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REVIEW ARTICLE

FATIGUE ANALYSIS OF ALUMINUM ALLOY WHEEL

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ABSTRACT

This paper deals with "Fatigue Analysis of Aluminum Alloy Wheel under various RPMs". During the part of project a static and fatigue analysis of aluminum alloy wheel was carried out using FEA package. The 3-dimensional model of the wheel was designed using UG (NX). Then the 3-D model was imported into ANSYS using the IGES format. The finite element idealization of this model was then produced. The analysis was performed in a static condition. This is constrained in all degree of freedom at the PCD and hub portion. The wheel is subjected to various RPMs. 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 fatigue sensitivity of alloy wheel.

Key Words: Aluminum Alloy Wheel, FEA, Unigraphics (NX), ANSYS.

INTRODUCTION

The wheel is a device that enables efficient movement of an object across a surface where there is a force pressing the object to the surface. Early wheels were simple wooden disks with a hole for the axle. Because of the structure of wood a horizontal slice of a trunk is not suitable, as it does not have the structural strength to support weight without collapsing; rounded pieces of longitudinal boards are required. The spoke wheel was invented more recently, and allowed the construction of lighter and swifter vehicles. Alloy wheels are automobile wheels which are made from an alloy of aluminum or magnesium metals (or sometimes a mixture of both). Alloy wheels differ from normal steel wheels because of their lighter weight, which improves the steering and the speed of the car, however some alloy wheels are heavier than the equivalent size steel wheel. Alloy wheels are also better heat conductors than steel wheels, improving heat dissipation from the brakes, which reduces the chance of brake failure in more demanding driving conditions. Over the years, achieving success in mechanical design has been made possible only after years of experience coupled with rigorous field-testing. Recently the procedures have significantly improved with the emergence of innovative method on experimental and analytical analysis. Alloy wheels intended for normal use on passenger cars have to pass three tests before going into production: the dynamic cornering fatigue test, the dynamic radial fatigue test, and the impact test. Many alloy wheels manufacturing company had done numerous amount of testing of their product but their method on simulation test on alloy wheel information often kept limited. Alloy wheels were first developed in the last sixties to meet the demand of race track enthusiasts who were constantly looking for an edge in performance and styling.

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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, allow 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. This paper is organized as follows: section II classification of alloy wheels. In section III we discuss different types of alloy wheels in automobile world. In section IV we discuss about alloy wheel imperfections. In section V work summarization. Finally, the paper concludes with section VI.

RELATED WORK

Fatigue as a technical problem became more evident around the middle of 19th 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 coworkers and others in 1930. 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.

FATIGUE ANALYSIS

Fatigue is one of the important material properties where the component subjected to cyclic loading. Due to cyclic loading, the materials undergone stress and nucleate micro cracks essentially on the surface of the component. It is understood that tensile stress is always assisted in nucleation and propagation of cracks and leads to failure. In the present investigation S-N curve (fatigue curve) is generated through FE analysis for the material used in the present investigation.

Fatigue is an important consideration for components and structures subjected to repeated loadings, 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 aluminium 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.

STATIC AND FATIGUE ANALYSIS PROCEDURE

The present work deals with estimating the fatigue life of aluminum alloy wheel by conducting the tests under various RPMs 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 3-dimensional model of the wheel was created in Unigraphics (NX) and the file was exported in IGES (International Graphics Exchange Specification) format into ANSYS. The 3-dimensional model that was developed is shown in the Figure 1.

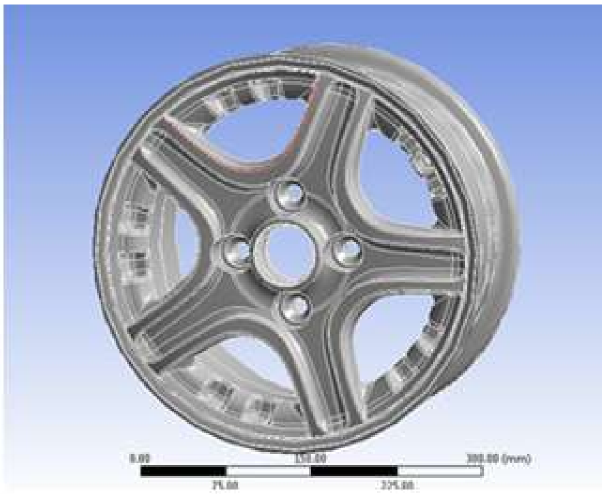

Figure 1. 3D model of Aluminium Alloy Wheel

Meshing is done by using ANSYS Workbench as shown in Figure 2.

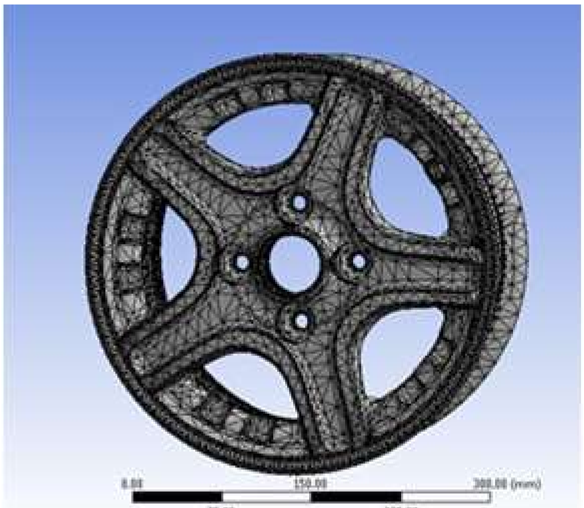

Figure 2. Meshing of Aluminium Alloy Wheel

RESULTS AND DISCUSSION

Results that are common to both types of fatigue analyses are listed below:

- Fatigue life
- Fatigue damage at a specified design life
- Fatigue factor of safety at a specified design life
- Fatigue sensitivity chart

The results that are only available for Stress Life are:

- Equivalent alternating stress

The results that are only available for Strain Life are:

- Hysteresis

Effects of various changes

Effect on Stress: Various values of RPMs were changed in the model and the stresses were computed with the help of ANSYS Workbench. The changes made and their respective effects are shown in the Figures as follows:

The maximum stress in the wheel with 2000rpms was found to be 1.35E+08 Pa. After changing the value to 2500rpms, as shown in Figure 3, the resulting maximum stress was computed to be 1.33E+08 Pa. Figure 4 shows the area of maximum stress. The maximum stress at different RPMs can be seen below respectively.

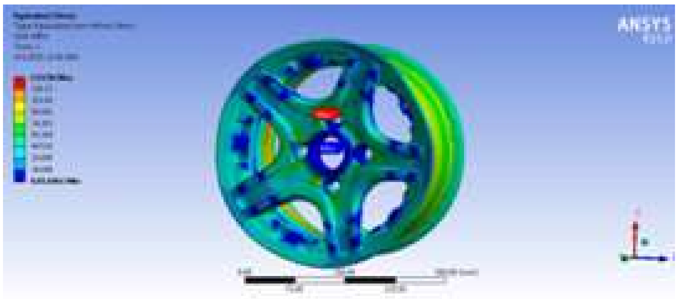

Figure 3. Static structural results on wheel

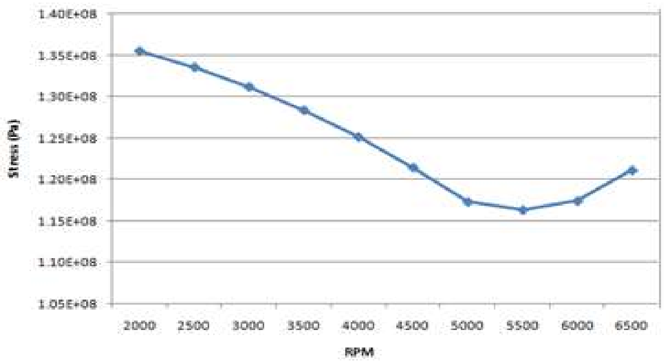

Figure 4. Stress Vs. RPM

Effect on Fatigue Life: With different values of RPMs, fatigue life also gets effected which is also computed with the help of ANSYS Workbench. The changes made and their respective effects are shown in the Figures as follows:
The minimum fatigue life of the wheel with 2000rpms was found to be 1.6307E+05 cycles. After changing the value to 2500rpms, as shown in Table 1, the resulting maximum stress was computed to be 1.8443E+05 cycles. Figure 5 shows the area of maximum stress. The minimum fatigue life at different RPMs can be seen below respectively.

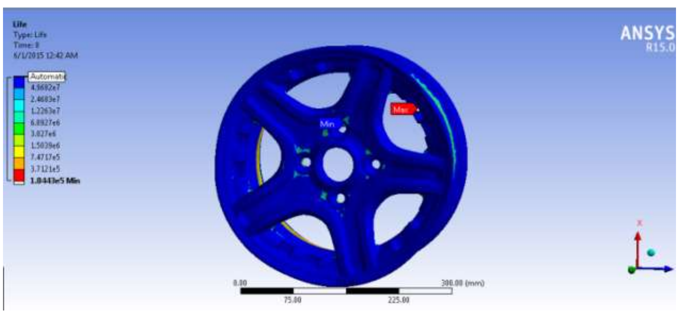

Figure 5. Fatigue life of Aluminium Alloy Wheel

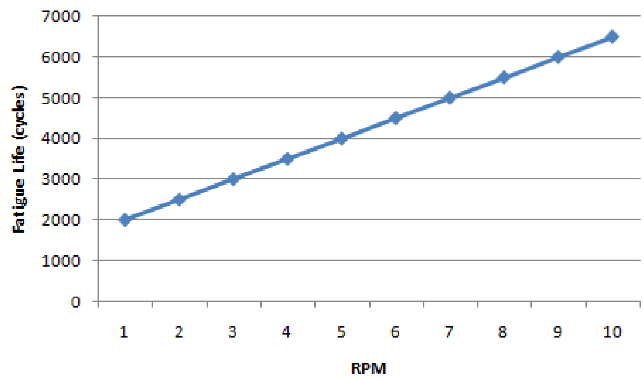

Figure 6. Fatigue Life Vs. RPM

Table 1. Change in Fatigue Life w.r.t.. RPM

RPM	Fatigue Life [Cycles]
2000	1.63E+05
2500	1.84E+05
3000	2.14E+05
3500	2.56E+05
4000	3.14E+05
4500	3.96E+05
5000	5.14E+05
5500	5.47E+05
6000	5.11E+05
6500	4.04E+05

In Table 2 alternating stress vs cycles is given. Also it is graphically denoted in Figure 7. The proposed safety factors will be useful for manufacturers/designers for reliable fatigue life prediction of similar structural components subjected to different RPMs.

Table 2. Change in Fatigue Life w.r.t. RPM

Cycles	Alternating Stress MPa
24076	1.63E+05
34527	1.84E+05
51601	2.14E+05
77110	2.56E+05
1.886e+05	3.14E+05
1.8509e+05	3.96E+05
2.9425e+05	5.14E+05
5.1319e+05	5.47E+05
8.7774e+05	5.11E+05
1.7667e+06	4.04E+05

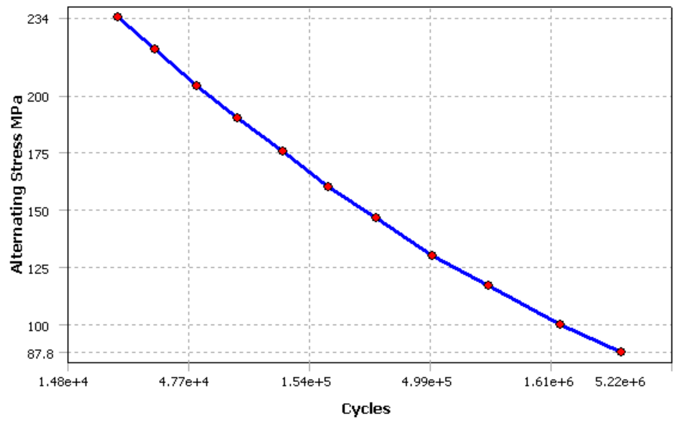

Figure 7. Alternating Stress vs Cycle

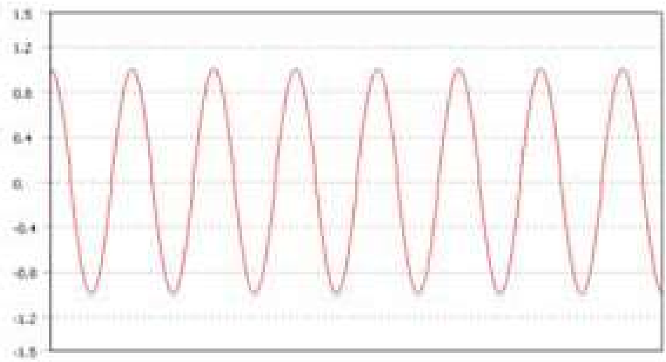

Figure 8. Constant amplitude fully reversed

Conclusion

From the study carried out, the following broad conclusions are arrived.

- Finite Element Analysis (FEA) offers a suitable alternative to the traditional techniques of testing and experimentation. By using ANSYS we determine the total deformation and stresses developed in a alloy wheel.
- The results obtained using FEA are close to the experimental results calculated using traditional methods.
- The areas of maximum stress can be easily visualized with the help of FEA.
- The accuracy of results by using the sub-modeling technique depends on
- meshing of the geometry model and defining the physical and material property values.
- The study of effects of various variations in the model using FEA is cost effective and time saving as compared to traditional techniques.

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