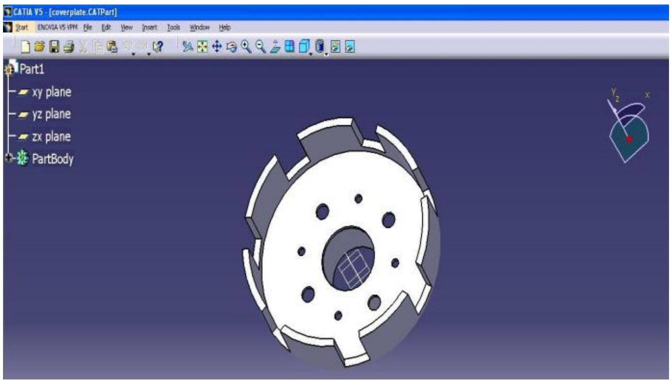

Fig -2: Inner View of Modeled Cover Plate

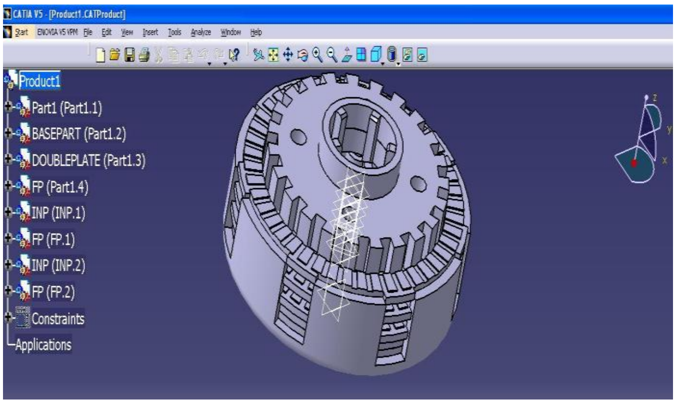

Fig 3: Assembly of Multi-Plate Clutch

4. ANALYSIS

The ANSYS software is a handy tool that has the capability to decide the type of elements that are required for the analysis purpose. The Finite Element Method is a mathematical tool used to compute ordinary equations and partial differential equations. Since it is a numerical tool, it has the ability to solve the complex problems that are represented in differential equations form.

Mesh generation is one of the most critical aspects of engineering simulation. Too many cells may result in long solver runs, and too few may lead to inaccurate results. ANSYS Meshing technology provides a means to balance these requirements and obtain the right mesh for each simulation in the most automated way possible. ANSYS Meshing technology has been built on the strengths of stand-alone, class-leading meshing tools. The strongest aspects of these separate tools have been brought together in a single environment to produce some of the most powerful meshing available. This helps in automatic choosing of elements and nodes and thus simplifies the job of FEM model creation. The meshing is performed by opening the ANSYS meshing application in workbench environment wherein the sizes of the elements are controlled.

4.1 Structural Analysis

Structural analysis is the process of determining the effects of loads on physical structures and their components. Structural analysis incorporates in the fields of applied mechanics, materials science and applied mathematics to compute a structure's deformations, internal forces, stresses, support reactions, accelerations, and stability. The results of the analysis are used to verify a structure's fitness for use, often saving physical tests.

A structural model which created can be used to predict the behavior of their modal structure, under the action of external forces. The response is usually measured in terms of deflection and stress

4.2 Model Analysis

A Model Analysis is a Free Vibration Analysis it is find out The Maximum frequency generated within a product.

4.3 Thermal Analysis

In this Analysis we are going to find out how the Temperature Distribution is takes place and Heat flux of the product and Thermal gradient in the product.

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Table -1: Cork Material Properties

Material Properties	Units
Young's Modulus (EX)	32Mpa
Poisson's Ratio (PRXY)	0.25
Density	180kg/m³
Thermal Conductivity	2.564X10^{-7}w/m°c
Specific Heat	6.959J/kg°C
Co-efficient of Expansion	1.3553X10^{-8}w/m°c

4.3.1 Structural Analysis

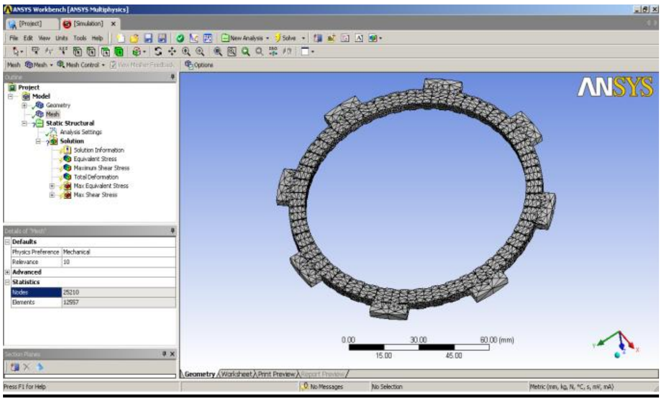


Fig - 4: Meshed Finite Element Model of Friction Plate used for Analysis

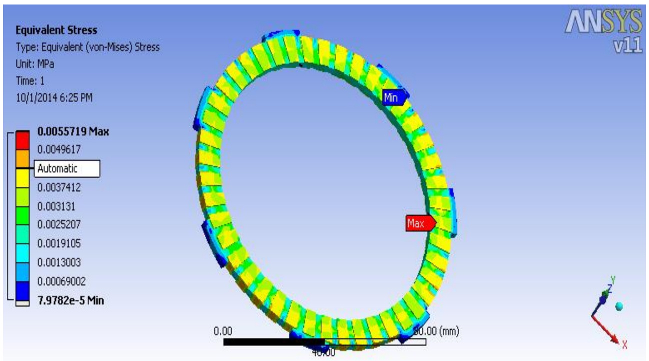


Fig – 10: Equivalent (Von-Mises) Stresses Distribution over the Entire Surface of the Cork Friction Plate

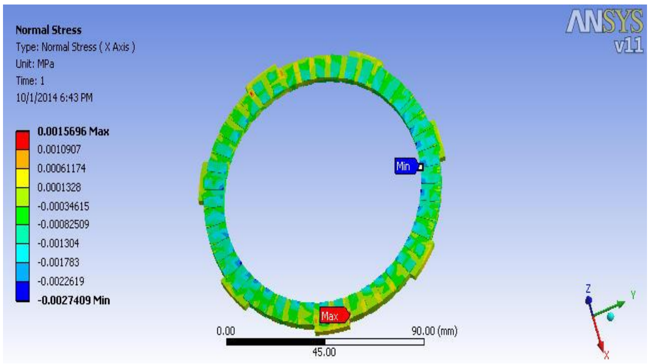


Fig - 5: Normal Stresses Distribution over the Entire Surface of the Cork Friction Plate

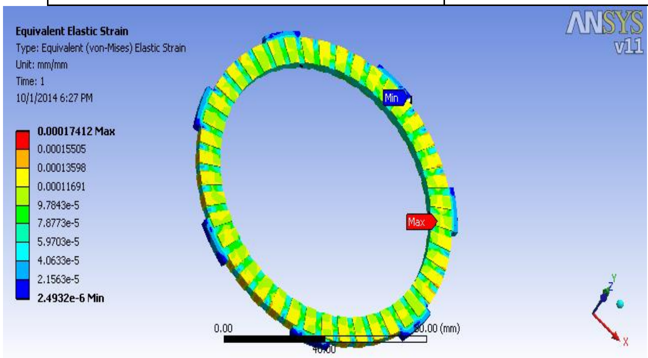


Fig -6: Equivalent-Elastic (Von-Mises) Strain distribution over the Entire Surface of the Cork Friction Plate

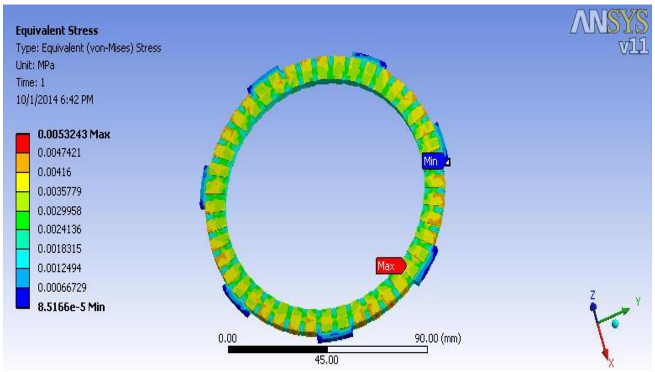


Fig - 7: Equivalent (Von-Mises) Stresses Distribution over the Entire Surface of the Copper Friction Plate.

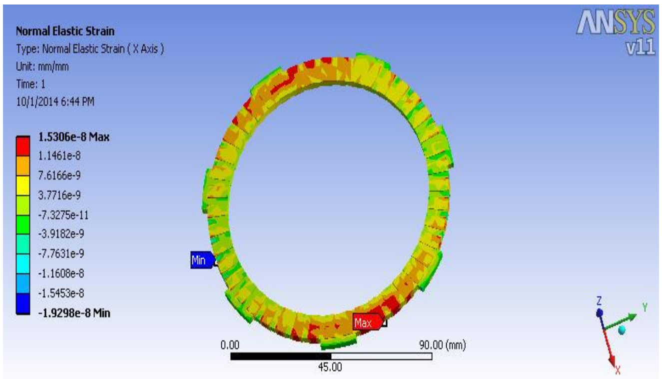


Fig - 8: Normal Strain Distribution over the Entire Surface of the Copper Powder Metal Friction Plate

4.3.2 Modal Analysis of Friction Plate

Table -2: Copper Powder Material Properties

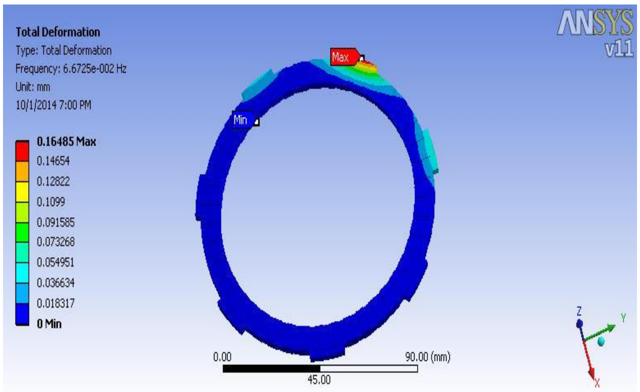


Fig - 9: Mode 2 (Cork Friction Plate)

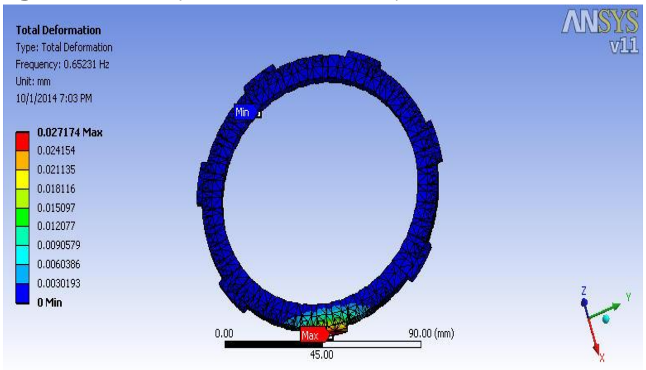


Fig - 10: Mode 1(Copper Powder Metal Friction Plate)

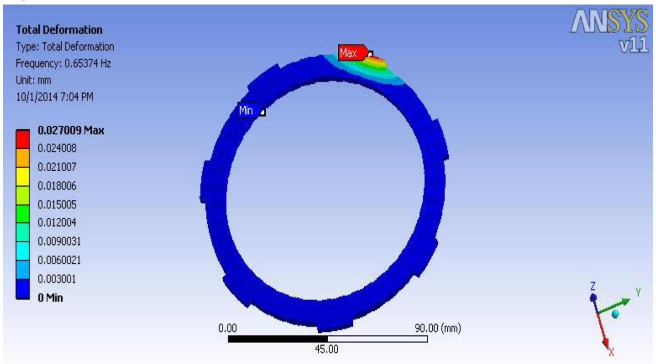


Fig - 11: Mode-2 (Copper Powder Metal Friction Plate)

4.3.3 Thermal Analysis of Friction Plate
Heat Flux

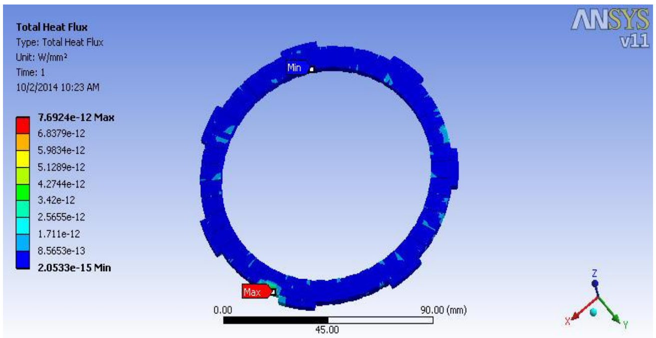


Fig - 12: Heat Flux Distribution over surface of Multi-Plate Clutch of Cork Material

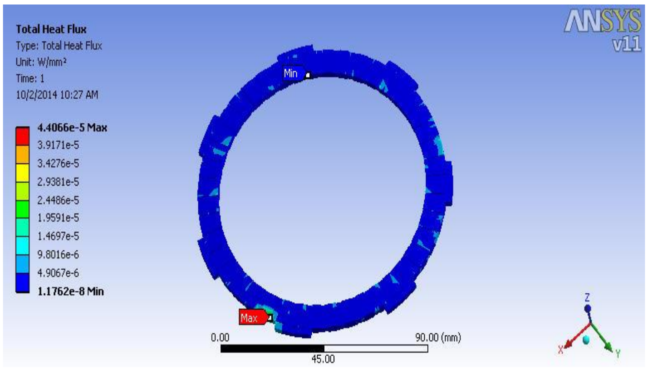


Fig - 13: Heat Flux Distribution over surface of Multi-Plate Clutch of Copper powder Material

Temperature Distribution

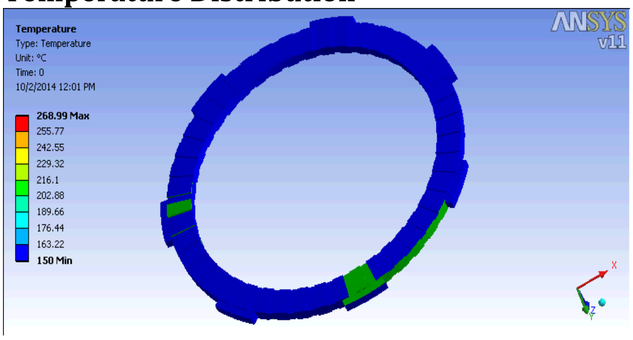


Fig - 14: Temperature distribution over surface of Multi-Plate Clutch of Cork material

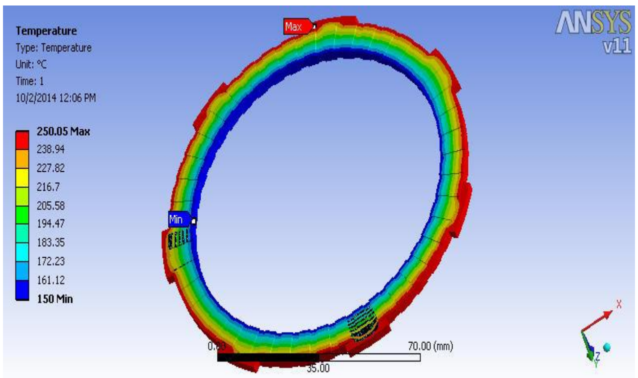


Fig - 15: Temperature distribution over surface of Multi-Plate Clutch of Copper powder material

Fig - 16: Cork Material Coated Friction Plate

Fig – 17 : Copper Powder Coated Metal Friction Plate

5. RESULTS & DISCUSSIONS

Table -3: Results from Structural Analysis

Material	Von-Mises Stress (Mpa)	Normal Stress (Mpa)	Von-Mises Strain	Normal Strain	Total Deformation (mm)
CORK	0.005 571	0.0015 696	0.000 1741	4.783 9e-5	0.0004 800
COPPER	0.005 3243	0.0011 393	3.943 9e-8	1.530 6e-8	1.3971 e-7

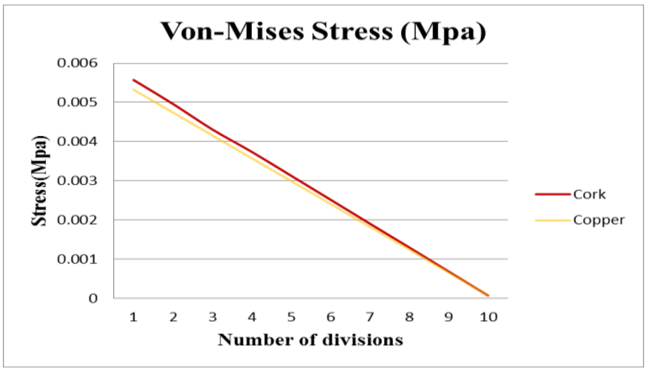
Table -4: Results from Modal Analysis

S.NO	Cork material Frequency (Htz)	Copper Material Frequency (Htz)
1	6.664e-002	0.65231
2	6.725e-002	0.65374

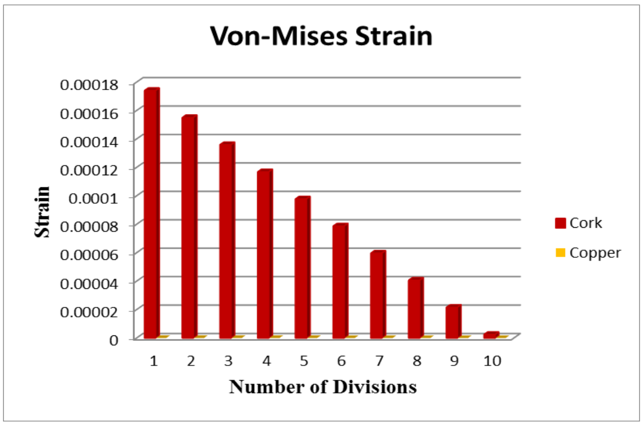
Table -5: Results from Thermal Analysis

S.NO	Material	Heat Flux (w/m^2)	Temperature Distribution(°C)
1	Cork	7.6924E-12	268.99
2	Copper	23.343	250.05

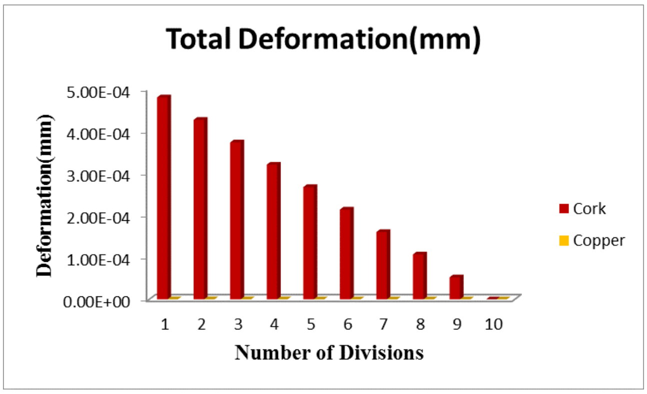
Graphs



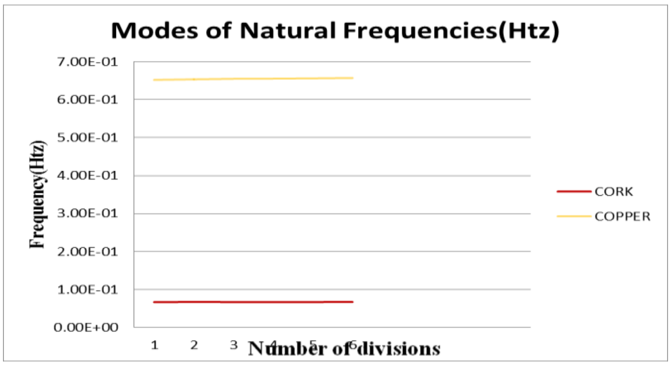
Graph –1: Von-Mises Stress (Mpa) for Cork vs Copper Metal



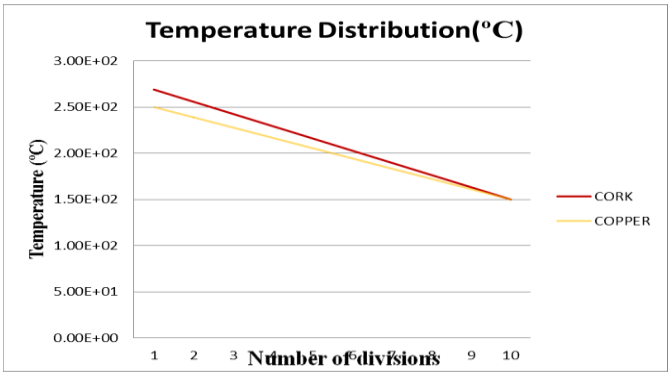
Graph –2: Von-Mises Strain for Cork vs Copper Metal



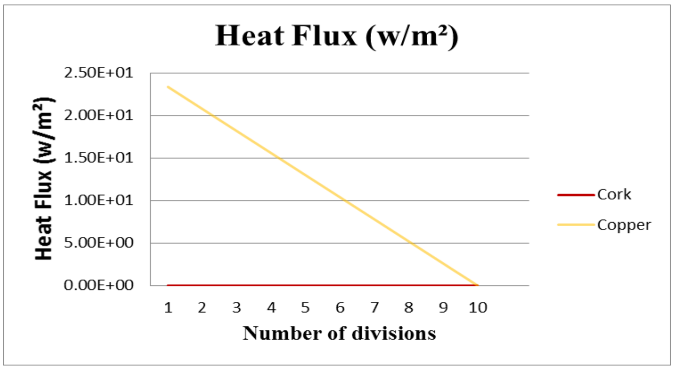
Graph –3: Total-Deformation for Cork vs Copper Metal



Graph –4: Different Modes between Cork vs Copper Metal



Graph –5: Temperature Distribution between Cork vs Copper Metal



Graph –6: Heat Flux Distribution between Cork vs Copper Metal

6. CONCLUSIONS

Structural, Modal and Thermal analysis is done on the wet friction plates to verify the strength. Friction materials used are Cork and Copper Powder Metal. Material used for inner disc is steel and outer disc is bronze. By observing the analysis results, design is safe. Total Deformation and stress, Strain values are less for Copper Powder Metal. Copper powder metal is having capability to with stand high frequency up to 6.5231Htz. Temperature Distribution and Heat flux values for copper metal is moderate than cork Material usage of Copper powder Metal as surface lining is better than using cork. Hence we conclude that for multi plate clutches using Copper powder metal as friction material Strength is Improved, Deformation is reduced and Material Life of the Clutch is improved. To improve Performance of clutch Lubricant Oil is maintained and servicing of Automobile is done in Perfect Time.

SCOPE OF FUTURE WORK

2D and 3D Computations were carried out for multi-plate clutch in present analysis. Some of the suggested work is outlined below:

- Model analysis can be generated for multi-plate clutch by varying the Design of Friction plate Teeth.
- Transient Thermal analysis for various temperatures can be carried out.
- For the present case only computations were performed. Fabrication work can be carried out.

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