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Analysis of Single Plate Friction Clutch Using Finite Element Method

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Abstract— **A friction clutch is a most essential component in the process of power transmission. The role of clutch is to initiate the motion or increase the velocity of a body generally by transferring kinetic energy from another moving body. To avoid failure and to have optimal weight and cost, it is necessary to find the stresses and analyze vibration characteristics of a clutch. The present paper deals with designing a friction clutch assembly using Pro-e software and its structural analysis using ANSYS software. Modal analysis is done to optimize the natural frequency of the single plate friction clutch to avoid being in resonance with the engine frequency range. The results show that natural frequencies of original model and natural frequencies of simplified model are in good agreement with each other.**

Keywords:- *single plate friction clutch, Natural frequency, finite element Analysis.*

I INTRODUCTION

All During the course of over 100 years of automotive history, almost all components have undergone enormous technological development Reliability, production costs and ease of maintenance, as well as environmental compatibility have been and continue to be the criteria demanding new and better solutions from automotive engineers. Clutch is a mechanism which enables the rotary motion of one shaft to be transmitted, when desired, to a second shaft the axis of which is coincident with that of the first. The clutch is a mechanical device, which is used to connect or disconnect the source of power from the remaining part of power transmission system at the will of the operator. The main primary function of the clutch is to transmit the torque from engine to driven shaft & engage and disengage the transmission system. The secondary function is related to vibration & damping. When the friction clutch begins to engage, slipping occurs between the contact surfaces such as pressure plate, friction plate and flywheel and due to this slipping, heat energy will be generated on friction plate surfaces. A popularly known application of clutch is in automotive vehicles where it is used to connect the engine and the gear box. Clutches are also used extensively in production machinery of all types. In friction clutches, the connection of the engine shaft to the gear box shaft is affected by friction between two or more rotating concentric surfaces. The surfaces can be pressed firmly against one another when engaged and the clutch tends to rotate as a single unit.

Clutch closed

In the engaged state, the force of the diaphragm spring acts on the pressure plate. This pushes the axially movable clutch disc against the flywheel. A friction lock-up connection is created. This allows the engine torque to be directed via the flywheel and the pressure plate to the transmission input shaft.

Clutch open

When the clutch pedal is pressed, the release bearing is moved against the diaphragm spring load in the direction of the engine. At the same time, the diaphragm springs are deflected over the support rings, and the force on the pressure plate is reduced. This force is now so low that the tangential leaf springs are able to move the pressure plate against the diaphragm spring load. This creates play between the friction surfaces, allowing the clutch disc to move freely between the flywheel and the pressure plate. As a result, the power flow between the engine and transmission is interrupted.

In single plate clutch, a friction plate is held between flywheel and pressure plate. There are springs depending upon design arranged circumferentially, which provide axial force to keep the clutch in engaged position. The friction plate is mounted on a hub which is splined from inside and thus free to slide over the gear box shaft. Friction facing is attached to the friction plate on both sides to provide two annular friction surfaces for the transmission of power. A pedal is provided to pull the pressure plate against the spring force whenever it is required to be disengaged. Ordinarily it remains in engaged position. When the clutch pedal is pressed, the pressure plate is moved to the right against the force of the springs. This is achieved by means of a suitable linkage and a thrust bearing. With this movement of the pressure plate, the friction plate is released and clutch is disengaged.

In actual practice the construction of clutch is differs. The pressure plate, the springs, the release lever and the cover forms the sub-assembly, called cover assembly which can be mounted directly to the engine block, placing the clutch plate in between the flywheel and pressure plate with the clutch shaft inserted in. Rajesh Purohit et al (2014) presented the design and finite element analysis of an automotive clutch assembly. The assembly consists of a clutch plate, a pressure plate and a diaphragm spring. The material selected for the three parts are structural steel, cast iron GS-70-02 and spring steel. Structural static structural analysis of each part was done. The plots for equivalent stress, total deformation and factor of safety were obtained and analyzed. The finite element analysis was carried out in pre-processing, solving and post-processing. Uniform wear theory was used for analysis. The Solid Works Office Premium software and ANSYS software has been used for designing and analysis purpose. The results show that designed friction clutch assembly is safe.

O.I. Abdullah et al (2013) investigated stresses and deformations of a dry friction clutch system. To study the stresses and deformations for clutch the finite element method is used. There are five algorithms used for surface-to-surface contact type are Penalty method, Augmented Lagrange, Lagrange multiplier on contact normal and penalty on tangent, Pure Lagrange multiplier on contact normal and tangent, Internal multipoint constraint method. To obtain pressure distribution between contact surfaces Penalty and Augmented Lagrangian algorithms are used. ANSYS 13 software has been used to perform the numerical calculations. The effect of contact stiffness factor FKN on pressure distribution between contact surfaces, stresses and deformations was studied.

O.I. Abdullah et al (2013) explained optimization of shape and design parameters of the rigid clutch disc using FEM. The numerical solution of computing the stresses and vibration characteristics of rigid clutch disc is presented. Two types of rigid clutch discs have been investigated the reference and new suggested model. The response of the new suggested models have been compared with the reference model. For numerical solution ANSYS and Solid Works have been used. The results show that by adjusting the design parameters stresses and vibration characteristics can be controlled and suggested models improve the response of friction clutch.[3]

Ali Belhocine et al (2016) explained a numerical parametric study of mechanical behavior of dry contact slipping on disc pads interface. The determination and visualization of structural deformations due to contact of slipping between the disc and pads is presented. The variations of stresses in rotating disc and ring bodies are predicted by meshed models. A convergence test is intended to evaluate the influence of the mesh on the accuracy of the numerical solution. Using the developed model, the influence of design parameters on result was examined using Finite Element Method. Influence of fine mesh, pad material, young's modulus of pad material, friction coefficient, rotational speed of the disc on the computation results was studied.[4]

V.J. Deshbhratar et al (2013) analyzed design and Structural Analysis of single plate friction clutch. In design of friction clutches knowledge of thermo-elasticity is very important. The stress analysis of single plate clutch of an automobile is presented. The stresses and forces in the clutch disc are tried to reduce with the help of software. For modeling and analysis pro-e and ANSYS software are used. Based on the results it is clear that value of equivalent stresses for given loading conditions are less than allowable stresses for particular condition. Hence the design is safe and the efficient and reliable design of clutch is find out.[5]

Animesh Agrawal et al (2014) presented Optimization of Multi plate friction clutch for maximum torque transmitting capacity using uniform wear theory. Uniform wear theory is used to solve the optimized results for multi plate clutch. Operation research is the branch of mathematics which deals with application of scientific methods and technique to design problems and establishing optimal solutions. The two methods used for optimization are stochastic programming and geometric programming. In actual practice, due to tolerances design variable becomes probabilistic. This gives proper considerations at the time of design. [6]The objective function was calculated by variation in value of number of friction surface, in value of friction coefficient, in value of intensity of pressure. The result charts can be used for design purpose so as to improve the design.

II MODELLING OF SINGLE PLATE FRICTION CLUTCH

The clutch assembly model has been entirely modelled by Pro- E software. First of all sketch command of the pro-e is opened. Then by using 2d commands sketch is created. Then 3D model of clutch assembly created by using extrude and revolve commands.

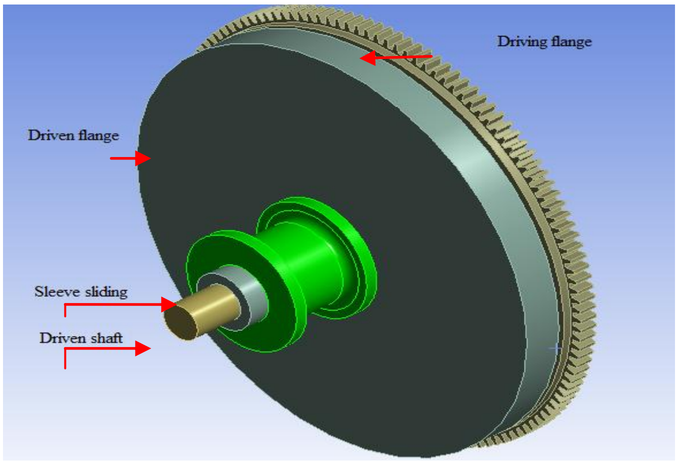


Figure1Model of single plate friction clutch

III MATERIAL SELECTION

The following materials are selected for finite element analysis.

1) Clutch base plate: Structural steel
2) Pressure plate: Grey cast iron
3) Friction material: Kevlar aramide fiber 49

Table1.Material properties

Properties	Material 1 (structural steel)	Material 2 (grey cast iron)	Material 3 (Kevlar aramide fiber 49)
Density(kg/m^3)	7850	7200	1410
Young's modulus(Mpa)	$2*10^{11}$	$1.2*10^{11}$	$1.12*10^{11}$
Poisson's ratio	0.3	0.29	0.36
Bulk modulus(pa)	$1.6667*10^{11}$	$9.5328*10^{10}$	$1.3333*10^{11}$
Shear modulus(pa)	$7.692*10^{10}$	$4.6512*10^{10}$	$4.1176*10^{10}$

IV FINITE ELEMENT ANALYSIS

Meshing

Basic theme of finite element analysis is to make calculations at only limited number of points and then interpolate the results for entire domain. Any continuous object has infinite degrees of freedom and it is just not possible to solve the problem in this format. Finite element method reduces degrees of freedom from infinite to finite with the help of discretization i.e. meshing.

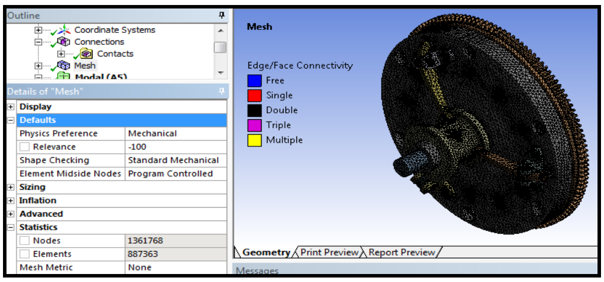


Figure 2 Meshing of single plate friction clutch assembly

Modal analysis

The modal analysis is considered essential step in the design process to estimate the vibration characteristics of the designed structure. Hence, the goal of a modal analysis is determining the natural frequencies and mode shapes. Modal analysis can also be taken as a basis for other more detailed dynamic analyses such as a transient dynamic analysis, a harmonic analysis or even a spectrum analysis based on the modal superposition technique. The main assumption in the modal analysis is that the system is linear and ignored nonlinearity in the system.

Boundary conditions

The Driving Flange is connected to the Engine Flywheel. The Driving Shaft is specified with the Cylindrical Support and the Driven Flange is connected to the Gear Box. It is modeled as the Elastic Support with Stiffness Value of 10000 N/mm^2.

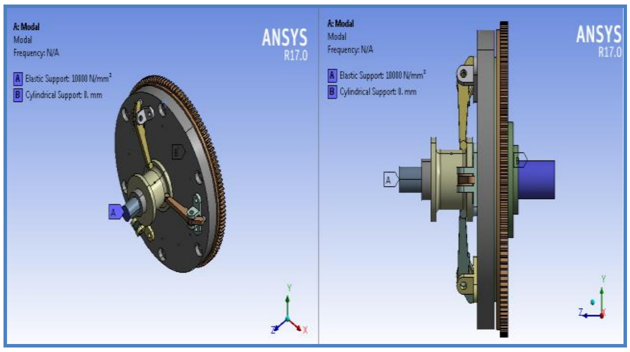
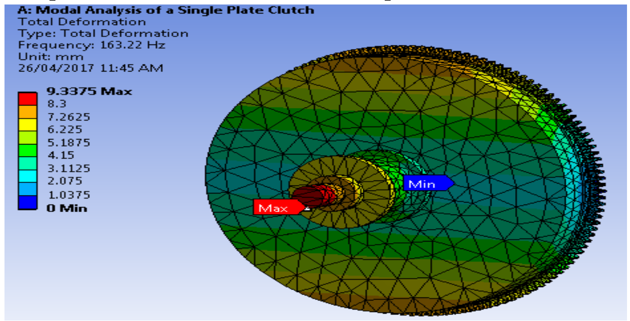


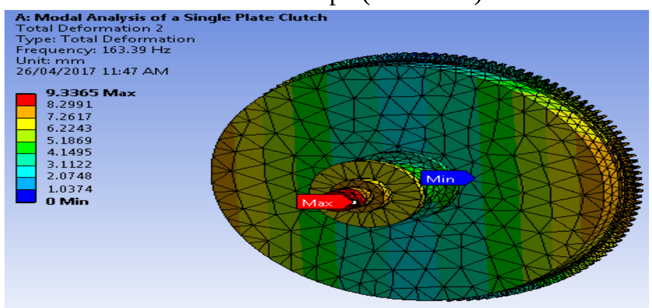
Figure3 Modal analysis- boundary conditions

Results of the Modal Analysis

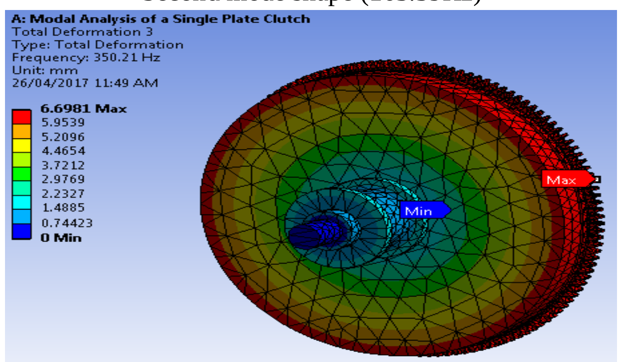
The natural frequencies of original model which are provided by the customer are 171.15 Hz, 171.43 Hz, 333.54 Hz, 578.58 Hz, 1031.7 Hz, and 1033.3Hz. Modal analysis is done for simplified model and the mode shapes are found out.



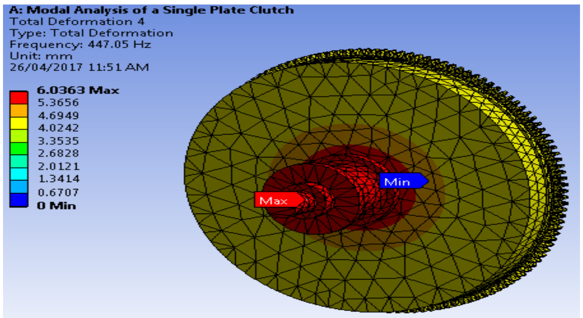
First mode shape (163.22Hz)



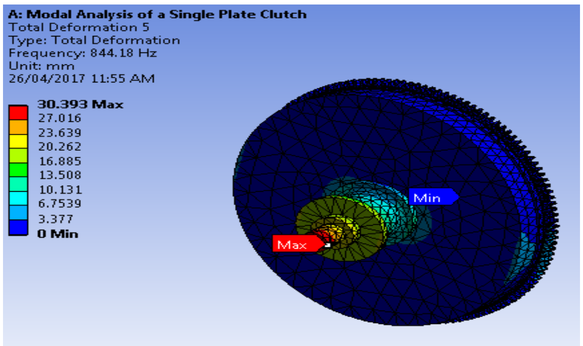
Second mode shape (163.39Hz)



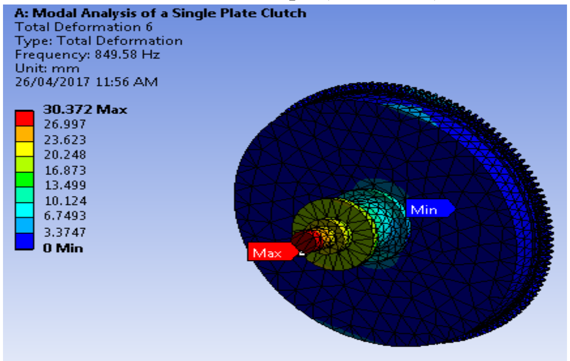
Third mode shape (350.21Hz)



Fourth mode shape (447.05Hz)



Fifth mode shape (844.18Hz)



Sixth mode shape (849.58Hz)

Using the Simplified Model, following is the outcome The First Natural Frequency is observed as 163.22 Hz whereas the Third Natural Frequency is observed as 350.80 Hz. Natural frequencies of original model and natural frequencies of simplified model are in good agreement with each other.

V CONCLUSION

In the present work, the modal analysis and transient structural analysis were performed. The 3D model of clutch assembly was created in Pro-e software. Finite element analysis was performed in ANSYS software. 3D model was built to obtain the optimal design parameters of the clutch.

The modal analysis of simplified clutch was performed to determine natural frequencies. The results show that natural frequencies of original model and natural frequencies of simplified model are in good agreement with each other.

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