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DESIGN OPTIMIZATION OF FLYWHEEL OF ROLLING MILL USING FEM

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Abstract: *This study exclusively focuses on exploring the property of flywheel geometry on its energy storage/deliver ability per unit mass, further defined as specific energy. In this paper we have studied various profiles of flywheel and the stored kinetic energy is calculated for the respective flywheel .various profiles designed are solid disk, disk rim ,webbed/section cut, arm/spoke flywheel. It shows that smart design of flywheel geometry could both have a major effect on the Specific Energy performance and reduce the operational loads exerted on the shaft/bearings due to reduced mass at high rotational speeds. Proficient flywheel design used to maximize the inertia of moment for minimum material used and guarantee high reliability and long life. FE analysis is carried out for different cases of loading on the flywheel and maximum stresses and total deformation are determined.*

Keywords— *Flywheel, specific energy, stored kinetic energy, flywheel geometry, operational loads, total deformation.*

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INTRODUCTION

Flywheel acts as a reservoir by storing energy during the period when the supply of energy is more than the requirement and releasing it during the period when the requirement of the energy is more than the supply. Flywheel provides an effective way to smooth out the fluctuation of speed. The stored kinetic energy relies on the mass moment of inertia and rotational speed. A flywheel is a mechanical device with a significant moment of inertia used as a storage device for rotational energy. Flywheels resist changes in their rotational speed, which helps steady the rotation of the shaft. Flywheels have become the subject of extensive research as power storage devices for uses in steel plant rolling mill. Flywheel energy storage systems are considered to be an attractive alternative to electrochemical batteries due to higher stored energy density, higher life term, and deterministic state of charge and ecologically clean nature. The performance of a flywheel can be attributed to three factors, i.e., material strength, geometry (cross- section) and rotational speed.

A. Material strength

Stronger materials could undertake large operating stresses, hence could be run at high rotational speeds allowing storing 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.

GEOMETRICAL DIMENTIONS OF FLYWHEEL

Flywheel used in the thresher machine is solid disk. Dimensions of flywheel are provided below. This flywheel is designed and analyzed.

Mass of flywheel (m) =200kg.

Outer diameter of flywheel (do) =800mm.

Inner diameter of flywheel (di) =100mm.

RPM (n)=650.

MATERIAL FOR FLYWHEEL

CAST IRON, ASTM 30, SAE 111

Density=7510 kg/m3.

Poisons ratio (υ)= 0.23.

Modulus of elasticity = 101 Gpa

Modulus of rigidity = 41 Gpa

Tensional/shear strength=276 mpa.

TABLE I: FUNCTIONAL VALUES OF SOLID FLYWHEEL

Type	Moment of inertia(I) Kg-m2	Kinetic energy stored (ΔE)KJ	Spe. Energy KJ/kg	Spe. Density Kj/m3
Solid	2.193	6.137	0.197	818.43

T-Θ DIAGRAM

T θ diagram for the solid flywheel used is:

Tmax = 71.15 Nm

Tmin= 64.76 Nm

Work done per cycle = 21.064 Nm

Maximum fluctuation of energy = 3.521 Nm

Coefficient of fluctuation of energy (CE) = 0.15

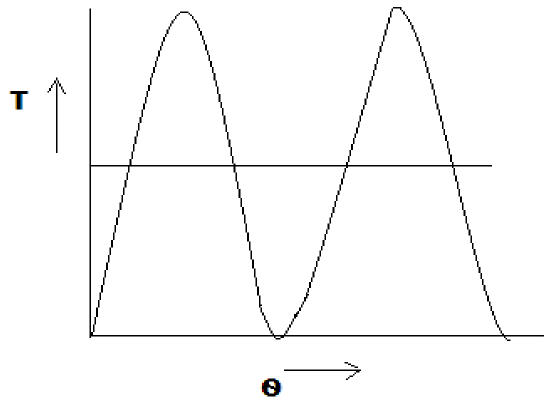


Fig 2 T θ diagram

OTHER FLYWHEEL GEOMETRIES

Other flywheel geometries taken under study are rim disk, webbed/ section cut, arm/spoke type. Keeping mass change as 100 kg to 200 and outside diameter 800 mm, stored kinetic energy is calculated for these profiles. This study clearly depicts the importance of flywheel geometry design selection and its contribution in the energy storage performance. Although this improvement is to be thought small, it still could be crucial for mission critical operations .other profiles of flywheel given below are designed and analyzed.

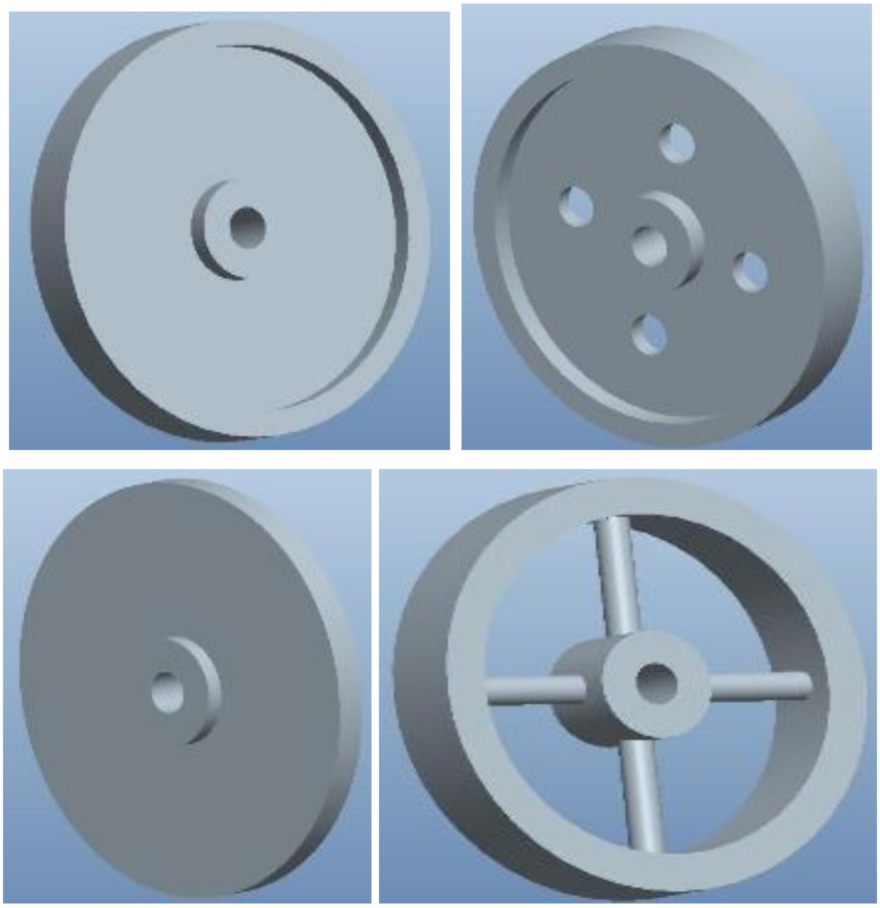


Fig3 Various profiles of flywheel

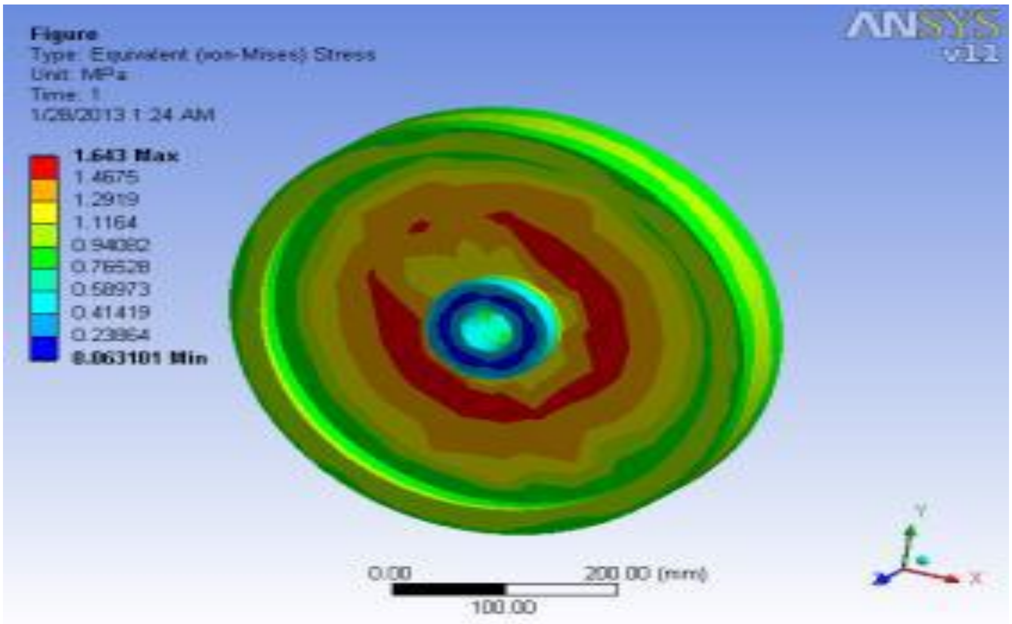
TABLE II COMPARISON OF FUNCTIONAL VALUES OF FLYWHEEL

Functional values	Solid	Rim	Web	Arm
Moment of inertia(I) Kg-m2	2.743	2.998	2.543	4.345
Kinetic energy(ΔE) stored KJ	6.345	8.002	8.347	12.334
Spe. Energy KJ/kg	1.007	.331	.234	.3218
Spe. Density KJ/m3	834.12	899.32	1001.2	1545

FINITE ELEMENT ANALYSIS OF FLYWHEEL

These four profiles of flywheel used are analyzed by FE software i.e. ANSYS software FE analysis is carried out for different cases of loading applied on flywheel and maximum stresses and total deformation are determined.

LOADING CONDITION:- ANGULAR VELOCITY



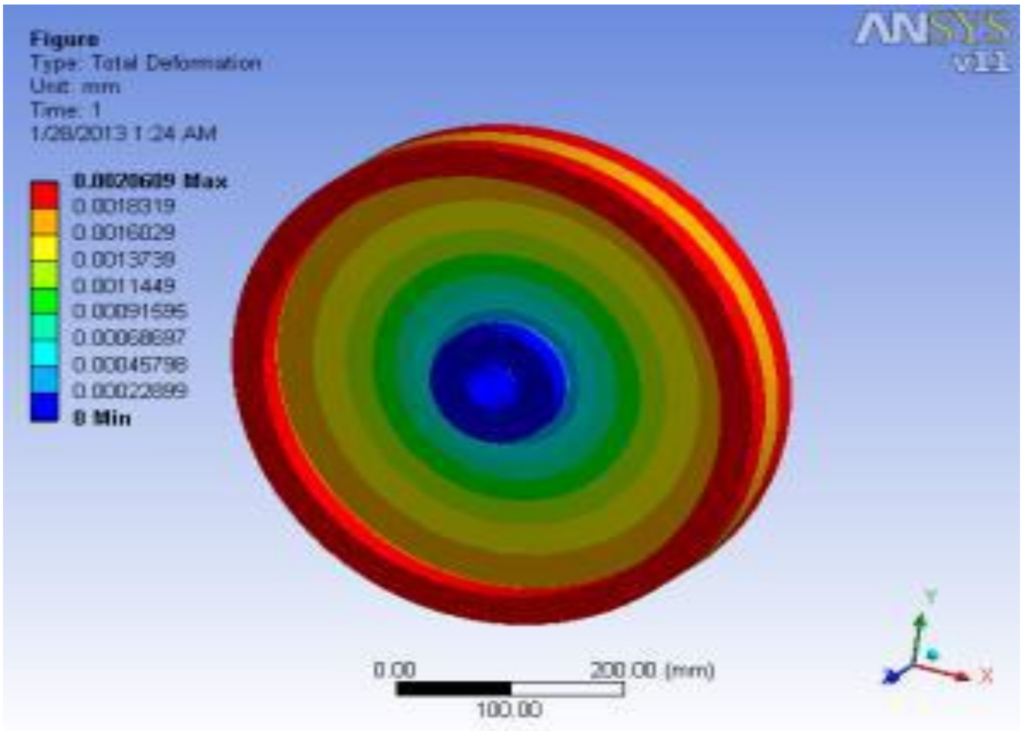


Fig 4 Analysis of rim type flywheel

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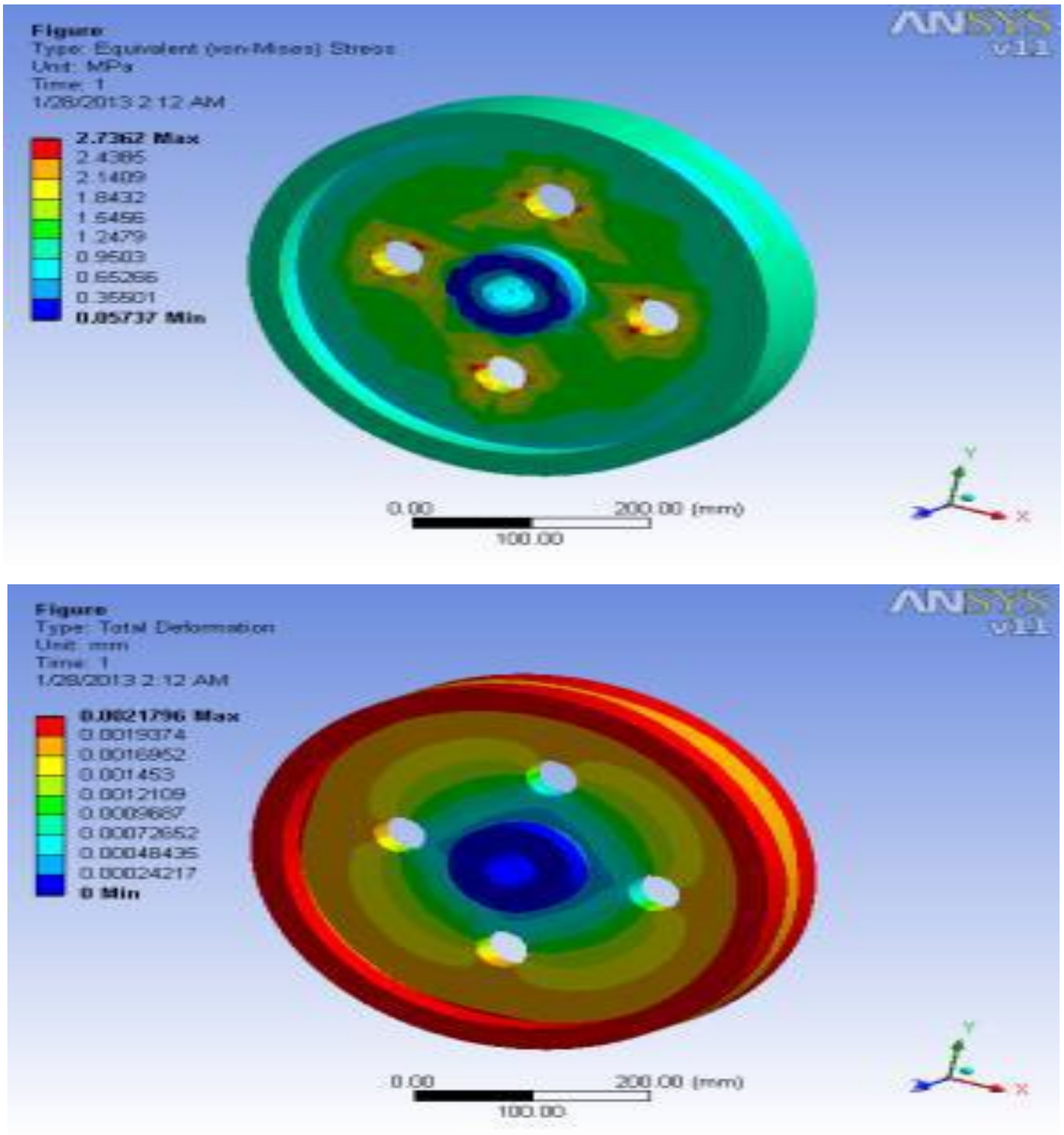
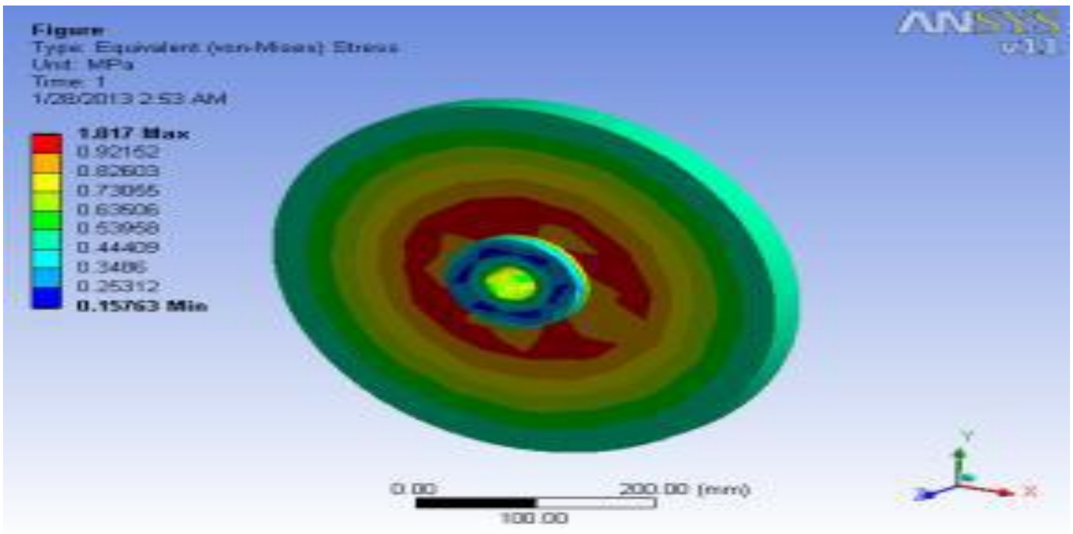


Fig 5 Analysis of section cut flywheel



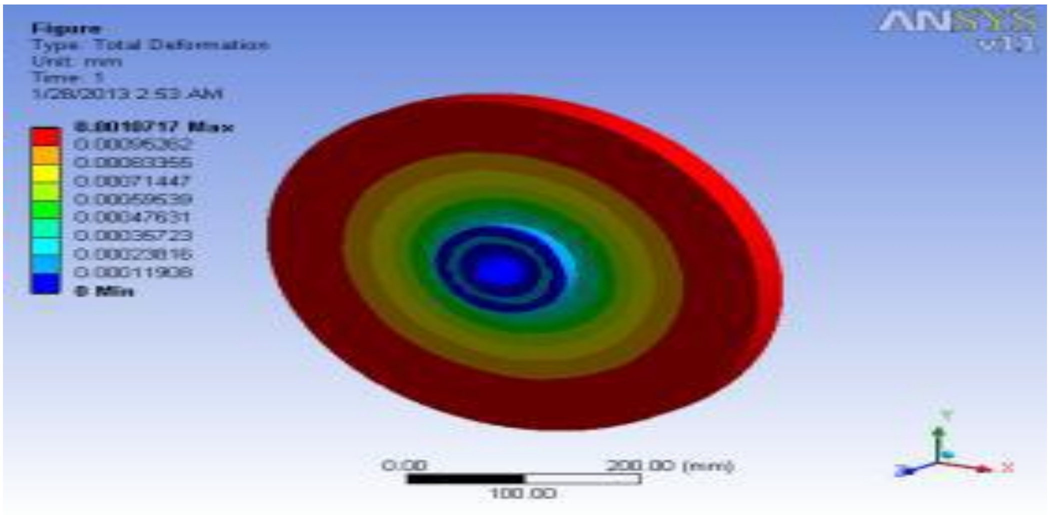
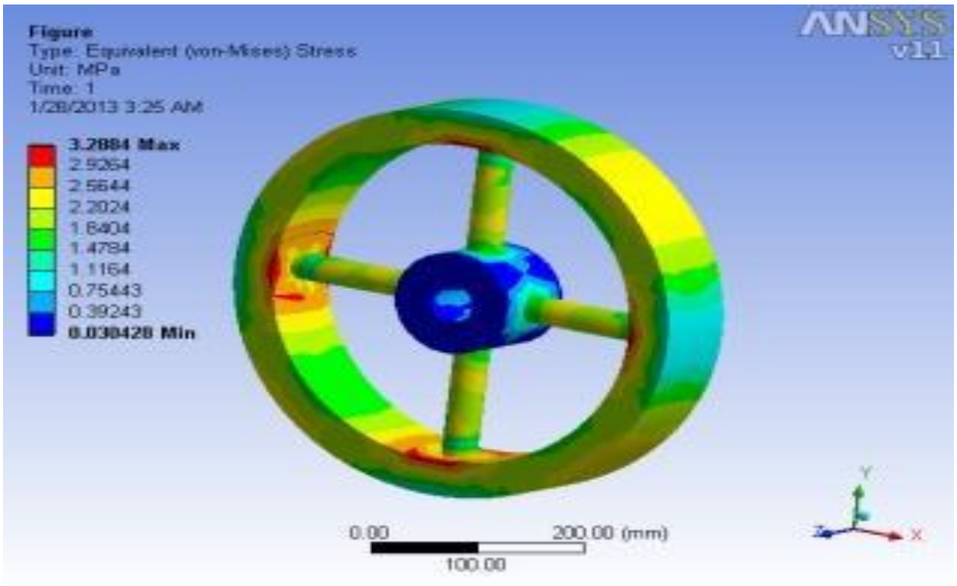


Fig 6 Analysis of solid flywheel



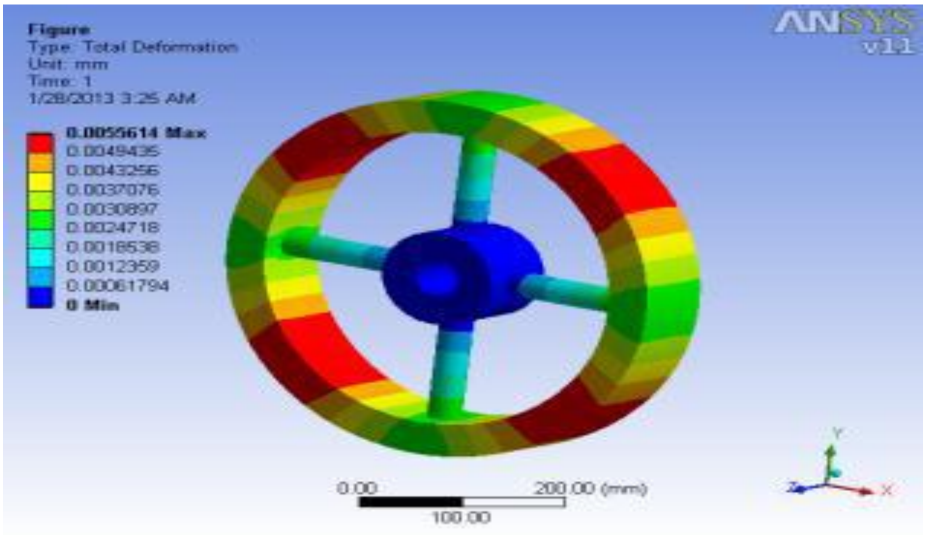


Fig 7 Analysis of spoke type flywheel

TABLE III COMPARISON OF ANALYSIS OF FLYWHEEL

Type of Flywheel	Load	stresses(mpa)	Total Deformation (mm)
Solid	ώ=78.53 rad/sec	2.017	**.00207**
Rim	ώ=78.53 rad/sec	**2.543**	**.00305**
Web	ώ=78.53 rad/sec	**3.234**	**.00312**
Arm	ώ=78.53 rad/sec	**4.227**	**.00645**

CONCLUSIONS

Smart design of flywheel geometry has major effect on its specific energy recital. Quantity of kinetic energy stored by wheel shaped structure flywheel is greater than any other flywheel. To obtain certain amount of energy stored; material induced in the spoke/arm flywheel is less than that of other flywheel, thus reduce the cost of the flywheel. From the analysis it is found that maximum stresses induced are in the rim and arm junction.

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