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A Review on Fatigue Life Prediction of a Heavy Vehicle Steel Wheel by using finite Element Analysis

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Abstract

This review reports the state of the art in modeling chemical and physical processes of Wheels have vital importance for the safety of the vehicle and a special care is needed in order to ensure their durability. The development of the vehicle industry has strongly influenced the design, the material selection and the manufacturing processes of the wheels. The wheels loading manner is a complex one; further improvement and efficient wheel design will be possible only if their loading will be better understood.

In this paper, the review about various papers which is based on analyzed with the finite element method, using the different loading test. The static stresses are studied in order to find the zones with higher stress concentration and to suggest the better design solution.

Keywords: fatigue life, wheel analysis, finite element analysis.

Objective of the Work

The aim of this paper is to establish the basis for further research: not only to outline the scope of the study and review the subjects belonging within the scope, but also to analyze the relationships between reviewed subjects. The main research will be focused on :

Stress Concentrators in order to understand where fatigue occurs.

Fatigue crack propagation in order to understand how fatigue occurs.

Fatigue life prediction methods in order to review existing approaches destined to analyze when fatigue occurs.

Introductions

The word fatigue comes from the Latin verb fatigue - "to tire". There are many ways to define engineering fatigue, some of them, are given below;

Definition evoking technical aspects of the word 'fatigue' is: fatigue is a term, which applies to changes in properties which can occur in a metallic material due to the repeated application of stresses and strains, although usually this term applies specially to those changes which lead to cracking and failure.

Another definition related to the word 'Fatigue' is: fatigue shows the inability of an engineer to design structures that support relatively small cyclic loads for a long time.

There has been research in the area of fatigue : Some of the earliest research was conducted during the first half of the nineteenth century. Some milestones during the development of fatigue science are well worth noting and are listed herein

1829 Albert, the German mining engineer, performed the first probable study of metal fatigue [2]. He rendered repeated load proof tests on mine-hoist chains made of iron.

1839 Poncelet introduced the term fatigue in connection with metal failure.

1843 W. J. M. Rankine, a British railway engineer, recognized the distinctive characteristics of fatigue fractures and noted the dangers of stress concentrations in machine components.

1860 Wöhler conducted systematic investigations of fatigue failure in railroad axles for the German Railway Industry. He observed that the strength of the steel axles subjected to cyclic loads was much lower than the static strength. His work also led to the characterization of fatigue behavior using stress amplitude-life (S-N) curves and the concept of the fatigue 'endurance limit'.

1910 Basquin proposed empirical laws to characterize the fatigue endurance limit of materials.

1913 Inglis , by using stress analyses, and

1921 Griffith, by using an energy concept, provided the mathematical tools for quantitative treatments of fracture in brittle solids.

1924 Palmgren developed a damage accumulation model for fatigue failure.

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1939 Westergaard developed a method to determine the stress and displacement field ahead of the sharp crack tip.

1945 Miner developed a damage accumulation model for fatigue failure.

1954 Coffin and Manson discovered independently that plastic strains are responsible for cyclic damage. They proposed an empirical relationship between the number of load reversals to fatigue failure and the plastic strain amplitude.

1957 Irwin showed that the amplitude of the stress singularity ahead of the crack could be expressed in terms of a scalar quantity known as the stress intensity factor (K).

1960 Dugdale [7] and 1962 Barrenblatt [8] introduced simple crack models.

1961Paris, Gomez and Andersonwere the first to suggest that fatigue crack propagation rate per stress cycle, da/dN, could be related to the range of the stress intensity factor, ΔK.

1970 Elber showed that fatigue cracks could remain closed even when subjected to cyclic tensile loads. His work created a base for development of the crack-closure concept.

Fatigue can be classified by the form in which it occurs : mechanical, creep, thermo mechanical, corrosion, rolling contact, and fretting fatigue (Suresh [5]). Fatigue can also be classified by the duration of the fatigue life : low-cycle and high-cycle fatigue. This study only examines Mechanical and high-cycle fatigue - the most common fatigue types in civil engineering.

A fatigue crack can propagate in three modes, depending on the relative orientation of loading to the crack (Figure 2.1). This study focuses on mode I crack growth - the most common crack propagation mode.

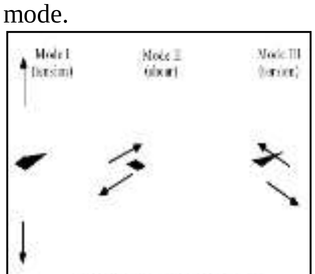

Figure 2.1 : Crack propagation modes

Stress Concentrators

Complex structural details contain regions where there are changes in geometry. These regions are called stress concentrators (Figure 2.2). Local stress fields near stress concentrators are considerably larger than nominal stress away from the stress concentrators.

Fatigue cracks typically appear near the stress concentrators. The stress concentrators, leading to the appearance of fatigue cracking, can be called crack initiators . Crack initiators can be holes, welds, notches, or regions where material structure changes. The fatigue crack itself is also a stress concentrator because a very intense stress field is present around the crack tip. In this study, the stress concentrators are classified into two groups : crack initiators and fatigue cracks

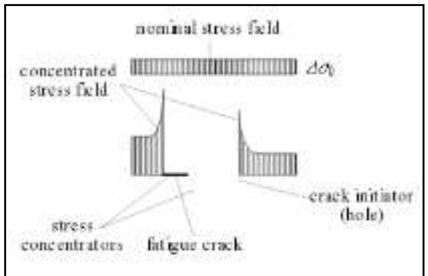

Figure 2.2 : Stress concentrators

The influence of the stress concentrators on fatigue behavior can be characterized by the linear-elastic stress field generated around the stress concentrator. Calculation of the linear-elastic stress field depends on the geometry of the stress concentrator. The geometry of the crack initiators usually differs from the geometry of the fatigue cracks; therefore, the calculation of the linear-elastic stress field around the crack initiators will be discussed separately of the calculation of the linear-elastic stress field around the fatigue crack.

Static & Fatigue Analysis Procedure

The proposed 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

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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.

Literature Review of Previous Work

Fatigue life prediction of a heavy vehicle steel wheel under radial loads by using finite element analysis by N.S. Kuralay et al.(Failure Analysis 20 (2012)) gives analysis about The origin of fatigue failure that occurs on the air ventilation holes of a newly designed heavy commercial vehicle steel wheel in dynamic radial fatigue tests is studied. In these tests, all of the test samples failed in the same regions. The cause of this damage was studied via **finite element analysis**. In order to determine the reason of the fatigue failure, stress analysis was performed via the finite element method. In this way, stress concentrated regions, where fatigue failure is expected, were determined. ***Mechanical properties of the wheel material were determined by tensile tests and hardness measurements.*** The fatigue life of the damaged wheel was estimated using the stress–life (S–N) approach, utilizing the ultimate tensile strength of the processed wheel material and the Marin factors determined for the critical regions. To extend the life of the wheel disc and delay the onset of fatigue, design enhancement solutions were applied.

Fatigue Life Analysis of Aluminum Wheels by Simulation of Rotary Fatigue Test by Liangmo Wang et al. (Journal of Mechanical Engineering 57(2011)) explain how To improve the quality of aluminum wheels, a new method for evaluating the fatigue life of aluminum wheels is proposed in this paper. The **ABAQUS software** was used to build the static load finite element model of aluminum wheels for simulating the rotary fatigue test. ***The equivalent stress amplitude was calculated based on the nominal stress method by considering the effects of mean load, size, fatigue notch, surface finish and scatter factors. The fatigue life of aluminum wheels was predicted by using the equivalent stress amplitude and aluminum alloy wheel S-N curve.*** The results from the aluminum wheel rotary fatigue bench test showed that the baseline wheel failed the test and its crack initiation was around the hub bolt hole area that agreed with the simulation. Using the method proposed in this paper, the wheel life cycle was improved to over 1.0×10^5 and satisfied the design requirement. The results indicated that the proposed method of integrating finite element analysis and nominal stress method was a good and efficient method to predict the fatigue life of aluminum wheels.

N. Satyanarayana & Ch.Sambaiah et. al. Fatigue Analysis of Aluminum Alloy Wheel Under Radial Load by gives 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***.

Structural and Fatigue Analysis of Two Wheeler Lighter Weight Alloy Wheel by M. Saran Theja et al. (IOSR Journal of Mechanical and Civil Engineering) gives the vehicle may be towed without the engine but at the same time even that is also not possible without the wheels, the wheels along the tire has to carry the vehicle load, provide cushioning effect and cope with the steering control. *Generally wheel spokes are the supports consisting of a radial member of a wheel joining the hub to the rim. The most commonly used materials for making Wheel spokes are with features of excellent lightness, thermal conductivity, corrosion resistance, characteristics of casting, low temperature, high damping property, machine processing and recycling, etc.* This metal main advantage is reduced weight, high accuracy and design choices of the wheel. This metal is useful for energy conservation because it is possible to re-cycle. Spokes make vehicles look great but at the same time they require attention in maintenance. To perform their functions best, the spokes must be kept under the right amount of tension.

The two main types of motorcycle rims are solid wheels, in which case the rim and spokes are all cast as one unit and the other spoke wheels, where the motorcycle rims are laced with spokes. These types of wheels require unusually high spoke tension, since the load is carried by fewer spokes. If a spoke does break, the wheel generally becomes instantly unridable also the hub may break. Presently, for motor-cycles Aluminium alloy wheels are used, currently now replacing by new magnesium alloy due its better properties than Al-alloy. ***An important implication of this paper or the problem stated here is to “analyses the stress and the displacement***

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distribution comparing the results obtained". In addition, this work extends Proper analysis of the wheel plays an important role for the safety of the rider. This paper deals with the static &fatigue analysis of the wheel. The present work attempts to analyse the safe load of the alloy wheel, which will indicate the safe drive is possible.

A typical alloy wheel configuration of ***Suzuki GS150R*** commercial vehicle is chosen ***for study***. Finite element analysis has been carried out to determine the safe stresses and pay loads.

Alexandru Valentin et al. "Mechanical testing methods concerning the stress analysis for a vehicle wheel rim" (Mechanical Testing and Diagnosis ISSN 2247 – 9635, 2012) inform about life of wheels.

Wheels have vital importance for the safety of the vehicle and a special care is needed in order to ensure their durability. The development of the vehicle industry has strongly influenced the design, the material selection and the manufacturing processes of the wheels. The wheels loading manner is a complex one; further improvement and efficient wheel design will be possible only if their loading will be better understood.

In that paper, ***the car rim is analyzed with the finite element method***, using the 400 loading test. The static stresses are studied in order to find the zones with higher stress concentration and to suggest the better design solution. The results have been compared to those obtained using an experimental stand.

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