A Review Paper on Structural and Parametric Analysis of Composite Flywheel

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***Abstract*— Flywheel energy storage (FES) can have energy fed in the rotational mass of a flywheel, store it as kinetic energy, and release out upon demand. For example, in I.C. engines, the energy is developed only in the power stroke which is much more than engine load, and no energy is being developed during the suction, compression and exhaust strokes in case of four stroke engines. The excess energy is developed during power stroke is absorbed by the flywheel and releases its to the crank shaft during the other strokes in which no energy is developed, thus rotating the crankshaft at a uniform speed. The current paper is focused on the analytical design of flywheel & FEM analysis flywheel used in Press. Different types of forces acting on flywheel & design parameters has taken into consideration for optimizing design of flywheel By using ANSYS stresses obtained & compared with analytical calculations, also weight is compared.**

Keywords—Flywheel, Composite, FEA.

I. INTRODUCTION

Flywheels have been used for a so many time as Mechanical Energy Storage (MES) devices. The past form of a flywheel is Potter's wheel that uses stored energy to aid in Shaping [6]. The word 'flywheel' appeared first during the start of industrial revolution. During this period, there were two important developments, one is the use of flywheels in steam engine and other is widespread use of iron. Iron material has high integrity that flywheels made up of wood, stone, or clay [6].

Today the most of the finding efforts are being spent on improving energy storage capacity of flywheel to deliver high power at transfer times, lasting longer than conventional battery powered technologies . Mainly the performance of a flywheel can be attributed to three factors i.e. Material strength, Geometry and Rotational speed [5].

A flywheel is a mechanical device with a significant moment of inertia used as a storage device for rotational energy. Flywheels have become the subject of extensive research as power storage devices for uses in vehicles [1]. Flywheel is like as a reservoir to store energy when supply is more than requirement and to release the energy when requirement is more than supply [2]. Flywheel provides an effective way to smooth out the function of speed. Flywheel energy storage are considered to be an alternative to electromechanical batteries due to higher stored energy density, high life time and deterministic state of change and ecologically clean nature [2].

Many machines have a load patterns that cause the torque time function to vary over the cycle. Internal combustion engine with one or two cylinders are a typical examples. Piston compressor, Punch presses, rock crusher etc. are the other system than have flywheel [3].

It is now accepted that the present production and use of energy pose a serious threat to the global environment and consequent climate change. Accordingly more and more countries are examining a whole range of new policies and technology issue to make their energy future 'sustainable' [9]. Flywheel is proving to be an ideal form of energy storage an amount of its high efficiency, long cycle life, wide operating temperature range, free form depth of discharge effect and high power and energy density on both a mass and a volume basis [9].

The amount of stored energy is determined by the size, weight and the maximum allowed rotational speed of the flywheel within its centrifugal strength limit. In order to maximize energy storage capacity the rotor has to be designed to rotor as fast as possible without any material failure thereby high strength fiber reinforced polymer composite have been widely used to fabricate flywheel rotor [10].

Composite flywheel is currently being developed for energy storage. To satisfy the high performance and low weight constraints, high strength carbon fiber composites are the material of choice for flywheel construction. Recently, several composite flywheel have been developed for commercial power generation and vehicles, such as buses and trains. Composite flywheels are crucial component of the system. There have been numerous R & D programs of composite flywheel in the past [8].

FUNCTION OF FLYWHEEL

a). Flywheel is like as a reservoir to store energy when supply is more then requirement and release the energy when requirement is more than supply.

b). Flywheel provide the effective way to smooth out the function of speed.

c). The amount of stored energy is determined by the size, weight and the maximum allowed rotational speed of the Flywheel within it centrifugal strength limit.

d). Recently, several composite Flywheel have been developed for commercial power generation and vehicles such as buses and trains.

II. LITERATURE REVIEW

Phanindra Mudragadda [Et.al] have designed a four wheeler Flywheel used in a petrol engine using theoretical calculation. They have validate the design of Flywheel on A360 & Cast iron. They observed that, for all the materials the stress values are less than their respective permissible yield stress values. By comparing the results for two material, the stress value for aluminium alloy A360 is less than that of Cast iron [1].

Nagraj R. M. have presented a work on comparison of existing Flywheel material with composite one. They got a result from design & analysis methods that for energy storage low density and high strength is required in turns stresses and deformation should be low. So the Existing Gray cast iron Flywheel are having more stress and deformation whereas the test material is comparatively low. Therefore they suggest to use aluminium in Flywheel for high energy storing purpose with low density and less mass [2].

Snehal R. Raut [Et.al] have focused on the analytical design of Flywheel & FEM analysis of Flywheel used in press. They have considered the different types of force acting on Flywheel & design parameters has taken in consideration. They have discuss the different parameter like material stress acting on the Flywheel efficiency, cost of the Flywheel, output energy storing capacity of existing Flywheel. They have made a model in Pro-E as Web type Flywheel and 4,6,8 arm Flywheel. They conclude that web construction having maximum weight. All taper arm respectively 4,6,8 arm are having mass less than elliptical arm flywheel [3].

Kishore D. Farde [Et.al] have observed that turning moment diagrams for the cycle show periods during which torque is in excess of the mean torque responsible for the constant power output also periods during which the torque is than the mean torque. Thus the speed of the Flywheel would increase during periods of excess of torque during the cycle and speed will fail during the period of the deflect torque during the cycle. In their paper work they have used the composite material which allow a higher rotational speed and are better choice than metals when designing Flywheel rotors. They have observed that theoretical specific energy of composite rotor is around five times higher than metallic ones. In future they are going to design & analyze the composite Flywheel i.e. Steel (Rim) and Flywheel body to reduce weight for space aircraft & F1 race car application.

S.M.Choudhary [et.al] have studied various profiles of Flywheel and the stored kinetic energy is calculated for the respective flywheel. Results shows that efficient Flywheel design maximize the inertia of moment for minimum material used and guarantee high reliability and long life. Amount of Kinetic energy stored by wheel-shaped structure Flywheel is greater than any other flywheel. They found that certain amount of energy stored in Spoke/Arm Flywheel is less than the other Flywheel, thus reduce the cost of the Flywheel. And they found the Maximum stresses induced are in the Rim and Arm junction [2].

M. Lavakumar [Et.al] have establish the design and analysis of Flywheel to minimize the fluctuation in torque. The Flywheel is subjected to a constant rpm. The objective of this work is to design and optimize for the best material. Von-Misses stress for both material (Mild steel and Mild steel alloy) are compared, and the best material is suggested for manufacture of Flywheel [6].

Akshay P. Pundey [Et.al] have presented the investigation of a Flywheel to counter the requirement of smoothing out the large oscillation in velocity during a cycle of an I.C. Engine. A Flywheel is designed and analyzed by using FEA method. They have calculate the stresses inside the Flywheel. Finally the comparison study between the design and analysis with existing Flywheel is carried out [7].

Francisco Diaz-Gonzalez [Et.al] have proposes an energy management strategy for a Flywheel based energy storage device. They formulate the optimum operation to determine storage. The main objective of the Flywheel is to smooth the net power flow injected to the grid by a variable speed wind turbine. The result show that the higher mean wind power, the higher mean rotating speed of the Flywheel. The simulation results for the Flywheel with proposed energy management algorithm is able to achieve a 91.9 % of the turbulent energy component reduction in the high frequency components of the wind power. This result is close to the 91.7 % obtained by the optimal operation of the Flywheel [8].

Sushama G. Bawane [Et.al] have used optimization technique for various parameters like material, cost for Flywheel. These parameters are optimized and by applying an approach for modification of various working parameter like efficiency, output, energy storing capacity and compare the result with existing Flywheel result. FEA provides the ability to analyze the stresses and displacement of a part or Assembly, as well as the reaction forces of other elements are to impose. At last the design objective could be simply to minimize cost of Flywheel by reducing material [9].

Sudipta Saha [Et.al] have done work on the performance of the Flywheel. They found that the performance can be attributed to three factors (1) Material strength, (2) Geometry, (3) Rotational Speed. The material strength is directly determines the Kinetic energy level that could be produced safely combines with rotor speed. In Their study solely focuses on exploring the effect of Flywheel geometry on its energy storage capability per unit mass, Further defined as specific energy. The CAE Analysis and optimization procedure result show that smart design of Flywheel geometry could both have a significant effect on the performance and reduce the operational loads exerted on the shaft due to reduced mass at high rotational speed [10].

S. M. Dhengle [Et.al] have discussed the many cases of Flywheel failure. Among them maximum tensile stress and bending stress induced in the Rim and tensile stress induced in the Arm under the action of centrifugal forces are the main cause of the Flywheel failure. Hence their work evaluation of stresses using the Finite Element Method and results are validated by analytical calculations. The Finite Element Analysis is carried out for different cases of loading applied on the Flywheel and maximum Von-Misses stress and deflection in the rim are determined. From this Analysis they have found that Maximum stresses induced are in the rim & arm junction. Due to tangential forces maximum bending stresses occurs near the Hub end of the arm [11].

J. G. Bai [Et.al] have developed prototype of Flywheel Energy Storage System (FESS) with Active Magnet Bearing (AMB) and AMB's-parameters are obtained by parameter identification. They have make Analysis on Flywheel parameter as mass, diameter, rotating speed and energy storage. They have placed two AMB on the top of rotor and two AMB on bottom, that control the unbalanced force and gyroscopic effect of the Flywheel rotor and energy loss covered by the bearing is also minimize by carefully design [12].

Jerome Tzeng [Et.al] have studied with the intent of implement composites in high performance Flywheels. The potential failure mechanism of Flywheel constructed with fiber composites was evaluated. They have used Analytical method to predict creep and pre-load loss due to the time dependent behavior of composites. Then they have test the material of T1000G Graphite / Epoxy composite. They have check the fracture toughness which is a critical property of for the composite Flywheel subjected to a very high operating stress. The material test matrix performance Flywheel was proposed from a design point of view of high performance Flywheels. The proposed design and test procedure indeed considers the long term behavior of Flywheels, such as creep, stress relaxation, fatigue and fracture of composites [13].

S. M. Arnold [Et.al] have observed the problem in a Flywheel rotating disk. They have make a analytical model to performing elastic stress analysis for single/ multiple, annular / solid, anisotropic / isotropic disk, which is subjected to pressure surface traction, body force is summarized. They have considered the important parameters like mean radius, thickness, material property, load gradation and speed, all of which must be simultaneously optimized to achieve the best and most reliable design. They have done analysis in two failure, one is static limit and other is cyclic limit with respect to constant thickness. They have made analysis with material PMC and TMC with either and annular or solid geometry. They observed that an annular anisotropic disk is more efficient than its solid counterpart [14].

Haichang Liu [Et.al] have offers significant operating cost saving to the internal storage system, the commercialization of Flywheel Energy Storage (FES) was not very successful. They have implemented new technologies, Flywheel energy storage will continue to develop and key issue will be solved and reduced gradually. They considered three major advancement for next technique. Their objective is enhance the following performance characteristics:- specific energy =200 Wh/Kg and specific power = 30Kw/kg. The second is to improve its efficiency by reduction of loss. Helium-air mixture gas condition or vacuum enclose with better heat exchangers will be selected according to different operation condition. They have found that if the cost of FES can be lowered, they will be widely used both in civil and military industries and play a significant role in securing global energy sustainability [15].

III . CONCLUSION

From the review of literature it analyzed that Flywheel is very important component for store energy in Automobile and other industrial applications like compressor, punching press and I.C. Engine etc. Flywheels are widely used with respect to different cross-section, material properties and as per the application of Flywheel. From the literature the Authors have worked on different geometries and cross –sections of the flywheel. Some Authors have used only analytical method and some have used modeling software tool and Analysis software tool to check the design. They have done parametric analysis of the flywheel e.g.: speed, diameter of Flywheel, Mass. And they have make a comparison with the existing result. Some Authors have done only structural analysis of flywheel. They have check the stability of Flywheel on different composite material like Aluminum Alloy 7050, carbon fiber, TMC (Titanium Matrix Composite) etc. and make a comparison with existing one.

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