ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Design and Analysis of Fly Wheel and By Using CATIA and ANSYS Software

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Abstract:

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. 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.

Countering the requirement of smoothing out the large oscillations in velocity during the cycle of an I.C engine a flywheel is used. As the load on flywheel increases deformation and stresses also increases. The modeling of flywheel is created in CATIA tool and is imported to ANSYS for analysis. Finite Element Analysis is used to calculate the stresses inside the flywheel. The analysis of flywheel had done for two materials.

In first flywheel with Gray Cast Iron (Ultimate stress-214Mpa density-7510 Poisons ratio-0.23) is analyzed and stress inside the flywheel are estimated. In second composite material S-glass-Epoxy (ultimate stress-4800Mpa density-2000 Poisons ratio-0.25) is analyzed and the stress inside the flywheel are estimated and compared the results of both materials.

The analysis on various geometric forms of Flywheel such as solid type, rim type, web type & spoke type of flywheel has been carried out Using modeling package such as CATIA& ANSYS & appropriate results have been extracted & moreover analysis has been carried out on the specific rotation of fly wheel & appropriate Speed can be determined

1.1 INTRODUCTION:

A flywheel is a rotating mechanical device that is used tostore Rotational Energy. Flywheels have a significant moment of inertia and thusresist 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 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 its rotational speed.

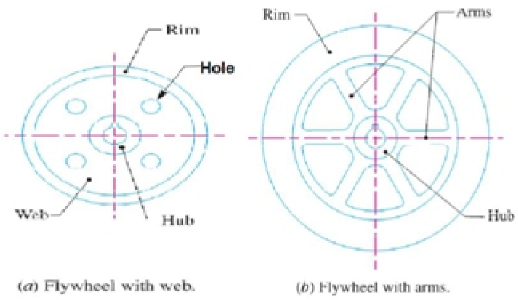

Figure 1.1: Types of Flywheel

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 momentum of a flywheel is purposely transferred to a load when energy is transferred to or from the flywheel.

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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.Carbon-composite flywheel batteries have recently been manufactured and are proving to be viable in real-world tests on mainstream cars. Additionally, they are more eco-friendly, as it is not necessary to take special measures in the disposal of them.

1.2 HISTORY:

The principle of the flywheel is found in the Neolithic Spindle and the potter's wheel.The flywheel as a general mechanical device for equalizing the speed of rotation is, according to the American medievalist Lynn White, recorded in the De diversibus artibus (On various arts) of the German artisan Theophilus Presbyter (ca. 1070–1125) who records applying the device in several of his machines.In the Industrial Revolution, James Watt contributed to the development of the flywheel in the steam engine, and his contemporary James Pickard used a flywheel combined with a crank to transform reciprocating into rotary motion.

1.3 What is a flywheel used for?

There are at least two mechanical purposes for flywheels. The most common is moderating speed fluctuations in an engine through its inertia. This is precisely the purpose for the flywheel you might find in an everyday single cylinder gas engine, such as a push power lawn mower. Since the flywheel is heavy, quick spurts by the engine or sudden loads (such as hitting a clump of weeds) are evened out.

Figure 1.2: A mechanical flywheel on a water pump.

Photo courtesy Stirling Technology

A second use for flywheels is much more interesting to researchers in modern energy storage technology. When we spin a flywheel, we invest a certain amount of energy which increases the momentum of the flywheel. Some of this energy is lost over time to friction; however, if we hold the flywheel in a relatively friction free environment (say by suspending it in a magnetic field in a vaccum), then it is able to store the energy we used to spin it in the form of kinetic energy.

Later, we may be able to retreive this energy either through direct mechanical, or electrical translation. For example, we may fix magnets to the flywheel and be able to use it as the core for an electrical generator. Of course, as we take away energy (in the form of electricity), the flywheel slows down; so we haven't gained anything, but we have managed to store the power in the flywheel for a while.

Figure 1.3: Prototype electro-mechanical battery from Larwence Livermore National Labs.

Photo courtesy Larwence Livermore National Laboratories

1.4 FUNCTIONS OF FLYWHEEL:

The function of the flywheel is to store excess energy during period of harvestation and it supplies energy during period of starvation. 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.

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1.5 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.

1.6 THEORETICAL ANALYSIS:

A flywheel with variable moment of inertia, conceived by Leonardo da Vinci.A flywheel is a spinning wheel or disc with a fixed axle so that rotation is only about one axis. Energy is stored in the rotor as kinetic energy, or more specifically, rotational energy.

$$I= 2\ I\omega$$

1.7APPLICATIONS

1.7.1.1 AUTOMOTIVE:

In the 1950s, flywheel-powered buses, known as gyro busses, were used in Yverdon, Switzerland and there is ongoing research to make flywheel systems that are smaller, lighter, cheaper and have a greater capacity. It is hoped that flywheel systems can replace conventional chemical batteries for mobile applications, such as for electric vehicles. Proposed flywheel systems would eliminate many of the disadvantages of existing battery power systems, such as low capacity, long charge times, heavy weight and short usable lifetimes. Flywheels may have been used in the experimental Chrysler Patriot, though that has been disputed.Flywheels have also been proposed for use in continuously variable transmissions. Punch Power train is currently working on such a device.During the 1990s, Rosen Motors developed a gas turbine powered series hybrid automotive power train using a 55,000 rpm flywheel to provide bursts of acceleration which the small gas turbine engine could not provide. The flywheel also stored energy through regenerative braking. The flywheel was composed of a titanium hub with a carbon fiber cylinder and was gimbal-mounted to minimize adverse gyroscopic effects on vehicle handling. The prototype vehicle was successfully road tested in 1997 but was never mass-produced.

In 2013, Volvo announced a flywheel system fitted to the rear axle of its S60 sedan. Braking action spins the flywheel at up to 60,000 rpm and stops the front-mounted engine. Flywheel energy is applied via a special transmission to partially or completely) carbon fiber power the vehicle. The 20 centimeters (7.9 in), 6 kilograms (13 lb flywheel spins in a vacuum to eliminate friction. When partnered with a four-cylinder engine, it offers up to a 25 percent reduction in fuel consumption versus a comparably performing turbo six-cylinder, providing an 80 hp boost and allowing it to reach 100 kilometers per hour (62 mph) in 5.5 seconds. The company did not announce specific plans to include the technology in its product line.

1.7.1.2 RAIL VEHICLES:

Flywheel systems have also been used experimentally in small electric locomotives for shunting or switching, e.g. the Sentinel-Oerlikon Gyro Locomotive. Larger electric locomotives, e.g. British Rail Class 70, have sometimes been fitted with flywheel boosters to carry them over gaps in the third rail. Advanced flywheels, such as the 133 kWh pack of University of Texas at Austin, can take a train from a standing start up to cruising speed.

The Parry People Mover is a railcar which is powered by a flywheel. It was trialled on Sundays for 12 months on the Stourbridge Town Branch Line in the West Midlands, England during 2006 and 2007 and was intended to be introduced as a full service by the train operator London Midland in December 2008 once two units had been ordered. In January 2010, both units are in operation.

1.7.1.3 RAIL ELECTRIFICATION:

FES can be used at the line side of electrified railways to help regulate the line voltage thus improving the acceleration of unmodified electric trains and the amount of energy recovered back to the line during regenerative breaking, thus lowering energy bills. Trials have taken place in London, New York, Lyon and Tokyo, and New York MTA 's Long Island rail road is now investing $5.2m in a pilot project on LIRR's West Hempstead Branch line.

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1.7.2 UNINTERRUPTIBLE POWER SUPPLIES:

Flywheel power storage systems in production as of 2001 have storage capacities comparable to batteries and faster discharge rates. They are mainly used to provide load leveling for large battery systems, such as an uninterruptable power supply for data centers as they save a considerable amount of space compared to battery systems.Flywheel maintenance in general runs about one-half the cost of traditional battery UPS systems. The only maintenance is a basic annual preventive maintenance routine and replacing the bearings every five to ten years, which takes about four hours. Newer flywheel systems completely levitate the spinning mass using maintenance-free magnetic bearings, thus eliminating mechanical bearing maintenance and failures.

1.7.3 LABORATORIES:

A long-standing niche market for flywheel power systems are facilities where circuit-breakers and similar devices are tested: even a small household circuit-breaker may be rated to interrupt a current of 10,000 or more amperes, and larger units may have interrupting ratings of 100,000 or 1,000,000 amperes. The enormous transient loads produced by deliberately forcing such devices to demonstrate their ability to interrupt simulated short circuits would have unacceptable effects on the local grid if these tests were done directly from building power. Typically such a laboratory will have several large motor-generator sets, which can be spun up to speed over some minutes; then the motor is disconnected before a circuit breaker is tested.Other similar high power applications are in tokamak fusion (like the Joint European Torus) and laser experiments, where very high currents are also used for very brief intervals. JET has two 775 ton flywheels that spin up to 225 rpm. Each flywheel stores 3 GJ.

1.7.4 AMUSEMENT RIDES:

The Incredible Hulk roller coaster at Universal's Island of Adventure features a rapidly accelerating uphill launch as opposed to the typical gravity drop. This is achieved through powerful traction motors that throw the car up the track. To achieve the brief very high current required to accelerate a full coaster train to full speed uphill, the park utilizes several motor generator sets with large flywheels. Without these stored energy units, the park would have to invest in a new substation or risk browning-out the local energy grid every time the ride launches.

1.7.5 PULSE POWER:

Since FES can store and release energy quickly, they have found a niche providing pulsed power.

LITRATURE REVIEW

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.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 a visual 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 vibration analysis result by AVL\EXCITE is compared with the angular displacement of a desire free head 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.

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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

2.2DEVELOPMENT TOOLS:

2.2.1 CATIA (Computer Aided Three-dimensional Interactive Application):

It is a multi-platform CAD/CAM/CAE commercial software suite developed by the French company Dassault Systemes. Written in the C++ programming language, CATIA is the cornerstone of the Dassault Systemes Commonly referred to as a 3D Product Lifecycle Management software suite, CATIA supports multiple stages of product development from conceptualization, design (CAD), manufacturing (CAM), and engineering (CAE).

CATIA facilitates collaborative engineering across disciplines, including surfacing & shape design, mechanical engineering, equipment and systems engineering. 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.

2.2.2ANSYS:

The ANSYS Workbench environment is an intuitive up-front finite element analysis tool that is used in conjunction with CAD systems and/or Design Modeler. ANSYS Workbench is a software environment for performing structural, thermal, and electromagnetic analyses. The class focuses on attaching existing geometry, setting up the finite element model, solving, and reviewing results. The class will describe how to use the code as well as basic finite element simulation concepts and results interpretation. The finite element method (FEM) is a method for dividing up a very complicated problem into small elements that can be solved in relation to each other. Its practical application is often known as finite element analysis (FEA).

2.3 ALGORITHM:

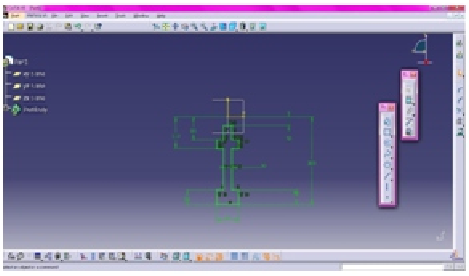
Step 1: A fully constraint model of the flywheel is created by using the CATIA software and is saved.

Step 2: The fully constrained model created in the first step is imported in to the ANSYS for analysis.

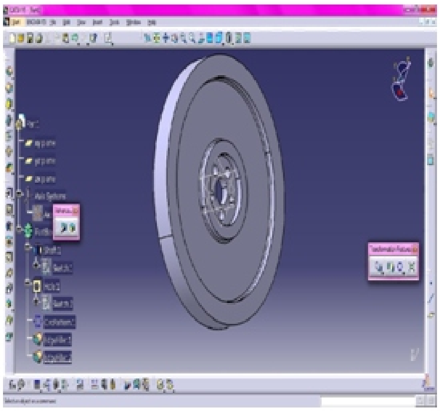
Step 3: The imported model is analyzed in ANSYS A.P.D.L and stress and deformation are to be obtained for Cast Iron and S-glass Epoxy.

Step 4: The same model is analyzed by using ANSYS Work Bench and the stress and deformation can be analyzed.

Step 5: The results obtained in the step 3 are compared and selected the best material with less deformation and stress.



Sketcher of flywheel



Flywheel

GEOMETRIC PROFILE OF SOLID TYPE

FLYWHEEL

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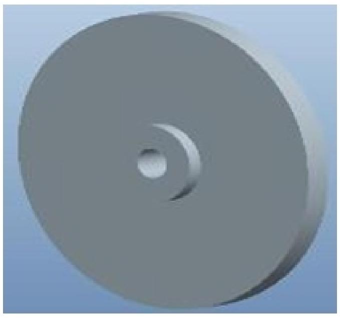
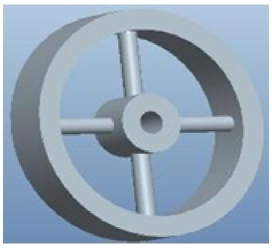
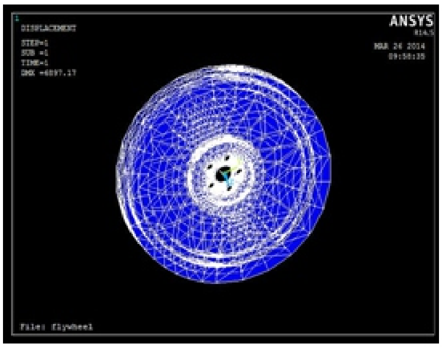
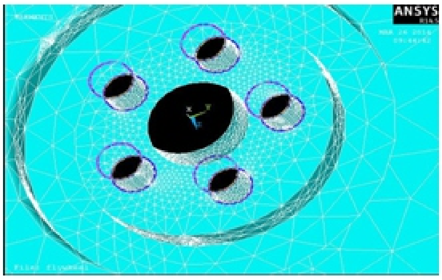
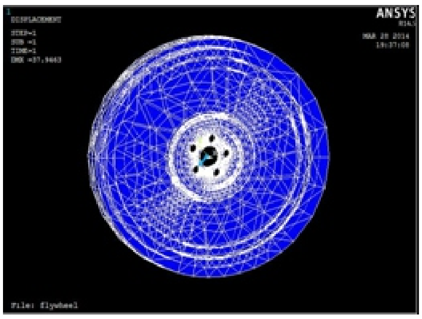


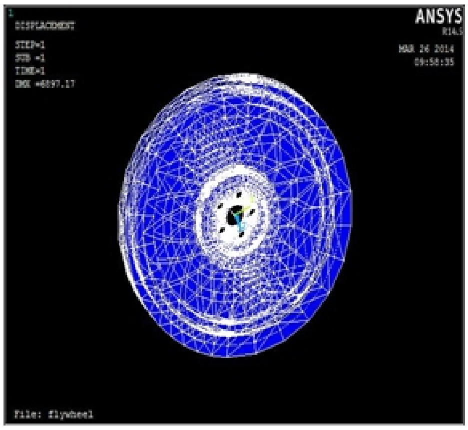




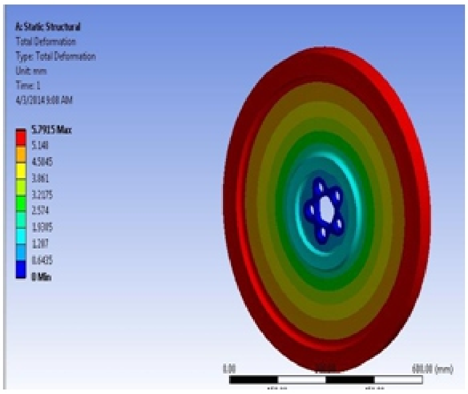




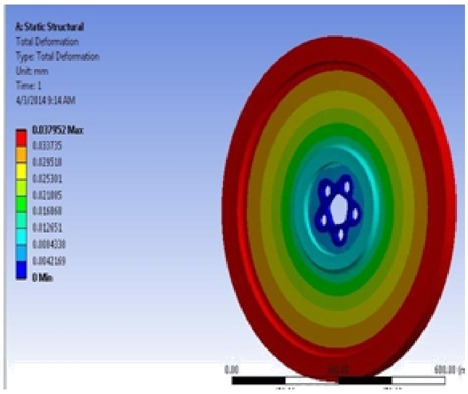
deformed shape for S – Glass Epoxy



Deformed shape for Cast Iron



Total Deformation for S-Glass Epoxy



Total Deformation for Cast Iron

ISSN No: 2348-4845
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CONCLUSION:

The subject of the flywheel is very extensive and is difficult to explain in few pages. This attempt is to summarize some important results by conducting the structural analysis on flywheel with Cast Iron and S-glass Epoxy.

Conducted the structural analysis on flywheel stresses and deformation are founded and observed. By observed results concluded that the most effective material is S-glass Epoxy because S-glass Epoxy has less deformation and less Equivalent Stress when compared to the Cast Iron.