A Review on Design and Material selection for improvement in performance of Flywheel

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Abstract *:* Flywheel is the kinetic energy storage device has the ability to store large amount of energy and retrieve it efficiently which has its application in the high speed technology such as NASA rovers and hybrid cars. Researches are being done to improve the energy storage capacity of the flywheel system. The energy storing capacity of the flywheel mainly depends on the material, geometric design and the rotational speed. This study proposes the analysis of most common three geometries with the three different materials. This work deals with the literature survey on various types of design and materials used in flywheels to see the effect of material and geometry on performance of flywheel.

Key words : Flywheel, Geometry, Material, NASA rovers.

INTRODUCTION

Flywheels have been considered for use as the energy storage system on the proposed orbiting space station because of their potentially high storage density [1]. Flywheel is a rotating mass which can store energy in the form of mechanical energy due to high speed of rotation. Flywheel energy storage systems are considered to be an attractive alternative to electrochemical batteries due to higher stored energy density, higher life cycle, charge/discharge behaviour and ecologically clean nature. The fly energy storage system consists of Bearing, motor/generator, housing and power transformation system [2]. The motor spins the flywheel, which stores energy mechanically and it slows down while delivering the energy to the load Recent improvements in material, superconductor bearings and levitation [3,4] and power electronics make flywheels a competitive choice for a various energy storage applications like space station storage, Uninterruptable Power Supplies, Military vehicles and Pulsed Power Devices[5,6]. Using high strength materials allows to store more kinetic energy in the flywheel.The energy storing capacity of the flywheel mainly depends on the material, geometric design and the rotational speed. This study proposes the analysis of most common four geometries with the three different materials. A finite element model of the four geometries are constructed and the materials based on their strength are selected. Each combination of material and design is analysed using explicit finite element analysis approach to obtain kinetic energy and mass. While analysis the dimensions are kept same for all cases. The results obtained from the analysis is optimized for better performance levels. .

LITERATURE REVIEW

Literature survey is performed by studying various designs and the material from the work of the different authors and their effect on the performance of the storage capacity of the flywheel.

Design of the flywheel

S.Nagaya, et al [8] created Two flywheel rings made up of composite fibre resin mould plastic are fabricated by setting both back surface together and tested by analysis of stress and displacement at expansion fit and displacement at rated rotation speed.Development of flywheel ring of 1200 mm in diameter for 10kWh class flywheel energy storage is successful. The flywheel ring had no problem for rotating upto20,000rpm. K.Dems et al [9] generated evolutionary algorithm and used in two approaches to determine the optimum shape of reinforcement ,while the finite element method was applied in order to analyse the mechanical response of flywheel.The analysis for the composite flywheel, when compared with the flywheel with large number of discrete ribs,gives fairly good results and it is much faster than the analysis for discrete model of reinforcements. M.A.Arslan [10] Six different 2D axis symmetric geometric models are constructed. A 360 flywheel volume and 2D geometry is analysed for the kinetic energy,mass and maximum stress, a simple optimization is performed to come up with better specified energy levels of the designs.The study depicts the importance of the flywheel geometry design selection and its contribution in the energy storage capacity. Y.Gowayed, et al [11] used optimum structure design of MDC flywheel using non-linear optimization via a sequential quadratic programing approach and parametric finite element analysis to address the problem. Analytical tools were developed to optimize design of a novel multi-direction composite flywheel rotor. L. Hong, et al [12] used Finite Element Analysis to obtain the stress distribution of the flywheels no wrapped by composite material and wrapped by composite material rotating at suitable angular velocity are studied and designed the flywheel energy storage wrapped with composite material by interference fit to hub.By wrapping of composite material, the Radial and circumferential stress reduced and strength of flywheel enhance. S.K.Haa, et al [13] calculated stress and strength ratio distribution of the hybrid rim type composite flywheel rotor made of various materials. Using the developed analysis thermally induced residual stress effect can be calculated.The results are compared with Finite Element Method, the introduction of the modified generalised modified plane strain assumption is much more efficient and easier to use than the finite element approach. G. Portnov, et al [14] estimated and analysed the possibility of using force winding coupled with in SITU curing to increase the energy capacity of hybrid steel-composite cylindrical flywheel.The application of a linear elastic model for calculating the winding stress may be attractive when winding with continuous in SITU curing is used. T. Kamf [15] generated three models are generated using solid disc design and different layer of materials consisting of isotropic and orthotropic materials. Each model is created by adding the layers upto three and with the varying thickness. The FEM models are then simulated in the solidworks and matlab.The ratio between carbon and glass fiber composite coupled with the weight of the magnets in the core. W. Wan [16] createdmultilayer flywheel rim design of carbon fibre /glass fibre hybrid composite and calculations are done. By changing the thickness ratio of the layers finite element analysis is done for each structure.By adjusting the ratio of carbon to glass fibre which can change the material properties will effect the radial stress and strain distribution of wheel rim.

Material for flywheel

S.K.Ha [17] proposed a numerical method based on the assumption of generalized plane strain(GPS) state is presented for calculating stress and strength ratio distribution of the rotating composite flywheel rotor of varying material properties in the radial direction.It is found that the most effective way of increasing the total energy storage in changing material properties is to arrange softer material in the inner side and stiffer material in the outer side of the rotor.

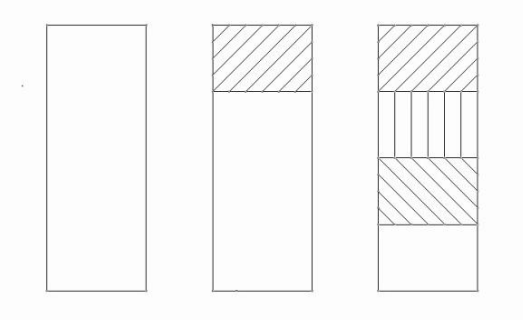
H.Chen, et al [18] created a fully parametric model of the flywheel made up of different material compared with each other by using 3 dimensional stress distribution of flywheel in finite element analysisto meet the designing of reasonable safety composite flywheel.Analysis showed that the higher stresses are lied on the same middle section of different material properties flywheel. S.Tang, X.Xia [19] did the Manual Method and Finite Element Method using solid disc flywheel design to calculate the stress of isotropic material flywheel battery rotor as the strength of metal is much lower than composite material.It is concluded that the method of manual calculation of stress approximate the Finite Element Method.The key factor of rotor material is ratio of Yield strength to the density of material. E.L.Danfelt, et al [20] choose multi-rimmed flywheel configuration because of its superior operating characteristics and versatility.The Kevlar-49/epoxysystem is adopted as the basic composite material, which is sandwiched between thin layer of rubber.A general stress analysis procedure is developed for the multi-rimmed structure.The multi-rimmed configuration is desirable, the method of analysis is workable and the optimization procedure canbe applied in general when other failure criteria and performance characteristics are pre formed.

Applications of Flywheel

Y.suzuki, et al [5] used proper mixture of helium-air gas to the conventional flywheel Uniterruptible Power Supply(UPS) and calculate idling energy loss of flywheel UPS and purposed the novel utilisation of a low speed steel flywheel energy storage. Using helium-air mixture gas,the idling loss of the flywheel energy storage system can be reduced.To protect from short time voltage fluctuation can allow frequency and voltage fluctuation, capacitor self-exited flywheel generator is more available. M. Olszewski [1] proposed the use of improved fibers in experimental flywheel rims for significant gain in flywheel storage density by referring Graphite fiber technology. A flywheel energy storage module suitable for the needs of space station is described. The anticipated improvement in energy storage density by fully realization of fibers strength, To determine potential performance for flywheel storage system substantially. Z. Kohari, et al [2] studied system consisting of an High temperature superconductor (HTS) based levitated flywheel as the energy storage unit and solar cells as the power supply installed and investigated as a model of viable variant of the mini power plant concept. A model was developed o identify the frictional coefficient to make flywheel adaptable with superconducting bearings as kinetic energy storages with very low losses. D. A. Christopher and R. Beach [6] studied the advantages offered by the flywheel system development are studied and the technological improvement to be done to use for the small, medium and large size of spacecraft are examined. NASA teamed with USAF Philips laboratory to develop multi-wheel system with planned to be tested extensively to verify power and altitude control performance. H.Liu and J.Jiang [7] studied the key factors of FES has been done which directly influence the amount of energy storage and flywheel specific energy. The Design and material of flywheel tested by US flywheel systems(USFC) and other organisation. The keyfactors of FES technology is described and summarize its application including International space station (ISS). Huang, et al [12] demonstrate how to apply Kumar and Datta's modelling techniques to two different kinds of heterogeneous flywheel. Parametrisation and numerical analysis are used to aid modelling and various calculations. Dutta's modelling methods are applied successfully in heterogeneous flywheel modelling applications. N.Kashima, et al [14] proposed the structure of the axial gap type motor/generator of 17kW of power output and 10,000 rpm of maximum rotational speed is develop. By variation of gap between the stator and rotor, the maximum attainable rotational speed and efficiency is calculated. 95.7% of generator efficiency and 95.9% of motor efficiency without mechanical loss is achieved .

Flywheel analysis

Fully parametric FEM flywheel model of each design is created as shown in fig.1. Analysis is carried out by considering the combination of the each design with the material selected. The 2 D model is analyzed using implicit FEM approach to obtain the maximum and minimum stress levels of the geometry combined with the each material. Then the 360 degree models of each 2D design is created and is analyzed using explicit analysis for the kinetic energy and the mass of the model each combined with the different material. By comparing Stress distribution, kinetic energy and the mass of each design the better design and material combination is determined.



a) Solid b) hollow c) multi layer

fig.1 Flywheel Geometry

Conclusion

Improved energy storage capacity: By selecting the proper design and combining it with the suitable material having high strength and low weight the increased kinetic energy of the model should be achieved. Maximum and minimum stress levels: The optimum stress level should be obtain by performing the implicit analysis on the created flywheel models .

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