FEA Analysis of Weight Reduction of Flywheel

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Abstract— Flywheel is a device to smoothen the cyclic fluctuation of speed change when delivering constant output power from the engine. The main objective of the project is to reduce weight of automobile. If Engine flywheel has more weight than its need, then it will decrease fuel efficiency. If engine flywheel has less weight than its need, it will consequently enhance speed fluctuation, vibration and noise. Researcher has taken up one case study of Tata truck (LPT2521BS IV) for weight reduction without changing energy storage capacity. The author has reduced the weight by changing the geometry. The geometry has been changed in such a way that radius of gyration is changed, weight is reduced but mass moment of inertia remains unchanged. Different Researcher also used different hole pattern at different radius to take advantage of reducing weight. Modified flywheel has been manufactured by machining process on actual flywheel. It will be help in Verified "ANSYS" analysis result. So, the paper focuses on 1. Different Geometrical modeling with actual and modified flywheel 2. "ANSYS" analysis.

Key words: Automobile, Flywheel, Weight Reduction, Design, FEA Analysis

I. Introduction

In automobile, Flywheel has been used for three purposes: 1. as an engine part 2. In Break energy recovery system 3. In energy storage system instead of batteries. Here Paper will be focused on engine flywheel related work.

Function of engine flywheel is following: 1.Flywheel is like as a reservoir to store energy when supply is more than requirement and release the energy when requirement is more than supply. 2. Flywheel provides the effective way to smooth out the function of speed. 3. To remove vibration and noise in running condition. 4. Engine is started by mechanical energy of flywheel.

Performance of flywheel mainly can be attributed to three factors i.e. Material strength, geometry & rotational speed. Amount of stored energy is determined by size, weight & maximum allowed rotational speed of the flywheel within its centrifugal strength limit. Smart design of flywheel geometry could have both. It has a significant effect on the specific energy performance & reduce operational load exerted on shaft/ bearing due to reduced mass at high rotational speed.

II. Different Method to Reduce Weight Based on Literature

- By changing shape/Geometry in solid disc type actual flywheel [6].
- By changing type of flywheel means to select rim type flywheel instead of disc type flywheel [8].
- By use of 'Flower Pollination Algorithm'
- By use of composite material [2].
- By concept of Active Flywheel [1].
- By concept of Dual Mass Flywheel [5], [7].
- By concept of Compact flywheel system [3], [4].

III. Actual Flywheel Details

A. *Model of vehicle: tata truck LPT2521 BS I*

- Weight of flywheel= 27.3 kg
- Flywheel dimension =430 mm * 30 mm
- Power: 750 N.m at 1100-1800 rpm and 210 HP at 2300 rpm
- Actual flywheel is Disk type at 1500RPM ,
- Mass moment of inertia I = $\frac{1}{2} m r^2$

  [Here, $I = mK^2$ & $K = \frac{r_{\max}}{\sqrt{2}}$]

  = $0.5 * 27.3 * 0.215^2$
  = 0.66 kg.m^2
- Angular Velocity $\omega = \frac{2\pi N}{60}$

  = 2 *3.14 * 1500/60
  = 157 radian/sec

Fig. 1: Actual flywheel photo of Tata truck LPT2521 BS IV

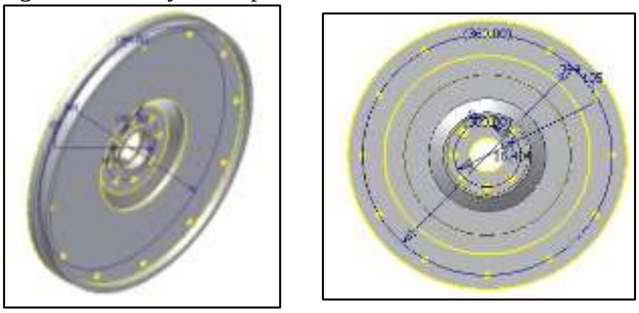

Fig. 2: Actual flywheel model in inventor

- Kinetic energy in flywheel $= \frac{1}{2} I \omega^2$
  $= ½ * 0.66 * 157^2$
  $= 8134.2$ Joule
- Surface speed = 33.776 m/sec
- Centrifugal force = $m \omega^2 r$
  $= 27.3 * 157^2 * 2$
  $= 1345835$ N

IV. MODIFIED FLYWHEEL DETAILS

Geometrical shapes have generated in "INVENTOR" software.19-20 geometrical models have generated by used of different curve on one side of geometry which is opposite side of clutch plate and pressure plate assembly. "ANSYS" software gives mass of model and mass moment inertia at each axis like X-axis, Y-axis & Z-axis. Each model also analyzed about stress like principle stress, Maximum shear stress and Equivalent stress (Von-misses stress). Author has analyzed all models' data and choose model for modified flywheel.

Fig. 3: Modified flywheel photoes

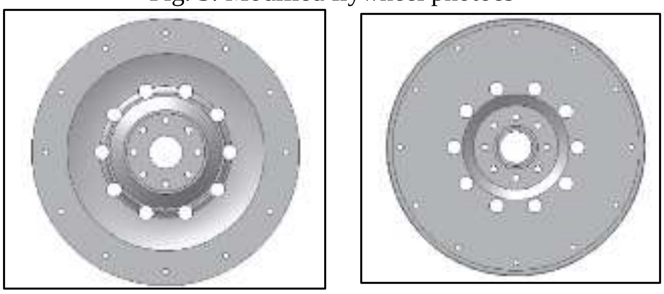

Fig. 4: Designed flywheel photo of Inventor software

Here, one geometry has been selected to modification which has 10 hole of 20Ø at 210 Ø circumferance and 10 mm deep curve.

A. ANSYS analysis of designed flywheel

1) Material selection:

Material, class, specification	Gray cast iron, ASTM 30, SAE 111
Ultimate strength	Tension$_{ut}$ =214 Mpa Shear$_{ut}$ =303 Mpa
Torsional shear strength	276 Mpa
Modulus of Elasticity	Tension E=101 Gpa Shear G= 41 Gpa
Density	7510kg/m^3
Poisson's ratio	0.23

Table 1: Properties of Gray Cast Iron

2) Boundary condition & loading condition:

This flywheel is used for gear box no.75. It faces 750 N.m. And clutch plate & pressure plate forces are also applied on flywheel but it is negligible.

- On the surface of the shaft hole
  - Displacement in X =0,
  - Displacement in Y =0 ,
  - Displacement in Z =0,
  - Rotation about Y axis =0,
  - Rotation about Z axis =0,
  - Rotation about X axis will be permitted.

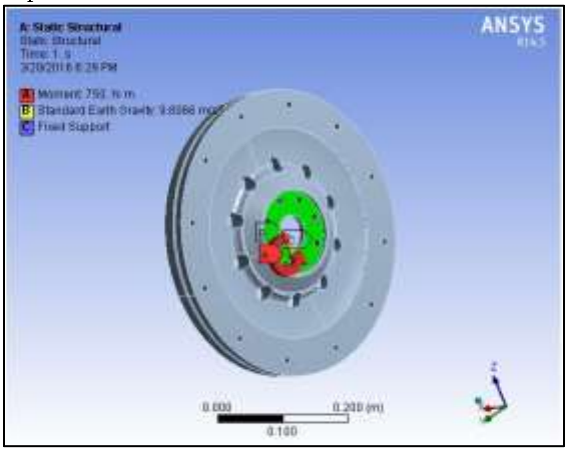

Fig. 5: Loading condition in model

3) Result:

1) Mass of proposed flywheel= 24.324 kg
2) Volume = 3.37* 10-3 m3
3) Mass moment of inertia= 0.66228 kg.m2
4) Radius of Gyration = 0.23345 m
5) Max shear stress = 244 Mpa as shown in Fig.6.

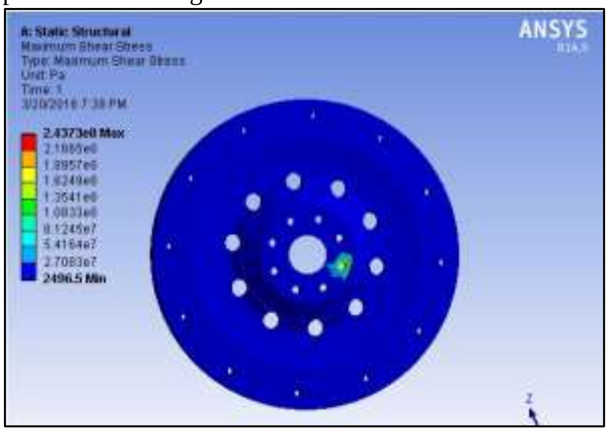

Fig. 6: Max. shear stress plot in ANSYS

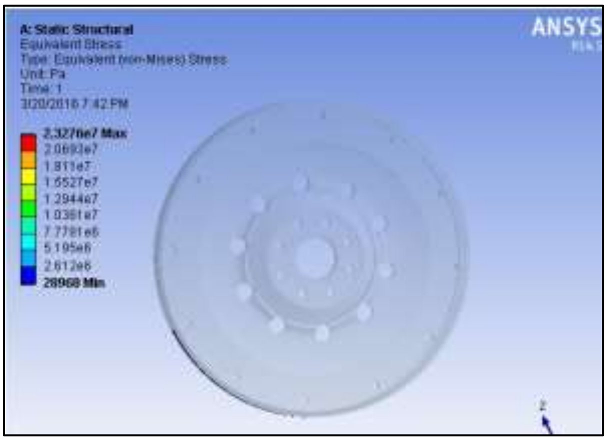

Fig. 7: Equivelant stress(Von-misses stress)

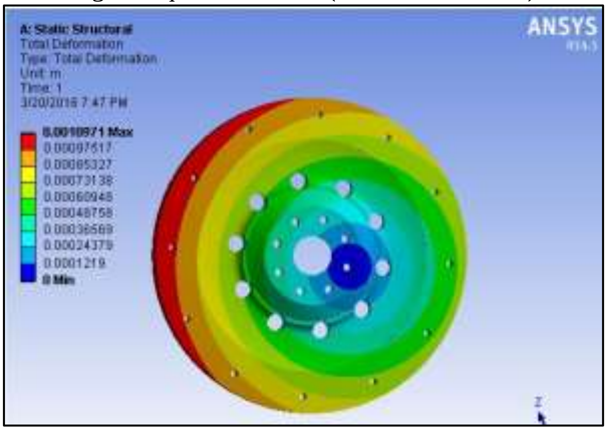

Fig. 8: Total deformation

6) Equivalent von-misses stress= 23 Mpa as shown in Fig. 7.
7) Total max. Deformation= 0.0011 m as shown in Fig. 8.

B. Comparison of Actual & Modified flywheel

1) This time is calculated by using the stop watch as soon as weight starts moving down.
2) Take different weights and corresponding time and complete the observation table.
   - For falling mass, Initial velocity = 0

     Height of fall= h=1.2 m
     Time of fall= t
     Acceleration a = 2h/t
     Tension (T) = m(g-a)
     Mass Moment Of Inertia= (T*r2)/a in kg.m^2

Sr. No.	Mass (m) [Kg]	Time (t) [sec]	A=2h/t [m/s^2]	Tension (T) T=m(g-a) [kg.m/s^2]	Mass M.I.= ($T*r^2$)/a [kg.m^2]
1.For Actual flywheel	2 kg	18.12 sec	0.132	19.335	0.677 kg.m^2
2.For Modfied flywheel	2 kg	17.74 sec	0.135	19.33	0.662 kg.m^2

Table 2: Observation Table for Moment Of Inertia

V. CONCLUSION

Here following will be derived from above research work.

1) Weight is reduced. Weight of designed flywheel is 24.324 kg and actual has 27.3 kg so weight is reduced 10% by Geometry change option.
2) Radius of gyration is increased. It is 227 mm for actual & 233.5 mm for designed flywheel.
3) Moment of Inertia is same for both.
   In Ansys analysis, Designed flywheel moment of inertia is 0.66228 kg.m^2. And for actual flywheel moment of inertia is 0.67 kg.m^2.
4) In Ansys analysis, Stress is within limit for designed flywheel. So new flywheel is safe in working.

So it is concluded that Weight is reduced 3 kg or 10% of total weight without effecting energy storage capacity.

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