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Abstract - In this paper a detailed "Fatigue Analysis of Aluminum Alloy Wheel under Radial Load". During the part of project a static and fatigue analysis of aluminum alloy wheel A356.2 was carried out using FEA package. The 3 dimensional model of the wheel was designed using CATIA. Then the 3-D model was imported into ANSYS using the IGES format.

The finite element idealization of this modal was then produced using the 10 node tetrahedron solid element. The analysis was performed in a static condition. This is constrained in all degree of freedom at the PCD and hub portion. The pressure is applied on the rim. We find out the total deformation, alternative stress and shear stress by using FEA software. And also we find out the life, safety factor and damage of alloy wheel by using S-N curve. S-N curve is input for a A.356.2 material.

Keywords: *Aluminum Alloy Wheel, A356.2, FEA, CATIA,ANSYS*

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. Original equipment manufacturers soon realized that a significant market opportunity was being lost as car owners were leaving car show rooms with stock wheels and driving down to a dealer for fitment with high priced custom alloy wheels. 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. Tried and wheels on the race tracks, off-road and cross country, under some of the toughest road-conditions, alloy wheels are now considered the de-facto standard for many world cars. With this increased demand came new developments in design, technology and manufacturing processes to produce a superior with a wide variety of designs.

The key to an alloy wheel is the quality of the casting. The casting integrity depends on the process used. 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. Hence these wheels are generally not preferred by international OEMs. Centrifugal and squeeze casting yields a good quality wheel, but have the disadvantage of being unable to manufacture non-axis metric design wheels. As such this technology has not become popular.

Low pressure die casting allows precise control during the casting and cooling cycle. Significantly reducing cavities, porosity and uneven shrinkage. This technology is amenable to large scale production and automation, and is today considered as the state of the art technology for manufacture of alloy wheels. Low pressure die casting is incorporated by most of the world's leading OEM suppliers.

II. RELATED WORK

Fatigue as a technical problem became more evident around the middle of 19^{th} century. About 100 years later, in the middle of 20^{th} century, Peterson in 1950 and Timoshenko in 1954 reviewed the developments of fatigue problems in two historical papers. Peterson reviewed the discussion on fatigue problems during meetings of mechanical engineers at Birmingham held in 1850. He also mentioned historical ideas about fatigue as a material phenomenon and the microscopic studies carried out by Gough and co-workers and others in 1930.

Timoshenko in his review discussed the significance of stress distributions and emphasized stress concentrations around notches. According to Timoshenko, the importance was recognized by design engineers around the end of 19^{th} century, and the knowledge was further refined in the beginning of 20^{th} century. Timoshenko considered experimental studies on stress distributions and stress concentration to be of prime importance. He mentioned several developments on strain measurements, Strain gauges and photo-elastic models.

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 necessary performance and durability requirements. Moreover, in order to ensure driving comfort and road handling characteristics, the wheel must be as light as possible. Nowadays, reduction in wheel weight is a major concern in wheel industry. For wheel manufacturers, reduction in wheel weight means a reduction in material cost. In order to reduce the manufacturing cost, wheel weight must be minimized, while wheel must still have enough mechanical performance to suffer normal or severe driving conditions.

Traditionally, wheel design and development is very time consuming, because it needs a number of tests and design iterations before going into production. In modern industry, how to shorten development time and to reduce the number of times of test are important issues. In order to achieve the above objectives, computer aided engineering (CAE) is a useful tool and has been recently carried out to perform a wheel design.

III. FATIGUE ANALYSIS

Fatigue is an important consideration for components and structures subjected to repeated loading s, is one of the most difficult design issue to resolve. Experience has shown that large percentage of structural failure are attributed to fatigue and as a result, it is an area which has been and will continue to be the focus of both fundamental and applied research. Fatigue design provisions are only recently included in the aluminum association specialization.

Related loadings of a component or structure at stresses the design allowable for static loadings may cause a crack or racks to form. Under cyclic loading these cracks may continue to grow and precipitate a failure. When the remaining structure can no longer carry the loads. The mechanism of crack formation and growth is called fatigue.

The dramatic examples of fatigue failures include the first two cornet jet aircraft and the point pleasant 'silver bridge' which cause numerous fatalities and significance property damage, because of the many service failures, the design of components and structures subjected to repeated loadings must consider fatigue performance. This is particular structures designed for minimum weight.

The first dictionary definition of fatigue deals with weariness from labor or exertion for tired material.

The appropriate definition is the tendency of a material to break under repeated cyclic loading at a stress considerer 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.

IV. MATERIAL INTRODUCTION

A mathematical model of the low-pressure die casting process for the production of A356 aluminum alloy wheels has been developed to predict the evolution of temperature within the wheel and die under the auspices of a collaborative research agreement between researchers at the University of British Columbia and a North American wheel casting facility. The heat transfer model represents a three-dimensional, 30◦ slice of the wheel and die, and was developed within the commercial finite-element package, ABAQUS. Extensive temperature measurements in the die and in the wheel taken over several cycles in the casting process were used to develop key process boundary conditions and validate the model.

The predicted and measured temperatures agree very well, with the maximum difference less than 20 ◦C at the majority of locations examined. A heat flux analysis conducted with the model has identified the complex path that the heat follows within the die and wheel during the solidification process.

A solidification path analysis conducted with the model showed the presence of a hot spot in the rim/spoke junction area, which was confirmed by the observation of macro-porosity in a sectioned wheel.

Fatigue analysis using FEA package:

A simple methodology to predict crack initiation life is described in the fatigue damage assessment of metallic structures typically used in ground vehicle industry. A phenomenological constitutive model is integrated with a notch stress–strain analysis method and local loads under general multiaxial fatigue loads are modeled with linear elastic FE analyses. The computed stress–strain response is used to predict the fatigue crack initiation life using effective strain range parameters and two critical plane parameters.

The proposed methodology is employed in the fatigue test cycle prediction of the biaxial cornering tests of light-alloy wheels. Numerical simulations indicate that estimates using critical plane models provide better correlations between the cornering test cycles and predicted cycles. Also, comparisons in terms test failure locations and estimated crack initiation sites are given.

The finite element is a mathematical method for solving ordinary and partial differential equations. Because it is a numerical method, it has the ability to solve complex problems that can be represented in differential equation form. As these types of equations occur naturally. In virtually all fields of the physical sciences, the applications of the Finite element method are limitless as regards the solution of practical

Due to the high cost of computing power of years gone by, FEA has a history of being used to solve complex and cost critical problems. Classical methods alone usually cannot provide adequate information to determine the safe working limits of a major civil engineering construction or an Automobile or a Nuclear reactor failed catastrophically the economic and social costs would be unacceptably high.

In recent years, FEA has been used almost universally to solve structural engineering problems. One discipline that has relied heavily on this technology is the Automotive and Aerospace industry. Due to the need to meet the extreme demands for faster, stronger, efficient and light weight Automobiles and Aircrafts, manufactures have to rely on the Technique to stay components and the high media coverage that the Industry is exposed to, Automotive and Aircraft companies need to ensure that none of their components fail, that is to cease providing the FEA has been used routinely in high volume production and manufacturing Industries for many years. As to get a product design wrong would be detrimental. For example, if a large manufacturer had to recall one model alone due to a piston design fault. They would end up having to replace up to 10 million pistons. Similarly, if an oil platform had to shut down due to one of the major components.

Part Design using CATIA:

We Created sketched features including, cuts, and slots made by either, extruding, revolving sweeping along a2-d sketched trajectory, or blending between parallel sections, create “pick and place” features, such as holes, shafts, chamfer, rounds, shell, regular drafts, flanges ribs etc.

We also sketched cosmetic features, reference datum planes, axes, points, curves, coordinate systems, and shapes for creating non solid reference datum, modify, delete, suppress, redefine, and reorder features. Created geometric tolerances and surface finished on models, assign defines, and units, material properties or user specified mass properties to a model.

V. STATIC & FATIGUE ANALYSIS PROCEDURE

The present work deals with estimating the fatigue life of aluminum alloy wheel by conducting the tests under radial fatigue load and comparison of the same with that of finite element analysis. Fatigue life prediction using the stress approach is mostly based on local stress, because it is not possible to determine nominal stress for the individual critical areas.

The necessary material data for fatigue life prediction with the stress concept is the well known S–N curve. Therefore, S–N curves are required for each specimen which reflects the stress condition in the critical area of the component.

In the fatigue life evaluation of aluminum 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. In general, the newly designed wheel is tested in laboratory for its life through an accelerated fatigue test before the actual production starts. Based on these test results the wheel design is further modified for high strength and less weight, if required.

The specification of the wheel used in the project is as follows. In the present work the designation of the wheel employed: 17*6

Wheel Specifications	
Rim diameter	431.8mm
Rim width	152.4mm
Offset	45mm
PCD	100mm
Hub diameter	135mm

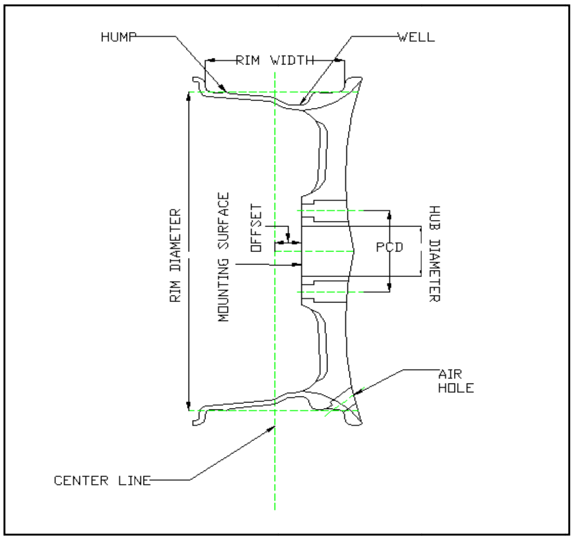

Figure 1. 2D Diagram of aluminum wheel

The 3-diemensional modal of the wheel was created in CATIA and the file was exported in the IGES (international graphics exchange specification) format into ANSYS. The 3-diemesional modal that was developed is shown in Fig. 2.

Figure 2. 3D Model of Aluminum alloy wheel

The mesh was meshed with 10- node tetrahedral structural solid elements. The wheel was meshed using an element edge length is 5mm. The total number of nodes and elements is212319 and 117243 respectively. The finite element realization of the wheel obtained is shown in Fig.3.

The meshing was performed using the mesh generate option in the ANSYS workbench.

Table 1: Properties of the Material (A356.2)

Structural	
Young's Modulus	69000 MPa
Poisson's Ratio	0.33
Density	2.685e-006 kg/mm³
Thermal Expansion	1.2e+005 1/°C
Tensile Yield Strength	229. MPa
Compressive Yield Strength	250. MPa
Tensile Ultimate Strength	279. MPa
Thermal	
Thermal Conductivity	6.05e-002 W/mm·°C
Specific Heat	434. J/kg·°C
Electromagnetics	
Relative Permeability	0.
Resistivity	0. Ohm·mm

Figure 3. Meshing of alloy wheel

VI. RESULTS AND DISCUSSIONS

In Table 1 and Table 2 properties of the material and alternating stress vs cycles is given. Also it is graphically denoted in Fig .4.

Table 2: Alternating Stress Vs Cycles

Cycles	Alternating Stress MPa
24076	234.12
34527	220.
51601	204.
77110	190.
1.1886e+005	175.59
1.8509e+005	160.
2.9425e+005	146.32
5.1319e+005	130.
8.7774e+005	117.06
1.7667e+006	100.
3.2e+006	87.76

In Fig.4 constant amplitude fully reversed load is given. Life and load of the wheel is shown in Fig.6.

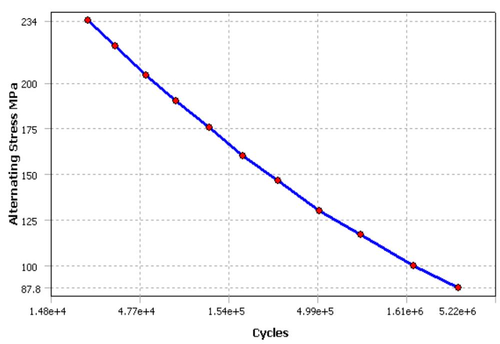

Figure 5 . Alternating Stress vs Cycle

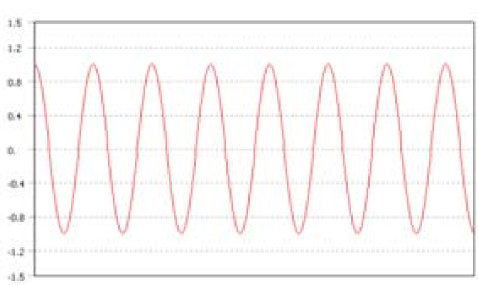

Figure 6. Constant amplitude fully reversed

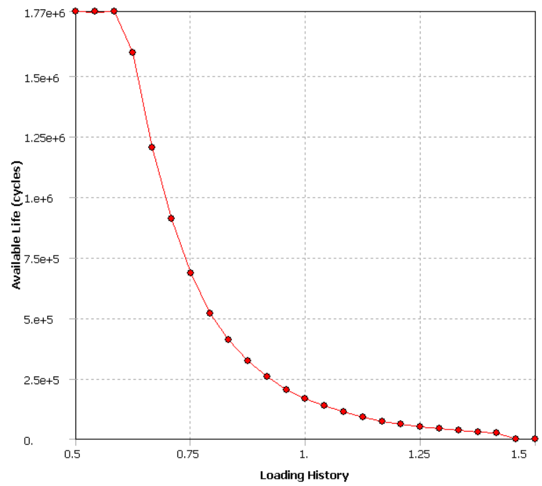

Figure 7. Life & Load

After completion of meshing we apply pressure 2.8653 Mpa at rim

The total deformation of wheel maximum is 0.2833mm and minimum is 0.031478 at hub portion. The alloy wheel of shear stress maximum is 48.195 and minimum is -48.241 at hub.

The equivalent stress is 163.97 and 0.038. The life of wheel maximum 1.7667e6 cycles and the minimum cycles of wheel is 1.6533e5 at a cross sectional area of wheel. The wheel safety maximum at a hub portion because the load is maximum acting at a rim. Minimum load is acting at a hub. The damage of wheel high at a cross sectional area of wheel spokes.

Finite element analysis is carried out by simulating the test conditions to analyze stress distribution and fatigue life, safety and damage of alloy wheel.

The S–N curve approach for predicting the fatigue life of alloy wheels by simulating static analysis with cyclic loads is found to converge with experimental results. Safety factors for fatigue life and radial load are suggested by conducting extensive parametric studies.

The proposed safety factors will be useful for manufacturers/designers for reliable fatigue life prediction of similar structural components subjected to radial fatigue load.

By using ANSYS we determine the total deformation and stresses developed in a alloy wheel.

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