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Design Consideration of Compact Flywheel by Effectiveness Analysis

Vishal J Dhore, Prof. E. R. Deore[2]

[1,2]*Mechanical Engineering Department,*
S S V P S Bapusaheb Shivajirao Deore College of Engineering, Dhule, India

Abstract— Conventional flywheel system uses a single rim flywheel. The performance of the flywheel depends upon its mass, so also it encounters a lot of air friction and leads to more in-efficiency and more occupation. Flywheel releases stored energy by applying torque to a mechanical load, thereby decreasing the flywheels rotational speed. The dissertation work shows the flywheel optimum design model which fulfils minimum criteria of inertia result into safe and efficient working. In this study work on CAD base design and analysis with experimental base model generation in a feasible area of design. For a optimum design consideration of flywheel compare parameters like torque, power, efficiency with respective to speed. This paper shows calculation of the software base stress analysis on the basis of conventional and new compact design flywheel. The efficiency calculation in a compact flywheel shows 30% improvement as compared to conventional flywheel.

Keywords-FEA, Effectiveness, Conventional Flywheel, Compact Flywheel

I. INTRODUCTION

A flywheel is a rotating mechanical device that is used to stored rotational energy. Flywheels have a significant moment of inertia and thus resist changes in rotational speed. The amount of energy stored in a flywheel is proportional to the square of its rotational speed. Energy is transferred to a flywheel by an applying torque to it, thereby increasing its rotational speed and hence its stored energy. Conversely, a flywheel releases stored energy by applying torque to a mechanical load, thereby decreasing the flywheels rotational speed.

Conventional flywheel system uses a single rim flywheel. The performance of the flywheel depends upon its mass, so also it encounters a lot of air friction and leads to more in-efficiency and more occupation. On the other hand lighter flywheel leads to some problem like to get harder to kick through, requires slightly higher idle speed screw setting for stable idle, is more likely to stall when cold out of tune, easier to shift, has better braking (unless you disconnect the motor by pulling the clutch in while braking), requires more delicate touch with the clutch in traffic, harder on the primary chain, less tolerant of walking speed in gear.

The engine‘s ignition-induced rotational speed irregularity causes torsional vibration in the vehicle‘s driveline. At a given speed the ignition frequency is equal to the natural frequency of the driveline so that extremely high vibrations amplitudes occur that causes transmission rattle and body boom. Also more mass increases the cost of DMF.

II. METHODOLOGY

As per the study of problems and limitations in the design of conventional flywheel, new design for compact flywheel is needed and as per the requirement here in this paper we suggested new design consideration with feasibility analysis. For new design of compact flywheel suggested design is as per the flow chart diagram.as shown in fig.1

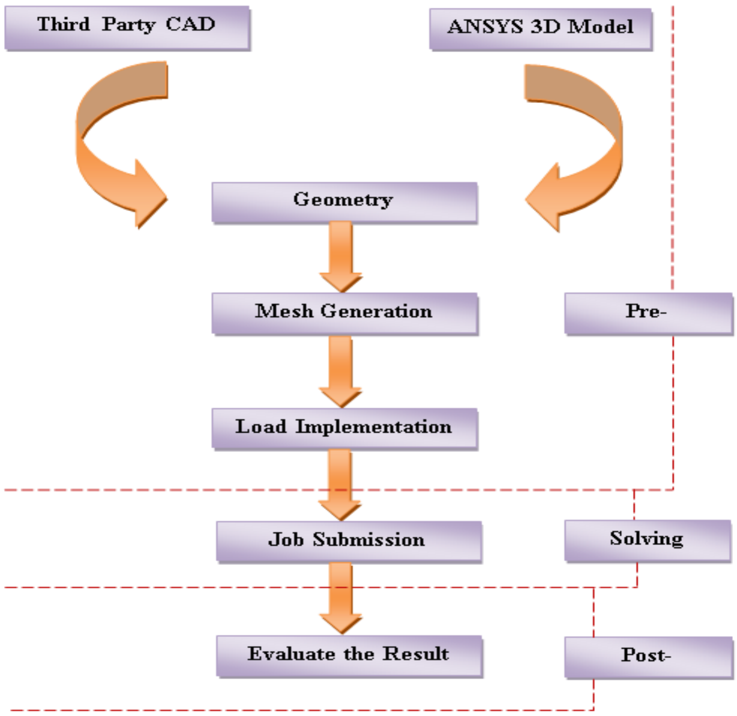

Figure. 1 Steps in Design in Compact Flywheel

The CAD based model is analyzing by ANSYS for stress calculation. Sun gear of compact flywheel is analyzed by loading condition for stress calculation with checking feasibility conditions. After the stress analysis of sun gear by using the ANSYS software, for checking the weather the design of sun gear is safe or not, if it fail in this then again design the up till sun gear to sustain the stress. After that then calculating the effectiveness of compact flywheel using inertia augmentation mechanisms for predating the newly design compact flywheel using inertia augmentation mechanism is efficient and effective.

ANSYS Mechanical software offers a comprehensive product solution for structural linear or nonlinear and dynamics analysis. The product provides a complete set of elements behaviour, material models and equation solvers for a wide range of engineering problems. In addition, ANSYS Mechanical offers thermal analysis and coupled-physics capabilities involving acoustic, piezoelectric, thermal–structural and thermoelectric analysis.

ANSYS software works on the basic concept which is FEM (Finite Element Method). Among the various numerical methods available, finite element method is most popular and widely used. It is perhaps the most sophisticated tool for solving engineering problem. With the introducing of new materials, viz. Composites, fibre reinforced materials etc. The conventional method fails to give solution in many cases, or it become quite uneconomical or time consuming. Moreover, many structures or its components may have complicated shapes whose analysis by the conventional method become very cumbersome and in few cases almost impossible to analyze. Structures having any shape and made of any material can be analyzed by finite element method.

There is no engine speed or other condition where extra flywheel weight helps.

1. Flywheel mass optimization will lead to better acceleration characteristics of the vehicle.
2. Lowered weight of fly wheel system will reduce system weight thereby leading to better fuel economy of vehicle
3. Compact size : The size of the flywheel will lead to better cabin space of vehicle
4. Lowered weight of flywheel will reduce the overall material cost
5. Engine life increases due to balanced power output.

The flywheel optimum design which fulfil minimum criteria of inertia with weight result into safe and efficient working.

III. STRESS AND EFFECTIVENESS ANALYSIS OF FLYWHEEL ELEMENTS

Design of compact flywheel is get finalized after validation of results came from software based analysis. Stress calculation through application of loading conditions gives us effectiveness in working environment. The effect of inertia augmentation can be seen by the difference in the fluctuation of energy in the compact flywheel and the Conventional flywheel. ANSYS Software is used for stress calculation and effectiveness calculating based on their results.

The basis of the finite element method is the representation of a body or a structure by an assemblage of subdivision called finite elements. These elements are considered interconnected joints, which are called nodes or nodal points. Simple functions are chosen to approximate the distribution of variation of the actual displacement over each finite element. The unknown magnitude or amplitudes of displacement functions are the displacement (or its derivatives) at the nodal points. Hence the final solution will yield the approximate displacements at discrete locations in the body, i.e. at the nodal points.

From the computational point of view, finite element analysis can be well organized in three basic components.

a. Pre - processor
b. Processor
c. Post – Processor

3.1. Steps in Analysis

In the analysis of design basically some steps are followed which are as follows.

a) Model Generation
b) Meshing
c) Boundary Condition and Load application
d) Stress Calculation
e) Effectiveness Analysis

3.2. Elemental Analysis

Compact flywheel elements such as sun gear, planet gear, flywheel shaft, base plate, mass lever and mass hinge pin are analyzed for feasible solution.

3.2.1 Sun Gear

The sun gear is central main gear in flywheel which is mainly consider in the design of flywheel.

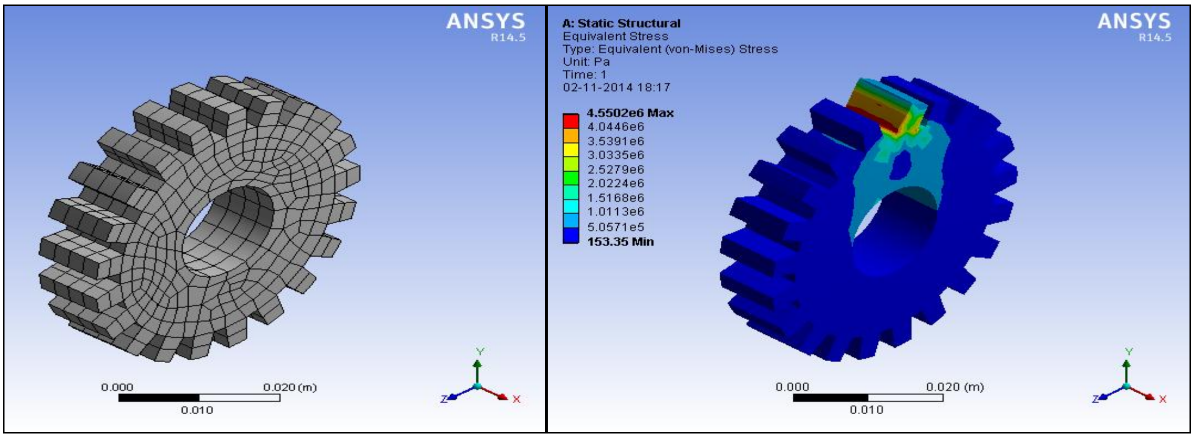

Figure. 2 Model Analysis of Sun Gear

As per the given material condition is up to the 144 N/mm^2 and by stress calculation the tooth static stress is up to the 4.5 N/mm^2 which is in safe zone for working for gear material E24.

3.2.2 Planet Gear

Planet gear is main part in a flywheel along with the sun gear which transfers motion from input to output by revolving in planetary arrangement of flywheel assembly.

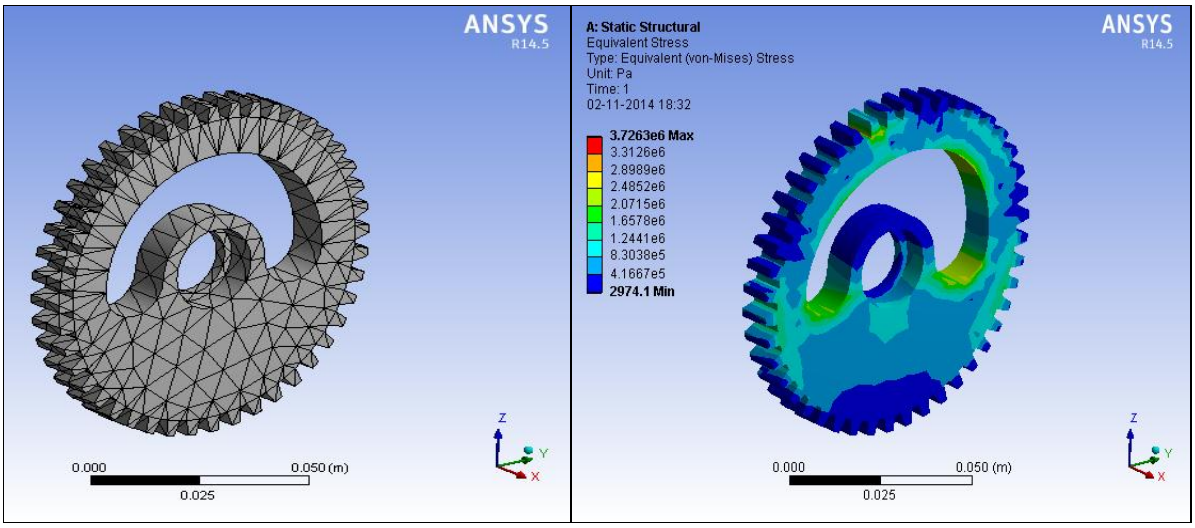

Figure. 3 Model Analysis of Planet Gear

As per the given material condition is up to the 144 N/mm^2 and by stress calculation the tooth static stress is up to the 3.7 N/mm^2 which is in safe zone for working for gear material E24.

3.2.3 Mass Hinged Pin

Mass hinged pin is a central supporting part which hold the eccentric mass with planet gear in flywheel assembly.

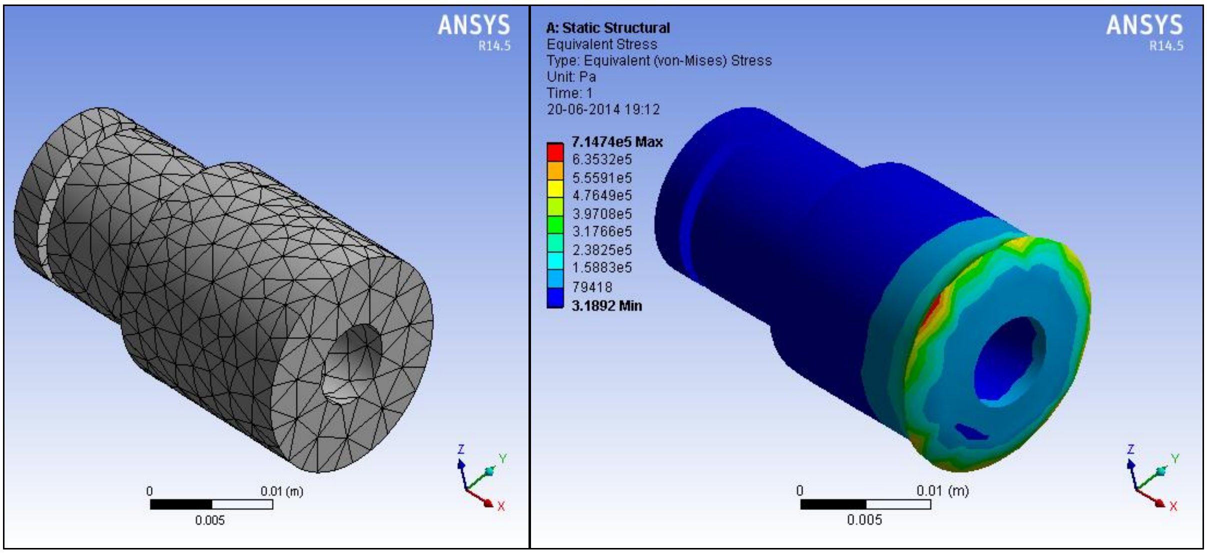

Figure. 4 Model Analysis of Mass Hinged Pin

Maximum stress induced in the pin = 0.7 N/mm^2 which is less than the allowable stress hence the pin safe under shear failure.

3.2.4 Mass Lever

The planetary arrangement in a flywheel assembly with reference to shaft is supported by mass lever which hold and position planet gears.

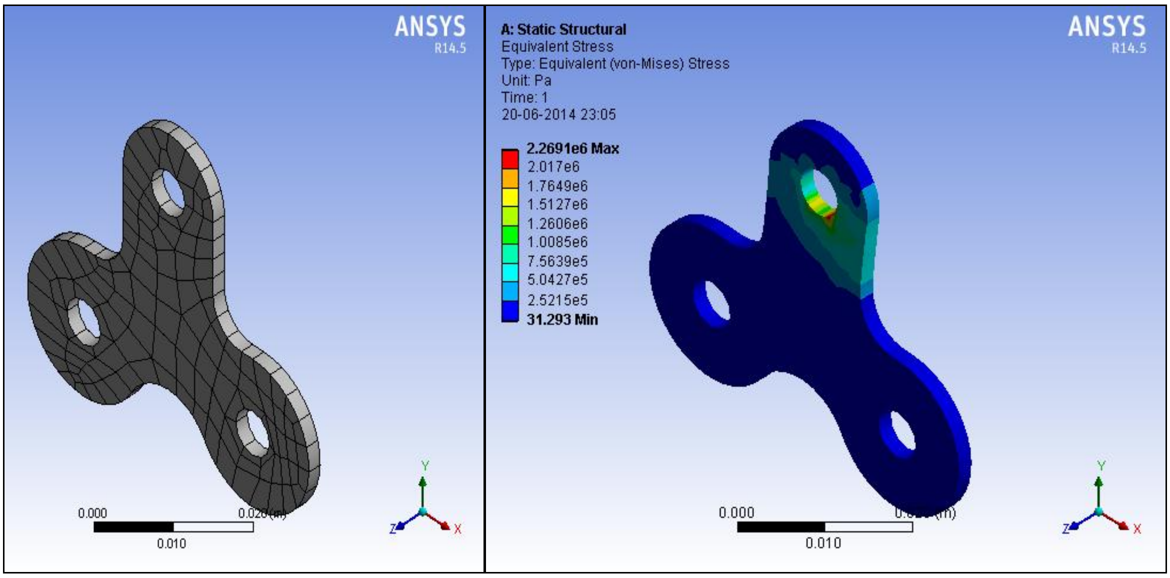

Figure. 5 Model Analysis of Mass Lever

Maximum bending stress induced in the pin = 2.26 N/mm^2 which is less than the allowable stress hence the pin safe under bending failure.

3.2.5 Flywheel Shaft

Flywheel shaft is a central supporting elements along these movement of planetary gear with eccentric mass is takes place

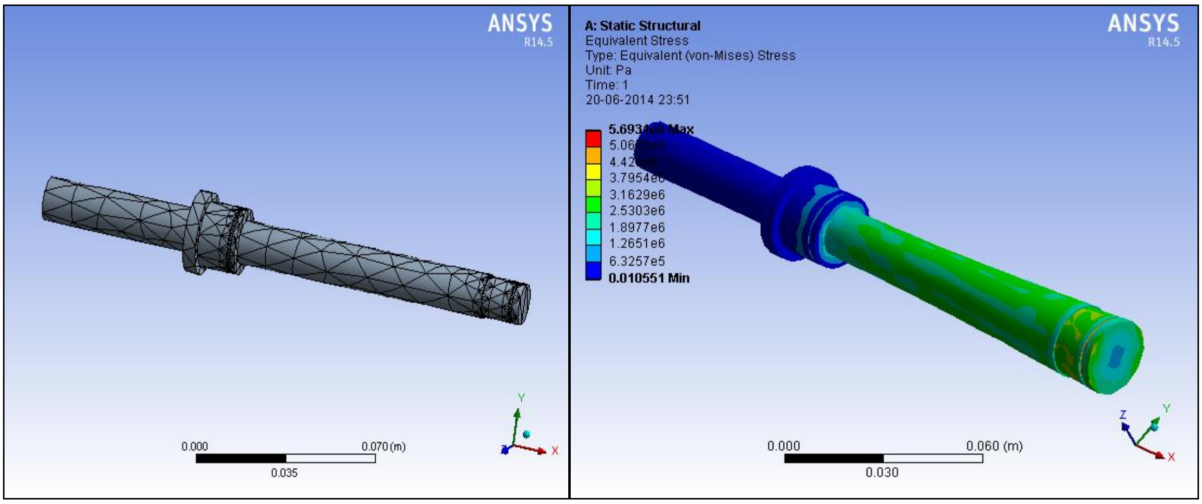

Figure. 6 Model Analysis of Flywheel Shaft

Maximum torsional shear stress induced in the flywheel shaft = 5.69 N/mm2 which is less than the allowable stress hence the pin safe under Torsional shear failure.

3.2.5 Flywheel Base

It is a base plate for flywheel assembly which holds the central assembly along the peripheral movement.

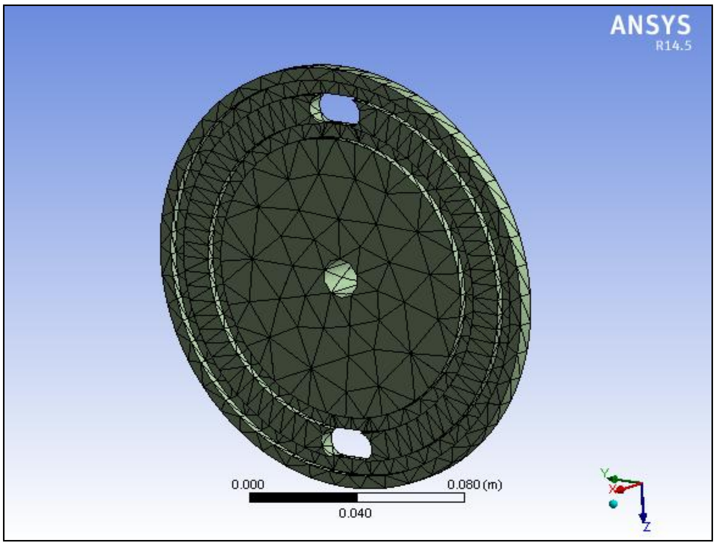

Figure. 7 Meshing of Flywheel Base

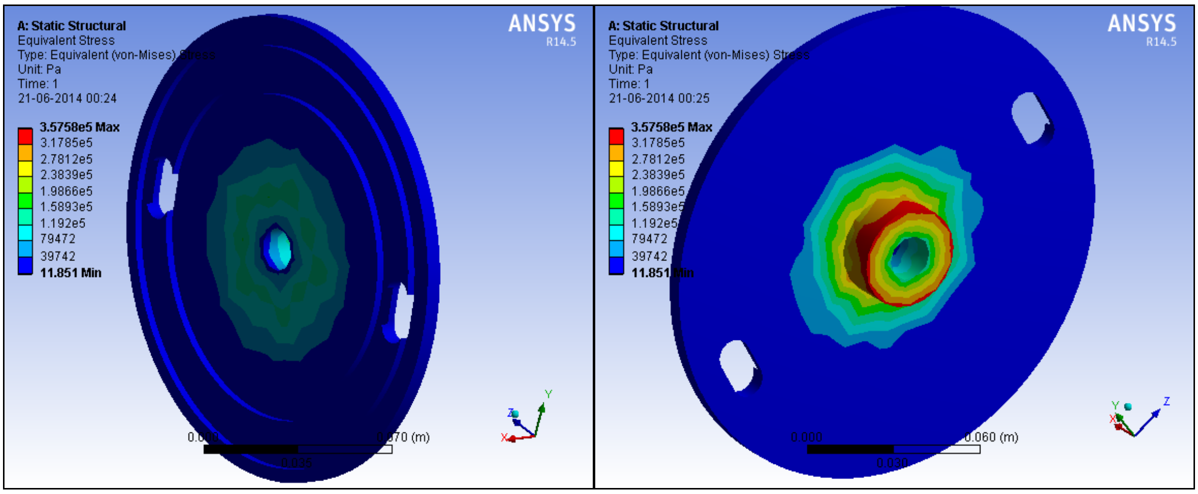

Figure. 8 Model Analysis of Flywheel Base

Maximum torsional shear stress induced in the flywheel base = 0.357 N/mm2 which is less than the allowable stress hence the flywheel base safe under Torsional shear failure.

3.3 Effect of Increased Inertia of Compact flywheel

The effect of inertia augmentation can be seen by the difference in the fluctuation of energy in the Compact flywheel and the Conventional flywheel.

3.3.1 Compact Flywheel

Maximum fluctuation of energy of Dual mass flywheel = ΔE_{cf}

$$= m\, R^2 \omega^2_{cf}\ Cs$$

Where, m = mass of flywheel =1.9 kg

R= Mean Radius of rim = 68 mm =0.068 m

ω_{cf} = mean angular speed of dual mass flywheel

$= 2\pi\ (N1 + N2)/2$

$= 2\pi\ (1430 + 930)/2$

$\omega_{cf} = 7414$ rad/sec

C_s = Coefficient of fluctuation of speed = N1-N2 /N

Where N= (N1 +N2)/2

= 1180

Cs = 1430-930 /1180

= 0.423

$\Delta E_{cf} = m\ R^2 \omega^2_{cf}\ Cs$

$= 1.9 \times 0.068^2 \times 7414^2 \times 0.423$

$\Delta E_{cf} = 204.27$ KJ

3.3.2 Conventional Flywheel

Maximum fluctuation of energy of Conventional flywheel = ΔE_{cnv}

$= m\ R^2 \omega^2_{cnv}\ Cs$

Where, m =mass of flywheel =1.9 kg

R= Mean Radius of rim = 68 mm = 0.068 m

ω_{cnv} = mean angular speed of dual mass flywheel

$= 2\pi\ (N1 + N2)/2$

$= 2\pi\ (1315 + 910)/2$

$\omega_{cnv} = 6990$ rad/sec

Cs = Coefficient of fluctuation of speed = N1-N2 /N

Where N = (N1 +N2)/2

= 1112

Cs = 1315-910 /1112

= 0.364

$\Delta E_{cnv} = m\ R^2 \omega^2_{cnv}\ Cs$

$= 1.9 \times 0.068^2 \times 6990^2 \times 0.364$

$\Delta E_{cnv} = 156.25$ KJ

3.4 Calculating Effectiveness

Effectiveness (έ) = $\Delta E_{cf} / \Delta E_{cnv}$

= 204.27 /156.25

=1.30

Thus the Compact flywheel is 1.3 times effective than the Conventional flywheel, it means that the compact flywheel have 30 % more efficiency than the conventional flywheel.

3.5 New Suggested Compact Flywheel Design

As per the design consideration of flywheel with reference to conventional flywheel and analyzed results of new design elements here we suggested new design assembly as shown in figure. 9 for compact flywheel with 1.3 times effective than the conventional flywheel.

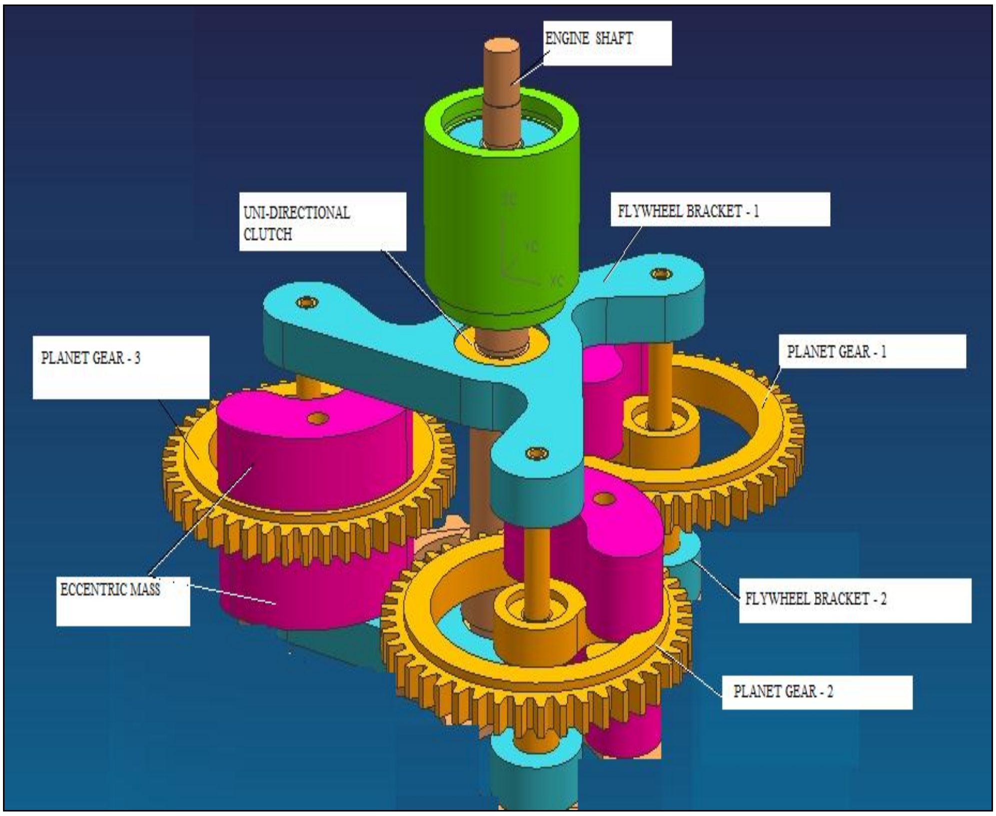

Figure.9 New Suggested Compact Flywheel

IV. CONCLUSION

A flywheel is a rotating mechanical device that is used to stored rotational energy. Flywheels have a significant moment of inertia and thus resist changes in rotational speed. Flywheel releases stored energy by applying torque to a mechanical load, thereby decreasing the flywheels rotational speed.

This dissertation work shows the flywheel optimum design model which fulfils minimum criteria of inertia with weight result into safe and efficient working. In this study work for a better design considering and compare parameters like torque, power, efficiency with respective to speed to optimize the design of flywheel. Results came from the experimental study and analysis shows the feasible area of design.

The efficiency calculation in a compact flywheel shows 30% improvement as compared to conventional flywheel.

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