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.

What does a flywheel do?

The flywheel or torque converter helps the engine to run smoothly by absorbing some of the energy during the power stroke and releasing it during the other strokes.

The vibration damper (harmonic balancer) dampens crankshaft torsional vibrations that result from the power impulses. As each cylinder fires, it causes the crank throw for that cylinder to speed up. The rest of the crankshaft tends to stay slightly behind, causing a twist. This causes Torsional vibrations, which are dampened or partially absorbed by the vibration damper.

The flywheel contributes to the uniform rotation of the crankshaft and helps the engine overcome loads when starting the automobile from rest and also during operation. Even though the power impulses of a multicylinder engine follow each other or overlap, additional smoothing out of the power impulses is desirable. The engine flywheel does this job. The flywheel is a relatively heavy metal wheel which is firmly attached to the crankshaft. Because of its rotation the flywheel acquires kinetic energy; when the flywheel speeds up, it stores additional kinetic energy, and when it slows down it gives back that energy. The amount of energy which a flywheel will store for a given change in speed depends on its inertia, which, in turn, depends on its mass and its effective diameter. The energy which the engine pistons deliver to the crankshaft fluctuates, being greatest when a piston has started on its power stroke, much less on the exhaust and suction strokes, and negative during the compression stroke. These fluctuations in energy to and from the crankshaft.

II - LITERATURE SURVEY

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.

2.1. Detail History

In 2005 JohnA.Akpobi & ImafidonA.Lawani have proposed, a computer-aided-designs of software for flywheels using object-oriented programming approach of Visual Basic. The various configurations of flywheels (rimmed or solid) formed the basis for the development of the software. The software's graphical features were used to give avisual interpretation of the solutions. The software's effectiveness was tested on a number of numerical examples, some of which are outlined in this work.

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 cross-sections 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.

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.

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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.

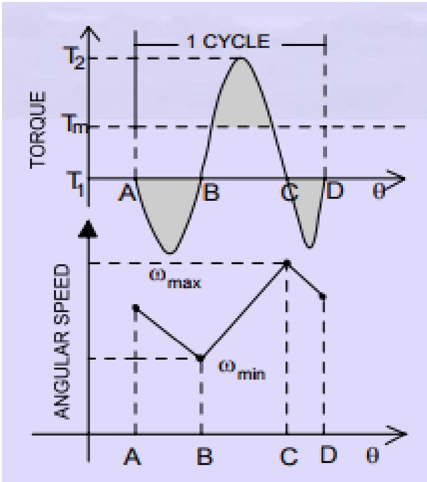
A number of concept design tools that provide up-front Industrial Design concepts can then be used in the downstream process of engineering the product. These range from conceptual Industrial design sketches, reverse engineering with point cloud data and comprehensive freeform surface tools.

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.

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.



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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.

4.1 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.

V - DESIGN METHODLOGY OF PETROL ENGINE FLYWHEEL

Introduction to CATIA

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).

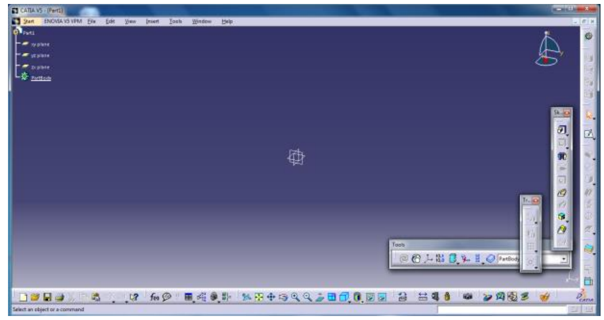

Fig: 5.1: Home Page of CatiaV5

Modeling of Automobile flywheel in CATIA V5

This Automobile 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.

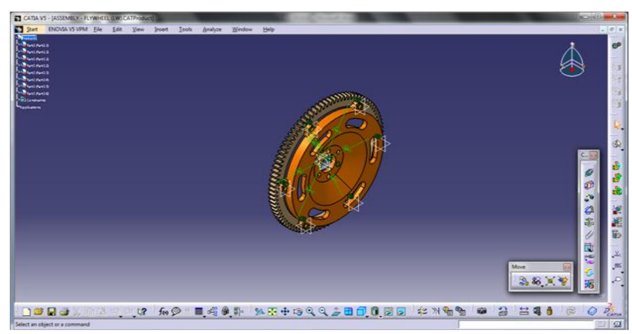

Fig: 5.2: Model design of Automobile flywheel in CATIA-V5

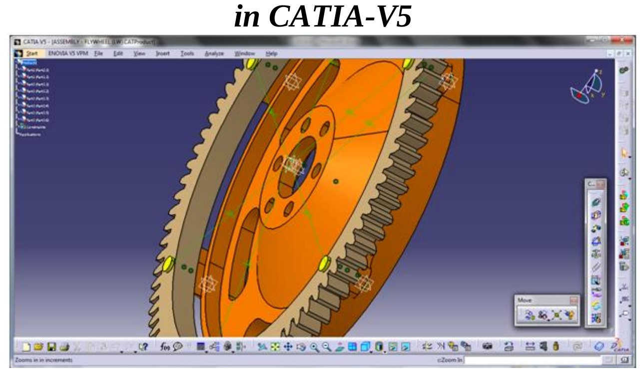

Fig: 5.3: Model arrangement in CATIA-V5

VI - ANALYSIS OF AUTOMOBILE FLYWHEEL

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6.1 Procedure for FE Analysis Using ANSYS:

The analysis of the Automobile 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 of rod assembly machine.

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

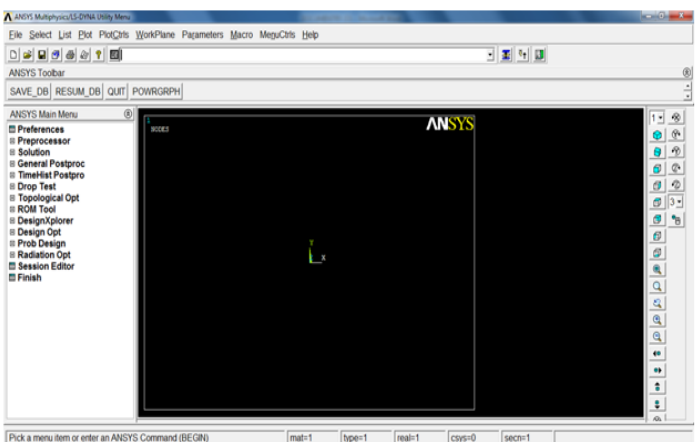

Fig.6.1: Import panel in Ansys.

Rod is modeled with 1d element and shown as above and assembled with adjacent components. Few components are solved using Thermal Analysis for checking the stress and displacements while flowing the fluid.

After completing the meshing of each assembly components next is to do analysis based on the OEM (Original Equipment of Manufacturer) application. So all the models which are analyzed, we need to mention in the Ansys software to get accurate results as per the original component. Some of the components are needed to be solved using thermal analysis.

VII - DISCUSSION ON ANALYSYS RESULT

7.1 Structural Analysis Results for Flywheel:

7.1.1 Results of Displacement Analysis:

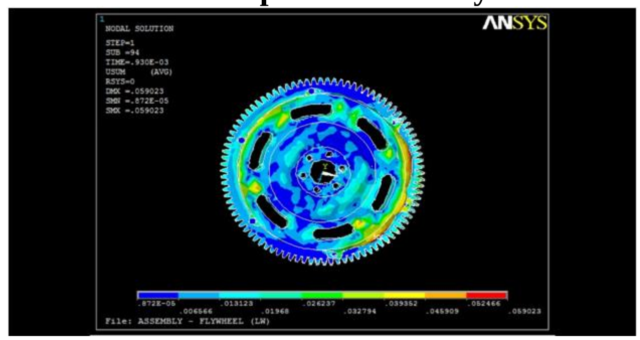

***Fig: 7.1: Displacement of* FLYWHEEL ASSEMBLY**

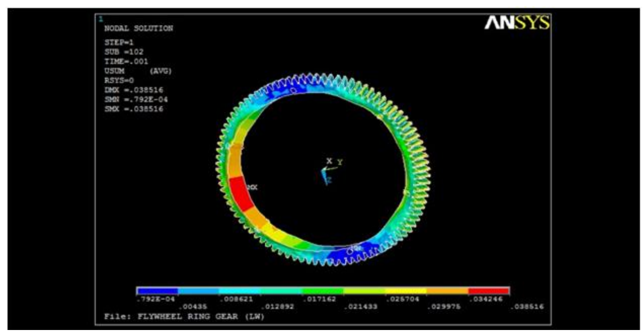

***Fig: 7.2: Displacement of* FLYWHEEL RING GEAR**

7.1.2 Results of Stress analysis:

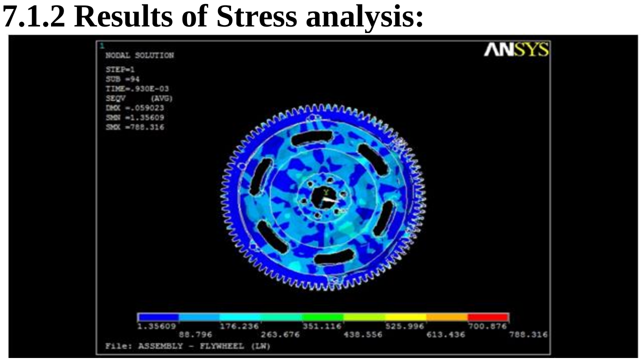

***Fig: 7.3: Stress Analysis of* FLYWHEEL ASSEMBLY**

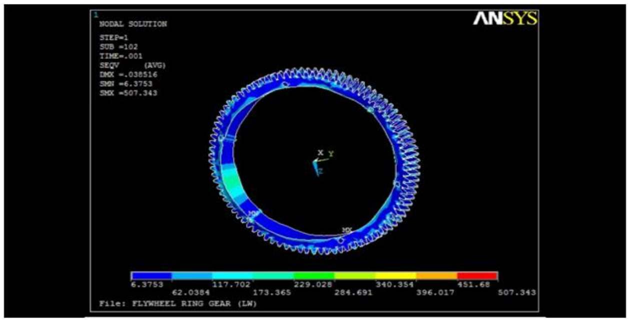

Fig: 7.4: Stress Analysis of **FLYWHEEL RING GEAR**

7.1.3 Results of Strain analysis:

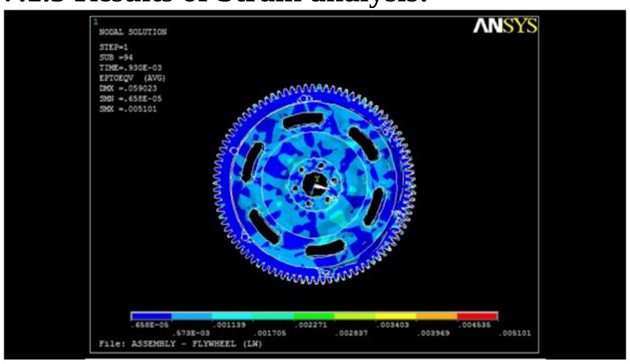

Fig: 7.5: Strain Analysis of **FLYWHEEL ASSEMBLY**

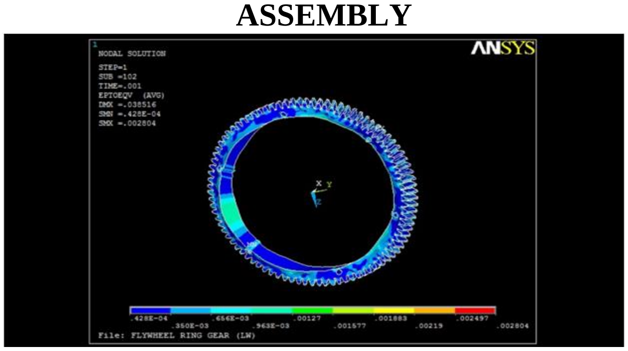

Fig: 7.6: Strain Analysis of **FLYWHEEL RING GEAR**

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.

Structural Analysis

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

Structural Analysis at Variable Speeds

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

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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