

# Static and Dynamic Analysis of A Single Plate Clutch

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**Abstract-** The energy necessary for the motion of a vehicle is transmitted by the engine to the wheels through the flywheel, the clutch system and the driveline. 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. The present used material for friction disc is Cast Iron and aluminum alloys. In this project analysis is performed using composite materials. The composite materials are considered due to their high strength to weight ratio. In this paper composite material E Glass Epoxy and Aluminum Metal Matrix Composite are taken. A single plate clutch is designed and modeled using solid works software. Static analysis and Dynamic analysis are done on the clutch to determine stresses and deformations using materials Grey Cast Iron, Aluminum alloy 7075, E Glass Epoxy and Aluminum Metal Matrix Composite. Analysis is done in Ansys.

**Keywords-** Clutch, composite materials, Ansys, Solid works, MMC.

## INTRODUCTION

In an automobile several mechanical parts used, which conveys their own vital role to move the vehicle on road. Different mechanisms used for the proper functioning of machine parts and also provides comfort to the driver and take care of machine parts. The vehicle's wheel moves with the help of a transmission shaft together with a clutch mechanism.

The engine has the capability to produce the power but the power cannot be consumed directly by vehicles wheel, so there is a facility of a complete sequence of a mechanism used in a respective manner to transfer the rotational motion from engine to wheels via a transmission system. The main function of the clutch is to engage or disengage the transmission shafts according to the requirement. It is being placed between the engine shaft and gear shaft (gearbox). During the period of starting, gear changing, and stopping the vehicle, the clutch is used for disengagement. In the modern automobile industry, various types of clutch used on behalf of the convenience of the vehicle design. In this article, we are concentrated only on single plate clutch type clutch mechanism.

As by its name it is clear that it contains only one clutch plate and works on the principle of friction. This type of clutch is divided mainly into two members, first one is mounted on driver shaft and another one is on the drive shaft. In both of this one shaft is fixed and the other is movable, rotates in axial direction. The fixed shaft allows moving with the help of clutch mechanism in respective manner of splined shaft (movable shaft).

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. A popularly known application of clutch is in automotive vehicles where it is used to connect the engine and the gear box. Here the clutch enables to crank and start the engine disengaging the transmission Disengage the transmission and change the gear to alter the torque on the wheels. Clutches are also used extensively in production machinery of all types.

## II. LITERATURE SURVEY

**May Thin Gyan [1]** This paper explains the design of single plate clutch 2 drawing is drafted by using theoretical calculations. The strength of friction plate is done by using Solid Works. Friction materials used are

cast iron, alloy steel and copper. By observing the analysis results are shown the stress, strain and displacement values of the three materials. When comparing the stress values of the three materials, the stress values of other two materials are greater than the stress value of cast iron. The result of this paper, using cast iron as friction material is advantageous than using alloy steel and copper as friction material. The cast iron using as friction material is the best for single plate clutch.

**RaviKiran M. Tate [2]** In this paper they have modeled a single plate clutch from theoretical calculation and the 3D drafting is done through CATIA V5. The clutch base plate and Friction liner plate are analyzed through ANSYS. The friction material is taken as FTL097 and it is found that Maximum stress in all conditions is well below the allowable limit hence both parts are safe, Negligible deformation is seen in case of clutch liner thereby suitable for clutch lining as it will result in lesser wear.

**Sandhya Rani [3]** In this paper structural analysis is conducted for validating design by varying the friction surfaces material. By extracting the result, find out the best material for the lining of friction surfaces. Here Materials used as liner is composite materials. They are carbon- carbon composites, Kevlar29 and ceramic composites. Comparison is done for above materials to validate better lining material for clutch plate.

**Nivas [4]** In this paper Maximum deformation in mm (pressure plate) is found out after analyzing the materials, then von mises stress in MPa (overall component) also found out by which they conclude suitability of EN GJS-400-15 steel for the production of clutch plate is better than Grey Cast Iron (FG300). En 15 steel reduces the Stress on the support link is 167.911 MPa, where as the yield stress of FG300 is 181.033, so the life of the material should be high. Stress on the pressure plate is reduced to 46.937 MPa, whereas stress on grey cast iron is 52.145 Mpa.

**Virendra Kumar Patel [5]** This paper explains the friction force produced by the clutch pressure plate should be directly proportional to the Normal load after analyzing the materials, they found out von mises stress in MPa (overall component) than conclude the suitability of EN GJS-400-15 steel for the production of clutch plate is better than Grey Cast Iron (FG300).

**S. Jaya Kishore [6]** In this paper they have designed a multi plate clutch using theoretical calculations. 2D drawings are drafted from the calculations. 3D model of the multi plate clutch parts and assembly are done in CREOPro/Engineer software. Structural analysis is done on the friction plates to verify the strength. Friction materials used are Cork and Powder Metal. By observing the analysis results, the stress and strain values for copper

powder metal is less than Cork respective values. So, they expected that for multi plate clutches using powder metal as friction material is advantageous than using cork as friction material.

**SyambabuNatalapati [7]** The aim of this paper is to develop the material selection method and select the optimum material for the application of brake disc system emphasizing on the substitution of this cast iron by any other lightweight material. Two methods are introduced for the selection of materials, such as cost per unit property and digital logic methods. Material performance requirements were analyzed, and alternative solutions were evaluated among cast iron, aluminium alloy, titanium alloy, ceramics and composites. Mechanical properties including compressive strength, friction coefficient, wear resistance, thermal conductivity and specific gravity as well as cost, were used as the key parameters in the material selection stages. The analysis led to aluminium metal matrix composite as the most appropriate material for brake disc system.

**Khamlichi [8]** In this work, a rational approach based on Taguchi technique and Pin-on-disk test is used to study the friction coefficient behavior of clutch facings as function of material formulation. Experiments were designed according to the orthogonal array L8 where the chosen factors are temperature and sliding speed. A complex interaction exists between the surface texture of the produced clutch facings and the used manufacturing process parameters, particularly those associated to molding and grinding operations.

Since it is not straightforward to render this effect in terms of explicit factors, it is roughly considered here as noise affecting a chosen wear path during Pin-on-disk testing. Signal over noise ratio should be sufficiently high in order that qualification test results obtained for a given material formulation could be possible. For the set of parameters considered during the actual experiment, the friction coefficient behavior of clutch facings was shown to be mainly controlled by the sliding speed or by the interaction between the sliding speed and temperature.

### III. SINGLE PLATE CLUTCH

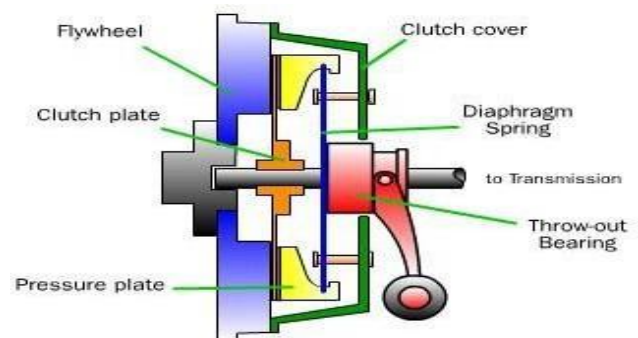


Fig 1. Single plate clutch.

The clutch used in automotive applications is generally a single plate dry clutch. In this type the clutch plate is interposed between the flywheel surface of the engine and pressure plate.

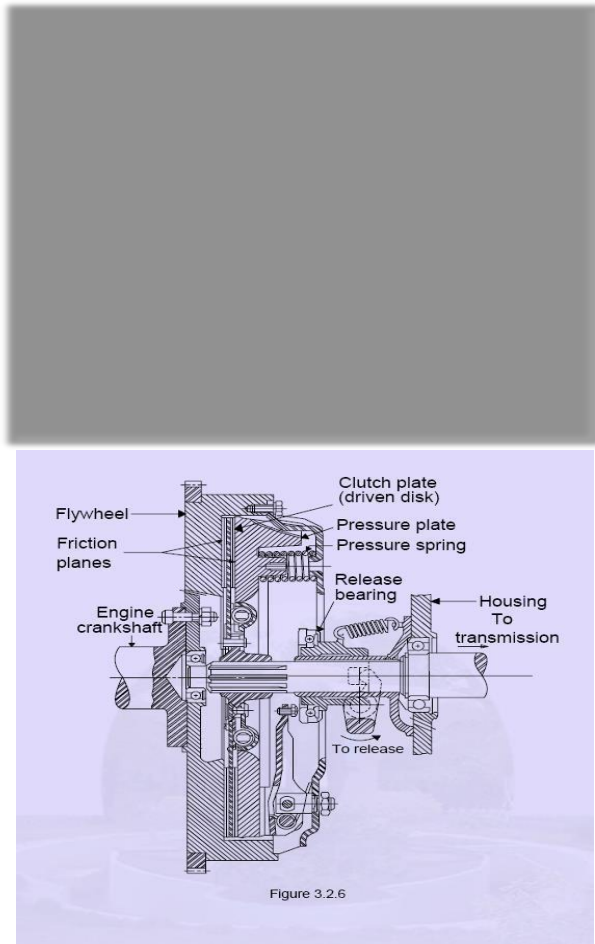


Fig 2. Parts of clutch plate.

Basically, the clutch needs three parts. These are the engine flywheel, a friction disc called the clutch plate and a pressure plate. When the engine is running and the flywheel is rotating, the pressure plate also rotates as the pressure plate is attached to the flywheel. The friction disc is located between the two. When the driver has pushed down the clutch pedal the clutch is released. This action forces the pressure plate to move away from the friction disc. There are now air gaps between the flywheel and the friction disc, and between the friction disc and the pressure plate. No power can be transmitted through the clutch.

### 1. Operation of Clutch:

When the driver releases the clutch pedal, power can flow through the clutch. Springs in the clutch force the pressure plate against the friction disc. This action clamps the friction disk tightly between the flywheel and the pressure plate. Now, the pressure plate and friction disc rotate with the flywheel.

As both side surfaces of the clutch plate is used for transmitting the torque, a term 'N' is added to include the number of surfaces used for transmitting the torque.

By rearranging the terms, the equations can be modified, and a more general form of the equation can be written as

$$T=N.f.F_a.R_m$$

T is the torque (Nm).

N is the number of frictional discs in contact. F is the coefficient of friction  $F_a$  is the actuating force (N).

$R_m$  is the mean or equivalent radius (m).

Note that

$$N = n_1 + n_2 - 1$$

Where  $n_1$  = number of driving discs  $n_2$  = number of driven discs

Values of the actuating force F and the mean radius  $r_m$  for the two conditions of analysis are summarized and shown in the table.

## IV. METHOD OF ANALYSIS

The torque that can be transmitted by a clutch is a function of its geometry and the magnitude of the actuating force applied the condition of contact prevailing as well between the members. The applied force can keep the members together with a uniform pressure all over its contact area and the consequent analysis is based on uniform pressure condition.

### Uniform Pressure and wear:

However, as the time progresses some wear takes place between the contacting members and this may alter or vary the contact pressure appropriately and uniform pressure condition may no longer prevail. Hence the analysis here is based on uniform wear condition.

### 2. Elementary Analysis:

Assuming uniform pressure and considering an elemental area  $dA$

$$dA = 2\pi.r.dr$$

The normal force on this elemental area is

$$dN = 2.\pi.r.dr.p$$

The frictional force  $dF$  on this area is therefore

$$dF = f.2.\pi.r.dr.p$$

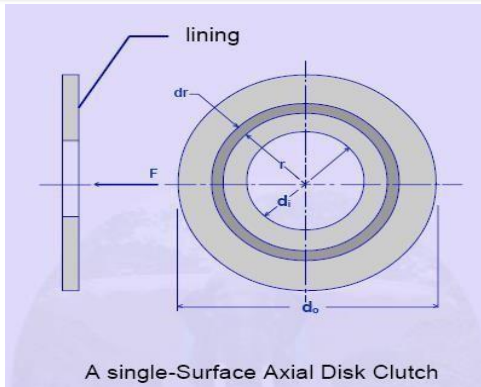


Fig 3. A single-surface axial Disk Clutch.

Now the torque that can be transmitted by this elemental are is equal to the frictional force times the moment arm about the axis that is the radius 'r' i.e.

$$\begin{aligned} T &= dF \cdot r \\ r &= f \cdot dN \\ r &= f \cdot p \cdot A \\ T &= f \cdot p \cdot 2 \cdot \pi \cdot r \cdot dr \cdot r \end{aligned}$$

The total torque that could be transmitted is obtained by integrating this equation between the limits of inner radius r<sub>i</sub> to the outer radius r<sub>o</sub>

$$T = \int_{r_i}^{r_o} 2\pi p f r^2 dr = \frac{2}{3} \pi p f (r_o^3 - r_i^3)$$

Integrating the normal force between the same limits we get the actuating force that need to be applied to transmit this torque.

$$\begin{aligned} F_a &= \int_{r_i}^{r_o} 2\pi p r dr \\ F_a &= \pi (r_o^2 - r_i^2) p \end{aligned}$$

Equation 1 and 2 can be combined together to give equation for the torque

$$T = f F_a \cdot \frac{2}{3} \frac{(r_o^3 - r_i^3)}{(r_o^2 - r_i^2)}$$

### 3. Specific Capabilities of Ansys:

#### 3.1 Structural:



Fig 4. Structural analysis.

Structural analysis is probably the most common application of the finite element method as it implies bridges and buildings, naval, aeronautical, and mechanical structures such as ship hulls, aircraft bodies, and machine housings, as well as mechanical components such as pistons, machine parts, and tools.

#### 3.2 3d Model of Single Plate Clutch:

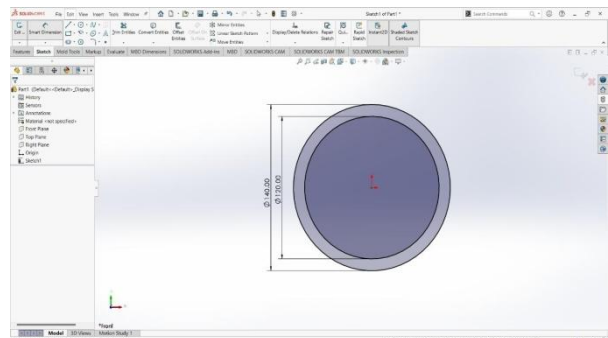


Fig 5. Sketch of plate.

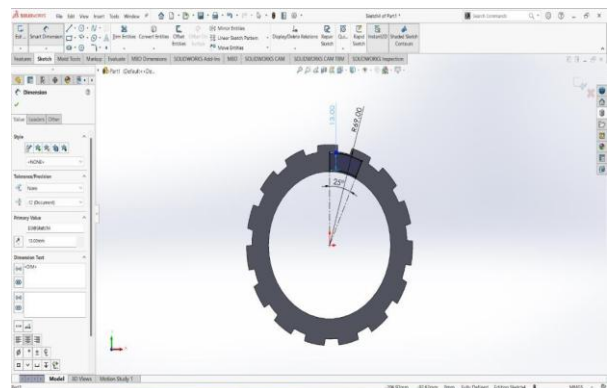


Fig 6. Extrude 3.

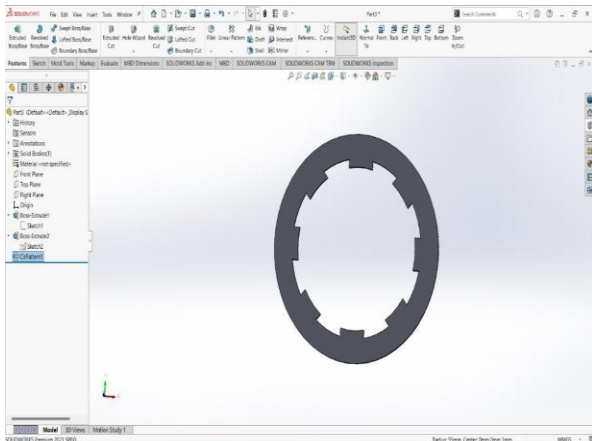


Fig 7. Pattern of extrude.

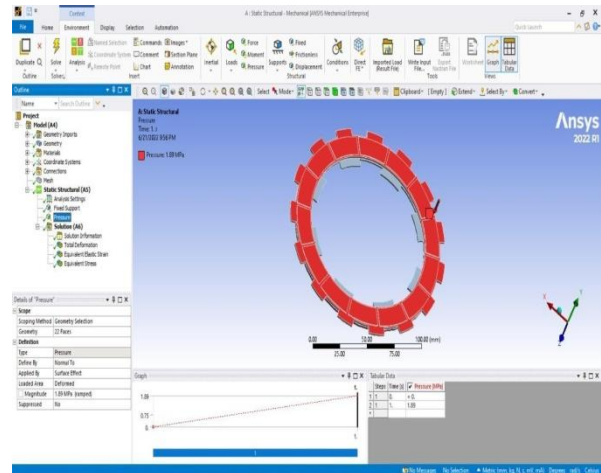


Fig 10. Pressure is applied on friction plate.

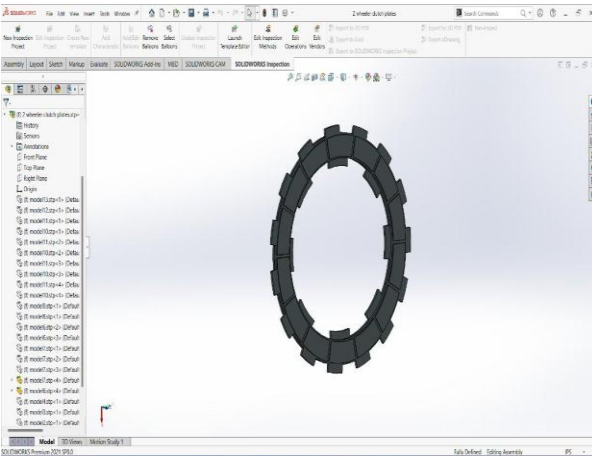


Fig 8. Assembly of single plate clutch.

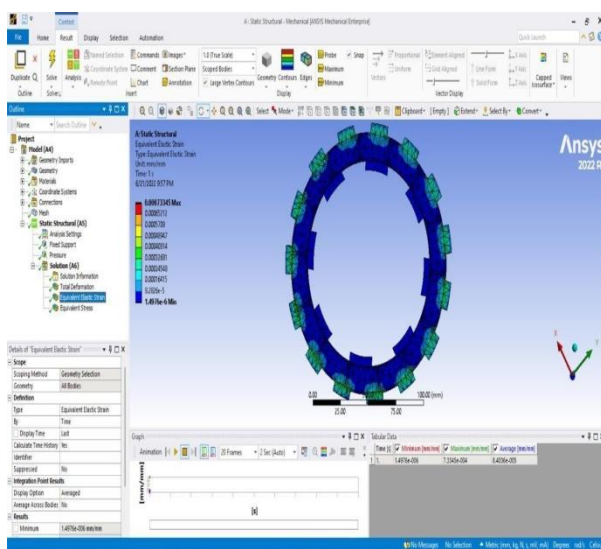


Fig 11. Strain of single plate clutch for Aluminum 7075.

## V. ANALYSIS OF SINGLE PLATE CLUTCH

### 1. Static Structural Analysis:

#### 1.1 Aluminium 7075:

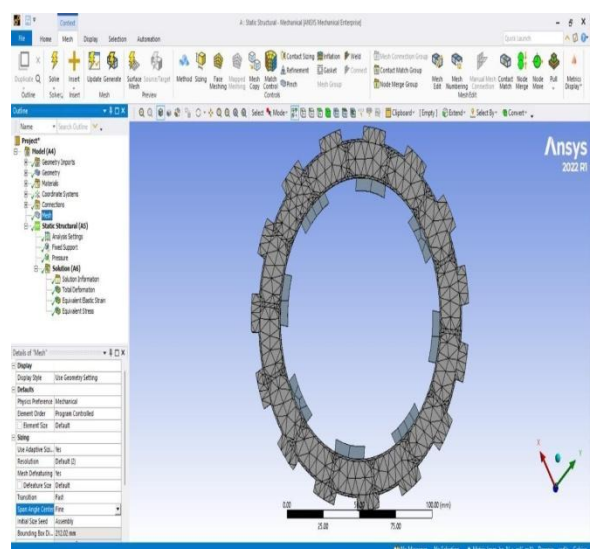


Fig 9. Meshed model.

#### 1.2 Aluminum MMC:

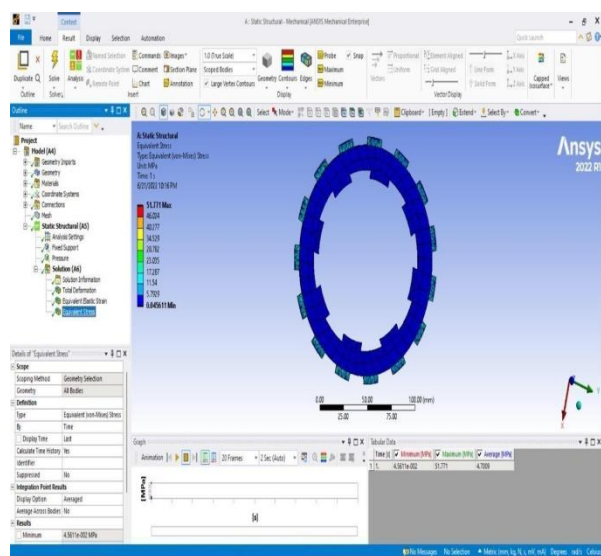


Fig 12. Stress of single plate clutch for Aluminum MMC.

**1.3 Gray Castiron:**

Fig 9.12 Total deformation of single plate clutch for Grey cast iron.

**1.4 E-Glass Epoxy:**

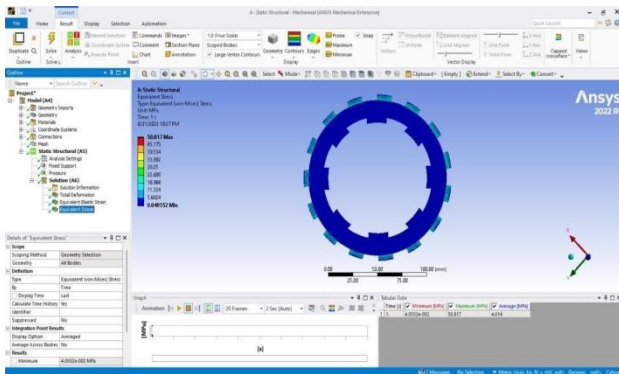


Fig 13. Stress of single plate clutch for E-glass epoxy.

**2. Modal Analysis:**

**2.1 Aluminum 7075:**

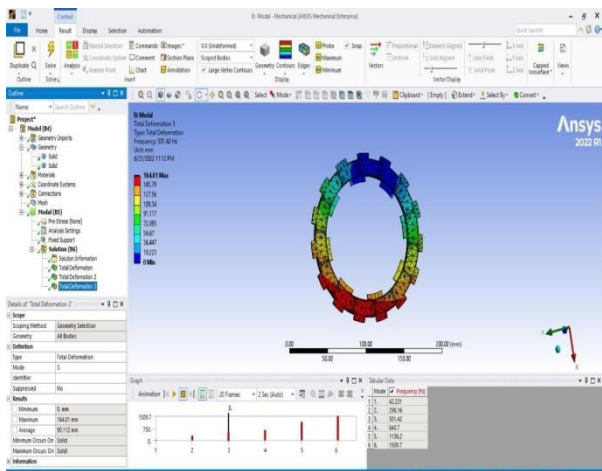


Fig 14. Total deformation at mode 3 of single plate clutch for Aluminum 7075.

**2.2 Aluminum MMC:**

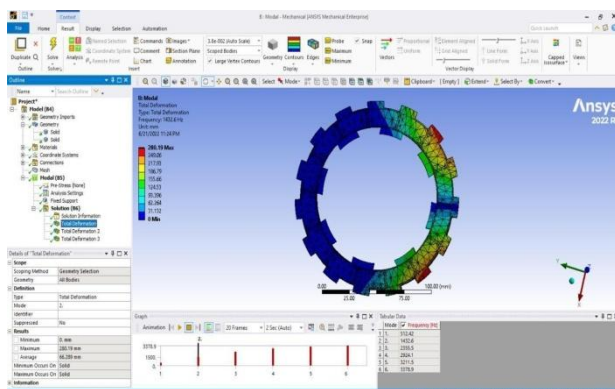


Fig 15. Total deformation at mode 1 of single plate clutch for Aluminum MMC.

**2.3 Grey Cast Iron:**

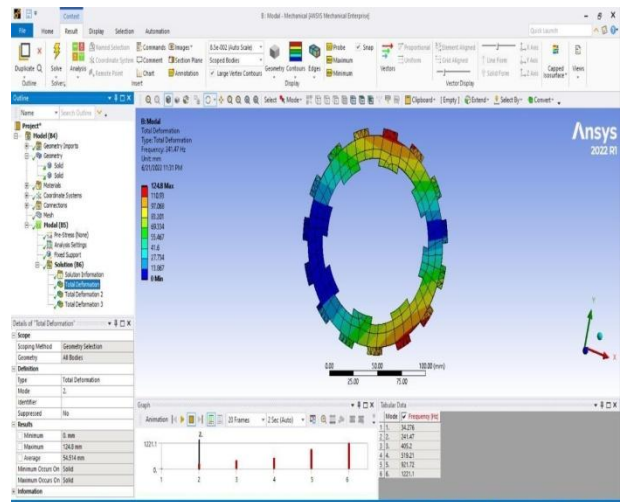


Fig 16. Total deformation at mode 1 of single plate clutch for Grey Cast Iron.

**2.4 E-Glass Epoxy:**

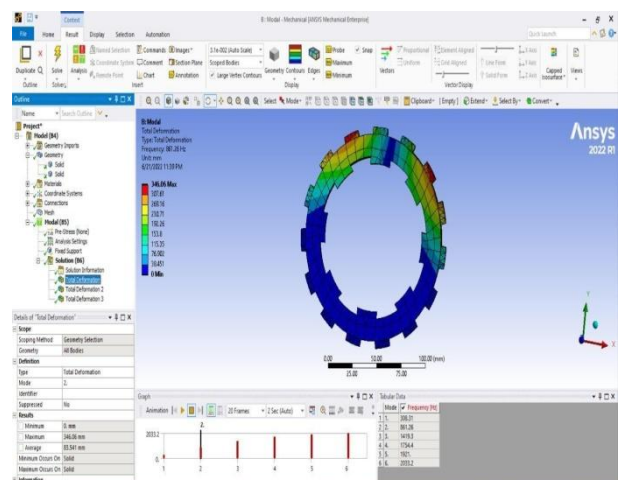


Fig 17. Total deformation at mode 1 of single plate clutch for E Glass Epoxy.

**VI. RESULTS & DISCUSSIONS**

**1. Static Structural Analysis Table:**

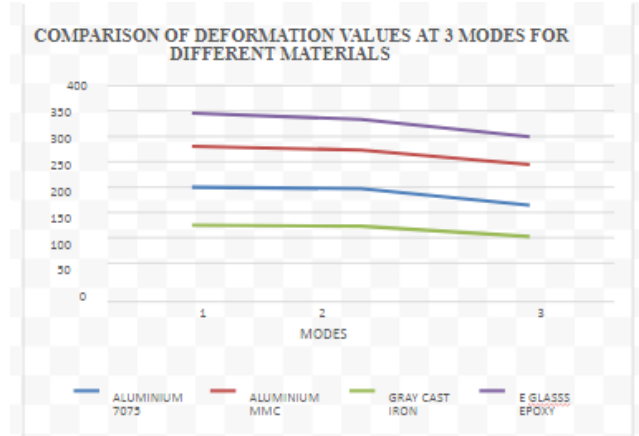
Table 1. Static Analysis Results.

Materials	Aluminium 7075	Aluminium MMC	Gray Cast Iron	E Glass Epoxy
Total Deformation	0.0098953	0.0062744	0.0060423	0.0098953
Equivalent Strain	0.00073345	0.00046285	0.00044552	0.00073348
Equivalent Stress	50.814	51.771	52.102	50.817

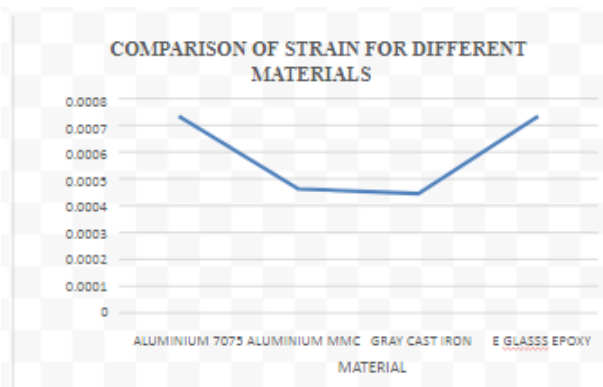
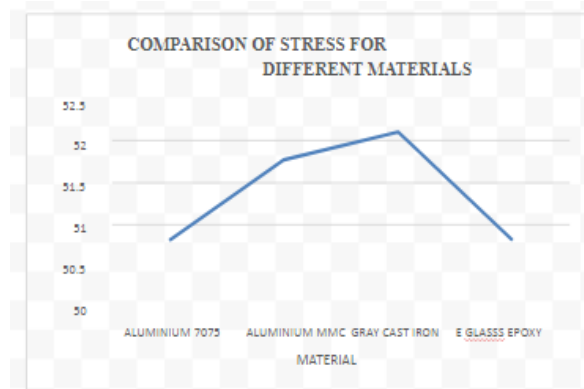
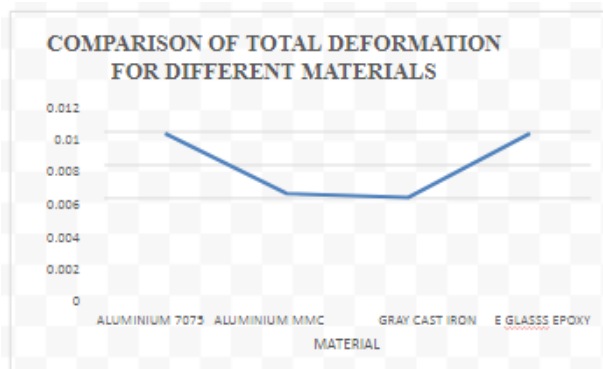
## 2. Modal Analysis Table:

Table 2. Modal Analysis Results.

Materials	Aluminium 7075	Aluminium Mmc	Gray Cast Iron	E Glass Epoxy
Total Deformation	199.89	280.19	124.8	346.06
Total Deformation 2	196.96	273.33	123.05	333.46
Total Deformation 3	164.01	244.37	102.46	299.25



## 3. Graphs:



## VII. CONCLUSION

In this project, a single plate clutch is modeled in 3D modeling software SOLID WORKS. Present used material for clutch is Cast Iron. In this, it is replaced with Aluminum alloy 7075, Aluminum metal matrix composite, Grey cast iron and composite material E – Glass Epoxy. The advantage of using aluminum alloys is their light weight. The advantage of using composite material is their strength to weight ratio. Static and modal analysis is performed on the clutch using Ansys.

By observing the static analysis results, the analyzed stress values are less than the respective yield stress values of Aluminum alloy 7075, Aluminum MMC, Gray cast iron and E – Glass epoxy. So using the materials is safe. By comparing the results between materials, E – Glass Epoxy is more advantageous than other materials due to its less weight and high strength. By observing modal analysis results, the deformations are more when E – Glass Epoxy is used when compared to other materials. So it can be concluded that E Glass Epoxy is better.

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