ISSN: 0975-766X
CODEN: IJPTFI
Available Online through
Research Article
www.ijptonline.com

FINITE ELEMENT ANALYSIS ON A COMPOSITE FLYWHEEL

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Received on 22-05-2016 *Accepted on 25-06-2016*

Abstract

A flywheel is a device which stores energy when the supply is more than demand and releases when the supply becomes less. This paper presents analysis of composite flywheel includes stress and thermal analysis. While the machine is operated, stresses are induced on the flywheel the induced are due to centrifugal forces, due to change of speed and load and shrinkage stress due to unequal rate of cooling and casting. In this paper, stress and thermal analysis and find that amount of energy stored, critical stress regions and overall stress distribution along with heat distribution are performed. By knowing the above terms we can take necessary measure to prevent the damage occurred and improve the efficiency either by increasing the energy stored or by changing the type of material we use. By improving the energy storage and thus an increase the speed of the flywheel there by meeting needs with less amount of input.

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 fly wheel is to smoothen out variations in the speed of a shaft caused by torque fluctuations[1]. 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[2].

Thermal analysis includes the heat distribution along the flywheel which can be processed through various softwares. Technically the change in heat does not affect the function of the flywheel to a great extent but in the stress analysis we will come to know that expansion occurs due to centrifugal forces also. The flywheel is free to expand on the ends there are no thermal stresses involved in the flywheel there we can concentrate on the hot points on the flywheel and know the heat distribution by which we can know if there is any change in the material properties of the flywheel[3].

Energy storage has become essential in present day scenario. Flywheels are energy storage devices therefore they play a major role in the field of engineering. There are different researches done about increase in the energy storage of the flywheel. The other research was about design analysis of flywheel in petrol engine shown in several papers[4-5]. The other research was conducted on the Hybrid flywheel rotor system by Han Yang University in Korea. There are a lot of researches in the flywheel department the main aim in most of them was to increase the energy stored so as to increase the speed of the flywheel thereby increasing the efficiency. Some of them included in determining the proper material needed for increased energy storage like use of composite materials in airplanes. The researcher was used advanced composite materials for the flywheel design. The goal of the project was to integrate this flywheel in the electric vehicle[6]. Similarly in one new type of flywheel design was done using composite material by the authors for the braking of the rail transit train which consumes a lot of energy while braking[7-8]. The new design was checked by FES. A pollution free bus called the Gyrobus was built in Switzerland which was powered by flywheel. Thus flywheels energy storage was increased. The Gyrobus would be able to carry 20-25 passengers on a short route without continuous electric supply. The research in this area is still ongoing and shows some promise. Flywheel can be seen as an energy storage device in future. The area covered in this project includes stress and thermal analysis of a flywheel, and involves simulations in Matlab, Ansys and Solid works. The focus of this project is in increasing obtained energy with given conditions. This review involves the final calculations of the project and the thermal and stress analysis done in the software, 'ANSYS'.

2. 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 spoken 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.

Arm Type Flywheel: 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 mr2.

Stresses in Flywheel:

Flywheel being a rotating disc, centrifugal stresses acts upon its distributed mass and attempts to pull it apart. Its effect is similar to those caused by an internally pressurized cylinder.

The point of most interest is the inside radius where the stress is a maximum. What causes failure in a flywheel is typically the tangential stress at that point from where fracture originated and upon fracture fragments can explode resulting extremely dangerous consequences, Since the forces causing the stresses are a function of the rotational speed also, instead of checking for stresses, the maximum speed at which the stresses reach the critical value can be determined and safe operating speed can be calculated or specified based on a safety factor. Generally some means to preclude its operation beyond this speed is desirable, for example like a governor.

Design Process of a Flywheel:

The basic parameters are assumed including Rated Power, Material and its properties and space conditions etc.

The mean Torque will be calculated along with Work done per cycle and Energy absorbed etc.

Usually cast steel is taken as flywheel material and from its hoop stresses, its diameter will be determined.

It is assumed that most of the mass of the flywheel is concentrated at the rim, thus the cross sectional such as width and thickness of the rim will be calculated.

Arms of the flywheel will be designed using maximum bending stress conditions.

The stresses in the flywheel will be analyzed using Ansys software and calculations in

Matlab will be compared.

Figure 1 Composite Flywheel.

3. Results and Discussion

To design a flywheel depends on different factors such as Material availability, Design demands, environment of the flywheel, stress withstanding capacity. The flywheel which we reckon to design and analyze has the following specifications.

The specifications of the flywheel are

Specifications

Angular Velocity (ω) = 28rad/s

Maximum Torque (Tmax) = 1600N-m

Minimum Torque (Tmin) = 500N-m

Thickness (t)= 0.025m (25mm)

PoissonsRatio(cast iron)= 0.21-0.26

Poissonsratio(steel) =0.3

Coefficient of fluctuation of speed (Cs) =0.2

In stress analysis of the fly wheel, different grades of cast iron and steel were used to obtain the behaviour of radial and tensile stresses with respect to radius. These analyses will help in determining the material chosen for the flywheel. For designing purposes a pool of materials are chosen among which the analyses are conducted to find out the perfectly suitable material for the flywheel under material optimization as well as critical stress levels at high speeds. The material considered for this analysis include Cast Iron grade FG150, Cast Iron grade FG300 and steel. These materials are standard selection in the industry and are repeatedly used depending on the running conditions and running criteria.

Loads: the loads acting on the flywheel are moment or torque, value is 1050N-m and the angular velocity is acted upon the flywheel of magnitude 28rad/s and a fixed support is placed at the center as of that of a rotating shaft. The analysis settings fig.2 is shown below in figure 2

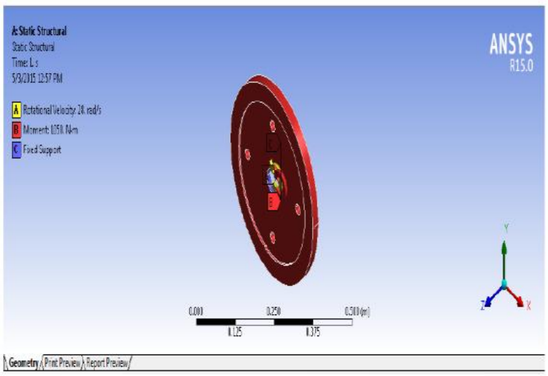

Figure 2Load on Flywheel.

The solution of the ANSYS includes the 'Total deformation' as shown in the figure below figure 3. Different colours indicate the length of deformation of the flywheel due to the loads applied.

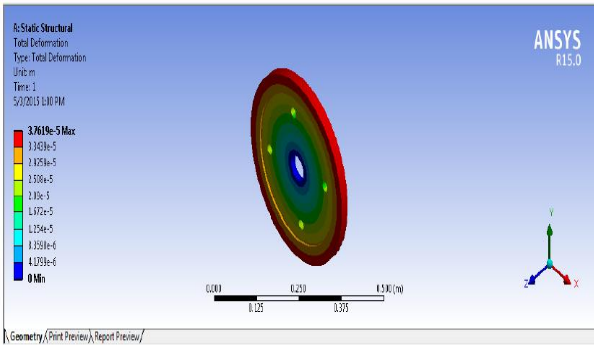

Figure 3 Total Deformation.

The solution also includes maximum and minimum principal stresses and variation of them through the radius of the flywheel. As shown in the manual calculation in the above discussion the stress variation is almost the same in practical case too in the Flywheel analysis as done in ANSYS. The figure 4 represents the principal stresses are shown below. The values of stress are around 3.8903E+06 from the below figures.

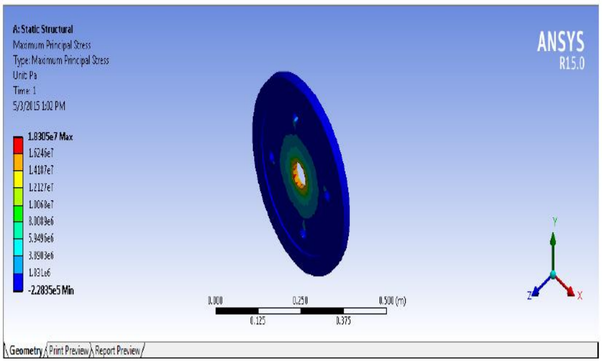

Figure 4 Principal stress plot.

Thermal: The thermal analysis of the flywheel allows us to know about the temperature distribution of the flywheel. The flywheel is basically connected to the crankshaft whose temperature is around 1000C and the heat transfer takes place by convection and radiation the heat transfer coefficient of cast iron and air is 5.7W/m2K. Thus the temperature distribution through the flywheel is known as shown in the figure fig (h) below

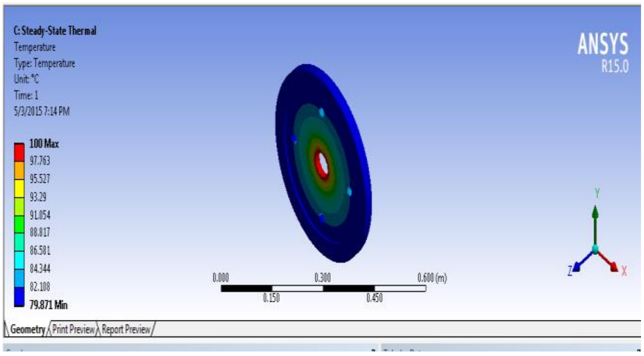

Figure 5 Temperature plot.

The Energy stored for different grades of cast iron and steel are calculated. The values are shown in the Table 1 below.

Table 1 Material Energy stored

Cast iron FG150	2.145kJ
Cast iron FG250	2.150kJ
Mild steel	2.156kJ

The difference in the energy stored is not very high but stress induced in the FG150 is less which increases the life time of the Flywheel.

4. Mat lab Process

The coding was done with the help of the software called 'MatLab'. The coding so done was to obtain an optimum material for the flywheel component in the mean time an analysis of variation of flywheel along with the change in density of the material were done and graphs obtained thereof. The materials considered for flywheel selection include cast iron grade FG150, GradeFG300 and steel. A separate code was written to obtain optimum radius for a flywheel of steel.

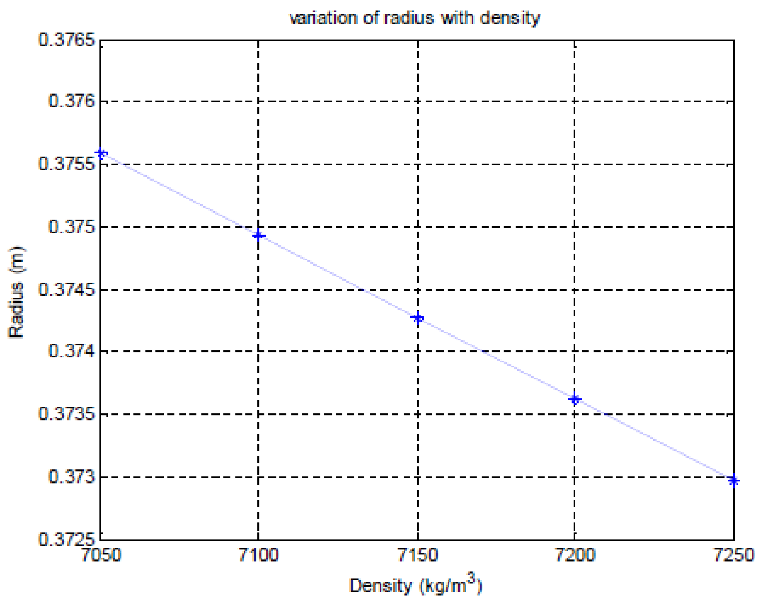

Figure 6 Variation of radius with density.

The results obtained show a negative linear variation in radius with an increase in density

Radius of FG150: 0.3756 m

Radius of FG300: 0.3739 m

The stress analysis done using Matlab coding gave the results for the optimum material selection fore cast iron grade FG300 is shown in fig. 7.

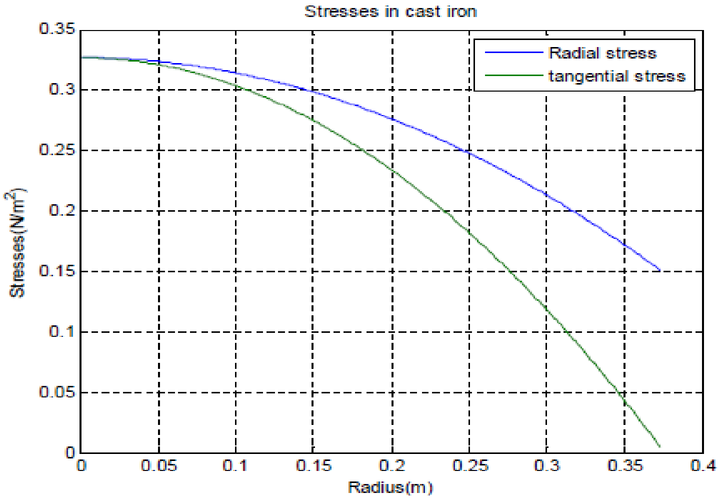

Figure 7 Stresses in Cast Iron.

This curve shows a trend of variation of stress and radius in cast iron grade FG300.

Thus, for stress analysis of cast iron specimen FG150 (density= 7050kg/m^3)

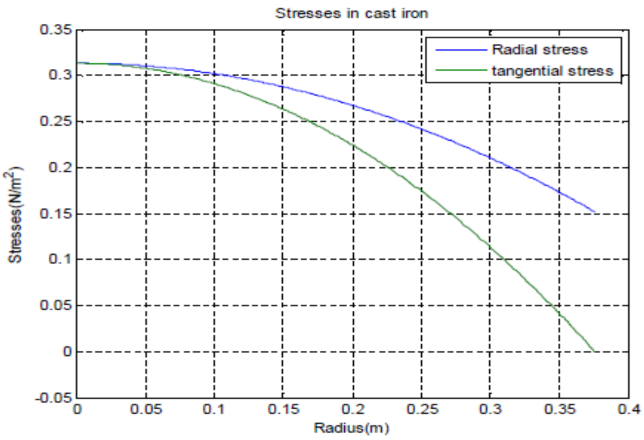

Figure 8 Stresses in Cast Iron FG 150.

A similar result is obtained and the variation is strikingly similar except for the numerical values. The Mat lab code used to analyze stresses in steel (density = 7800kg/m3) material.

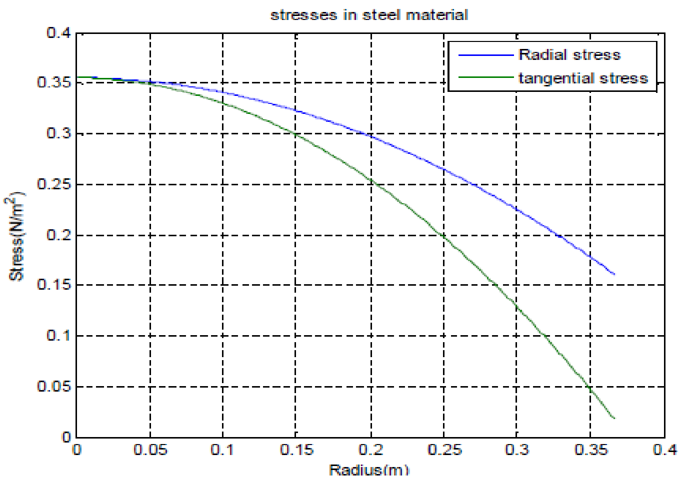

Figure 9 Stresses in Steel.

The MATLAB analyzing done also shows the decreasing trend of stress as it is apparent with the graphs.

5. Conclusion

Thus, the Stress distribution of the flywheel and thereby determine the energy stored in the flywheel and also examine the life of the flywheel since it depends on the stress induced in it. From the above discussions we can conclude that FG150 has lowest stress this can be due to amount of Carbon in it which is more than that of other materials. The graph drawn between radius of the flywheel and the density the radius increases as the density increases. The ultimate tensile strength of the cast iron is $2.4*10^8$Pa and the stress obtained is around $1.86*10^7$Pa which implies it is below the permissible limit. Hence, the design is safe and satisfactory.

References

1. Mehmet Ali Arslan, Flywheel geometry design for improved energy storage using finite element analysis, Materials and design, Vol.29(2), pp. 514-518.
2. Janse van Rensburg, P.J. "Energy storage in composite flywheel rotors". University of Stellenbosch.
3. Jump uprossetaTechnik GmbH, Flywheel Energy Storage, German, retrieved February 4, 2010.
4. Zhang Da-lun, Mechanics of Materials, Tongji University Press, Shjanghai, 1993.
5. Huang Xi-kai, Machine Design, Higher Education Press, Beijing, 1995.
6. Robert L. Norton, Design of Machinery, McGraw-Hill Inc, New York, 1992.
7. K. Lingaiah, Machine Design Data Handbook, McGraw-Hill Inc, New York, 1994. [8]ANSYS User's Manual, Swanson Analysis Systems, Inc., Houston.

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