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Finite Element Analysis of Single Plate Clutch by using Ansys

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Abstract: 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 thesis analysis is performed using composite materials. The composite materials are considered due to their high strength to weight ratio. In this thesis composite material kevlar and aluminium Metal Matrix Composite are taken. A single plate clutch is designed and modeled using Catia V5 software. Static analysis is done on the clutch to determine stresses and deformations using materials Grey Cast Iron, sintered iron, kevlar and aluminium Metal Matrix Composite. Analysis is done in Ansys16.0. Theoretical calculations are also done to determine stresses.
Keyword: Clutch, Static analysis, Ansy16.0s, Catia V5.

I. INTRODUCTION

Although the first use of a dry single-plate clutch was by Duryea in 1893, it was not until 1921 that a design was developed that would not burn out in a few hundred miles, thanks to Englishman Herbert Frood, who perfected more durable friction materials. In the simplest application, clutches connect and disconnect two rotating shafts (drive shafts or line shafts). In these devices, one shaft is typically attached to an engine or other power unit (the driving member) while the other shaft (the driven member) provides output power for work. While typically the motions involved are rotary while linear clutches are also possible. Some of the consideration for designing clutch assembly is Suitable Friction Material for friction liner, Sufficient torque transmitting capacity, Engagement with minimum Shock and jerking, Weight of rotating parts should be low to decrease the inertial forces to increase the sensitivity of application of forces, Suitable provision for changing the friction lining and thermal distribution due to frictional heat should be uniform and the rate of increase of temperature should be less. In case of clutch the main problem occurs in the clutch material. The material gets damaged and so the maximum performance can’t be achieved further. Some important requirements of clutch material is high co-efficient of friction, co-efficient of friction should be remain constant throughout the working temperature of clutch plate, good thermal conductivity for better thermal distribution, remain unaffected by environmental conditions, moisture and dirt particles, high resistance to abrasive and adhesive wear, good resilience to provide good distribution of pressure at the connecting surfaces.

II. LITERATURE REVIEW

A. May Thin Gyan

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.

B. Virendra Kumar Patel

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 misses 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).they take friction plate of sintered iron which have good performance index.

C. Sandhya Rani

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.

D. Ravikiran M. Tate

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.

E. S. Sreevani

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.

III. SCOPE OF PRESENT WORK

In this system, friction plate of single plate clutch will be studied by doing structural analysis on different materials. Previous research was done on cast iron and ceramics. In this research static structural analysis of cast iron, sintered iron kevlar and aluminium metal matrix composite, for a friction plate will be done because composite material have high strength to weight ratio.
The objectives of this study are:

A. To develop 3D CAD model of single plate clutch and friction plate.
B. To study the behavior of different material of single plate clutch under static analysis.
C. To calculate the total deformation, stress, strain which is developed on a friction plate of cast iron, sintered iron, Kevlar, and aluminium metal matrix composite.
D. To compare all the four results and conclude a best material for the selection of a friction plate.

IV. METHOD AND MATERIAL

A model is created with the help of computer aided drafting software, CATIA V5. Using CATIA software we can create 3D model of friction plate as per measurement data and can Import the CATIA Model (IGES) in the Ansys Workbench 16.0 for pre-processing and then the structural analysis is done on the friction plate. The Analysis involves the discretization called meshing, boundary conditions and loading. For analysis we take cast iron, sintered iron, kevlar and aluminium metal matrix composite.

A. Specifications of friction plate

Power = 52.5KW @ 3600 rpm
Torque = 195 N-m @1400-2200RPM
Material used is pressed asbestos on cast iron or steel $\mu = 0.35$
Maximum operating temperature ^{0}C = 150 – 250
Maximum pressure N/mm^2 = 0.4
r1 and r2 outer and inner radius of friction faces r_1 =114.5mm and r_2 =80 mm
R = mean radius of friction surfaces
For uniform pressure

$$R = \frac{2}{3} \times \frac{r1^3 - r2^3}{r1^2 - r2^2} = \frac{2}{3} \times \frac{114.5^3 - 80^3}{114.5^2 - 80^\wedge 2} = 98.26mm = .09826m$$

For uniform wear $R = \frac{r1+r2}{2} = \frac{114.5+80}{2} = 97.25mm = .09725mm$

B. Considering Uniform Pressure

When the pressure is uniformly distributed over the entire area of the friction face then the intensity of pressure P

$P = W/ \{\pi (r_1^2 - r_2^2)\}$

Where W = axial thrust with which the friction surfaces are held together.

In general frictional torque acting on the friction surfaces or on the Clutch is given by-

$T = n \times \mu \times W \times R$

n = no of pairs of friction surfaces for single plate clutch n = 2

R = mean radius of friction surfaces

μ = coefficient of friction

$T = 195 = 2 \times 0.35 \times W \times 0.9826$

$W=2835.04 N/m^2$

$$P = \frac{W}{\pi(r1^2 - r2^2)} = \frac{2835.04}{\pi(0.1145^2 - 0.80^2)} = 136.392 \times 10^3 N/mm\text{^}2$$

C. For Considering Uniform Axial Wear

Axial force is required to engage the clutch

$W=2\pi C (r_1-r_2)$

$C=P \times r$ (C=constant)

The maximum intensity pressure occurs at inner radius (r_2) of friction surface

$C = P_{max} \times r_2$

$C = W/ (r_1-r_2) = 2835.04/(.1145-.080) = 13078.58$

$P_{max} = C/r_1 = 13078.58/0.08 = 164871 N/m^2 = 0.165 MPa$

The minimum intensity pressure occurs at outer radius (r_1) of friction surface

$P_{min} = C/r_1 = 13277.79/0.1145 = 115963 N/m^2 = 0.115 MPa$

Figure 1 and 2 shows the single plate clutch and friction plate. The average pressure on the friction surface

P_{avg}= (Total force on friction surface) / (Cross -sectional area of friction surface)

$P_{avg} = W/\pi(r_1^2-r_2^2) = 136392 N/m^2$

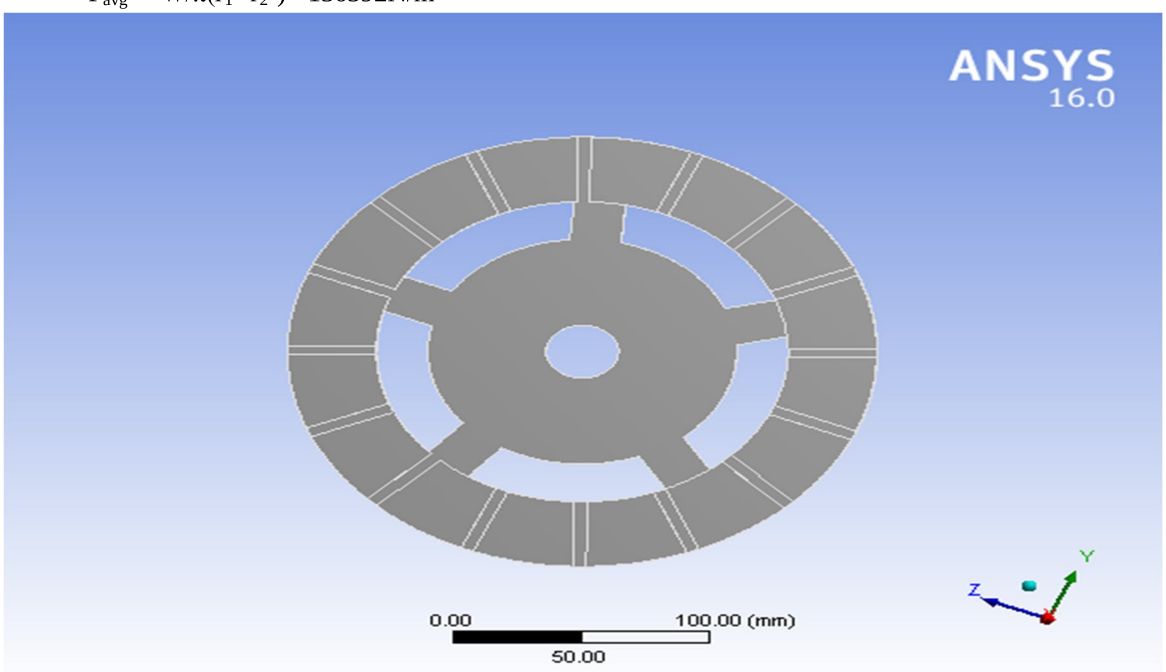

Fig: 1- clutch plate

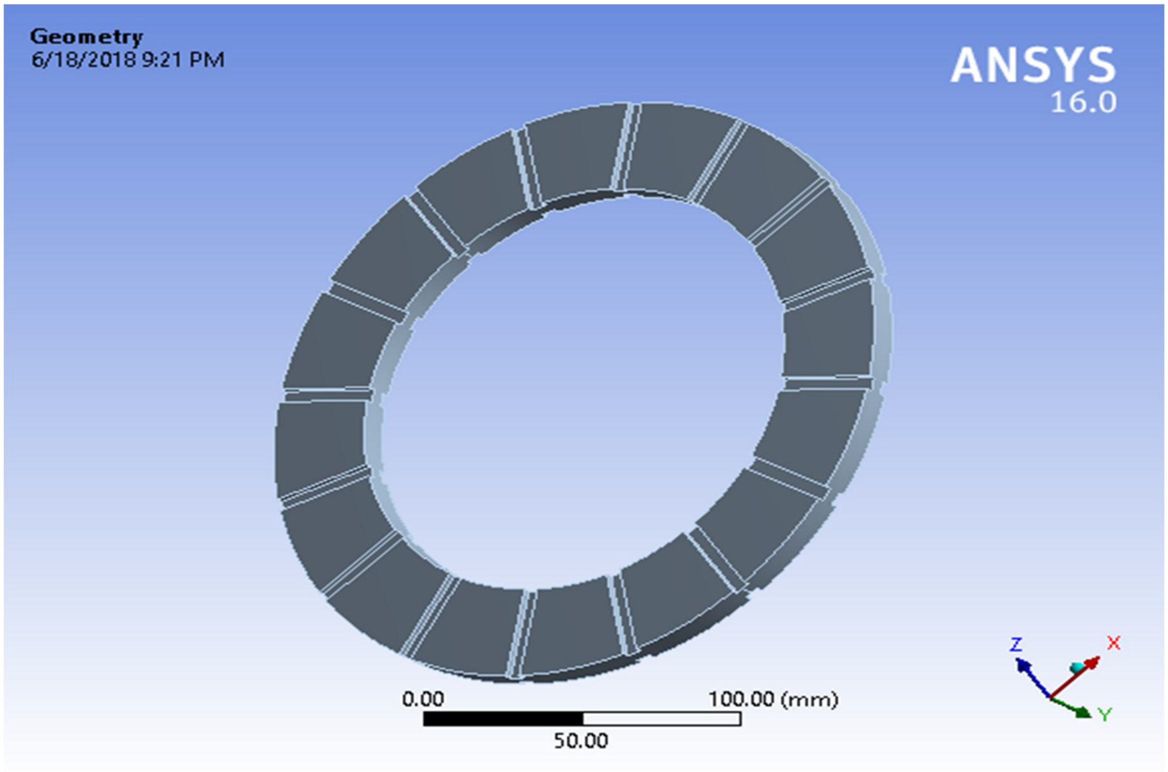

Fig: 2 – friction plate

D. Material properties of friction plate

PROPERTIES / MATERIAL	Density (Kg/m^3)	Poisons Ratio (μ)	Young's modulus (E) GPa
Grey cast iron	7200	0.27	110
Sintered iron	6200	0.34	275.79
Kevlar	1440	0.36	112
Aluminium metal matrix composite	2800	0.30	115

V. BOUNDARY CONDITION

From above literature review (1), pressure is applied on the outer surface of the friction plate.
The boundary condition of clutch system are given as follows,
Pressure applied on plate: 0.165 MPa
Ambient temperature: 22^{0}C
Maximum temperature generated: 150-200^{0}C

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VI. ANALYSIS OF FRICTION PLATE

Finite element analysis of single plate clutch is done with the help of Ansys workbench 16.0 software. Static stress analysis is done for different materials and same operating conditions.

Static Structural Analysis

For Stress analysis, pressure is applied on the friction pad of friction plate which is 0.165MPa.

A. Grey Cast Iron

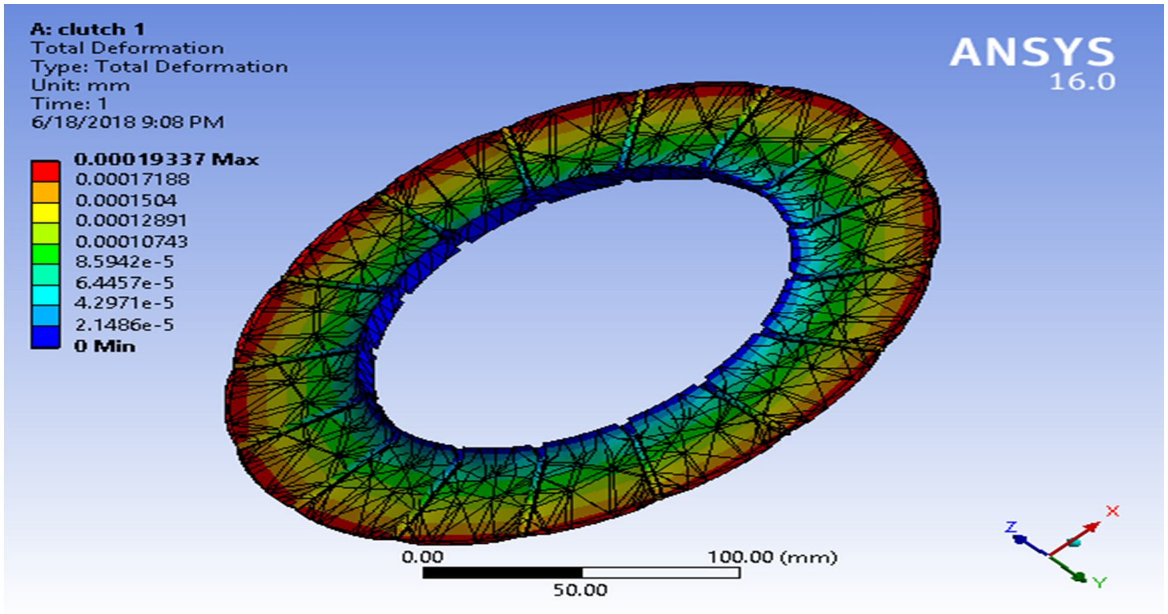

Fig: 3- total deformation of grey cast iron

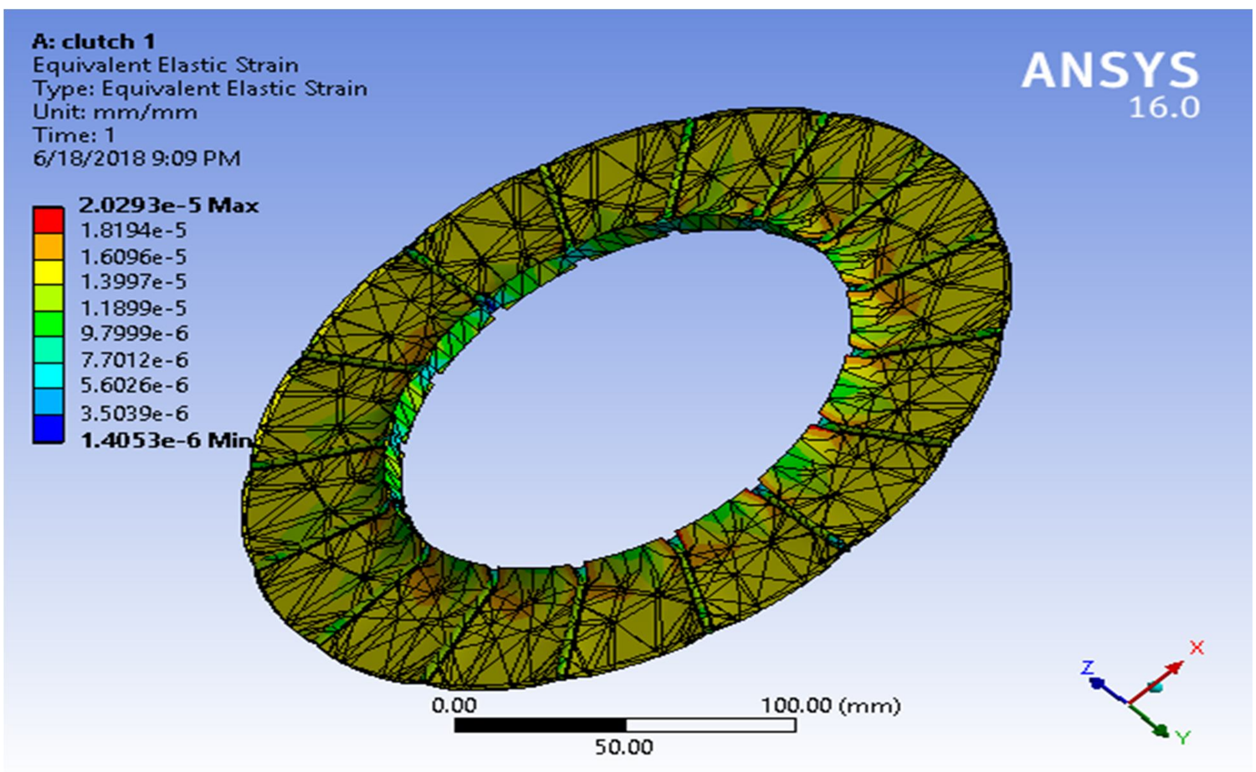

Fig: 4- equivalent strain of grey cast iron

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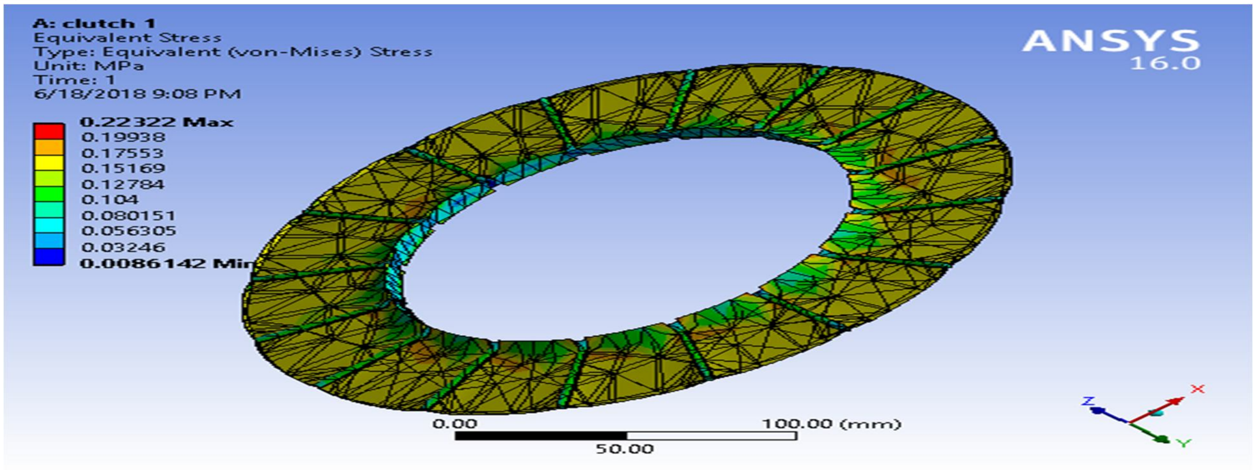

Fig: 5- equivalent stress of grey cast iron

B. Sintered Iron

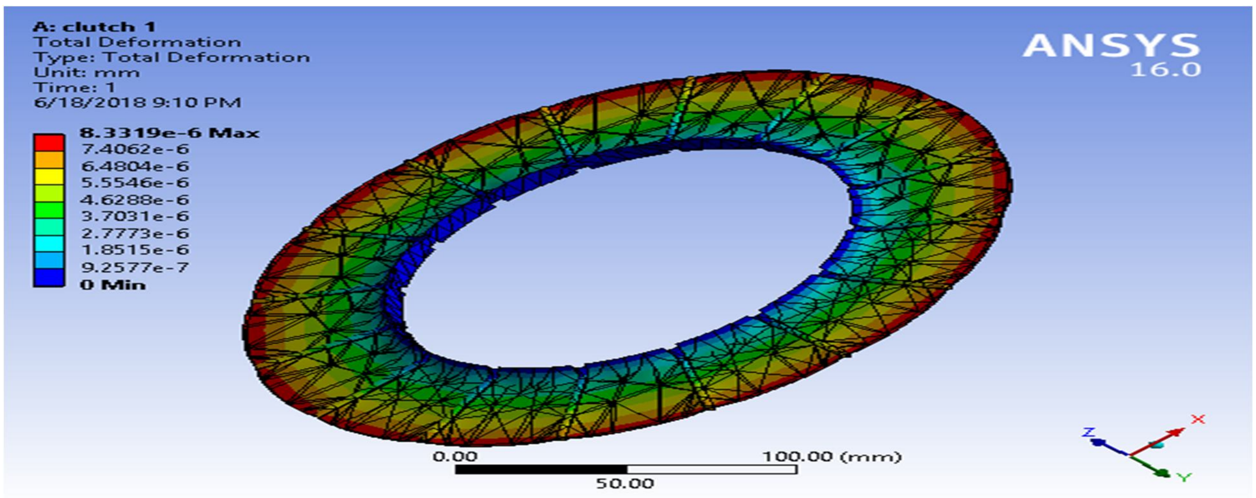

Fig: 6- total deformation of sintered iron

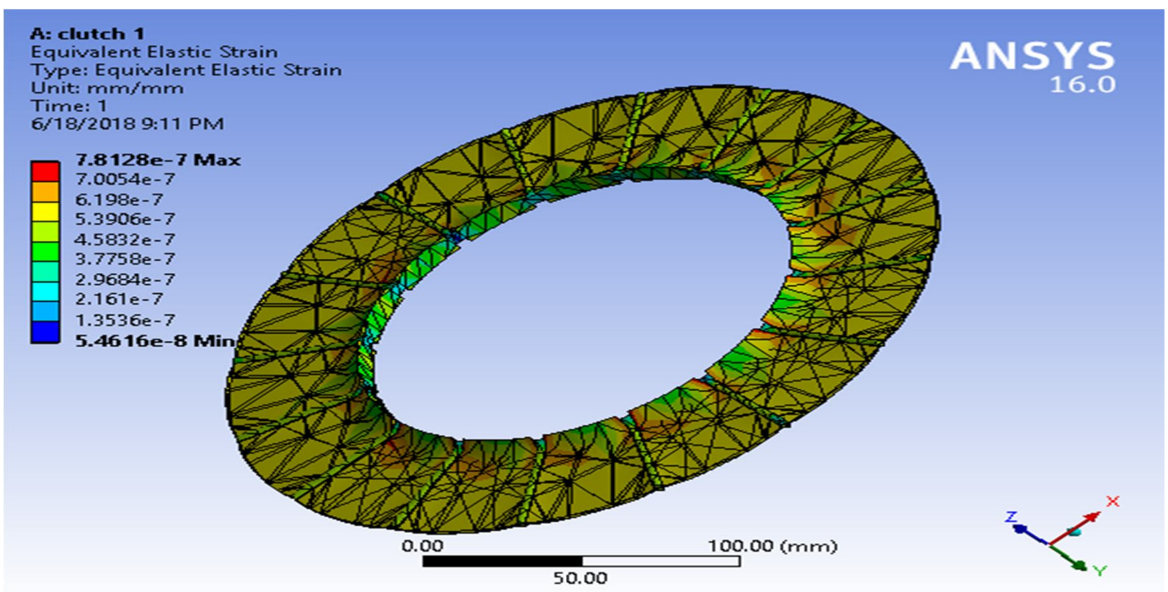

Fig: 7- equivalent strain of sintered iron

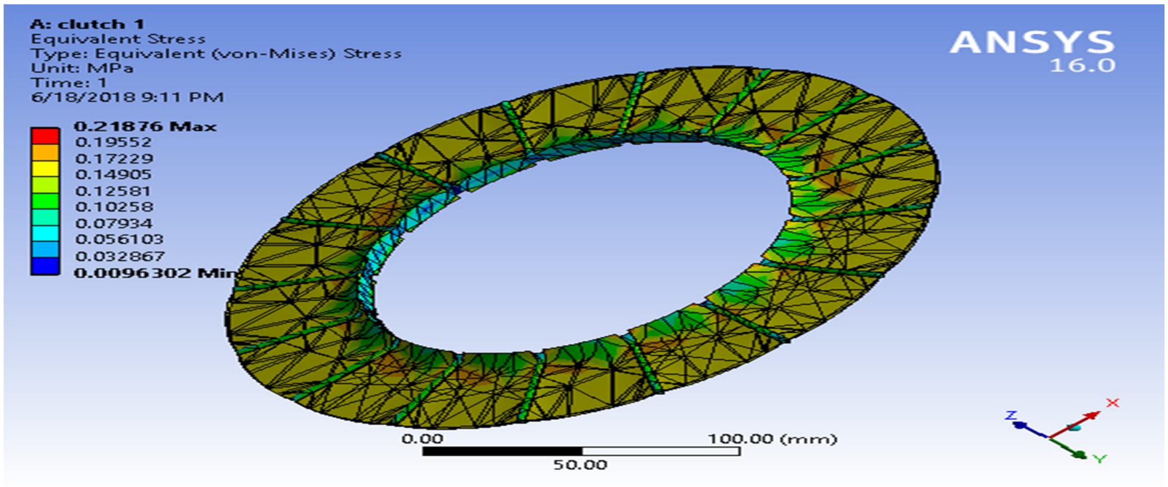

Fig: 8- equivalent stress of sintered iron

C. kevlar

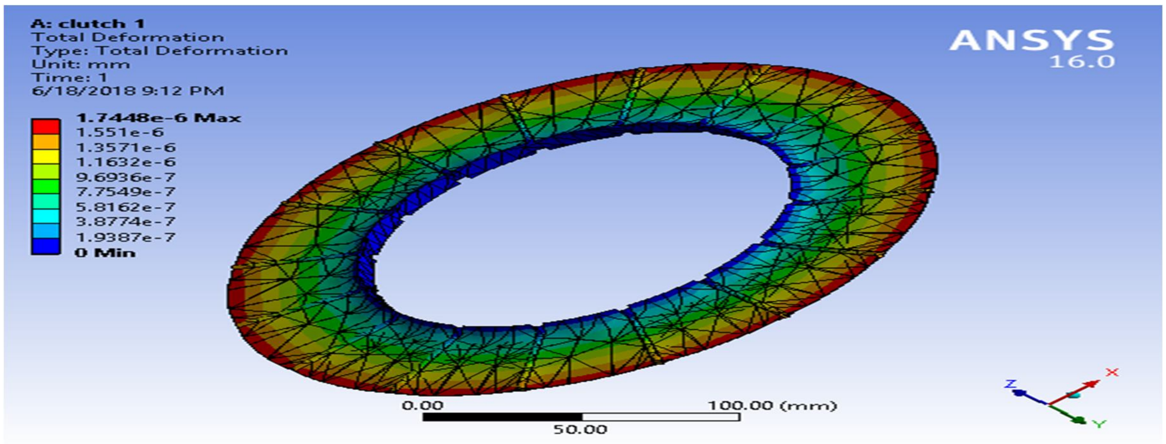

Fig: 9- total deformation of kevlar

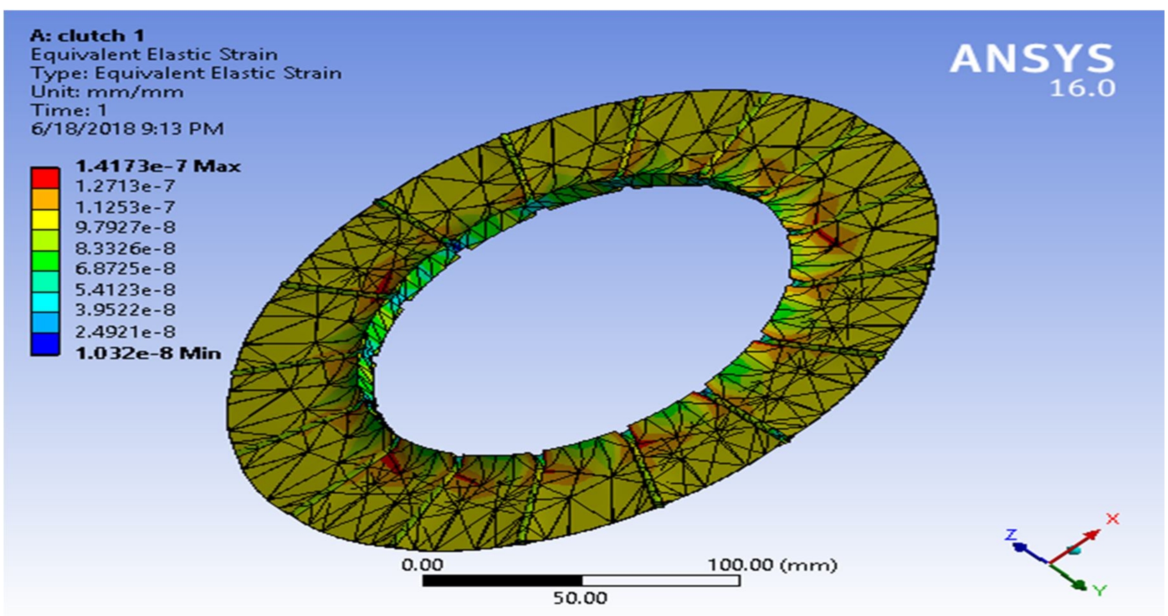

Fig: 10- equivalent strain of kevlar

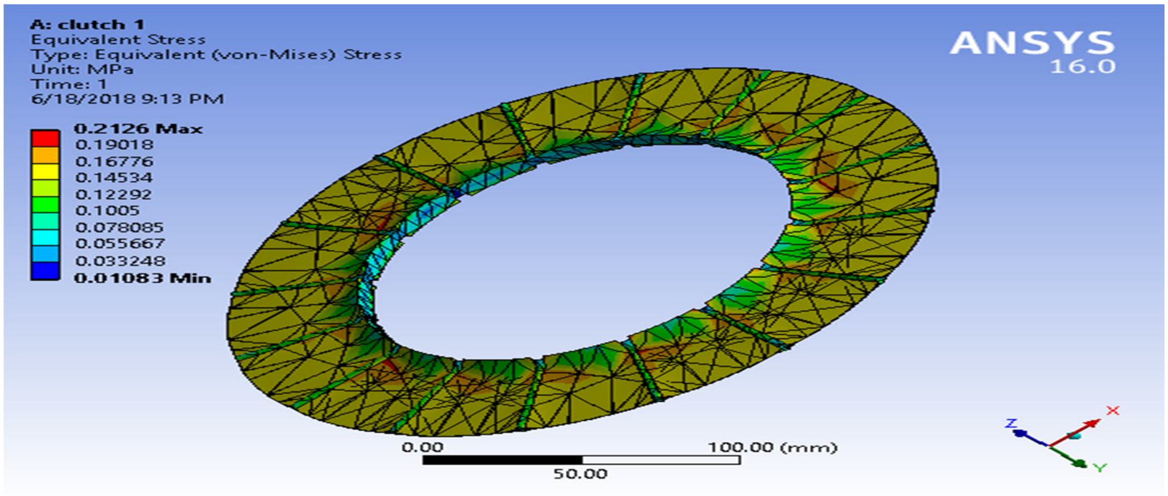

Fig: 11- equivalent stress of kevlar

D. Aluminium Metal Matrix Composite

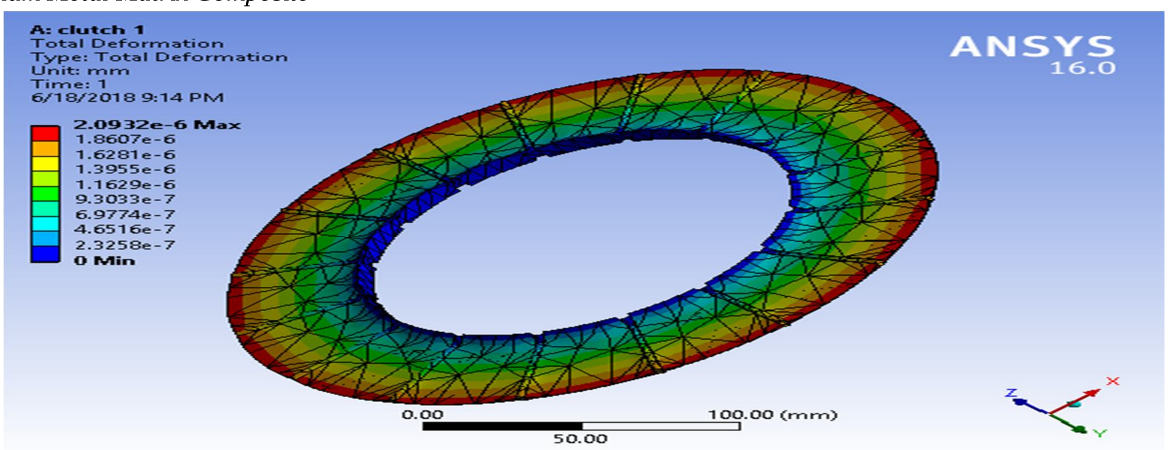

Fig: 12- total deformation of aluminium metal matrix composite

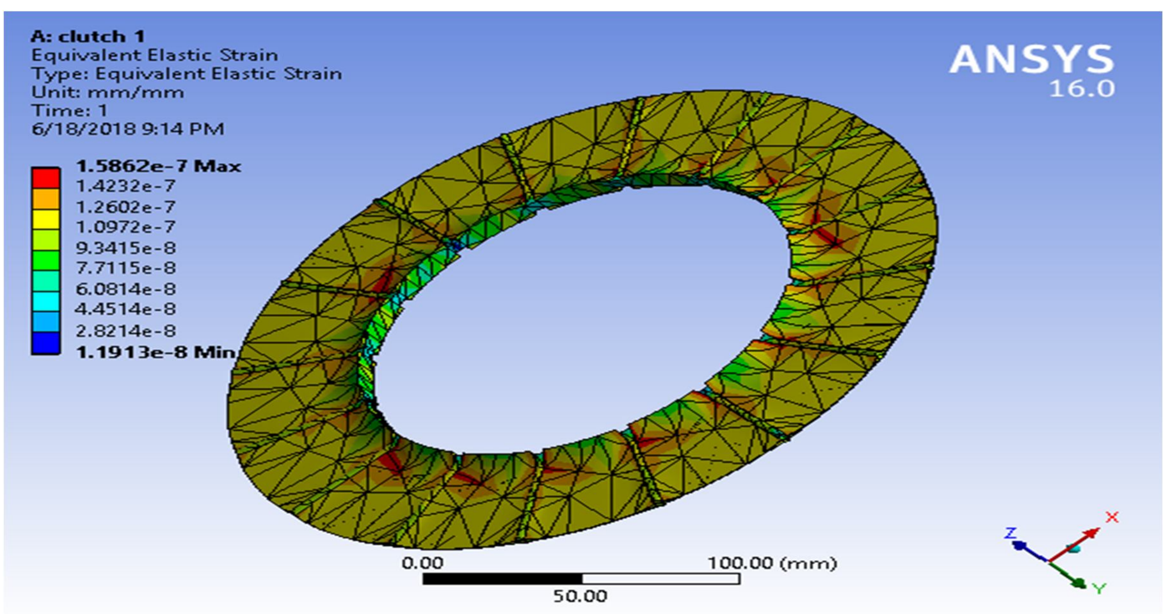

Fig: 13- equivalent strain of aluminium metal matrix composite

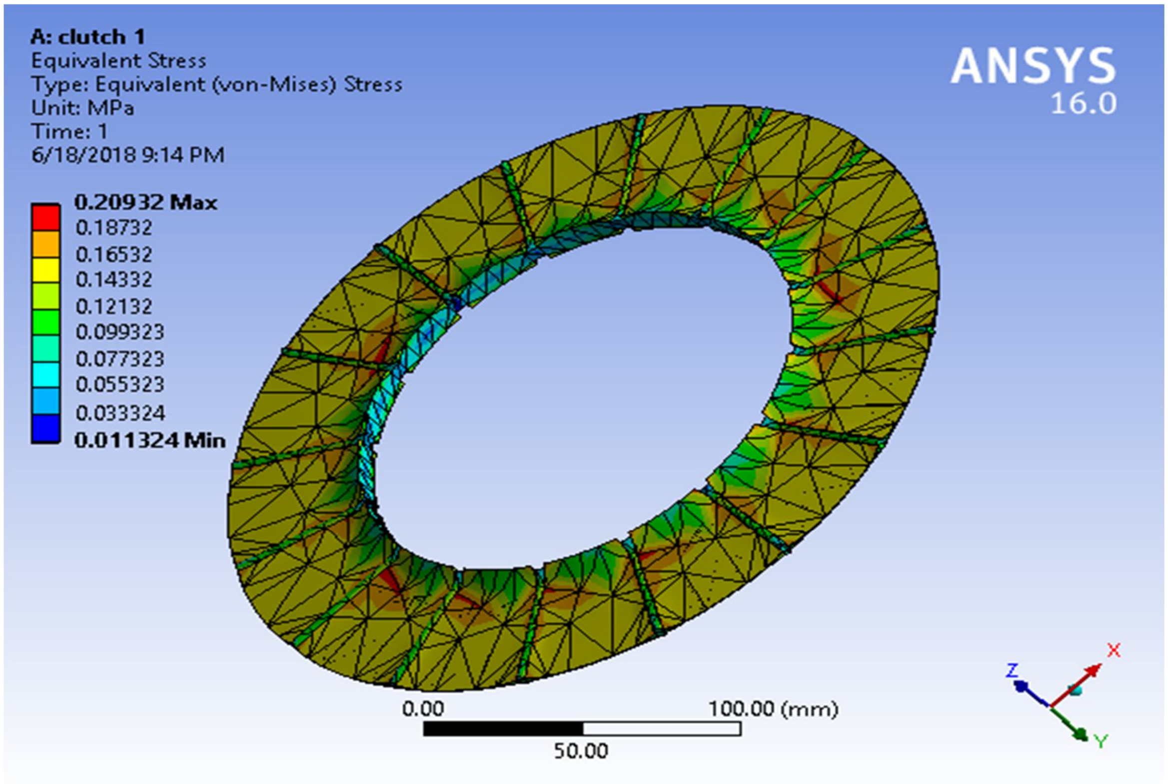

Fig: 14- equivalent stress of aluminium metal matrix composite

VII. RESULTS

Static Structural analysis

Parameters / Metal	Total deformation (mm)	Equivalent strain (mm/mm)	Equivalent stress (MPa)
Cast iron	.00019337	2.0293×10^{-5}	0.22322
Sintered iron	8.3319×10^{-6}	7.8128×10^{-7}	0.21876
Kevlar	1.7448×10^{-6}	1.4173×10^{-7}	0.21260
Aluminium metal matrix	2.0932×10^{-6}	1.5862×10^{-7}	0.209320

VIII. CONCLUSION

In our project we have designed a friction plate of single plate clutch y using catia V5. Structural analysis is done on the friction plate to find out the equivalent stress on the friction plate y using different friction materials such as cast iron, sintered iron Kevlar and aluminium metal metrix composite. From above results we can conclude that sintered iron, kevlar and aluminum metal matrix composite compared to cast iron, shows less value of deformation as well as less von-mises stress under static structural analysis. In addition aluminium metal matrix composite has very high strength to weight ratio compared to cast iron and hence cast iron can be replaced by aluminium metal matrix. Aluminium metal matrix is better than all three other material.

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