IJARI

International Journal of Advance Research and Innovation
Vol. 8(3), Jul-Sept 2020, pp. 53-62
Doi: 10.51976/ijari.832009
www.gla.ac.in/journals/ijari

Article Info

Received: 11 Jan 2020 | Revised Submission: 29 May 2020 | Accepted: 30 Jul 2020 | Available Online: 15 Sept 2020

Design and Analysis of Single Plate Clutch by Mathematical Modelling and Simulation

Kedar Kishor Patil, Vinit Randive**, Sahil Mulla**, Rajkumar Parit**, Sagar Mane** and Sunil Kadam***

ABSTRACT

This paper addresses Modeling and analysis of single plate clutch which is used in Tata Sumo vehicle. Clutch is the most significant component located between engine and gear box in automobiles. The static and dynamic analysis were developed for a clutch plate by using finite element analysis (FEA). The 3D solid model was done using CATIA V5R16 version and imported to ANSYS work bench 19.0 for structural, thermal and modal analysis. The mathematical modelling was also done using six different materials (i.e. Steel, Stainless Steel, Ceramics, Kevlar, Aluminum alloy and Gray Cast iron); then, by observing the results, comparison was carryout for materials to validate better lining material for single plate clutches using ANSYS workbench 19.0 and finally conclusion was made.

Keywords: *Modeling single plate clutch using CATIA; Analysis of single plate clutch using ANSYS; Clutch materials; Tata Sumo.*

1.0 Introduction

Clutch is the first element of power train used on the transmission shafts. The main function of clutch is to engage and disengage the engine to transmission, when the driver needs or during shifting of gear. When the clutch is in engaged position, the power flows from the engine to the wheel and when it is in disengage position, the power is not transmitted to the wheel. In automobile, a gearbox is required to change the speed and torque of the vehicle. If we change a gear, when the engine is engaged with gearbox or when the gears are in running position then it can cause of wear and tear of gears. To overcome this problem a clutch is used between gearbox and engine. Some friction plates, sometimes known as clutch plates are kept between these two members. The clutch is based on the friction. When two friction surfaces brought in contact and pressed, then they are united due to friction force between them. The friction between these two surfaces depends on the area of surface, pressure applied upon them and the friction material between them. The driving member of a clutch is the flywheel mounted on the engine crankshaft and the driven member is pressure plate mounted driving shaft to the driven shaft so that the driven shaft may be started or stopped at will, without stopping the driving.

The two main types of clutch are: positive clutch and friction clutch. Positive clutches are used when positive drive is required. The simplest type of a positive clutch is a jaw or claw clutch. A friction clutch has its principal application in the transmission of power of shafts and machines which must be started and stopped frequently. The force of friction is used to start the driven shaft from rest and gradually brings it up to the proper speed without excessive slipping of the friction surfaces. In automobiles, friction clutch is used to connect the engine to the drive shaft. The primary aim of this work is to design a rigid drive clutch system that meets multiple objectives such as Structural strength.

Gradual engagement clutches like the friction clutches are widely used in automotive applications for the transmission of torque from the flywheel to the transmission. The three major components of a clutch system are the clutch disc, the flywheel and the pressure plate. Flywheel is directly connected to the engine's crankshaft and hence rotates at the engine rpm. Bolted to the clutch flywheel is the second major component: the clutch pressure plate.

**Corresponding author; Department of Mechanical Engineering, Bharati Vidyapeeth's College of Engineering Kolhapur, Maharashtra, India (E-mail: kedarkishorpatil@gmail.com)*
***Department of Mechanical Engineering, Bharati Vidyapeeth's College of Engineering Kolhapur, Maharashtra, India*

The spring-loaded pressure plate has two jobs: to hold the clutch assembly together and to release tension that allows the assembly to rotate freely. Between the flywheel and the pressure plate is the clutch disc. The clutch disc has friction surfaces similar to a brake pad on both sides that make or break contact with the metal flywheel and pressure plate surfaces, allowing for smooth engagement and disengagement. In an automobile clutch is need for torque transmission; gradual engagement; heat dissipation; dynamic balancing; vibration damping; size; inertia and ease of operation of vehicle.

2.0 Selection of Material

The following materials used for Friction clutch plate:

2.1. Gray cast iron as friction material

Gray has a graphitic microstructure. The clutch disc is generally made from grey cast iron this is because it has a good wear resistance with high thermal conductivity and the production cost is low compare to other clutch disc materials.

2.2. Kevlar 49 as friction material

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.

2.3 Ceramic as friction material

Table 1: Comparison of Materials Based on its Mechanical Property

Sr.No.	Material	*Specific Strength (kN-m/kg)*	Yield Strength (Mpa)	Elastic Modulus (Gpa)	Friction coefficient	Density [kg/m^3]
1	Steel	*46*	420	210	0.42	7861
2	Stainless Steel	*65*	505	195	0.57	7610
3	Ceramics	*6.7*	457	33	0.4	3500
4	Kevlar 49	*23.8*	370	72	0.5	1470
5	Aluminum alloy 6061	*4.5*	275	69.7	0.23	2700
6	Gray Cast iron	*19.1*	720	24.1	0.28	7200

Ceramic clutch plates are, ironically, made with a combination of copper, iron, bronze, and silicon and graphite. Because of their metallic content, these discs can withstand a lot of friction and heat. This makes them ideal for race cars and other high-speed vehicles that need to engage and disengage from fast-moving flywheels.

2.4 Aluminum alloy as friction material

The unique properties of aluminum composites are better comparing to other conventional materials. Aluminum composites can use because of its strong bonding, good corrosion resistance, good wet ability, low density and high flexibility.

2.5 Steel as friction material

Steel is the primary mating surface used in clutches and can be used as the primary heat sink or the means to dissipate the energy into the ambient surroundings. In a "wet" or oil-immersed application, oil molecules are trapped between the steel mating plate and the friction material. The surface roughness of the steel mating plate and the texture of the friction material combine on shear of the oil to deliver a co-efficient of friction of up to 0.15. However, these discs are high-friction. This means that the engagement and disengagement of the clutch won’t always be very smooth.

3.0 Calculations

Clutch plate of a TATA SUMO was selected for analysis.

Table 2: Specifications of Tata Sumo Vehicle

Parameter	Value
Torque (T)	300 N-m at 1000 rpm
Outer Radius of Friction Face (R_o)	160 mm
Inner Radius of Friction Face (R_i)	90 mm
Maximum Power	64 KW at 3000 rpm
Maximum Pressure Intensity (P)	0.5N/mm^2

3.1Torque transmission under uniform pressure

This theory applies to new clutch. In new clutches the pressure can be assumed as uniformly distributed over the entire surface area of the friction disk. With this assumption, the intensity of pressure between disks, is regarded as constant.

3.2 Torque transmission under uniform wear

This theory is based on the fact that the wear is distributed uniformly across the entire friction disk surface area. This assumption can be used for worn out clutches or old clutches. The axial wear of the friction disk is proportional to frictional work. The work done by the friction is proportional to the frictional force and the rubbing velocity. The uniform-pressure theory is applicable only when the friction lining is new. When the friction lining is used over a period of time, wear occurs. Therefore, the major portion of the life of friction lining comes under uniform-wear criterion. Hence, in the design of clutches, the uniform wear theory is used.

Uniform Pressure Theory

$$P = \frac{F}{\pi(R_o^2 - R_i^2)}$$

$$T = \mu F \frac{2}{3} \frac{(R_o^3 - R_i^3)}{(R_o^2 - R_i^2)}$$

Uniform Wear Theory

$$P = \frac{F}{2\pi r(R_o - R_i)}$$

Where Pr=constant

$$T = \mu F \frac{1}{2}(R_o + R_i)$$

Where,
P=normal pressure
F=axial force
μ=coefficient of friction between the surfaces
T=friction torque

R_o = outer radius
R_i = inner radius

3.3 Calculation for the friction lining based on uniform wear theory and uniform pressure theory

- Effective mean radius r for uniform wear theory = $\frac{Ri+Ro}{2} = \frac{90+160}{2}$ = 125 mm
- Effective mean radius r Uniform pressure theory $= \frac{2(R_0^3 - R_i^3)}{3(R_0^2 - R_i^2)} = \frac{(2*160*160*160)-(2*90*90*90)}{(3*160*160)-(3*90*90)}$ = 128.6 mm
- Area of friction pads (A) = $\pi (R_o^2 - R_i^2)$ = $\pi (160^2 - 90^2)$
- = 54977.87 mm^2
- Angular velocity (ω) =2πN/60
= (2π*3000)/60
= 314.16 rad/sec.
- Heat generation in watts (Q_g) = Coefficient of friction * Maximum Pressure *Angular velocity
= μ*Pmax*ω
- Heat flux obtained in clutch plate (Q_f) = heat generated in clutch plate/surface area = Qg/A

Table 3:Results for Uniform Wear and Uniform Pressure Theory

Sr. No.	Materials	Coefficient of friction [μ]	Uniform pressure		Uniform wear		Heat Flux (Q_F) (Watt/mm²)
			Axial force [N]	Pressure [N/mm²]	Axial force [N]	Pressure [N/mm²]	
1.	Steel	0.16	14580	0.27	15000	0.27	$4.57*10^{-4}$
2.	Stainless Steel	0.15	15552	0.29	16000	0.29	$4.28*10^{-4}$
3.	Ceramics	0.6	03888	0.07	04000	0.07	$1.71*10^{-3}$
4.	Kevlar	0.5	04665	0.09	04800	0.08	$1.42*10^{-3}$
5.	Aluminum alloy	0.23	10142	0.19	10435	0.18	$6.57*10^{-4}$
6.	Gray Cast iron	0.28	08332	0.15	08571	0.16	$08.0*10^{-4}$

4.0 FEA Analysis

Finite element analysis is the computational tool most widely accepted in engineering analysis. The clutch plate assembly is modelled in CATIA software imported to ANSYS to do static structural analysis, thermal analysis and modal analysis. Using different lining materials finite element analysis has been done.

Figure 1: CATIA Model of Tata Sumo Clutch Plate

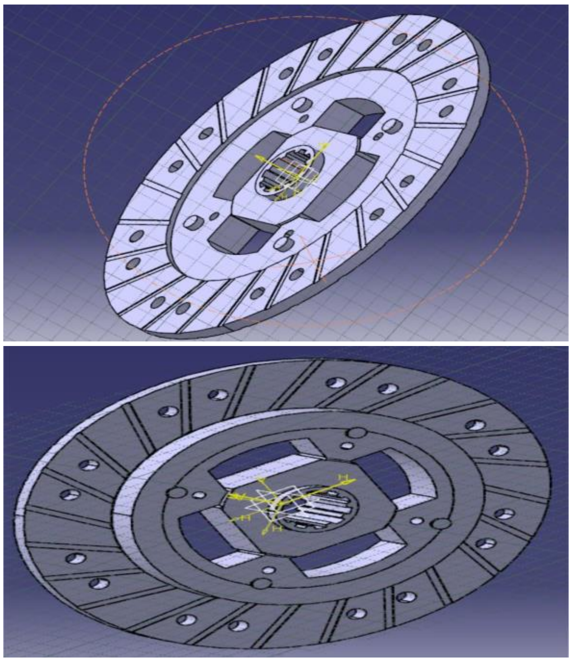
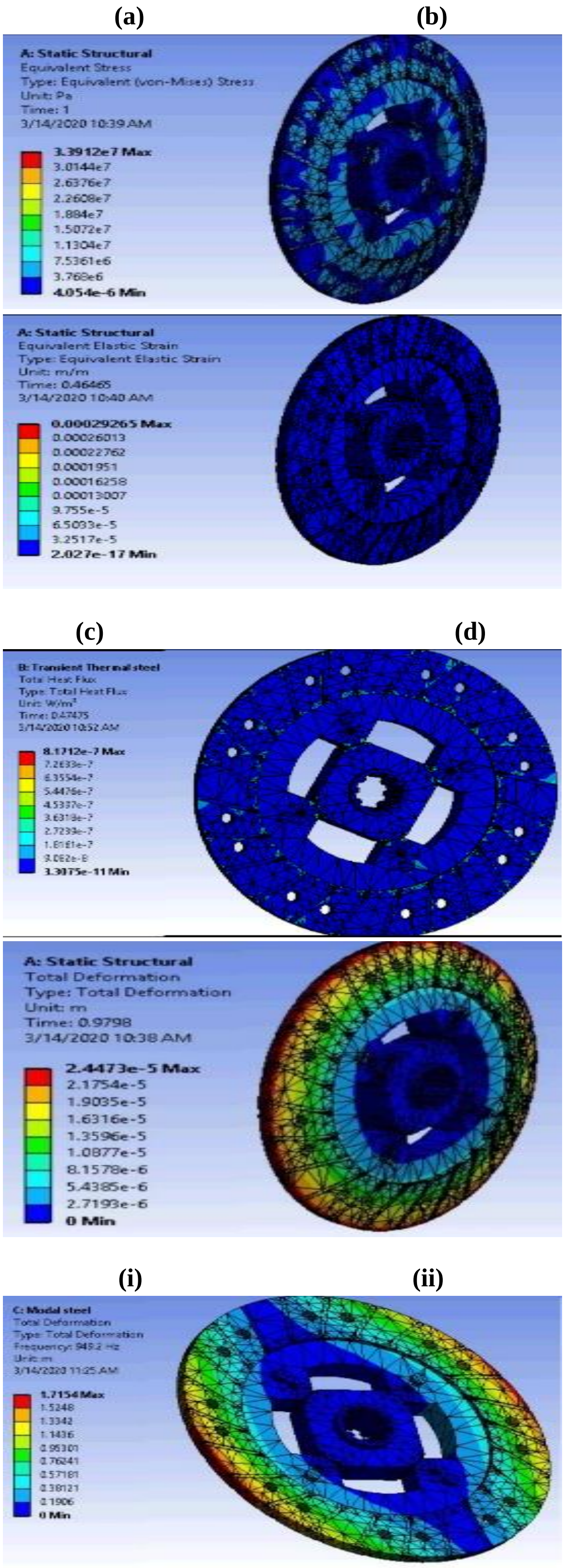


Figure 2: Structural Steel as Friction Material as Friction Material (A) Von-Mises Stress; (B) Von-Mises Strain; (C) Total Heat Flux;(D) Total Deformation; (i to vi) First Six Modal Frequencies



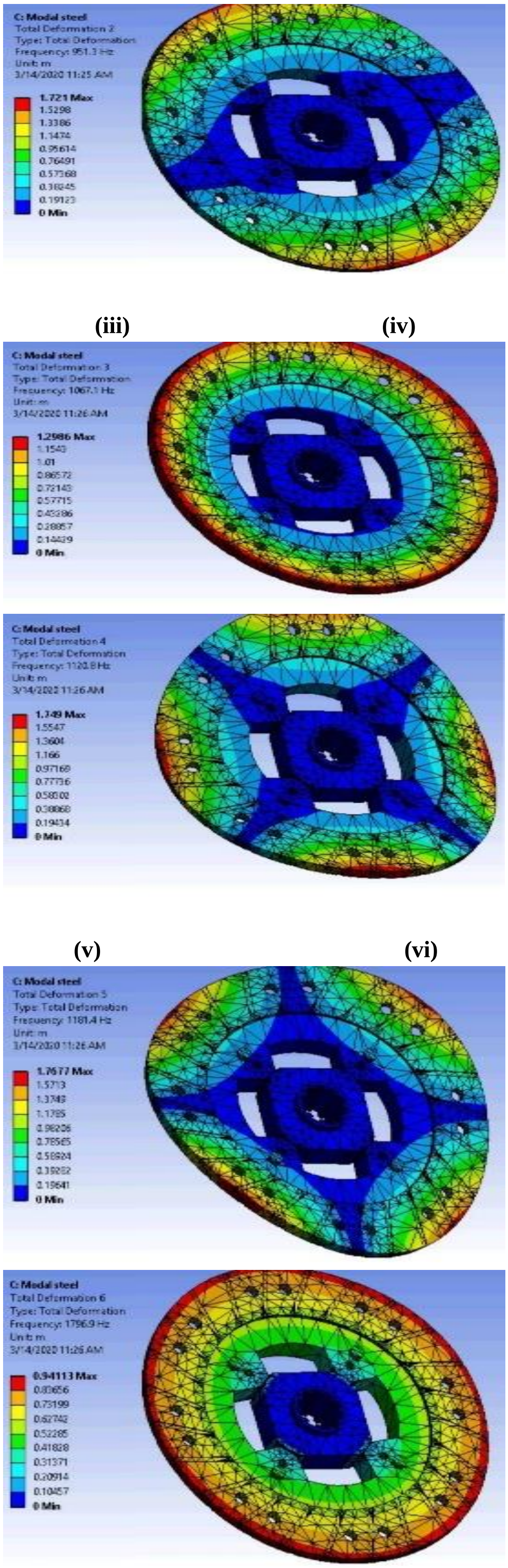
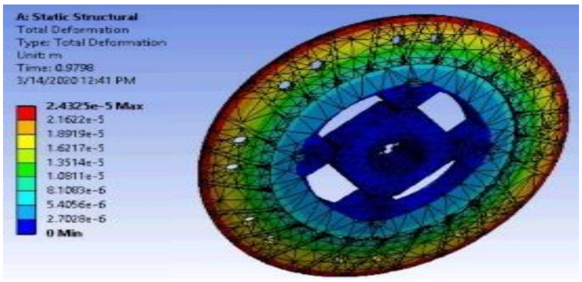
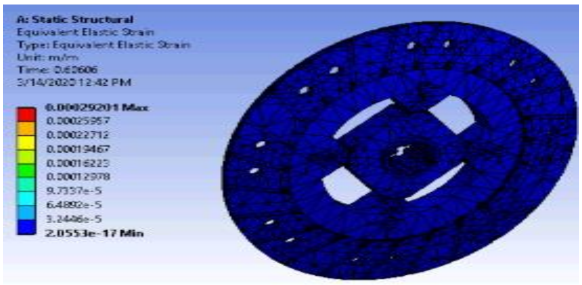


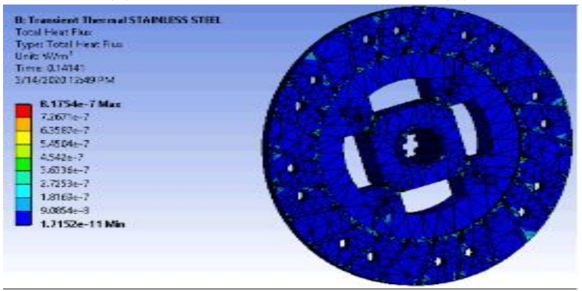
Figure 3: Stainless Steel as Friction Material (A) Von-Mises Stress; (B) Von-Mises Strain; (C) Total Heat Flux; (D) Total Deformation; (i to vi) first six modal frequencies

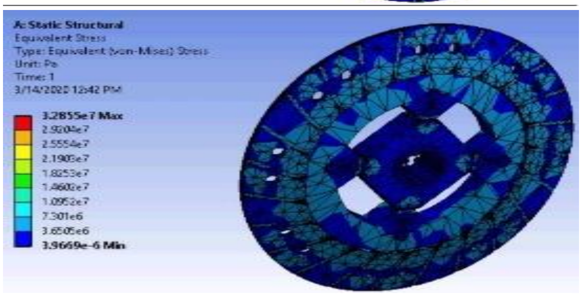
(a) **(b)**



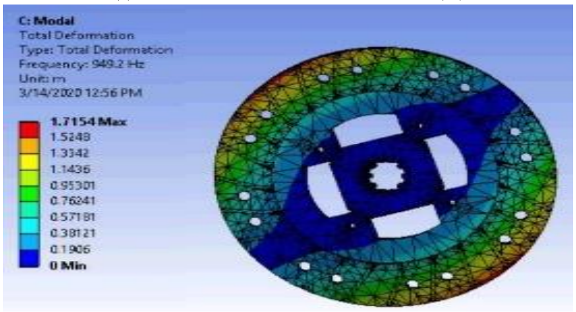


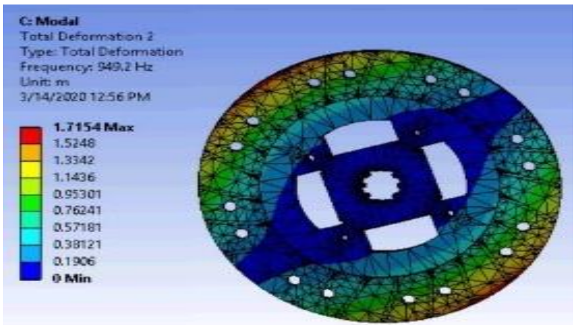
(c) **(d)**



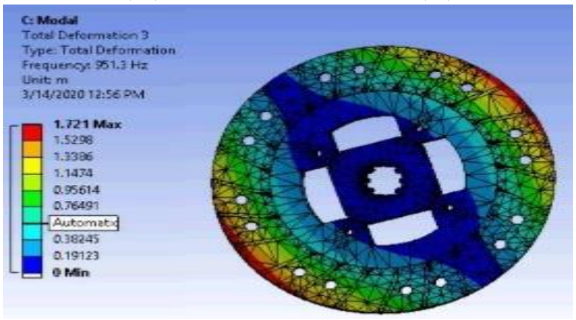


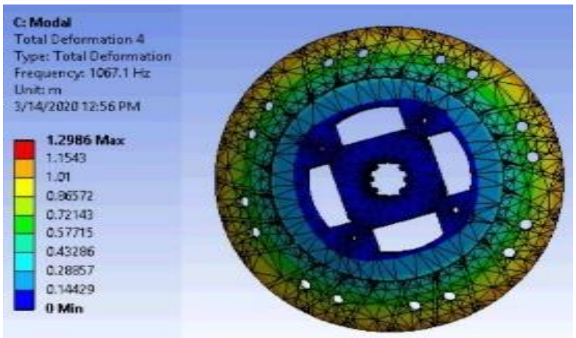
(i) **(ii)**



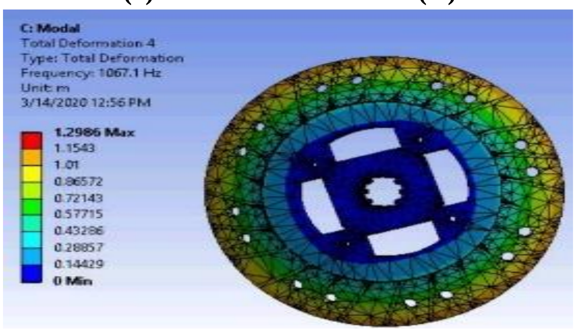


(iii) **(iv)**





(v) **(vi)**



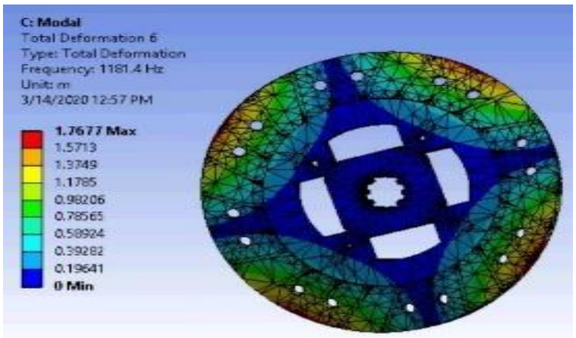
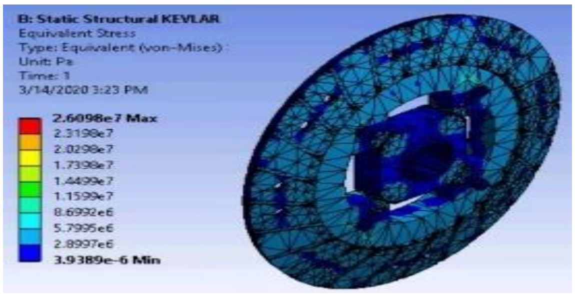
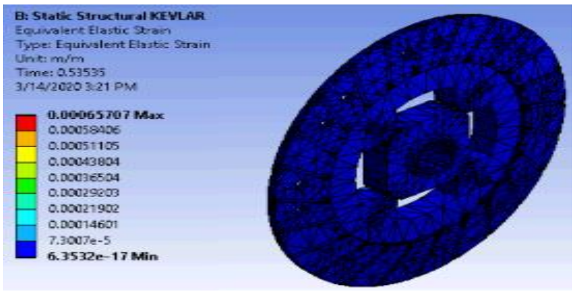


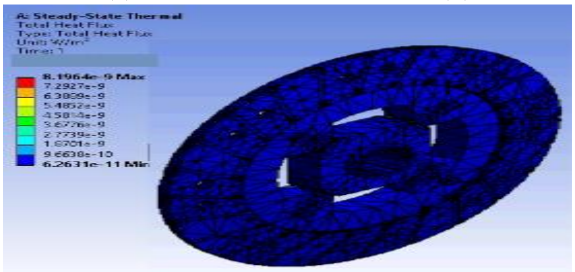
Figure 4: Kevlar 49 as Friction Material (A) Von-Mises Stress; (B) Von-Mises Strain; (C) Total Heat Flux; (D) Total Deformation; (i to vi) First Six Modal Frequencies

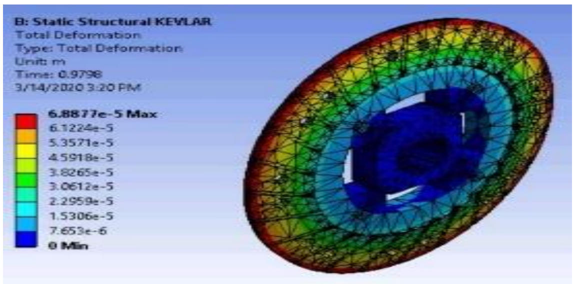
(a) **(b)**



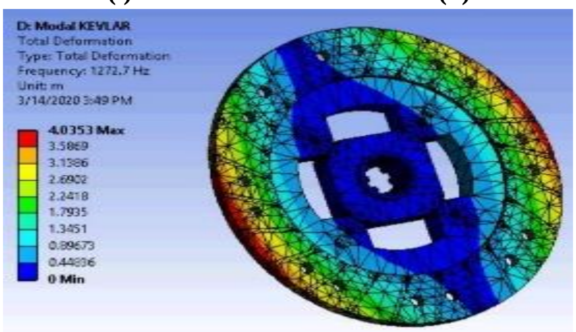


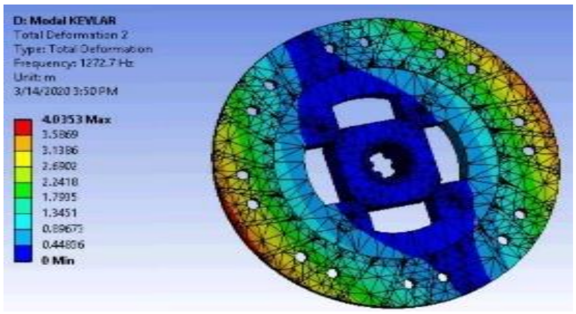
(c) **(d)**



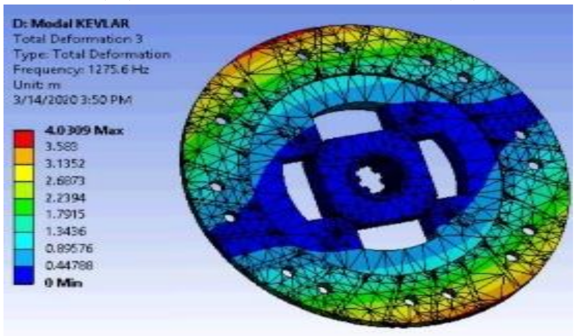


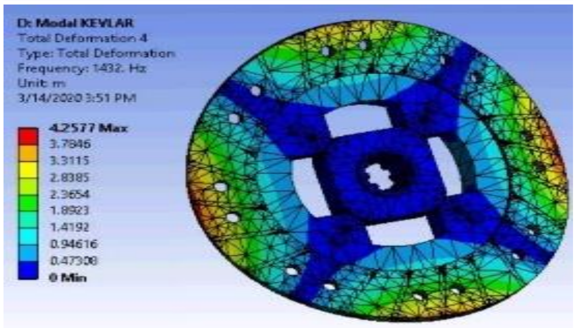
(i) **(ii)**



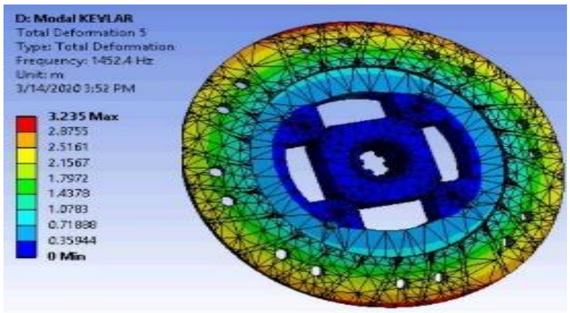


(iii) **(iv)**





(v) **(vi)**



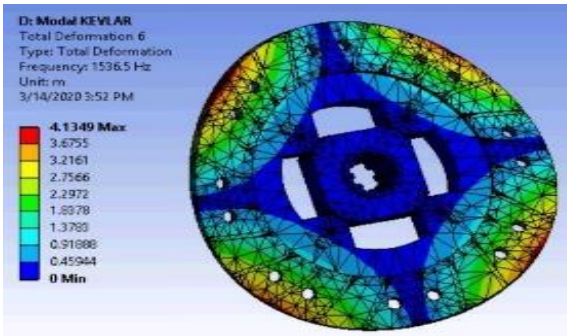
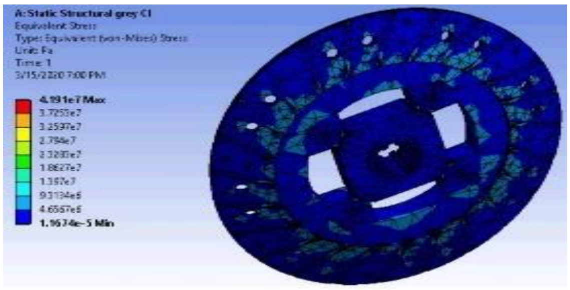
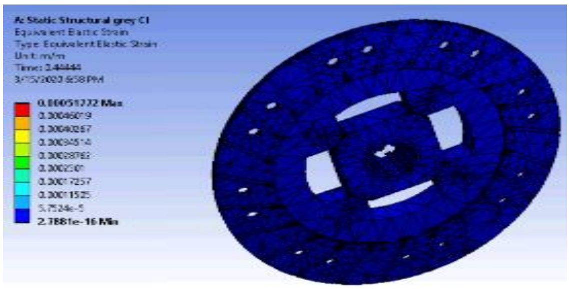


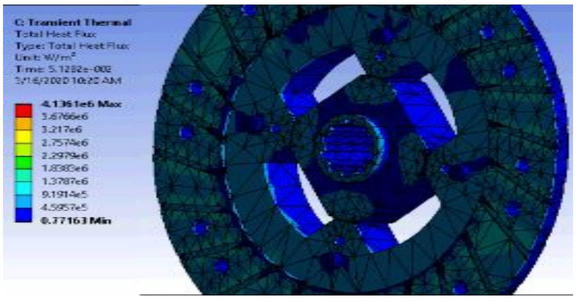
Figure 5: Grey Cast Iron as Friction Material (A) Von-Mises Stress; (B) Von-Mises Strain; (C) Total Heat Flux; (D) Total Deformation; (i to vi) First Six Modal Frequencies

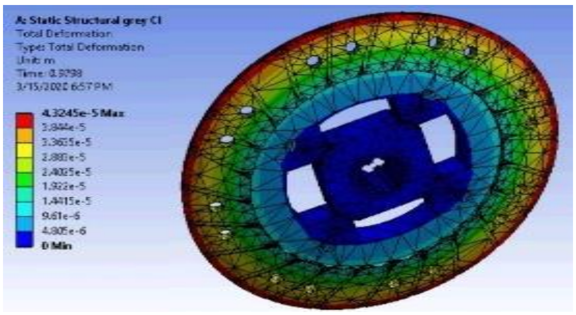
(a) **(b)**



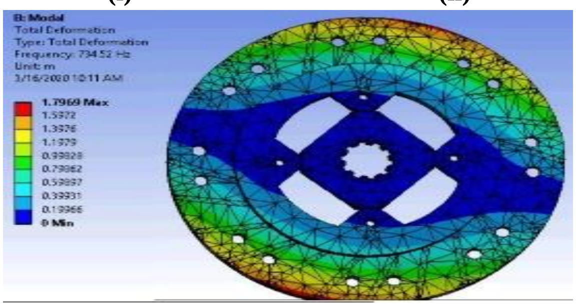


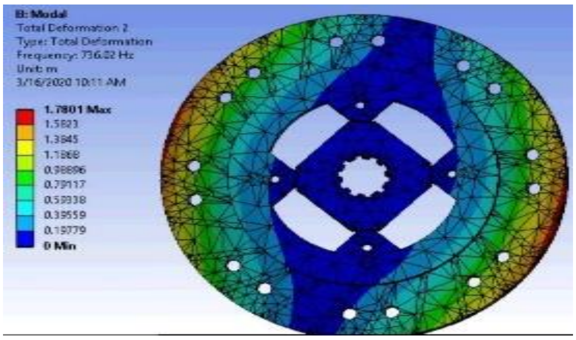
(c) **(d)**



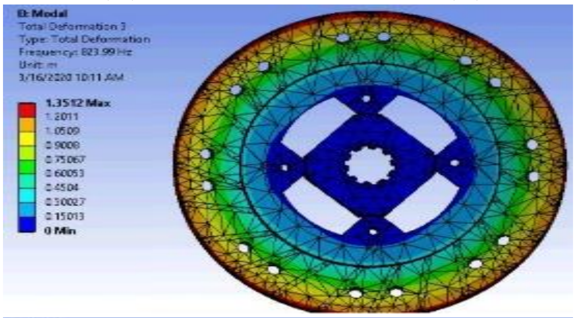


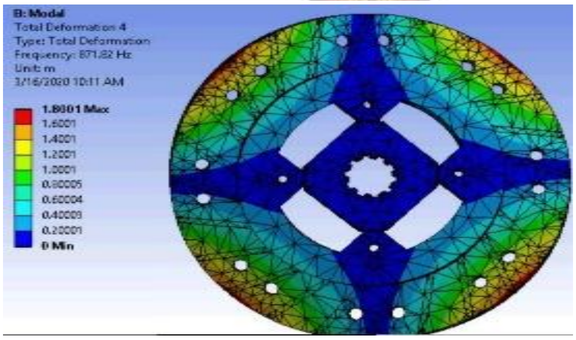
(i) **(ii)**



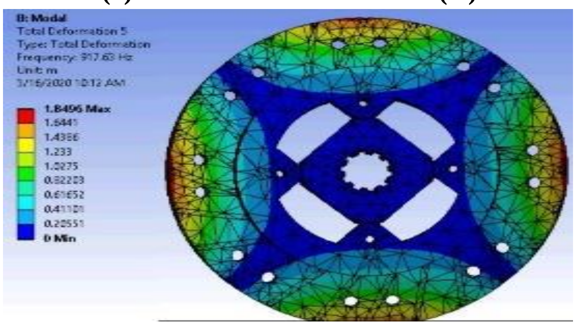


(iii) **(iv)**





(v) **(vi)**



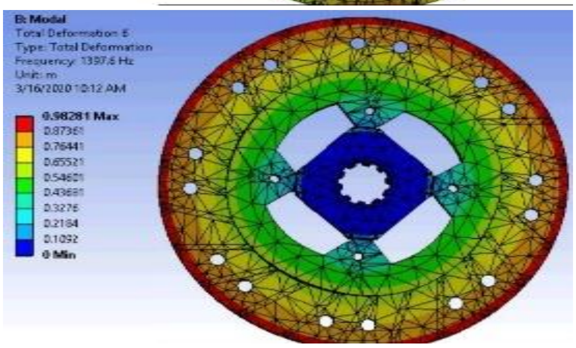
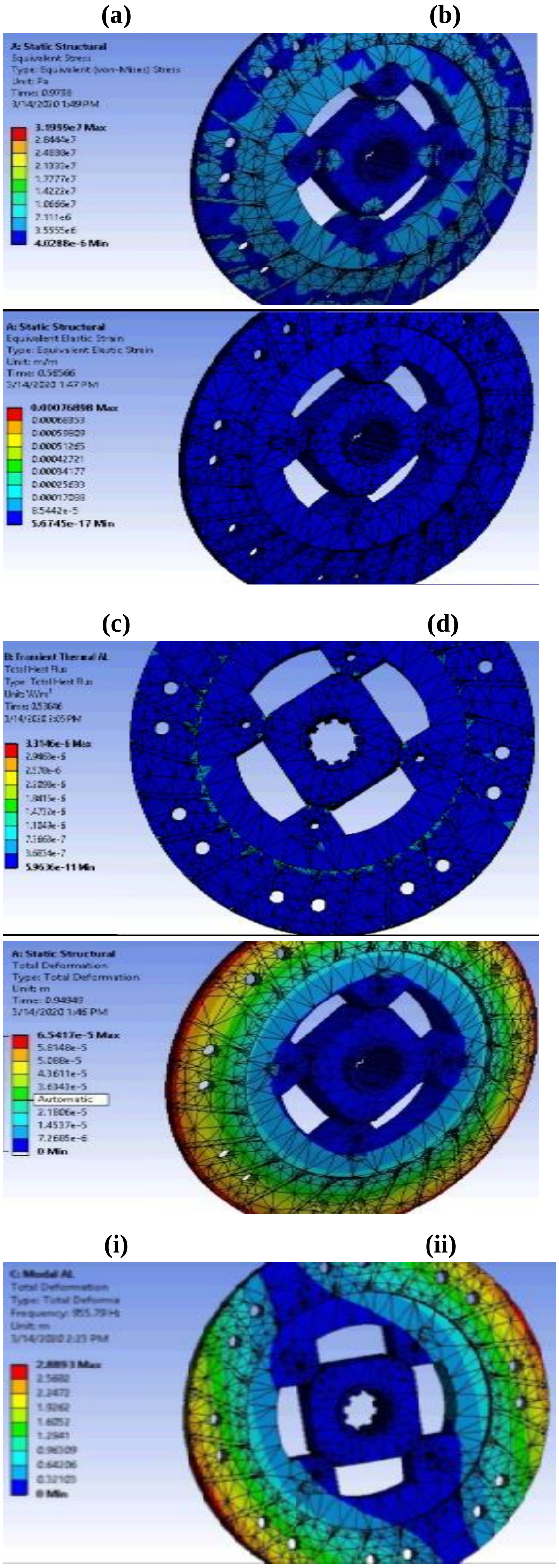


Figure 6: Aluminum alloy as Friction Material as Friction Material (A) Von-Mises Stress; (B) Von-Mises Strain; (C) Total Heat Flux; (D) Total Deformation; (i to vi) First Six Modal Frequencies



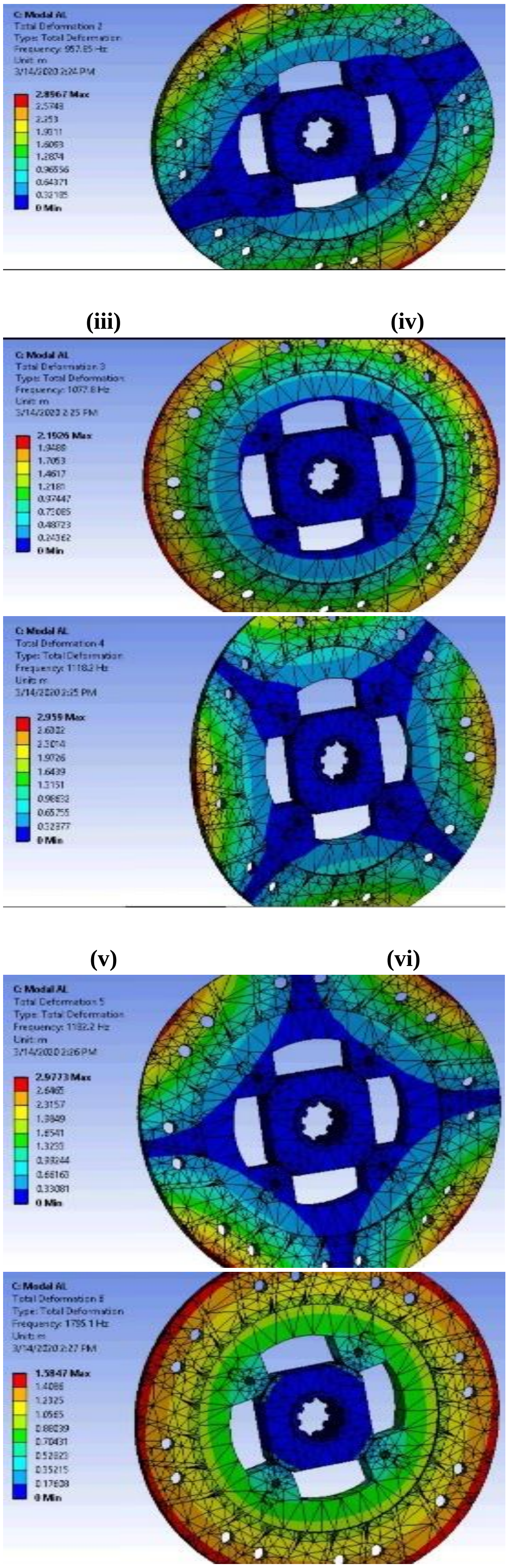
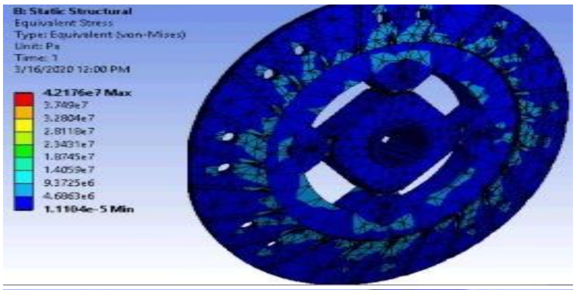
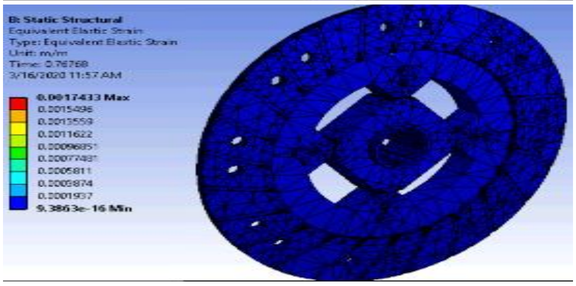


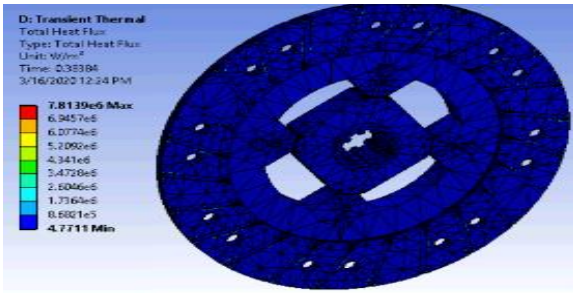
Figure 7:Ceramic as Friction Material (A) Von-Mises Stress; (B) Von-Mises Strain; (C) Total Heat Flux; (D) Total Deformation; (i to vi) First Six Modal Frequencies

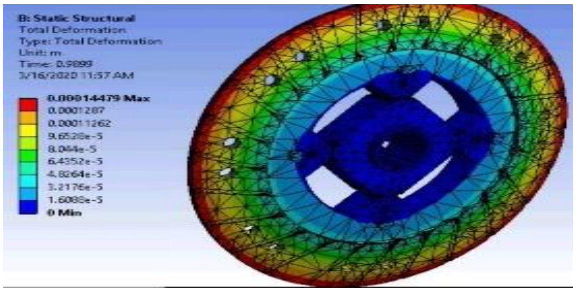
(a) **(b)**



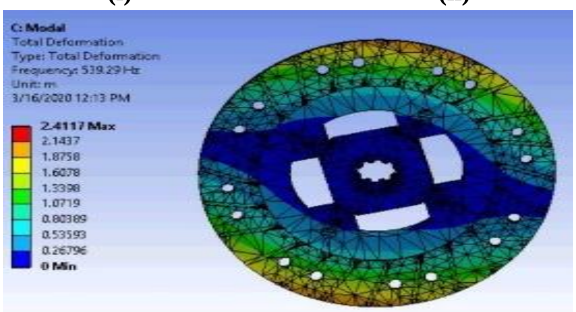


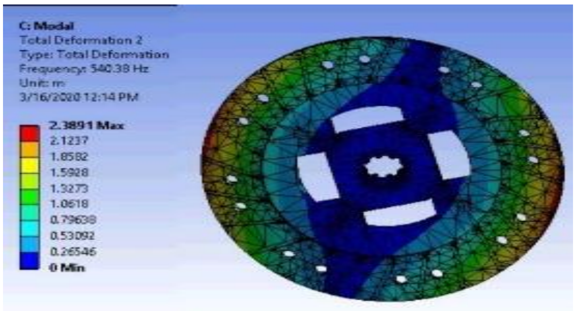
(c) **(d)**



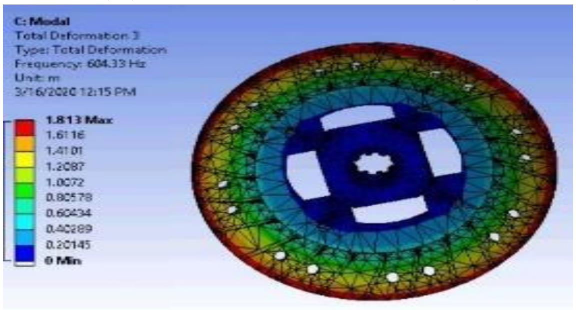


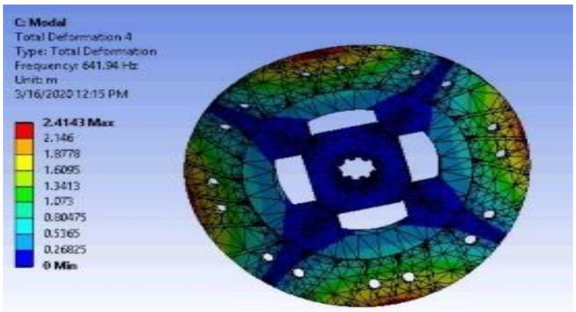
(i) **(ii)**



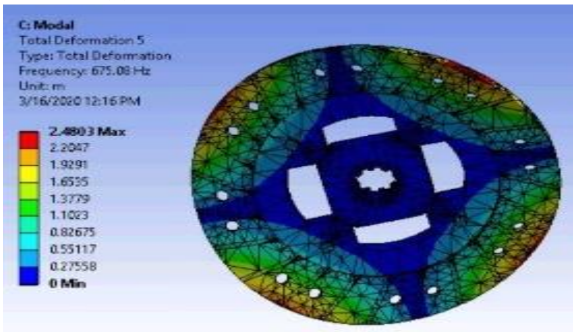


(iii) **(iv)**





(v) **(vi)**



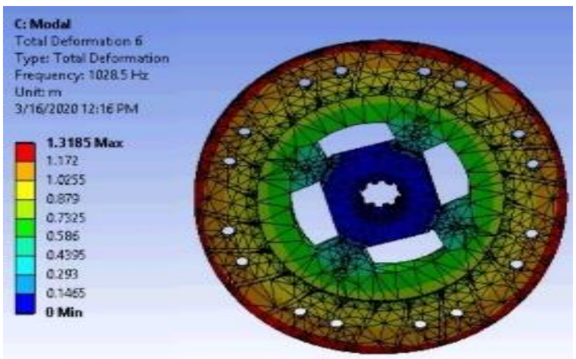


Table 4: Results for Structural Analysis in ANSYS

Sr. No.	Materials	Total Deformation [m]	Von mises Equivalent Stress [Pa]	Von mises Equivalent Strain	Total Heat Flux [W/m^2]	Poisson's Ratio	Youngs Modulus [Pa]
1.	Structural Steel	$2.4473*10^{-5}$	$3.3912*10^{7}$	$2.926*10^{-4}$	$8.17*10^{-7}$	0.3	$2.00*10^{11}$
2.	Structural Steel	$2.4473*10^{-5}$	$3.2855*10^{7}$	$2.920*10^{-4}$	$8.17*10^{-7}$	0.31	$1.93*10^{11}$
3.	Kevlar 49	$6.8877*10^{-5}$	$2.6098*10^{7}$	$6.570*10^{-4}$	$8.18*10^{-9}$	0.44	$6.20*10^{10}$
4.	Gary Cast Iron	$4.3245*10^{-5}$	$4.1913*10^{7}$	$5.177*10^{-4}$	$4.13*10^{6}$	0.28	$1.10*10^{11}$
5.	Aluminum Alloy	$6.5417*10^{-5}$	$3.1999*10^{7}$	$7.689*10^{-4}$	$3.31*10^{-6}$	0.33	$7.10*10^{10}$
6.	Ceramic	$1.4794*10^{-5}$	$4.2176*10^{7}$	$1.740*10^{-4}$	$7.81*10^{6}$	0.27	$4.10*10^{11}$

Table 5: Results for Natural Frequencies Obtained from Modal Analysis in ANSYS

First Six Modal Frequencies in Hz	Materials					
	Structural Steel	Structural Stainless Steel	Kevlar 49	Gary Cast Iron	Aluminium Alloy 6061	Ceramic
1.	949.2	949.2	1272.7	734.52	955.1	539.29
2.	951.3	951.3	1275.6	736.02	957.8	540.38
3.	1067.1	1067.1	1432	823.99	1077.8	604.33
4.	1120.8	1120.8	1452.4	871.82	1118.2	641.94
5.	1181.4	1181.4	1536.5	917.63	1182.2	675.08
6.	1796.9	1796.9	2302.3	1397.6	1785.1	1028.5

5.0 Conclusions

In this work, clutch plate of Tata Sumo has been designed. Clutch plate has been modelled in CATIA software and simulated using ANSYS software for different materials. Effect of same pressure intensity of 0.5N/mm^2 for different materials has observed. Heat flux, Total deformation, stress, strain and first six modal frequencies for different materials are observed. By comparing the results tabulated in table 4 it is clear that ceramic has less deformation and less modal frequencies than all other. This data helps the researchers to select proper material to reduce wear and increase life of clutch.

References

[1] S Narayan. Effects of Various Parameters on Piston Secondary Motion, SAE Technical Papers, 79 (1), 2015doi.org/10.4271/2015-01-0079.

[2] Ch.Vasantha Lakshmi, V SandhyaRani. Design and Structural Analysis of Composite Coated Clutch Plate by using Composite Materials, International Journal and Magazine of Engineering, Technology, Management and Research.

[3] A C Automotive, Internet address: http://www.acautomotive1.co.uk/clutches.

[4] S Narayan. A review of diesel engine acoustics, FME Transactions, 42(2), 2014, 150-154, doi: 10.5937/fmet1402150N.

[5] MG Pawar, MK Waramble, GR Jodh. Design and Analysis of clutch using Sintered iron as a Friction material, International Journal of Innovative Technology and Exploring Engineering. December 2013.

[6] P Naga karna, Tippa Bhimasankhara Rao. Analysis of Friction clutch plate using FEA, International Journal of Engineering Research and Development, 3, 2013.