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Radial Fatigue Analysis of An Alloy Wheel

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ABSTRACT:
Importance of wheel in the automobile is obvious. The vehicle (car) may be towed without the engine but at the same time even that is also not possible without the wheels, the wheels along the tyre has to carry the vehicle load, provide cushioning effect and cope with the steering control. The main requirements of an automobile wheel are; it must be strong enough to perform the above functions. It should be balanced both statically as well as dynamically. It should be lightest possible so that the unsprung weight is least.

The Wheel has to pass three types of tests before going into production, they are Cornering fatigue test, Radial fatigue test and Impact test. In this thesis radial fatigue analysis is done to find the number of cycles at which the wheel is going to fail. The 2D of the wheel was created in MDT, the drafting package and the same was exported to ANSYS, the finite element package using IGES translator where the 3D model of the wheel is created. The wheel is meshed using SOLID 45 element. A load of 2500N was applied on the hub area of the wheel and a pressure of 0.207N/mm2 is applied on the outer surface of the rim. The pitch circle holes are constrained in all degrees of freedom. The analysis is carried under these constraints and the results are taken to carryout for further analysis i.e. fatigue module to find the life of the wheel.

Key words: Automobile wheel design, Static design, Dynamic design, Light design, Unsprung weight, Radial fatigue test and Impact test

I. INTRODUCTION

The tyre works as a wheel only after it is installed on the rim and is inflated. Therefore, the tyre and wheel assembly influences the function and the performance of the vehicle. The tyre is designed and manufactured to suit a standard rim and once installed on the correct rim the tyre will perform up to its desired level. It is needless to say that the life of the tyre will be shortened if it is installed on an unsuitable rim. The rim is actually the name for the cylindrical part where the tyre is installed. A wheel is the name for the combination between the rim and disc plate. Once the disc plate is installed inside the cylinder this assembly becomes a wheel. Toyo Tyre Talk at this time would like to introduce basic technical knowledge about passenger vehicle rims. The rim used for vehicles is provided depending on each countries standard. This international standard, similar to tyres, provides for a basic dimension for the rim diameter, width, and the flange shape, etc. and is common to every country in the world. Recently the shape of the rim has settled to 5 degree Drop Center Rim to provide for international harmony.

Wheel is generally composed of rim and disc. Rim is a part where the tyre is installed. Disc is a part of the rim where it is fixed to the axle hub. Offset is a distance between wheel mounting surface where it is bolted to hub and the centerline of rim. The flange is a part of rim, which holds the both beads of the tyre. Bead seat comes in contact with the bead face and is a part of rim, which holds the tyre in a radial direction. Hump is bump what was put on the bead seat for the bead to prevent the tyre from sliding off the rim while the vehicle is moving. Well is a part of rim with depth and width to facilitate tyre mounting and removal from the rim.

First one is Aluminum Alloy Wheel is a metal with features of excellent lightness, thermal conductivity, corrosion resistance, characteristics of casting, low temperature, machine processing and recycling, etc. This metals main advantage is reduced weight, high accuracy and design choices of the wheel. This metal is useful for energy conservation because it is possible to re-cycle aluminum easily. Second one is Magnesium Alloy Wheel is about 30% lighter than aluminum, and also, excellent as for size stability and impact resistance. However, its use is mainly restricted to racing, which needs the features of lightness and high strength at the expense of corrosion resistance and design choice, etc. compared with aluminum. Recently, the technology for casting and forging is improved, and the corrosion resistance of magnesium is also improving. This material is receiving special attention due to the renewed interest in energy conservation. Third one is Titanium Alloy Wheel is an excellent metal for corrosion resistance and strength (about 2.5 times) compared with aluminum, but it is inferior due to machine processing, designing and high cost. It is still in the development stage although there is some use in the field of racing. And final one is Composite Material Wheel , is different from the light alloy wheel, and it (Generally, it is thermoplastic resin, which contains the glass fiber reinforcement material) is developed mainly for low weight. However, this wheel has insufficient reliability against heat and for strength. Development is continuing.

Objective of the project is the work involves in finding the fatigue life of newly designed aluminum alloy wheel due to static loads. The project mainly involves in modeling of the wheel using MDT and ANSYS, and the analysis is performed on the modeled component using ANSYS. Analysis that is performed typically includes static analysis.

II. EXPERIMENTAL SET UP OF AN ALLOY WHEELS – RADIAL FATIGUE TEST

1.1. SCOPE

This annex specifies a laboratory test procedure to evaluate the fatigue test on an alloy wheel. It is intended to for passenger car applications. With the purpose of screening and/or quality control of the wheel.

Fig. 1.1. Radial Fatigue Test Machine.

1.2. TEST PROCEDURE

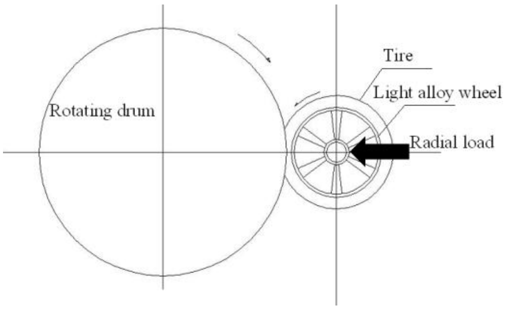

Fig. 1.2 Model Equipment for Radial Fatigue Test

The wheel with tyre is going to fix to the machine equipment and it should be in contact to the rotating drum the drum is going to revolve by the motor by our required speed .so here the important thing is we have to apply load on the tyre for it we have to tie up a rope to the wheel and to the rotating drum sideward block so that the load required has to be set up by tightening the rope. In this way the motor has to be run for our required speed and we have to do this test continuously for two three hours and by taking short durations or long time we can do the experiment test by the way we have to note the cycles . At last after so many days we are going to get failure. By that we can estimate the life of the alloy wheel. In this way it is time taking test procedure, and we have to take correct procedure to follow up.

III. FINITE ELEMENT ANALYSIS OF WHEEL

The 2D of the wheel was created in MDT, the drafting package and the same was exported to ANSYS, the finite element package using IGES translator where the 3D model of the wheel is created.

2.1 Solid Model Of Wheel and :

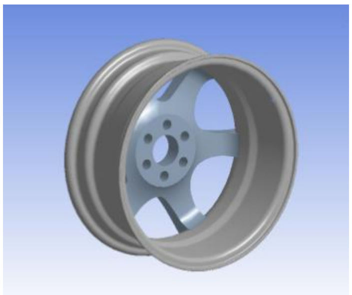

Fig. 2.1. Solid Model of Aluminum Alloy Wheel

2.2. Meshing

The process of dividing the object in to different elements is called meshing. Meshing thus holds a very important place in the finite element analysis.

An in-depth study of meshing assumes a very important role.

The wheel is meshed using SOLID 45 element. The number of elements was found to be 9988 and the number of nodes was found to be19903.

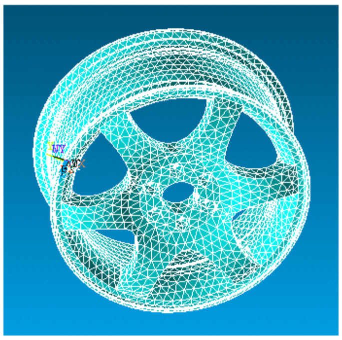

Fig. 2.2. Plot for meshed Model of Wheel by 3-D 4-Node Tetrahedral Structural Solid with Rotations (Solid45)

2.3. Boundary Conditions:

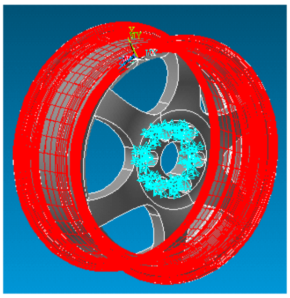

Fig. 2.3. Boundary conditions for model analysis

A pressure of 0.207N/mm^2 is applied on the outer surface of the rim. The pitch circle holes are constrained in all degrees of freedom.

2.4. Loading conditions:

Here the load of 2500N is applied throughout the inner surface of the hub diameter by taking one middle node.

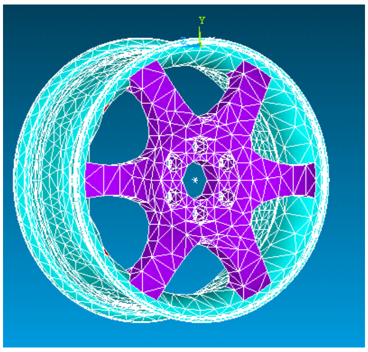

Fig. 2.4. Loading conditions for model analysis

2.5. Problem:

The problem stated here is to analyze the fatigue failure of an alloy wheel. The load has to be distributed on the hub diameter surface.

2.5.1. Material Properties of an alloy – A356.0-T61 ; Permanent Mold Cast (Aluminum Alloy)

Subcategory: Aluminum Alloy; Nonferrous Metal; Aluminum Casting Alloy: Aluminum A356.0 – T61; UNS A13560; AAA356.0-T61;

Composition:

Component	Wt%	Component	Wt%
Al	93	Mn	Max 0.1
Cu	Max 0.2	Si	6.5-7.5
Fe	Max 0.2	Ti	Max 0.2
Mg	0.25-0.45	Zi	Max 0.1

Table. 2.1. Aluminum Alloy Material Data

Yield strength of the material = 195N/mm^2
Young's modulus = 72400N/mm^2
Density = 2.72e-9kgs^2/mm^4
Poisson's ratio = 0.33

2.5.2. Load given: Gross weight of the vehicle on wheels;

619 + 5x70 + 50 = 1500kg.

619--------kreb weight of vehicle
5-----------No. Of Persons in car
70---------Weight of each person
50----------Overages added.
Load on each wheel: 1019/4=254.85kg.(2500N)

2.5.3. Pressure Load:

Consider 30 psi of air pressure load acting on the outer surface of the wheel. Therefore
30 = 30x0.4535x9.81/(25.4)^2 = 0.207 N/mm^2

2.6. Steps in doing a Fatigue Evaluation:

1. Enter POST1 and Resume Your Database
2. Establish the Size, Fatigue Material Properties, and Locations
3. Define material fatigue properties.
4. Store Stresses and Assign Event Repetitions and Scale Factors
5. Activate the Fatigue Calculations

IV. RESULTS AND DISCUSSIONS

3.1. Analysis Under Radial Load

The total weight of a car is balanced with vertical reaction force from the road through the tyre. This load constantly compresses the wheel radially. While the car is running, the radial load becomes a cyclic load with the rotation of the wheel. Hence, the evaluation of wheel fatigue strength under radial load is an important performance characteristic for structural integrity.

Total Deformation Analysis

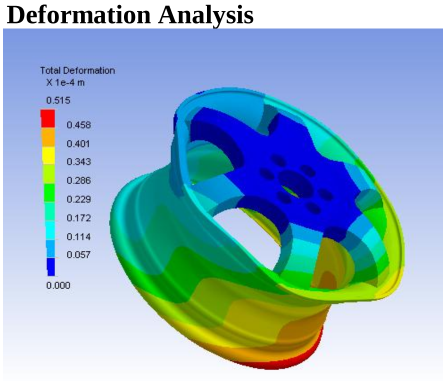

Fig. 3.1. Total deformation under radial load.

3.2 Total deformation of engine side:

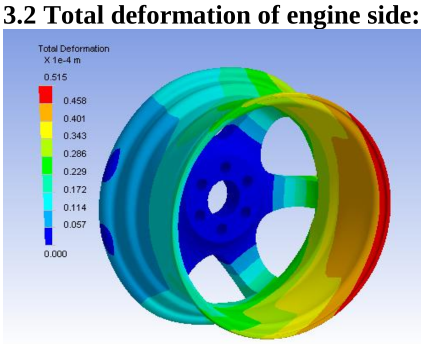

Fig. 3.2. Total deformation of engine side.

3.3. Maximum Shear Stress

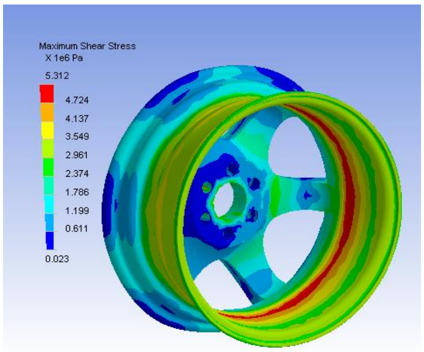

Fig. 3.3. Maximum Shear Stress

3.4. Equivalent (von-Mises) Stress.

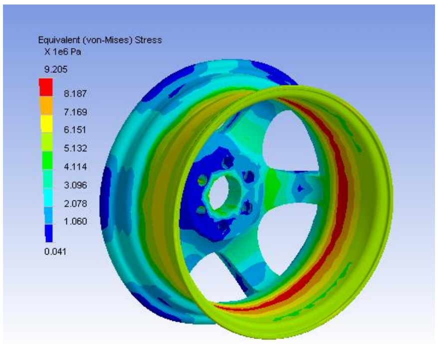

Fig. 3.4. Equivalent (von-mises) Stress.

3.5. Equivalent Alternating Stress

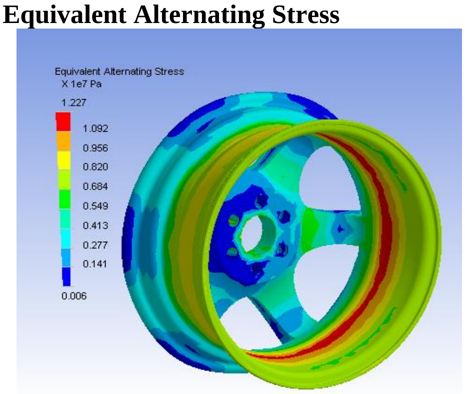

Fig. 3.5. Equivalent Alternating Stress.

3.6. Safety Factor:

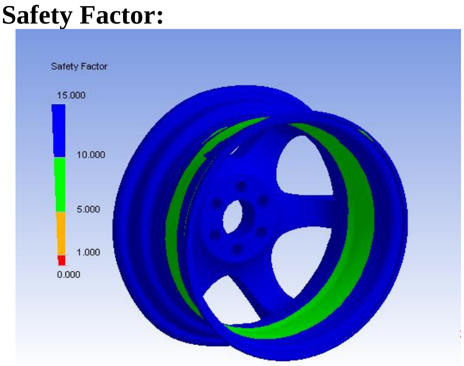

Fig. 3.6. Safety Factor.

3.7 S – N Curve:

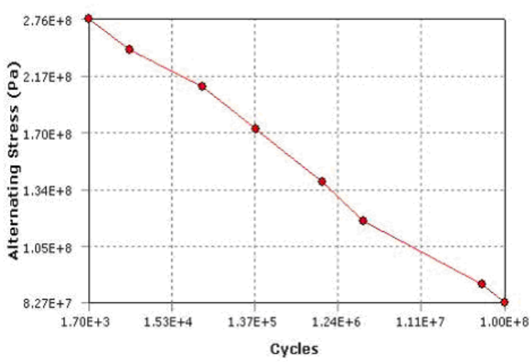

Fig. 3.7 S-N Curve

S.No.	Cycles	Alternating Stress (Pa)
1	17000	2.758e+008
2	50000	2.413e+008
3	34000	2.068e+008
4	1.4e+00 5	1.724e+008
5	8.e+005	1.379e+008
6	2.4e+00 6	1.172e+008
7	5.5e+00 7	8.963e+007
8	1.e+008	8.274e+007

Table. 3.1 S-N Curve

3.8 Fatigue Results:

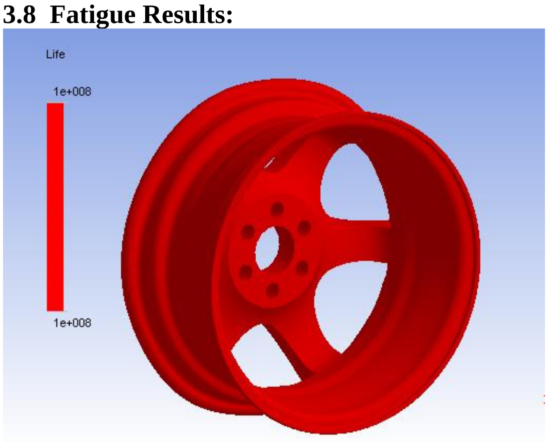

Fig.3.8 Fatigue Results

3.9 Result:

Name	Type	Scale Facto r	Stress Component	Infinite Life
Fatigue Tool	Fully Reversed	1.0	Signed Von-Mises	$1.0\text{x}10^{9}$

Table 3.2. Fatigue result

V. CONCLUSIONS AND FUTURE SCOPE

As in the case of an automobile wheel maximum load is applied on the alloy wheel. Analysis of the wheel plays an important role for the safety of the passenger cars. This project deals with the fatigue analysis of the wheel, as explained in the previous chapters.

The 2D of the wheel was created in MDT, the drafting package and the same was exported to ANSYS, the finite element package using IGES translator where the 3D model of the wheel is created. The wheel is meshed using SOLID 45 element. A load of 2500N was applied on the hub area of the wheel and a pressure of 0.207N/mm2 is applied on the outer surface of the rim. The pitch circle holes are constrained in all degrees of freedom. The analysis is carried under these constraints and the results are taken to carryout for further analysis i.e fatigue module to find the life of the wheel. Various number of cycles the analysis has been done. Finally we found Equivalent (Von-Mises) Stress we find 9.205x1e6 Pa maximum stress. And the minimum stress is 0.041x1e6 Pa. and the deformation is observed as the 0.515x1e-1 mm after running the fatigue cycles we found that the infinite life at 1.0x109 cycles.

Same analysis can be performed with alternate materials by applying load at different areas on the wheel, to reduce the weight, which ultimately reduces the overall cost, with increase in lifetime, and we can find the failure by changing loads by increasing or decreasing according to our requirements of that particular wheels we also change the models or design of the wheel and to test for the fatigue and comparing with the two models which will give the more life we can identify and we can develop that model. And also the various tests have to be done by other two tests such as cornering test and impact test.

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