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DESIGN AND OPTIMIZATION OF PETROL ENGINE FLYWHEEL FOR VARIABLE SPEEDS

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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 I.C. engines, the energy is developed only in the power stroke which is much 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 it's to the crank shaft during the other strokes in which no energy is developed, thus rotating the crankshaft at a uniform speed. The flywheel is located on one end of the crankshaft and serves two purposes. First, through its inertia, it reduces vibration by smoothing out the power stroke as each cylinder fires. Second, it is the mounting surface used to bolt the engine up to its load. The aim of the project is to design a flywheel for a multi cylinder petrol engine flywheel using the different speeds and to analyze to get better results. A 2D drawing is drafted using the calculations. A parametric model of the flywheel is designed using 3D modeling software Catia. The forces acting on the flywheel are also calculated. The strength of the flywheel is validated by applying the forces on the flywheel in analysis software Ansys. Analysis is done for two materials Cast Iron and Aluminum Alloy to compare the results. Catia is the standard in 3D product design, featuring industry-leading productivity tools that promote best practices in design. Ansys is general purpose finite element analysis (FEA) software package. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user-designated size) called elements.*

I- INTRODUCTION

The flywheel is a cast iron, aluminum, or zinc disk that is mounted at one end of the crankshaft to provide inertia for the engine. Inertia is the property of matter by which any physical body persists in its state of rest or uniform motion until acted upon by an external force. Inertia is not a force, it is a property of matter.

During the operation of a reciprocating engine, combustion occurs at distinct intervals. The flywheel supplies the inertia required to prevent loss of engine speed and possible stoppage of crankshaft rotation between combustion intervals.

During each stroke of an internal combustion engine, the flywheel, crankshaft, and other engine components are affected by fluctuations in speed and force. During the power event in a four-stroke cycle engine, the crankshaft is accelerated rapidly by the sudden motion of the piston and connecting rod assembly. The flywheel smooths out some of the rpm and force deviation by its resistance to acceleration. The inertia of the flywheel provides a dampening effect on the engine as a whole to even out radial acceleration forces and rpm deviations produced in the engine.

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The flywheel resists any sudden change of crankshaft (engine) speed. Thus, when a power impulse starts (with its initial high pressure), the crankshaft is given a momentary hard push (through the connecting rod and crankshaft). But the flywheel resists the tendency of the crankshaft to surge ahead. Thus, the momentary power peaks are leveled off so the engine runs smoothly.

The heavier the engine flywheel, the smoother the engine will idle. However, because of its inertia, an excessively heavy flywheel will cause the engine to accelerate and decelerate slowly. For this reasort, heavy, duty or truck engines have large and heavy flywheels. While racing engines or high performance engines have light flywheels.

A big heavy flywheel helps the engine lug away, even at low rpm, but won't freely "rev" (changes in rpm are slower) as the energy accumulated in the flywheel needs to dissipate. Around the flywheel are the teeth that are moved by the starter motor gear, to start your engine. Seen on this image of an engine flywheel.

II - LITERATURE SURVEY

Literature review is an assignment of previous task done by some authors and collection of information or data from research papers published in journals to progress our task. It is a way through which we can find new ideas, concept. There are lot of literatures published before on the same task; some papers are taken into consideration from which idea of the project is taken.

Mission critical technology programs are recently focused on storing energy more efficiently using flywheel than rechargeable chemical batteries while also providing some control advantages. Flywheel is essentially a simple device for storing energy in a rotating mass has been known for centuries. It is only since the development of high-strength materials and magnetic bearings that this technology is gaining a lot more attention. Exploration of highstrength materials allows designers to reach high operating speeds, yielding more kinetic energy. Using magnetic bearings make it possible to reach high operating speeds providing cleaner, faster and more efficient bearing equipment at extreme temperatures. Recently designed flywheels could offer orders of magnitude increases in both performance and service life and in addition, large control torques and momentum storage capability for spacecraft, launch vehicles, aircraft power systems and power supplies

The flywheel system mainly consists of flywheel rotor, motor/generator, magnetic bearings, housing and power transformation electronic system In the development of the flywheel, current researches have focused on increasing the performance while meeting the safety considerations, i.e., material, housing and bearing failures. Investigation of energy storage and failure considerations starts with the calculation of kinetic energy.

In 2012 Sushama G Bawane, A P Ninawe and S K Choudhary had proposed flywheel design, and analysis the material selection process. The FEA model is described to achieve a better understanding of the mesh type, mesh size and boundary conditions applied to complete an effective FEA model.

Saeed Shojaei , Seyyed Mostafa Hossein Ali Pour Mehdi Tajdari Hamid Reza Chamani have proposed algorithms based on dynamic analysis of crank shaft for designing flywheel for I.C.engine , torsional vibrasion analysis result by AVL\EXCITE is compared with the angular displacement of a desire free haed of crank shaft ,also consideration of fatigue for fatigue analysis of flywheel are given.

Sudipta Saha, Abhik Bose, G. SaiTejesh, S.P. Srikanth have propose the importance of the flywheel geometry design selection and its contribution in the energy storage performance. This contribution is demonstrated on example crosssections using computer aided analysis and optimization procedure. Proposed Computer aided analysis and optimization procedure results show that smart design of flywheel geometry could both have a significant effect on the Specific Energy performance and reduce the operational loads exerted on the shaft/bearings due to reduced mass at high rotational speeds.

Bedier B. EL-Naggar and Ismail A. Kholeif had is suggested the disk-rim flywheel for light weight. The mass of the flywheel is minimized subject to constraints of required moment of inertia and admissible stresses. The theory of the rotating disks of uniform thickness and density is applied to each the disk and the rim independently with suitable matching condition at the junction. Suitable boundary conditions on the centrifugal stresses are applied and the dimensional ratios are obtained for minimum weight. It is proved that the required design is very close to the disk with uniform thickness.

Dr. Robert Hebner, et.al. In the past year, the researchers at the Center for Electro mechanics at The University of Texas at Austin (UT-CEM) and the Nanotech Institute at The University of Texas at Dallas (UTD) began research efforts on improved flywheel designs and flywheel materials to meet energy storage requirements for the grid. UT-CEM's initial effort focused on determining the power and energy requirements for a flywheel energy storage system at various points on the grid. UT-CEM researchers used real-world data from a newly developed community in Austin, TX to analyze the effect of energy storage at the home level, transformer level, and the community distribution level. With requirements defined, an optimization code was developed for sizing a flywheel energy storage system for the grid. Results of this optimization are shown for today's flywheel using conventional materials.

Rudolf Glassner, Kottes A dual mass flywheel for a drive train of motor vehicle includes a primary flywheel mass, a secondary flywheel mass & coupling device. The coupling device includes at least two pivot levers associated with secondary flywheel mass that interact with the controlleled profile formed on the primary mass. The pivot levers are pretension against the controlled profile in radial direction by an elastic element. A control segment of elastic element is disposed radially inside the control profile.

III - OBJECTIVES AND METHODOLOGY

The objective of this project work is to successfully and to develop a design of a flywheel for a Petrol Engine at Variable Speeds. This mechanism is to be reliable, simple, and practically feasible. The aim of this project of flywheel mechanism is to provide a design to the automobile engine on unbanked curves. This system is also supposed to enhance the engine comfort as the side force felt by the flywheel at variable speeds in an engine taking a position is comparatively less in a direct transmission system.

The methodology adopted to use standard and presently used components in design rather than to design all components from ground up. The advantage of this method is that, you do not have to spend ridiculous amount and time in testing the integrity of each part as they have already proved their worth in real world applications.

Initially the design was adopted from an already existing flywheel and minor changes were made to suite our purpose, the mechanism first devised was based on using of the engine by its study lifting and lowering each wheel of the car. This mechanism was later taken in testing phase due to following conditions.

1. Through its inertia, it reduces vibration by smoothing out the power stroke as each cylinder fires, and the load will be taken up by the flywheel itself.

2. Wear and tear of flywheel and contact surface is too high to be satisfactorily used at apart in a engine.

3. The forces acting on the flywheel are also calculated. The strength of the flywheel is validated by applying the forces on the flywheel.

4. Analysis is done for both materials Cast Iron and Aluminum Alloy to compare the results at variable speeds.

Due to these conditions, the flywheel design was taken and a fully new design was defined. The software to be used in design is Catia V5 and testing of design is Ansys.

3.1 Summary of capabilities

Like any software it is continually being developed to include new functionality. The details below aim to outline the scope of capabilities to give an overview rather than giving specific details on the individual functionality of the product.

Catia Elements is a software application within the CAID/CAD/CAM/CAE category, along with other similar products currently on the market.

Catia Elements is a parametric, feature-based modeling architecture incorporated into a single database philosophy with advanced rule-based design capabilities.

The capabilities of the product can be split into the three main heading of Engineering Design, Analysis and Manufacturing. This data is then documented in a standard 2D production drawing or the 3D drawing standard ASME Y14.41-2003.

3.2 Engineering Design

Catia Elements offers a range of tools to enable the generation of a complete digital representation of the product being designed. In addition to the general geometry tools there is also the ability to generate geometry of other integrated design disciplines such as industrial and standard pipe work and complete wiring definitions. Tools are also available to support collaborative development.

A number of concept design tools that provide up-front Industrial Design concepts can then be used in the downstream process of engineering the product. These range from conceptual Industrial design sketches, reverse engineering with point cloud data and comprehensive freeform surface tools.

3.3 Analysis

Ansys Elements has numerous analysis tools available and covers thermal, static, dynamic and fatigue FEA analysis along with other tools all designed to help with the development of the product. These tools include human factors, manufacturing tolerance, mould flow and design optimization. The design optimization can be used at a geometry level to obtain the optimum design dimensions and in conjunction with the FEA analysis.

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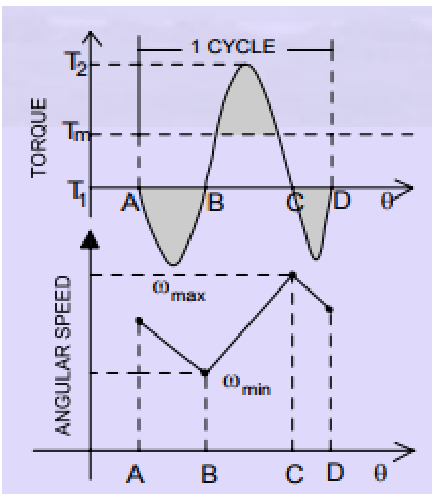
IV - DESIGN TERMINOLOGY OF FLYWHEEL

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.



Flywheels-Function need and Operation 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.

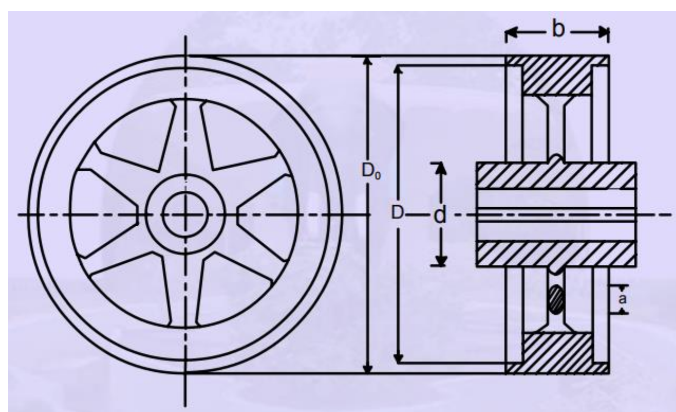
Flywheel absorbs mechanical energy by increasing its angular velocity and delivers the stored energy by decreasing its velocity.

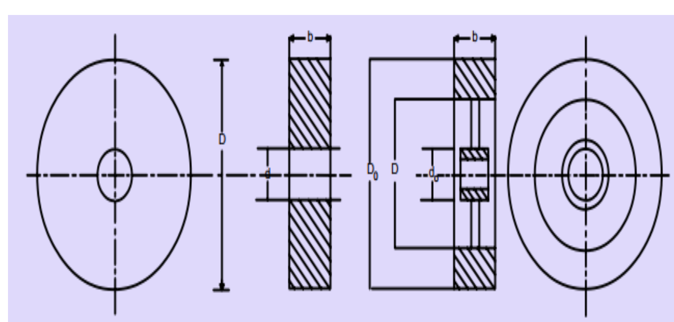
Design Approach

There are two stages to the design of a flywheel. First, the amount of energy required for the desired degree of smoothening must be found and the (mass) moment of inertia needed to absorb that energy determined. Then flywheel geometry must be defined that caters the required moment of inertia in a reasonably sized package and is safe against failure at the designed speeds of operation.

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.





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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 ri and out side radius r_o, the mass moment of inertia I is

$$\mathbf{I_m = mk^2}$$

V - DESIGN METHODLOGY OF PETROL ENGINE FLYWHEEL

CATIA (Computer Aided Three-dimensional Interactive Application) is a multi-platform CAD/CAM/CAE commercial software suite developed by the French company Dassault Systems. Written in the C++ programming language, CATIA is the cornerstone of the Dassault Systems product lifecycle management software suite. CATIA competes in the high-end CAD/CAM/CAE market with Cero Elements/Pro and NX (Unigraphics).

CATIA can be applied to a wide variety of industries, from aerospace and defense, automotive, and industrial equipment, to high tech, shipbuilding, consumer goods, plant design, consumer packaged goods, life sciences, architecture and construction, process power and petroleum, and services. CATIA V4, CATIA V5, Pro/ENGINEER, NX (formerly Unigraphics), and Solid Works are the dominant systems.

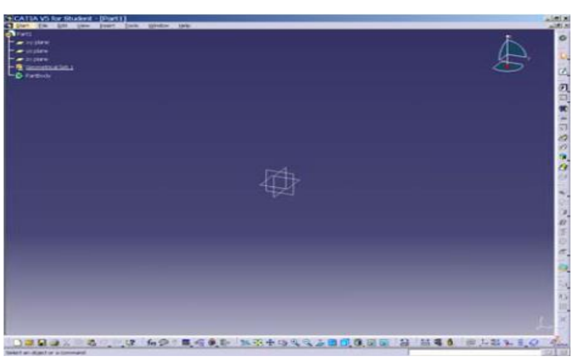

Fig: 5.1: Home Page of CatiaV5

Modeling of Petrol Engine Flywheel in CATIA V5

This Petrol Engine Flywheel is designed using CATIA V5 software. This software used in automobile, aerospace, consumer goods, heavy engineering etc. it is very powerful software for designing complicated 3d models, applications of CATIA Version 5 like part design, assembly design.

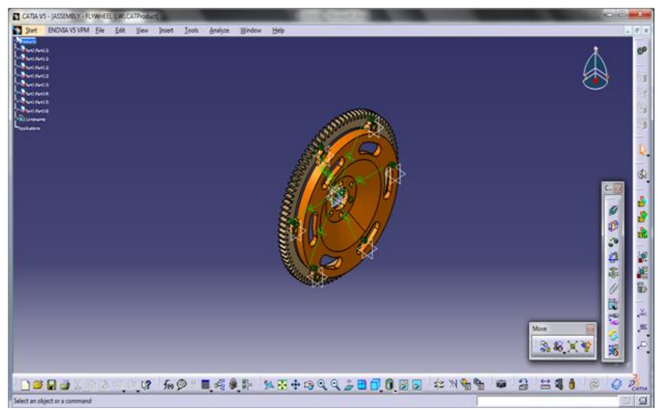

Fig: 5.2: Model design of Petrol Engine Flywheel in CATIA-V5

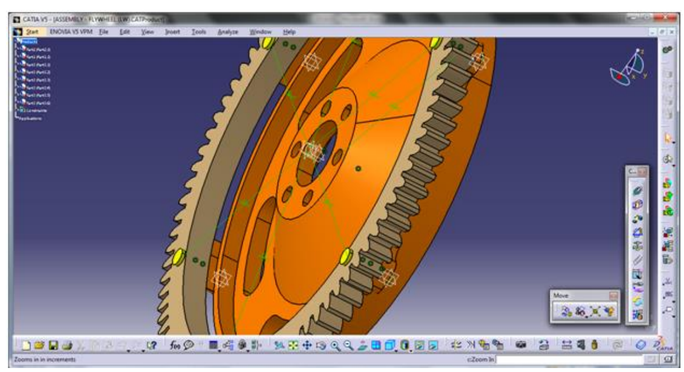

Fig: 5.3: Model arrangement of Petrol Engine Flywheel components in CATIA-V5

VI - ANALYSIS OF PETROL ENGINE FLYWHEEL FOR VARIABLE SPEEDS

6.1 Procedure for FE Analysis Using ANSYS:

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The analysis of the flywheel is done using ANSYS. For compete assembly is not required, is to carried out by applying moments at the rotation location along which axis we need to mention. Fixing location is bottom legs.

6.2 Preprocessor

In this stage the following steps were executed:

- **Import file in ANSYS window**

File Menu > Import> STEP > Click ok for the popped up dialog box > Click

Browse" and choose the file saved from CATIAV5R20 > Click ok to import the file

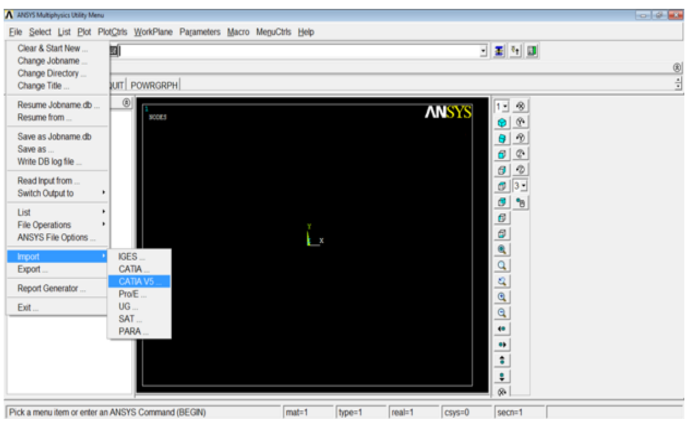

Fig.6.1: Import panel in Ansys.

Meshed View of Flywheel components:

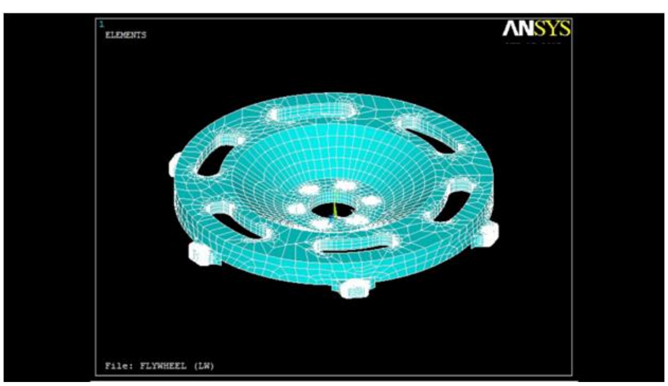

***Fig.6.20 Meshing* FLYWHEEL**

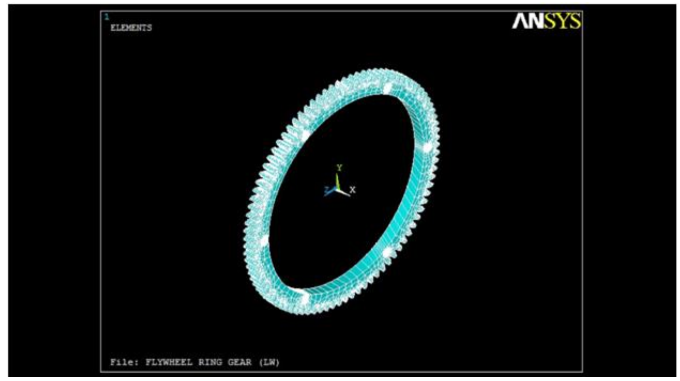

***Fig.6.21 Meshing* FLYWHEEL RING GEAR**

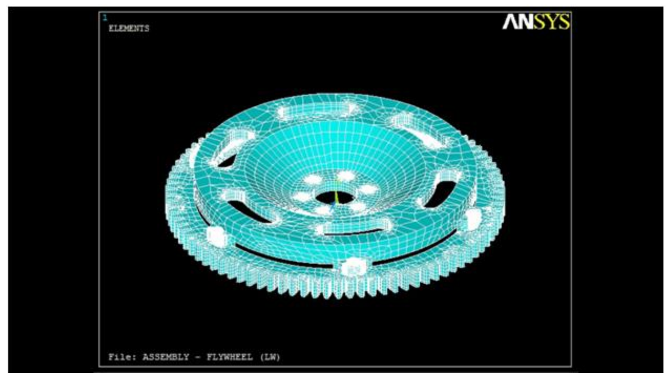

***Fig.6.22 Meshing* FLYWHEEL ASSEMBLY**

Flywheel are modeled with element and shown as above and assembled with adjacent components. Few components are solved using Rotational Force Analysis for checking the stress and displacements while rotating.

VII - DISCUSSION ON ANALYSYS RESULT

7.1 Structural Analysis Results for Flywheel:

7.1.1 Results of Displacement Analysis:

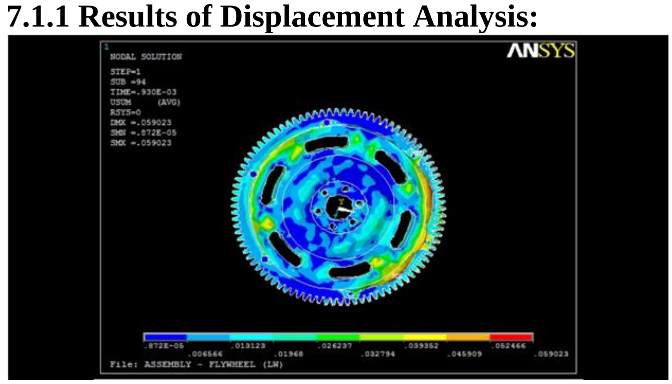

***Fig: 7.1: Displacement of* FLYWHEEL ASSEMBLY**

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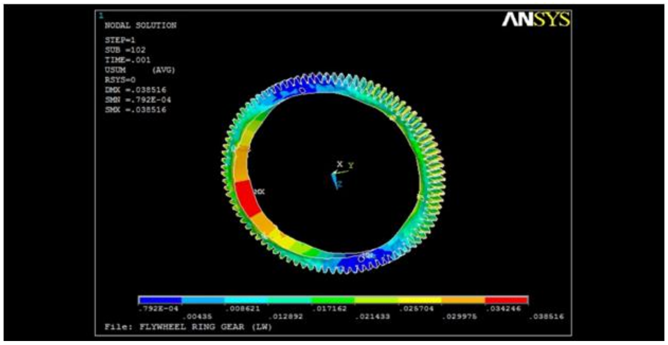

Fig: 7.2: Displacement of **FLYWHEEL RING GEAR**

7.1.2 Results of Stress analysis:

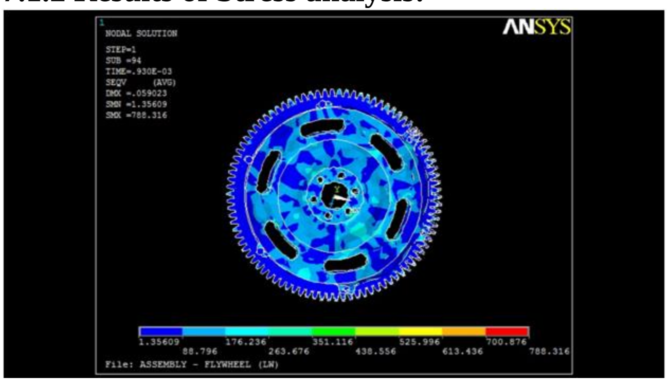

Fig: 7.3: Stress Analysis of **FLYWHEEL ASSEMBLY**

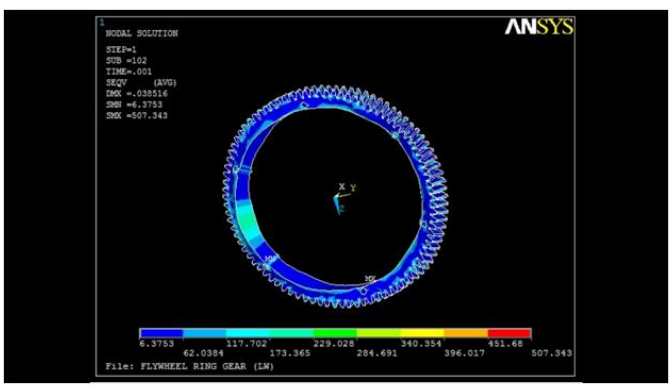

Fig: 7.4: Stress Analysis of **FLYWHEEL RING GEAR**

7.1.3 Results of Strain analysis:

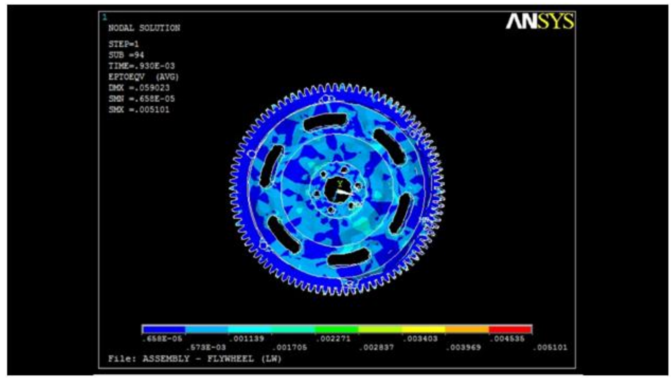

Fig: 7.5: Strain Analysis of **FLYWHEEL ASSEMBLY**

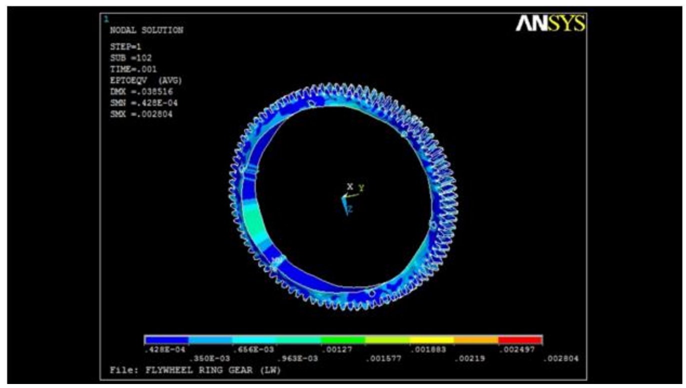

Fig: 7.6: Strain Analysis of **FLYWHEEL RING GEAR**

VIII - CONCLUSION

It can be seen from the above result that, our objective to find out after the loads falling on the flywheel in the Petrol Engine with variable speeds. The design has been successful. As shown above figures the displacement of the complete design assembly is meshed and solved using Ansys and displacement is 0.059 mm which is very less. This is showing us that clearly each component in assembly is having minor displacement.

Structural Analysis

Stress is at the fixing location (Minimum Stress which is acceptable). The value is 1.356 MPa which is very less compared to yield value; this is below the yield point.

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The maximum stress is coming, this solution solving with the help of Ansys software so that the maximum stress is 788.31 MPa which is very less. So we can conclude our design parameters are approximately correct. Strain acting by the designed model is at the fixing location. The value is 0.0051 MPa.

Dynamic Analysis

S. No	Results	Al – 3500	CI – 3500	Al – 10000	CI – 10000
01	Displacement (in mm)	0.0462	0.0645	0.1341	0.0921
02	Rotational (in mm)	0.0899	0.0699	0.1767	0.0999
03	Von Misses Stress (Mpa)	518.96	657.47	937.91	1504.49
04	Von Misses Strain (Mpa)	0.0033	0.0037	0.0097	0.0053

The design of the flywheel in the Petrol Engine with variable speeds mechanism worked flawlessly in analysis as well. All these facts point to the completion of our objective in high esteem.

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