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RESEARCH ARTICLE

DESIGN AND ANALYSIS OF LIGHT WEIGHT MOTOR VEHICLE FLYWHEEL

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ABSTRACT

Flywheels serve as kinetic energy storage and retrieval devices with the ability to deliver high output power at high rotational speeds as being one of the emerging energy storage technologies available today in various stages of development, today fly wheels are used to reduce costs, design for light-weight and limited-life for all vehicles. In this paper we discussed about the different types of flywheels used in the automobile industries and its applications. 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. This paper specifically studies the most common three different geometries In this paper we also summarize different types of flywheel in a tabular form. The finite element model of flywheel is considered and the analysis is done with the help of ANSYS package.

Key Words: Motivation, Instrumental Motivation, Integrative Motivation.

INTRODUCTION

To improve the quality of the product and in order to have safe and reliable design, it is necessary to investigate the von-mises stresses induced in the component during working condition. Flywheels resist changes in their rotational speed, which helps steady the rotation of the shaft when a fluctuating torque is exerted on it by its power source. Flywheels have become the subject of extensive research as power storage devices for uses in vehicles. The spoke wheel was invented more recently, and allowed the construction of lighter and swifter vehicles. This paper deals with FE analysis of flywheel. FE analysis is carried out using ANSYS, by applying RPM force on total body of flywheel disk. The results of FE analysis are verified by analytical calculations of the von-mises stress and fatigue life. The stress analysis of the mild steel flywheel is carried out under different cases on (1) Simple flywheel disk (2) Four circular cut flywheel disk (3) Six slot cut flywheel disk to find out which one is optimum among them.

Design of Flywheel

A flywheel is a rotating wheel or disc with a fixed axle so that rotation is only about one axis. Energy is stored in the rotor as kinetic energy:-

$$E_k = \frac{1}{2} I \omega^2$$

Where:

- ω is the angular velocity, and
- I is the moment of inertia of the mass about the center of rotation. The moment of inertia is the measure of resistance to torque applied on a rotating object,
- The moment of inertia for a solid cylinder is

$$I = \frac{1}{2} m r^2$$

- for a thin walled empty cylinder is $I = mr^2$,
- and for a thick walled empty cylinder is $I = \frac{1}{2} m \left(r_{\text{external}}^2 + r_{\text{internal}}^2 \right)$,where,
- m =mass
- r=redius
- When calculating with SI units mass, kilograms, for radius, meters; and for angular velocity, radians per second. The resulting answer would be in joules.
- $\sigma_t = \rho r^2 \omega^2$

Where:

- $\sigma_t$is the tensile stress
- $\rho$is the density
- r is the radius
- $\omega$is the angular velocity

This formula can also be simplified using specific tensile strength and tangent velocity:

- $\frac{\sigma_t}{\rho} = v^2$

Where:

- $\frac{\sigma_t}{\rho}$ is the specific tensile strength of the material
- $v$is the tangent velocity of the disk

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There are two principles in the rotating disks. The tangential stress and radial stress.

Fig 2.1. Simple flywheel

Mechanical properties of Mild Steel Flywheel

A light weight motor vehicle flywheel used mild steel material. The materials and their properties are given in the Table:

An initial mesh as shown in Figure reveals that the model is very large and requires too many elements if direct auto meshing is applied. To avoid this over discrimination, local meshing needed to be applied depending on the area of interest.

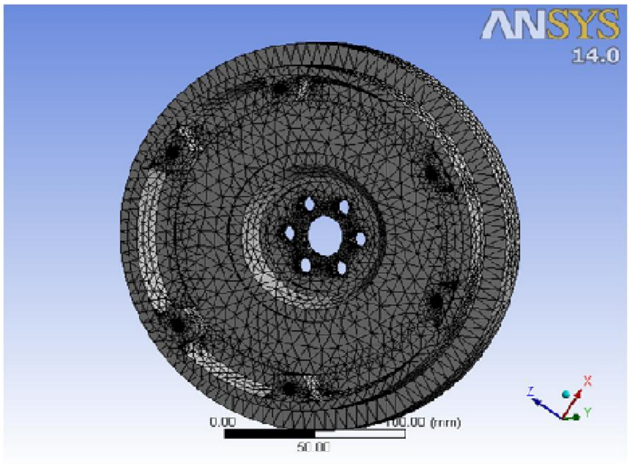


Fig. 4.2. Meshing in global flywheel model

Table 3.1 Mild steel materials and their properties

Type of steel	designation	UTS (MPa)	Yield strength (Mpa) Thickness (mm)			Elongation Gauge 5.65 So	Charpy V – notch values journales (min)
			<20	20--40		>40	
Mild steel	Fe410 C	410	250	240	230	23	27

Table 3.2. Static Analysis for Mild Steel

property	value	unit
denity	7870	kg
Tensile yield strenth	2.50E+08	pa
Compressive yield strength	2.50E+88	Pa
Tensile ultimate strength	0.00E+00	pa
Compressive ultimate strength	0.00E+00	pa

Static structural and Impact analysis of Flywheel

Static analysis is used to determine the displacements, stresses, strains, and forces in structures or components caused by loads that do not induce significant inertia and damping effects. Steady loading and response conditions are assumed; that is, the loads and the structure's response are assumed to vary slowly with respect to time

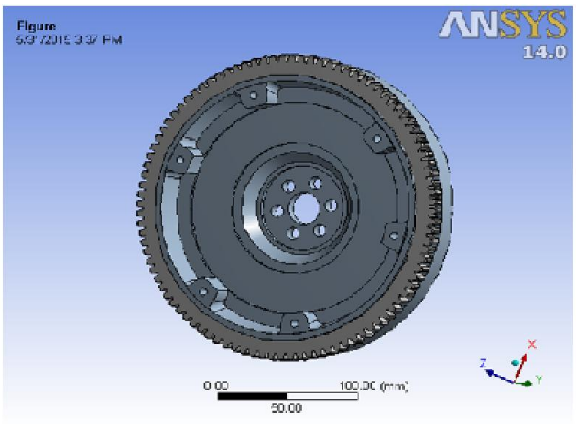


Fig. 4.1. Solid model of flywheel

Static Structural Loading Condition

This test is performed to analysis the effect of static force acting on the flywheel. The static force being applied on the flywheel is to simulate an incident of an attempt to break the flywheel by pushing the shaft with rotational force on y-axis. The cylindrical support 2mm

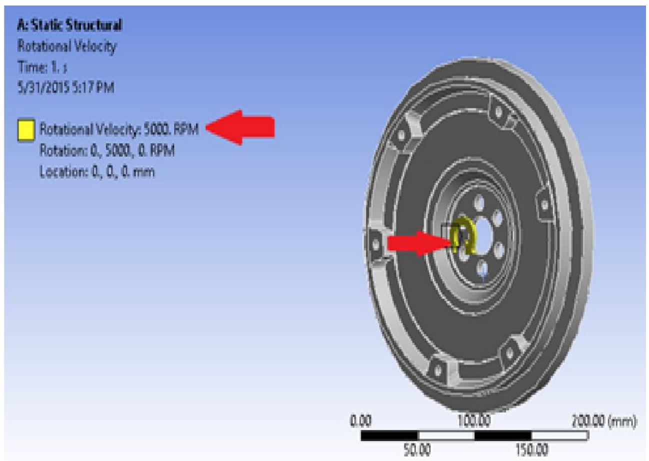


Fig. 4.3. Static loading conditions

RESULTS AND DISCUSSION

Stress analysis

Stresses and factor of safety were calculated in the static structural test for the flywheel.

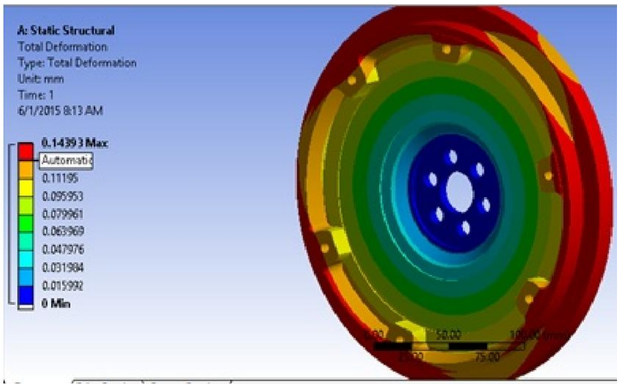


Fig. 5.1 Static structural results on flywheel total deformation

The static structural results on flywheel as show in Figure areas, the maximum total deformation is 0.14393 max. and minimum total deformation is 0. The deformation is shown in Figure 5.1 as red colour on outer side of the flywheel.

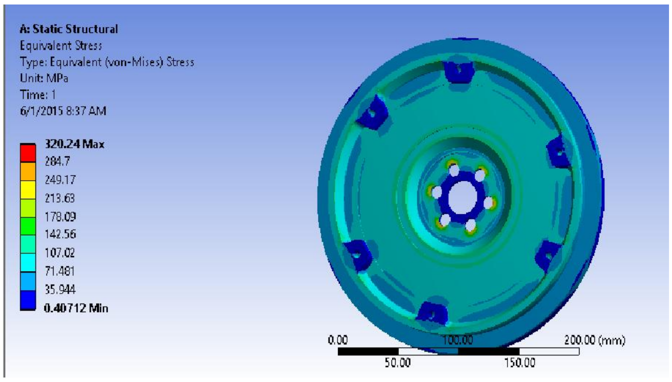


Fig. 5.2. Area of maximum stress on flywheel

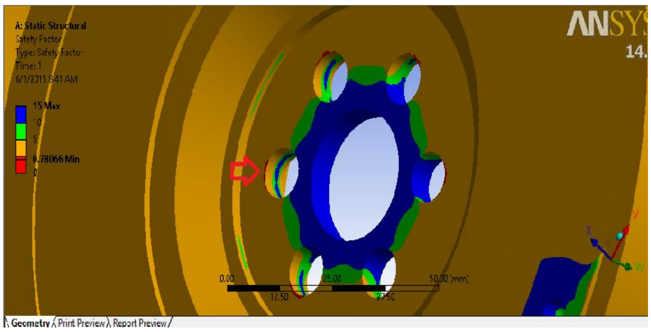


Fig. 5.3. Minimum factor of safety for static analysis

The values were found out to be:
Max. Stress: 320.24MPa
Min. Factor of Safety: 0.78066
The material used in flywheel is Mild Steel (EN-1A to BS:970). The yield strength of this material is 6.5e+008 Pa. Factor of safety can be calculated with the help of the equation given below:

$$\text{FOS} = \frac{\textit{Yield stress of the material}}{\textit{Maximum allowable stress}}$$

Since we know that the flywheel passes the static structural test during experimental testing, these values are in accordance with the experimental results obtained in the traditional testing methods.

Fatigue Analysis

While many parts may work well initially, they often fail in service due to fatigue failure caused by repeated cyclic loading. Characterizing the capability of a material to survive the many cycles a component may experience during its lifetime is the aim of fatigue analysis. In a general sense, Fatigue Analysis has three main methods, Strain Life, Stress Life, and Fracture Mechanics; the first two being available within the ANSYS Fatigue Module.

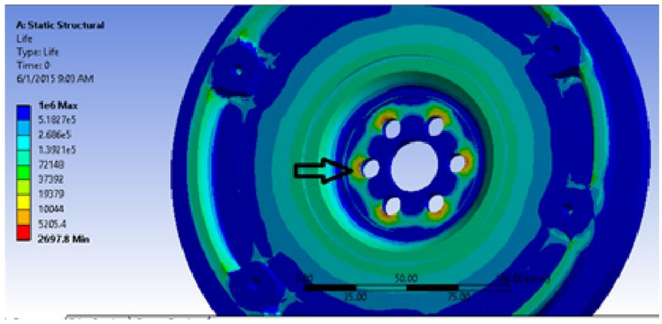


Fig. 5.3. Area of minimum stress fatigue life

Fatigue Safety Factor

Fatigue Safety Factor is a contour plot of the factor of safety with respect to a fatigue failure at a given design life. The maximum Factor of Safety displayed is 15. Like damage and life, this result may be scoped. For Fatigue Safety Factor, values less than one indicate failure before the design life is reached.

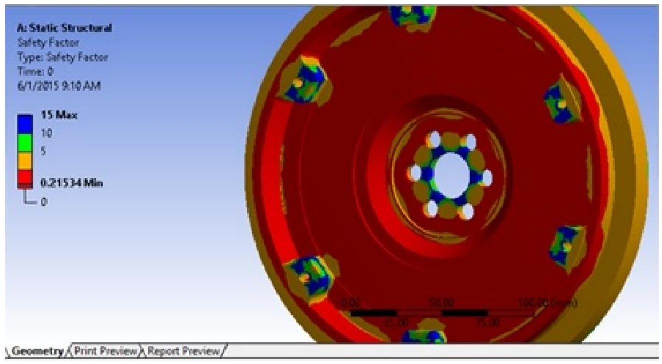


Fig. 5.4. Area of minimum stress fatigue safety factor

Impact Analysis

Simple flywheel disk

Impact analysis results were found for the flywheel casing model. A comparison of the results of both the cases is given below:

: Max. Stress: 320.24MPa
Min. Factor of Safety: 0.78066

The material used in flywheel is Mild Steel (EN-1A to BS:970). The yield strength of this material is 6.5e+008 Pa

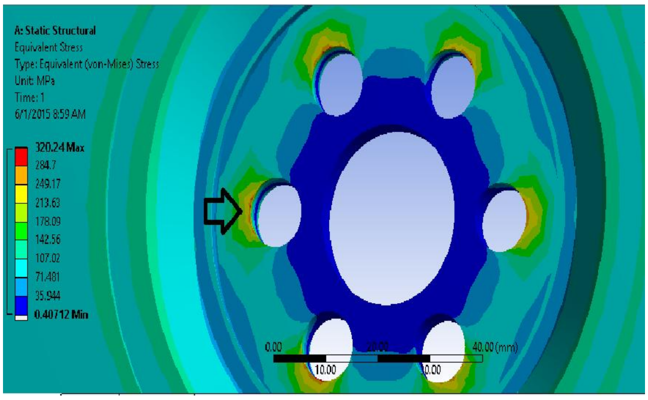


Fig. 5.5. Stress distribution in flywheel casing due to impact loading

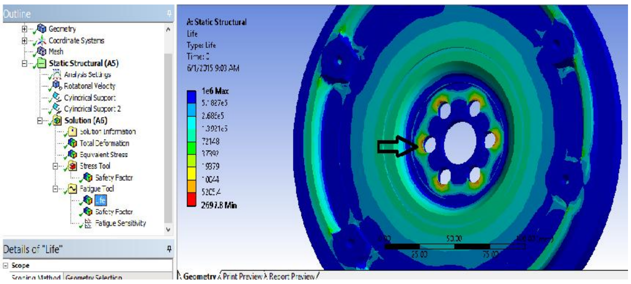


Fig. 5.6. Area of minimum stress fatigue life

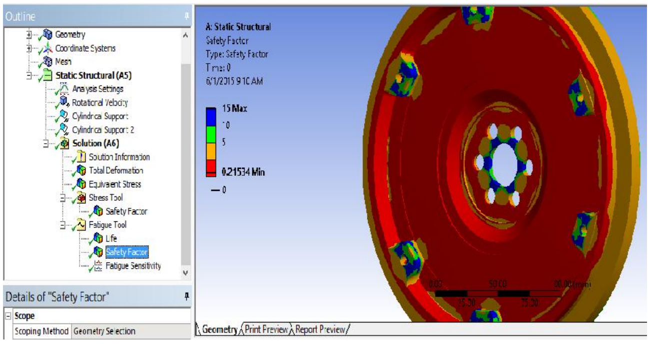


Fig. 5.7. Area of minimum stress fatigue safety factor

RESULT

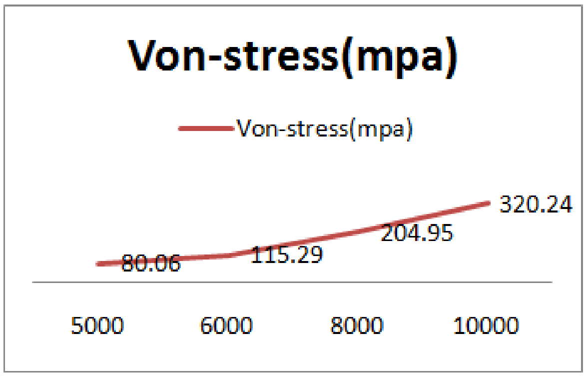
Density:-7.87gm/cc

Mass:- 4.3608 kg/

Volume:-5.5552e+005 mm³

Table 5.1 Result simple flywheel

Case	Rpm	Von-stress(mpa)	Fatigue Life(min)	Safety Factor
1	5000	80.06	4.2343e5	3.152
2	6000	115.29	85309	2.130
3	8000	204.95	10789	1.219
4	10000	320.24	2697.8	0.7806



RPM

Figure 5.8. Fatigue Stress Vs. RPM

Four Circuler cut flywheel disk

Impact analysis results were found for the flywheel casing model. A comparison of the results of both the cases is given below:

Max. Stress: 331.24MPa
Min. Factor of Safety: 0.7536

The material used in flywheel is Mild Steel (EN-1A to BS:970). The yield strength of this material is 6.5e+008 Pa

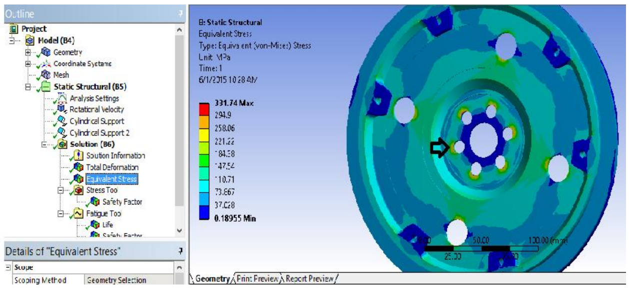


Fig.5.9 Maximum Von- stress on four circular cut flywheel disk after 10000 RPM

RESULT

Density:-7.87gm/cc

Mass:- 4.272 kg

Volume:-5.5552e+005 mm³

Table 5.2 Result of four hole flywheel Disk

Case	Rpm	Von-stress(mpa)	Fatigue Life(min)	Safety Factor
1	5000	82.935	3.4561e5	3.0144
2	6000	119.43	74954	2.0933
3	8000	212.31	9610.3	1.1775
4	10000	331.74	2419.1	0.7536

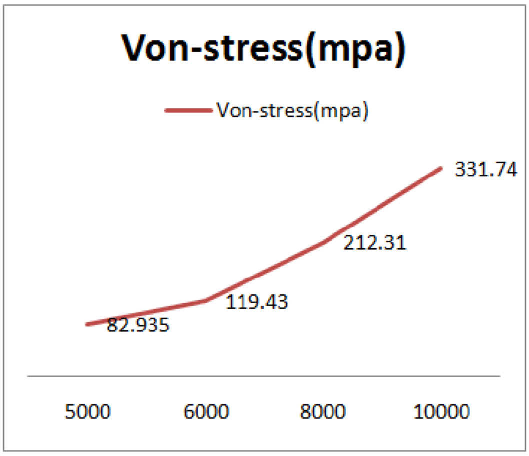


Fig. 5.10 Fatigue Stress Vs. RPM

Six Slot Cut Flywheel Disk

Impact analysis results were found for the flywheel casing model. A comparison of the results of both the cases is given below:-

Max. Stress: 297.12 MPa
Min. Factor of Safety: 0.84141

The material used in flywheel is Mild Steel (EN-1A to BS:970). The yield strength of this material is 6.5e+008 Pa

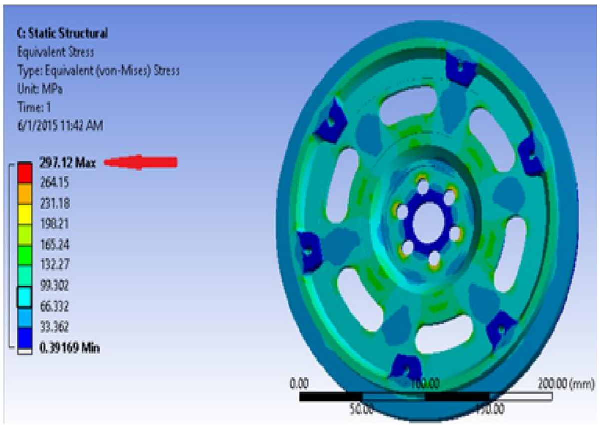


Fig 5.11. Maximum Von- stress on six cut slot flywheel disk after 10000RPM

Table 5.3. Result of six slot flywheel Disk

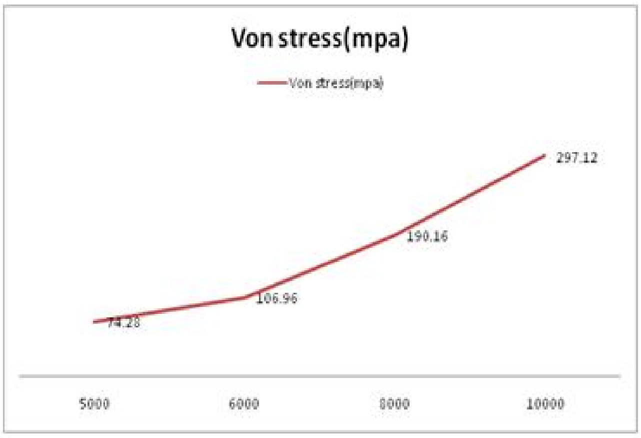
Case	Rpm	Von stress(mpa) (max)	Fatigue Life(min)	Safety Factor (min)
1	5000	74.28	1e6	3.3656
2	6000	106.96	2.8863e5	2.3372
3	8000	190.16	30848	1.3147
4	10000	297.12	6778.5	0.84141

RESULT

Density:-7.87gm/cc

Mass:- 4.272 kg

Volume:-5.5552e+005 mm³



RPM
Fig.5.10. Fatigue Stress Vs. RPM

Conclusion

Results shows that efficient flywheel design maximizes the inertia of moment for minimum material used and guarantee high reliability and long life. Smart design of flywheel geometry has significant effect on its specific energy performance. Amount 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 flywheel disk. Out of these three impact analysis cases taken on Flywheel, six slot cut flywheel disk is the best, having better life and safety factors rather than simply flywheel disk and four hole flywheel disk. The fatigue life in six slot cut flywheel disk on 10000 RPM is 6778.5 and safety factor is 0.84741 which is better than the other two cases.

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