Design, Development and Testing of Full Face and Staggered Geometry of Friction Lining in Automated Single Plate Clutch

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Abstract— *The clutch is a mechanical device, which is used to connect or disconnect the source of power from the remaining parts of the power transmission system at the will of operator. Disengage clutch, change gear, gradually engage clutch thus three operations are to be performed while moving from one gear to another. Hence in all 15 operations are performed to move to the top gear, it is important to note out of the 15 operations performed to reach the top gear 10 operations are clutch operations. By making clutch operations automatic it will reduce human effort. Automatic clutch control has another advantage, i.e. out of three pedals one of clutch pedal is eliminated. And elimination of clutch pedal will lead to easy driving as the controls become simple. Important part in clutch design is design of the clutch plate and selection of appropriate material for the clutch linings. The conventional liners used in single plate clutch are asbestos base with coefficient of friction close to 0.4 resulting in lower friction force and lower power transmission ability. Hence it is decided to replace the frication material as FTL095 as moulded lining with non-asbestos base to confirm to the present environmental norms. Secondly it is observed that the friction lining applied to the clutch are full faced, but it is a fact that the wear rate increases with the increase in temperature. If the clutch is not provided with proper ventilation and heat dissipation, it will glaze and low transmission.*

Keywords— Clutch Plate, FEA analysis, Full Face Friction Lining, Staggered Geometry

I. INTRODUCTION

The clutch is a mechanical device, which is used to connect or disconnect the source of power from the remaining parts of the power transmission system at the will of operator. The clutch can connect or disconnect the driving shaft and driven shaft. An automotive clutch can permit the engine to run without driving the car. This is desirable when the engine is to be started or stopped, or when the gears to be shifted. Clutch is a mechanism for transmitting rotation, which can be engaged and disengaged. The clutch connects the two shafts so that they can either be locked together and spin at the same speed (engaged), or be decoupled and spin at different speeds (disengaged). Depending on the orientation, speeds, material, torque produced and finally the use of the whole device, different kinds of clutches are used. The clutch in itself is a mechanism, which employs different configurations. The friction clutch is an important component of any automotive machine. It is a link between engine and transmission system which transmit the power, in form of torque, from engine to the gear assembly. When vehicle is started from standstill clutch is engaged to transfer torque to the transmission, and when vehicle is in motion clutch is first disengaged of the drive to allow for gear selection and then again engaged smoothly to power the vehicle. Generally there are two types of clutches based on type of contact,

- Positive clutch
- Friction clutch

Multi plate clutch comes under the category of friction clutch. Multi plate clutch is an extension of single plate type where the number of friction and metal plates is increased. The increase in the number of friction surfaces obviously increases capacity of clutch to transmit torque, without changing size. Alternatively, the overall diameter of clutch is reduced for the same torque transmission as a single plate clutch.

Disengage clutch, change gear, gradually engage clutch thus three operations are to be performed while moving from one gear to another. Hence in all 15 operations are performed to move to the top gear, it is important to note out of the 15 operations performed to reach the top gear 10 operations are clutch operations. By making clutch operations automatic it will reduce human effort. Automatic clutch control has another advantage, i.e. out of three pedals one of clutch pedal is eliminated. And elimination of clutch pedal will lead to easy driving as the controls become simple.

Important part in clutch design is design of the clutch plate and selection of appropriate material for the clutch linings. The conventional liners used in single plate clutch are asbestos base with coefficient of friction close to 0.4 resulting in lower friction force and lower power transmission ability. Hence it is decided to replace the frication material as FTL095 as moulded lining with non-asbestos base to confirm to the present environmental norms.

Secondly it is observed that the friction lining applied to the clutch are full faced, but it is a fact that the wear rate increases with the increase in temperature. If the clutch is not provided with proper ventilation and heat dissipation, it will glaze and low transmission.

II. LITERATURE REVIEW

Oday I. Abdullah [1] have used finite element technique to study the effect of radial and/or circumferential grooves (classic models) on the temperature distribution for dry friction clutch during a single engagement.

Koos van Berkel et.al. [2] have use two gear shafts and two clutches to perform automated gear shifts at a high comfort level.

Ganesh Raut et.al. [3] in this paper they have designed a multi plate clutch by using empirical formulae. A model of multi plate clutch has been generated in CATIA V5 and then imported in ANSYS workbench. They conducted structural analysis by varying the friction surfaces.

Mamta G. Pawar et.al. [4] have used slipping mechanism of the clutch generates heat energy due to friction between the clutch disc and the flywheel. At high sliding velocity, excessive frictional heat is generated which lead to high temperature rise at the clutch disc surface, and this causes thermo-mechanical problems such as thermal deformations and thermo-elastic instability which can lead to thermal cracking, wear and other mode of failure of the clutch disc component.

O.I. Abdullah et. al. [5] in this paper high thermal stresses, generated between the contacting surfaces of the clutch system (pressure plate, clutch disc and flywheel) due to the frictional heating during the slipping, are considered to be one of the main reasons of clutch failure.

V Mani Kiran Tipirineni [6] have used Finite Element Analysis providing a means for non-destructive analysis, which is used to analyze the clutch driven plate.

Nitinchandra R. Patel et.al. [7] in this paper compliant clutch is made from polypropylene material and there is no anyone connecting parts. It has rigid body design since revolute joints are replaced by flexible segment.

III. EXPERIMENTAL SETUP

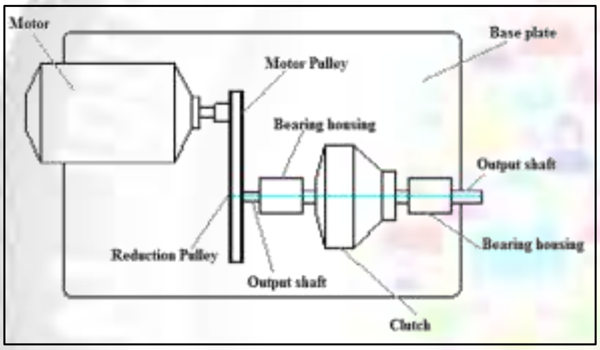

Fig. 1: Test rig of Automatic centrifugal clutch

The scope of project is design and development of the automatic centrifugal clutch and demonstrate the capabilities of clutch as to the automatic functioning as to speed changes from the engine.

In order to demonstrate the functionality of the clutch the test rig set up is developed where in the input shaft or driver shaft of clutch is driven by a variable speed motor of ac/dc type, speed control achieved by means of a continuously variable rheostat. The output shaft shall carry a dynobrake pulley if the brake dynamometer testing is to be carried out in order analyze the torque transmitting capacity of clutch.

IV. DESIGN OF COMPONENTS

A. Selection of Motor

Therefore motor is selected of 50 watt power and its torque is 265.2N mm at 1800 rpm.

B. Design of Belt Drive

In practice, the designer has to select a V- belt from the catalogue of manufacturer. The cross-section of the V-belt is Z.

C. Design of Input Shaft

One important approach of designing a transmission shaft is to use the ASME code. The diameter of shaft is 16mm.

D. Selection of Ball Bearing

Principal dimensions (mm)			Basic load rating (N)	
D	D	B	C	C_o
16	26	5	1680	930

Table 1: Material specification:

E. Design of clutch Plate

Design of clutch is based on uniform Wear theory.
Inner Diameter = d = 46 mm
Outer Diameter = D = 86 mm
Thickness of clutch plate (t) = 9 mm.

F. Design of spring

Wire Diameter mm	Outer Diameter mm	Stiffness Of spring Per turn K_1 N/mm	Permissible load	
			Static Load N	Dynamic Load N
1.0	12.0	7.98	32.4	14.5

Table 2: Material Specification

G. Design of Key

Selecting of parallel key from data book for given application.

Diameter	Above	17
	up to	22
Key cross section	Width	6
	Height	6

Table 3: Material specification

V. FEA ANALYSIS AND THEORETICAL ANALYSIS

A. Analysis of Input Shaft

1) FEA Analysis

a) Creation of Geometry

This can either created in ANSYS or imported.

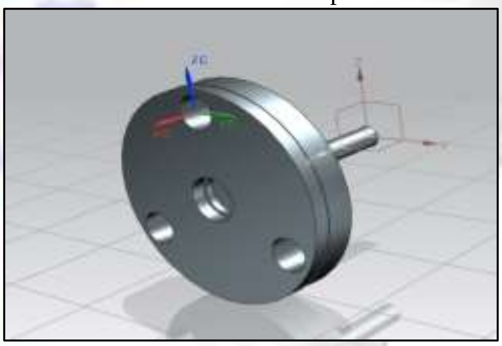

Fig. 2: CAD Model of input shaft

b) Element type

3D solid: Solid 92

c) Material properties:

EX = 210000 N/mm^{2,} PRXY = 0.3

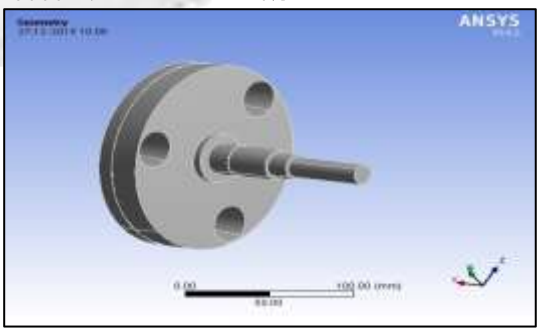

Fig. 3: CAD Model imported in ANSYS of input shaft

d) Meshing

CAD model is converted into FE model by creating nodes and elements.

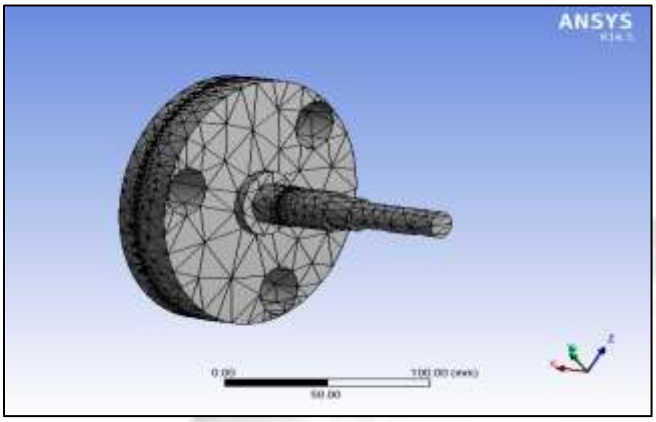

Fig. 4: Meshing of input shaft

2) Define Load

a) Displacement Constraints

This is used to specify where the model is fixed (zero displacement locations).

Solution > Define Loads > Apply > Structural > Displacement.

b) Concentrated Load

Force/ Moment is a point load, applied on a node or key points, specifying the force/moment magnitude and direction.

Solution > Define Loads > Apply > Structural > Force/ Moment.

Torque (M_t) = 252.2 Nmm.

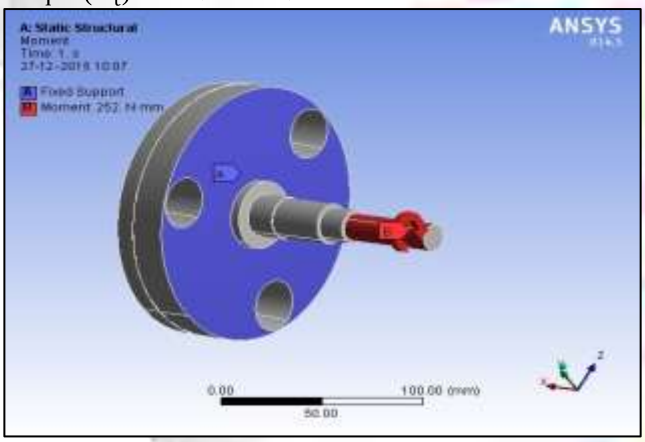

Fig. 5: Applying boundary condition to input shaft

c) Plot results

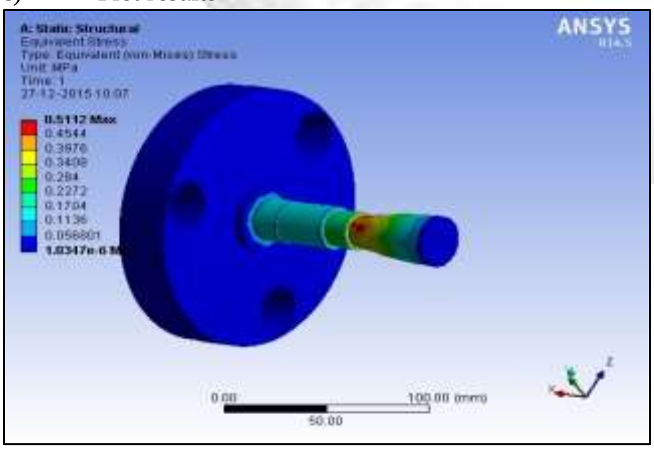

Fig. 6: Equivalent stress Analysis of input shaft

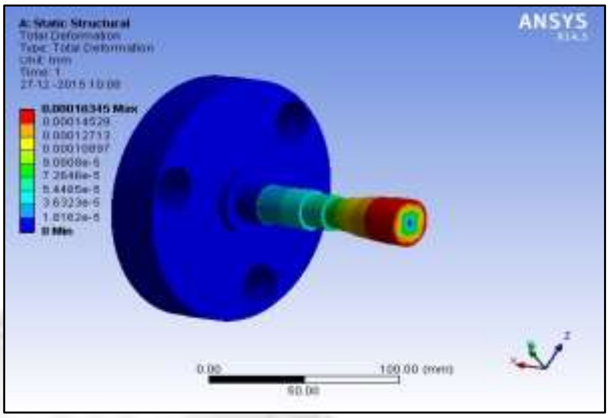

Fig. 7: Total Deformation for input shaft

d) Theoretical Analysis

1) Result & Discussion

Part Name	Maximum theoretical stress N/mm2	Von-mises stress N/mm2	Maximum deformation mm	Result
Input shaft	0.4123	0.5112	0.00016	safe

Table 4: Analysis result table for input shaft

B. Analysis of Clutch Plate

1) FEA Analysis

a) Creation of Geometry

This can either created in ANSYS or imported.

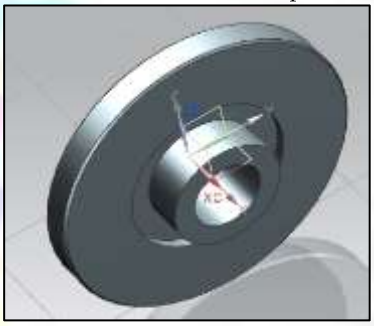

Fig. 8: CAD Model of clutch plate

b) Element type:

3D solid: Solid 92

c) Material properties:

EX = 210000 N/mm^2, PRXY = 0.3

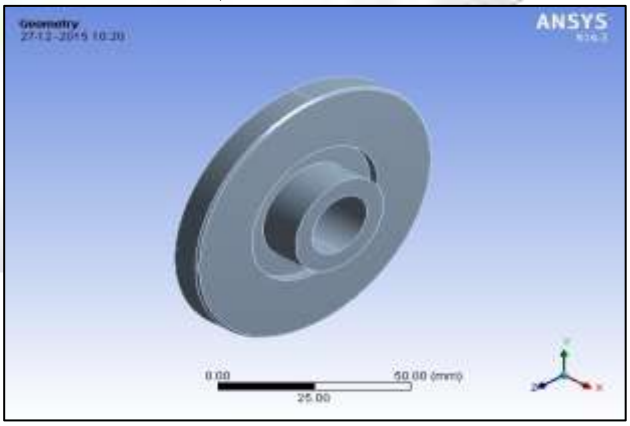

Fig. 9: CAD Model imported in ANSYS of clutch plate

d) Meshing:

CAD model is converted into FE model by creating nodes and elements.

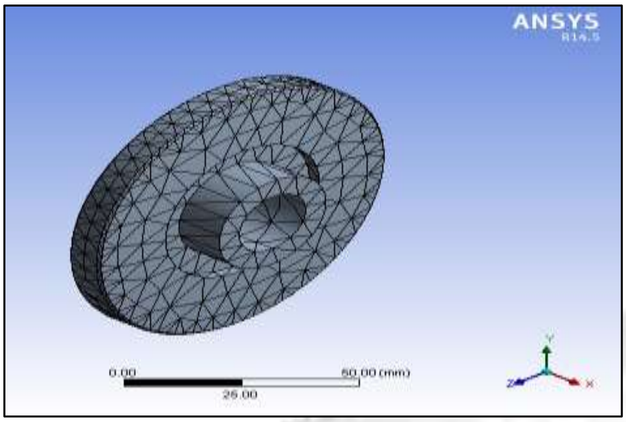

Fig. 10: Meshing of clutch plate

2) Define Load

a) Displacement Constraints

This is used to specify where the model is fixed (zero displacement locations).

Solution > Define Loads > Apply > Structural > Displacement.

b) Concentrated load

Force/ Moment is a point load, applied on a node or key points, specifying the force/moment magnitude and direction.

Solution > Define Loads > Apply > Structural > Force/ Moment.

Torque (M_t) = 252.2N mm.

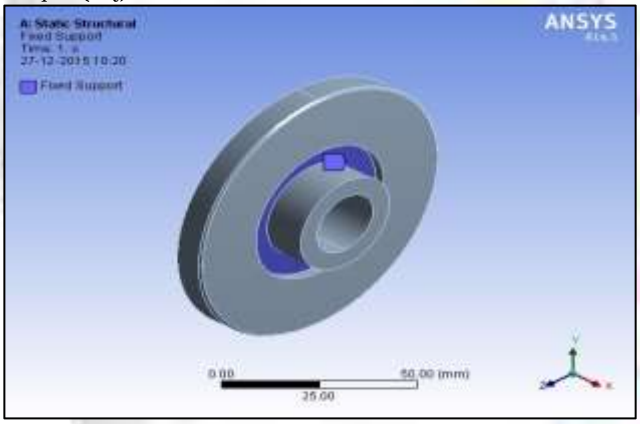

Fig. 11(a): Applying boundary condition to clutch plate

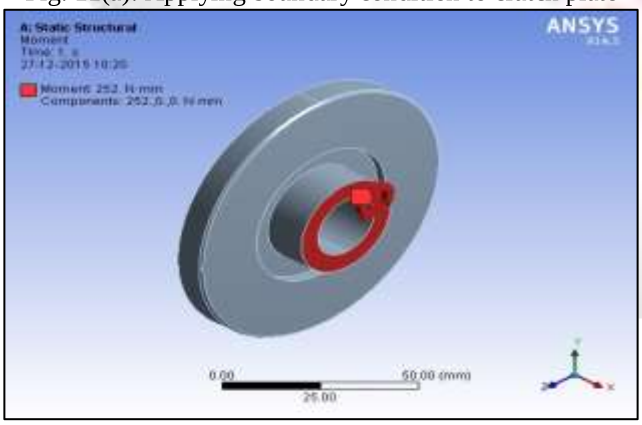

Fig. 11(b): Applying boundary condition to clutch plate

c) Plot results

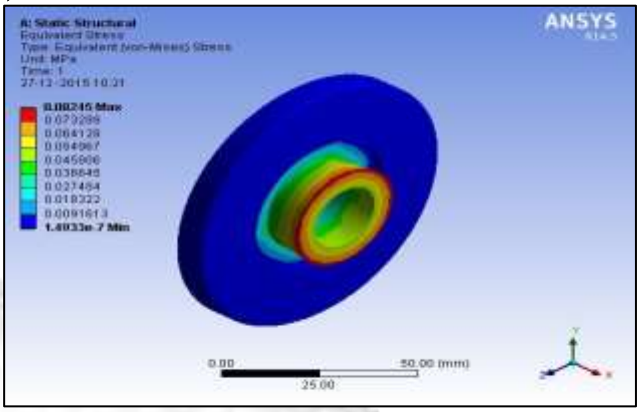

Fig. 12: Equivalent stress Analysis of clutch plate

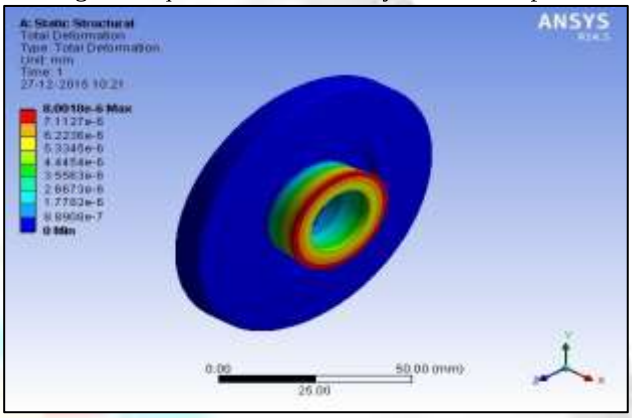

Fig. 13: Total Deformation for clutch plate

d) Theoretical Analysis

1) Result & discussion

Part Name	Maximum theoretical stress (N/mm²)	Von-mises stress (N/mm²)	Maximum deformation (mm)	Result
Clutch	0.0143	0.08245	8.01 E-6	safe

Table 5: Analysis result table for clutch plate

C. Analysis of Pressure Plate

1) FEA Analysis

a) Creation of Geometry

This can either created in ANSYS or imported.

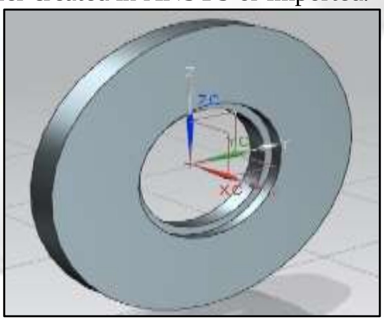

Fig. 14: CAD Model pressure plate

b) Element type

3D solid: Solid 92

c) Material properties

EX = 210000 N/mm2, PRXY = 0.3

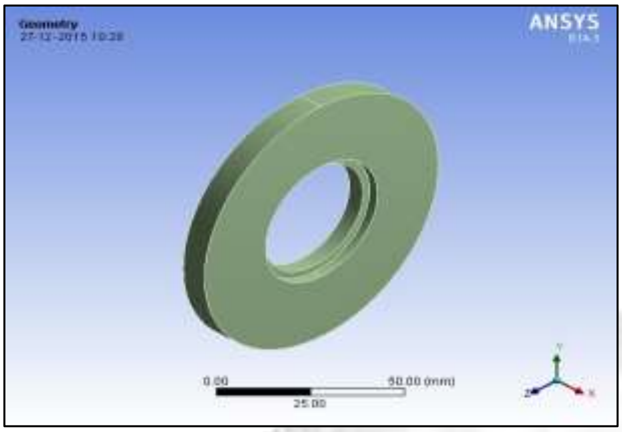

Fig. 15: CAD Model imported in ANSYS of pressure plate

d) Meshing

CAD model is converted into FE model by creating nodes and elements.

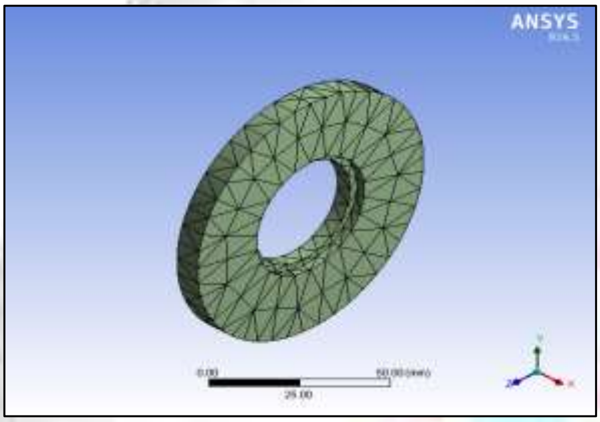

Fig. 16: Meshing of pressure plate

e) Plot results

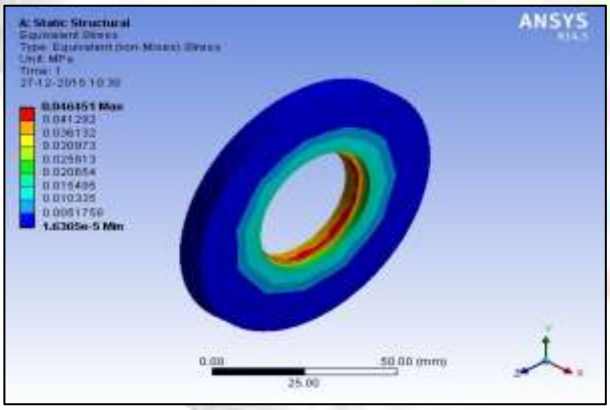

Fig. 17: Equivalent stress Analysis of pressure plate

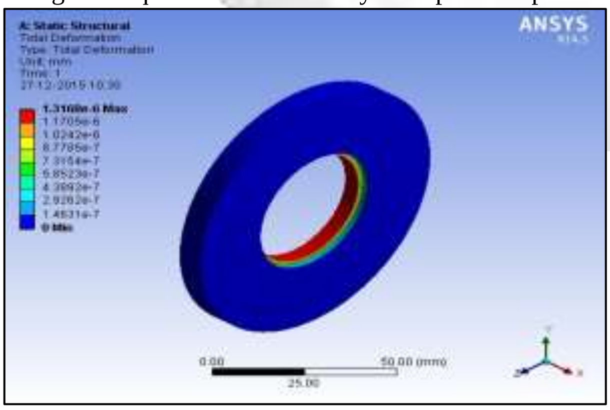

Fig. 18: Total Deformation for pressure plate

f) Theoretical Analysis

1) Result & discussion

Part Name	Maximum theoretical stress (N/mm²)	Von-mises stress (N/mm²)	Maximum deformation (mm)	Result
Pressure Plate	0.01465	0.04645	1.3 E-6	safe

Table 6: Analysis result table for pressure plate

D. Analysis of Output Shaft

1) FEA Analysis

a) Creation of Geometry

This can either created in ANSYS or imported.

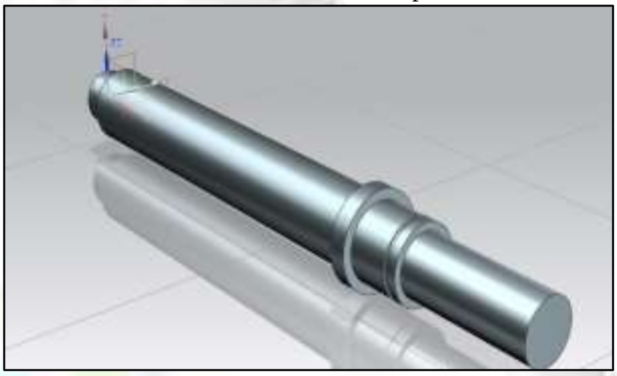

Fig. 19: CAD Model of output shaft

b) Element type

3D solid: Solid 92

c) Material properties

EX = 210000 N/mm2, PRXY = 0.3

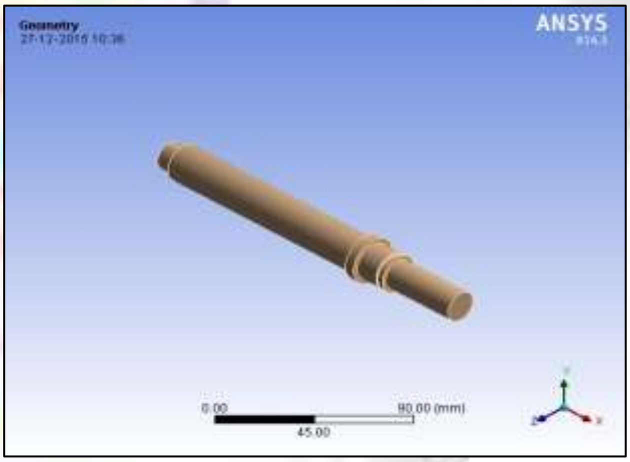

Fig. 20: CAD Model imported in ANSYS of output shaft

d) Meshing of output shaft

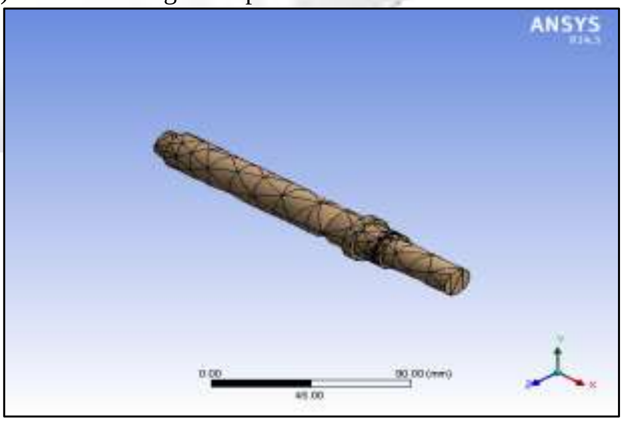

Fig. 21: Meshing of output shaft

e) Define load

1) Displacement Constraints

This is used to specify where the model is fixed (zero displacement locations).

Solution > Define Loads > Apply > Structural > Displacement.

2) Concentrated load

Force/ Moment is a point load, applied on a node or key points, specifying the force/moment magnitude and direction.

Solution > Define Loads > Apply > Structural > Force/ Moment.

Torque (M_t) = 252.2 Nmm.

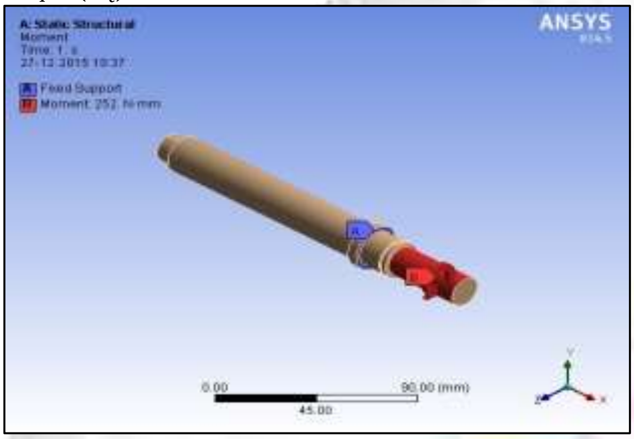

Fig. 22: Applying boundary condition of output shaft

2) Plot results

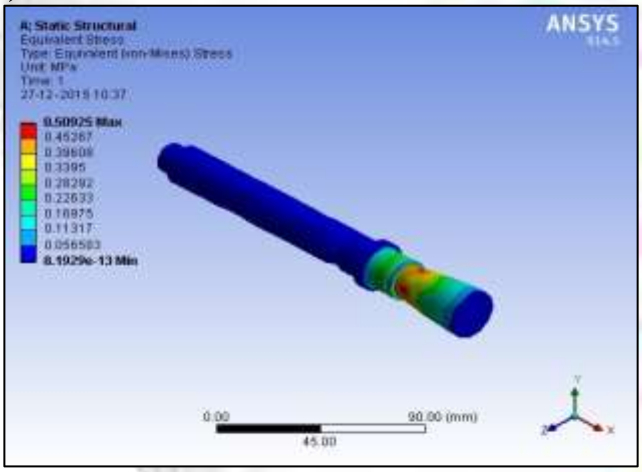

Fig. 23: Equivalent stress Analysis of output shaft

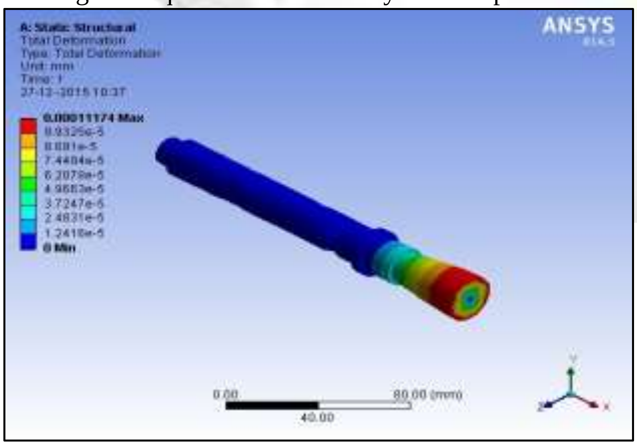

Fig. 24: Total Deformation for output shaft

3) Theoretical Analysis

a) Result & discussion

Part Name	Maximum theoretical stress (N/mm²)	Von-mises stress (N/mm²)	Maximum deformation (mm)	Result
Output shaft	0.3135	0.5109	0.000116	Safe

Table 7: Analysis result table for output shaft

VI. TESTING OF FULL FACE AND STAGGERED GEOMETRY OF FRICTION LINING

A. Introduction

Here, the testing is carried out of full face and staggered geometry of friction lining of clutch plate. The load is applied with the help of rope dynobrake. Mass is attach from 0.5 Kg to 4 Kg and corresponding speed (rpm) is measured with the help of tachometer.

These readings are taken for both the conditions i.e. full face and staggered geometry. From this observation following parameters are calculated.

1) Output torque = (Weight in pan) × (Radius of Dynobrake)
2) Output power = $\frac{2\times\pi\times N\times T_{(o/p)}}{60\times10^6}$
3) Input power = $\frac{2\times\pi\times N\times T_{(i/p)}}{60\times10^6}$
4) Efficiency = $\frac{\text{Output power}}{\text{Input power}}$

In order to conduct trial, a dynobrake pulley cord, weight pan are provided on the output shaft.

Diameter (Effective) of Dynobrake pulley = 25 mm.

Fig. 25: Experimental setup

B. Testing of full faced geometry of Friction Lining

1) Observation Table for full face Geometry

Sr. No.	Load (Kg)	Speed (rpm)
1.	0.5	1433
2.	1.0	1343
3.	1.5	1201
4.	2.0	1097
5.	2.5	985
6.	3.0	892
7.	3.5	810
8.	4.0	668

Table 7: Reading for full face Geometry

2) Result Table

Sr. No.	Load (Kg)	Speed (rpm)	Torque (N mm)	Power (Kw)	Efficiency (%)
1.	0.5	1433	61.3125	0.0092	18.40
2.	1.0	1343	122.625	0.01724	34.50
3.	1.5	1201	183.937	0.02313	46.28
4.	2.0	1097	245.25	0.02817	56.36
5.	2.5	985	306.56	0.03162	63.26
6.	3.0	892	367.87	0.03436	68.74
7.	3.5	810	429.18	0.03640	72.82
8.	4.0	668	490.5	0.03431	68.65

Table 8: Result for full face Geometry

3) Graphs

a) Graph of Load Vs Speed

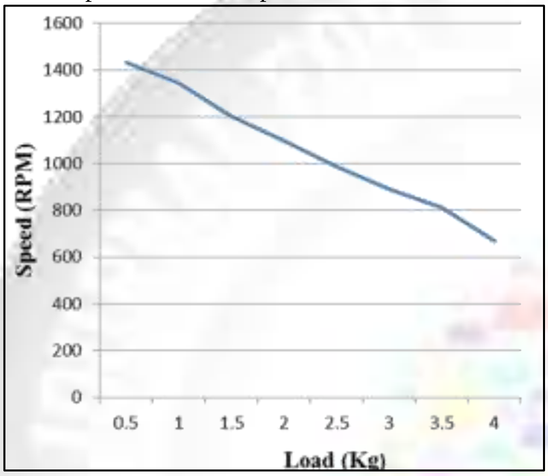

Fig. 26: Graph of Load Vs Speed

b) Graph of Load Vs Torque

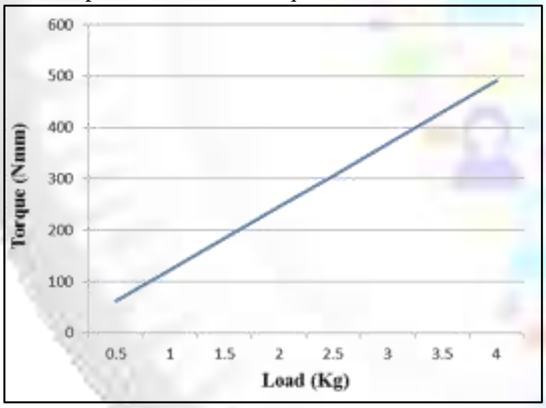

Fig. 27: Graph of Load Vs Torque

c) Graph of Load Vs Power

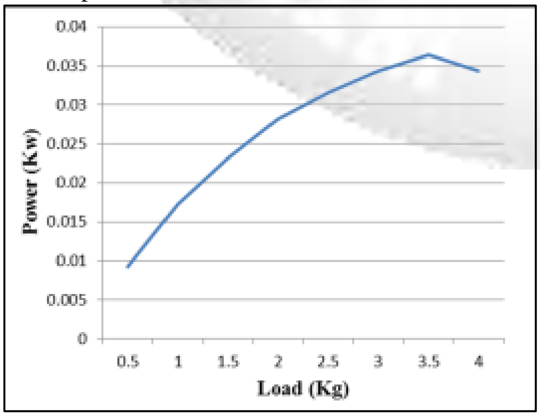

Fig. 28: Graph of Load Vs Power

d) Graph of Load Vs Efficiency

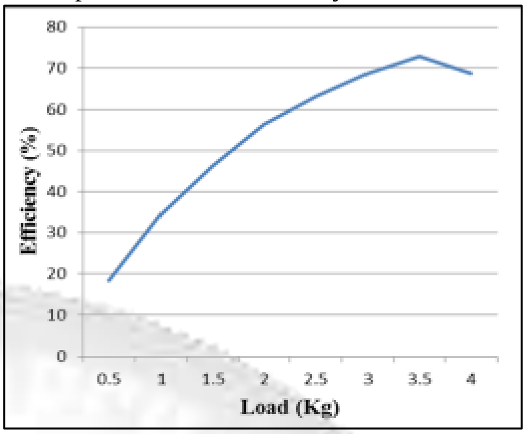

Fig. 29: Graph of Efficiency Vs Speed

C. Testing of staggered geometry of friction lining

Diameter (Effective) of Dynobrake pulley = 25 mm.

1) Observation Table for Staggered Geometry

Sr. No.	Load (Kg)	Speed (rpm)
1.	0.5	1400
2.	1.0	1274
3.	1.5	1154
4.	2.0	1068
5.	2.5	942
6.	3.0	807
7.	3.5	789
8.	4.0	626

Table 3: Reading for staggered Geometry

2) Result Table

Sr. No.	Load (Kg)	Speed (rpm)	Torque (Nmm)	Power (Kw)	Efficiency (%)
1.	0.5	1400	61.3125	0.00898	17.98
2.	1.0	1274	122.625	0.01635	32.73
3.	1.5	1154	183.937	0.02222	44.47
4.	2.0	1068	245.25	0.02742	54.87
5.	2.5	942	306.56	0.03024	60.50
6.	3.0	807	367.87	0.03108	62.20
7.	3.5	789	429.18	0.03346	70.95
8.	4.0	626	490.5	0.03215	64.33

Table 6.4: Result for Staggered Geometry

3) Graph

a) Graph of Load Vs Speed

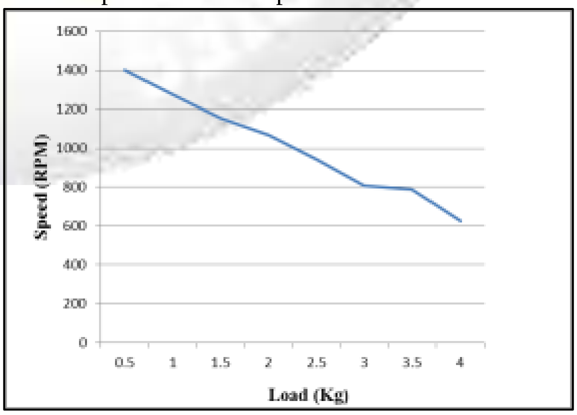

Fig. 30: Graph of Load Vs Speed

b) Graph of Load Vs Torque

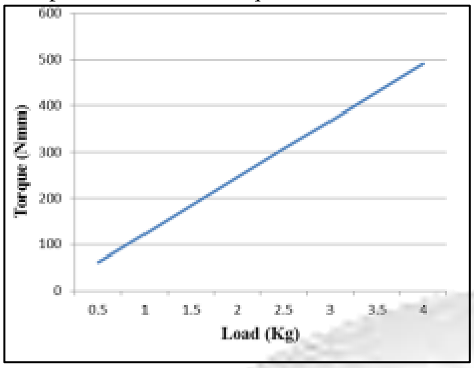

Fig. 31: Graph of Load Vs Torque

c) Graph of Load Vs Power

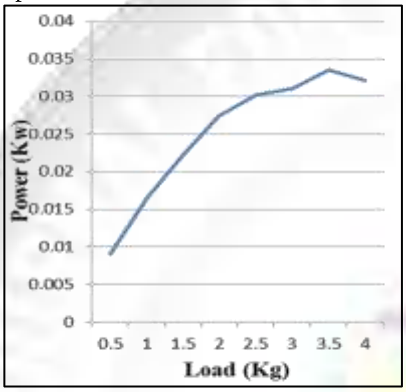

Fig. 32: Graph of Load Vs Power

d) Graph of Load Vs Efficiency

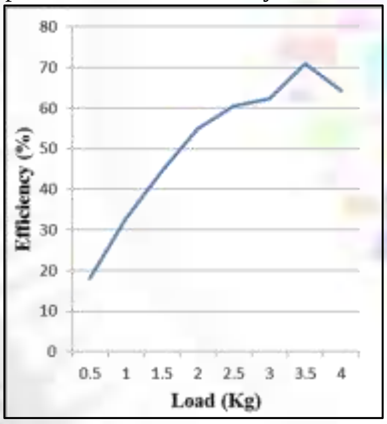

Fig. 33: Graph of Load Vs Efficiency

4) Comparison Graphs

a) Graph of Load Vs Speed

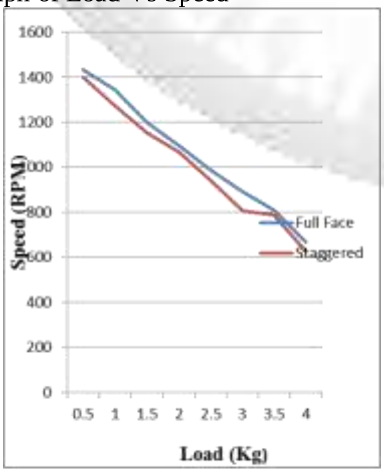

Fig. 34: Graph of Load Vs Speed

b) Graph of Load Vs Power

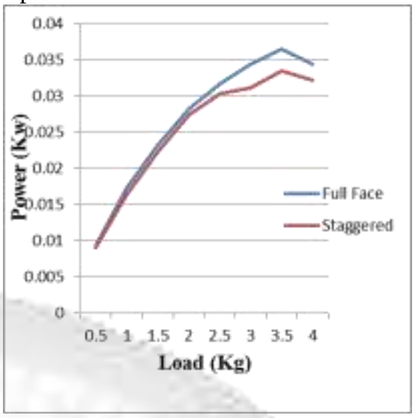

Fig. 35: Graph of Load Vs Power

c) Graph of Load Vs Efficiency

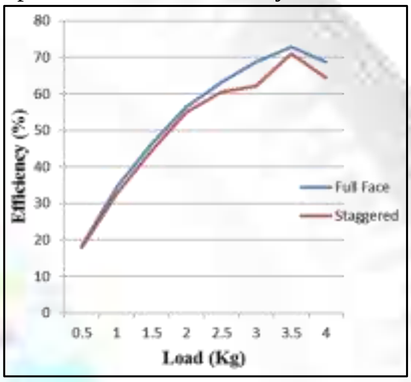

Fig. 36: Graph of Load Vs Efficiency

VII. Conclusion

In dissertation work design, development and testing of full face and staggered geometry of friction lining in automated single plate clutch is done. Following conclusions are drawn from testing on single plate automated clutch.

- The theoretical and FEA analysis shows that the stresses in the components like input shaft, clutch plate, pressure plate and output shaft are approximately equal. And design is safe under given operating condition.
- Testing of full face and staggered geometry of friction lining of clutch shows the torque transmission capacity remains moreover similar.
- It can be predicted that the life of the staggered friction lining of automated clutch can be longer as compared to full face geometry. The reason for this prediction can be, as there is staggered friction lining which are on the limited portion of the disc. It show faster rate of heat dissipation.

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