DESIGN AND ANALYSIS OF FRICTION CLUTCH PLATE USING DIFFERENT MATERIALS

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ABSTRACT
The clutch is one of the main components in automobiles. The engine power transmitted to the system through the clutch. The failure of such a critical component during service can stall the whole application. The driven main plate failed normally during its operation due to cyclic loading. In design of the friction clutches of automobiles, knowledge on the thermo-elasticity a priori is very informative in the initial design stage. Especially, the precise prediction technique of maximum structural stress should be requested in design of mechanical clutches for their durability and compactness.

This project explains the Static structural analysis and Modal analysis of the clutch plate by changing circle diameter and applying two types of materials. This project finds the stresses, deformations and frequencies in failure region during operation. It also suggests design modifications to improve the life time of the clutch plate.

INTRODUCTION

A clutch is a mechanical device that engages and disengages the power, transmission, especially from driving shaft to driven shaft. Clutches are used whenever the transmission of power or motion must be controlled either in amount or over time (e.g., electric screwdrivers limit how much torque is transmitted through use of a clutch; clutches control whether automobiles transmit engine power to the wheels).

In the simplest application, clutches connect and disconnect two rotating shafts (drive shafts or line shafts). In these devices, one shaft is typically attached to an engine or other power unit (the driving member) while the other shaft (the driven member) provides output power for work. While typically the motions involved are rotary, linear clutches are also possible.

In a torque-controlled drill, for instance, one shaft is driven by a motor and the other drives a drill chuck. The clutch connects the two shafts so they may be locked together and spin at the same speed (engaged), locked together but spinning at different speeds (slipping), or unlocked and spinning at different speeds (disengaged).

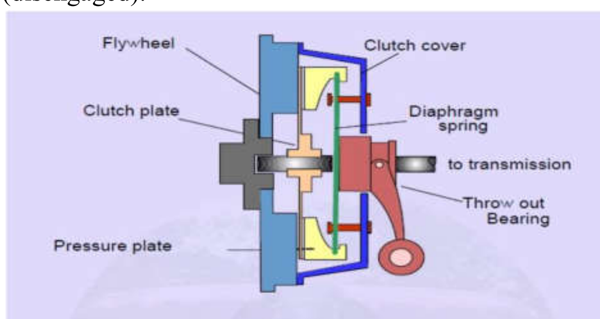

Fig.1: Clutch plate with mountings

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.

LITERATURE REVIEW

G. K. Gangwar, Madhulika tiwari, has research in "Modeling and Simulation in hydraulic Energy Saving System: An Overview" stated that by using the flywheel technology or hydraulic accumulator the

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effective conservative energy can produce in the hybrid vehicle.

Shrikant V. Bhoyar, G.D. Mehta, J.P. Modak, have make designed for the load lifting application Conference, 14th July 2013, Tirupati, India, ISBN: 978-81-927147-9-0 In this study, a simple transmission system consisting gearbox, clutch and engine are specially designed for lifting of load application. Stiffness and equivalent stiffness of all the three shafts have been calculated. Equivalent mass moment of inertia is also calculated. From by using this data, given by Prof. DOW, have calculated the engagement duration period for the selected transmission power system and the dissipation of energy has been plotted during the engagement. The excitation effect of torque and damping coefficient on the amplitude of vibration is plotted for various values of excitation speeds. Results shows increment in damping coefficient and the amplitude of vibration decreases with the decrease in the excitation of torque and the vibration amplitude also be decreases.

Karanjkar A. S., Barve P. C., Adhav R. B., Pandey M. D., Prof. Londhe B.C. Prof. Bhane A.B., "Modeling and Simulation of Multi-Drive Clutch (ISSN 2347-6435(Online) Volume 4, Issue 4, April 2015) they have stated in this paper the design of clutch by combining the operation of the centrifugal action in the single plate clutch system of the transmission mechanism to overcome the wearing effect when there is the transmission of power from one shaft to that of the other shaft that is from driving shaft to the driven shaft.

P. Naga Karna, Tippa Bhimasankara Rao," Analysis of Friction Clutch plate using FEA", e-ISSN: 2278-067X, p-ISSN: 2278-800X, Volume 6, Issue 2 (March 2013), PP. 81-87 they have compared the two materials like aluminum and the steel of wet clutch plates by taking the observations of the stress distribution and the temperature distribution of the clutch plate by taking the dimensions of the plate in existence and also take models in the pro-e and the analysis have been taken by using the ansys.

Static And Dynamic Analysis of Clutch Plate with Crack by N.V. Narasimharao has Done Research Work On Investigate How A Crack Propagates And Grows In A Clutch. A Clutch Plate Is Analyzed For Crack Propagation For Different Materials Aluminum Alloy 6061, Aluminum Alloy 7475, Composite Materials S2 Glass And Kevlar. Theoretical Calculations Are Done To Determine Stress Intensity Factor, Crack Extension Force, Crack Opening Displacement. . From Dynamics And Fracture Mechanics, It Is Well Known That Accelerated Crack Nucleation And Micro-Crack Formation In Components Can Occur Due To Various Reasons, Such As Transient Load Swings, Higher Than Expected Intermittent Loads, Or Defective Component Materials. Normal Wear Causes Configuration Changes That Contribute To Dynamic Loading Conditions That Can Cause Micro Crack Formation At Material Grain Boundaries In Stress Concentrated Regions (Acute Changes In Material Geometry). So, Finally They Conclude That If The Crack Propagates In The Composite Materials, They Tend To Fail Faster Than Aluminum Alloys Thereby Reducing Their Life. So Care Should Be Taken For Composite Materials Not To Get The Crack.

TYPES OF CLUTCHES

Following are the two main types of clutches commonly used in engineering practice:

- Positive clutches
- Friction clutches

Positive clutches

The positive clutches are used when a positive drive is required. The simplest type of a positive clutch is a jaw or claw clutch. The jaw clutch permits one shaft to drive another through a direct contact of interlocking jaws. It consists of two halves, one of which is permanently fastened to the driving shaft by a sunk key. The other half of the clutch is movable and it is free to slide axially on the driven shaft, but it is prevented from turning relatively to its shaft by means of feather key.

A square jaw type is used where engagement and disengagement in motion and under load is not necessary. This type of clutch will transmit power in either direction of rotation. The spiral jaws may be left-hand or right-hand, because power transmitted by them is in one direction only. This type of clutch is occasionally used where the clutch must be engaged and disengaged while in motion. The use of jaw clutches are frequently applied to sprocket wheels, gears and pulleys. In such a case, the non-sliding part is made integral with the hub.

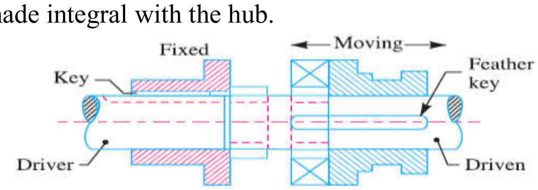

Fig.2: Square jaw clutch

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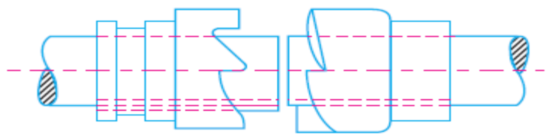

Fig.3: Spiral jaw clutch

Friction clutches

A friction clutch has its principal application in the transmission of power of shafts and machines which must be started and stopped frequently. Its application is also found in cases in which power is to be delivered to machines partially or fully loaded. The force of friction is used to start the driven shaft from rest and gradually brings it up to the proper speed without excessive slipping of the friction surfaces. In automobiles, friction clutch is used to connect the engine to the drive shaft. In operating such a clutch, care should be taken so that the friction surfaces engage easily and gradually bring the driven shaft up to proper speed. The proper alignment of the bearing must be maintained and it should be located as close to the clutch as possible. It may be noted that:

1. The contact surfaces should develop a frictional force that may pick up and hold the load with reasonably low pressure between the contact surfaces.
2. The heat of friction should be rapidly *dissipated and tendency to grab should be at a minimum.
3. The surfaces should be backed by a material stiff enough to ensure a reasonably uniform distribution of pressure.

TYPES OF CLUTCH FAILURES

1. Burnt hub, Pulley, and/or Coil.
2. Bearing failure.
3. Noisy Bearing.
4. Un-burnished clutch.
5. Improper rotor to hub air gap.
6. Misaligned belt or use of wrong clutch.
7. Open circuit inside field coil.
8. Failed field coil mounting flange welds.
9. Faulty lead wire.

TYPES OF FRICTION CLUTCHES

Though there are many types of friction clutches, yet the following are important from the subject point of view:

- Disc or plate clutches (single disc or multiple disc clutch),
- Cone clutches, and
- Centrifugal clutches

SOLIDWORKS

Solid Works is mechanical design automation software that takes advantage of the familiar Microsoft Windows graphical user interface.

It is an easy-to-learn tool which makes it possible for mechanical designers to quickly sketch ideas, experiment with features and dimensions, and produce models and detailed drawings.

A Solid Works model consists of parts, assemblies, and drawings.

- Typically, we start with a sketch, make a base element, and after that add more highlights to the model. (One can likewise start with an insert surface or strong geometry).
- We are allowed to refine our plan by including, changing, or reordering highlights.
- Associativity between parts, assemblies, and drawings that progressions made to one view are consequently made to every other view.
- We can create illustrations or congregations whenever in the design procedure.

Several ways a part can be builded like

Layer-cake approach: The layer-cake approach constructs the section one piece at a time, including each layer, or feature, onto the past one.

Potter's wheel approach:

The potter's wheel approach manufactures the part as a solitary rotated feature. As a solitary draw speaking to the cross area incorporates all the data and measurements important to influence the part as one to include.

Manufacturing approach:

In an assembly, the simple to draw relations is mates. Similarly as outline relations characterize conditions, for example, tangency, parallelism, and concentricity as for portray geometry, get together mates characterize identical relations as for the individual parts or segments, permitting the simple development of assemblies. Solid Works likewise incorporates extra propelled mating highlights, for example, designed gear and cam supporter mates, which permit displayed, adapt congregations to precisely recreate the rotational development of a real apparatus prepare.

At long last, sketches can be made either from parts or congregations. Perspectives are naturally produced from the strong model, and notes, measurements and resistances would then be able to be effortlessly added to the illustration as required. The illustration module incorporates most paper sizes and norms.

A Solid Works display comprises of parts, assemblies, and drawings.

(1) Part: Individual segments are attracted the type of part illustrations.

(2) Assembly: The individual parts are collected in this district.

(3) Drawings: This contains definite data of the get together.

MODELLING OF CLUTCH PLATE

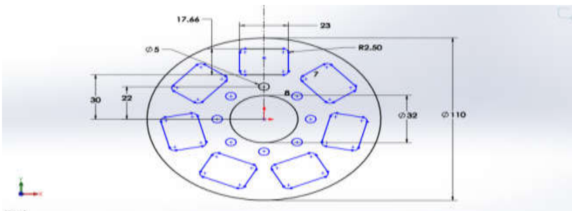

Fig.4: 2-D sketch circular clutch plate.

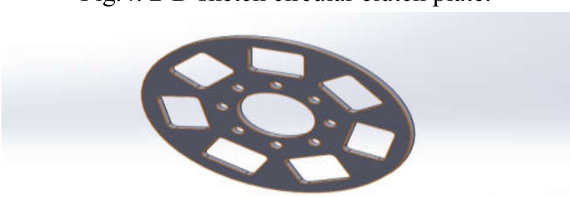

Fig.5: Full view of solid clutch plate of 5mm diameter hole

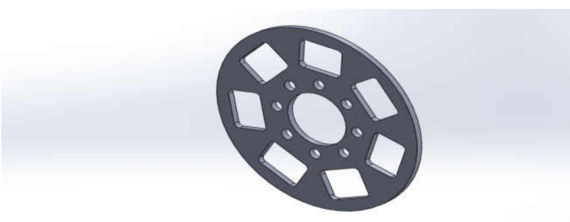

Fig.6: 6mm hole diameter clutch plate

Fig.7: 7mm hole diameter clutch plate

INTRODUCTION TO ANSYS

ANSYS 16.0 conveys creative, emotional reproduction innovation progresses in each, real physics teach, alongside changes in figuring pace and upgrades to empowering advances, for example, geometry taking care of, cross section and post-preparing. These progressions alone speak to a noteworthy advance ahead on the way ahead in Simulation Driven Product Development. Yet, ANSYS has come to considerably facilitate by conveying this innovation in an inventive reenactment structure, ANSYS Workbench 16.0. The ANSYS Workbench condition is the paste that ties the reproduction procedure; this has not changed with version.16.0. In the first ANSYS Workbench, the client cooperated with the investigation in general utilizing. The stage's undertaking page: propelling the different applications and following the subsequent documents utilized during the time spent making an examination. Tight joining between the segment applications yielded remarkable usability for setup and arrangement of even complex multi material science reproductions.

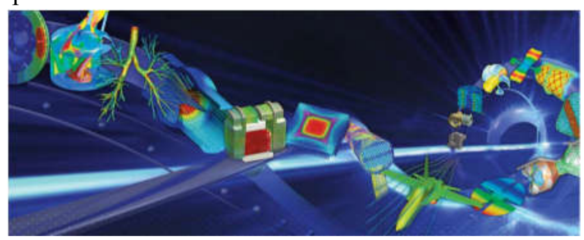

Fig.8: Ansys simulation

Analysis Types:

The different type of analysis that can be performed in ANSYS

1. Structural static analysis.
2. Structural dynamic analysis.
3. Structural buckling analysis
   - Linear buckling
   - Non linear buckling
4. Structural non linearity
5. Static and dynamic kinematics analysis
6. Thermal analysis
7. Electromagnetic field analysis
8. Electric field analysis
9. Fluid flow analysis
   - Computational fluid dynamics
   - Pipe flow
10. Coupled-field analysis

Advantages of ANSYS:

1. The ANSYS program is an adaptable and practical device which helps in the diminishment of modify on model.

2. ANSYS program is a graphical UI that encourages the clients with simple and instinctive way to program orders, documentation and capacities.

3. Keeping in mind the end goal to diminish the creation costs, ANSYS empowers to improve the plan in the advancement procedure itself.

4. ANSYS program helps in outlining the PC models and concentrate the physical reactions, for example, feelings of anxiety, temperature appropriation.

ANALYSIS OF CLUTCH PLATE

Material properties:

Material	Density (Kg/mm^3)	Poison ratio	Young's modulus (Pa)
Structural steel	7850	0.3	2E+11
Stainless steel	7750	0.31	1.93E+11

Table.1: Material properties

At constant pressure:

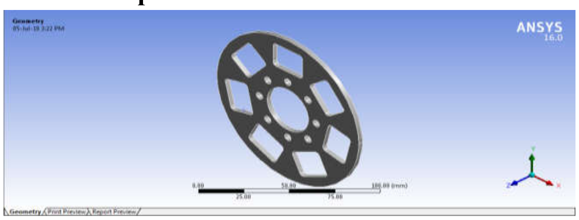

Fig.9: Model of 5mm clutch plate at constant pressure

Element size: 1mm

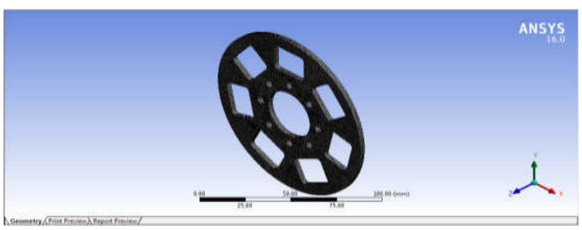

Fig.10: Mesh view of 5mm clutch plate at constant pressure

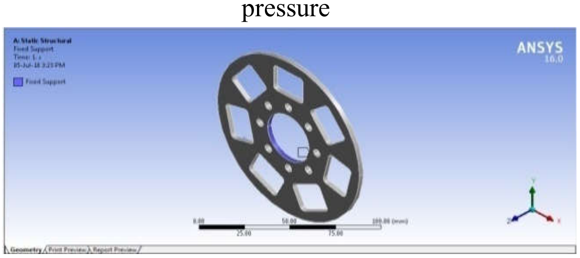

Fig.11: Fixed support to the 5mm clutch plate at constant pressure

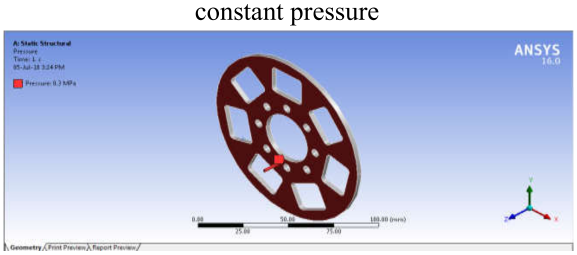

Fig.12: Pressure 0.3 MPa application view of 5mm clutch plate at constant pressure

FOR 5mm DIAMETER HOLE

Material: Structural steel

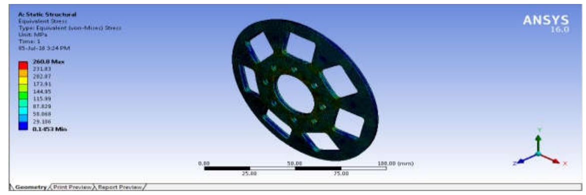

Fig.13: Maximum stress view of 5mm clutch plate for Structural steel material at constant pressure

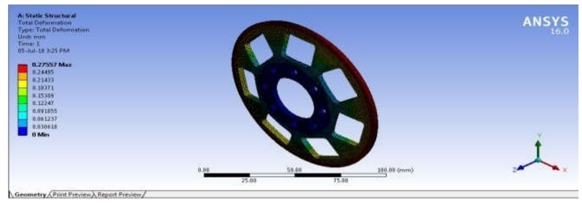

Fig.14: Total deformation view of 5mm clutch plate for Structural steel material at constant pressure

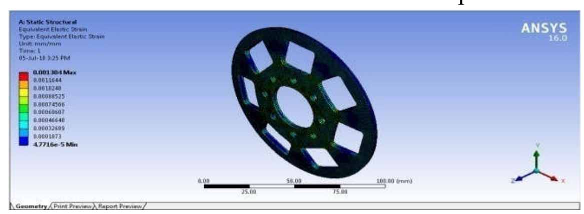

Fig.15: Maximum stress view of 5mm clutch plate for Structural steel material at constant pressure

Material: Stainless steel

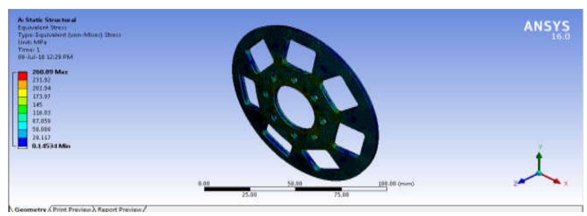

Fig.16: Maximum stress view of 5mm clutch plate for Stainless steel material at constant pressure

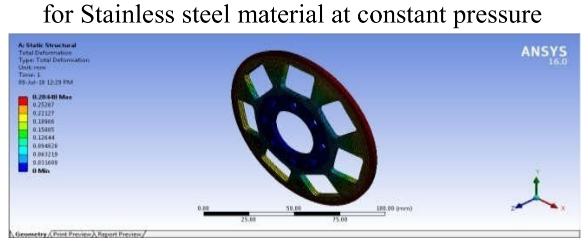

Fig.17: Total deformation view of 5mm clutch plate for Stainless steel material at constant pressure

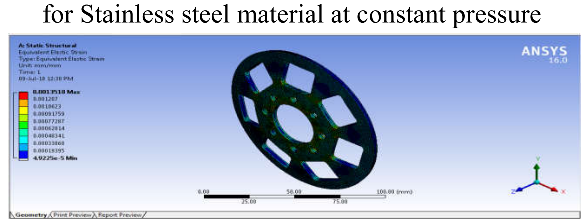

Fig.18: Maximum strain view of 5mm clutch plate for Stainless steel material at constant pressure

Modal analysis:

Material: Structural steel

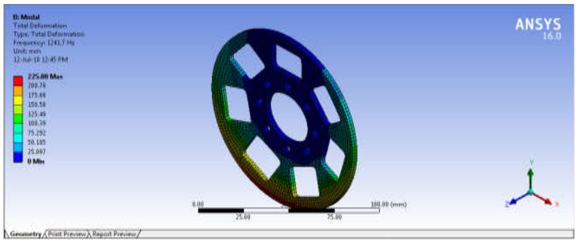

Fig.19: Mode shape 1 of 5mm clutch plate for Structural steel material at constant pressure

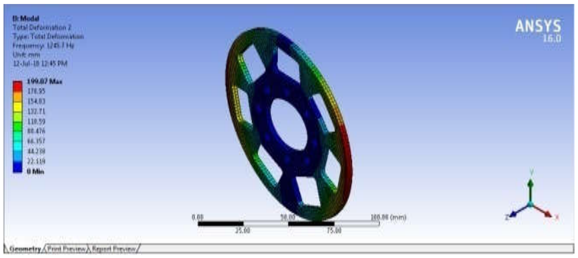

Fig.20: Mode shape 2 of 5mm clutch plate for Structural steel material at constant pressure

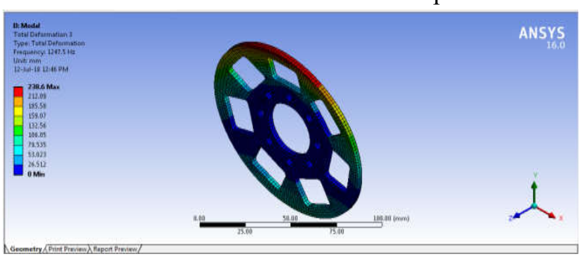

Fig.21: Mode shape 3 of 5mm clutch plate for Structural steel material at constant pressure

Material: Stainless steel

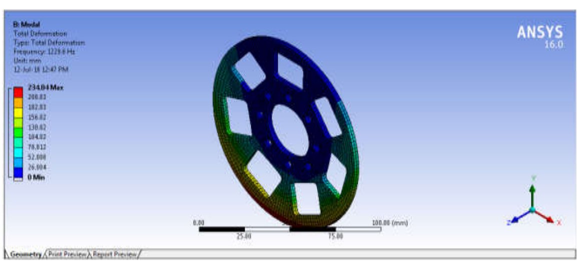

Fig.22: Mode shape 1 of 5mm clutch plate for Stainless steel material at constant pressure

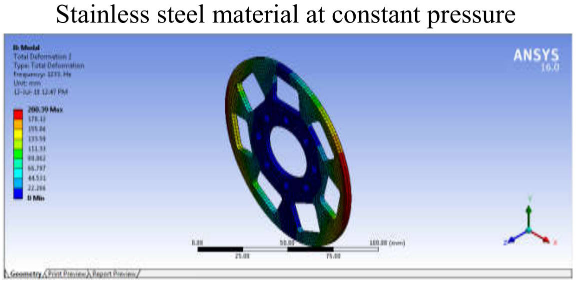

Fig.23: Mode shape 2 of 5mm clutch plate for Stainless steel material at constant pressure

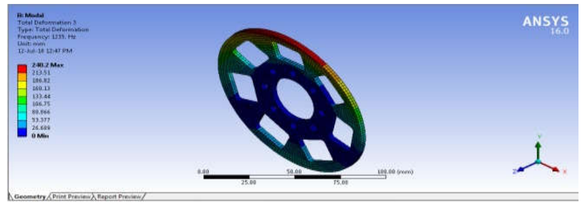

Fig.24: Mode shape 3 of 5mm clutch plate for Stainless steel material at constant pressure

FOR 6mm DIAMETER HOLE

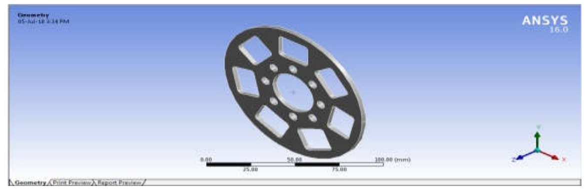

Fig.25: Model view of 6mm diameter hole clutch plate at constant pressure

Element size: 1mm

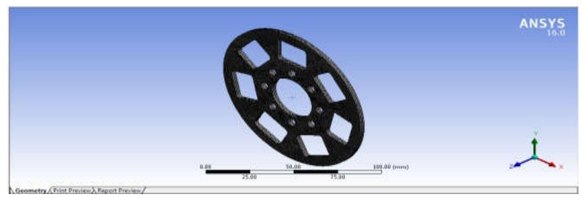

Fig.26: Mesh view of 6mm diameter hole clutch plate at constant pressure

Material: Structural steel

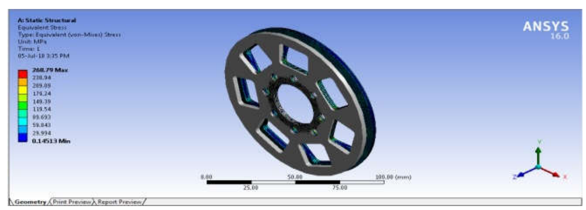

Fig.27: Maximum stress view of 6mm clutch plate for Structural steel material at constant

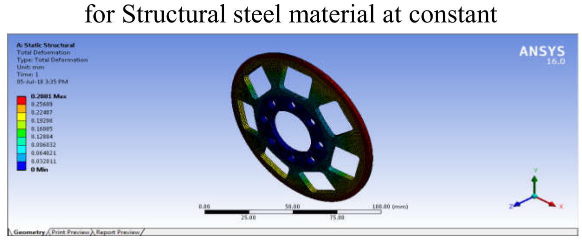

Fig.28: Total deformation view of 6mm clutch plate for Structural steel material at constant pressure

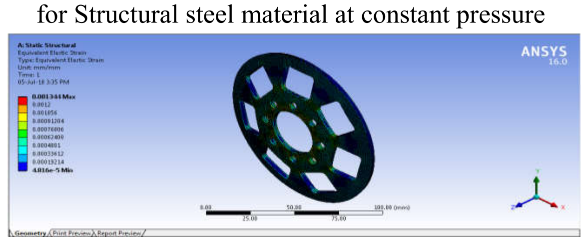

Fig.29: Maximum strain view of 6mm clutch plate for Structural steel material at constant pressure

Material: Stainless steel

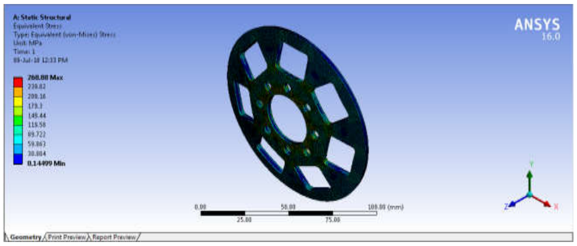

Fig.30: Maximum stress view of 6mm clutch plate for Stainless steel material at constant pressure

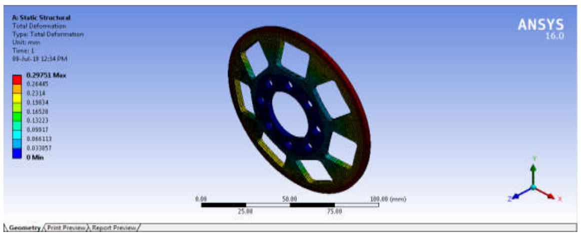

Fig.31: Total deformation view of 6mm clutch plate for Stainless steel material at constant pressure

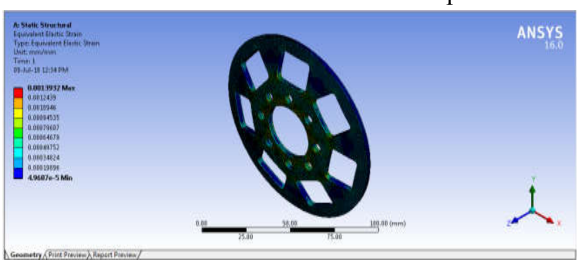

Fig.32: Maximum stain view of 6mm clutch plate for Stainless steel at constant pressure

Modal analysis:

Material: Structural steel

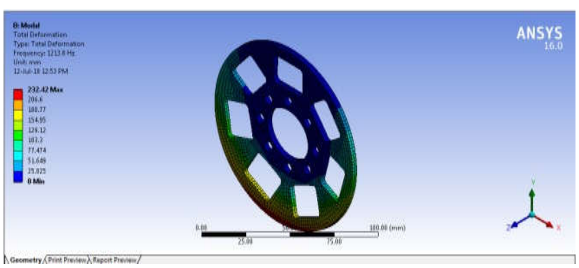

Fig.33: Mode shape 1 of 6mm clutch plate for Structural steel material at constant pressure

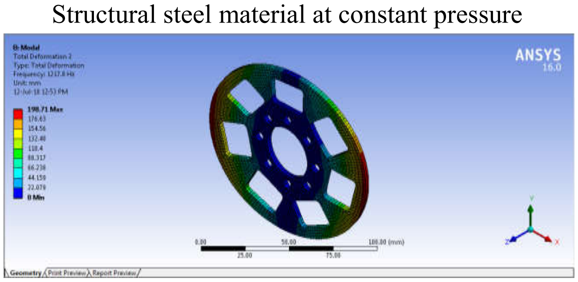

Fig.34: Mode shape 2 of 6mm clutch plate for Structural steel material at constant pressure

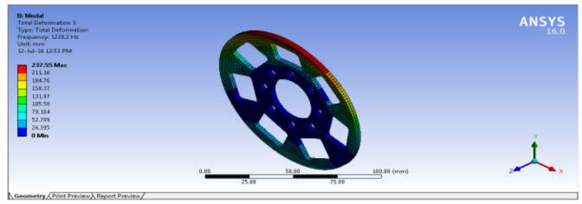

Fig.35 Mode shape 3 of 6mm clutch plate for Structural steel material at constant pressure

Material: Stainless steel

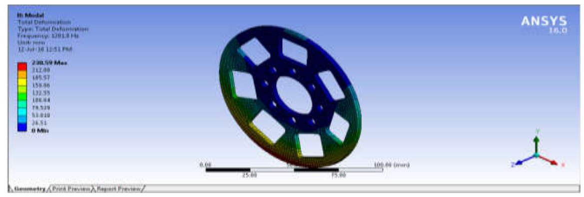

Fig.36: Mode shape 1 of 6mm clutch plate for Stainless steel material at constant pressure

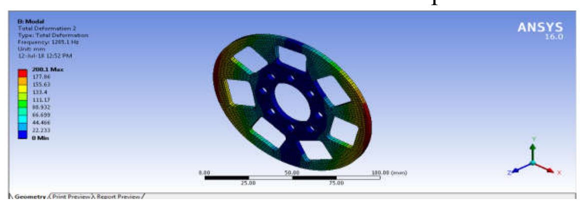

Fig.37: Mode shape 2 of 6mm clutch plate for Stainless steel material at constant pressure

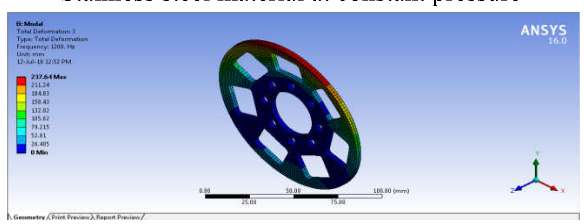

Fig.38: Mode shape 3 of 6mm clutch plate for Stainless steel material at constant pressure

FOR 7mm DIAMETER HOLE

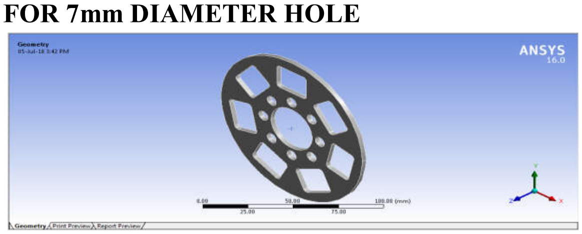

Fig.39: Model view of 7mm diameter hole clutch plate at constant pressure

Element size: 1mm

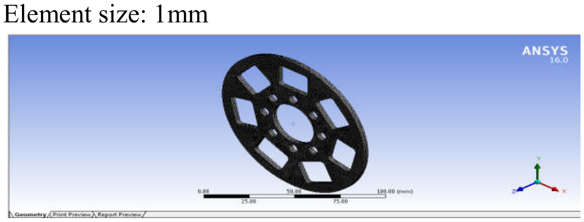

Fig.40: Mesh view of 7mm diameter hole clutch plate at constant pressure

Material: Structural steel

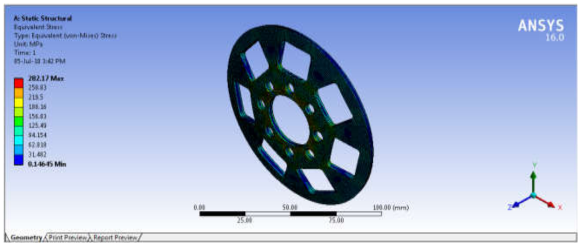

Fig.41: Maximum stress view of 7mm clutch plate for Structural steel material at constant pressure

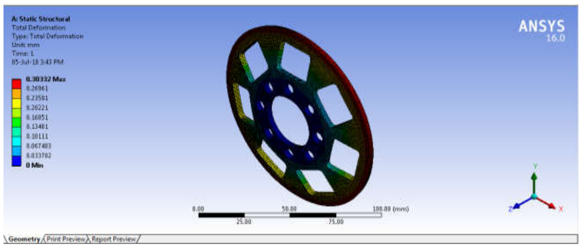

Fig.42: Total deformation view of 7mm clutch plate for Structural steel material at constant pressure

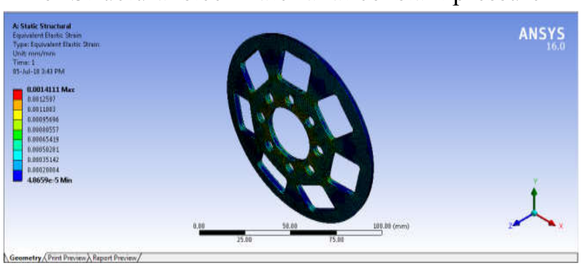

Fig.43: Maximum strain view of 7mm clutch plate for Structural steel material at constant pressure

Material: Stainless steel

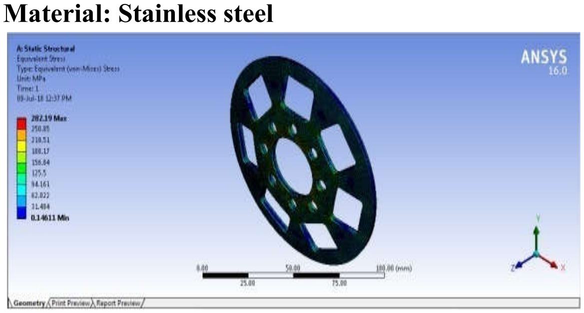

Fig.44: Maximum stress view of 7mm clutch plate for Stainless steel material at constant pressure

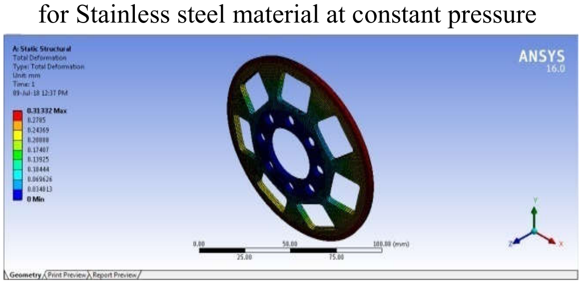

Fig.45: Total deformation view of 7mm clutch plate for Stainless steel material at constant pressure

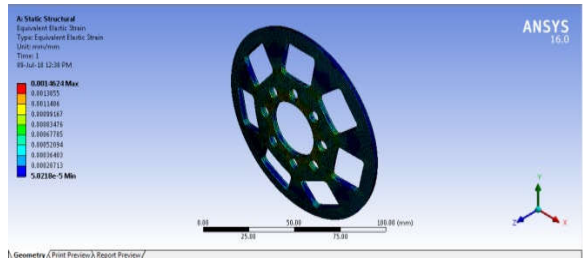

Fig.46: Maximum strain view of 7mm clutch plate for Stainless steel material at constant pressure

Modal analysis:

Material: Structural steel

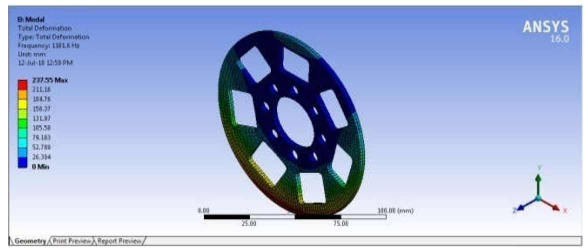

Fig.47: Mode shape 1 of 7mm clutch plate for Structural steel material at constant pressure

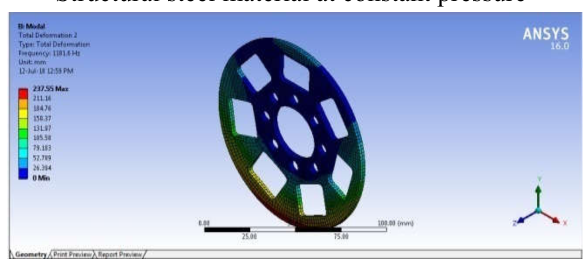

Fig.48: Mode shape 2 of 7mm clutch plate for Structural steel material at constant pressure

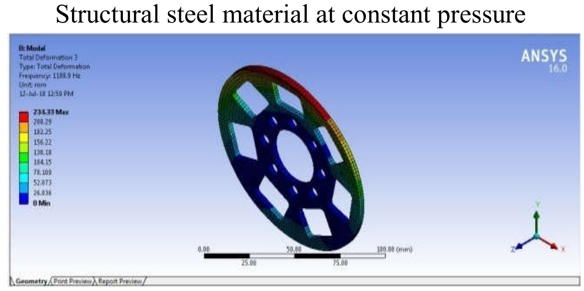

Fig.49: Mode shape 3 of 7mm clutch plate for Structural steel material at constant pressure

Material: Stainless steel

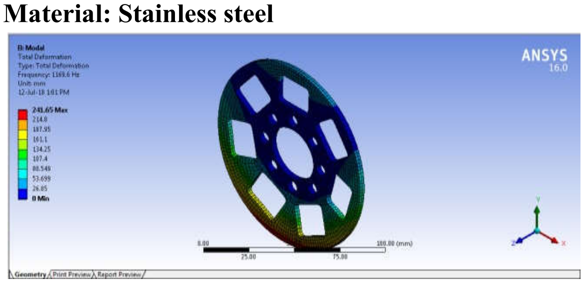

Fig.50: Mode shape 1 of 7mm clutch plate for Stainless steel material at constant pressure

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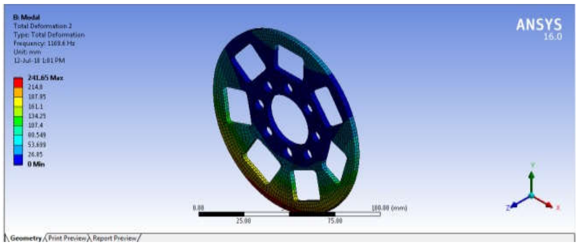

Fig.51: Mode shape 2 of 7mm clutch plate for Stainless steel material at constant pressure

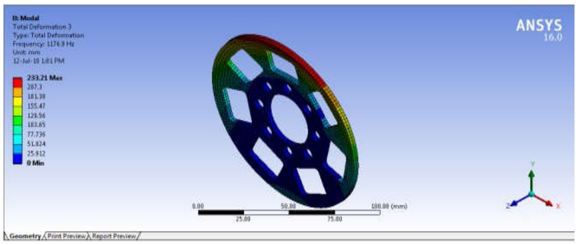

Fig.52: Mode shape 3 of 7mm clutch plate for Stainless steel material at constant pressure

THEORITICAL CALCULATIONS

For 5mm hole diameter

Area, A = $[\pi(r_1^2 - r_2^2)] - (7xLxB) - 8[\pi\ r_3^2]$

$= [\pi(55^2\text{-}16^2)] - (7x23x17.66) - 8[\pi(5/2)^2]$

$= 6075.06\ mm^2$

Torque, T = F_r x r

$= \mu.p \times A \times (r_1+r_2)/2$

For structural steel, $\mu = 0.45$

T = 0.45 x 0.3 x 6075.06 x (55+16)/2

= 29.11472505 KN-mm

For stainless steel, $\mu = 0.5$

T = 0.5 x 0.3 x 6075.06 x (55+16)/2

= 32.3496945 KN-mm

For 6mm hole diameter

Area, A = $[\pi(r_1^2 - r_2^2)] - (7xLxB) - 8[\pi\ r_3^2]$

$= [\pi(55^2\text{-}16^2)] - (7x23x17.66) - 8[\pi(6/2)^2]$

$= 6002.9\ mm^2$

Torque, T = F_r x r

$= \mu.p \times A \times (r^1+r^2)/2$

For structural steel, $\mu = 0.45$

T = 0.45 x 0.3 x 6002.9 x (55+16)/2

= 28.76889825 KN-mm

For stainless steel, $\mu = 0.5$

T = 0.5 x 0.3 x 6018.311429x (55+16)/2

= 32.0475083 KN-mm

For 7mm hole diameter

Area, A = $[\pi(r_1^2 - r_2^2)] - (7xLxB) - 8[\pi\ r_3^2]$

$= [\pi(55^2\text{-}16^2)] - (7x23x17.66) -8[\pi(7/2)^2]$

$= 5917.62\ mm^2$

Torque, T = F_r x r

$= \mu.p \times A \times (r^1+r^2)/2$

For structural steel, $\mu = 0.45$

T = 0.45 x 0.3 x 5917.62 x (55+16)/2

= 28.3601938 KN-mm

For stainless steel, $\mu = 0.5$

T = 0.5 x 0.3 x 5917.62 x (55+16)/2

= 31.5113265 KN-mm

ANALYSIS USING TORQUE

For 5mm hole diameter

Material: Structural steel

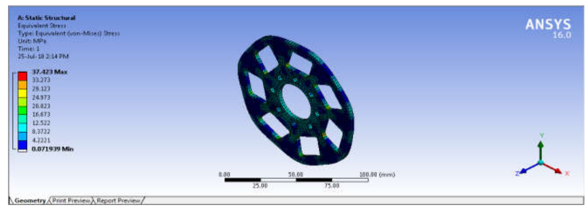

Fig.53: Maximum stress view of 5mm clutch plate for Structural steel material at applied torque

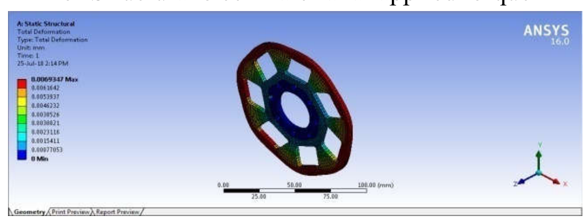

Fig.54: Total deformation of view of 5mm clutch plate for Structural steel material at applied torque

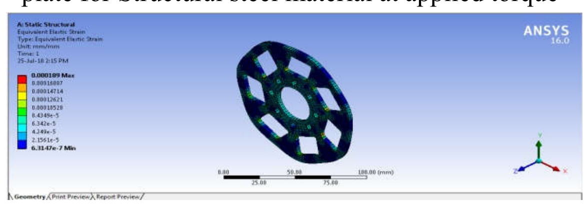

Fig.55: Maximum strain view of 5mm clutch plate for Structural steel material at applied torque

Material: Stainless steel

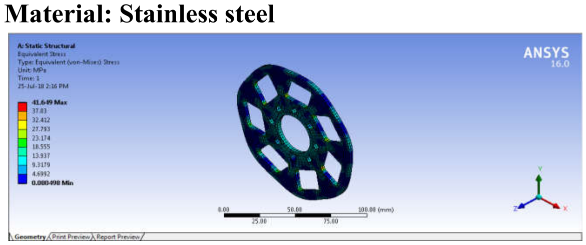

Fig.56: Maximum stress view of 5mm clutch plate for Stainless steel material at applied torque

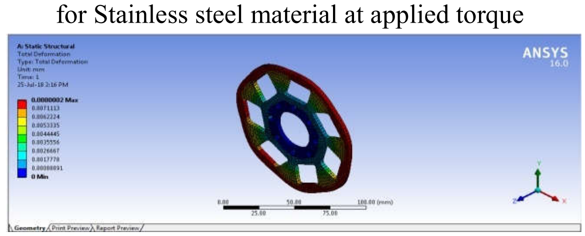

Fig.57: Total deformation view of 5mm clutch plate for Structural steel material at applied torque

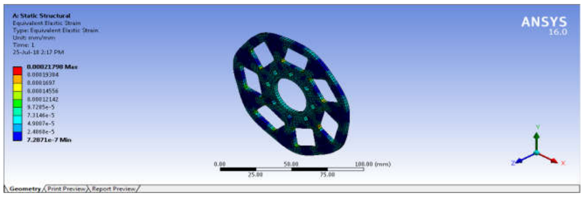
Fig.58: Maximum strain view of 5mm clutch plate for Structural steel material at applied torque

For 6mm hole diameter

Material: Structural steel

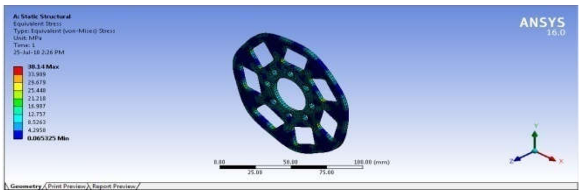
Fig.59: Maximum stress view of 6mm clutch plate for Structural steel material at applied torque

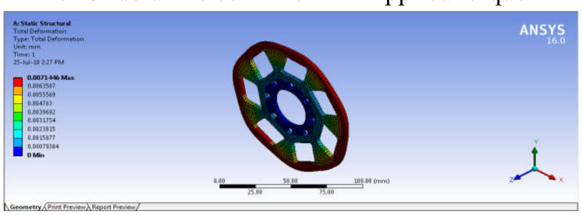
Fig.60: Total deformation view of 6mm clutch plate for Structural steel material at applied torque

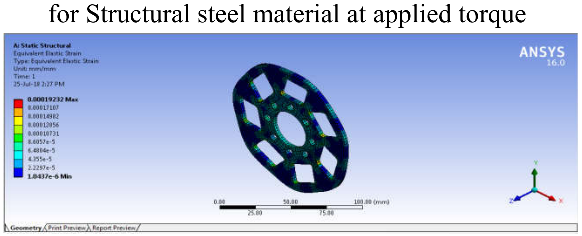
Fig.61: Maximum strain view of 6mm clutch plate for Structural steel material at applied torque

Material: Stainless steel

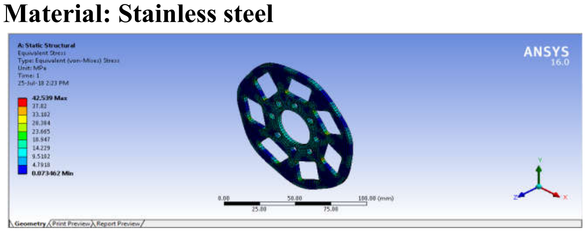
Fig.62: Maximum stress view of 6mm clutch plate for Stainless steel material at applied torque

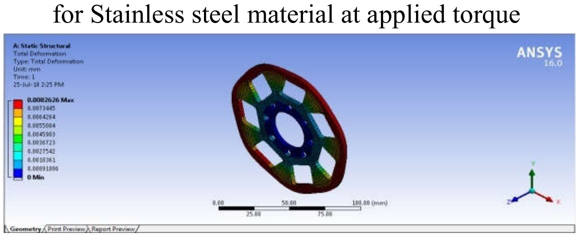
Fig.63: Total deformation view of 6mm clutch plate for Stainless steel material at applied torque

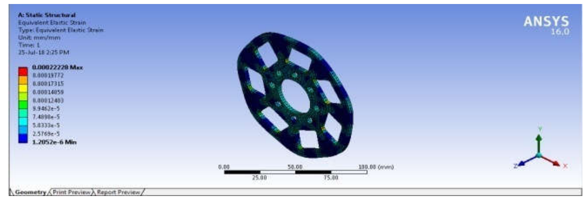
Fig.64: Maximum strain view of 6mm clutch plate for Stainless steel material at applied torque

For 7mm hole diameter

Material: Structural steel

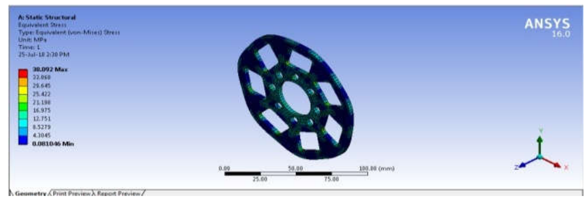
Fig.65: Maximum stress view of 7mm clutch plate for Structural steel material at applied torque

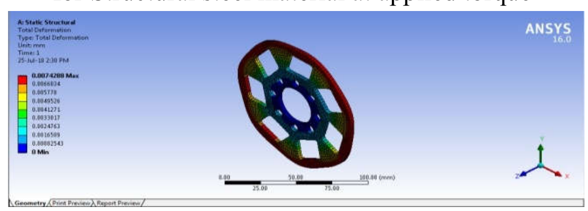
Fig.66: Total deformation view of 7mm clutch plate for Structural steel material at applied torque


Fig.67: Maximum strain view of 7mm clutch plate for Structural steel material at applied torque

Material: Stainless steel


Fig.68: Maximum stress view of 7mm clutch plate for Stainless steel material at applied torque

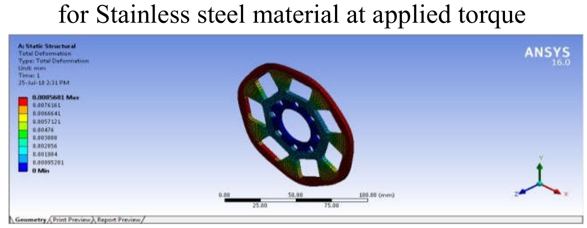
Fig.69: Total deformation view of 7mm clutch plate for Structural steel material at applied torque

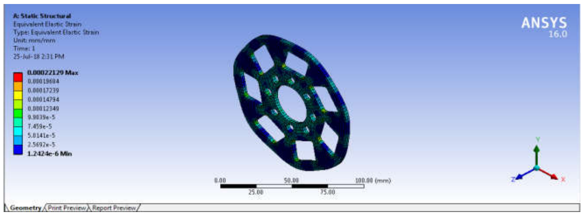

Fig.70: Maximum strain view of 7mm clutch plate for Structural steel material at applied torque

RESULTS

USING CONSTANT PRESSURE:

FOR 5mm DIAMETER HOLE

Materials	Maximum stress (MPa)	Total deforma-tion (mm)	Maximum strain
Structural steel	260.8	0.27557	0.001304
Stainless steel	260.89	0.28448	0.0013518

Table.2: Static analysis results of 5mm diameter hole clutch plate at constant pressure

GRAPH:

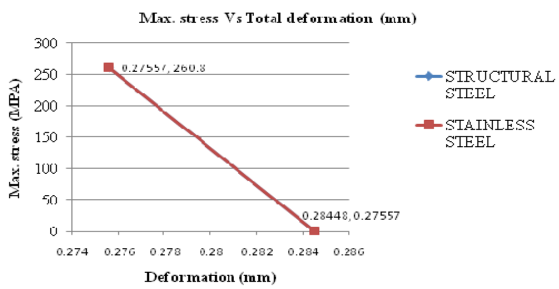

Fig.71: Graph of Max. stress Vs Total deformation for 5mm hole diameter

MODAL ANALYSIS

Materials		Structural steel	Stainless steel
Mode 1	**Frequency (Hz)**	1241.7	1229.6
	Total deformation (mm)	225.88	234.04
Mode 2	**Frequency (Hz)**	1245.7	1233.0
	Total deformation (mm)	199.07	200.39
Mode 3	**Frequency (Hz)**	1247.5	1235
	Total deformation (mm)	238.6	240.2

Table.3: Modal analysis results of 5mm diameter hole clutch plate at constant pressure

GRAPH

Deformation 1

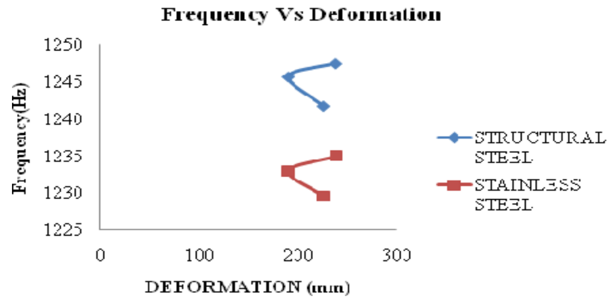

Fig.72: Graph of Modal analysis (Frequency Vs Deformation) at three different modes for 5mm hole diameter

Deformation 2

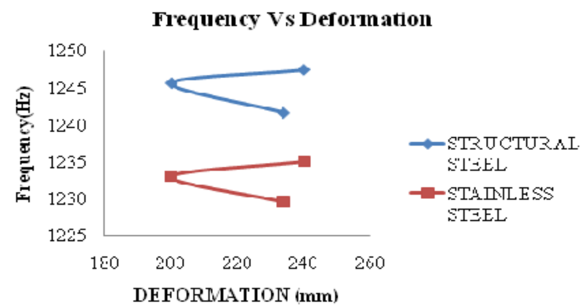

Fig.73: Graph of Modal analysis (Frequency Vs Deformation) at three different modes for 5mm hole diameter

FOR 6mm DIAMETER HOLE

Materials	Maximum stress (MPa)	Total deformation (mm)	Maximum strain
Structural steel	268.79	0.2881	0.001344
Stainless steel	268.88	0.29751	0.0013932

Table.4: Static analysis results of 6mm diameter hole clutch plate at constant pressure

GRAPH

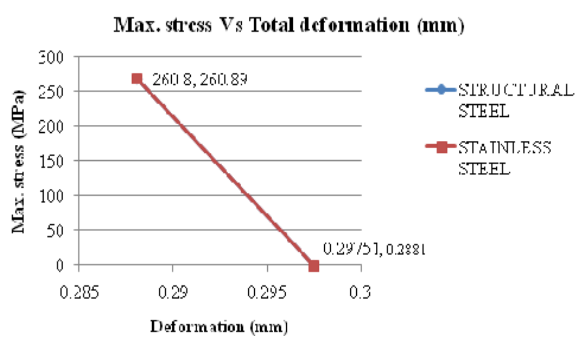

Fig.74: Graph of Max. stress Vs Total deformation for 6mm hole diameter

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Modal analysis

Materials		Structural steel	Stainless steel
Mode 1	Frequency (Hz)	1213.8	1201.8
	Total deformation (mm)	232.42	238.59
Mode 2	Frequency (Hz)	1217.8	1205.1
	Total deformation (mm)	198.71	200.1
Mode 3	Frequency (Hz)	1220.2	1208.0
	Total deformation (mm)	237.55	237.64

Table.5: Modal analysis results of 6mm diameter hole clutch plate at constant pressure

GRAPH

Deformation 1

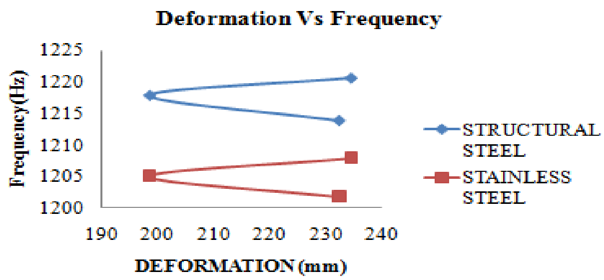

Fig.75: Graph of Modal analysis (Frequency Vs Deformation) at three different modes for 6mm hole diameter

Deformation 2

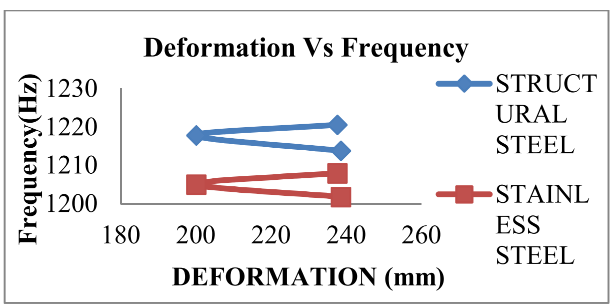

Fig.76: Graph of Modal analysis (Frequency Vs Deformation) at three different modes for 6mm hole diameter

FOR 7mm DIAMETER HOLE

Materials	Maximum stress (MPa)	Total deformation (mm)	Maximum strain
Structural steel	282.17	0.30332	0.0014111
Stainless steel	282.19	1.31332	0.001462

Table.6: Static analysis results of 7mm diameter hole clutch plate at constant pressure

GRAPH:

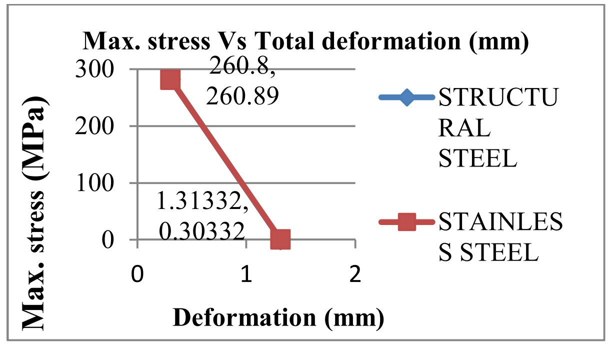

Fig.77: Graph of Max. stress Vs Total deformation for 7mm hole diameter

Modal analysis

Materials		Structural steel	Stainless steel
Mode 1	**Frequency (Hz)**	1181.6	1169.6
	Total deformation (mm)	237.55	241.65
Mode 2	**Frequency (Hz)**	1181.6	1169.6
	Total deformation (mm)	237.55	241.65
Mode 3	**Frequency (Hz)**	1188.9	1176.9
	Total deformation (mm)	234.33	233.21

Table.7: Modal analysis results of 7mm diameter hole clutch plate at constant pressure

GRAPH

Deformation 1

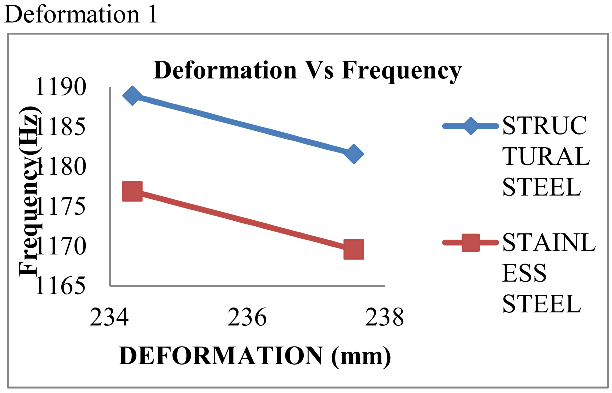

Fig.78: Graph of Modal analysis (Frequency Vs Deformation) at three different modes for 7mm hole diameter

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Deformation 2

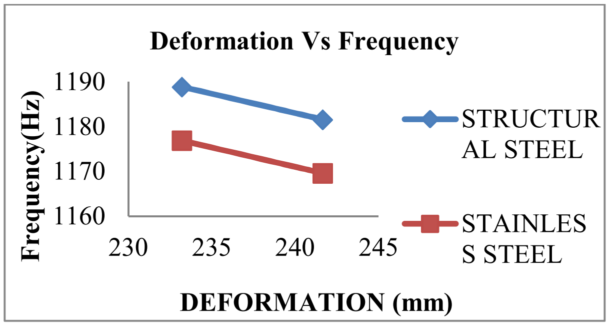

Fig.79: Graph of Modal analysis (Frequency Vs Deformation) at three different modes for 7mm hole diameter

TORQUE CALCULATION RESULTS

Materials	Torque (KN-mm)		
	5mm	6mm	7mm
Structural steel	29.11472505	28.76889825	28.3601938
Stainless steel	32.3496945	32.0475083	31.5113265

Table.8: Theoretical Toque results

GRAPH

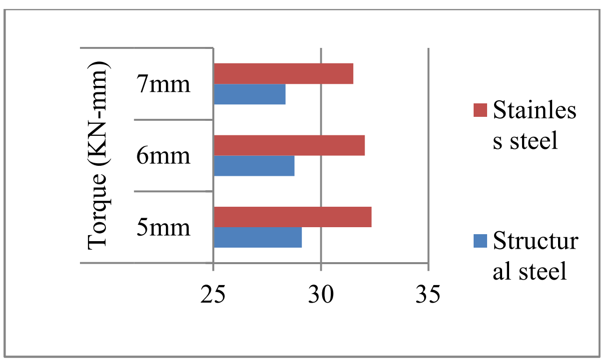

Fig.80: Theoretical torque distribution for two different materials at various configurations

RESULTS FOR TORQUE APPLY

HOLE DIAMETER OF 5mm

Materials	Torque (KN-mm)	Maximum stress (MPa)	Total deformation (mm)	Maximum strain
Structural steel	29.11472505	37.423	0.0069347	0.000189
Stainless steel	32.3496945	41.649	0.0080002	0.00021798

Table.9 Static analysis results of 5mm diameter hole clutch plate at theoretical torque results

GRAPH

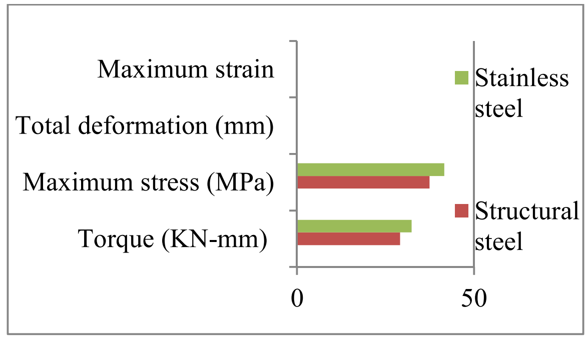

Fig.81: Graph of Static analysis results of 5mm diameter hole clutch plate at theoretical torque results

HOLE DIAMETER OF 6mm

Materials	Torque (KN-mm)	Maximum stress (MPa)	Total deformation (mm)	Maximum strain
Structural steel	28.76889825	38.14	0.0071446	0.00019232
Stainless steel	32.0475083	42.539	0.0082626	0.00022228

Table.10: Static analysis results of 6mm diameter hole clutch plate at theoretical torque results

GRAPH:

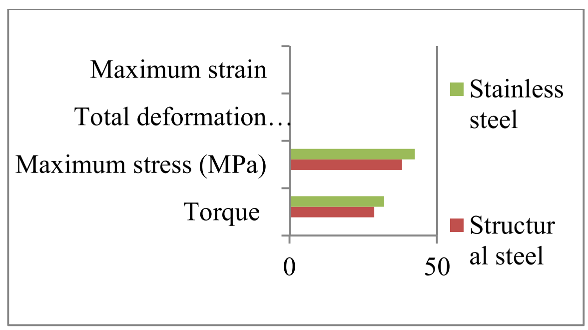

Fig.82: Graph of Static analysis results of 6mm diameter hole clutch plate at theoretical torque results

HOLE DIAMETER OF 7mm

Materi-als	Torque (KN-mm)	Maximum stress (MPa)	Total deforma-tion (mm)	Maximum strain
Structu-ral steel	28.36019385	38.092	0.0074288	0.00019188
Stain-less steel	31.5113265	42.389	0.0085681	0.0002229

Table.11: Static analysis results of 7mm diameter hole clutch plate at theoretical torque results

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GRAPH:

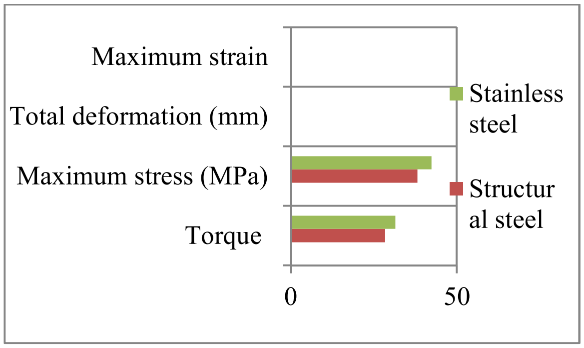

Fig.83: Graph of Static analysis results of 7mm diameter hole clutch plate at theoretical torque results

CONCLUSION

- Design and analysis of friction clutch plate is done
- Modeling of friction clutch plate is done in Solid works 2016 design software
- First 5mm diameter hole friction clutch plate then 6mm and 7 mm diameter hole are modeled.
- The models are saved as IGS files to import in Ansys 16.0
- Structural analysis is carried out in Ansys by applying two different materials such as Structural steel and Stainless steel at 0.3 MPa force is applied on friction plate clutch for three different diameter holes of friction clutch plate.
- The material properties of the above materials are studied
- The Static analysis results are analyzed and tabulated.
- From the results we can conclude that already 5mm diameter hole is existing by we reduced it to 6mm and 7mm by varying the diameter hole from the analysis Stainless steel material for 6mm diameter hole is showing less stress compared to 7mm thickness friction clutch plate.
- Modal analysis is carried out in Ansys by applying two different materials such as Structural steel and Stainless steel by importing Static analysis results.
- In the Modal analysis, the 6mm hole diameter plate shows the optimum frequency of 1201.8 Hz for Stainless steel at mode 1, as compared other plates.
- We calculate Torque using material properties and area of the clutch plate.
- Using Ansys software by applying torque on the plate we get max stress, total deformation and max strain values.
- The stainless steel material of 6mm hole diameter shows the maximum torque of 32.0475083 KN-mm and low deformation of 0.17093 mm as compare to 7mm hole diameter.
- Hence we can conclude that the friction clutch plate containing 6mm diameter hole applied with Structural steel material is showing best results.

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