STRUCTURAL ANALYSIS OF FLYWHEEL FOR COMPRESSION IGNITION ENGINE

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ABSTRACT

A flywheel used in machines serves as a reservoir which stores energy during the period when the supply of energy is more than the requirement and releases it during the period when the requirement of energy is more than supply. For example, in compression ignition engines, the energy is developed only in the power stroke which is more than engine load, and no energy is being developed during the suction, compression and exhaust strokes in case of four stroke engines. The excess energy is developed during power stroke is absorbed by the flywheel and releases its to the crank shaft during the other strokes in which no energy is developed. The flywheel located on one end of the crankshaft. The main aim of this project is a parametric model of the flywheel is designed using 3D modeling software. The force acting on flywheel is also calculated by using some theoretical formulas. The strength of the flywheel is validated by applying the forces on the flywheel in analysis software ANSYS. Structural analysis and model analysis is done on the flywheel. For structural analysis is used to determine whether flywheel withstands under working conditions. Model analysis is done to determine the number of mode shapes for flywheel analysis is done for two materials Cast iron and Aluminum alloy A360 to compare the results. These results lead us to the determination of vibrations in existing flywheel. By predicting the vibrations concentration areas, the flywheel working life increase and reduce the vibrations on the engines.

Keyword: - *stroke engine, absorbed, crankshaft and predicting the vibrations*

1. Introduction

A flywheel is an inertial energy-storage device. It absorbs mechanical energy and serves as a reservoir, storing energy during the period when the supply of energy is more than the requirement and releases it during the period when the requirement of energy is more than the supply. The main function of a fly wheel is to smoothen out variations in the speed of a shaft caused by torque fluctuations. If the source of the driving torque or load torque is fluctuating in nature, then a flywheel is usually called for. Many machines have load patterns that cause the torque time function to vary over the cycle. Internal combustion engines with one or two cylinders are a typical example. Piston compressors, punch presses, rock crushers etc. are the other systems that have fly wheel. Flywheel absorbs mechanical energy by increasing its angular velocity and delivers the stored energy by decreasing its velocity.

Flywheels are typically made of steel and rotate on conventional bearings; these are generally limited to a revolution rate of a few thousand RPM. Some modern flywheels are made of carbon fiber materials and employ magnetic bearings , enabling them to revolve at speeds up to 60,000 RPM (1 kHz). Carbon-composite flywheel batteries have recently been manufactured and are proving to be viable in real-world tests on mainstream cars. Additionally, their disposal is more eco-friendly.

Common uses of a flywheel include:

- Providing continuous energy when the energy source is discontinuous. For example, flywheels are used in reciprocating engines because the energy source, torque from the engine, is intermittent.
- Delivering energy at rates beyond the ability of a continuous energy source. This is achieved by collecting energy in the flywheel over time and then releasing the energy quickly, at rates that exceed the abilities of the energy source.

Controlling the orientation of a mechanical system. In such applications, the angular moment of a flywheel is purposely transferred as a torque to the attaching mechanical system when energy is transferred to or from the flywheel, thereby causing the attaching system to rotate into some desired position.

2. DESIGN AND DETAILS OF MODEL

2.1 DESIGN PARAMETERS:

Flywheel inertia (size) needed directly depends upon the acceptable changes in the speed.

2.1.1 SPEED FLUCTUATION:

The change in the shaft speed during a cycle is called the speed fluctuation .

$$F = \omega_{max} - \omega_{min}$$

We can normalize this to a dimensionless ratio by dividing it by the average or nominal shaft speed (ω_{avg}) .

$$C_f = (\omega_{max} - \omega_{min})/\omega$$

Where

ω_{avg} = Nominal angular velocity.
ω = Nominal angular velocity, and
ω_{avg} = The average or mean shaft speed desired.

This coefficient is a design parameter to be chosen by the designer.

The smaller this chosen value, the larger the flywheel have to be and more the cost and weight to be added to the system. However the smaller this value more smoother the operation of the device. It is typically set to a value between 0.01 to 0.05 for precision machinery and as high as 0.20 for applications like crusher hammering machinery.

2.1.2 DESIGN EQUATION:

The kinetic energy E_k in a rotating system = $\frac{1}{2} I\omega^2$

Hence the change in kinetic energy of a system can be given as,

$$E_K = \frac{1}{2} I_m [\omega_{max}^2 - \omega_{min}^2]$$

$$E_K = E_2 - E_1$$

$$\omega_{avg} = \frac{\omega_{max} + \omega_{min}}{2}$$

$$E_K = \frac{1}{2} I_s (2\omega_{avg})(C_f \omega_{avg})$$

$$E_2 - E_1 = C_f I \omega^2$$

$$I_s = \frac{E_K}{C_f \, \omega_{avg}^2}$$

Thus the mass moment of inertia I_m needed in the entire rotating system in order to obtain selected coefficient of speed fluctuation is determined using the relation , The above equation can be used to obtain appropriate flywheel inertia I_m corresponding to the known energy change E_k for a specific value coefficient of speed fluctuation C_f.

2.1.3 Torque Variation and Energy

The required change in kinetic energy E_k is obtained from the known torque time relation or curve by integrating it for one cycle.

$$\int_{\omega_{min}}^{\omega_{max}} (T_1 - T_{avg}) \, d\theta = E_K$$

2.2 GEOMETRY OF FLYWHEEL:

The geometry of a flywheel may be as simple as a cylindrical disc of solid material, or may be of spoked construction like conventional wheels with a hub and rim connected by spokes or arms Small fly wheels are solid discs of hollow circular cross section. As the energy requirements and size of the flywheel increases the geometry changes to disc of central hub and peripheral rim connected by webs and to hollow wheels with multiple arms. The following figures shows the general geometry of the two types of the flywheels.

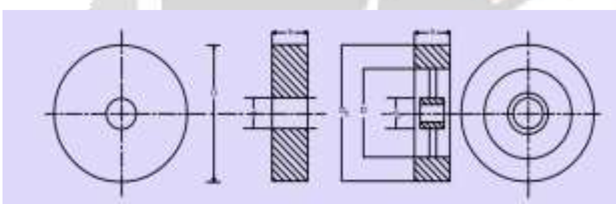

Fig 1. Geometry of solid disc type flywheel

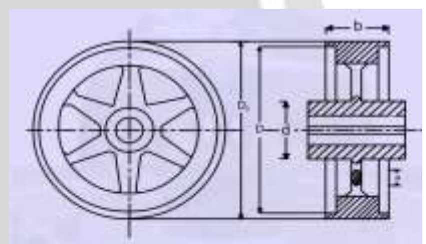

Fig 2. Geometry of rim type flywheel

The latter arrangement is a more efficient of material especially for large flywheels, as it concentrates the bulk of its mass in the rim which is at the largest radius. Mass at largest radius contributes much more since the mass moment of inertia is proportional to mr^2 .

For a solid disc geometry with inside radius r_i and out side radius r_o, the mass moment of inertia I is

$$I_m = mk^2 = \frac{m}{2}\left[r_o^2 + r_i^2\right]$$

The mass of a hollow circular disc of constant thickness t is

$$m = \frac{W}{g} = \pi \frac{\gamma}{g} \left[r_o^2 - r_i^2\right] t$$

Combing the two equations we can write

$$I_m = \frac{\pi}{2} \frac{\gamma}{g} \left[r_o^4 - r_i^4\right] t$$

Where is material’s weight density γ

The equation is better solved by geometric proportions i.e by assuming inside to out side radius ratio and radius to thickness ratio.

2.3 STRESSES IN FLYWHEEL:

Flywheel being a rotating disc, centrifugal stresses acts upon its distributed mass and attempts to pull it apart. Its effect is similar to those caused by an internally pressurized cylinder

$$\sigma_t = \frac{\gamma}{g}\omega^2\left[\frac{3+v}{8}\right]\left[r_i^2 + r_o^2 - \frac{1+3v}{3+v}r^2\right]$$

$$\sigma_r = \frac{\gamma}{g}\omega^2\left[\frac{3+v}{8}\right]\left[r_i^2 + r_o^2 - \frac{r_i^2 r_o^2}{r^2} - r^2\right]$$

where

γ = material weight density,
ω= angular velocity in rad/sec.
ν= Poisson's ratio, is the radius to a point of interest,
r_i and r_o are inside and outside radii of the solid disc flywheel.

Analogous to a thick cylinder under internal pressure the tangential and radial stress in a solid disc flywheel as a function of its radius r is given by:

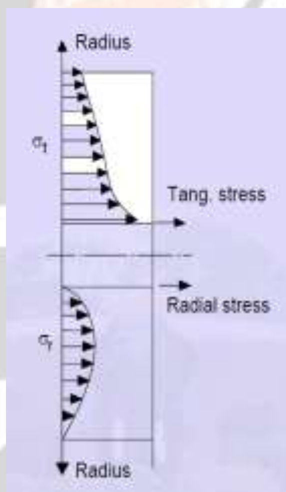

Fig 3. Tangential and radial stress in a flywheel

The point of most interest is the inside radius where the stress is a maximum. What causes failure in a flywheel is typically the tangential stress at that point from where fracture originated and upon fracture fragments can explode resulting extremely dangerous consequences, Since the forces causing the stresses are a function of the rotational speed also, instead of checking for stresses, the maximum speed at which the stresses reach the critical value can be determined and safe operating speed can be calculated or specified based on a safety factor. Generally some means to preclude its operation beyond this speed is desirable, for example like a governor.
Consequently

Factor of Safety [N] = $N_{os} = \frac{\omega}{\omega_{yield}}$

3. Design and Details of Model

Each of them containing modules, even electronics circuit design, that is mean CATIA have too many modules. CATIA is considered as a CAM program, in addition to it is CAD program, in the meaning that you export files to CNN machines and then manufactured, CATIA also supports graphics from other programs such as AutoCAD, for example, it is possible to copy a drawing from AutoCAD and enter it to CATIA and then make on it CATIA operations, CATIA files can be kept with drawings extension which is supported by AutoCAD or the default extension has.

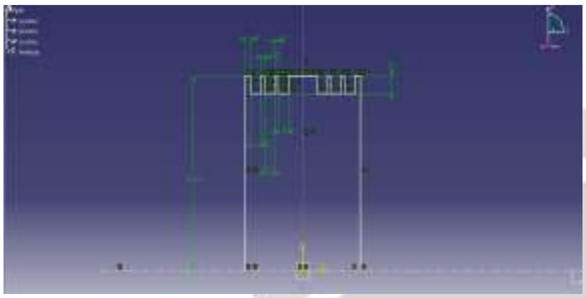

Fig 4. Flywheel sketcher

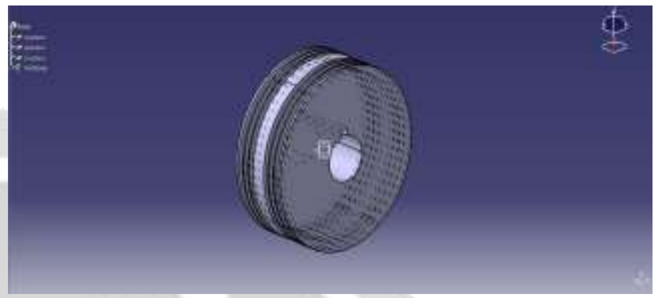

Fig 5. Flywheel Geometry

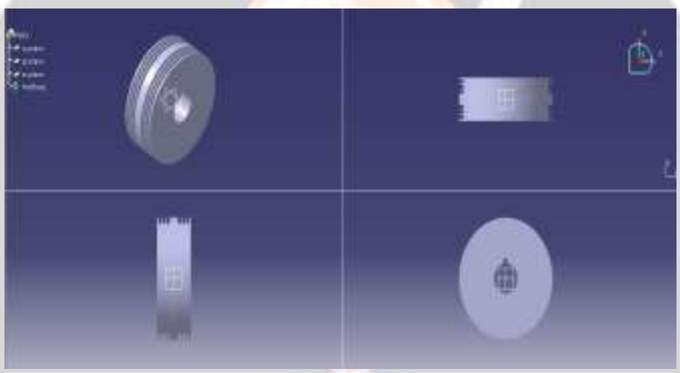

Fig 6. Flywheel final views

Using the Generate Mesh option creates the mesh, but does not actually create the relevant mesh files for the project and is optional if you already know that the mesh is acceptable. Using the Update option automatically generates the mesh and creates the relevant mesh files for your project and updates the ANSYS Workbench cell that references this mesh.

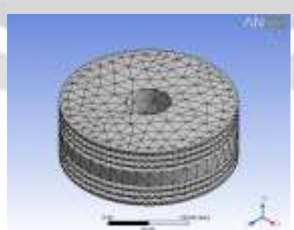

Fig 7. Mesh generation on flywheel

4. RESULTS AND DISCUSSION

Pressure value (N/mm^2)	Material	Deformation (mm)	Equivalent (von-mises)stress (MPa)		Maximum principal elastic starin	
			Maximum	**Minimum**	**Maximum**	**Minimum**
0.17221	**Aluminum 6063**	3.3866×10^{-6}	3.1665×10^{-7}	2.8132×10^{-8}	2.0504×10^{-12}	2.9699×10^{-13}
	Structural steel	1.2022×10^{-6}	3.1804×10^{-7}	2.6565×10^{-8}	7.1223×10^{-13}	9.9737×10^{-14}
	Titanium	2.5047×10^{-6}	3.1521×10^{-7}	2.9862×10^{-8}	1.5471×10^{-12}	2.2984×10^{-13}
0.25849	**Aluminum 6063**	4.5544×10^{-6}	4.2583×10^{-7}	3.7833×10^{-8}	2.7574×10^{-12}	3.9941×10^{-13}
	Structural steel	1.6168×10^{-6}	4.277×10^{-7}	3.5725×10^{-8}	9.5782×10^{-13}	1.3413×10^{-13}
	Titanium	3.3684×10^{-6}	4.239×10^{-7}	4.0159×10^{-8}	1.709×10^{-12}	2.5364×10^{-13}
0.39	**Aluminum 6063**	6.8627×10^{-6}	6.2493×10^{-7}	5.9035×10^{-8}	-3.026×10^{-13}	-9.4099×10^{-12}
	Structural steel	2.4362×10^{-6}	6.2557×10^{-7}	5.5302×10^{-8}	-8.4588×10^{-14}	-3.3629×10^{-12}
	Titanium	5.0755×10^{-6}	6.2475×10^{-7}	6.3249×10^{-8}	-2.7596×10^{-13}	-6.9068×10^{-12}

TABLE 1. Results for stress and strains at different materials

MODEL ANALYSIS 1:

At pressure value 0.17221 N/mm^2

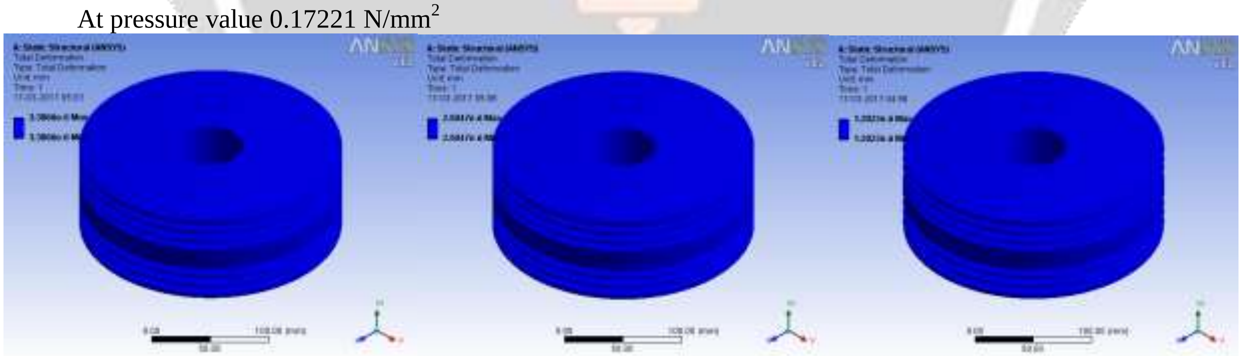

Fig 8. Total deformation

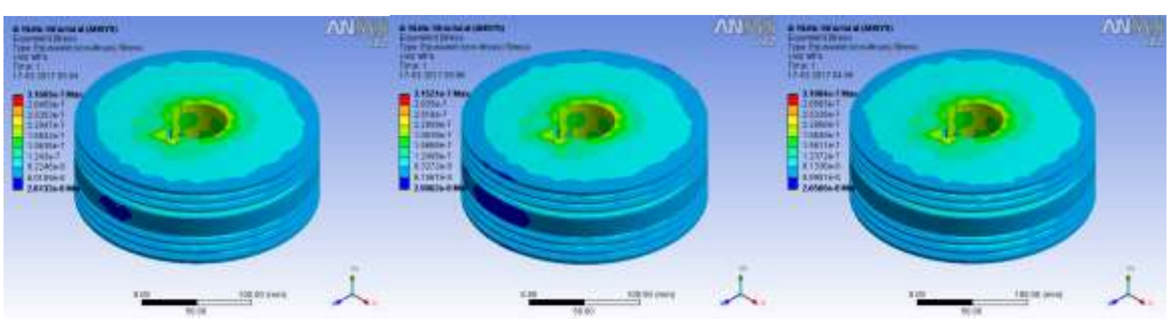

Fig 9. Equivalent (von-mises) stress

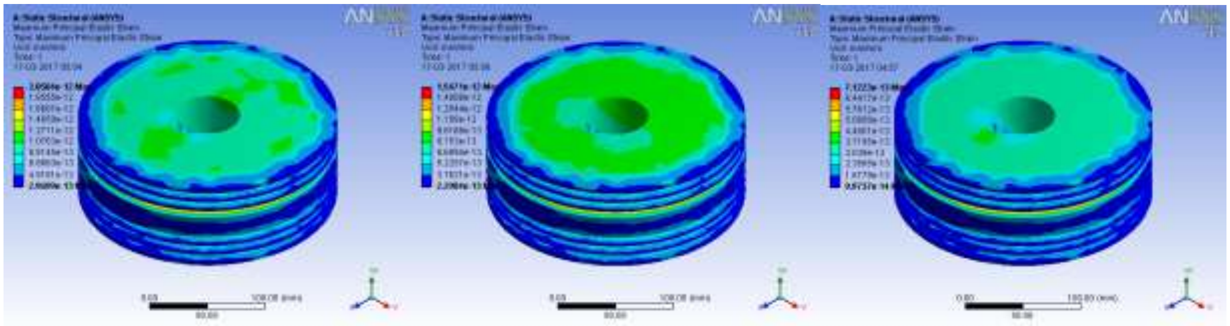

Fig 10. Maximum principal elastic strain

MODAL ANALYSIS 2:

At pressure value 0.25849 N/mm^2

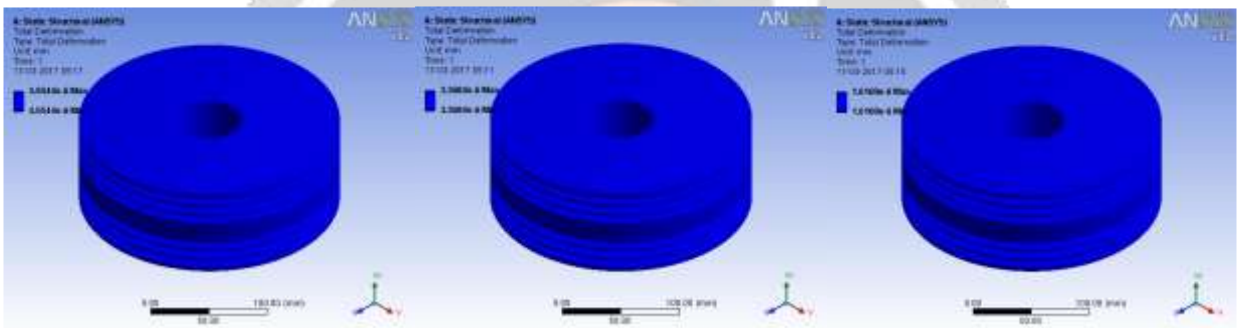

Fig 11. Total deformation

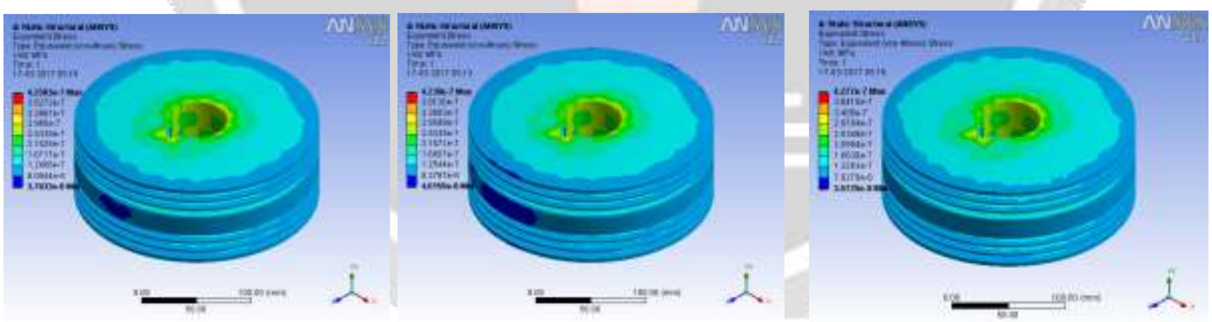

Fig 12. Equivalent (von-mises) stress

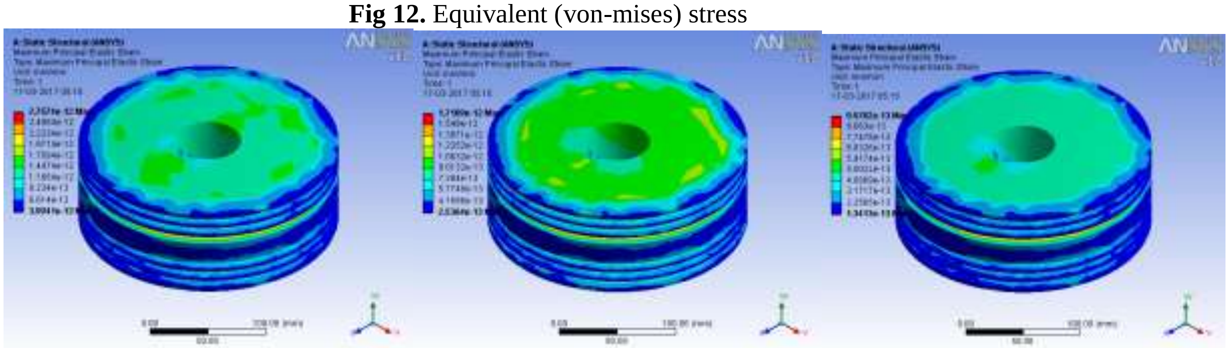

Fig 13. Maximum Principal elastic strain

MODAL ANALYSIS 3:

At pressure value 0.39 N/mm^2

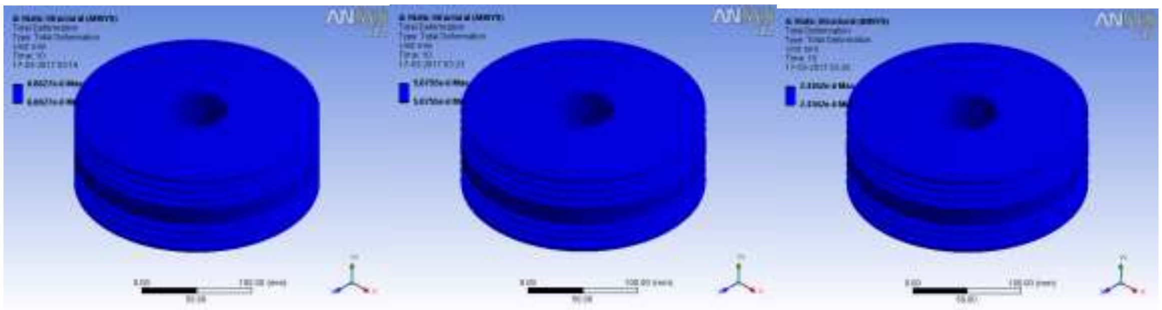

Fig 14. Total deformation

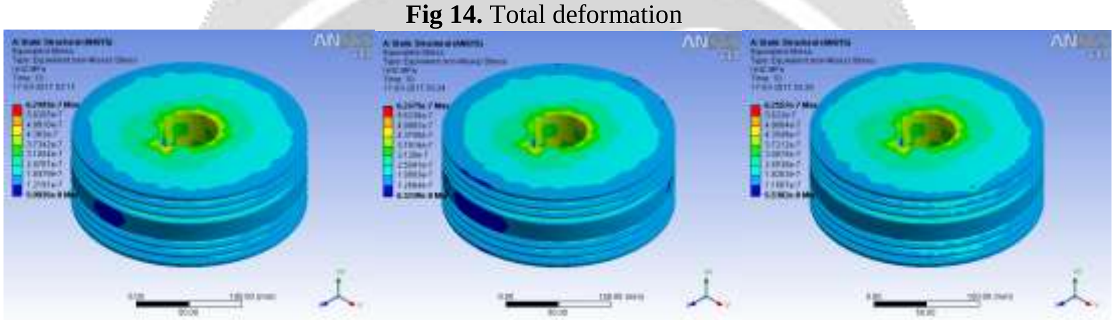

Fig 15. Equivalent (von-mises) stress

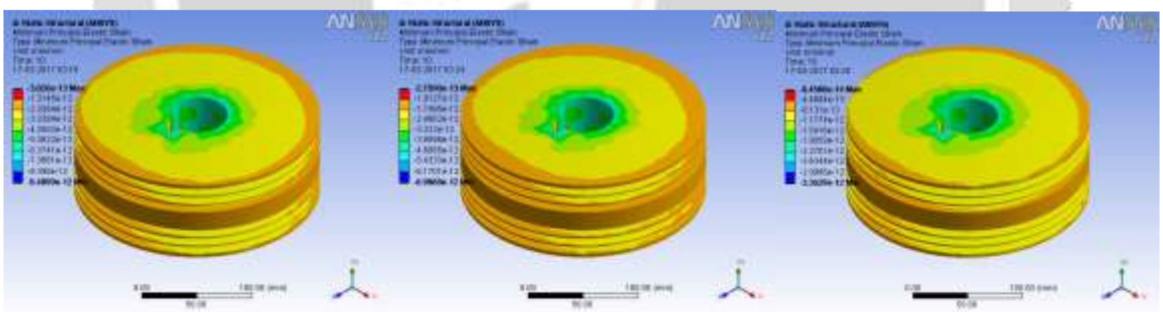

Fig 16. Maximum principal elastic strain

4. CONCLUSION

In this project we have designed a flywheel which is used in compression ignition engine using theoretical calculations.2D drawing is created and modeling of flywheel is done using CATIA software. We have done static structural and modal analysis on flywheel using three materials Aluminum 6063, Structural steel and Titanium at different pressure values. By observing the results in deformation aspect structural steel is less than the other two materials. In equivalent (von-mises) stress, aluminum 6063 is less than the other materials. Coming to the maximum principal elastic strain titanium is less than the other materials. We have calculated tensile and radial stress for all materials from that results aluminum 6063 less than other materials. For cost factor analysis structural steel is cheaper than the other two materials and its elongation property is also higher than the aluminum and titanium.

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BIOGRAPHIES

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