International Journal of Emerging Technologies in Engineering Research (IJETER)
Volume 5, Issue 3, March (2017) www.ijeter.everscience.org

Static and Dynamic Analysis of Single Plate Clutch in Four Wheeler Application Using ANSYS

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Abstract – Clutch is one of the essential components in automobiles. It is located between the engine and the gear box. The main function of the clutch is to initiate the motion or increase the velocity of the vehicle by transferring kinetic energy from the flywheel. This type of clutch is a dry friction clutch. The present used material for friction disc is Alloy steel Single plate clutch replaced with various material. The design of single plate clutch is drawn by using theoretical calculation results. A single plate clutch is designed and modeled using CREO 2.0 software. Static analysis and Dynamic analysis carried by using ANSYS 15.0. Finally the plots for equivalent stress, strains and total deformation were obtained for different friction materials for friction clutch plate, Uniform wear theory were used for the analysis. The comparison result is done for using materials to define the best material for friction plate.

Index Terms – Stress, Pressure, Creo, Analysis, ANSYS, Clutch, Friction Plate.

1. INTRODUCTION

A clutch is a mechanical device which provides driving force to another mechanism, typically by connecting the driven mechanism to the driving mechanism. Its opposite component is a brake, which inhibits motion. Clutches are useful in devices that have two rotating shafts. In these devices, one shaft is typically attached to a motor or other power unit (the driving member), and the other shaft (the driven member) provides output power for work to be done. In a drill, for instance, one shaft is driven by a motor, and the other drives a drill chuck.

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).A Clutch is a machine member used to connect the driving shaft to a driven shaft, so that the driven shaft may be started or stopped at will, without stopping the driving shaft. A clutch thus provides an interruptible connection between two rotating shafts. Clutches allow a high inertia load to be stated with a small power.

The friction materials which are suitable for friction clutch plate are Gray cast iron, En-Gjs-400 – 15Steel, E Glass Epoxy, Aluminium Alloy A360, Silicon Carbide, and Kevlar 49.Mainly there are two types of clutches, one is single plate clutch which is used for small duty vehicles and the other is multi plate clutch, which has number of friction plates and steel plate's assembly used for heavy duty vehicles.

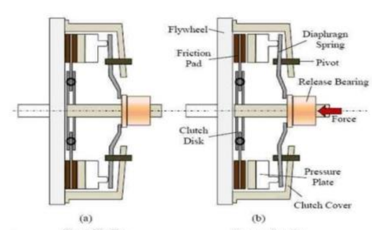

Fig 1: Engagement and disengagement of clutch plate

Fig 1(a) shows the engagement position of clutch plates, during this the clutch pedal is engaged with flywheel which transmit power from the engine to the clutch and it is transmitted towards the transmission. Fig (b) shows the disengagement of clutch plates, which does not transmit power towards the transmission.

The past literature that May Thin Gyan, Hla Min Htun, and HtayHtay Win [1] are proposed different materials for a single plate clutch and structural analysis of a single clutch plates. B.Sreevani, and M.Murali Mohan [2] has focused on comparision of different materials for single plate clutch and static and dynamic analysis of single plate clutch. Vishal J. Deshbhratar, and Nagnath U. Kakde [3] has performed design and Structural Analysis of Single PlateFriction Clutchthe values of Equivalent stresses for material loading conditions it is clearly seen that these are less than the allowable stresses for that particular material under applied conditions the part not going to yield and hence the design is safe. G.Kannan, K.Krishnamoorthy, and K.Loheswaran [4] has performed Review on Different Materials Utilized in Clutch Plate. Anil Jadhav, GauriSalvi, Santosh Ukamnal, and Prof.P.Baskar[5] were demonstrated Static Structural Analysis of Multiplate Clutch with Different FrictionMaterials the result of stress distribution has been carried out. AbhijitDevaraj [6] performed optimize the design of the clutch plate, so as to deliver maximum performance and last longer.A.Krishna Reddy, SeshaTalpa Sai, and Mangeelal **[7]**has performed stresses as well as deformationclear the idea about what parameter should have been taken into account while defining the single plate friction clutch. SagarOlekar, Kiran Chaudhary, Anil Jadhav, and P. Baskar [8] were demonstrated the total deformation of clutch plate for different materials to find the better lining material and structural analysis of multi plate clutch using ANSYS. Ganesh Raut, Anil Manjare, and P.Bhaskar [9] were demonstrated the static analysis on Friction clutch by using Finite element analysis the results of stress distribution, maximum shear stress and total deformation has been carried out. Shaik Mohammad Ali and N.Amaranageswara [10] has studied about different materials for friction clutch plate and find the stress values for structural analysis and temperature values for thermal analysis of positive multiple Friction plate using FEA.

In this Project, The present used material for friction disc is Alloy steel Single plate clutch replaced with various material the design of single plate clutch was done by using CREO 2.0 software and static and dynamic analysis was done by using ANSYS 15.0, by selecting the friction materials as Gray cast iron, En-Gjs-400 – 15Steel, E Glass Epoxy, Aluminium Alloy A360, Silicon Carbide and Kevlar 49.Finally comparing the stresses, strains and total deformation are obtained, the best material for friction clutch plate has been found.

2. NOMENCLATURE AND SELECTION OF MATERIALS

2.1 Nomenclature

ri	Inner Radius
ro	Outer Radius
R	Mean Radius of Friction Surfaces
n	Numbers of Contact Surfaces
P	Pressure
W	Axial thrust with friction surface
T	Torque
μ	Coefficient of friction
C	Constant
Pmin	Minimum Intensity Pressure
Pavg	The Average pressure on the friction surface

2.2 Selection of materials

The following are the different types of materials used for clutch plate

2.2.1. Gray cast iron

Gray iron, or grey cast iron, is a type of cast iron that has a graphitic microstructure. It is named after the gray color of the fracture it forms, which is due to the presence of graphite. It is the most common cast iron and the most widely used cast material based on weight.

The clutch disc is generally made from grey cast iron (Afferents et al. 2003; Poser et al. 2005). This is because grey cast iron has a good wear resistance with high thermal conductivity and the production cost is low compare to other clutch disc materials such as A1-MMC (aluminum-metal matrix composite), carbon composites and ceramic based composites (Terhech et al. 1995; Jang et al. 2003). High thermal conductivity of diffusivity of the material is considered advantageous because heat is

Then allowed to dissipate at higher rate (Bostwick and Szadkowski 1998). In this project, BS200 or ASTM G2500 grade grey cast iron is selected as the material for the commercial clutch disc.

2.2.2. En-Gjs-400 – 15steel

This material grade is the most common used cast iron in China and worldwide. Its tensile strength, ductility and toughness are much better than grey cast iron, and its mechanical properties could be compared with cast steel. However, its disadvantages are also obvious. Its shrinkage rate is large, so easily to cause shrinkage defects. The casting process is more complex and requirements to raw pig iron is also higher than other cast iron. Moreover, the technical requirements to the whole production process are also strict and high.

EN-GJS-400-15 are SG iron grades containing graphite nodules or spheres, Spheroidal Graphite. The rounded graphite nodules produces a more ductile cast iron that inhibits the formation of cracks. SG iron has a greater fatigue and impact resistance compared to grey iron.

2.2.3. E Glass Epoxy

The commonly used fibers are carbon, glass, etc. The main advantage of glass fibers is low cost. It has high strength, high chemical resistance and good insulating properties. The disadvantages are low modulus of elasticity, poor adhesion to polymer, low fatigue strength and high density which increase spring weight and size. The types of glass fibers are C-glass, S-glass and E-glass. The E-glass fiber is a high quality glass, which is used as standard reinforcement fiber for all the present systems well complying with mechanical property requirements. Thus, E-glass fiber was found appropriate for this application.

2.2.4. Aluminium Alloy A360

Aluminium-Silicon (Al-Si) alloys are most flexible materials, comprising 85% to 90% of the total aluminium shed parts produced for the automotive industry. Depending on the Si focus in weight percent (wt. %), the Al-Si alloy systems drop into three major categories: hypoeutectic (<12% Si), hypereutectic (14-25% Si) and eutectic (12-13% Si). However, most Al-Si alloys are not suitable for towering temperature applications because tensile and fatigue strengths are not as high as preferred in the temperature range of 500 °F - 700 °F. In recent years, the development of diesel and direct fuel injection gasoline engines with lofty specific powers have resulted in a big performance impact on piston materials due to enlarged combustion pressures and piston temperatures. While wear resistance is usually linked with surface hardness resulting from matrix properties and wear resistance in these alloys results from the presence of large volume fraction of hard primary silicon particles in the microstructure. Enlargement in the popularity of these alloys has accelerated in recent years. Hypereutectic aluminium-silicon alloys are relatively more difficult to cast and machine. Matrix-hardening alloys also provide improved wear resistance.

2.2.5. Silicon Carbide

Silicon and carbon with chemical formula SiC. Silicon carbide powder has been mass-produced since 1893 for use as a course. Grains of silicon carbide can be bonded together by sintering to form very hard ceramics that are widely used in applications requiring high staying power, such as car brakes, car clutches, grinding wheels, cutting tools and ceramic dishes in bulletproof vests. Electronic applications of silicon carbide as light emitting diodes (LEDs) and detectors in early radios were first established around 1907 and today SiC is widely used in high-temperature/high-voltage semiconductor electronics. Single crystals of silicon carbide can be grown by the Lely method; they can be cut into trinkets known as artificial moissanite. Silicon carbide with high surface area can be produced from SiO2contained in plant material. SiC particulates can be used as reinforcement, whiskers or fibers to improve the properties of the composite. When surrounded in metal matrix a composite SiC certainly improves the overall strength of the composite also it improves deterioration and wear resistance. Aluminum MMCs reinforced with SiC particles have up to 20% improvement in lower coefficient of thermal expansion, yield strength and higher modulus of elasticity than the corresponding un-reinforced matrix alloy. Sic based composite has high hardness, it can also use in number of applications such as in cutting tools, jeweler, structural materials, electronic circuits, automobile parts, and nuclear fuel particles, etc. For these reasons and also it is used in brake discs, aerospace, automotive industry and bicycle frames.

2.2.6. Kevlar 49

Kevlar was introduced by DuPont in the 1970s. It was the first organic fiber with sufficient tensile strength and modulus to be used in advanced composites. Originally developed as a replacement for steel in radial tires, Kevlar is now used in a wide range of applications. Kevlar 49 is the registered trademark for a paraaramid synthetic fiber, comparable to other aramids such as Nomex and Technora. Developed by Stephanie K. wolek at DuPont in 1965, this high strength material was used commercially for the first time in the early 70s as are placement for steel in racing tires. As it can withstand high impact it is also used to make modern drum lining. It is suitable for mooring lines when used as a woven material, for underwater applications and for possible replacement as lining material.

Table 1 Materials properties used for friction plate

SI.no	Materials	Young's Modulus (GPa)	Density Kg/m^3	Poisson's Ratio
1	Gray Cast Iron	120	7200	0.29
2	En-Gjs-400 – 15Steel	210	7850	0.3
3	E Glass Epoxy	276	1900	0.34
4	Aluminium Alloy A360	71	2700	0.33
5	Silicon Carbide	410	3100	0.14
6	Kevlar 49	154	1439.5	0.36

3. MATHEMATICAL CALCULATION

3.1 Specifications

Power = 73 hp @ 4700 rpm

Torque = 202.5 N-m @ 2800 rpm

Material used is pressed asbestos

μ =0.3

Maximum operating temperature .C = 150-250^{0}c

Maximum pressure P = 300 kN/m2

Outer ro and inner ri radius of friction faces

r_o=0.1145 mm, r_i= 0.0802 mm

n= numbers of contact surfaces

n= 2

R= mean radius of friction surfaces

For uniform pressure:

$R = 2/3[(r_o^3-r_i^3) / (r_0^2-r_i^2)]$ **(1)**

$= 2/3[(0.1145^3-0.0802^3) / (0.1145^2-0.0802^2)]$

= 0.09836m

For Uniform Wear

$R = (r_0+r_i) / 2$ **(2)**

= (0.1145+0.0802) / 2

= 0.09735m

3.2 MATHEMATICAL CALCULATION

A. For considering Uniform Pressure

When Uniformly Distributed pressure is applied over the entire area of friction face,

$$p = \frac{\text{load}}{\text{contacting surface area}} = \frac{W}{\pi\left(R_1^{\ 2} - R_2^{\ 2}\right)} \quad \textbf{(3)}$$

Where,

W = Axial thrust with friction surface

Frictional torque acting on the friction surfaces is included by

$T = n*\mu*w*R$ **(4)**

Where,

n = no of contact surfaces

μ = Coefficient of friction

R = mean radius of friction surfaces

T = 135 N-m

$W = T / (n*R*\mu)$ **(5)**

= 202.5 / (2*0.3*0.09735)

W = 3466.8721 N.

$P = W / [\pi (r_0^2-r_i^2)]$ **(6)**

$= 3466.8721 / [\pi (0.1145^2-0.0802^2)]$

P = 165.24 KN/m^2

B. For Considering Uniform Axial wear

Axial force is required to engage the clutch

$W = 2*C*\pi*(r_0-r_i)$ **(7)**

C = P*r [C = Constant]

The Maximum intensity pressure occurs at inner radius of friction surfaces

$C = P_{max}*r_i$ **(8)**

$C = W / \{2\pi*(r_0-r_i)\}$ **(9)**

= 3466.8721 / {2π (0.1145-0.0802)}

C = 16086.584 N/m

P_{max}= C / r_i

= 16086.584 / 0.0802

= 200.5808x10^3 N/m^2

The minimum intensity pressure occurs at outer radius of friction surface

P_{min}= C / r_0

= 16086.584 / 0.1145

= 140.4942x10^3 N/m^2

The Average pressure on the friction surface

P_{avg}= Total force on the friction surface / cross sectional area of friction surface

$P_{avg} = W / \{\pi (r_0^2-r_i^2)\}$

$P_{avg} = 3466.872 / \{\pi (0.1145^2-0.0802^2)\}$

P_{avg}= 165.2448x10^3 N/m^2

The maximum pressure applying on the friction plate.

P=200.2249×10^3 N/m^2.

The materials properties using in friction plate.

4. DESIGNING AND ANALYSIS OF SINGLE PLATE CLUTCH

The clutch design features 4 windows which can house springs which damper shatter to achieve an easy operation and to reduce the impact to the gear box at the engagement. The design also consists of a hole for the Hub to pass through at the Centre and 6 rivet holes.

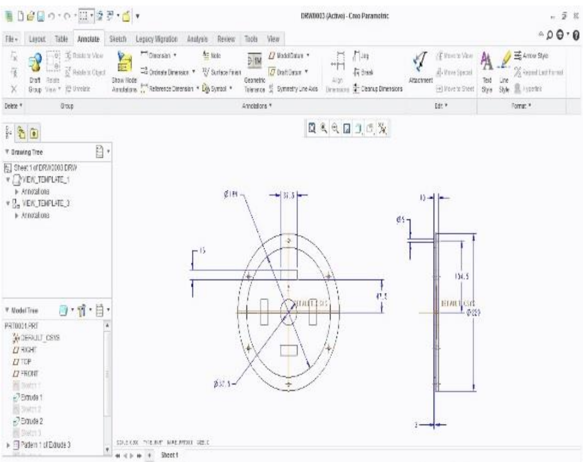

Fig 1. 2D sketch of clutch plate

4.1 Modelling

A 3D model of the clutch plate was prepared based on the sketch shown in figure 4.2 using creo 2.0 software as shown in figure

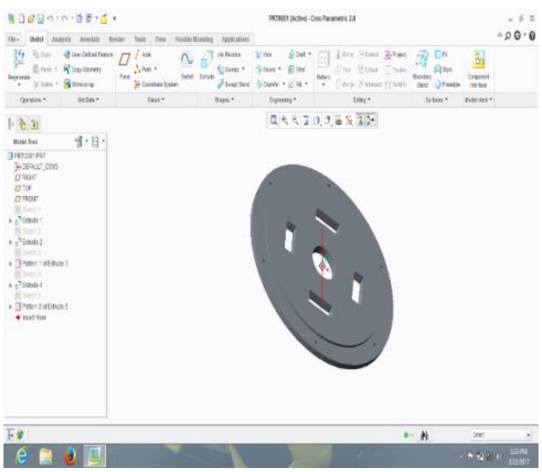

Fig 2. 3D model of the single plate clutch

4.2 Analysis

The 3D part model was then imported into Ansys Workbench analysis software. The material properties were assigned to the geometry as shown in table 1. The model was then meshed /divided into a finite number of elements using fine mesh option as shown in figure.

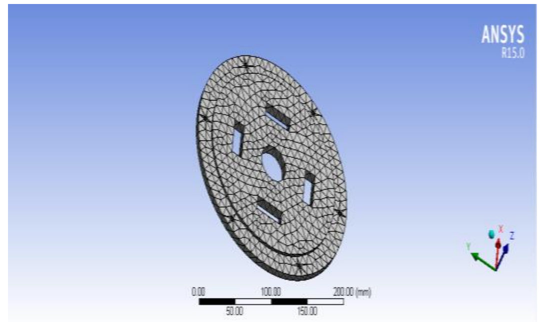

Fig 3. Meshed view of the Single plate clutch

A pressure plate is needed for engaging and disengaging the clutch disk. The pressure plate is riveted to the clutch. A clutch release bearing is positioned in front of a diaphragm spring. The pressure disk is mounted in a flexible manner

Such that when the release bearing is pushed inwards the pressure plate disengages and when release bearing is released the clutch comes in contact again with the pressure plate. Based on this logic boundary conditions were applied to the geometry.

5. STATIC STRUCTURAL ANALYSIS FOR SINGLE PLATE CLUTCH

5.1 Gray cast iron

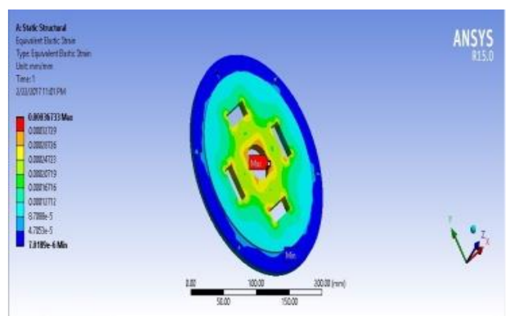

Fig 1.Equivalent elastic strain

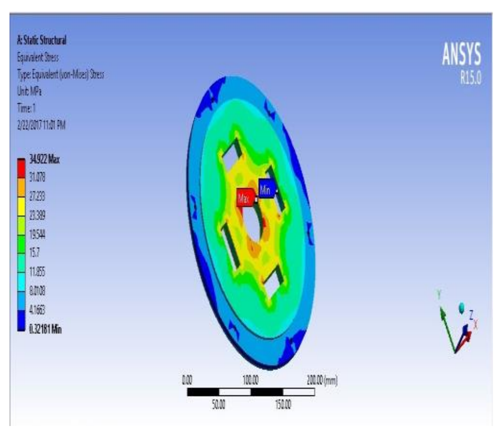

Fig 2. Equivalent (vonmises) stress

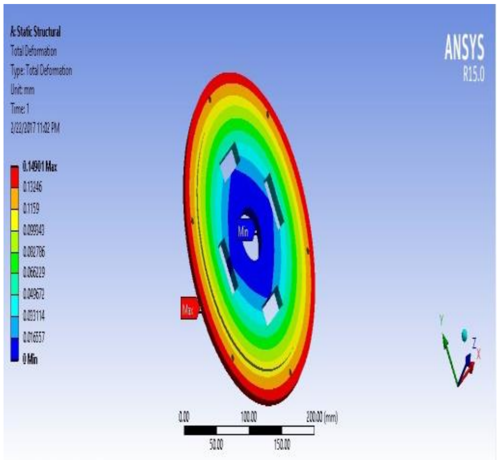

Fig 3.Total deformation

5.2 En-Gjs-400 – 15Steel

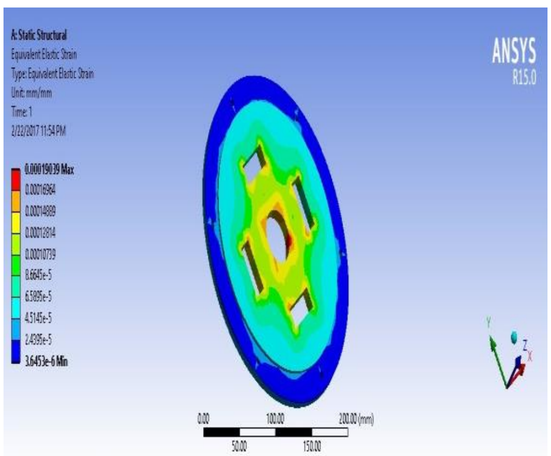

Fig 4.Equivalent elastic strain

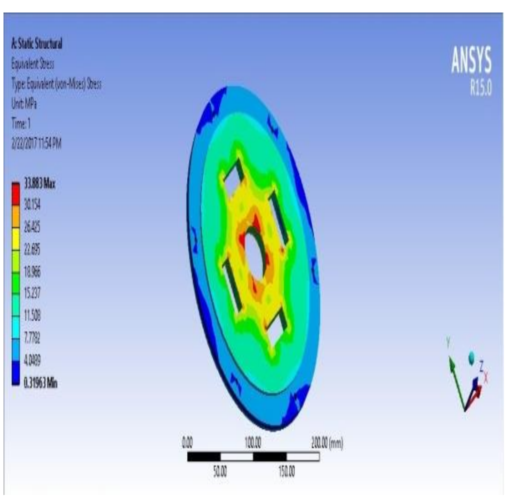

Fig 5. Equivalent (vonmises) stress

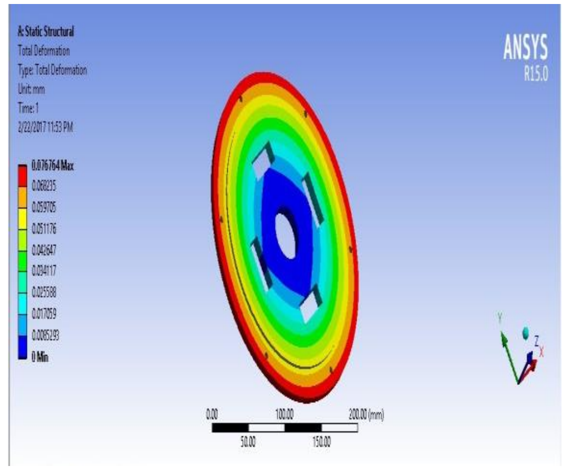

Fig 6.Total deformation

5.3 E Glass Epoxy

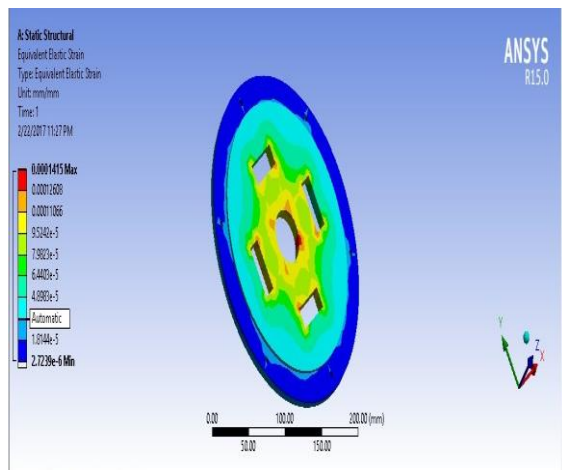

Fig 7.Equivalent elastic strain

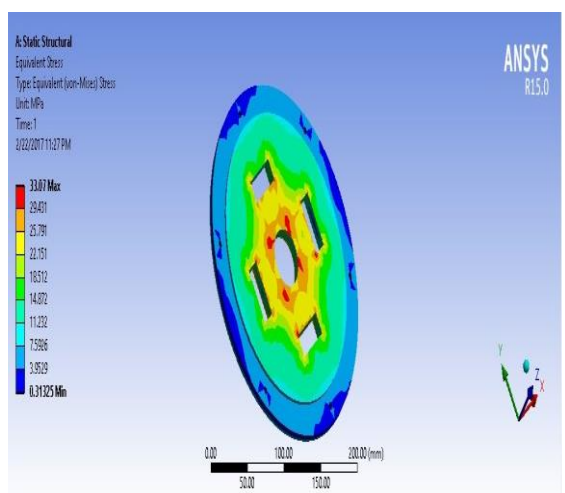

Fig 8. Equivalent (vonmises) stress

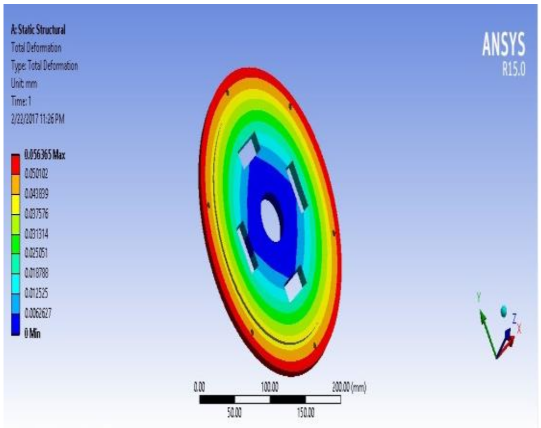

Fig 9.Total deformation

5.4 Aluminium Alloy A360

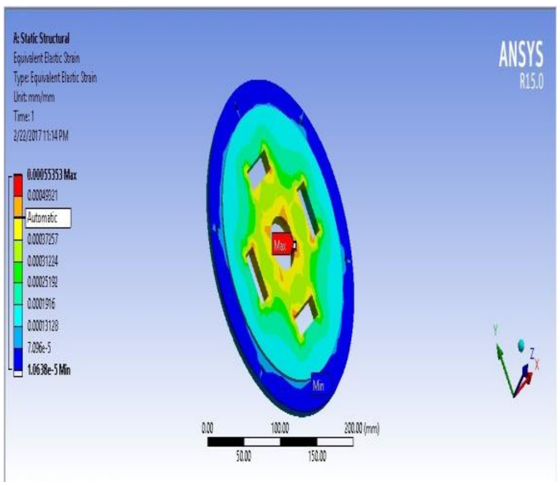

Fig 10.Equivalent elastic strain

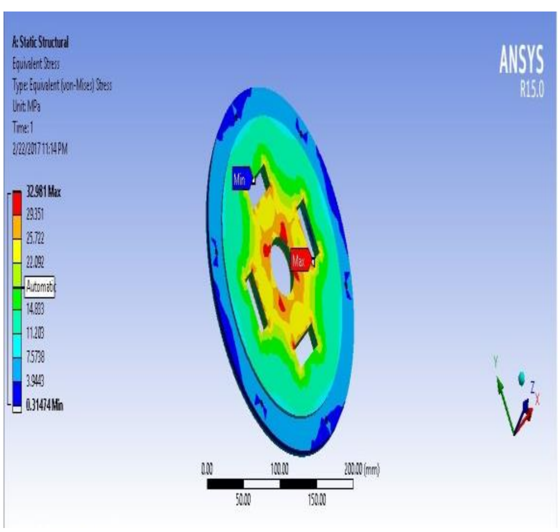

Fig 11. Equivalent (vonmises) stress

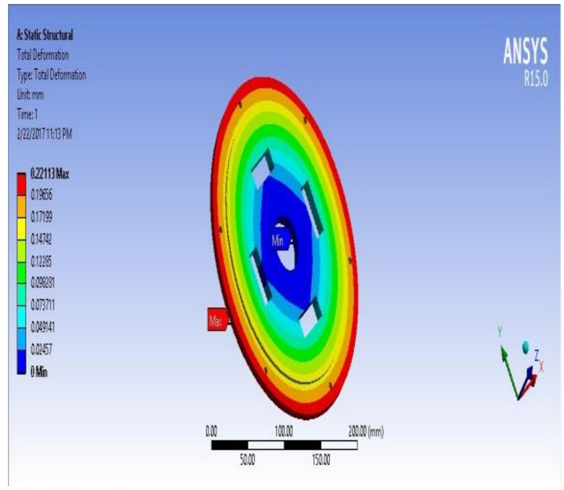

Fig 12.Total deformation

5.5 Silicon Carbide

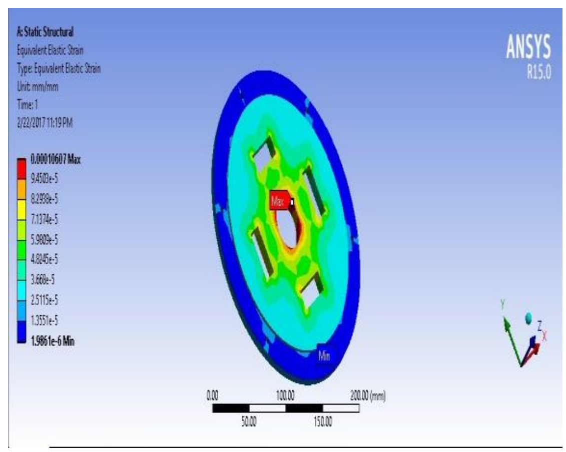

Fig 13.Equivalent elastic strain

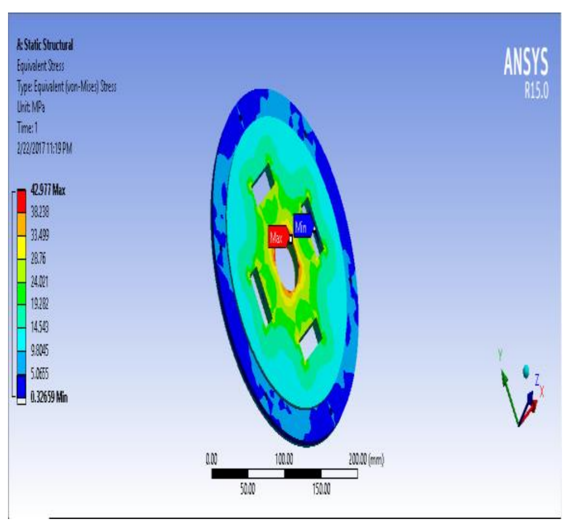

Fig 14.. Equivalent (vonmises) stress

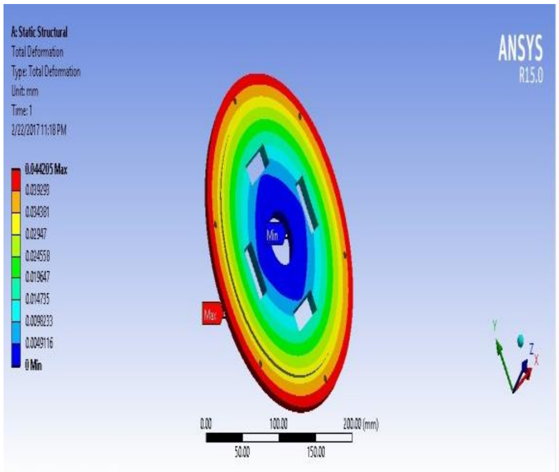

Fig 15.Total deformation

5.6 Kevlar 49

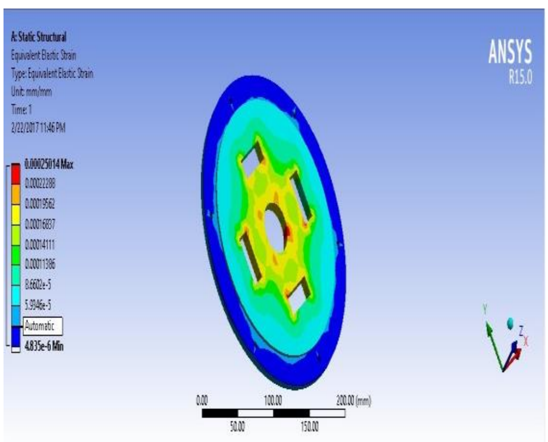

Fig 16.Equivalent elastic strain

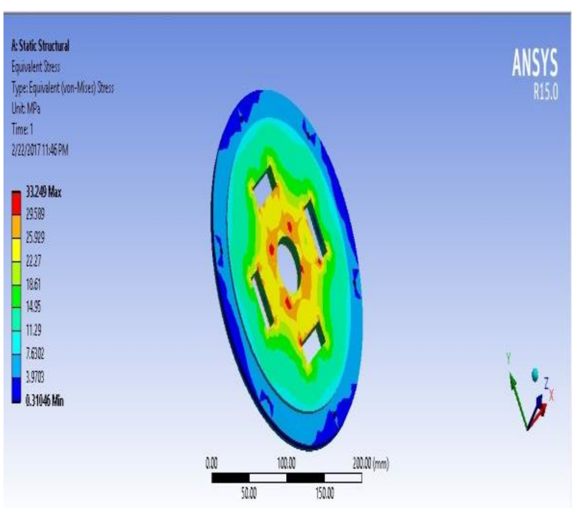

Fig 17. Equivalent (vonmises) stress

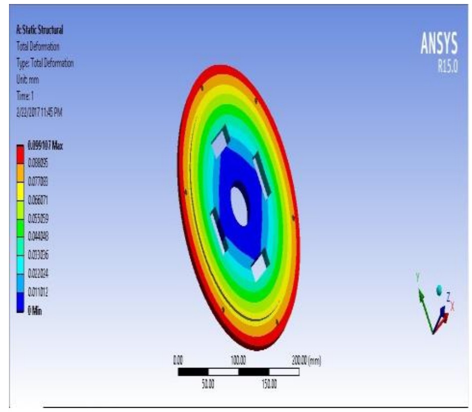

Fig 18.Total deformation

5.7 Table 2 Static analysis results

Material	Vonmises Strain	Vonmisses Stress (Mpa)	Total Deformation (mm)
Gray Cast Iron	0.00036733	34.922	0.14901
En-Gjs-400 – 15Steel	0.00019039	33.883	0.076764
E Glass Epoxy	0.0001415	33.07	0.056365
Aluminium Alloy A360	0.00055353	32.981	0.22113
Silicon Carbide	0.00010607	42.977	0.044205
Kelvar 49	0.00025014	33.249	0.099107

6. DYNAMIC ANALYSIS FOR SINGLE PLATE CLUTCH

6.1 Gray cast iron

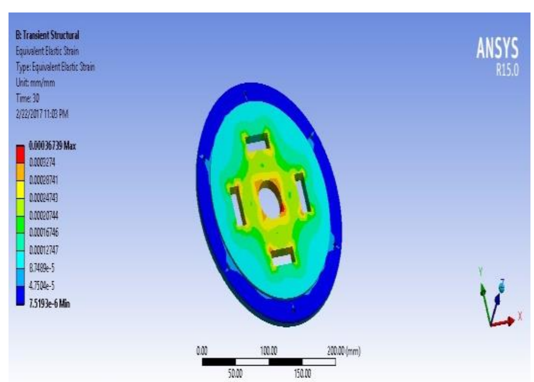

Fig 1.Equivalent elastic strain

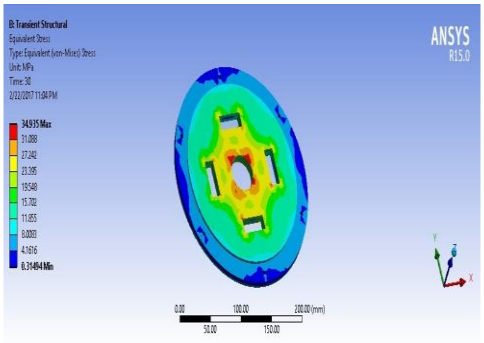

Fig 2. Equivalent (vonmises) stress

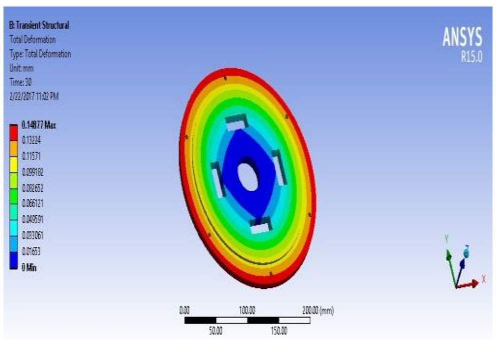

Fig 3.Total deformation

6.2 En-Gjs-400 – 15Steel

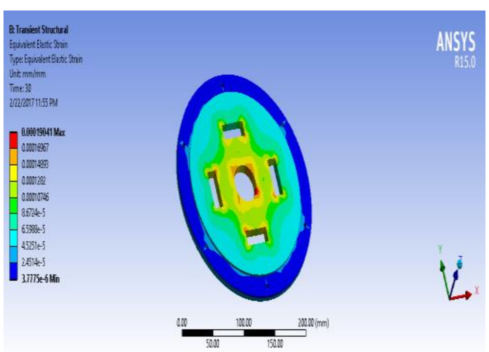

Fig 4.Equivalent elastic strain

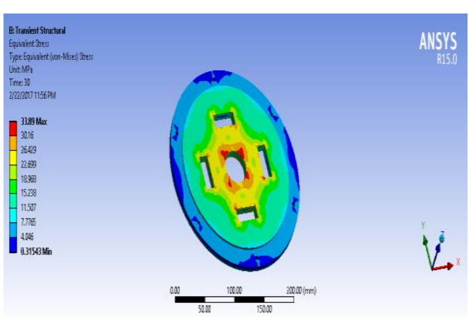

Fig 5. Equivalent (vonmises) stress

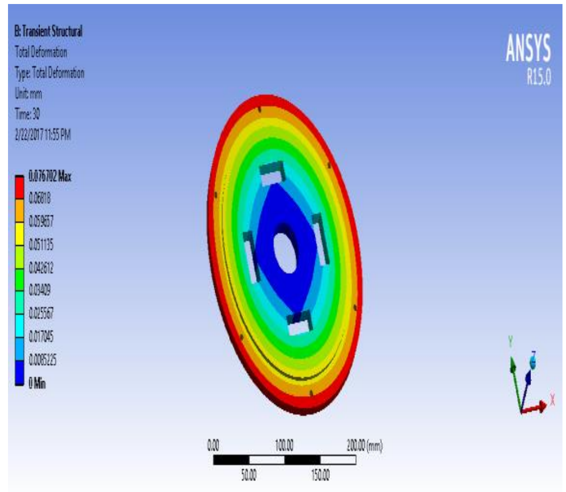

Fig 6.Total deformation

6.3 E Glass Epoxy

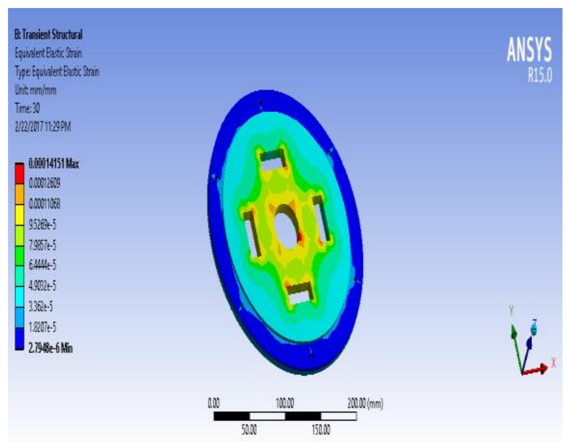

Fig 7.Equivalent elastic strain

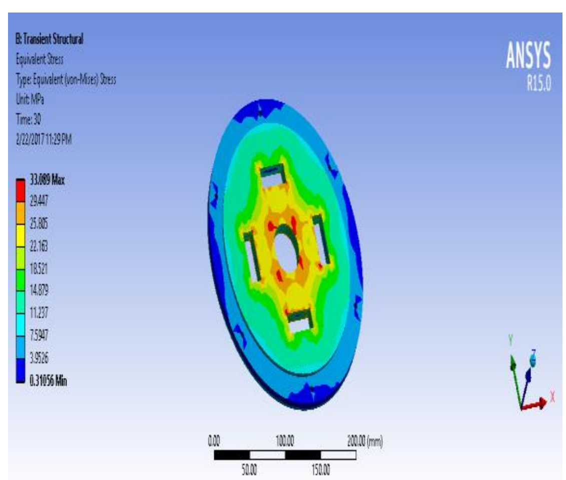

Fig 8. Equivalent (vonmises) stress

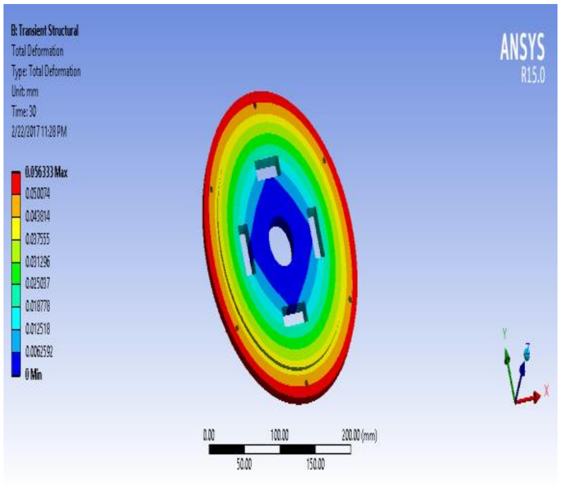

Fig 9.Total deformation

6.4 Aluminium Alloy A360

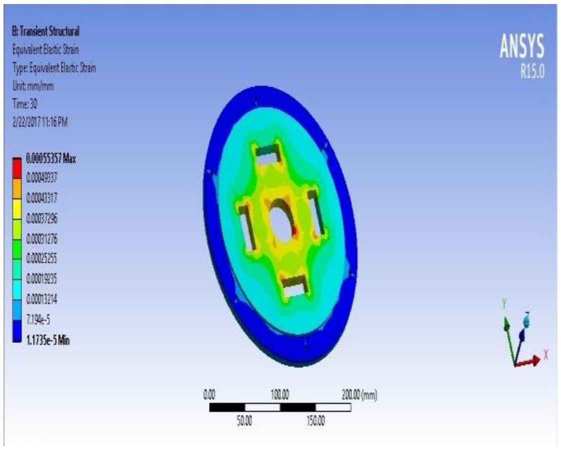

Fig 10.Equivalent elastic strain

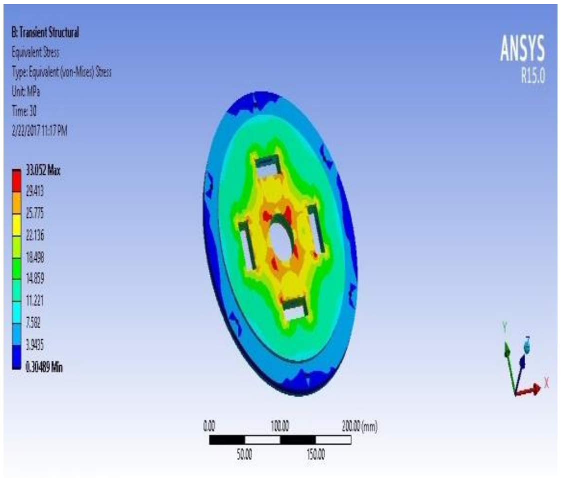

Fig 11. Equivalent (vonmises) stress

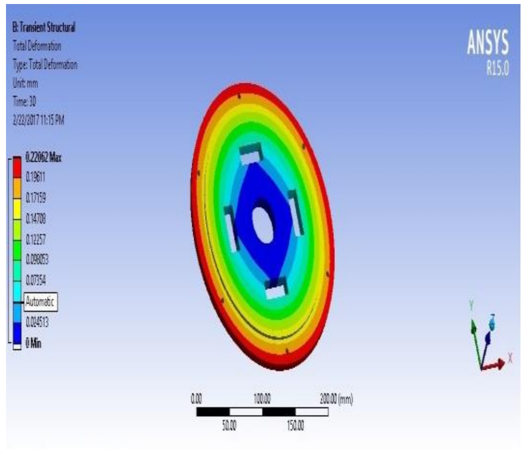

Fig 7 Total deformation

6.5 Silicon Carbide

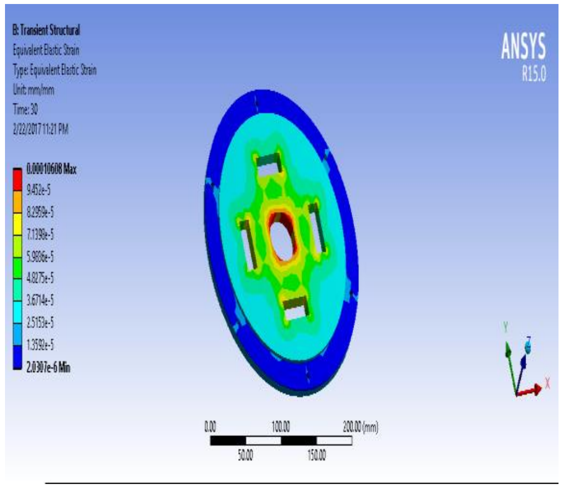

Fig 13.Equivalent elastic strain

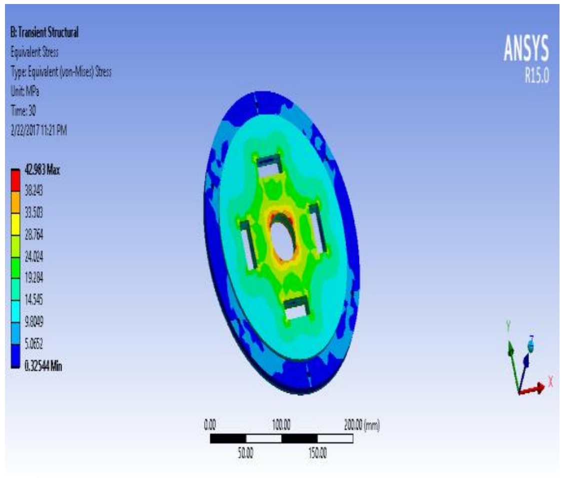

Fig 14. Equivalent (vonmises) stress

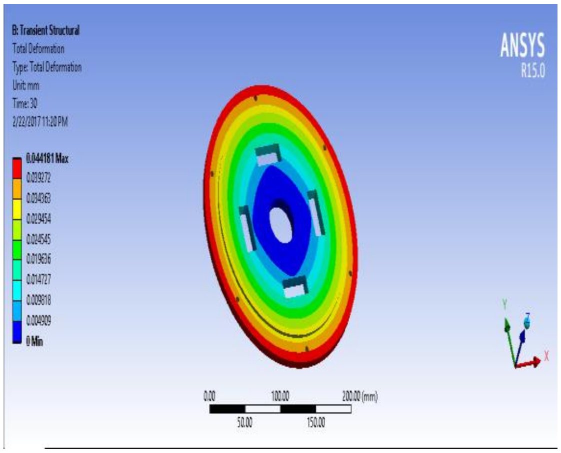

Fig 15.Total deformation

6.6 Kevlar 49

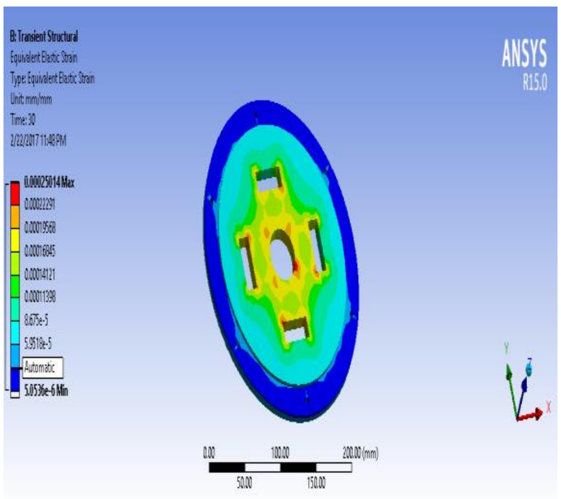

Fig 16.Equivalent elastic strain

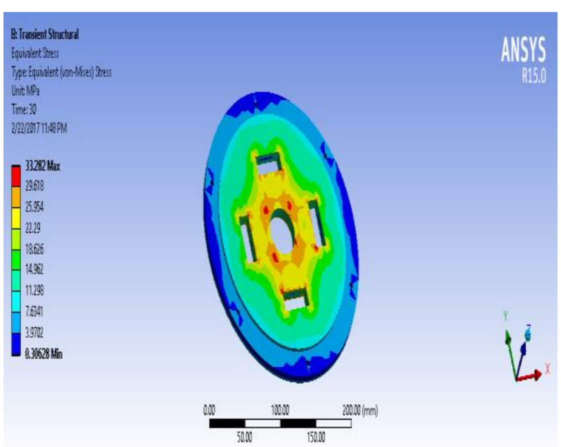

Fig 17. Equivalent (vonmises) stress

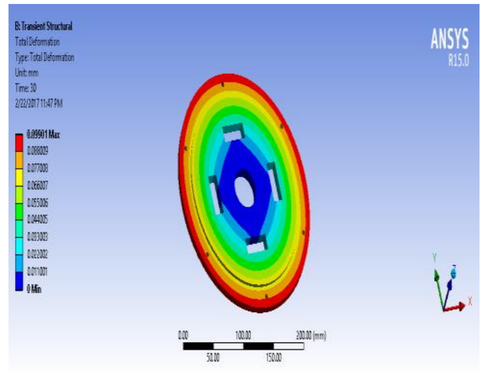

Fig 18.Total deformation

6.7 Dynamic Analysis Table

Material	Vonmises Strain	Vonmisses Stress (Mpa)	Total Deformation (mm)
Gray Cast Iron	0.00036739	34.935	0.14877
En-Gjs-400 – 15Steel	0.00019041	33.89	0.076702
E Glass Epoxy	0.00014151	33.089	0.056333
Aluminium Alloy A360	0.00055357	33.052	0.22062
Silicon Carbide	0.00010608	42.983	0.044181
Kelvar 49	0.00025014	33.282	0.09901

Table 3. Dynamic Analysis Results

7. RESULTS AND DISCUSSION

The design parameters (VonMises stress, VonMises strain and total deformation) obtained from the analysis were used to study the behavior of materials on the single plate clutch.

From the Table 2 and Table 3, the maximum stress value obtained for the overall component using Aluminium Alloy A360 friction material is 32.981 Mpa which is much less than the yield strength of material. Also, the maximum strain and maximum total deformation values obtained from the analysis are 0.00055353and 0.22113mm which are very less than the deformation limit of material (1mm).

In order to transmit the maximum torque from the engine to gearbox material should not get deformed beyond the safe limit. Ultimately, from the analysis, for all the materials, it is observed that for the rated torque the maximum stress developed in the clutch plate is very less than the yield strength of the material.

8. CONCLUSION

In this project, a single plate clutch is modelled in 3D modelling software CREO 2.0 and theoretical calculations and also static and dynamic analysis has done by using ANSYS Workbench 15.0. Present used material for clutch is Alloy steel. In this project, it is replaced with Gray cast iron, En-Gjs-400 – 15Steel, E Glass Epoxy, Aluminium Alloy A360, Silicon Carbide and Kevlar 49.Has been selected for friction plate and static and dynamic analysis has been done to find the total deformation, equivalent (vonmises) stress and equivalent elastic strain. By comparing the results it is clear that Aluminium Alloy A360 has less deformation than other materials. So using the materials is safe. By comparing the results between materials, Aluminium Alloy A360 is more advantageous than other materials due to its less weight and high strength.

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