Comparative Analysis of Performance of Full Face and Staggered Geometry Friction Lining in Automated Single Plate Clutch

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Abstract- *The clutch is part that is used to connect the driver element to the load or driven element at the will of the operator. The clutches are categorized as manual engagement or automated clutches. The automatic clutches form an integral part of the modern automatic transmission system. The conventional method of application of friction material in clutch is on the complete face, but as the power transmitted is not a function of area of friction lining, but the rate of clutch wear and power transmitted is affected by temperature of friction surface. Thus by providing the clutch face lining as staggered face lining with the face split in six equal segment by providing air gap between two segment that will help in heat dissipation and lowered friction lining temperature. This will increase integrity and better power transmission ability of the clutch. The paper discusses the test and trial and comparative performance analysis of both arrangement, load, output speed, output torque, output power and efficiency.*

Keywords- Friction, Full face lining, Performance analysis, Staggered face lining.

I. INTRODUCTION

Conventional transmission system uses single plate clutch with a manual transmission gear box. The modified system utilizes the centrifugal force developed by engine acceleration, whereas the temporary dis-engagement of clutch required at the time of gear change is a solenoid actuated by switch in gear change knob. The hold time of the solenoid is only a few seconds thus prolongs solenoid life and reduces power consumption from battery.

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 co-efficient of friction close to 0.4 resulting in lower friction force and lower power transmission ability. Hence it is decided to replace the friction material as FTL095 as molded 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 ability.

The conventional clutches use full face lining for the clutch means that the entire face of clutch is lined with friction material and conventionally the friction lining material used is asbestos base. Here in the project non-asbestos liners will be used and the two conditions of liner application will be studies namely the full face lining and the staggered lining. Test will be done to evaluate torque versus load, power versus load, efficiency versus load and comparative analysis will be done for the same.

Friction lining material:

FTL095: Non-asbestos friction lining made of heat resisting organic fibre and fine brass wire impregnated with special resin binder. It does not contain glass fibre.

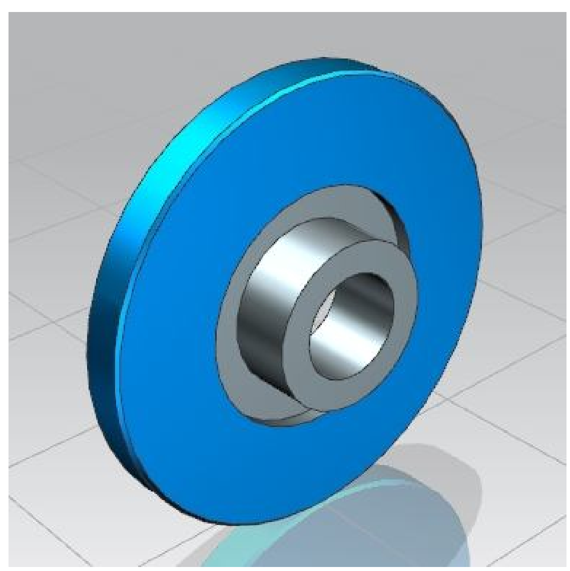


Fig. 1 Full face friction lining

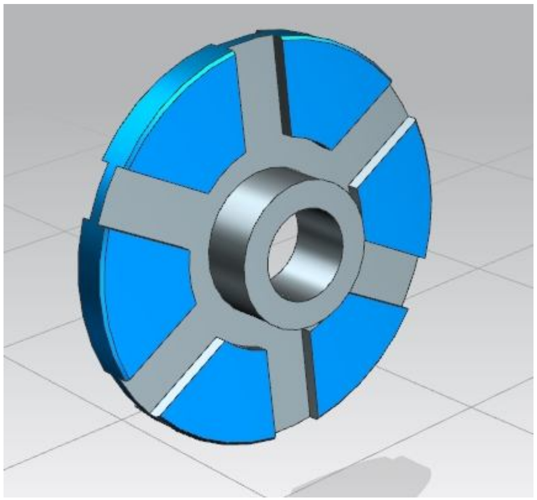


Fig. 2 Staggered face friction lining

1.1 Problem Definition

The conventional clutches use full face lining for the clutch means that the entire face of clutch is lined with friction material the power transmitted is not a function of area of friction lining, but the rate of clutch wear and power transmitted is affected by temperature of friction surface. Thus by providing the clutch face lining as staggered face lining by providing air gap between two segment that will help in heat dissipation and lowered friction lining temperature. Conventionally the friction lining material used is asbestos base but present stringent environmental norms the asbestos liners are banned in operation hence there is need to develop high performance non-asbestos liners. Thus it is proposed to develop non-asbestos liners and the two conditions of liner application will be studied namely the full face lining and the staggered lining.

1.2 Objectives

- Design of automated single plate clutch system for maximum power transmission capacity based on constant wear theory of clutch design.
- Developments of test-rig with automated single plate clutch arrangement to test the developed staggered geometry moulded friction linings.
- Design and analysis of the clutch plate with full face lining and staggered lining
- Test & Trial on developed clutch to determine maximum torque carrying capacity, transmission efficiency. Plot Performance Characteristic Curves (Torque /Power /Efficiency) Vs Load.

1.3 Scope

The scope of project is design and development of the Newton automatic centrifugal clutch 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 an variable speed motor of ac/dc type, speed control achieved by means of an continuously variable rheostat.

1.4 Methodology

- System design and Mechanical design of the Automated single plate clutch system as per configuraton.
- 3-D modelling using Unigraphix Nx 8.0 and analysis using Ansys.
- Manufacturing of model.
- Result and Discussion based on experimentation.

II. DESIGN OF AUTOMATED SINGLE PLATE CLUTCH

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 an variable speed motor of ac/dc type, speed control achieved by regulator.

2.1 Design of Clutch Plate:

Table 1: Material Selection for clutch plate:- PSG (1.10 & 1.12) + (1.17)

Designation	Ultimate Tensile Strength (N/mm2)	Yeild Strength (N/mm2)
EN24	800	680

fs allowable = 0.18 x 800 = 144 N/mm2
T design = 0.252 Nm

Check for Torsional Shear Failure of Shaft.
Td = (Π/16) x fsact x (D4- d4) /D
fsact =(16 x Td x D)/Π x (D4- d4)
=(16 x 0.252 x 10 3 x 32.4)/[Π x (324- 204)]
fs act = 0.04 N/mm2
As fs act <fs all

⇒Clutch plate is safe under torsional load.

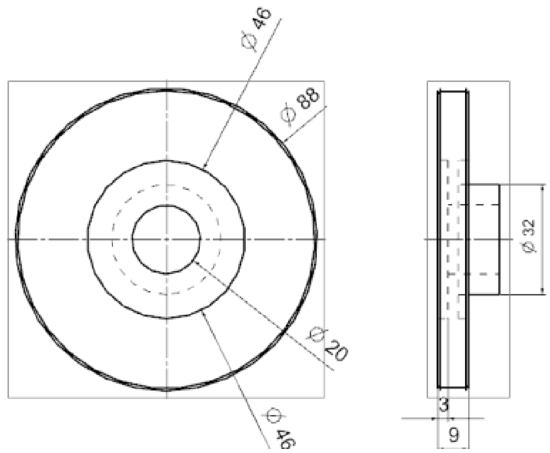


Fig. 3 Clutch plate with full face Lining

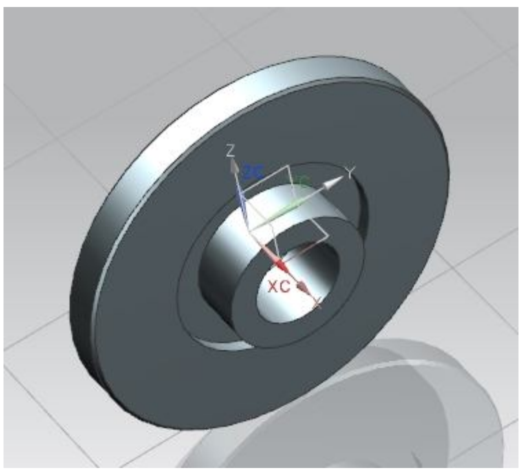


Fig. 4 3-D model of clutch plate

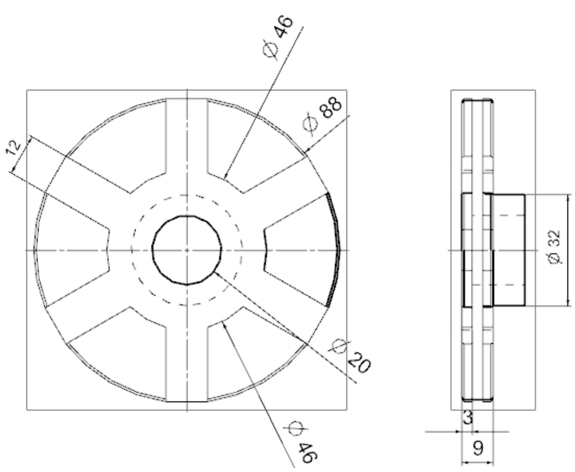


Fig 5. Clutch plate with Staggered Face Lining

2.2 Design of Pressure Plate:

Table 2: Material Selection for Pressure Plate: -Ref:- PSG (1.10 & 1.12) + (1.17)

Designation	Ultimate Tensile Strength (N/mm2)	Yeild Strength (N/mm2)
EN24	800	680

fs allowable = 0.18 x 800 =144 N/mm2

T design = 0.252 Nm

Check for Torsional Shear Failure

Td = (Π/16) x fsact x((D4- d4) /D)

fsact = (16 x Td x D)/(Π x (D4- d4))

= (16 x 0.252 x 10 3 x 42)/(Π x (424- 374))

⇒fs act = 0.044 N/mm2

As fs act <fs all

⇒ Pressure plate is safe under torsional load.

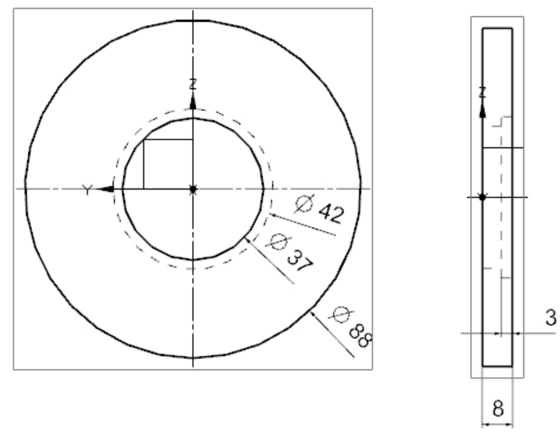


Fig. 6 Pressure plate

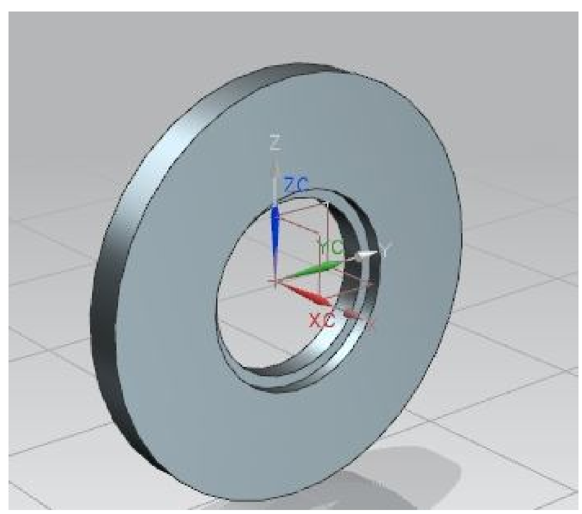


Fig. 7 3-D model of Pressure Plate

III. FINITE ELEMENT ANALYSIS

3.1 Analysis of Clutch Plate with full Face Lining:

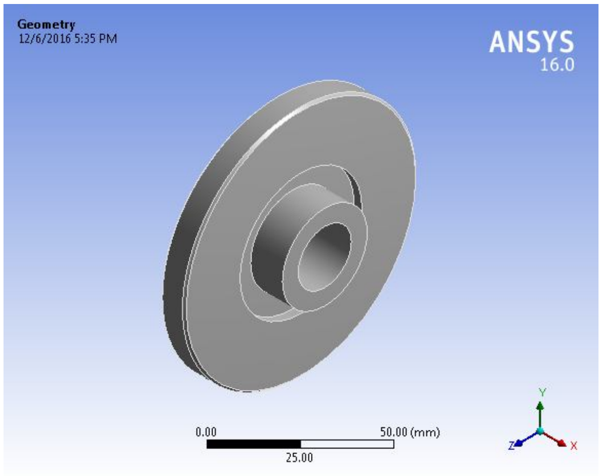


Fig. 8 Geometry of Clutch Plate

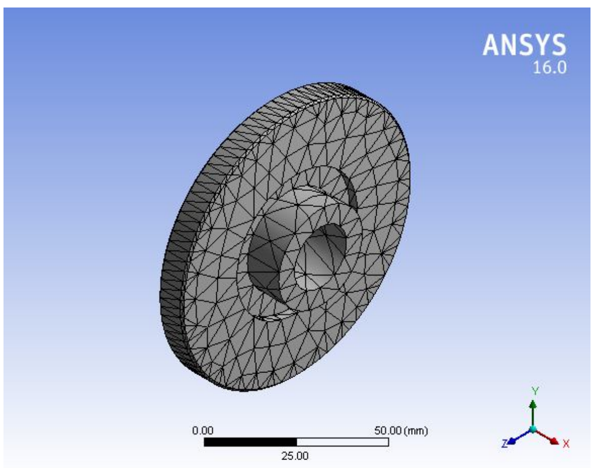


Fig. 9 Mesh Details of Clutch Plate

Mesh Details : No Element 2456, No. of Nodes 4712

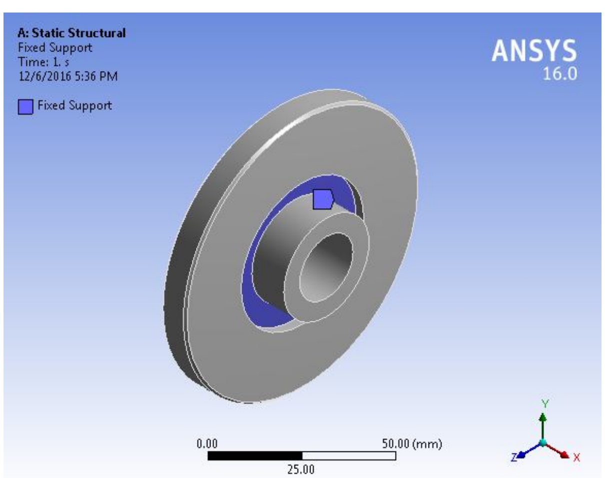


Fig. 10 Boundary conditions for clutch plate

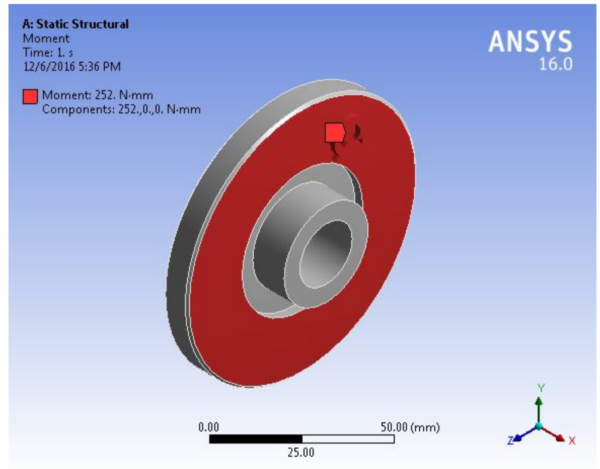


Fig. 11 Boundary conditions for clutch plate

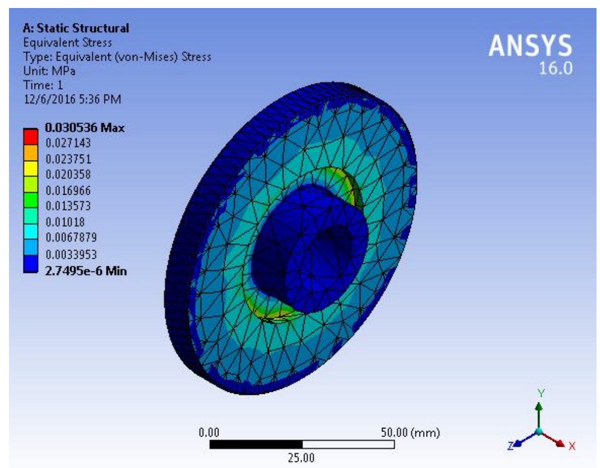


Fig. 12 Equivalent stress for clutch plate.

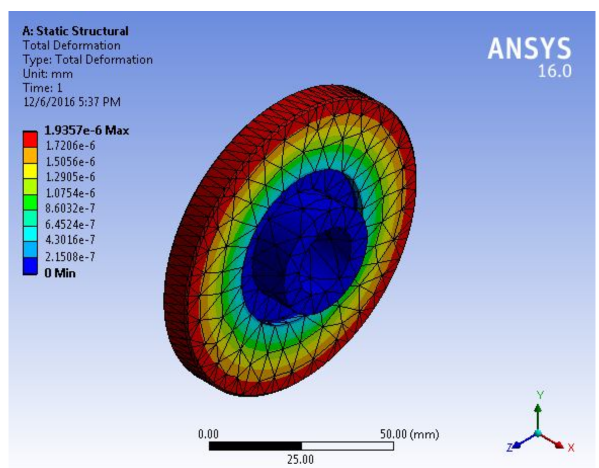


Fig 13 Total deformation for clutch plate

Table 3 : Result & discussion for clutch plate with full face lining.

Part Name	Maximum theoretical stress (MPa)	Von-mises stress (MPa)	Maximum deformation mm	Result
Clutch plate	0.04	0.0305	1.93 E-6	safe

1. Maximum stress by theoretical method and Von- mises stress are well below the allowable limit, hence the clutch plate with full face lining is safe.
2. Clutch plate shows negligible deformation under the action of system of forces.

3.2 Analysis of Clutch plate with Staggered Geometry friction lining

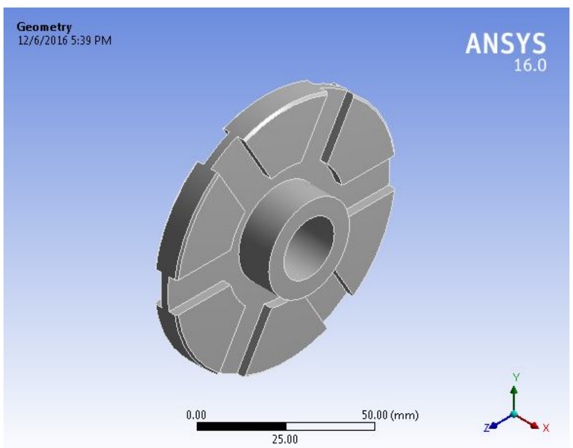


Fig. 14 Geometry of clutch plate with staggered face lining.

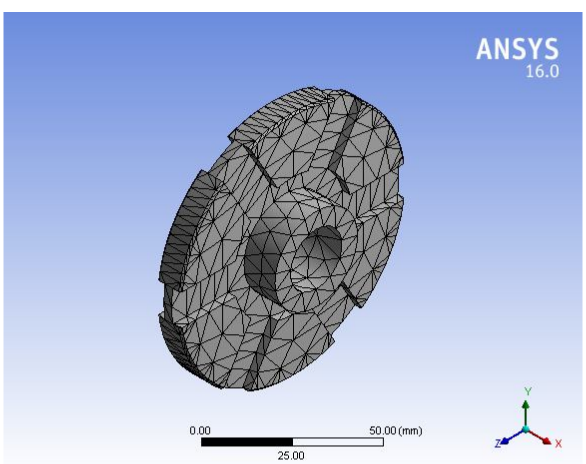


Fig 15 Mesh details of clutch plate with staggered face lining

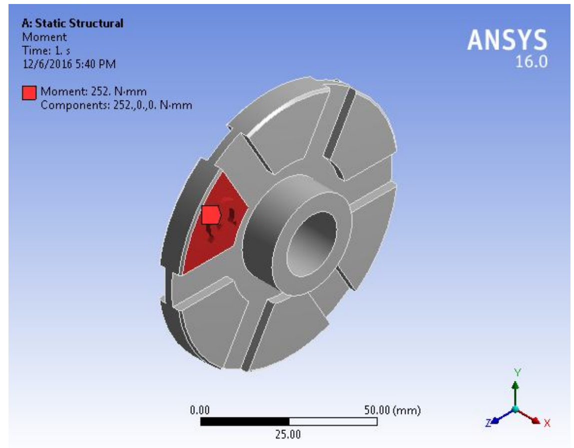


Fig. 16 Boundary conditions for clutch plate with staggered geometry lining

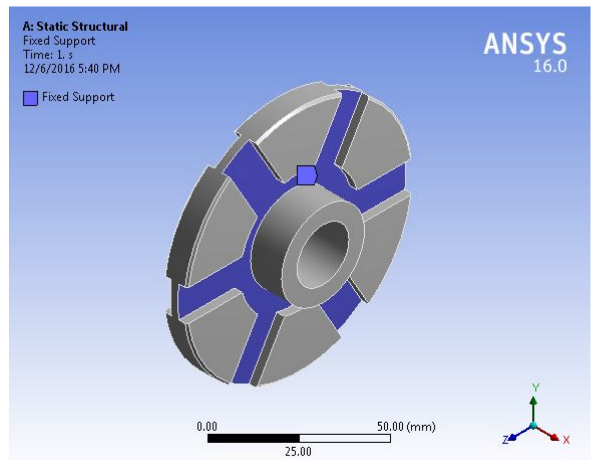


Fig. 17 Boundary conditions for clutch plate with staggered face lining

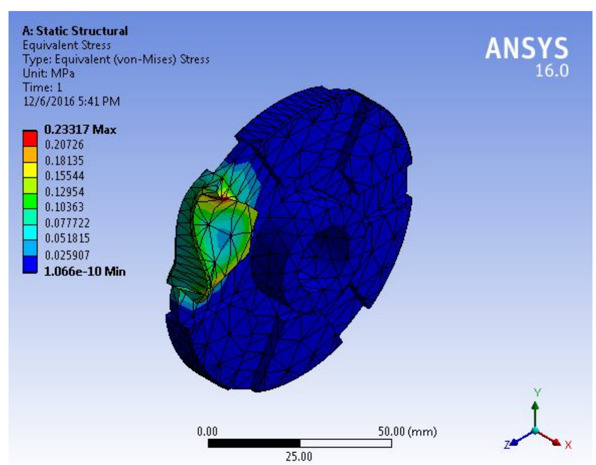


Fig. 18 Equivalent stresses for clutch plate with staggered geometry lining

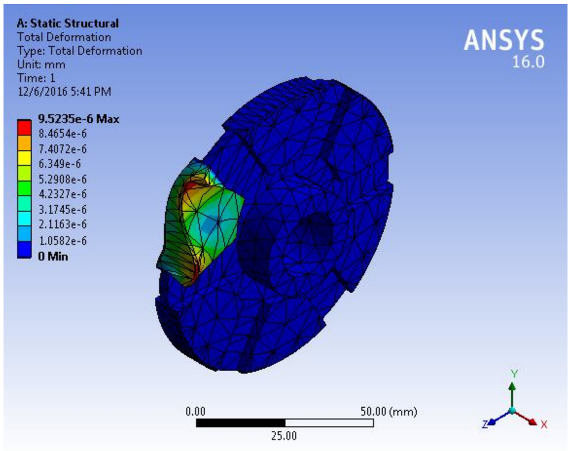


Fig. 19 Total deformation of clutch plate with staggered geometry lining

Table 4: Result & discussion for clutch plate with staggered face lining

Part Name	Maximum theoretical stress (MPa)	Von-mises stress (MPa)	Maximum deformation mm	Result
Clutch plate	0.04	0.233	9.52 E-6	safe

1. Maximum stress by theoretical method and Von-mises stress are well below the allowable limit, hence the clutch plate with staggered face lining is safe.
2. Clutch plate with staggered face lining shows negligible deformation under the action of system of forces.

3.3 Stresses Comparison of Full face Lining and Staggered Lining:

Maximum Von- mises stress in Clutch plate with full Face lining is less (0.032 MPa) as compared to clutch plate with staggered face lining (0.233MPa). Maximum deformation of clutch plate with full face lining is 1.93 x 10-6 mm which is less as compared to staggered face lining (9.52 x 10-6mm). But maximum Von- mises Stress values and maximum deformation values are well below the allowable limit. So clutch plate is safe with full face lining as well as staggered face lining.

IV. TESTING

Fig.20 Experimental set up

4.1 Input Data:

- Drive Motor: AC 230 volt, 0.5 amp , 50 watt , 0 to 9000 RPM, TEFC motor.
- Diameter of pulley= 65 mm

4.2 Procedure

- Start motor by turning electronic speed variable knob.
- Let mechanism run and stabilize at certain speed (660 rpm)
- Place the pulley cord on pulley and add 100 gm weight into the pan . Note down the output speed for this load by means of tachometer.
- Add another 100gm weight and take reading .
- Tabulate the reading in observation table.
- Plot Torque versus load and Power versus load characteristics.

4.3 Observations for Full Face Friction Lining:

Table 5: Observation Table for Full Face Friction Lining

Sr. No.	Load	Speed
1	0.1	650
2	0.2	641
3	0.3	630
4	0.4	620
5	0.5	606
6	0.6	500
7	0.7	395

4.4 Observations for Staggered Geometry moulded Friction:

Table 6: Observation Table for Staggered face lining

Sr. No.	Load (kg)	Speed (rpm)
1	0.1	662
2	0.2	651
3	0.3	638
4	0.4	629
5	0.5	610
6	0.6	510
7	0.7	405

V. RESULTS AND DISCUSSIONS

5.1 Result Tables:

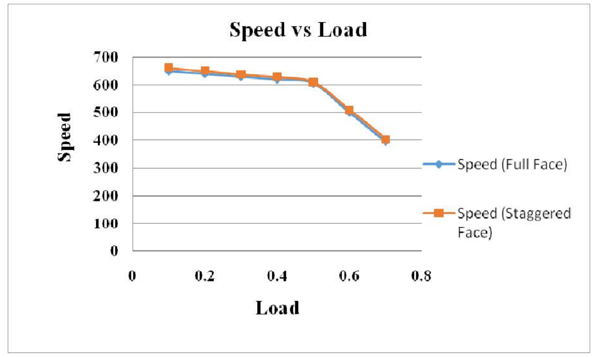
Table 7: Result Table (Full Face lining)

Sr. No	Load (kg)	Speed (rpm)	Torque (Nm)	Power (watt)	Efficienc y
1	0.1	650	0.03188	2.17045	15.50325
2	0.2	641	0.06376	4.28080	30.57717
3	0.3	630	0.09564	6.31101	45.0786
4	0.4	620	0.12753	8.28111	59.15084
5	0.5	606	0.15941	10.11618	72.2584
6	0.6	500	0.19129	10.01748	71.55344
7	0.7	395	0.22317	9.232779	65.9484

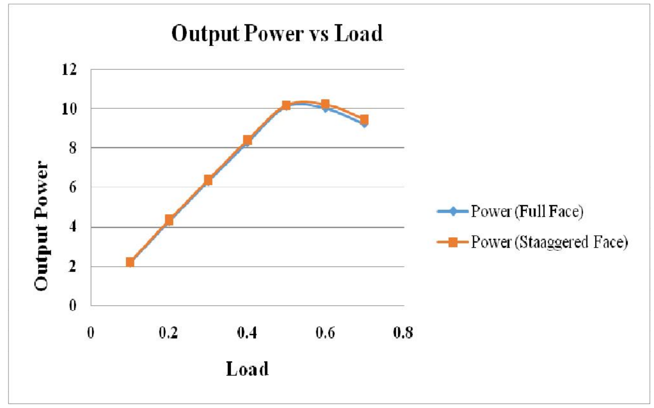
Table 8: Result Table (Staggered Face Lining)

Sr. No.	Load (kg)	Speed (rpm)	Torque (Nm)	Power (watt)	Efficiency
1	0.1	662	0.03188	2.21027	15.78764
2	0.2	651	0.06376	4.34758	31.05419
3	0.3	638	0.09564	6.39035	45.6450
4	0.4	629	0.12753	8.40023	60.0016
5	0.5	610	0.15941	10.18295	72.7353
6	0.6	510	0.19129	10.21783	72.98451
7	0.7	405	0.22317	9.46652	67.6180

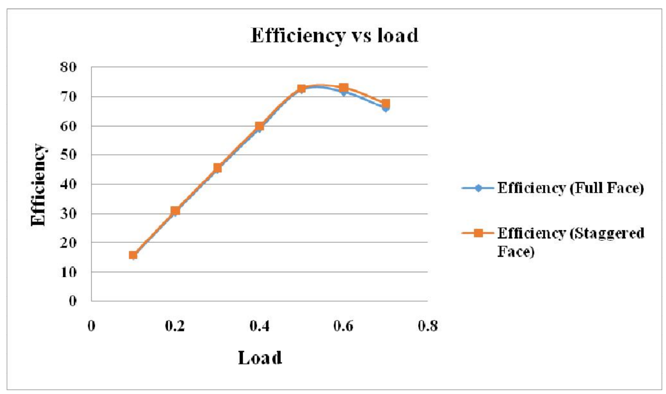
5.2 Comparison of Performances:



Graph 1: Speed vs Load (Comparison)



Graph 2 Output Power vs Load (Comparison)



Graph 3 Efficiency vs Load (Comparison)

1. Output speed of clutch drops with increase in load, drop in speed is low with staggered face lining as compared to full face lining.
2. increases with increase in load up to certain limit i.e. 0.5 kg then again drops slightly with further increase in load. Max power transmitted by full face lining is 10.11 W and by using staggered face lining is 10.21 W.
3. Efficiency of clutch increases with increase in load up to certain limit i.e. 0.5 kg then again drops slightly with further increase in load. Max efficiency of full face lining is 72.25 % and by using staggered face lining is 72.98%.

4. Power output value and Efficiency is higher (up to 2%) with staggered geometry lining as compared to full face lining.

VI. CONCLUSION

Staggered face friction linings are used in automated single plate clutch. High heat generated during application of clutch but this heat generated is not released as there is no provision in case of clutch plate with full face liners. The rate of clutch wear and power transmitted is affected by temperature of friction surface. In case of staggered geometry friction liners air gap between two segment that will help in heat dissipation and lowered friction lining temperature. This will increase integrity and better power transmission ability of the clutch.

Better heat dissipation with staggered geometry friction lining reduces the wear rate which increases the life of clutch.

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