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Investigation of Equivalent Alternating Stress and Damage in Arm Type Rotating Flywheel

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ABSTRACT

Flywheels have many causes of their failure. Among them, Equivalent Alternating Stress, Damage, maximum tensile and bending stresses induced in the rim and tensile stresses induced in the arm under the action of centrifugal forces. Due to these causes there is a definite Equivalent Alternating Stress and Damage of the flywheel. In this paper by using finite element method, evaluation of Equivalent Alternating Stress and Damage of flywheel are studied. For FE analysis the models of flywheel having four, six and eight no. arms are developed. For different cases of loading applied on the flywheel and the minimum Equivalent Alternating Stress and Damage are determined by using ANSYS. From this analysis it is found that as the No. of arms increases Equivalent Alternating Stress and Damage both decreases.

KEYWORDS :

1. Introduction

Fatigue analysis is the study of fatigue behaviour of the specimen which is under study. To improve the quality of product and to have reliable and safe design, it is necessary to investigate the Equivalent Alternating Stress of the flywheel during its working condition. Flywheel is a storage device which stores the energy. During rotation of flywheel, flywheel is subjected to centrifugal forces, due to which Equivalent Alternating Stress, Damage, maximum tensile and bending stresses are induced in a rim of flywheel.

In this paper Finite Element analysis of flywheel having 4,6 and 8 number of arms is carried out. Under different cases, fatigue analysis of the flywheel is carried out, such as (1) Keeping the angular velocity constant (2) By Increasing the angular velocity (3) By Combined loading of gravity and angular velocity (4) By Increasing angular velocity with considering the effect of gravity (5) By Providing the larger fillet size at both ends of the arm of flywheel. Using ANSYS, FE analysis is carried .

2. Geometrical Dimensions of Flywheel

It is intended to use the same geometric model of flywheel under identical loading condition for FE analysis and analytical estimation of stresses. The flywheel dimensions considered for this analysis are below:

Inner Diameter of flywheel rim () = 0.904m
Outer Diameter of flywheel rim = 1.1 m
Mean radius of flywheel rim (R) = 0.5 m
Mean Diameter of flywheel rim () = 1 m
Width of rim (B) = 0.147 m
Thickness of rim (H) = 0.098m
Diameter of shaft (d) =0.265 m
Radius of hub (r) =0.170
Diameter of hub () =0.340m
Hub length (L) = 0.147m
Minor axis of arm at hub end (b) = 0.051m
Major axis of arm at hub end (a) = 0.102m
Minor axis of arm at rim end (d) = 0.041m
Major axis of arm at rim end (c) = 0.082m

3. Flywheel Material properties

The properties of material considered for flywheel with the above geometrical dimensions of flywheel are given in table below

Table 4.1 Material Properties

Material	Gray cast iron
Ultimate strength	Sut=214MPa, Sus=303MPa
Modulus of elasticity & modulus of rigidity	E=101 GPa, G=41 GPa
Density	7510(Kg/m^3)
Poisson's Ratio	0.23

4. FE Analysis of Flywheel

The Finite Element models of 4, 6 and 8 no. of arms of flywheel are considered for FE analysis,. A SOLID 72 element and tetrahedral meshing is used for FE analysis. The Different cases taken for analysis of flywheel are given in coming parts.

Case 1: Analysis by taking the angular velocity constant

Fig.4.1 show the Equivalent alternating stress contour in the flywheel having 4, 6 and 8 No. of arms. Table 4.2 shows equivalent alternating stress and factor of safety in rim of flywheel with 4,6 and 8 No. of arms at angular velocity of 250 rad/sec. Variation of Damage and Equivalent Alternating Stress vs no. of arms of flywheel are shown Fig. 4.2 and 4.3 respectively.

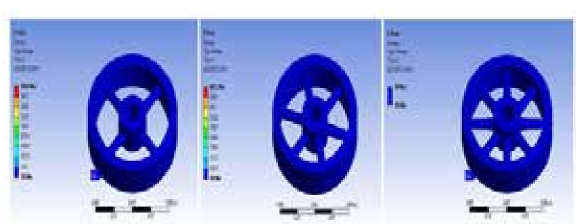

Figure4.1 Snapshot of Damage in 4, 6 and 8 arm flywheel without the effect of gravity.

Table 4.2 Equivalent alternating stress and factor of safety in the rim of flywheel with 4,6 and 8 no. of arms

No. of Arms	Angular Velocity	Equivalent alternating stress	Damage
4	250 rad/sec	4.1703× 10^8	18360
6	250rad/sec	3.8711× 10^8	4925
8	250rad/sec	3.2172× 10^8	100

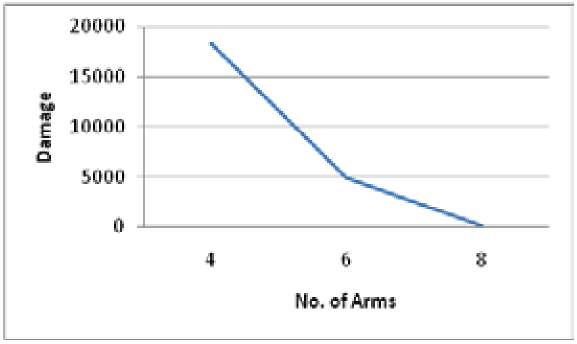

Figure4.2 Variation of Damage vs No. Of Arms

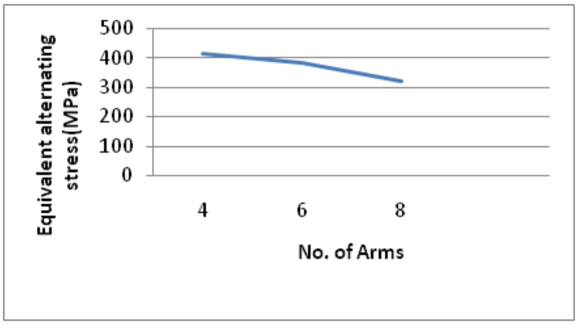

Figure4.3 Variation of Equivalent alternating stress vs No. Of Arms

Case 2: Analysis with increasing the flywheel angular velocity

Table 4.3 shows the Equivalent alternating stress and Damage by varying no. of arms and angular velocity of flywheel. The Fig. 4.4 and 4.5 shows variation of the Equivalent alternating stress and Damage vs increase in angular velocity of flywheel.

Table 4.3 The Equivalent alternating stress and Damage with increase in angular velocity

No. of Arms	Angular velocity	Equivalent alternating stress	Damage
4	250	4.1703× 10^8	18360
	255	4.3388× 10^8	34767
	260	4.5106× 10^8	62766
	265	4.6857× 10^8	1E+32
6	250	3.8711× 10^8	4925
	255	4.0275× 10^8	10131
	260	4.1870× 10^8	19611
	265	4.3496× 10^8	36126
8	250	3.2172× 10^8	100
	255	3.3472× 10^8	190
	260	3.4797× 10^8	512
	265	3.6149× 10^8	1229

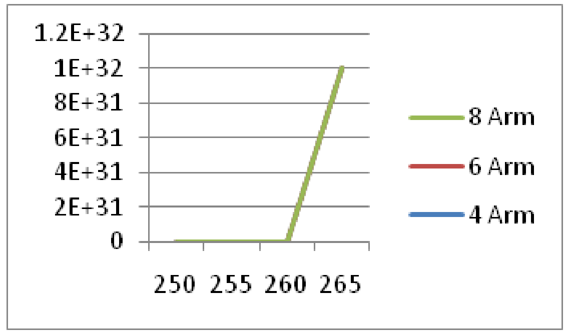

Figure4.4 Variation of Damage vs Angular Velocity

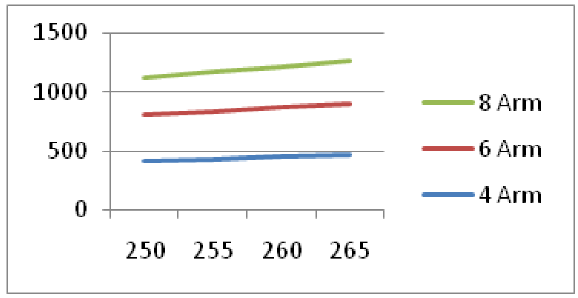

Figure4.5 Variation of Equivalent alternating stress vs Angular Velocity

Case 3: Analysis by combined loading of gravity and angular velocity

Figure4.6 shows Equivalent alternating stress contour of 4, 6 and 8 No. of arms. Table 4.4 shows Equivalent alternating stress and Damage in the rim of flywheel with 4, 6 and 8 No. of arms. Variation of Equivalent alternating stress and Damage for 4, 6 and 8 number of arms of flywheel are shown in Fig.4.7 and 4.8.

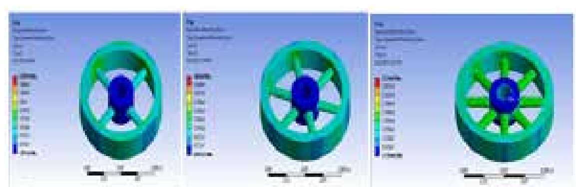

Figure4.6 Snapshot of Equivalent Alternating Stress with combined loading of angular velocity and gravity in 4, 6 & 8 arm type flywheel

Table 4.4 Equivalent alternating stress and Damage with combined loading of angular velocity and gravity

No. of arms	Angular velocity	Equivalent alternating stress	Damage
4	250rad/sec	4.1596× 10^8	17599
	Gravity z -9.81m/s^2		
6	250rad/sec	3.8659× 10^8	4801
	Gravity z -9.81m/s^2		
8	250rad/sec	3.2139× 10^8	100
	Gravity z-9.81m/s^2		

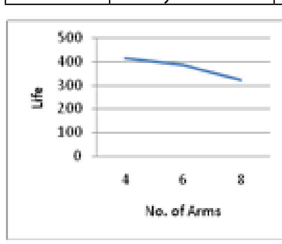

Figure4.7 Variation of Equivalent alternating stress vs No. of Arms with the effect of gravity

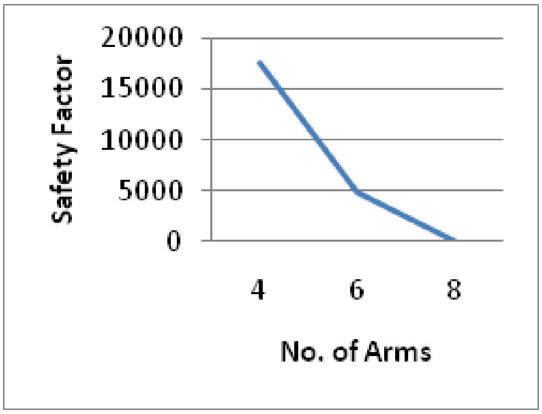

Figure4.8 Variation of Damage vs No. of Arms with the effect of gravity

Case 4: Analysis by increasing the angular velocity and considering the effect of gravity

Table 4.5 shows the Equivalent alternating stress and Damage by increasing the angular velocity with the effect of gravity for varying the number of arms. Fig.9 and10 shows variation in the equivalent alternating stress and Damage vs angular velocity with effect of gravity respectively.

Table 4.5 Equivalent alternating stress and Damage with the increase in the angular velocity with effect of gravity

No. of arms	Angular velocity	Equivalent Alternating Stress (Pa)	Damage
4	250rad/sec Gravity_z -9.81m/s^2	4.1596 × 10^8	17599
	255 rad/sec Gravity_z-9.81m/s^2	4.3281 × 10^8	33464
	260 rad/sec Gravity_z- 9.81m/s^2	4.4999 × 10^8	60581
	265 rad/sec Gravity_z -9.81m/s^2	4.6750 × 10^8	1E+32
6	250rad/sec Gravity_z -9.81m/s^2	3.8659 × 10^8	4801
	255 rad/sec Gravity _z-9.81m/s^2	4.0223 × 10^8	9903
	260 rad/sec Gravity_z-9.81m/s^2	4.1818 × 10^8	19214
	265 rad/sec Gravity_z-9.81m/s^2	4.3444 × 10^8	35468
8	250rad/sec Gravity_z-9.81m/s^2	3.2139 × 10^8	100
	255 rad/sec Gravity_z -9.81m/s^2	3.3439 × 10^8	185
	260 rad/sec Gravity_z-9.81m/s^2	3.4765 × 10^8	501
	265 rad/sec Gravity_z -9.81m/s^2	3.6116 × 10^8	1205

Case5: Analysis by providing fillet size(0.02m) at both the ends of arm

Table 4.6 shows Equivalent alternating stress and Damage by providing a fillet for 4,6 and 8 number of arms at constant angular velocity.

Table 4.6 Equivalent alternating stress and Damage by providing fillet size(0.02m) for 4,6 and 8 number of arms

No. of arms	Angular Velocity	Equivalent Alternating Stress (Pa)	Damage
4	250rad/sec	3.6995 × 10^8	2009
6	250rad/sec	3.3493 × 10^8	193
8	250rad/sec	3.1492 × 10^8	100

Case6: Analysis by providing larger fillet size(0.025m) at both ends of arm

Table 4.7 shows Equivalent alternating stress and Damage by providing a larger fillet for 4,6 and 8 number of arms at constant angular velocity.

Table 4.7 Equivalent alternating stress and Damage by providing fillet size(0.025m) size for 4,6 and 8 number of arms

No. of arms	Angular Velocity	Equivalent Alternating Stress (Pa)	Damage
4	250rad/sec	3.6805 × 10^8	1808
6	250rad/sec	3.0625 × 10^8	100
8	250rad/sec	2.582 × 10^8	100

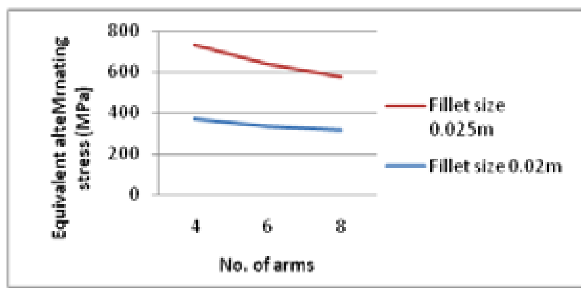

Figure4.9 Variation of Equivalent alternating stress vs No. of arms for different Fillet size

6. Discussion & Conclusion

It can also seen that as a number of arms increases from 4 to 8, the Equivalent Alternating Stress and Damage in the flywheel goes on decreasing. This is due to the reason that load of flywheel got shared by larger no. of arms. Table 4.3 it is also seen that, with increase in angular velocity the Equivalent Alternating Stress and Damage are decreasing. This is due to more centrifugal forces acting on rim of flywheel. When the gravity effect along with angular velocity are considered, It is observed from the table 4.3 and 4.5 that the Equivalent Alternating Stress and Damage are less than that of neglecting gravity effect. Thus the gravity effect contributes to fall in the Equivalent Alternating Stress and Damage in flywheel.

Table 4.6 and 4.7 shows the Equivalent Alternating Stress and Damge are calculated by varying the fillet size at arm and rim junction. It revealed that as fillet size goes on increasing the Equivalent Alternating Stress and Damage are decreasing considerably. Thus the suitable fillet size is recommended for lesser Equivalent Alternating Stress and Damage.

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