Static Structural Analysis of Flywheel

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Abstract— To improve the quality of the flywheel material and in order to have safe and reliable design, it is necessary to investigate the stresses induced in the component during working condition. This paper shows the comparison between von-mises stresses and total deformation of two different flywheel materials i.e., gray cast iron and aluminum alloy. First, the model of flywheel having six arms is developed using CATIA V5R20 and then analyzed by using ANSYS 14.5 workbench for constant angular velocity by considering two cases, first without gravity and second with gravity. Result shows that aluminium alloy has less von-mises stress and deformation compared to grey cast iron.

Keywords— Flywheel, CATIA V5R20, ANSYS 14.5.

1. INTRODUCTION

Flywheel acts as a reservoir by storing energy during the period when the supply of energy is more than the requirement and releasing it during the period when the requirement of the energy is more than the supply. A flywheel is a mechanical device with a significant moment of inertia used as a storage device for rotational energy. A flywheel is a heavy rotating body act as reservoir of energy. The energy is stored in the flywheel in the form of kinetic energy. The flywheel act as an energy bank between the source of power & the driven machinery. Depending upon the source of power & the type of driven machinery, there are two distinct application of the flywheel.

In certain cases, the power is supplied at uniform rate, while the demand for power from the driven machinery is variable e.g., a punch press is driven by an electric motor. In punching & shearing machines, maximum power is required only during a small part of the cycle, when actual punching or shearing takes place. During the remaining part of the cycle, negligible power is required to overcome the friction. If these machines are directly driven by an electric motor, a higher capacity motor corresponding to maximum power requirement during actual punching or shearing will be required. Such a motor will run almost idle during the remaining part of the cycle. It is obviously wasteful to provide such a large motor when its full capacity is needed but a small fraction of the time. Providing a flywheel to these machines allow a much smaller motor to be used. During the actual punching or shearing operations, energy will be taken from the flywheel, slowing it down .During the relatively long period between two punching or shearing operations, the motor will accelerate the flywheel back to its original speed. Thus the flywheel stores the kinetic energy during the idle portion of the work cycle by increasing its speed & delivers this kinetic energy during the peak-load period of punching or shearing .Therefore, when a flywheel is used between the motor & these machines, a smaller capacity motor is sufficient.

In other application, the power is supplied at variable rate, while the requirement of the driven machinery is at uniform rate e.g., machinery driven by an internal combustion engine. In IC engines, the power is generated at a variable rate. The flywheel absorbs the excess energy during the expansion stroke, when power developed in cylinder exceeds the demand. This energy is delivered during suction, compression exhaust strokes. The flywheel, therefore, enables the engine to supply the power at a practically uniform rate.

2. LITERATURE SURVEY

[1] Had proposed a flywheel of MARUTI-Omni which is designed, analyzed and optimized. They had optimized parameters like material, cost for flywheel by using optimization technique. They had used grey cast iron ASTM 30 to make flywheel due to its high density, low cost and excellent machinability. They modelled flywheel of MARUTI-Omni in CATIA and made structural analysis using ANSYS 11.0 Workbench to determine the maximum equivalent (von-mises) stresses, normal stresses, shear stresses and total deformation at loading conditions. They had set the target reduction of 20% material and got result as reduction of 1kg weight. At last they made comparison of values of maximum equivalent (von-mises) stresses, normal stresses, shear stresses and total deformation for gray cast iron and aluminium alloy concluded that grey cast iron is more suitable than aluminium alloy. **[2]** Investigated the stresses induced in arm type rotating flywheel. For this purpose they had made model of flywheel having 4, 6, and 8 arms and made FE analysis for different cases of loading applied on the flywheel to determine maximum von-mises stress and deflection. They used grey cast iron as a material of flywheel. They shows the comparison between analytical stresses and FE stresses in Rim by varying number of arms & made comparison between FE stresses on arm and analytical calculated bending stresses in arms. They concluded that as a number of arms increases from 4 to 8, the stresses in the arms goes on reducing.

This may be due to sharing of load by larger number of arms and shows the comparison of FE stresses and analytical bending stresses near the hub end of arm for 4, 6 and 8 arms flywheel under the influence of tangential forces on rim. **[3]** Had given main focus on various profiles of flywheel such as solid disk, disk rim, webbed/section cut, arm/spoke flywheel. Flywheel geometry has significant effect on its specific energy performance. They used cast iron as flywheel material and angular velocity of 78.53 rad/sec is applied on various profiles of flywheel. They made FE analysis for different profiles of flywheels to determine the maximum equivalent von mises stresses and the total deformation. Amount of kinetic energy stored by wheel –shaped structure flywheel is greater than any other flywheel. From the analysis it is found that maximum stresses induced are in the rim and arm junction. **[4]** Shows the design and analysis of flywheel to minimize the fluctuation in torque, the flywheel is subjected to a constant rpm. The objective of work is to design and optimize the flywheel for the best material. The flywheel is modeled with solid 95 (3-D element), the modeled analyses using free mesh. The FEM mesh is refined subject to convergence criteria. Preconditioned conjugate gradient method is adopted during the solution and for deflections. Von-misses stress for both materials (mild steel and mild steel alloy) are compared, the best material is suggested for manufacture of flywheel. **[5]** 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.

3. DEVELOPMENT TOOLS

CATIA (Computer Aided Three-dimensional Interactive Application): It 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 Commonly referred to as 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.
ANSYS: 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)

4. MODEL OF FLYWHEEL

Figure 1 shows the model of flywheel having six arms which is developed using CATIA V5R20.

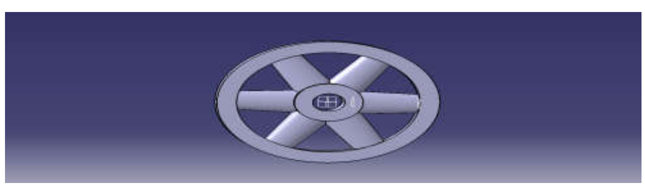

Fig.1 Model of Flywheel in CATIA V5R20

5. MATERIAL PROPERTIES OF FLYWHEEL

Two materials that are used for Design of Flywheel & their properties are given in Table 1.

Material	Grey Cast Iron	Aluminum Alloy
Ultimate Strength	Sut=214Mpa Suc=303Mpa	Sut=310Mpa Suc=280Mpa
Modulus of elasticity and Modulus of rigidity	E=101Gpa G=41Mpa	E=71Gpa
Density	$\rho=7510 kg/m^3$	$\rho=2.7\times10^{-6} kg/m^3$
Poisson's Ratio	μ=0.23	μ=0.33

Table.1 Material Properties

6. FINITE ELEMENT ANALYSIS OF FLYWHEEL

Loading Condition: Constant angular velocity of 25.12rad/sec. Boundary Conditions: Fixed support.
Case-I: For Grey Cast Iron.

(a) Considering without gravity.

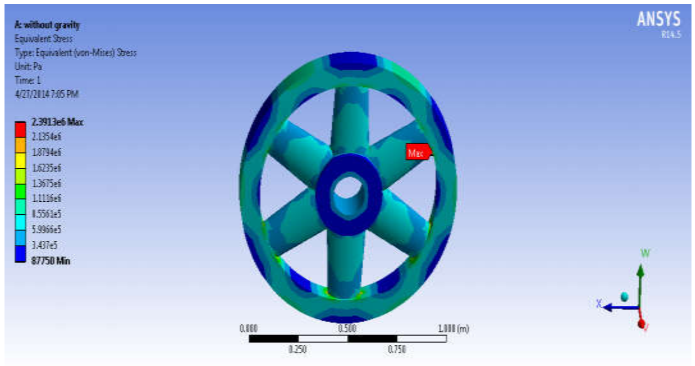

Fig.2 Von-Mises Stress

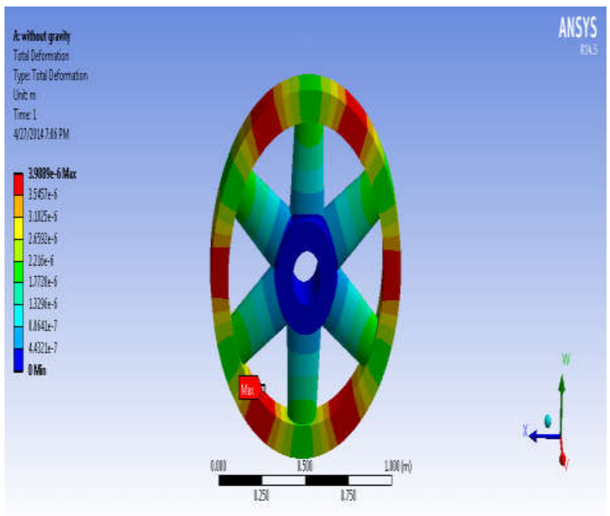

Fig.3 Total Deformation

(b) Considering with gravity

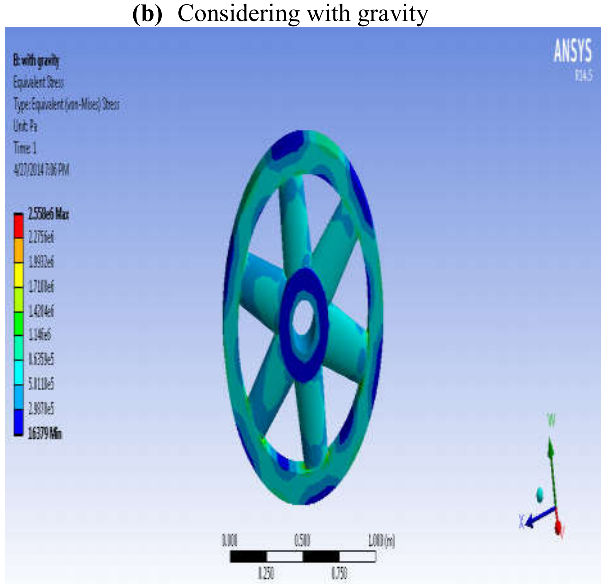

Fig.4 Von-Mises Stress

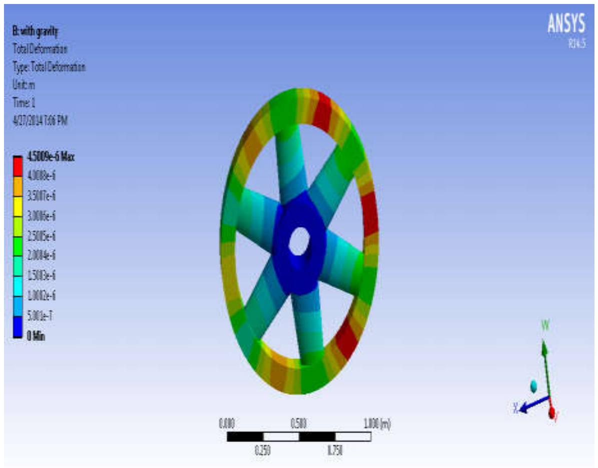

Fig.5 Total Deformation

Case-II: For Aluminium Alloy.

(a) Considering without gravity.

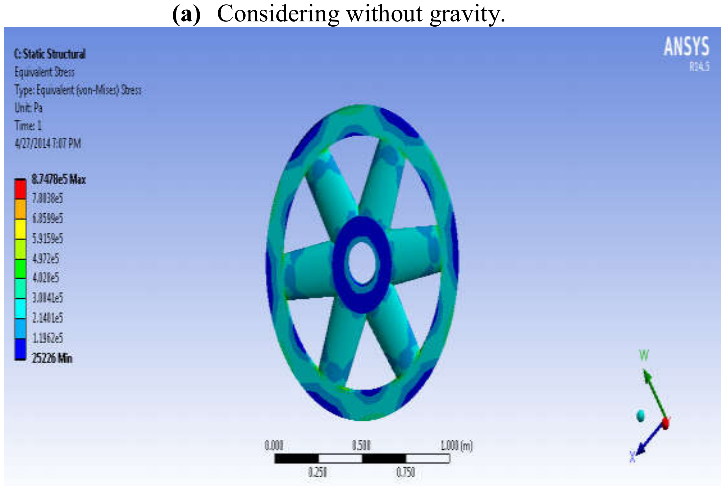

Fig.6 Von-Mises Stress

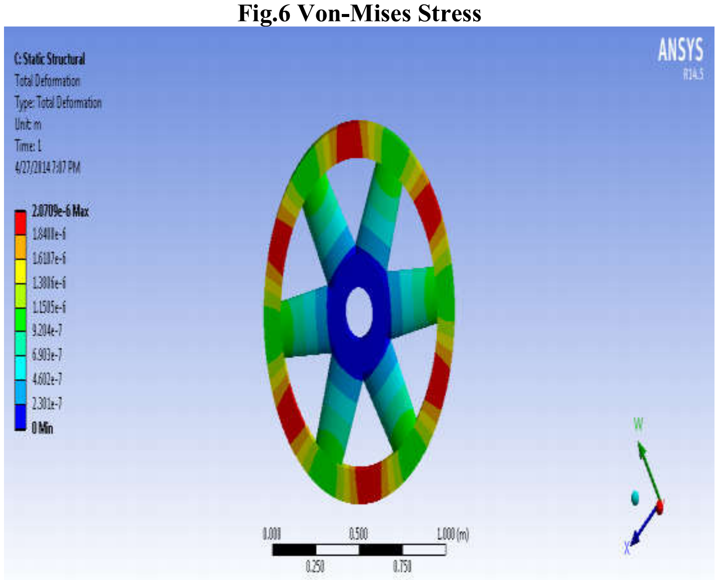

Fig.7 Total Deformation

(b) Considering gravity.

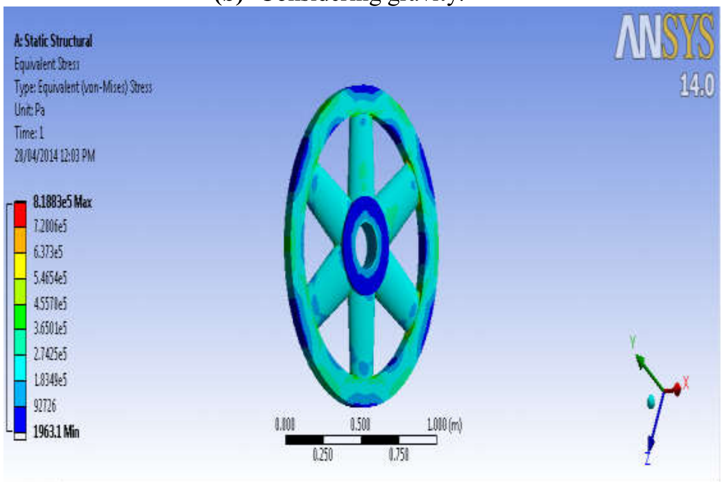

Fig.8 Von-Mises Stress

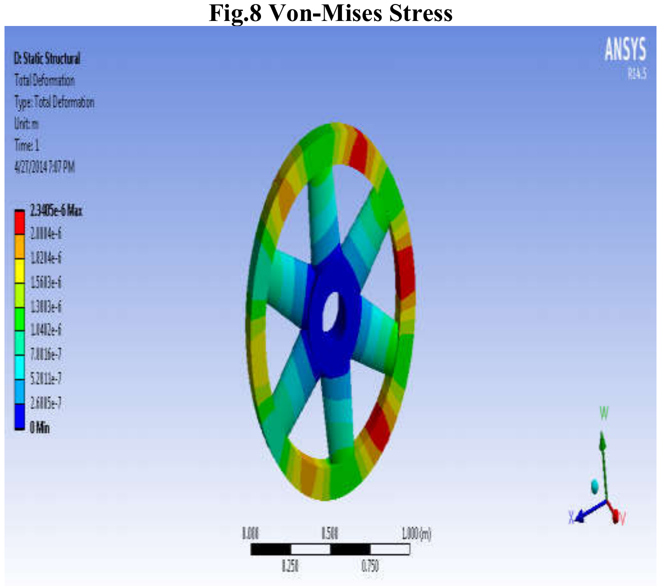

Fig.9 Total Deformation

7. RESULTS AND DISCUSSIONS

Materials	Without Gravity		With Gravity	
	Equivalent Von-Mises stress(Pa)	Total Deformation(m)	Equivalent Von-Mises stress(Pa)	Total Deformation(m)
Grey Cast Iron	$2.3913x10^{6}$	$3.9889x10^{-6}$	$2.558x10^{6}$	$4.5009x10^{-6}$
Aluminum Alloy	$0.8747x10^{6}$	$2.0709x10^{-6}$	$0.81883x10^{6}$	$2.3405x10^{-6}$

Table.2 Comparision of Results by ANSYS

8. CONCLUSION

The stress and deformation analysis of the flywheel having six arms for constant angular velocity of 25.12rad/sec is carried out under different cases such as (1) considering standard earth gravity and (2) considering without gravity. The analysis is carried on two different materials (1) Gray cast iron and (2) Aluminium alloy.

It can be observed from Table.2 that for gray cast iron, the von-mises stress and total deformation considering standard earth gravity are $2.558x10^6$ Pa and $4.5009x10^{-6}$ m. The von-mises stress and total deformation considering without gravity are $2.3913x10^6$ Pa and $3.9889x10^{-6}$ m. Also, for aluminium alloy, the von-mises stress and total deformation considering standard earth gravity is $0.81883x10^6$ Pa and $2.3405x10^{-6}$ m, the von-mises stress and total deformation considering without gravity are $0.8747x10^6$ Pa and $2.0709x10^{-6}$ m. Comparing the above two materials, it is observed that von-mises and deformation for grey cast iron are more than aluminium alloy. Therefore, it is better to use aluminium alloy**.**

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