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# Design and Analysis of Flywheel for Different Geometries and Materials

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## Abstract

Flywheel is a mechanical device used to store energy and utilize it whenever it required. Flywheels find its application in number of fields ranging from IC engine of 2-wheeler to more powerful jet engines. Increase in Kinetic Energy of flywheel is the most critical factor for the design engineers. The literature survey shows that flywheel can be redesign for mass optimization which results light weight and Increase in storage capacity. In this project work, an attempt is made to redesign the existing flywheel in terms of its geometry and different materials. Different cross sections of the flywheel are designed using 3D designing software Solidworks 2015. Finite Element analysis is used to calculate the Maximum Rotational speed the flywheel and the amount of Kinetic energy stored at that speed. The results shows that flywheel with Triangular cross sectional geometry and made of S-glass epoxy composite material stores highest Kinetic Energy per unit mass compare to all other combination of Geometries and materials. This New design of flywheel saves weight by 65.252kg compared to existing designs.

**Keywords:** Finite Element Analysis, Flywheel, Solidworks, S-glass Epoxy

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## 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 flywheel is to smoothen out variations in the speed of a shaft caused by torque fluctuations. Generally used materials for manufacturing of flywheels are Steel, Cast Iron, Aluminum Alloy, and Titanium. Cast iron is most preferred because of long term durability and its design can be easily modified by avoiding cost of complete replacement. 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 flywheel. Rating of Flywheel Kinetic Energy is defined interns of Energy Density.

The Energy Density is defined as the Energy per unit mass,

Where, $\omega$ = Angular velocity of the flywheel, $\sigma$ = Specific strength of a material , $\rho$ = Density of the material.

## 2. Selection and Dimensions of Flywheel

Thresher machine is used in agriculture sector to separate the comb from grain. Flywheels used in Thresher Machine are made of single solid disk cast iron material and is selected in this project work. Specifications are mentioned in the Table no 1.

**Table 1.** Flywheel Dimensions

| | |
|---|---|
| Mass of Flywheel (m) | 72kg |
| Outer Diameter ($D_o$) | 500mm |
| Inner Diameter ($D_i$) | 50mm |
| Thickness (t) | 50mm |
| RPM | 750 |

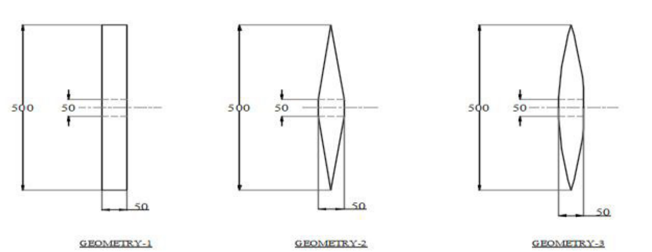


**Figure 1.** Different Cross sectional Flywheels.

## 3. Design of Flywheel Geometries

Single solid disk flywheels made of rectangular cross section is considered. Variation in cross section of the flywheel will results

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in variation of Maximum rotational speed and kinetic energy storage capacity. In this project work existing rectangular cross section flywheel designs are compared with different cross sectional are of flywheels. The redesign of flywheel is done by changing the cross-section and reducing the material by keeping outer diameter, inner diameter and thickness to be constant. Three Different geometries are considered for design and analysis.

## 4. 3D Modelling of Different Geometries of Flywheel

Designing and modeling of flywheel is done using SOLIDWORKS 2015. Solidworks is a solid modeler that makes use of parametric feature-based approach for creating models and assemblies. The following figures show the present as well as re-designed geometries of flywheel.

ANSYS Workbench, one can generate 3D models, FEA models, perform analysis and generate results of analysis.

## 5. Material Selection

Flywheels Kinetic Energy is Depends upon the mass Moment of inertia of the Cross section which intern depends on the material of flywheel. Hence selection of Material to enhance the rotational speed and kinetic energy of the existing system is a critical task for the engineers. Different composite materials are short listed depending upon the Energy storage capacity of the materials. Weighted Residual Method (WRM) is used to find the best materials out of the number of shorted one. S-glass epoxy stands at the top to full fill all the requirement of flywheel. It has good inner strength and variety in surface textures. It is cost effective and corrosion resistant. In this project work S- Glass Epoxy Flywheel is compared with Existing Cast Iron ASTM – 30 Flywheel.

**Table 2.** Flywheel Material Properties

| Material | Young's Modulus E, GPa | Poisson' s Ratio, | Density , kg/m$^3$ | Yield Strength, y MPa |
|---|---|---|---|---|
| Cast Iron ASTM-30 | 101 | 0.23 | 7510 | 260 |
| S- Glass Epoxy | 90 | 0.33 | 2190 | 190 |

## 6. Theoretical Calculation

For Flywheel Geometry 1 made of Cast Iron

1. Angular Velocity,

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2. Mass Moment of Inertia, $I = \frac{1}{2} mr^2 = \frac{1}{2} * 72.992 * (0.250)^2 = 2.281$ kg – m$^2$

3. Maximum Kinetic Energy, $KE = \frac{1}{2} I\omega^2 = 760.14$ KJ

## 7. Finite Element Analysis using ANSYS

Finite Element Method & Analysis is used to find the maximum Speed the flywheel can rotate without any failure and Amount of kinetic energy the flywheel can store at that maximum speed. Static structural analysis is used to find the Maximum Rotation speed and Explicit Dynamics is used to calculate the amount of kinetic Energy in the flywheel.

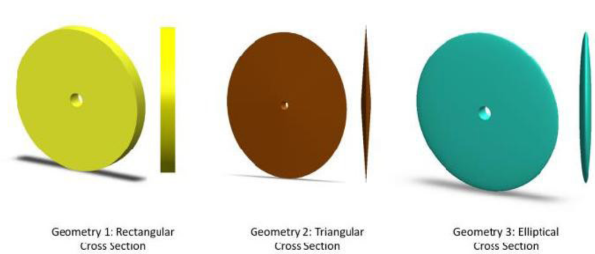
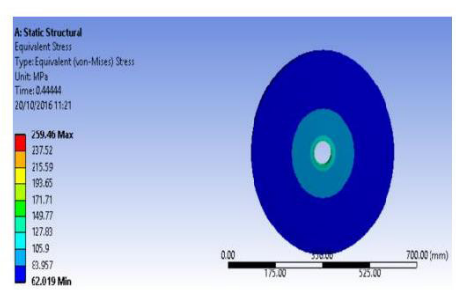
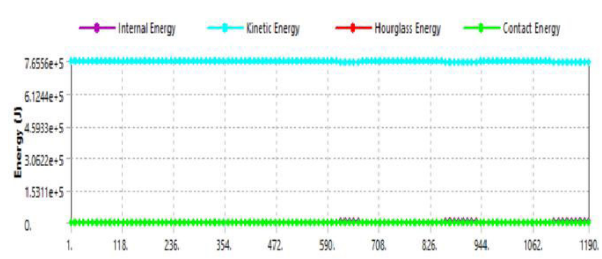



**Figure 2.** Different Cross sectional Flywheel Models.



ANSYS is a Computer Aided Finite Element Modeling (FEM) and Finite Element Analysis (FEA) tool developed by ANSYS Inc. In the Graphical User Interface (GUI) of

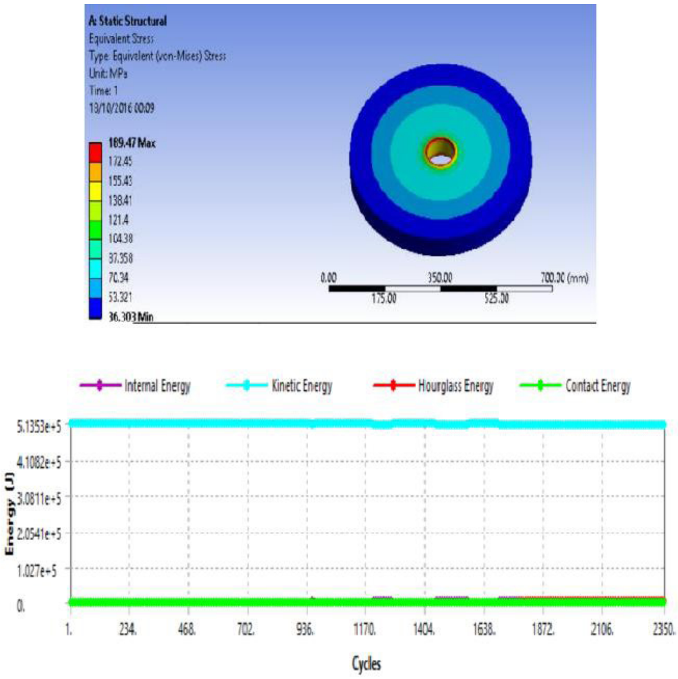



Figure 3. Stress distribution and KE of Geometry 1 with Cast Iron.

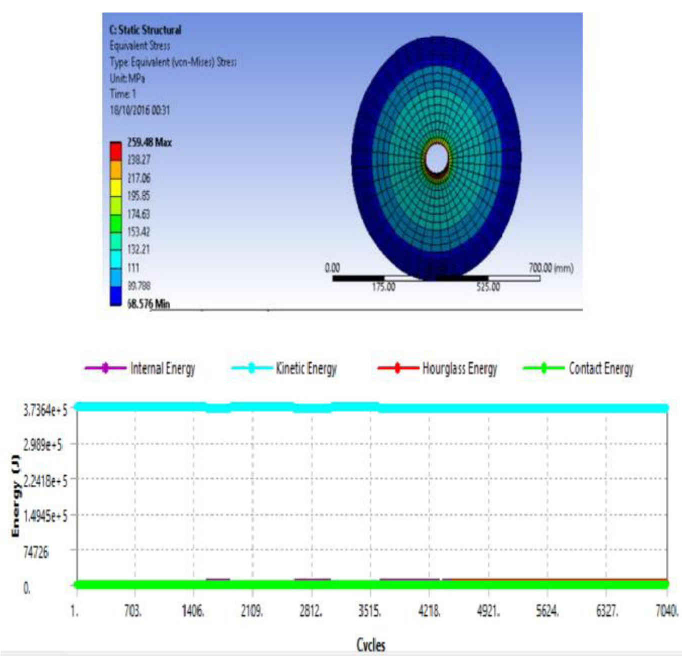



Figure 4. Stress distribution and KE of Geometry 1 with S-Glass Epoxy.

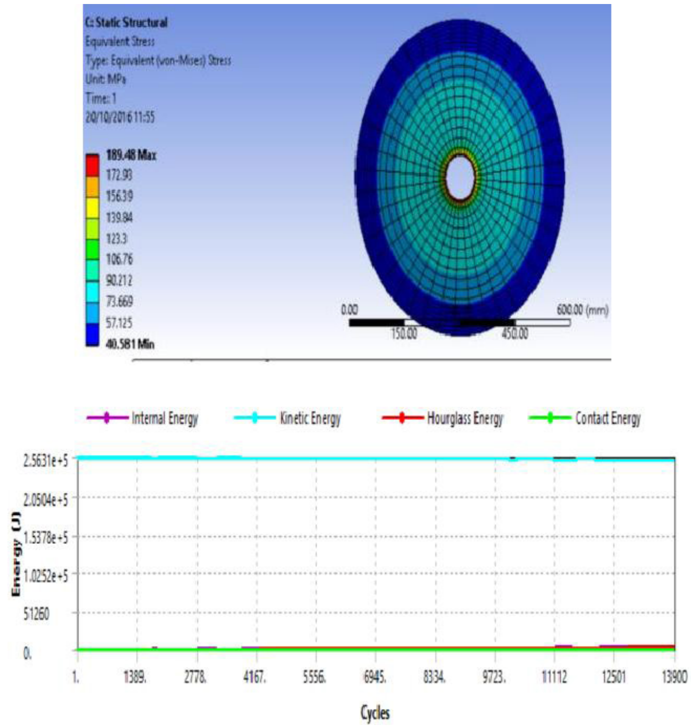



Figure 5. Stress distribution and KE of Geometry 2 with Cast Iron.

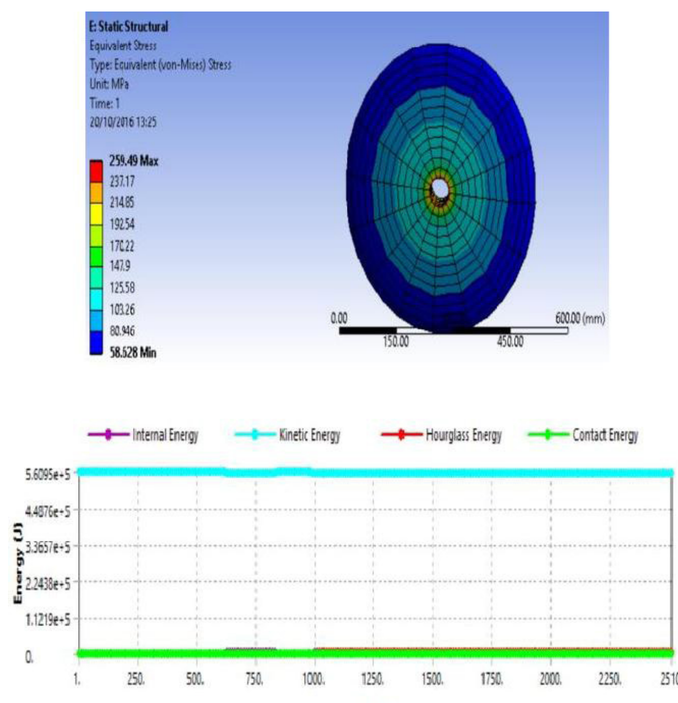



Figure 6. Stress distribution and KE of Geometry 2 with S-Glass Epoxy.

**Table 3.** Result table of ANSYS Simulation

| Geometry | Material | Mass (kg) | Speed (RPM) | Stress (MPa) | Kinetic Energy (KJ) | Kinetic Energy perkg (KJ/kg) |
|---|---|---|---|---|---|---|
| 1 | Cast Iron | 72.9 | 779 | 259.4 | 766 | 10.49 |
| | ASTM 30 | 92 | 6 | 6 | | |
| | S-Glass | 21.2 | 118 | 189.4 | 514 | 24.14 |
| | Epoxy | 85 | 24 | 7 | | |
| 2 | Cast Iron | 26.5 | 115 | 259.4 | 374 | 14.09 |
| | ASTM 30 | 43 | 43 | 8 | | |
| | S-Glass | 7.74 | 177 | 189.4 | 256 | 33.07 |
| | Epoxy | | 04 | 8 | | |
| 3 | Cast Iron | 50.2 | 901 | 259.4 | 561 | 11.17 |
| | ASTM 30 | 44 | 8 | 9 | | |
| | S-Glass | 14.6 | 137 | 189.4 | 379 | 25.87 |
| | Epoxy | 52 | 43 | 9 | | |

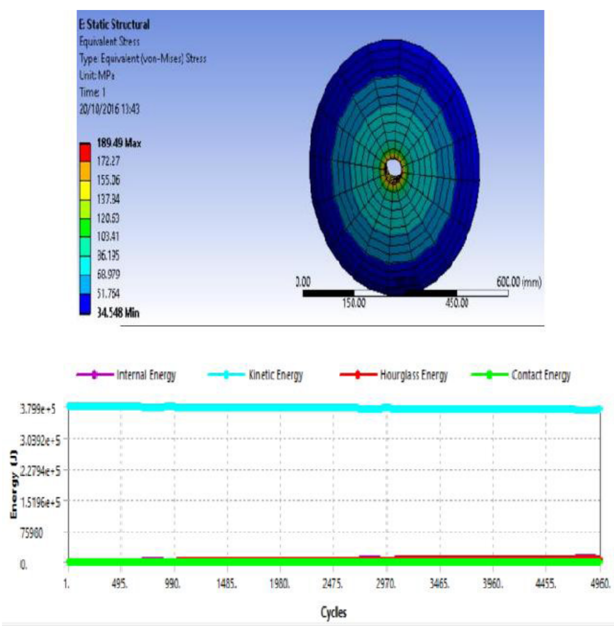



**Figure 7.** Stress distribution and KE of Geometry 3 with Cast Iron.

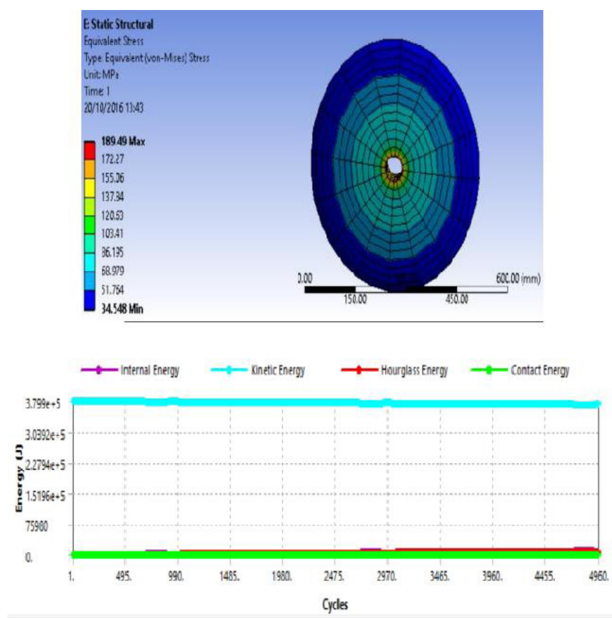



**Figure 8.** Stress distribution and KE of Geometry 3 with S-Glass Epoxy.

## 8. Result and Conclusion

The results shows that flywheel with Triangular cross sectional geometry and made of S-glass epoxy composite material stores highest Kinetic Energy per unit mass compare to all other combination of Geometry and material. We can observe that the mass is going on decreasing from present geometry to modified geometry thus increasing flywheels maximum rotational speed, and hence maximum Kinetic Energy to corresponding rotational speed. This New design of flywheel saves weight by 65.252kg compared to existing design of flywheel made of Cast iron ASTM 30.

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**Conflict of Interest:**

Author of a Paper had no conflict neither financially nor academically.