"Design and Analysis of flywheel for optimization"

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ABSTRACT

There are many causes of failure of flywheel. Maximum tensile and bending stresses induced in the rim and tensile stresses gets induced in the arm under the action of centrifugal forces are the main causes of flywheel failure. In this work stress evaluation in the rim and arm are studied using finite element method and results are validated by analytical calculations .The models of flywheel having solid, four and six no. arms are developed. The FE analysis is carried out for different loading conditions on the flywheel for different cases the maximum Von mises stresses and deflection in the rim are determined. From this analysis it is analysed that Maximum stresses induced are in the rim and arm junction. Due to application of tangential forces, maximum bending stresses occurs near the hub end of the arm. It is also observed that for low angular velocity the effect gravity on stresses and deflection of rim and arm is predominant. The FEM formulation carried out in ANSYS workbench R14.

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. A flywheel used in machines serves as a reservoir which stores 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 supply. Several hundred years ago pure mechanical flywheels where used solely to keep machines running smoothly from cycle to cycle, thereby render possible the industrial revolution. During that time several shapes and designs where implemented, but it took until the early 20th century before flywheel rotor shapes and rotational stress were thoroughly analyzed [1].Later in the 1970s flywheel energy storage was proposed as a primary objective for electric vehicles and stationary power backup. At the same time fiber composite rotors where built, and in the 1980s magnetic bearings started to appear [2]. Thus the potential for using flywheels as electric energy storage has long been established by extensive research. More recent improvements in material, magnetic bearings and power electronics make flywheels a competitive choice for a number of energy storage applications.

1.1 Factors Affecting Flywheel Performance

A. Material strength

Stronger materials could undertake large operating stresses, hence could be run at high rotational speeds allowing to store more energy. Hence could be run at high rotational speeds allow wing to store more energy.

B. Rotational speed

It directly controls the energy stored, higher speeds desired for more energy storage, but high speeds assert excessive loads on both flywheel and bearings during the shaft design.

C. Geometry

It controls the Specific Energy, in other words, kinetic energy storage capability of the flywheel. Any optimization effort of flywheel cross-section may contribute substantial improvements in kinetic energy storage capability thus reducing both overall shaft/bearing loads and material failure occurrences. Flywheel efficiency includes the amount of specific kinetic energy (energy per unit mass) and mechanical losses.

To improve the quality of the product and in order to have safe and reliable design, it is necessary to investigate the stresses induced in the component during working condition. When the flywheel rotates, centrifugal forces acts on the flywheel due to which tensile and bending stress are induced in a rim of flywheel. To counter the requirement of smoothing out the large oscillations in velocity during a cycle of a mechanism system, a flywheel is designed, optimized and analyzed. By using optimization technique various parameter like material, cost for flywheel can be optimized and by applying an approach for modification of various working parameter like efficiency, output, energy storing capacity, we can compare the result with existing flywheel result.

One of the major advantages of flywheels is the ability to handle high power levels. This is a desirable quality in e.g. a vehicle, where a large peak power is necessary during acceleration and, if electrical breaks are used, a large amount of power is generated for a short while when breaking, which implies a more efficient use of energy, resulting in lower fuel consumption. Individual flywheels are capable of storing up to 500MJ and peak power ranges from kilowatts to gigawatts, with the higher powers aimed at pulsed power applications. Stress analysis is the complete and comprehensive study of stress distribution in the specimen under study. To improve the quality of the product and in order to have safe and reliable design, it is necessary to investigate the stresses induced in the component during working condition. Flywheel is an inertial storage device which acts as reservoir of energy. When the flywheel rotates, centrifugal forces acts on the flywheel due to which tensile and bending stress are induced in a rim of flywheel.

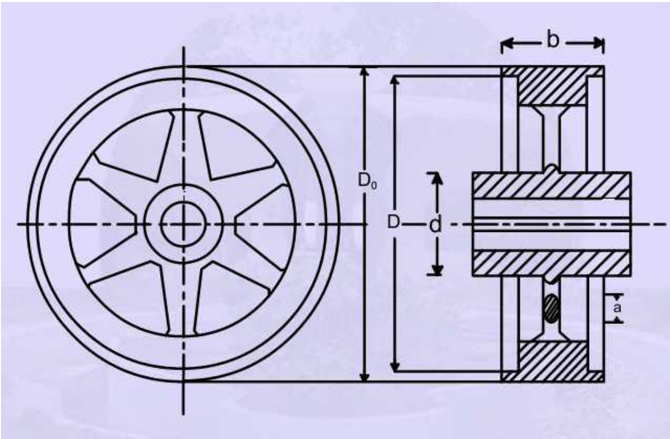

Fig.1.1Arm type of flywheel

The current paper is focused on the analytical design of arm type of flywheel which is used for punching press operation. Now in regard to the design of flywheel it is required to decide the mean diameter of the flywheel rim, which depends upon two factors such as availability of space and the limiting value of peripheral velocity of the fly wheel. However the current design problem is formulated for punching machine which has to be make holes of 30 holes/minute in a steel plate of 18mm thickness with space limitation that is the diameter of flywheel should not exceed 1000mm, hence it can be observed that the design of the flywheel is to be carried out (based) on the availability of space limitation.

I. LITERATURE REVIEW

JohnA.Akpobi&ImafidonA.Lawani [1] have proposed, a computer-aided-designs of software for flywheels using object-oriented programming approach of Visual Basic. The various configurations of flywheels (rimmed or solid) formed the basis for the development of the software. The software's graphical features were used to give avisual interpretation of the solutions. The software's effectiveness was tested on a number of numerical examples, some of which are outlined in this work.

Sushama G Bawane, A P Ninawe and S K Choudhary had proposed [2] flywheel design, and analysis the material selection process. The FEA model is described to achieve a better understanding of the mesh type, mesh size and boundary conditions applied to complete an effective FEA model.

SaeedShojaei , SeyyedMostafaHossein Ali Pour Mehdi Tajdari Hamid Reza Chamani [3] have proposed algorithms based on dynamic analysis of crank shaft for designing flywheel for I.C.engine , torsional vibrasion analysis result by AVL\EXCITE is compared with the angular displacement of a desire free haed of crank shaft ,also consideration of fatigue for fatigue analysis of flywheel are given.

SudiptaSaha, Abhik Bose, G. SaiTejesh, S.P. Srikanth have propose [4] 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.

Bedier B. EL-Naggar and Ismail A. Kholeif [5] had is suggested the disk-rim flywheel for light weight. The mass of the flywheel is minimized subject to constraints of required moment of inertia and admissible stresses. The theory of the rotating disks of uniform thickness and density is applied to each the disk and the rim independently with suitable matching condition at the junction. Suitable boundary conditions on the centrifugal stresses are applied and the dimensional ratios are obtained for minimum weight. It is proved that the required design is very close to the disk with uniform thickness

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Mofid Mahdi [6] the consumption of energy is increasing rastically. The available resources of energy are limited therefore; the search of new sources is a vital issue.This has to be done with efficient energy consumption and saving. A flywheel may provide a mechanical storage of kinetic energy. A capable flywheel must have a very high rotational speed which may lead to a high stresses.The stress state relies on the flywheel material properties, geometry and rotational speed. On the other hand, the stored kinetic energy relies on the mass moment of inertia and rotational speed. This paper considered three solid flywheel disk profiles that are constructed using functions of cubic splines. Using FEM, the cubic splines parameters are analyzed systematically to seek a maximum stored kinetic energy per unite mass. Subjected to maximum permissible effective stress, favorable flywheel disk profiles were achieved. All FEM computations were carried out using ANSYS.

II. ANALYTICAL METHODOLOGY

The method adopted for the design of flywheel for punching machine is Analytical method. Now let us determine the various parameters in regard with flywheel design.

- Mean speed of flywheel N= 9 Number of strokes/min
=9×30=270rpm
- Maximum shear stress required to punch a hole
=Shear strength ×resisting area
$=f_s \times \pi$ dt
=240× π×25×18
1000
=339.3kN
- Energy required to punch one hole
=average force × distance travelled by punch
=0.5×339.3× 18=3053.7N
- Since mechanical efficiency is less than 100%, assuming as 85% ,therefore
Total energy required, E=3053.7/0.85
=3592.6N-m
- Actual punching operation lasts for the $1/10^{th}$ of the cycle period. Therefore, during remaining period $9/10^{th}$ of the cycle period, the energy is stored by the flywheel. Thus fluctuation of energy =9/10× E= 3233.3Nm
- Maximum space available is 100mm,therefore considering as D=800mm to carry out design
- Rim Velocity= π× 0.8×270
60
=11.3m/s…which is less than the maximum permissible velocity for grey cast iron
- Mass of flywheel, m=fluctuation of energy
$V^2 \times C_s$
= 3233.3 = 253.3 Kg
11.3^2×0.1
- Assuming mass of rim as 90%of total mass,
m_{rim} =0.9×253.2=227.88Kg
- m_{rim}= πDhp ….used to determine dimensions of rim
Where, p=7100kg/$m^3$for C.I.
Therefore, h=90mm, b=150mm
- Outer diameter of flywheel=D_o=D+h=0.89m, which is less than the maximum space of 1m, hence the design dimensions are within limit.
- *To* determine Shaft diameter
- Bending moment M =weight of flywheel× overhang
=253.2×9.81× 0.2=496.78N-m
- Average torque =Energy required/min
2πN
= 107778
2π×270
=63.53N-m
- Assuming suddenly applied load condition with shock and fatigue factor of 1.5 and 2
- Equivalent torque =((Cm×M)2 +(Ct× T)2)1/2
=755.92N-m
- Shaft is made of medium carbon steel, with shear strength 360N-mm2, Factor of safety is 4,therefore shaft diameter can be determined by using torsion equation
- Shaft diameter,ds =34.96 say=40mm
- Hub diameter, dh= 2ds=80mm
- Length of hub, lh = 2.5 ds=100mm
- To determine the Stresses in the rim of flywheel
- Stresses in unstrained rim = pv2

= 7100×11.32 =0.9066MN/m2

_ Stresses in restrained rim = pv2(2πR2/ i2h)

=4.97 MN/m2

_ Total Stress in the rim ,

_ = 0.75 Stresses in unstrained rim+0.25 Stresses in

restrained rim

_ =1.922 MN/m2….which is less than the allowable

strength of C.I, hence design of rim is safe

_ To determine stress in arm of flywheel

Considering arm type flywheel of four arms

Bending stress in the arm =10N/mm2

=T(D-dh)

iDz

Where, Z=modulus of elasticity=1429.4mm3

i=numbers of arms=4

_ Direct stress due to centrifugal force =pv2=0.9066N/

mm2

_ Total stress = Bending stress+ Direct stress

=10+0.9066=10.9066N/mm2

_ Total stress is less than the allowable strength

20N/mm2, hence the design of the arms are safe.

IV CONCUSIONS

It can be conclude that in case of flywheel design it is first important to know the design requirement such as material, type, application, desired speed (peripheral velocity), availability of space, and dimensions of the flywheel.

_ The peripheral velocity of the flywheel is governed by allowable strength of the flywheel material, generally for grey cast iron it should be less than or greater than 25m/s.

_ In case of arm type of flywheel the numbers of arms selection depends upon the diameter of the flywheel, generally four numbers of arms are selected for diameter of flywheel which should be less than 0.75m.

_ As the current problem is related to the design of flywheel with consideration(limitation) of the space availability that is maximum space should be less than 1m, but after carrying out design the outer diameter of flywheel obtained is of 0.89m which is less than the required condition, hence can be concluded as design is safe.

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