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Failure Analysis of alloy wheel for Passenger car

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ABSTRACT

The alloy wheels of passenger cars are intended for better heat conduction and improved aesthetics appearance over steel wheels and are typically lighter. In order to achieve better quality, the parametric studies of alloy wheel are necessary. The manufactures carry out a number of wheel tests to ensure that the wheel meets the safety requirements and higher comfort level. For this simulations of alloy wheel for specific design and improvement is carried out through realistic loading conditions. The project summarizes the application of finite element analysis technique for analyzing stress distribution. The analysis is done for alloy wheel of Skoda Octavia passenger car. Radial fatigue test is carried on specimen according to industrial standards. The wheel is checked for life cycle and further improvement in parameter are suggested.

Keywords— **finite element analysis technique 2. Radial fatigue test 3. Life cycle**

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I.INTRODUCTION

Alloy wheels were first developed in the last sixties to meet the demand of racetrack enthusiasts who were constantly looking for an edge in performance and styling. It was an unorganized industry then. Since its adoption by OEM's, the alloy wheel market has been steadily growing. Today, thanks to a more sophisticated and environmentally conscious consumer, the use of alloy wheels has become increasingly relevant. With this Increased demand came new developments in design, technology and manufacturing processes to produce a superior with a wide variety of designs.In the fatigue life evaluation of aluminium wheel design, the commonly accepted procedure for passenger car wheel manufacturing is to pass two durability tests, namely the radial fatigue test and cornering fatigue test. Since alloy wheels are designed for variation in style and have more complex shapes than regular steel wheels, it is difficult to assess fatigue life by using analytical methods. For this simulations of alloy wheel for specific design and improvement is carried out through realistic loading conditions.

ii. Types of wheel (material)
Steel and light alloy are the foremost materials used in a wheel rim however some composite materials together with glass-fibre are being used for special wheels.

A. Wire spoke Wheel
Wire spoke wheel is an essential where the exterior edge part of the wheel rim and the axle mounting part are linked by numerous wires called spokes. Today's automobiles with their high horse power have made this type of wheel manufacture obsolete. This type of wheel is still used on classicvehicles.

B. Steel Disc Wheel
This is a rim which practices the steel made rim and the wheel into one by joining (welding), and it is used mainly for passenger vehicles especially original equipment tires.

C. Light Alloy wheel
These wheels are based on the use of light metals, such as aluminium and magnesium has come to be popular in the

market. This wheel rapidly become standard for original equipment vehicle in Europe in 1960's and for the replacement tire in United States in 1970's. The advantages of each light alloy wheel are explained as below.

i) Aluminium Alloy Wheel
Aluminium is a metal with features of excellent lightness, thermal conductivity, physical characteristics of casting, low heat, machine processing and reutilizing, etc. This metal main advantage is decreased weight, high precision and design choices of the wheel.

ii) Magnesium alloy Wheel
Magnesium is about 30% lighter than aluminium and also admirable as for size stability and impact resistance. However its use is mainly restricted to racing, which needs the features of weightlessness and high strength. It is expansive when compared with aluminium

iii) Titanium alloy wheels
Titanium is an admirable metal for corrosion resistance and strength about 2.5 times compared with aluminium, but it is inferior due to machine processing, designing and more cost. It is still in developed stage.

iv)Composite material wheel
The composite material wheel is different from the light alloy wheel, and it is developed mainly for low weight. However this wheel has inadequate consistency against heat and for best strength.

II.OBJECTIVE

1. Study of various parameters causes the failure of alloy wheels under radial loads
2. Failure analysis & fatigue life evaluation for alloy wheel under radial load.
3. Experimental results for combined loading

III.METHODOLOGY

1. The aim of project is to find fatigue life & damage factor of alloy for a specific vehicle passenger car.
2. Literature review on fatigue life of alloy wheel Under radial
3. Simulation and experimental results are compared of radial fatigue test.

IV. MATERIAL PROPERTIES

Material used Aluminium alloy A356.2

Table No1
Aluminium alloy A356.2 chemical composition

Sr. No.	Material	Percentage %
1.	Aluminum	91.37
2	Silicon	6.5- 7.5
3	Iron	0.12
3.	Manganese	0.05
4.	Magnesium	0.3-0.45
5.	Zinc	0.50
6	Titanium	0.20
7	Copper	0.10
	Other	0.15

V .INPUT DATA & ANALYTICAL CALCULATION

The wheels for passenger cars need satisfy three main testing industrial standards. They are as follows

1. Bending Endurance Test
2. Radial Endurance Test
   a) Pressure Loading
   b) Centrifugal Loading
   c) Vertical Loading

4.1 Bending Test
The bending moment to be imparted in test shall be in accordance to following formula:

$$M = ((\mu * R) + d) * F * S$$

Where
M = Bending moment in 'Nm'
μ = Friction Coefficient between the tyre and road Surface
R = Radius of tyre applicable to the wheel in 'm'
d = Offset of the wheel in 'm'
F = Maximum load acting on the tyre in 'N'
S = Coefficient specified according to the Standards
Tyre Specification Radial 256/60-R14
226 is the section width in millimeters
60 is the aspect ratio in percentage
R is the construction type i.e. Radial
14 is the rim diameter in inches
Aspect ratio = section height / section width
Section height = section width * Aspect ratio
= 225*0.60
= 153mm
= 0.153m
Rim Diameter = 14 inches
= 14* 2.54= 38.08cm
Rim Radius = 19.04cm
= 01904m.

Tyre radius = rim Radius + Section height

= 0.1904+ 0.153 = 0.3434m

According to the industrial Standards:
μ = 0.7
d = 0.037m
F =611.5Kg
= 5999.30N

S= 1.5
i) Bending Moment M = ((μ * R) +d) * F*S
= ((0.7*0.3689) + 0.037) * 5999.30*1.5
= 2656.76.16 Nm

ii) Radial Endurance Test
The radial load to be imparted in test shall be in accordance with following formula:
Fr = F *k
Where
Fr = Radial load in N
F = the maximum load coming on tyre in N
K = Coefficient according to the industrial Standards
According to the industrial Standards
F = 611.5 * 9.81
= 5999.8N

iii) Combined Load case
Radial load Fr = F * k
Where
F = Total force acting on wheel
K = 2.25 coefficient constant
Fr= F * k
= 5999.8 * 2.25
= 13497.3337 N
= 13.4973 KN

Centrifugal Load :
Angular velocity is calculated by using the formula
V = r * w
Maximum speed of the car is 90 Km/hr = 25 m/s
V = r * w
22.22= 0.3689 * w
W = 67.76 rad/ sec

From model we have,
Moment of inertia (I) = 90556.19mm^4
Distance from neutral axis (Y) = 18.07mm
Ultimate tensile stress = 250 MPa
Ultimate tensile stress = Direct stress + Bending stress

250= (P/A) + (M / Z) x 2.25 ------------- (2)
Where, 2.25 = Safety factor for dynamic loading condition
Z = Section modulus = I / Y

Checking cross section of arm for Max. Acceleration Torque
As per OEM Specification for passenger car we have,
Maximum Engine torque = 320 N-m @ 3000 rpm
1 st Gear ratio = 3.909
Differential gear ratio = 3.867
Max Torque at Axle = 320 *3.909*3.867
= 4837.1529 N-m
Max Torque at wheel = 4837.1529 / 2
= 2418.5 Nm
Now substituting values in equation (2) we have ,
(250/ 2.25) = [(970 *9.81) / 740.28] +[(2 *1043.01 *18.07*1000) / (5 *90556.19)]
111.11 = (12.85 + 83.25)
111.11> 96.10
Note : Ultimate tensile stress of aluminium alloy is higher than actual working stress hence design is safe for maximum acceleration torque.

VI. FATIGUE ANALYSIS

1. The modelling was done in solid works software. According to dimension of Skoda octiva alloy wheel. The dimension where found through reverse engineering i.e through CMM &Scanning.

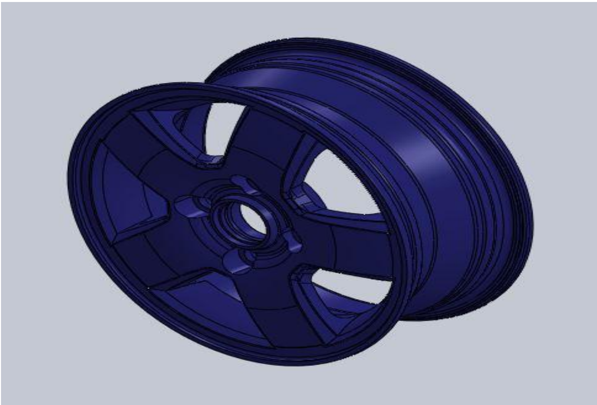


Fig 1. 3D Model of Skoda Octiva alloy wheel

2. Meshing
Then Step file is Imported in Hypermesh V 12. Its geometry is checked. The alloy wheel is meshed.

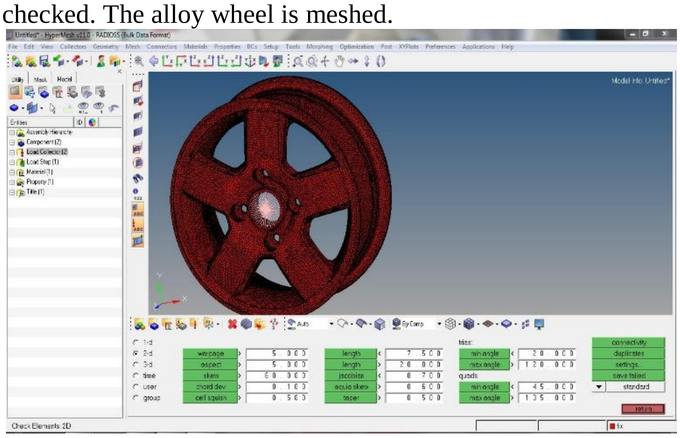


Fig 2 meshed Model

	Volume Tetrahedral Mesh
No of elements	226139
No of nodes	59485
Quality Index	
Criteria	No of element Failed
Aspect ratio	5
Skew	60

Table 3
Quality Index of alloy wheel for standard tetra mesh

3. Application of Boundary Conditions

1. Input Force: 13.49 KN of force is applied radial in downwards direction of alloy wheel.
2. Constraints: The bolt hole are constrained.

I.

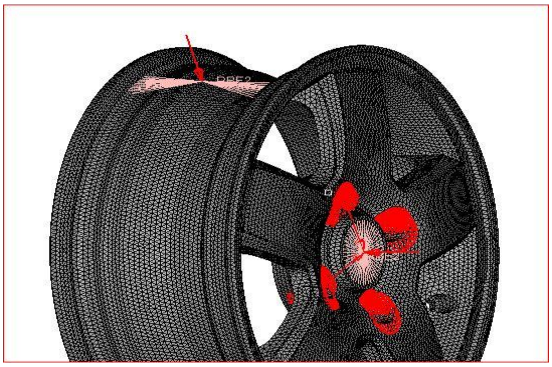
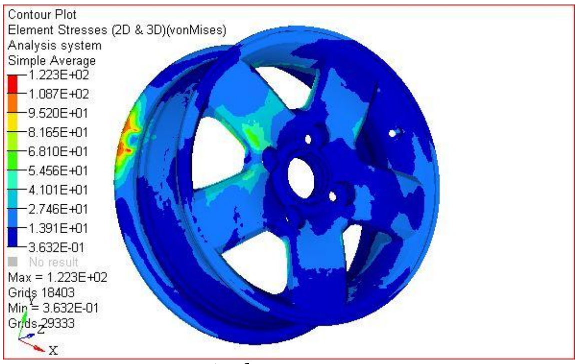


Fig 3 Boundary Condition Applied

3. Equivalent Stress

The Maximum and minimum stress are as 1.22e10^2 & 3.0361e-10^1

Fig 4



Equivalent stress

4. Damage factor

Damage factor for Skoda octiva alloy wheel under radial loads.

5. Life

The life of wheel was to found to be 1.101E+05 under radial loads.

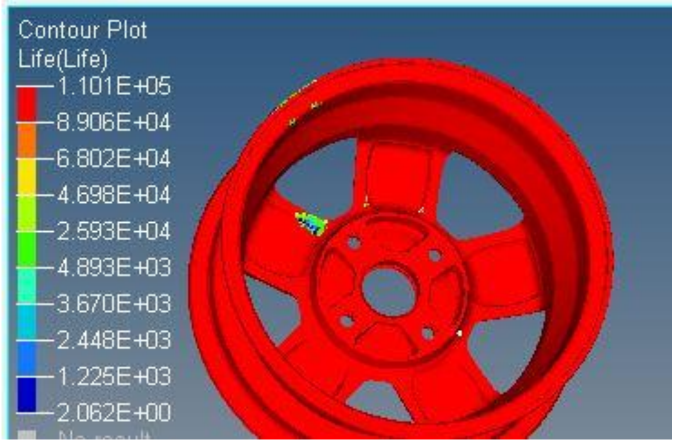


Fig 6 Fatigue life under radial Load

VI. RESULTS AND DISCUSSION

From the analytical calculations, force was found& then this force was applied taking into considered specification of car. The fatigue life was found to be 1.01E+05. Cycles. A parametric study was done on failure analysis of alloy wheel. Further improvement in various parameters are suggest in design & other factor

VII. CONCLUSIONS

Analysis was carried on alloy wheel for radial fatigue life & damage factor according AIS 073 Part I. The alloy wheel was checked for crack initiation .The Crack initiation process started at 1.01E+05.Fatigue life of alloy wheel under radial load was found out.

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