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Design and Fem Analysis of Car Alloy Wheel

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ABSTRACT
The requirements for improved stiffness, reliability, fatigue life and increased efficiency involves challenges of developing innovative design solutions. The present work mainly focus on the design of car alloy wheel, where the analytical and FEM analysis approach was implemented to analyze baseline design. Initially static analysis was performed to obtain total deformation, strain and the stress of car alloy wheel. Three Dimensional model was created using CATIA and FE software ANSYS was used for discretization and analysis to obtain expected solution. The results were obtained through linear static analysis in terms of Total deformation while Minimum principal stress, Max Principal stress were found to be nearly equal for both 6 arms wheel and 4 arms wheel and 22.16 % of reduction in weight was observed and hence overall weight of the car alloy wheel was optimized.
Keywords: Alloy wheel, Principal stress, Deformation & Fatigue Loading,

I. INTRODUCTION

Wheels have been made using various casting techniques such as sand casting, gravity die casting, centrifugal , squeeze and low pressure die casting. Sand and gravity castings are less controllable operations and have problem with blow holes and shrinkages.

Aluminum wheels should not fail during service as their strength and fatigue life are critical. In order to reduce costs, design for light-weight and limited-life is increasing being used for all vehicle component. In the actual product development automotive wheels have complicated geometry and must satisfy manifold design criteria, such as style, weight, manufacturability, and performance. In addition to a fascinating wheel style, wheel design also needs to accomplish a lot of engineering objectives including some required performance and durability requirements. The present research work is carried out in the automobile sector, specifically on the car alloy wheel rim design. To improve the quality of the wheel by evaluating the fatigue life, structural integrity, over speed & burst speed margin. Mainly to reduce cost and weight reduction & ease of replacing. Design modifications of the existing alloy wheel rim which is converting elliptical cross section in to an rectangular cross section for a good overall outlook and style. The pressure distribution about the rim surface is to be maintained at 32psi and load consideration on the rim when this pressure decreases below 32psi the load or stress will be more on the bolt and bolt holes. Over speed & burst speed margin is the limit where in the rim should withstand the stress & strain on the rim which is under operational condition and tough road condition. The tendency is a material to break under repeated cyclic loading at a stress considered less than the tensile strength in a static test. Fatigue cracks can terminate the usefulness of a structure or component by more ways than just fracture.

II. OBJECTIVES

2.1 Estimation of linear stress, strain and deformation of a car alloy wheel by linear static structural analysis
2.2 Material Optimization of alloy wheel of a car to increase the life and efficiency.
2.3 Evaluating the fatigue life over speed & burst speed margin.

III. ANALYTICAL APPROACH

3.1 Angular velocity
3.2 Bolt pretension
3.3 Area weighted mean hoop stress (AWMHP)
3.4 Burst speed margin
3.5 Over speed margin
3.6 Fatigue life
3.7 Weight comparison between 6 arms wheel and arms wheel
3.8 FE Analysis of 4 and 6 arms wheel

3.1. Angular Velocity

Conversion of 120 km/h velocity into angular velocity
1 km/h = 0.277m/sec
For 120 km/h = 33.33 m/sec

$$V = \omega r$$

Where
V=Linear velocity =33.33 m/sec
W= Angular velocity=? (To be calculated)
r= Radius of the rim =0.126 M
Therefore W= 264.52 radians/sec
or 2526 RPM

3.2 Bolt Pretension

$F_i = C\,A_S\,S_P$

Where

C = 0.75 constant for connection required joints.

A_S = Tensile shear area of the bolt.

$= [(d_1+d_2)/2]^2$

d_1 = minor diameter

d_2= major diameter

= [(16.755+14.761) / 2)] 2

A_S =248.31 mm²

S_P = Proof stress (85% of yield)

= (0.85* tensile yield strength (229))

Therefore Fi = (0.75 * (248.31)*(0.85*229))

F_i = 36250.156 N

3.3. Area Weighted Mean Hoop Stress

AWMHS =F/TL

Where; F= Force, T= Thickness, L = Length

Hoop Stress = [(383744) / (20*160)]

Hoop Stress = 119.92 N/mm^2

3.4 Burst Speed Margin

$$\sqrt{\frac{uts}{Hoop\ stress}} \geq 1.25$$

$\sqrt{279/119.92} \geq 1.25$

Therefore 1.525 ≥ 1.25

3.5 Over Speed Margin

0.2% of proof stress/AWMHS ≥ 1.7

Where

0.2% of proof stress of aluminium 356 is 210 Mpa.

210 / 119.92

1.751 ≥ 1.7

3.6 Fatigue Life

Number of cycles:

$$N_f = \left\{\frac{[\sigma_{ult} - \sigma_{ult}(\frac{1}{fos} - \frac{\sigma_a}{\sigma_e})]}{\sigma_a}\right\}^{\frac{1}{0.08}}$$

Where, N_f =Fatigue life

σ_{ult}=Ultimate stress

fos=Factor of Safety

σ_e=Endurance limit

b = Fatigue strength exponent

σ_a=Alternating stress

$$N_f = \left\{\frac{580 - 580(\frac{1}{1.4} - \frac{140.96}{102})]}{102}\right\}^{\frac{1}{0.000008}}$$

$$N_f = 1.16 \times 10^6$$

3.7 Weight comparison between 6 arms wheel and 4 arms wheel

3.7.1 Modeling of 6 Arms wheel

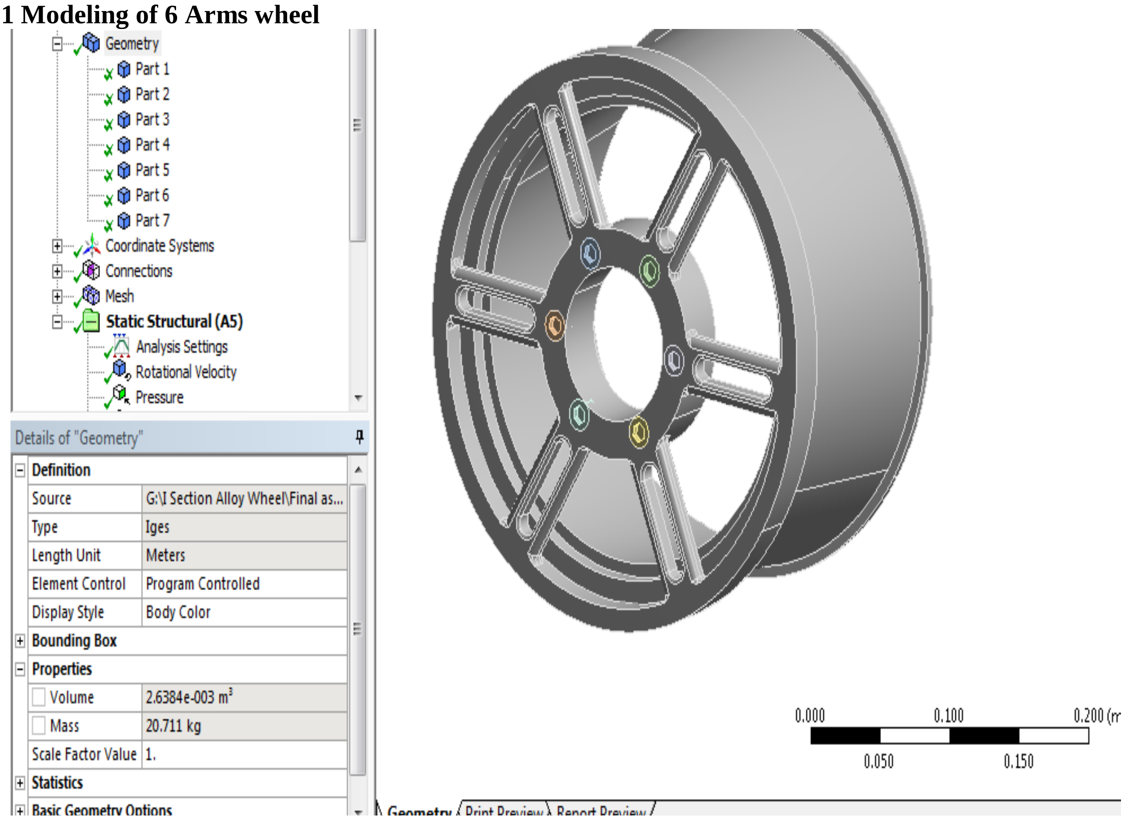


Fig.1: Model of 6 arms wheel

3.7.2 Modeling of 4 Arms wheel

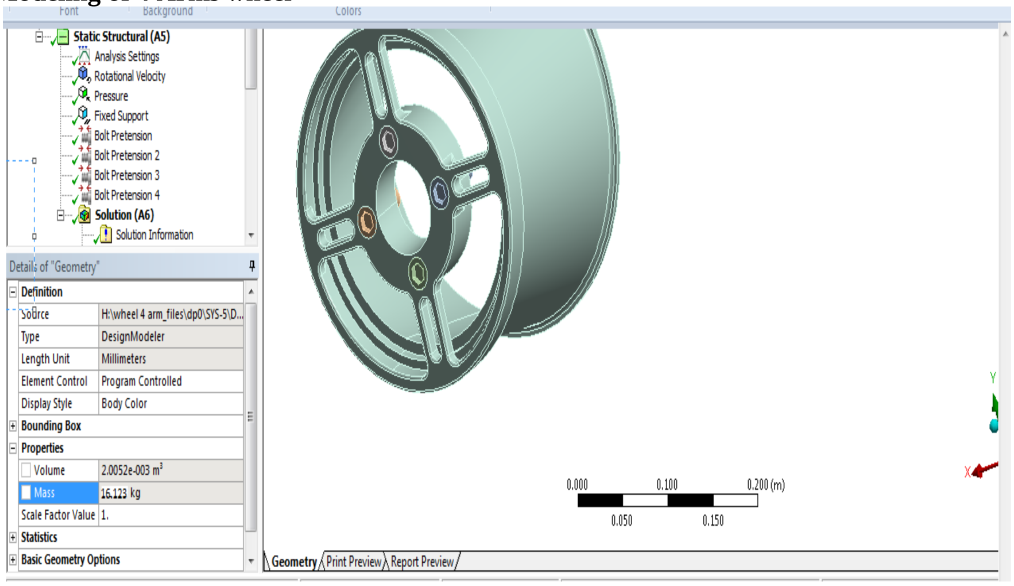


Fig. 2: Model of 4 arms wheel

The weight of 4 arms and 6 arms wheel it was observed that the weight of 6arms is 20.711 kg and in case of 4 arms it was reduced for 16.123 kg.

Table 1

Material properties of aluminium 356 alloy

Base metal price	16% rel
Density	2.69g/cm3
Elastic modulus (youngs , tensile)	72 gpa
Electrical conductivity	40 %IACS
Elongation at break	4%
Fatigue strength	60mpa
Melting onset	557 *C
Shear modulus	27 gpa
Shear strength	190 mpa
Specific heat capacity	970 j/kg-k
Strength to weight ratio	97 kn-m/kg
Tensile strength ;ultimate	260 mpa
Tensile strength ; yield	160 mpa
Thermal conductivity	150 w/m-k
Thermal diffusivity	57
Thermal expansion	21.5um/m-k

Table 2

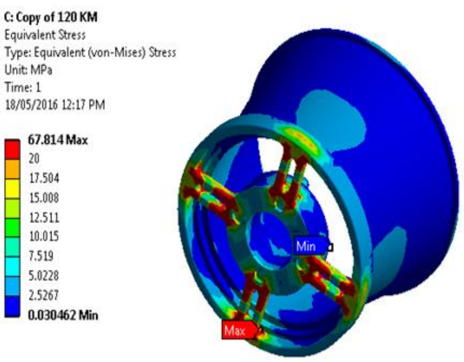
Aluminium 356 alloy composition

Aluminium (al)	90.1 to 93.3 %
Silicon (si)	6.5 to 7.5 %
Iron (fe)	0 to 0.6 %
Magnesium (mg)	0.2 to 0.45 %
Manganese (mn)	0 to 0.35 %
Zinc (zn)	0 to 0.35 %
Copper (cu)	0 to 0.25 %
Titanium (ti)	0 to 0.25 %
Residuals	0 to 0.15 %

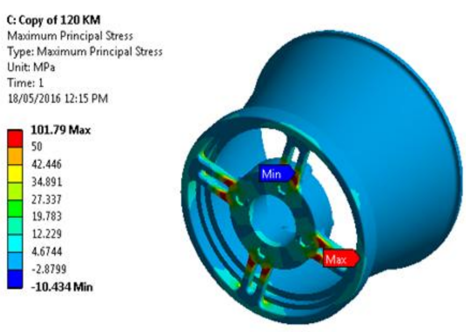
IV. LINEAR STATIC STRUCTURAL FEM ANALYSIS FOR 4 ARMS 6 ARMS WHEEL

4 Arms Wheel

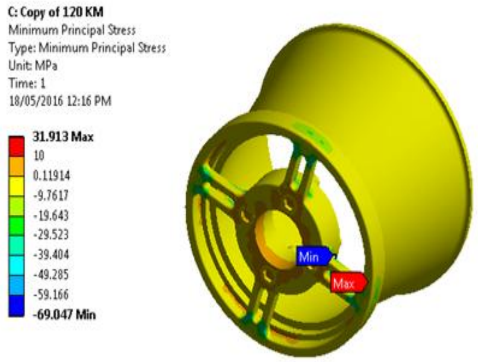
Equivalent Stress



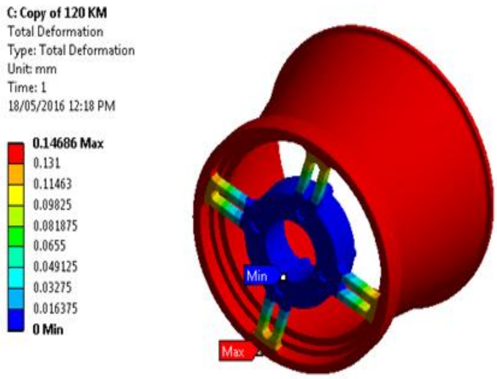
Maximum Principal Stress



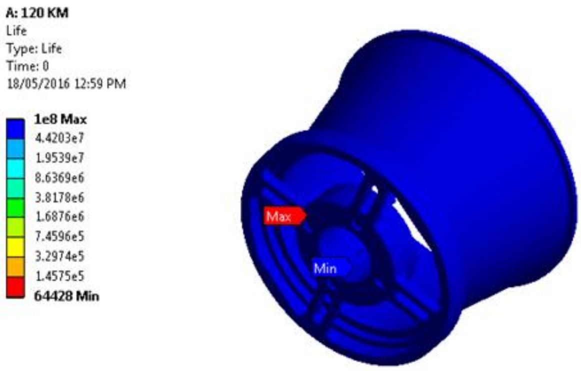
Minimum Principal Stress



Total Deformation



Fatigue Life



Life evaluation is validated using Goodman criteria and FEM approach found that the wheel can sustain 1×10^6cycles.

Figure 3: Deformation and different stresses in 4 arms wheel

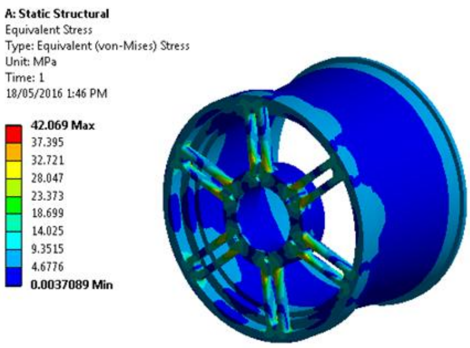
The model of 4 arms wheel as shown in above fig, was done in unigraphics and later loaded in to ansys 14 for linear static structural analysis was carried out. The meshing is done for the 4 arms wheel that is shown in above fig The boundary conditions were applied on the rim surface of the aluminium wheel ,presser-0.25 mpa ,rotational velocity – 222.2 rds or 2122 RPM ,bolt pretension-23340 N. after applying the boundary conditions we get following linear static structural analysis for 6 arms wheel results

1. von-mises stress= 67.814 mpa
2. maximum principal stress= 101.79 mpa
3. minumum principal stress=31.913 mpa
4. Total Deformation = 0.146868 mm

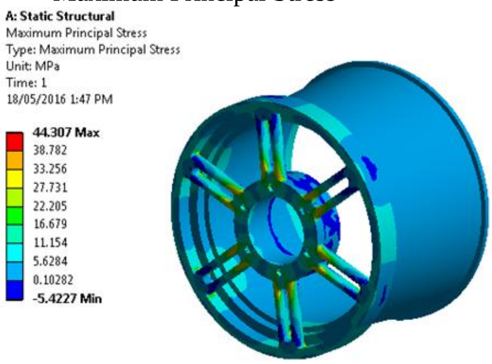
The above values are below the yield stress and safer side.

6 Arms Wheel

Equivalent Stress



Maximum Principal Stress



Minimum Principal Stress Total Deformation

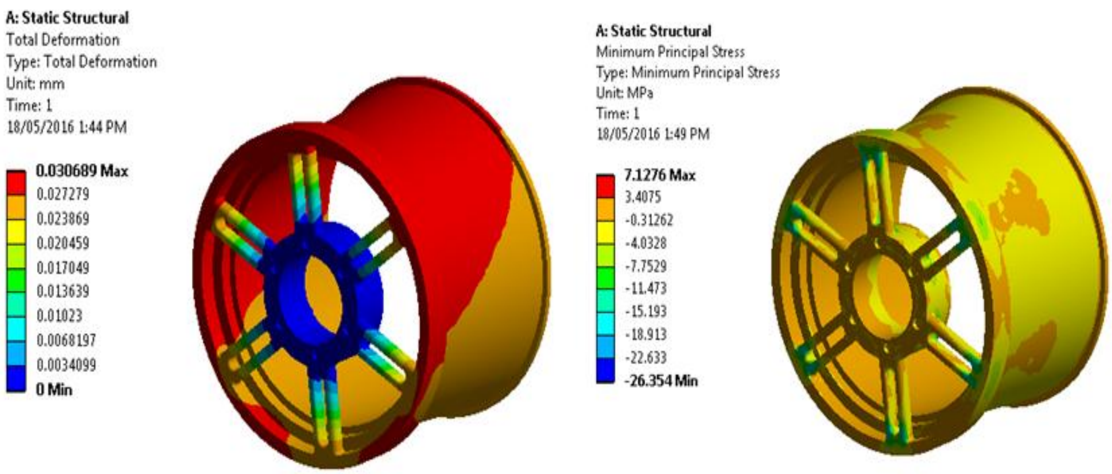


Fig. 4: Deformation and different stresses in 6 arms wheel

The model of 6 arms wheel as shown in fig 6.1 was done in unigraphics and later loaded in to ansys 14 for linear static structural analysis was carried out. The meshing is done for the 6 arms wheel. The boundary conditions were applied on the rim surface of the aluminium wheel ,presser-0.25 mpa ,rotational velocity – 222.2 rds or 2122 RPM ,bolt pretension-23340 N. after applying the boundary conditions we get the following results of linear static structural analysis for 6 arms wheel

1. von-mises stress= 42.069 mpa
2. maximum principal stress= 44.307 mpa
3. minumum principal stress=7.1276 mpa
4. Total Deformation = 0.030689 mm

The above values are below the yield stress and safer side.

Table 3 Comparison of 4 arms and 6 arms wheel

Parameters	**4 Arms Wheel**	**6 Arms Wheel**
Equivalent stress in MPa	67.81	42.069
Max Principal Stress in MPa	101.79	44.307
Min Principal Stress in MPa	31.91	0.037
Deformation in mm	0.1468	7.127
Fatigue Life in cps	1e8	1e8

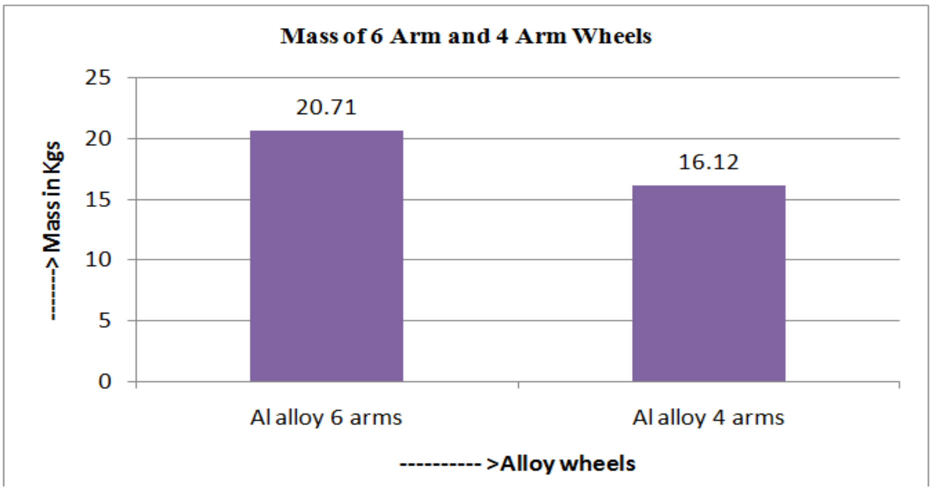


Fig. 5: Weight comparison of 6 arm 4 arm wheels

V. CONCLUSION

Linear Static Analysis is carried out on an aluminium alloy Wheel and for the 6 arm wheel the maximum equivalent stress was 42.069 MPa and for the 4 arm wheel it was 67.8 MPa which is much less than the yield stress of a given material and for applied load hence design is very safe for both the wheels. When considered weight criteria, 4 arm wheel weighs 16.12Kg and 6 arm wheel weighs 20.71 Kg. The best wheel is 4 arm wheel and total optimized weight was 4.588 kg resulting 22.16% of reduction in weight.

Life evaluation is validated using Goodman criteria and FEM approach found that the wheel can sustain 1×10^6cycles.

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