# STATIC AND FATIGUE ANALISYS OF ALUMINUM ALLOY WHEEL

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***Abstract*— The present thesis summarizes the application of Finite Element Analysis technique for analysing stress distribution and fatigue life of Aluminium alloy wheels subject to radial loads. Alloy wheels intended for use on passenger cars stipulate two types of fatigue tests, the Dynamic cornering fatigue test and the Dynamic radial fatigue test. As wheels undergo inconsistent, varying loads during their service life, fatigue behaviour is a key consideration in the design and performance evaluation. But, alloy wheels have more complex shapes than regular steel wheels, so it is difficult to assess fatigue life by analytical methods. Hence, Finite Element Analysis has been used to evaluate the performance of wheels over their life. The deflection for Alloy wheel Al 2024-T351 of this project is found to be around 0.164 mm which is much less than that of Aluminium A356.2 alloy wheel which is 0.2833mm.This shows that Al 2024-T351 is stiffer than Aluminium A356.2 alloy wheel. Static analysis results showed that the maximum shear stress and von- Mises stresses of A356.2 alloy wheel are 78.6% and 50% higher than the Al 2024-T351 alloy wheel.**

***Keywords*— Alloy wheel, Fatigue life, Fatigue failure**

## I. INTRODUCTION

Wheel is an important structural member of the vehicular suspension system that supports the static and dynamic loads encountered during vehicle operation. Since the rims, on which cars move, are the most vital elements in a vehicle, they must be designed carefully. Safety and economy are particularly of major concerns when designing a mechanical structure so that the people could use them safely and economically. Style, weight, manufacturability and performance are the four major technical issues related to the design of a new wheel and/or its optimization. The wheels are made of either steel or cast/forge Aluminum alloys. Aluminum is the metal with features of excellent lightness, corrosion resistance, etc. In particular, the rims, which are made of Aluminum casting alloys, are more preferable because of their weight and cost. In the real service conditions, the determination of mechanical behavior of the wheel is important, but the testing and inspection of the wheels during their development process is time consuming and costly.

## II. LITERATURE SURVEY

Fatigue analysis, as it known today has come a long way, 178 years ago, in 1837, Wilhelm Albert published the first article on fatigue, establishing a correlation between applied loads and durability. Two years later, in 1839, Jean-Victor Poncelet, designer of cast iron axles for mill wheels, officially used the term "fatigue" for the first time in a book on mechanics.[1]In19th century, it was considered to be mysterious that fatigue fracture did not show a visible plastic deformation. Systematic fatigue fractures tests were done in laboratories, notable by August Wohler. Fatigue was considered to be an engineering problem. [2]Fatigue is also the initiation and growth of a crack, or growth from a pre-existing defect, which progresses until a critical size is reached. [3]Aluminum wheels should not fail during service. In narrow sense, the term fatigue of materials and structural components means damage and damage due to cyclic, repeatedly applied stresses. [4]Traditionally, wheel design and development is very time consuming, because it needs a number of tests and design iterations before production.

## III FATIGUE ANALYSIS

It has been observed that material fail under fluctuating stresses. It is a stress magnitude which is lower than the ultimate tensile strength of the material the decreased resistance of the materials to fluctuating stresses is called FATIGUE.There is a basic difference between failure due to static load and that due to fatigue. The failure due to static load is illustrated by the simple tension test. And there is sufficient time for elongation of fibres. In this case the load is gradually applied. The fatigue failure begins with a crack at some point in the material. The crack is more likely to occur in the regions of discontinuity, such as oil holes, key ways, screw threads and regions in machining operations, such as scratches on the surface, stamp mark, inspection marks, internal crack due to defects in materials like holes etc. These regions are subjected to stress concentration due to the crack. The crack spreads due to fluctuating stresses, until the cross section of the component is so reduced that the remaining portion is subjected sudden fracture.

### A. FATIGUE LIMIT (ENDURANCE LIMIT)

The problem with Aluminium is it doesn't have a typical 'fatigue limit'. The more stress cycles that are imposed on Aluminium, the lower the stress cycles need to be to eventually result in failure. This is different than steel which has some distinct endurance limit. If a plot is drawn between peak alternating bending stress on y- axis against a log scale of life cycle on x- axis a knee in the curve at around $10^7$ cycles is appeared as shown in Fig.1, so by $10^8$cycles, the graph is almost flat. For Aluminium it isn't flat though, it continues to decline, meaning that as it continue to impose more cycles on test specimen, the peak alternating bending stress needed to result in failure continues to drop.

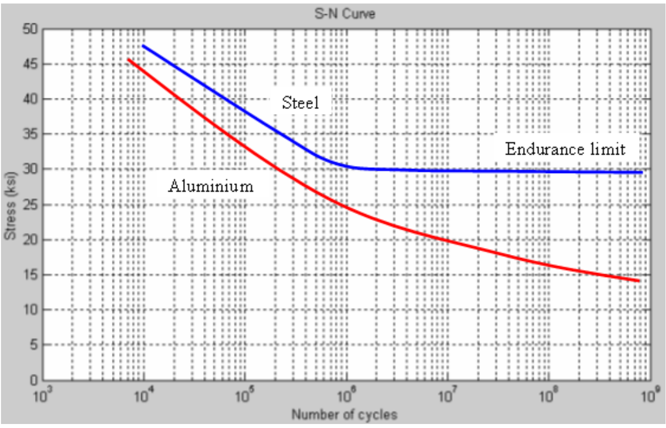


Fig.1 FATIGUE LIMIT

### B. FATIGUE FAILURE

Failure is one of most important aspects of material behaviour because it is directly influence the selection of material for certain application, the method of manufacturing and service life of component. Fatigue, or metal fatigue, is the failure of a component as a result of cyclic stress. The failure occurs in three phases: crack initiation, crack propagation, and catastrophic overload failure. The duration of each of these three phases depends on many factors including fundamental raw material characteristics, magnitude and orientation of applied stresses, processing history, etc. Fatigue failures often result from applied stress levels significantly below those necessary to cause static failure. Fatigue failures are typically characterized as either low-cycle (<1,000 cycles) or high-cycle (>1,000 cycles). The threshold value dividing low- and high-cycle fatigue is somewhat arbitrary, but is generally based on the raw material's behaviour at the micro structural level in response to the applied stresses. Low cycle failures typically involve significant plastic deformation .

Fig.2 FATIGUE FAILURE ON A WHEEL RIM

Fatigue failure is also due to crack formation and propagation. A fatigue crack will typically initiate at a discontinuity in the material where the cyclic stress is a maximum. Fatigue fracture typically occurs in material of basically brittle nature. External or internal cracks develop at pre-existing flaws or fault of defects in the material; these cracks then propagate and eventually they lead to total failure of part. The fracture surface in fatigue is generally characterized by the term "beach marks". Fatigue failure on a wheel rim is shown in Fig.2.

## IV . MODALING OF ALLOY WHEEL USING CATIA

### FEATURES OF CATIA

- Easy accessible software
- Predefined shapes
- Powerful in surfacing
- User pattern facilities
- Supports CSG and feature based
- Retrieving data is very easy

This is powerful program used to create complex designs with a great precision. The design intent of any 3-D modal of any assembly defined by its specification CATIA can be used to capture the design. Intent of any complex modal by incorporating intelligence to the design. To make the designing process simple and easy. The 3-D modal of the wheel was created in CATIA and the file was exported in the IGES (International Graphics Exchange Specification) format into ANSYS.

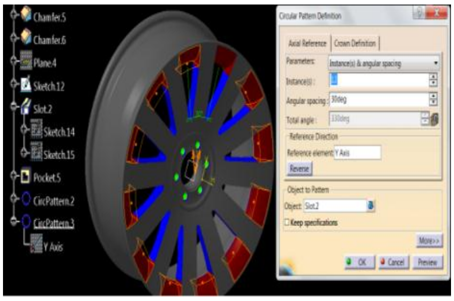


Fig.3 A 3-D model wheel created in CATIA

## V *FATIGUE ANALYSIS USING FEA PACKAGE*

The Finite Element Analysis 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. Now a days, even the most simple products rely on the Finite Element Method for design evaluation. This is because contemporary design usually cannot be solved as accurately & cheaply as FEM, using any other method that is currently available. Physical testing was the norm in years gone by, but now it is simply too expensive and time consuming.

The finite element method is a very important tool for those involved in engineering design; it is now used routinely to solve problems in the following areas:

- Structural Strength design
- Structural interaction with fluid flows
- Analysis of shock (underwater & in materials)
- Acoustics
- Thermal analysis
- Vibrations
- Crash simulations
- Fluid flows
- Electrical analyses
- Mass diffusion
- Buckling problems
- Dynamic analyses
- Electromagnetic evaluations
- Metal forming
- Coupled analyses

## VI. *RESULTS*

Static and Fatigue results are shown in Table1 and Table2

*TABLE 1*

*STATIC STRUCTURAL RESULTS*

| **Definition** | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Type** | **Von – Mises stress** | | **Shear stress** | | **Total deformation** | | **Directional deformation** |
| **Results** | | | | | | | |
| **Alloys** | | | | | | | |
| | **A 356.2** | **Al 2024** | **A 356.2** | **Al 2024** | **A356.2** | **Al 2024** | |
| **Minimum** | **3.8842e-002MPa** | **3.8842e-002MPa** | **-48.241 MPa** | **-48.241 MPa** | **0 mm** | **0 mm** | **-0.20193 mm** |
| **Maximum** | **163.97 MPa** | **81.985 MPa** | **48.195 MPa** | **24.097 MPa** | **0.283m** | **0.164 mm** | **0.20205 mm** |

*TABLE 2*

*FATIGUE RESULTS*

| Definition | | | | | |
|---|---|---|---|---|---|
| Type | Life | | Safety factor | Equivalent alternating stress | |
| Design life | 1.e+009 cycles | | | | |
| Results | | | | | |
| Alloys | A 356.2 | Al 2024 | | A 356.2 | Al 2024 |
| Minimum | 1.653e+005cycles | 1.653e+005cycles | 0.60985 | 3.88e-002MPa | 3.88e-002MPa |
| Maximum | 1.766e+006cycles | 1.767e+006cycles | 15 | **163.97 MPa** | **128.88 MPa** |

### B. *RESULTS WITH IMAGES*

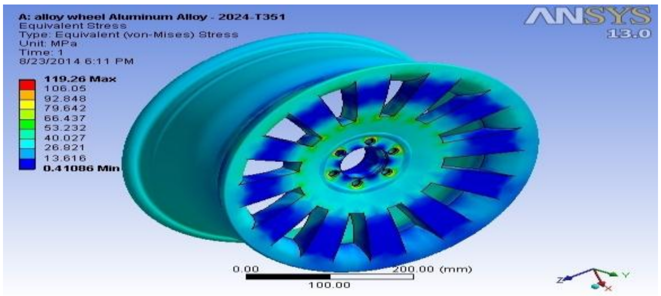


Fig. 4 Equivalent Stress on the Wheel

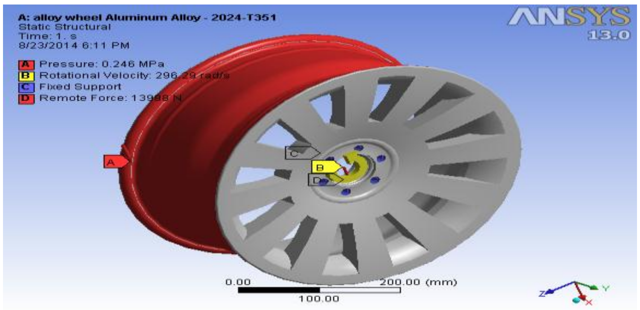


Fig. 5 Pressure acting on the Wheel

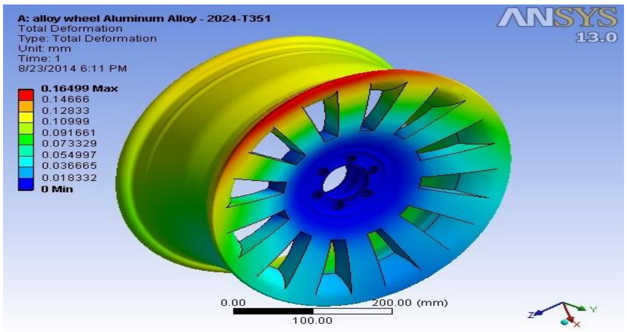


Fig. 6 Total Deformation of the Wheel

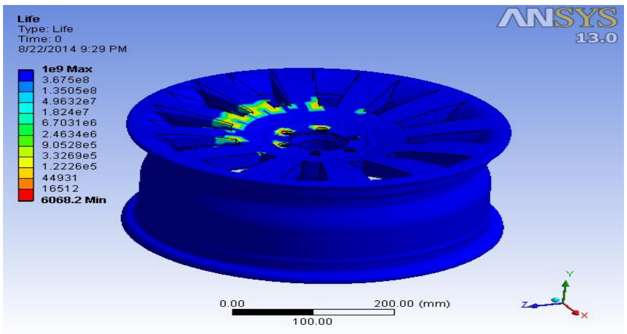


Fig7 Life of the Wheel

## VII. CONCLUSIONS

- The wheel is analyzed for the calculated loading condition and the relevant stress is obtained
- . In the case of pressure loading along with radial load, Von Mises stress obtained shows the maximum stress the wheel experiences under the pressure load and on the portion of the rim there is a gradual transition from compression to tension.
- For predicting the fatigue life of Aluminum alloy wheel the S – N curve approach is used.
- The proposed safety factors will be useful for manufacturers/ designers for reliable fatigue life prediction of similar structural components subjected to radial fatigue load.
- . From the analysis, finally, it can be concluded that as the speed increases Stress , displacement increases and life decreases.

## VIII. REFERENCES

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