Design and Dynamic Analysis of Flywheel

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May 27, 2021

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Abstract

A flywheel is an inertial energy-storage device. In this paper totally all dimensions have found theoretically for required power 20 KW and it is rotating from 400 RPM to 410 RPM. Fly wheel are modeled in PRO/E 5.0 software and this is analyzed with considering at different time interval and different loading conditions have found from theoretically. Countering the requirement of smoothing out the large oscillations in velocity during the cycle of a mechanism system, a flywheel is designed and analyzed. In that four time intervals are considered like motion less, starting position, changing speed and constant speed. Weight reduction is major important and maintain minimum stresses, here another three type of flywheels have chosen like flywheel with extended hub support, rim type and elliptically rim type.

Keyword

design of fly wheel

concentration at different stages

finite element technique.

I. INTRODUCTION

A flywheel is a rotating mechanical device that is used to store rotational energy. Common uses of a flywheel include. 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.

Flywheel is basically are chargeable battery. It is used to absorb electrical energy from a source, store it as kinetic energy of rotation, and then deliver it to a load at the appropriate time, in the form that meets the load needs. As shown in fig 1, a typical system consist of a flywheel, a motor/generator, and controlled electronics for connection to a large electric power system.

Fly wheels are generally using for 1.Providing continuous energy when the energy source is discontinuous. 2. Delivering energy at rates beyond the ability of a continuous energy source. This is achieved by collecting energy in the flywheel over time and then releasing the energy quickly, at rates that exceed the abilities of the energy source.

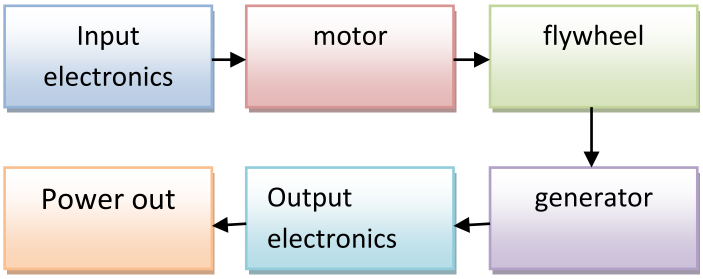


Fig.1

flywheel

II. LITERATURE REVIEW

Design optimization of flywheel of thresher using fem byS.M.Choudhary and D.Y.Shahare in his study solely focuses on exploring the effects of flywheel geometry on its energy st orage/deliver capability per unit mass, further defined as specific energy. Sudipta Saha, Abhik Bose, G. SaiTejesh, S.P. Srikanth have propose the importance of the flywheel geometry design selection and its contribution in the energy storage performance.

Saeed Shojaei , Seyyed Mostafa Hossein 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.

In 2012 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.

3 Design of fly wheel

Diameter has chosen according to space requirement as 0.6 m

Required power = 20 Kw and it is rotating from 400 RPM to 410 RPM. STORAGE OF ENERGY = 0.6 KN-M

Speed fluctuation

$C = N2 - N1$

$= 410 - 400$ 405

N= average speed in RPM

Coefficient of speed fluctuation =0.02469 Energy storage $\Delta E = MV^2 CS$

600= M (0.6 X ^{405})^{2}X $\overline{0.0}$2469

60

MASS M=150 KG

MASS (M) = Π X D X B X t X ρ 150 = Π X 0.6 X 0.118 X t X 7510

Required Thickness t = 0.089 m

Outer diameter of rim = D+t =0.6+0.089

Outer diameter of rim =0.6897 m

Inner diameter of rim = D-t = 0.6-0.089

Inner diameter of rim =0.511 m

Design of shaft hub andkey

Power P= 2 $X\ \Pi\ X\ N\ X\ T$60 20000= 2 $X\ \Pi\ X$ 405 X T60 T=471.57 N-M

N= average speed in RPM

Suppose max torque is equal to twice of mean torque THEN

= 43.14 N-M

Shear stresses of for shaft and key material is 40 N/mm2

Diameter of shaft. (D)=49.5 mm

Diameter of shaft. (D)= 50 mm

Outside diameter of hub may be assumed as twice the diameter of shaft Outside diameter of hub= 2 X D

Outside diameter of hub =100 mm

Suppose let we take Length of hub = width of rim Length of hub for fly wheel L=0.07m

Width of hub for fly wheel =12.5mm

Height of hub forflywheel=8.5mm

Material, class, specification	Gray cast iron, ASTM 30, SAE 111
Ultimate strength	Tension =214 M.Pa, shear =303 M.Pa
Modulus of elasticity	101 G.Pa
density	7510 kg/m^3
Poisson’s ratio	0.23

Material properties

Fly wheel arrangement to support and crank Design of loading applied in analysis

1.Fly wheel is in motion less : When fly wheel is in motion less position we have to considered as only gravitational force like 9.81 m/s^2.

2.Fly wheel is in starting position: At fly wheel is starting position we are considered the gravitational force and moment of fly wheel and angular velocity changes with respective to time like angular acceleration Force= 9.81 m/s^2.

Angular velocity of fly wheel is $= VELOCITY\ OF\ LINK/LENGTH\ OF\ LINK$

j = mass x length of link

= 150 X 0.1^2

=1.5 kg. m^2 ,(Length of crank is 0.1 m) Actual inertia moment of flywheel = 11.7278

Total moment of inertia = Equivalent inertia of moment + Actual inertia moment Drive force is equal to 5000 N.

Angular acceleration = drive moment / total moment of inertia

= 5000 X0.10 / (11.7228 +1.5)

=37.799 rad /sec^2

Moment applied for fly wheel = actual moment of inertia X angular acceleration

=11.7278 X 37.799

=221.651 N-M

Stages considered in flywheel: 1. fly wheel is in motion less 2.fly wheel is in starting 3.flywheel is at changing speed 4. Flywheel is at constant speed

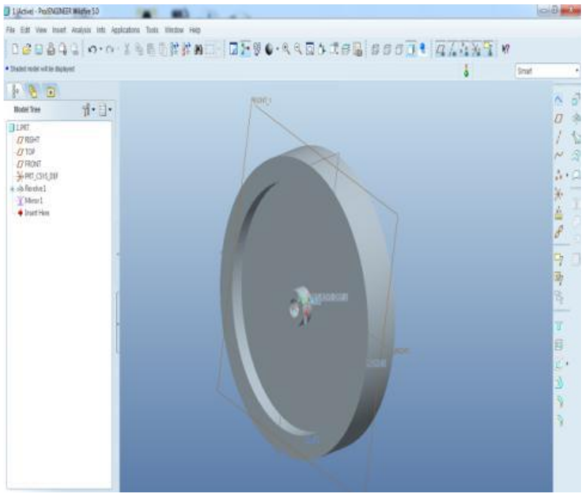
Advantages

1.Flywheels srote energy very efficiently (high turn-around efficiency) and have the the potential for very high specific power(~130W-h/kg or ~500 kJ/kg) compared with batteries.Flywheels have very high outpu tpotential and relatively longlife.

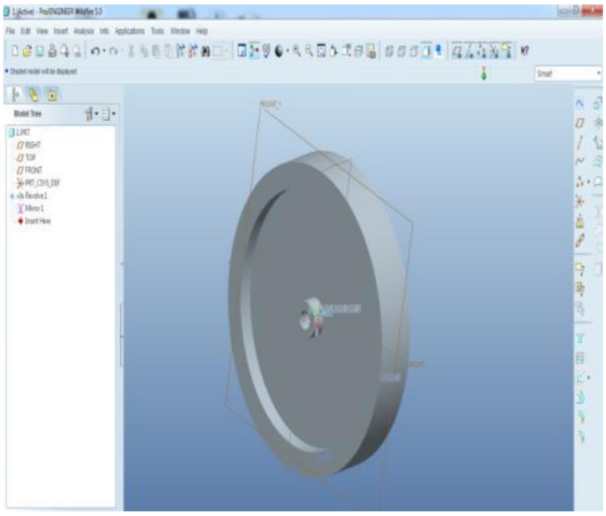
Flywheels are relatively unaffected by ambient temperature extremes. The energy efficiency (ratio of energy out per energy in) of flywheels can be as high as 90%. Typical capacities range from 3kWh to133kWh.Rapid charging of a system occurs in less than 15minutes.

II. INTRODUCTION TO PRO/ENGINEER

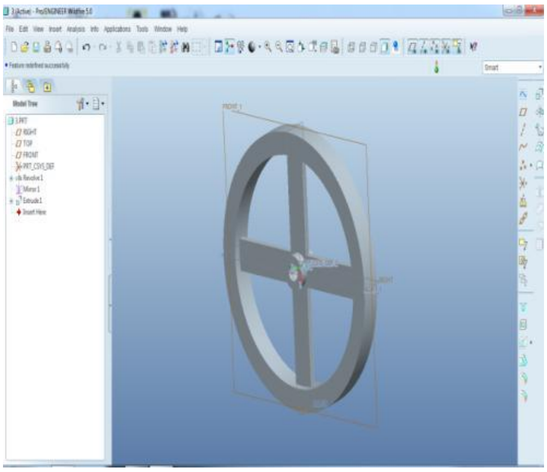
Pro/Engineer Wildfire is the standard in 3D product design, featuring industry-leading productivity tools that promote best practices in design while ensuring compliance with your industry and company standards. Integrated Pro/Engineer Cad/Cam/Cae solutions allow you to design faster than ever, while maximizing innovation and quality to ultimately create exceptional products.



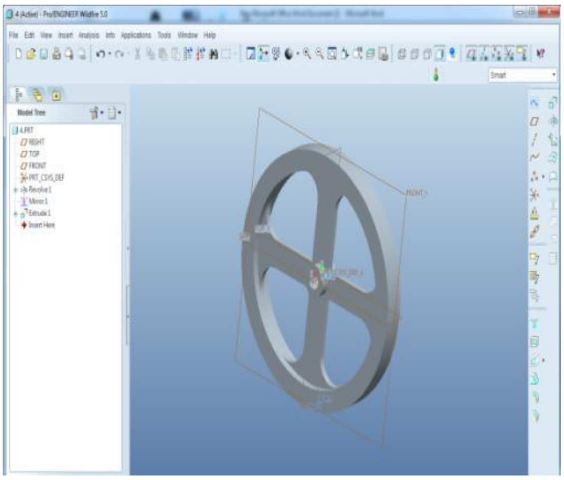
1 st model created in pro/e



2 nd model created in pro/e



3 rd model created in pro/e

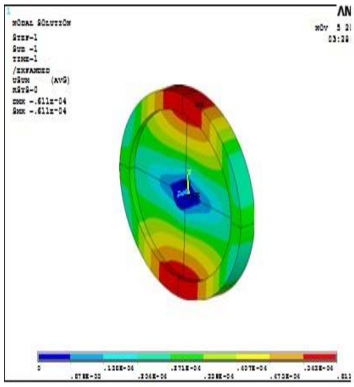


Fourth model created in pro/e

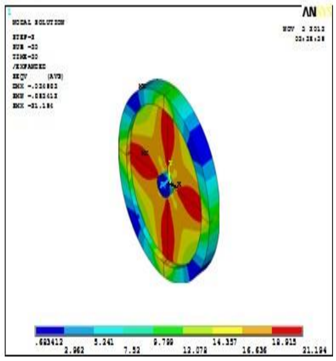
Structural Analysis Of Fly Wheel

Totally dynamic structural analysis is performed in ANSYS 12.0 software. In that brick 8 node has chosen for solid flywheel. ¼ models are considered in this analysis. Symmetric boundary conditions are applied and at hub support translation of x, y and directions are totally constrained. And rotation z is released as free to rotate.

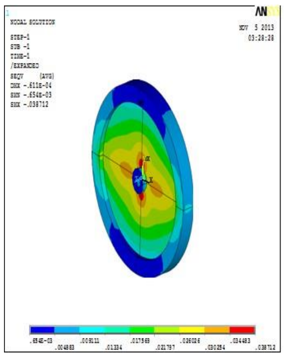
In that four time intervals are considered as first fly wheel is in motion less at which self weight is acting, at second interval fly wheel is start position in which moment, self weight and angular acceleration areapplied, at third interval fly wheel is at changing speed at which moment, angular acceleration, angular velocity and self weight is applied and at fourth stage fly wheel is in constant speed at which angular velocity and self is assigned.



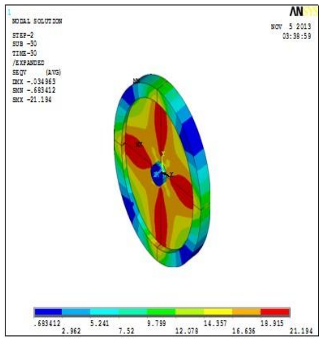
Stresses of 1st model at1sec



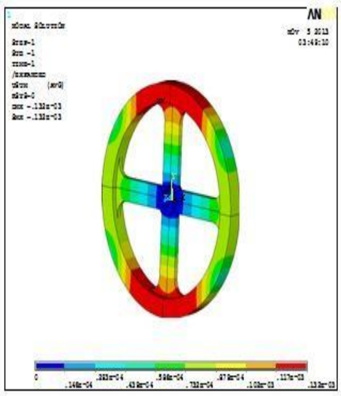
Deformation of 1st model At1 sec



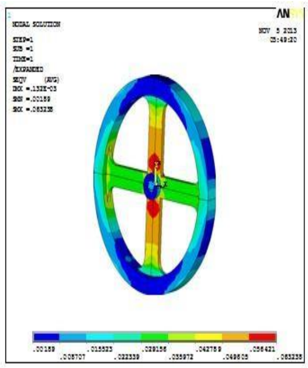
Stresses of 2nd model at 1 sec



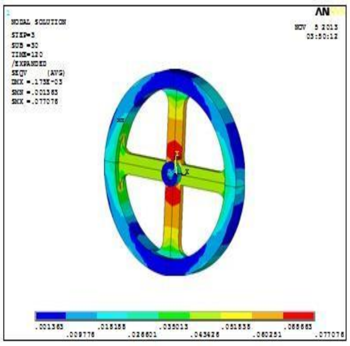
Deformation of 2nd model at1 sec

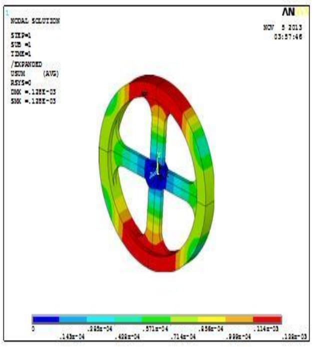


Stresses of 3rd model At 1 sec



Deformation of 3rd model at 1 sec





Stresses of 4th model At 1 sec

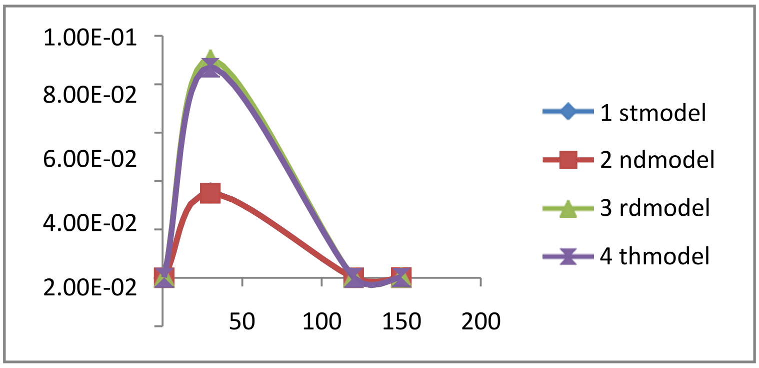
Deformation of 4th model at 1 sec

4 th model		
time	deformation	stresses
1	1.28E-04	0.65391
30	0.086919	38.064
120	1.58E-04	0.078093
150	2.21E-04	0.108759

3 rd model		
time	deformation	stresses
1	1.32E-04	0.6323
30	0.090301	39.652
120	1.73E-04	0.077076
150	2.33E-04	0.1074

1 st model		
time	deformation	stresses
1	6.11E-05	0.038712
30	0.35118	21.404
120	5.68E-05	0.036
150	4.61E-05	0.0294

1 st model		
time	deformation	stresses
1	6.09E-05	0.038
30	0.03496	21.194
120	6.60E-05	0.040552
150	9.35E-05	0.079077



Deformation plots for all models

Result

A structural analysis of was performed and normal stress are shown in fig 3. Flywheel was discredited into 19735 elements and 36539 nodes. Table 2 shows that normal stress obtained for Gray cast iron is 44.07 Mpa and similarly for S glass Epoxy is 11.54 Mpa.

Conclusion

Based on above design and analysis, the following conclusion can be drawn

1.The maximum stress and deflection usually occur at the starting and speed-changing stages, respectively. The situation of stress and deflection at these stages should be paid enoughattention.

2.The larger shaft-hole and longer hub are useful to decrease the stress caused by the drivemoment.

3.The stress and deflection are alternating transiently as the flywheel is running. These transient changes may lead to the fatigue failure of theflywheel.

4.The stress in the rim is not as large as estimated.

5.The wheel-shaped structure contributes to decrease stress concentration.

6.The wheel-shaped structure is advantageous to get good performance and reduce the cost.

7.The transition through large fillets is favorable to reduce stress concentration at the arms.

8.The over-long arms may result in the large deformation in the rim.

9.There exist certain relationships between angular velocity, stress and deflection at constant speed stage.

11.Model analysis are performed to find out natural frequencies and where the resonance will occur.

12.Harmonic analysis also performed to find out where the maximum deformation will occur at which frequency.

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