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Analysis of alternative Friction Surface Materials of Piaggio Ape Model Clutch Plate using FEA

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ABSTRACT
In a power transmission system of automobiles, Clutch plate is one of the most significance devices which are used to engage or disengage of power from the engine crank shaft to the gear box. For transmit maximum torque by using friction clutches is essential to select a proper friction material. The selection of friction material is one of the important tasks to increase a prolonged period of the clutch plate. In this study comparison is done for different friction materials to approve the better friction lining materials for Piaggio Ape clutch plate. This paper aimed to investigate structural behaviour by varying the friction surface material and keeping backing material aluminium same in a clutch plate. In this modelling of Piaggio Ape clutch plate has been created by solid work and then imported to ANSYS for power transmission application to study the structural analysis. Solid works is a software package for 3D modelling and ANSYS is commonly used in finite element analysis software package.
Keywords: Clutch plate, friction clutches, FEA, solid work, ANSYS, steel, aluminium, Grey Cast Iron.

I. INTRODUCTION

These are used to connect or disconnect the source of power to the other transmitting parts. This operation involves heavy and sudden forces results in stresses in the clutches.

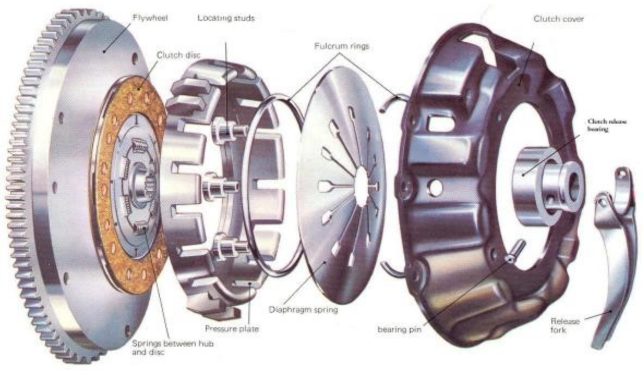

Figure 1: Clutch Plate connecting with different parts

Clutch is connecting section between shaft from the motor to gear box, which facilitate smooth engagement or disengagement.

As in the above figure, clutch contain fixed and movable disk. Movable disk is connected to gear box and fixed disk always run at motor speed, which should be disengaged with movable disk while changing the gear.

Types of clutches

- Friction type
- Positive type

Friction type: The clutch mechanism that is used to transmit torque in this type is the surface friction between two faces of the clutch. These are single plate, multi plate, conical plate, centrifugal plate.

Figure 2: Friction Plate

Positive plate: A clutch that consists of two mating surfaces with interconnecting elements, such teeth that lock together during engagement to prevent slipping. Positive clutches are also known as mechanical lock up clutches.

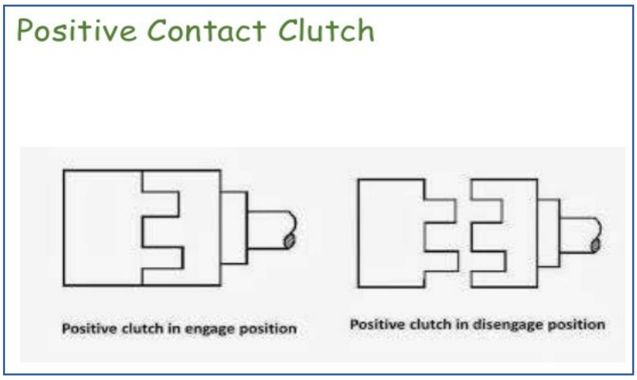

Figure 3: Square jaw, Spiral jaw

II. MATERIAL AND PROPERTIES

2.1 Available friction materials and their properties

Table-1: material properties

Material Combination	Coefficient of Friction		Temp. (max)	Pressure (Max)
	Wet	Dry	Deg.C	MPa
Cast Iron/Cast Iron	0,05	0,15-0,20	300	0,8
Cast Iron/Steel	0,06	0,15-0,20	300	0,8-1,3
Hard Steel/Hard Steel	0,05	0,15-0,20	300	0,7
Wood/Cast Iron-steel	0,16	0,2-0,35	150	0,6
Leather/Cast Iron-steel	0,12-0,15	0,3-0,5	100	0,25
Cork/Cast Iron-Steel	0,15-0,25	0,3-0,5	100	0,1
Felt/Cast Iron-Steel	0,18	0,22	140	0,06
Woven Asbestos/Cast Iron- Steel	0,1-0,2	0,3-0,6	250	0,7
Molded Asbestos/Cast Iron- Steel	0,08-0,12	0,2-0,5	250	1,0
Impregnated Asbestos/Cast Iron- Steel	0,12	0,32	350	1.0
Carbon-graphite/Cast Iron- Steel	0,05-0,1	0,25	500	2.1
Kevlar/Cast Iron- Steel	0,05-0,1	0,35	325	3,0

2.2 Desirable Properties for friction materials/linings for clutches

- The two materials in contact must have a high coefficient of friction.
- The materials in contact must resist wear effects, such as scoring, galling, and ablation.
- The friction value should be constant over a range of temperatures and pressures.
- The materials should be resistant to the environment (moisture, dust, pressure).
- The materials should possess good thermal properties, high heat capacity, and good thermal conductivity, withstand high temperatures.
- Able to withstand high contact pressures.
- Good shear strength to transferred friction forces to structure.

III. MODELING USING SOLID WORKS

3.1 SolidWorks: It is a 3D mechanical CAD (computer-aided design) program that runs on Microsoft Windows and is being developed by Dassault Systems SolidWorks Corp., a subsidiary of Dassault Systems, S. A. (Vélizy, France). SolidWorks currently available at markets several versions of the SolidWorks CAD software in addition to eDrawings, a collaboration tool, and DraftSight, a 2D CAD product.

The following drawings are designed as per the dimensions of Piaggio Ape Model Clutch Plate by using solidworks. The dimensions are shown in figure-4. The designed model is further analysed in ANSYS it is analysis software is based on the Finite Element Method (FEM).

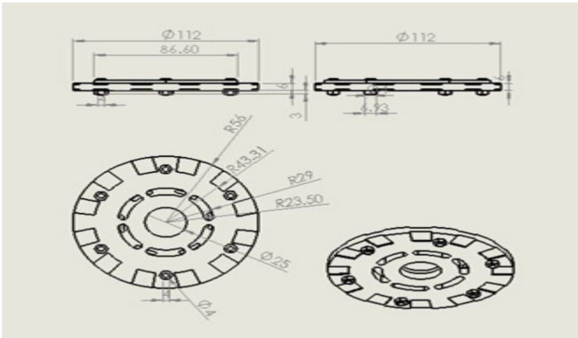

Figure 4: Drafting of clutch plate

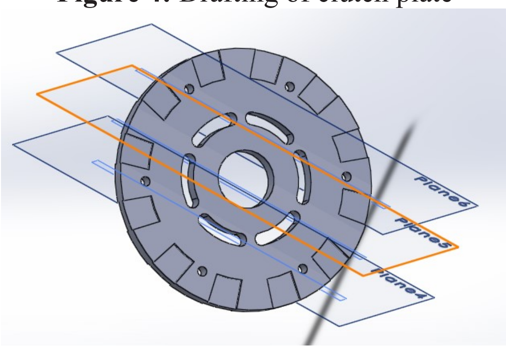

Figure 5: Modelling of clutch plate

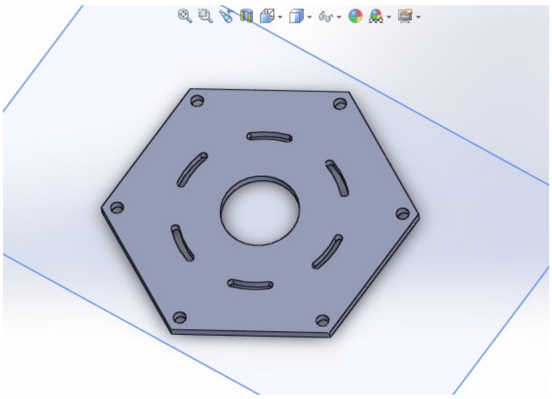

Figure 6: Modelling of friction plate

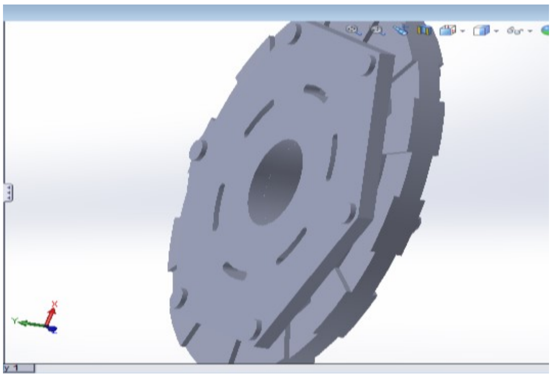

Figure 7: Assembly of clutch and pressure plate

3.2 FEA using analysis: ANSYS is one of the useful software for design analysis in mechanical engineering. This software is based on the Finite Element Method (FEM) to simulate the working conditions of your designs and predict their behaviour. FEM requires the solution of larges systems of equations. Powered by fast solvers, ANSYS makes it possible for designers to quickly check the integrity of their designs and search for the optimum solution. A product development cycle typically includes the following steps:

- ✓ Build your model in the Pro-Engineer system.
- ✓ Prototype the design.
- ✓ Test the prototype in the field.
- ✓ Evaluate the results of the field tests.
- ✓ Modify the design based on the field test results.

The analysis part of this work by using ANSYS is discussed in the next chapter. The next chapter contains the analysis conducted for the friction plate and pressure plate. Analyse the structural, thermal, and modal analysis.

IV. ANALYSIS OF A FRICTION PLATE

4.1 Structural Analysis: Kevlar as Friction Material

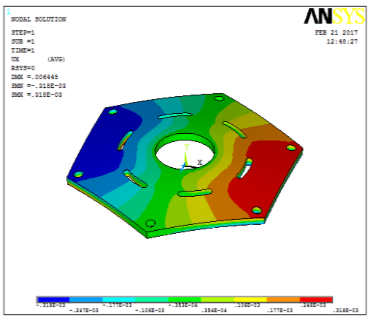

Figure 8 : Displacement along X-Direction in pressure plate

4.1.2 Structural Analysis: Organic Polyethylene as Friction Material

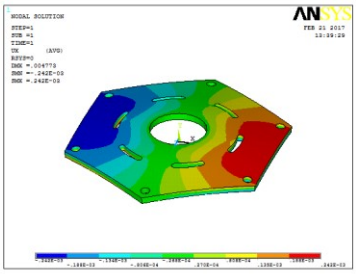

Figure 9: Displacement along X-Direction in pressure plate

4.1.3 Structural Analysis: Ceramic as Friction Material

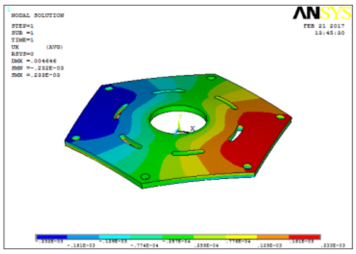

Figure 10: Displacement along X-Direction in pressure plate

4.1.4 Structural Analysis: Cork as Friction Material

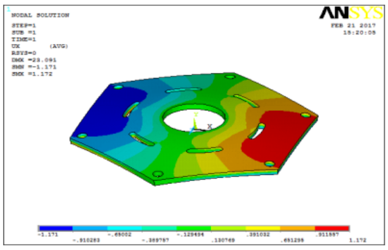

Figure 11: Stress along X-Direction in pressure plate

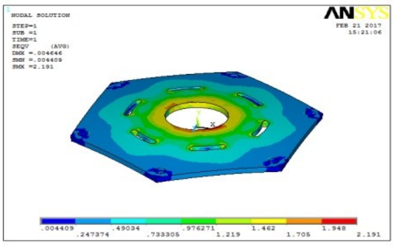

Figure 12: Von Misses Stress in pressure plate

4.1.5 Modal Analysis: Kevlar as Friction Material

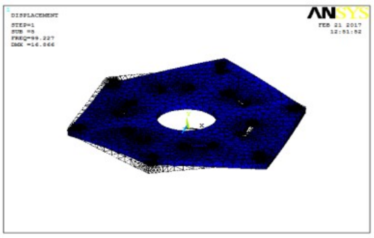

Figure 13: Displacement in pressure plate

4.1.6 Modal Analysis: Organic Polyethylene as Friction Material

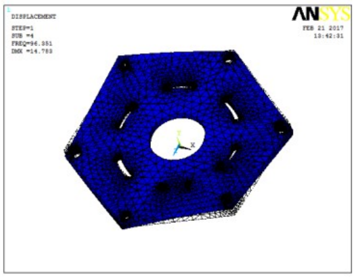

Figure 14: Displacement in pressure plate

4.1.7 Modal Analysis: Cork as Friction Material

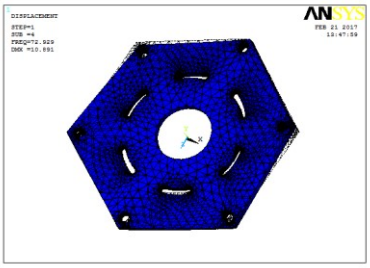

Figure 15: Displacement in pressure plate

4.1.8 Modal Analysis: Ceramic as Friction Material

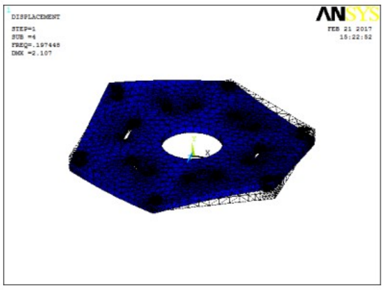

Figure 16: Displacement in pressure plate

4.1.9 Thermal Analysis: Kevlar as Friction Material

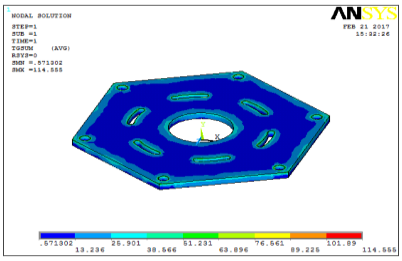

Figure 17: Thermal Gradient in pressure plate

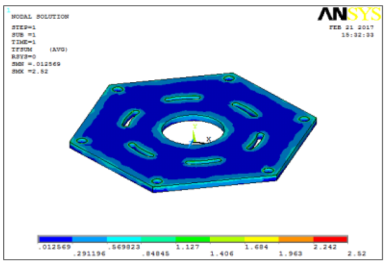

Figure 18: Thermal flux in pressure plate

4.1.10 Thermal Analysis: Ceramic as Friction Material

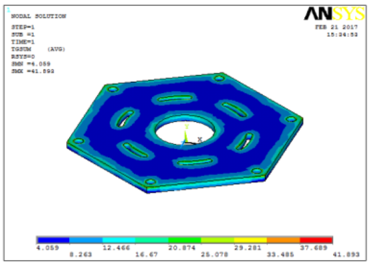

Figure 19: Thermal Gradient in pressure plate

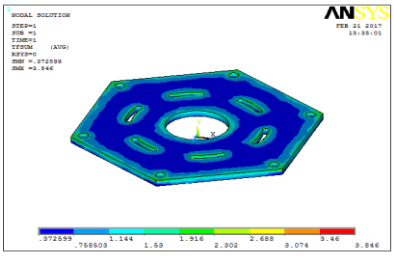

Figure 20: Thermal flux in pressure plate

4.1.11 Thermal Analysis: Polyethylene as Friction Material

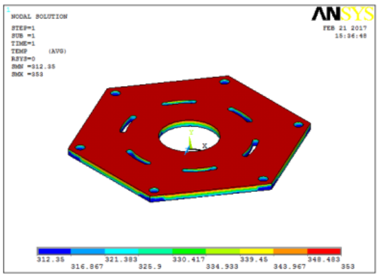

Figure 21: Temperature distribution in pressure plate

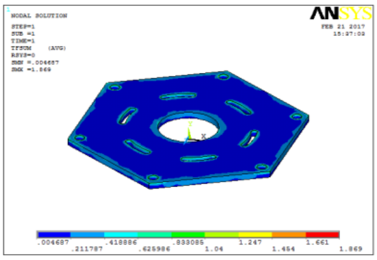

Figure 22: Thermal flux in pressure plate

4.1.12 Thermal Analysis using Cork as Friction Material

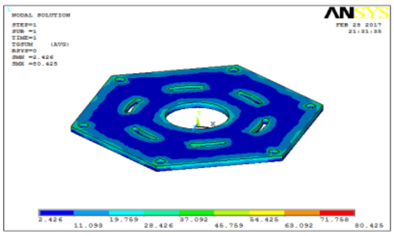

Figure 23: Thermal Gradient in pressure plate

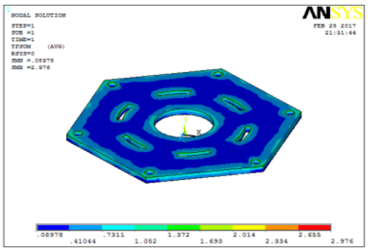

Figure 24: Thermal flux in pressure plate

4.2 Analysis of a clutch plate

4.2.1 Modal Analysis using Structural steel

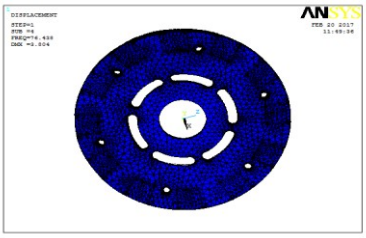

Figure 25: Displacement in clutch plate

4.2.2 Modal Analysis using Aluminium 6061

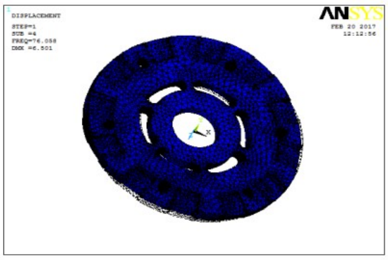

Figure 25: Displacement in clutch plate

4.2.3 Modal Analysis using Grey Cast Iron

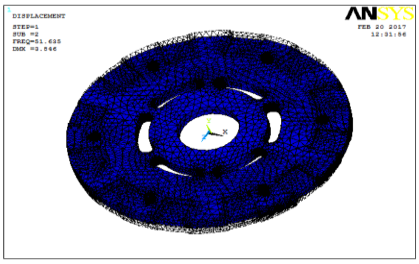

Figure 26: Displacement in clutch plate

4.2.4 Thermal Analysis using Structural steel

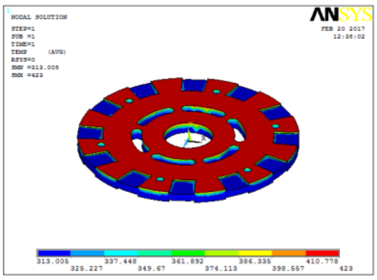

Figure 27: Temperature in clutch plate

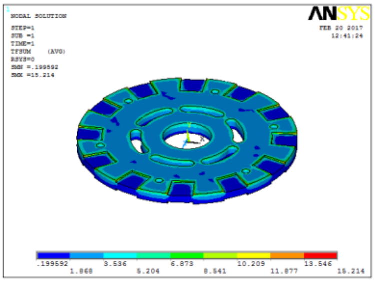

Figure 28: Thermal Flux in clutch plate

4.2.5 Thermal Analysis using Grey Cast Iron

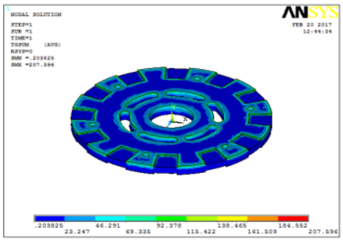

Figure 28: Thermal Gradient in clutch plate

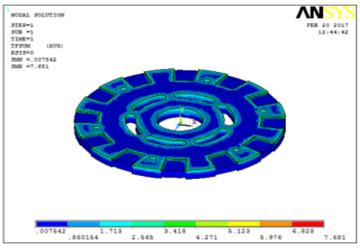

Figure 29: Thermal Flux in clutch plate

4.2.6 Thermal Analysis using Aluminium 6061

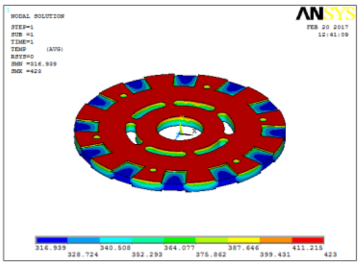

Figure 30: Temperature in clutch plate

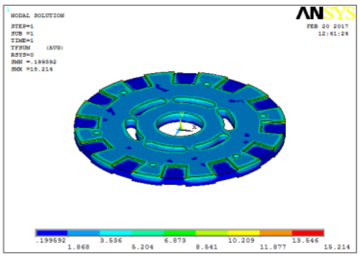

Figure 31: Thermal Flux in clutch plate

4.2.7 Structural Analysis using Grey Cast Iron

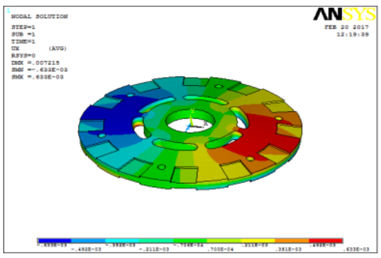

Figure 32: Displacement along x direction in clutch plate

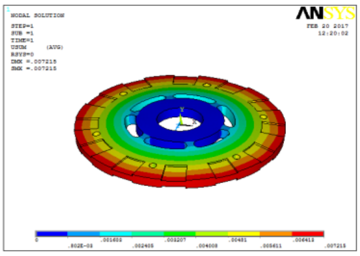

Figure 33: Displacement Vector Sum in clutch plate

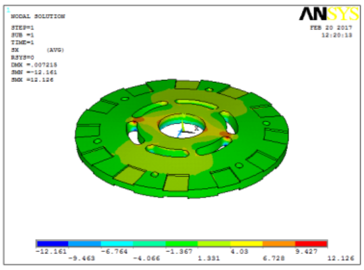

Figure 34: Stress along x direction in clutch plate

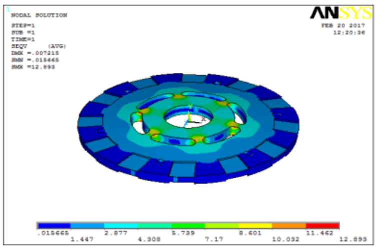

Figure 35: Von Misses Stresses in clutch plate

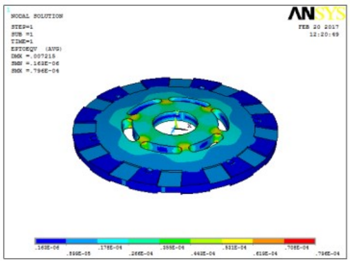

Figure 36: Von Misses Strain

4.2.8 Structural Analysis using Structural steel in clutch plate

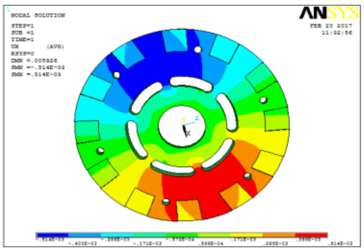

Figure 37: Displacement along x direction in clutch plate

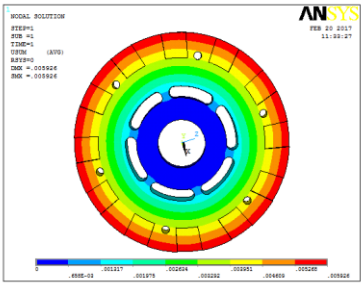

Figure 38: Displacement Vector Sum in clutch plate

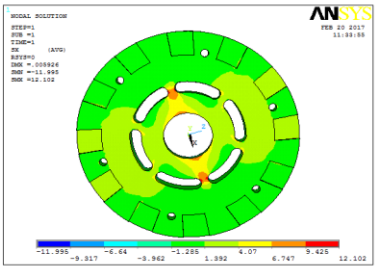

Figure 39: Stress along y direction in clutch plate

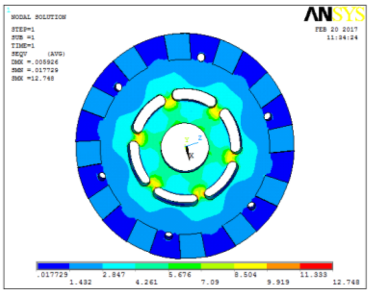

Figure 40: Von Misses Stresses in clutch plate

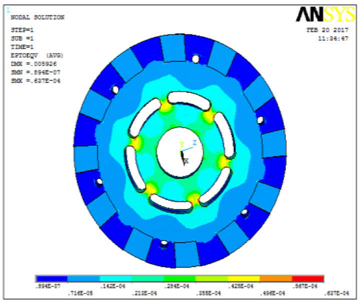

Figure 41: Von Misses Strain in clutch plate

4.2.9 Structural analysis: Aluminium 6061

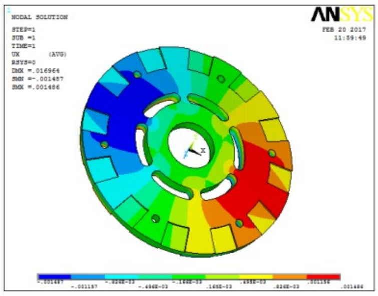

Figure 42: Displacement along x direction in clutch plate

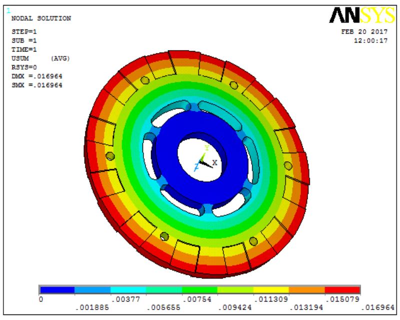

Figure 43: Displacement Vector Sum in clutch plate

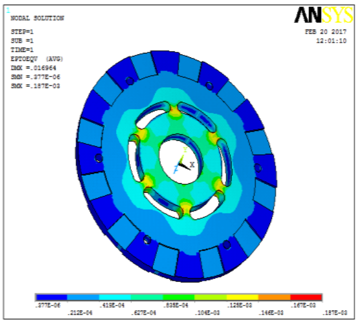

Figure 44: Von Misses Strain in clutch plate

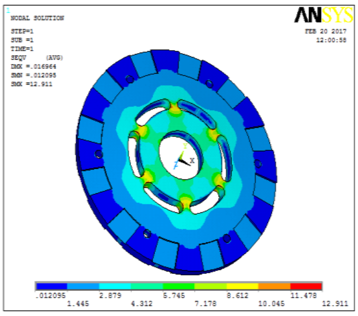

Figure 45: Von Misses Stress in clutch plate

VI. RESULTS

Table 2: Structural Analysis (Clutch Plate)

Material	Disp. X	Disp. Y	Disp. Z	DVS	Stress X	Stress Y	Stress Z	VMS
S.S	0.514 e -3	0.005909	0.513e-3	0.005926	12.102	3.307	11.857	12.748

Al 6061	0.001486	0.016915	0.001483	0.016964	12.135	4.122	12.385	12.911
GCI	0.633e-3	0.007194	0.631e-3	0.007215	12.126	4.123	12.367	12.893

Table 3: Modal Analysis (Clutch Plate)

Material	Disp. 1	Disp. 2	Disp. 3	Disp. 4	Disp. 5
S.S	3.702	3.692	2.653	3.804	3.807
Al 6061	6.32	6.325	4.518	6.501	6.516
GCI	3.843	3.846	2.748	3.954	3.963

Table 4: Thermal Analysis (Clutch Plate)

Material	Temperature	Temp Gradient	Thermal Flux
S.S	423	278.344	5.984
Al 6061	423	98.791	15.214
GCI	423	207.596	7.681

Table 5: Modal Analysis (Friction Plate)

Material	Disp. 1	Disp. 2	Disp. 3	Disp. 4	Disp. 5
Kevlar	17.371	15.523	12.46	17.426	16.666
Organic Polyethylene	15.344	13.782	10.975	14.783	15.685
Ceramic	2.184	1.964	1.564	2.107	2.236
Cork	11.165	9.639	7.965	10.891	11.228

Table 6: Thermal Analysis (Friction Plate)

Material	Temperature	Temp Gradient	Thermal Flux
Kevlar	353	114.555	2.52
Organic Polyethylene	353	186.858	1.869
Ceramic	353	41.893	3.846
Cork	353	80.425	2.976

Table 7: Structural Analysis (Clutch Plate)

Material	Disp. - X	Disp. -Y	Disp. - Z	DVS	Stress - X	Stress - Y	Stress - Z	VMS
Kevlar	0.318e-3	0.006438	0.313e-3	0.006445	2.413	0.627231	2.471	2.3
Organic Polyethylene	0.242e-3	0.004768	0.233e-3	0.004773	2.545	1.101	2.071	2.071
Ceramic	0.233e-3	0.004642	0.226e-3	0.004646	2.416	0.84007	0.134622	0.134622
Cork	1.172	0.045	1.126	2.545	1.101	2.532	2.071	2.19

V. CONCLUSION

- In our project we have designed a multi plate friction clutch plate and friction plate using reverse engineering process.
- Structural, modal, Fatigue and Thermal analysis is done on the Clutch plates to verify the strength.
- Structural, modal and Thermal analysis is done on the Friction to verify the strength.
- Friction materials used are Cork, Organic Polyethylene, Kevlar, and Ceramic. Material used.
- Clutch plate materials used are Stainless steel, Aluminium and Grey Cast Iron.
- By observing the analysis results, for clutch plate the original material stainless steel we replace with Aluminium 6061 and Grey cast iron by comparing the all Values the original material Stainless steel is better consider all the Analysis.
- By observing the analysis results, for friction the original material cork we replace with Organic Polyethylene, Kevlar, and Ceramic. By comparing the all Values the Ceramic material is comfortable for friction plate of clutches.
- Finally we have concluded that the Stainless steel is better for Clutch plate material and Ceramic is good for manufacturing friction material of Clutches.

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