Experimental Validation & Redesign of Wheel to Improve the Strength to Withstand the Operating Load

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Abstract **- Wheel is used in combination with axles used in facilitating transportation. Wheels are used in different applications. In this project we are concerned with improving the strength of the wheel to withstand the operating load. The wheel has to pass different tests before it is put into operation. Axial compression test and cornering fatigue test are the important tests among them and fatigue life of the wheel is calculated. The problem occurring with the base model of the wheel is studied firstly. The automotive wheel has to meet certain load carrying capacity during operation should and should adhere to some running conditions. But wheel manufactured sometimes will be unable to carry the expected loads and this must be validated with experimental results using FE methods. If the model is failing then one has to develop conceptual designs which are having more strength than previous design. And these models are checked numerically whether these designs are better than base design or not. A best design is suggested among these models which is having more strength than base design.**

Key words **– Hyper mesh, Abaqus, cornering fatigue test, axial compression test, cornering fatigue test, fatigue life.**

I. INTRODUCTION

A. Wheel

A wheel is a circular segment that is expected to turn on a hub bearing. The wheel is one of the principle parts of the wheel & axle which is one of the six basic machines. Wheels, in conjunction with axles, permit overwhelming items to be moved effortlessly encouraging development or transportation while supporting a load, or performing work in machines. Wheels are additionally utilized for different purposes, for example, a boat's wheel, guiding wheel, potter's wheel & axle. Regular illustrations are found in transport applications. A wheel incredibly decreases contact by encouraging movement by moving together with the
utilization of axles. For wheels to rotate, a moment must be applied to the wheel with reference to its axis, this may be applied by the way of gravity, or by the application of external force or torque [1].
The wheel is likely the most essential mechanical development ever. About each machine worked following the start of the Industrial Revolution [2] includes a solitary, essential standard exemplified in one of humanity's genuinely huge innovations. It's difficult to envision any motorized framework that would be conceivable without the wheel or the possibility of a symmetrical segment moving in a round about movement on a hub. From minor watch riggings to vehicles, plane motors and PC plate drives, the rule is the same.

II. PROBLEM DEFENITION & METHODOLOGY

The wheel has to satisfy different tests that are performed to check the strength of it and the
Wheel must be redesigned if it is failing in these tests. Here we have to study about the material data, boundary condition and loading conditions. We have to study about the dimensions of the existing design to model the design in modeling software. The elastic and plastic properties are to be considered while studying the existing design. Numerical techniques are used to solve the problems using the help of computers. Different tests are simulated to check the strength of the wheel and to predict the fatigue life of the wheel. The test results are compared with standard experimental data to validate the results. To improve the strength and life of the wheel we have to give modified design. These models will have more load carrying capacity and more life compared to previous design. The newly developed models are compared with existing model by carrying out same analysis steps followed previously. The validity of the new design is measured. And the best design is suggested among them.

- Study the existing design.
- To compare analytical and numerical results of diametrical compression of circular disc problem.
- Analyze the existing design using Numerical technique.
- Compare/Validate the numerical results with existing test Data.
- Provide modified designs (Concept 1, Concept 2 and Concept3)
- Validate the designs using Numerical technique developed.
- Estimate the Fatigue Life of the modified designs.
- Provide Conclusion on the best design

III. Material Selection

Here in this project aluminum Alloy 6063 [3] commonly known as an architectural alloy. It has reasonably

high tensile properties, excellent finishing characteristics and a high degree of resistance to corrosion

I. Wheel Models

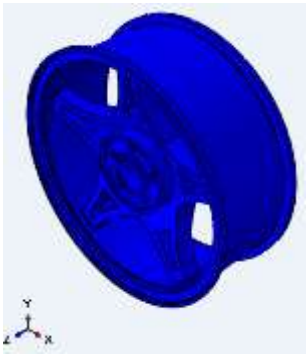

Figure 1 Initial Design

Figure 2 Conceptual Design 1

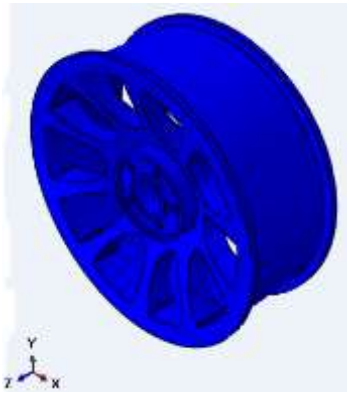

Figure 3 Conceptual Design 2

A. Mesh type and Number of Elements

Meshing is the process of converting infinite degree of freedom into finite degree of freedom. A continuum will be having infinite number of elements which will be having infinite degrees of freedom. Here I am using C3D4 elements (Continuum 3Dimensional 4 Node). C3D4 element means tetrahedral element having nodes at each corner or first order element.

I.Axial Compression Test

Three models of wheels can be seen in figure and named accordingly the wheels are modeled according to change the load transfer path and increase the load bearing area by increasing thickness and number of spokes and wheels are subjected to axial compression test [4] primarily to check the strength and load carrying capacity of the wheel and then best model is suggested according to its load carrying capacity

I. Boundary Conditions

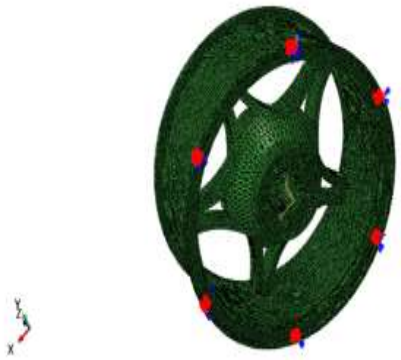

Figure 4 Fixing Location 1

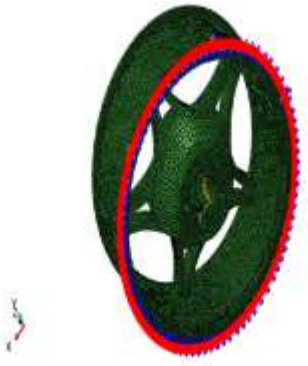

Figure 5 Fixing Location 2

The boundary conditions applied here are according to real testing condition. The wheel will be placed on a mounting

table and it is clamped at 6 locations in the real testing condition. In the FE software also the wheel will be fixed at its base and selected 6 locations which divides the wheel equally into 6 parts. Boundary conditions applied here is all DOF fixed. A displacement of 1.5 mm is given to wheel.

3.2 Deflection

The displacement allowable according to standard test conditions in Al type of wheel is 1.5mm so a displacement value of 1.5mm is given to all models. The reaction forces developed in different wheel models is then measured. Load v/s displacement graph is plotted for different models to compare the strength of the wheel.

3.3 Stresses Developed

The value of stress for different models can be seen from below figure. The stresses developed in initial design model in 326MPa, in conceptual design 1 model is 310MPa and in conceptual design-2 model is 274MPa

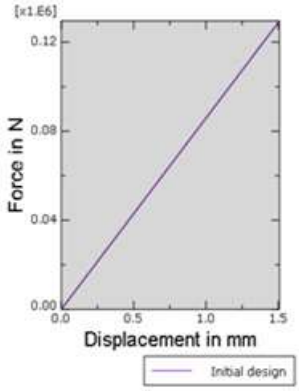

Figure 6 Load V/S Deflection Curve of Initial Design

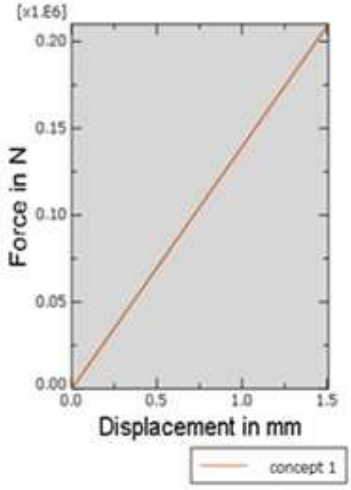

Figure 7 Load V/S Deflection Curve of Concept 1

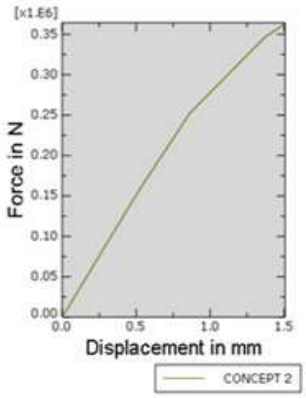

Figure 8 Load V/S Deflection Curve of Concept 2

From these graphs we can see that the load carrying capacity of conceptual design 2 model is more compared to other two. And hence we can conclude that this wheel is having more strength and can be subjected to other tests.

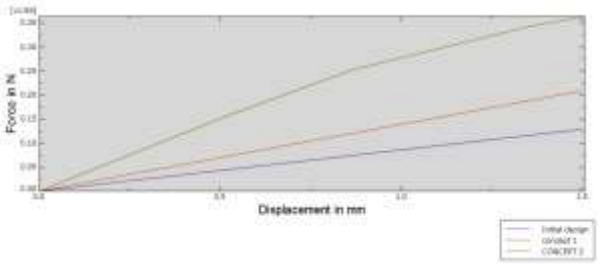

Figure 9 Combined Load V/S Displacement Graph

II. Cornering Fatigue Test

In fatigue analysis of wheel we have to forecast number of cycles required to initiate a small crack at stress concentration region. In fatigue failure this crack will grow subsequently and cause failure of component. In this paper bi-axial load notch strain approximation for loading is used to estimate the fatigue life of thin sheet in plane stress condition. The stressed region in wheel are rim well, weld zone between disk and cooling holes, bolt contact area and hat radius. The cornering fatigue test is used to simulate the dynamic loading [6] condition of the wheel during cornering on the road. The forces acting on the wheel are lateral force and vertical force between ground and tire.

Load = 5000N

Table 1 Fatigue Life of Different Wheel Models for 5000N

Model	Stress(MPa)	Fatigue life
Initial	422	Fail
Concept 1	192	10^5
Concept 2	164	$7x10^6$

From the above tables we can conclude that the fatigue life [5] of concept-2 model is more, which is improved from the base design. For a load of 5000N the initial model will fail.

III. Experimental Validation of Results with FE methodology

The initial design is tested experimentally and it could not carry expected loads, it was failing. So it has to be redesigned. Before proceeding with the redesigning we have develop FE methodology of experimental validation. But the design was not able to carry expected loads. Hence it has to be redesigned so that it can carry more loads. And then different conceptual designs are developed and they are validated with the FE methodology, from the graph it can be seen that the load carrying capacity of newly developed design is improved.

IV. CONCLUSION

In this project the wheel models are subjected to different tests like axial compression test and cornering fatigue test from these tests we can conclude in the following way.

Load carrying capacity of initial design is 128kN. Load carrying capacity of Concept design 1 is 208kN. Load carrying capacity of concept design 2 is 362kN

From the above results we can clearly see that load carrying capacity of conceptual design-2 is more compared to other two designs.

From cornering fatigue test results the fatigue life of different wheel models is found which can be seen in the table

From the table it is clear that the load carrying capacity of concept-2 design is more, which is having a fatigue life of $7x10^6$ cycles for the load of 5000N. For the same load of 5000N the initial design is failing and the concept-1 design is having a fatigue life of 10^5 cycles.

V. SCOPE FOR FURTHER WORK

As the wheel load carrying capacity is increased by changing the design and the fatigue life of the wheel is improved from the initial model to conceptual design. The wheels can be manufactured by using steel, aluminum, magnesium, titanium and composite materials. In this project I have used Al alloy material. It can also be replaced with low density materials like magnesium, titanium and composites. Use of these materials will reduce the weight of the wheel but we have to take care of the strength of the wheel. After replacing the material wheel must be capable of performing same intended function without failure. Reducing the weight of the wheel will improve the efficiency of the vehicle**.**

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