Analysis and Weight Optimization of Aluminum Alloy Wheel by Consideration of Natural Frequency of NVH Limit

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Abstract: Aluminum wheels should not fail during service. Their strength and fatigue life are critical. In order to reduce costs, design for light-weight and limited-life is increasingly being used for all vehicle components. In the actual product development, the rotary fatigue test is used to detect the strength and fatigue life of the wheel. Therefore, a reliable design and test procedure is required to guarantee the service strength under operational conditions and full functioning of the wheel. Loads generated during the assembly may cause significant levels of stress in components.

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. STRUCTURE OF WHEEL

Wheel and tyre are coupled which determines the direction of car and they ensure that cars moves. Wheel is a rotating load-carrying member between the tyre and the hub. It usually consists of two major parts: the rim; the wheel disc. The rim and wheel disc may be integral, permanently attached or detachable. Wheel nomenclature is stated in SAEJ1982 DEC91 (2) as below.

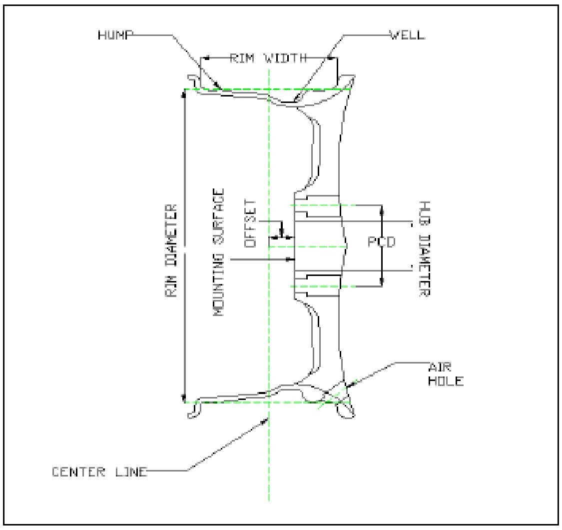


Fig 1. 2D Diagram of Alloy Wheel

III. LITERATURE SURVEY

- **Fatigue Analysis of Aluminum Alloy Wheel under Radial Load**

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. Fatigue as a technical problem became more evident around the middle of 19th century. About 100 years later, in the middle of 20th 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.

- **Fatigue Life Analysis of Aluminum Wheels by Simulation of Rotary Fatigue Test**

A fatigue lifetime prediction method of aluminum alloy wheels was proposed to ensure their durability at the initial design stage. To simulate the rotary fatigue test, static load FEM model was built using ABAQUS. The analysis results showed that the maximum stress area was located in the hub bolt hole area agreed with the fact. Therefore, the finite element model can achieve results consistent with that obtained from the actual static load test. The nominal stress method was used to predict the fatigue life of aluminum alloy wheels. In the nominal stress method, the fatigue life of aluminum wheels was predicted by using aluminum alloy wheel *S-N* curve and equivalent stress amplitude. The simulation result showed that baseline design fatigue life was lower than 1 × 105. After improving the weakness area of aluminum alloy wheels, the improved wheel life cycle exceeded 1 × 105 and satisfied the design requirement. Aluminum alloy wheel rotary fatigue bench test was conducted. The test result showed that the prediction of fatigue life was consistent with the physical test result. These results indicate that the fatigue life simulation can predict weakness area and is useful for improving aluminum alloy wheel. These results also indicate that integrating FEA and nominal stress method is a good and efficient method to predict aluminum alloy wheels fatigue life.

- **Simulation test of Automotive Alloy Wheel using Computer Aided Engineering Software**

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. Earlier 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.

IV. METHODOLOGY

In recent years, competition in the automobile market is getting increase with respect to fuel economy, especially for the light commercial vehicles. Moreover, there is a significant necessity about reducing fuel consumption level for automobile companies. The weight of a vehicle is one of the most important factor that affecting the fuel economy.

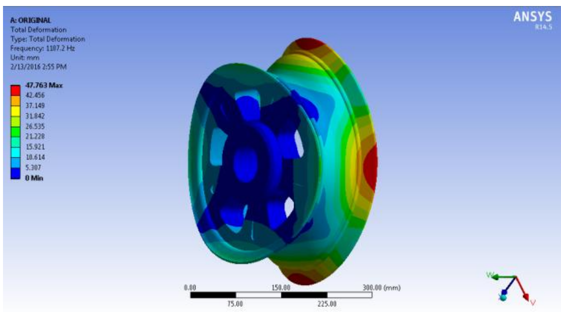
The weight minimization of wheel has more effective than the weight minimization of elsewhere in a vehicle due to the rotational moment of inertia effect during motion.

Therefore, the wheel design should be optimized by considering fundamental attributes of a light commercial vehicle such as NVH, Durability and Weight.

In this study, the modal correlation between CAE simulations and tests is performed. For this purpose, mode shapes and their natural frequencies obtained from CAE simulations are compared with experimental modal analysis results. After the correlation is provided, wheel design optimization proposals are given by considering NVH and Durability criteria.

V. MODELLING AND ANALYSIS WORK

- **EXISTING ALLOY WHEEL MODAL ANALYSIS**



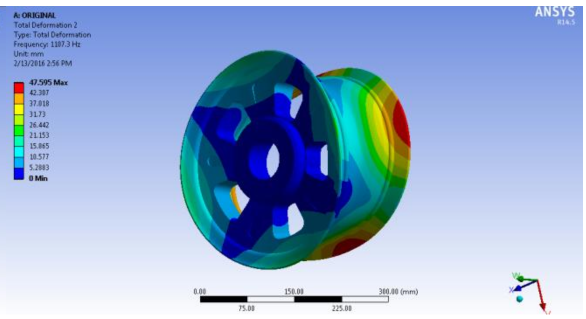


Fig2. 1st Mode of Vibration

Fig3. 2nd Mode of Vibration

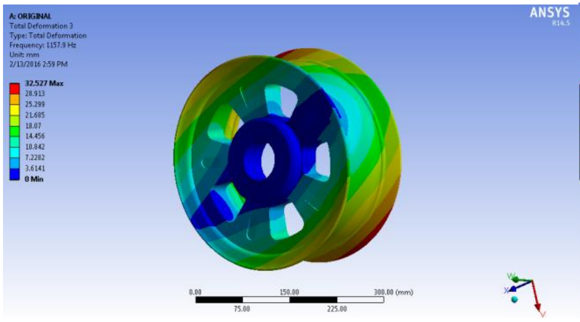


Fig4. 3rd Mode of Vibration

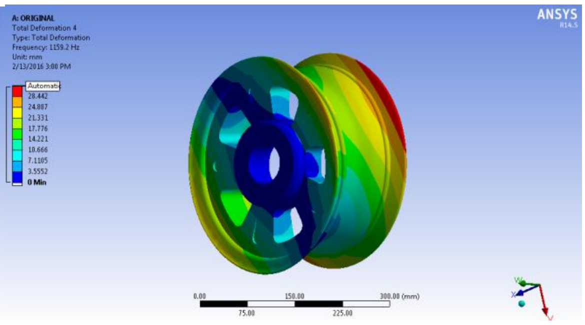


Fig5. 4th Mode of Vibration

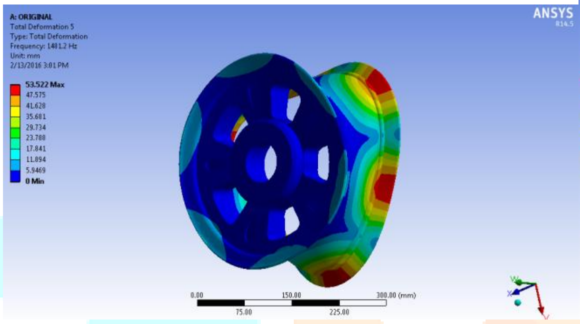


Fig6. 5th Mode of Vibration

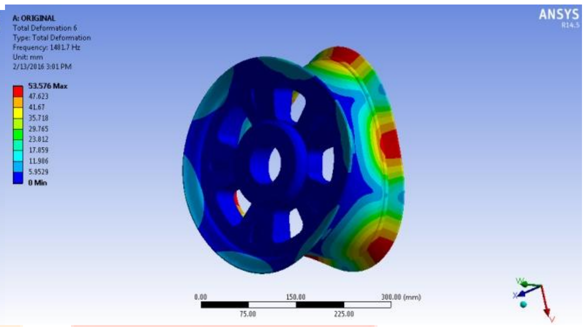


Fig7. 6th Mode of Vibration

- **OPTIMIZED ALLOY WHEEL MODAL ANALYSIS**

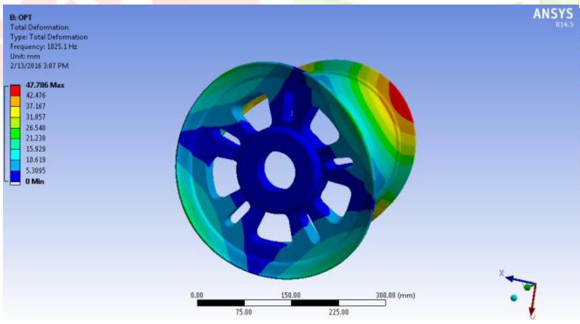


Fig8. 1st Mode of Vibration

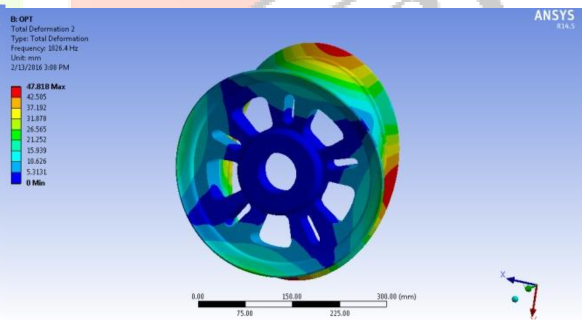


Fig9. 2nd Mode of Vibration

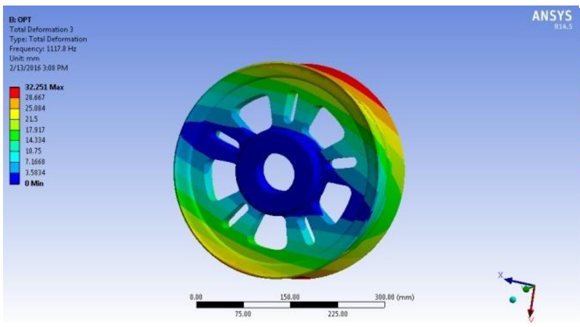


Fig10. 3rd Mode of Vibration

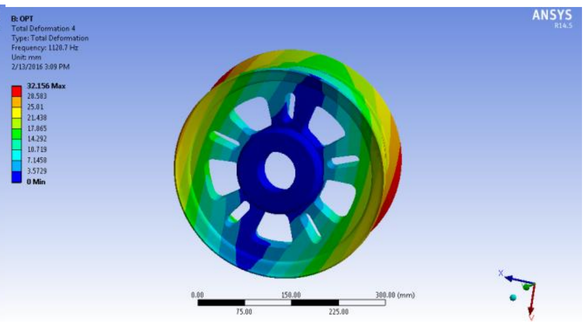


Fig11. 4th Mode of Vibration

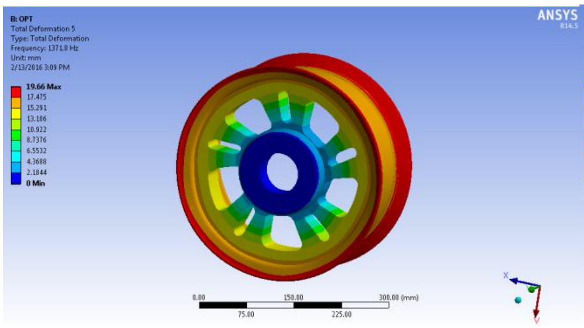


Fig12. 5th Mode of Vibration

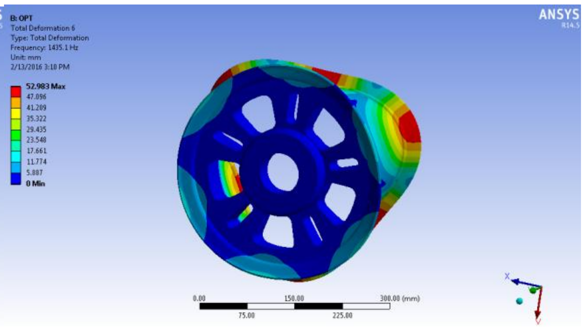


Fig13. 6th Mode of Vibration

VI. CONCLUSION

The fundamental natural frequency of light commercial vehicle wheel representing the dynamic behaviour of real alloy wheel is 1107.2Hz. 82.1 Hz frequency has been sacrificed from fundamental natural frequency for new design modification suggestion but new fundamental frequency is still greater than 350 Hz which is interior noise limit, so this proposal is acceptable from NVH point of view.

VII. REFERENCE

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