TRANSIENT ANALYSIS AND RANDOM VIBRATION ANALYSIS OF TITANIUM WHEEL UNDER RADIAL LOAD

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ABSTRACT

Although steel is the most common material used in wheel production which is an alloy of iron and carbon, but the term "alloy wheel" is usually reserved for wheels made from nonferrous alloys. Alloy wheels are wheels that are usually made from materials like aluminium, magnesium or titanium and mostly are mixtures of metal and other elements. They generally provide greater strength over pure metals, which are usually much softer and more ductile. Alloys are typically lighter for the same strength, provide better heat conduction, and often produce improved cosmetic appearance over steel wheels. In this research we proposed a detailed “Transient Analysis and Random Vibration Analysis of Alloy Wheel under Radial Load”. During the part of project a transient and random vibration analysis of alloy wheel was carried out using FEA package. The 3 dimensional model of the wheel was designed using SolidWorks. Then the 3-D model was imported into ANSYS using the IGES format. The study of stress generation due to time varying load and vibration in the titanium alloy wheel is done in transit vibration and random vibration.

Keywords:-FEM, ANSYS, Transient analysis, random vibration

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INTRODUCTION

Alloy wheels are wheels that are made from an alloy of aluminum or magnesium. Alloys are mixtures of metal and other elements. They generally provide greater strength over pure metals, which are usually much softer and more ductile. Alloys of aluminum or magnesium are typically lighter for the same strength, provide better heat conduction, and often produce improved cosmetic appearance over steel wheels. Although steel, the most common material used in wheel production, is an alloy of iron and carbon, the term "alloy wheel" is usually reserved for wheels made from nonferrous alloys. The earliest light-alloy wheels were made of magnesium alloys. Although they lost favor on common vehicles, they remained popular through the 1960s, albeit in very limited numbers. In the mid-to-late 1960s, aluminum-casting refinements allowed the manufacture of safer wheels that were not as brittle. Until this time, most aluminum wheels suffered from low ductility, usually ranging from 2-3% elongation. Because light-alloy wheels at the time that were often made of magnesium (often referred to as "mages"), these early wheel failures were later attributed to magnesium's low ductility, when in many instances these wheels were poorly cast aluminum alloy wheels. Once these aluminum casting improvements were more widely adopted, the aluminum wheel took the place of magnesium as low cost, high-performance wheels for motorsports. 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 wit high pried custom alloy wheels. Since its adoption by OEM’s, the alloy wheel market has been steadily growing.

1.2 Finite Element Methods (FEM)

To be competitive in a changing market it is necessary to deliver reliable products in the shortest period of time possible. Increasing competition and innovations in automobile sector tends to modify the existing products or replace old products by new and advanced products. Finite Element Analysis (FEA) was first developed in 1943 by R. Courant, who utilized the Ritz method of numerical analysis and minimization of variation calculus to obtain approximate solutions to vibration systems. Shortly thereafter, a paper published in 1956 by Turner established a broader definition of numerical analysis. The paper centered on the "stiffness and deflection of complex structures". By the early 70's, FEA was limited to expensive mainframe computers generally owned by the aeronautics, automotive, defense, and nuclear industries. Since the rapid decline in the cost of computers and the phenomenal increase in computing power, FEA has been developed to an incredible precision. Present day supercomputers are now able to produce accurate results for all kinds of parameters. Before the advancement of personal computers, only few institutions were able to perform Finite Element Analysis, making the design process extensive and exclusive in the automobile and aeronautic industries. The Finite Element Analysis (FEA) or Finite Element Method (FEM) is a numerical technique, which could give near accurate solutions to complex field problems. Basically this method involves dividing the complex structures into known number of smaller structures or elements. This ability of the method is called discretization or meshing, which makes the technique more effective in analyzing irregular shaped structures in a variety of engineering problems. Mathematically it is nothing but representing most of physical problems in terms of mathematical models formed by differential and integral equations. Complexities such as irregular shape of the object or boundary conditions involved in the physical problems can make these equations almost impossible to solve directly. In this situation finite element analysis technique is adopted to obtain near accurate solution for the physical problem by approximately solving the governing equations, which could not be solved otherwise.

The traditional product development process is based on fundamental engineering equations and effective in analyzing regular shaped simple problems. However for complex physical problems the design process is more dependent on extensive testing, which normally makes the process expensive. The modern product development process with FEA technology does not eliminate the product testing process, but its ability to analyze complex physical problem easily and effectively can reduce the initial prototype testing in the design stages of the product development process. This makes FEA technology valuable in today’s competitive industrial environment. Therefore in this research the solution is sought for a structural problem, originally designed by the traditional method. The following section discusses how the FEA technology is adopted in the product development process of the lock, which is originally designed by the traditional product development process. FEA uses a complex system of points called nodes which make a grid called a mesh. This mesh is programmed to contain the material and structural properties which define how the structure will react to certain loading conditions.

Nodes are assigned at a certain density throughout the material depending on the anticipated stress levels of a particular area. Regions which will receive large amounts of stress usually have a higher node density than those which experience little or no stress. Points of interest may consist of: fracture point of previously tested material, fillets, corners, complex detail, and high stress areas. The mesh acts like a spider web in that from each node, there extends a mesh element to each of the adjacent nodes.

1. LITERATURE REVIEW

Hardy et al. [1996] degrade the phase noise of quartz crystal oscillators under vibration, mainly due to the acceleration sensitivity of the quartz crystal element. It is shown that if a crystal mount resonance is excited by a random vibration profile then the phase noise close to the carrier, outside the random vibration profile, can be further substantially degraded. A consequence is that the vibration sensitivity would seem to increase rapidly at low vibration frequencies. For example, a crystal oscillator with a resonance at 1950 Hz subjected to a random vibration profile of 0.01 g2/Hz extending from 100 Hz to 3000 Hz compared with a profile of 100 to 500 Hz , where the resonance is not excited, can have over 40 dB degradation in the phase noise at 20 Hz from the carrier. The resonance level is shown to become non-linear with vibration power, possibly due to the large acceleration amplification of the resonance, 100 to 300 times. The vibration level where the resonance becomes non-linear varies by two orders of magnitude and starts as low as 0.0003 g2/Hz This phenomenon is demonstrated for four oscillators and investigated under varying acceleration levels in an attempt to quantify the nonlinear behavior. The nonlinear behavior of the resonance is believed to produce intermodulation of the mechanical vibration which leads to the degradation of the close to carrier phase noise.

Noori et al. [2000] observed that intelligent and adaptive material systems and structures have become very important in engineering applications. The basic characteristic of these systems is the ability to adapt to the environmental conditions. A new class of materials with promising applications in structural and mechanical systems is shape memory alloy (SMA). The mechanical behavior of shape memory alloys in particular shows a strong dependence on temperature. This property provides opportunities for the utilization of SMAs in actuators or energy dissipation devices. However, the behavior of systems containing shape memory components under random excitation has not yet been addressed in the literature. Such a study is important to verify the feasibility of using SMAs in structural systems. In this work a nondeterministic study of the dynamic behavior of a single-degree-of-freedom (SDOF) mechanical system, having a Nitinol spring as a restoring force element is presented. The SMA spring is characterized using a one-dimensional phenomenological constitutive model based on the classical Devonshire theory. Response statistics for zero mean random vibration of the SDOF under a wide range of temperature is obtained. Furthermore, nonzero mean analysis of these systems is carried out.

China et al. [2006] established a numerical model for new grain refinements of aluminum alloys automobile wheel, based on the traditional solidification mechanism. It is assumed that the constitutional under cooling generated by growth of a grain is equivalent to the under cooling required for nucleation of another adjacent grain; and the distance between nucleation events is defined as the relative grain size in the final microstructure; the negative thermal gradient and the latent heat at the grain-liquid interface are negligible in comparison to the amount of constitutional under cooling; the thermal physical parameters are fixed. On the basis of numerical model results, the constitutional under cooling and the relative grain size of the grain refinements have been calculated. The nucleation under cooling of the new grain is about 0.5-1.0K, which is lower than traditional aluminium alloys by 0.3-0.5K. The numerical model results can be used to investigate the grain refinement mechanism, and the new grain refinements can be used to produce aluminium alloys automobile wheel.

Han et al. [2006] studied the microstructure and properties of wheels from a low pressure casting A356 alloy. Present studies focus effect of intermetallic phases on mechanical properties of cast A356 alloy wheels. It was found that each alloy has different types of intermetallic phase in the microstructure. Also, low pressure casting A356 alloy wheel were remelted and tested for mechanical properties. It shows that 5976 alloy containing higher iron shows the decreased in strength and elongation. However, the hardness is higher than 5975 alloy. This is mainly due to the presence of brittle P-AlSiFe phase in the microstructure. The large size of 13-AlSiFe phase was usually precipitated in the slow solidification area.

Hsu et al. [2006] investigate the effects of board-level drop test based on the support excitation scheme incorporated with the sub model technique for stacked die packages. This paper also demonstrates the transient dynamic response for lead-free SAC405 (95.5Sn4Ag0.5Cu) solder balls subject to JEDEC pulse-controlled board-level drop test standard JESD22-B110A

Condition B[1]. To evaluate the structure of the interested area, a strip model sliced from the full test vehicle is used in this research. In addition, the sub model region is particularly chosen with strip model by performing the cut boundary interpolation. The envelope of equivalent stress for the outermost solder joint off the end of the strip model is plot to show the potential solder failure mode and mechanism. The cut boundary of sub model is verified and the mesh density of sub model is examined. For a refinery mesh of sub model, parametric studies are carried out to study the reliability of the outermost solder joint, and the results are summarized as design rules for the development of stacked-die packages.

Tsipas et al. [2007] observed systematic material failure of wheel suspension assemblies on several combat vehicles after about 10 years of continuous operation under severe cross-country route and environmental conditions. The present study focuses on the failure of the trail wheel trunion, cast from an Al-alloy. Visual inspection, macro graphic examination and microscopic observations revealed that cracking was initiated at the inner micro machined surface of the alignment lugs and propagated towards the external surface, during long term vehicle operation. Similar findings were observed on the conjugate trunion piece, where inter granular cracking was extended in a significant depth beneath the fracture surface. Failure is attributed to the existence of a stress gap, due to the different fixation configurations of the attachment pin on the alignment lug.

Cockcroft et al. [2007] developed a mathematical model of the low-pressure die casting process for the production of A356 aluminum alloy wheels 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.

2. CAD MODELING

SOLIDWORKS is solid modeling CAD (computer-aided design) software that runs on Microsoft Windows and is since 1997 produced by DassaultSystèm. SOLIDWORKS Corp., a subsidiary of DassaultSystèms, S. A.(Vélizy, France). SOLIDWORKS is currently used by over 2 million engineers and designers at more than 165,000 companies worldwide.

Solidworks is used for the 3D CAD modeling of Alloy Wheel.

The steps to complete the model are as follows:

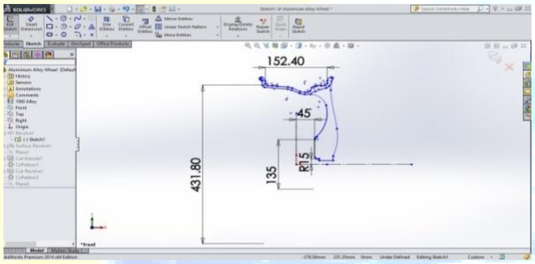


Figure: - 1 profile of alloy wheel

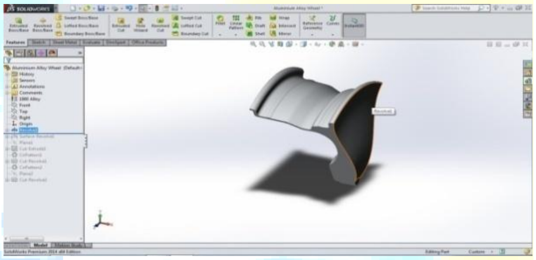


Figure: - 2 Revolve tool used

Draw the sketch profile of alloy wheel with the parameters of Rim diameter - 431.8mm, Rim width – 152.4mm, offset- 45mm, PCD- 100mm and Hub diameter- 135mm.

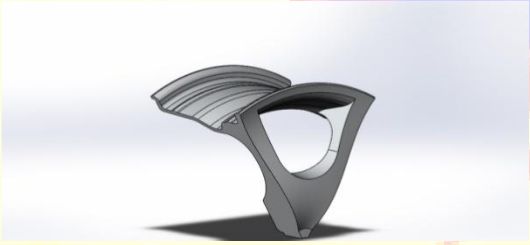


Figure: - 3 cut the material

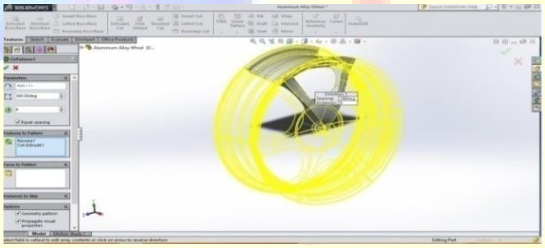


Figure: - 4 Circular pattern command

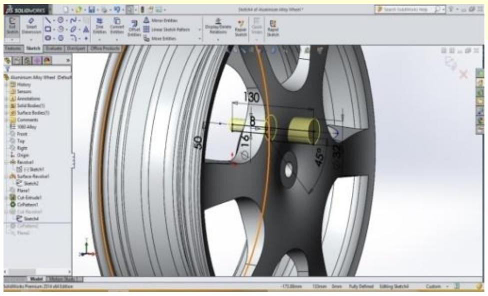


Figure: - 5 Make holes in alloy wheel

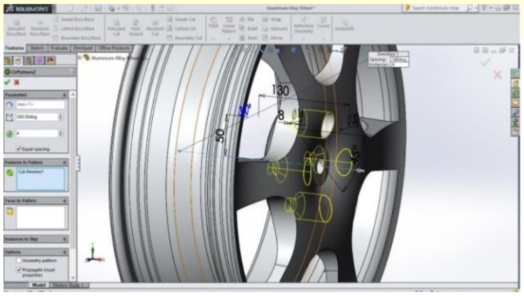


Figure: - 6 make all holes in alloy wheel

Now the solid works model will be saved as parasolid format (universal format) so that it is ready for data interoperability which means that the model can be opened and analyzed in ANSYS software.

Figure: - 7 Alloy Wheel

3. RESULTS AND DISCUSSIONS

We have successfully analyzed structurally the alloy wheel with the time varying pressure with ANSYS software and calculate maximum stress and deformation. We also study the stress occurs due to the random vibration. For this purpose we will select materials like Titanium and study the effect on stress and total deformation occurs on the titanium wheel is calculated. we also calculate the stress and total deformation with the time varying pressure and the graph will be plotted accordingly

1. For Titanium

A. Time varying from 0s to 10s with varying pressure-

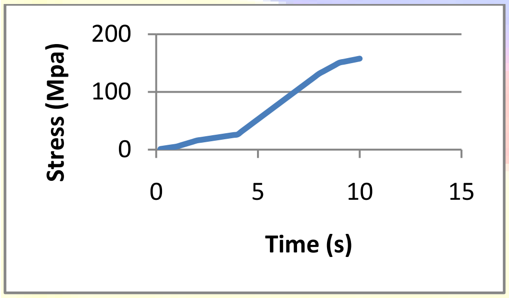


Figure:-8(a) Variation of Stress w.r.t time

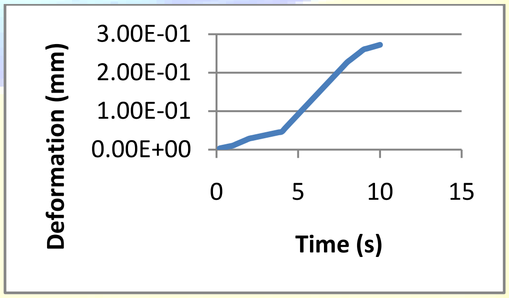


Figure:-8(b) Variation deformation w.r.t Time

B. For time varying 0s-1s with varying pressure-

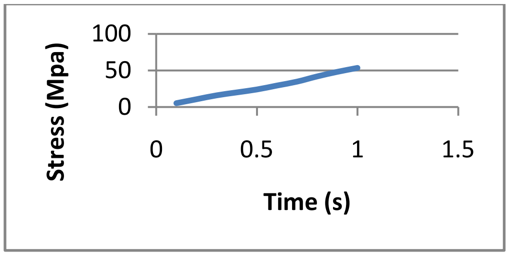


Figure: -9 (a) Variation of Stress w.r.t Time

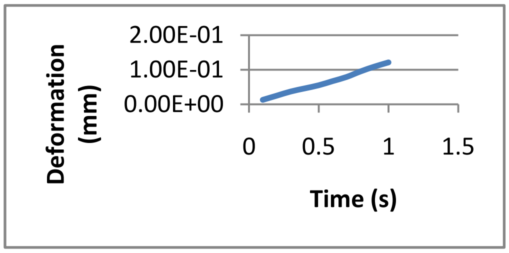
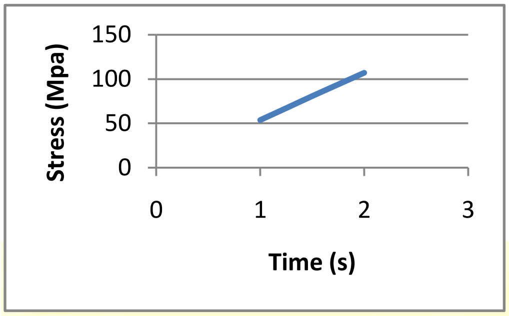


Figure: - 9 (b) Variation of Total Deformation w.r.t Time

C. Time varying 1s-2s with varying pressure-



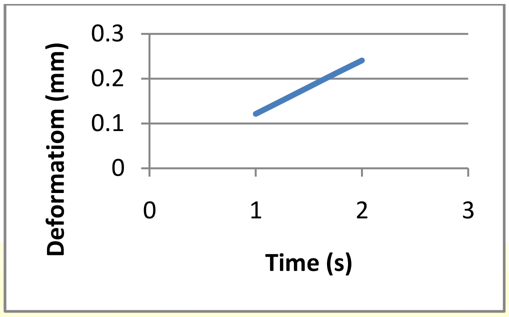
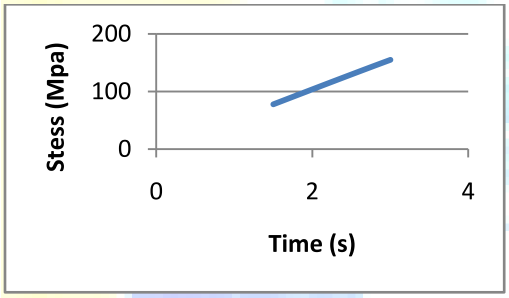


Figure: - 10 (a) Variation of Stress w.r.t Time **Figure: - 10 (b) Variation of Total deformation w.r.t Time**

D. Time varying from 2s-3s with varying pressure-



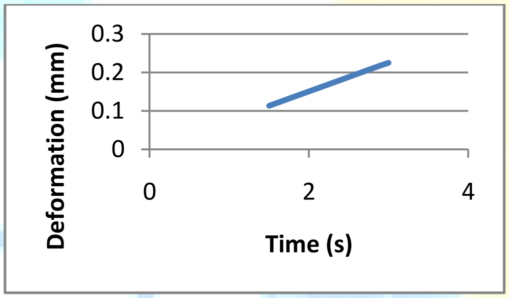


Figure: - 11 (a) Variation of Stress w.r.t Time **Figure: - 11 (b) Variation of Total deformation w.r.t Time**

4. CONCLUSION

The effect of Transient (Time Varying) load and the stress generated due to the vibration on an alloy wheel is calculated and studied for Titanium materials.

During the study of stress generation due to time varying load and vibration in the titanium alloy wheel the stresses is generating slowly by the variation in time. The maximum stress is generated in Titanium alloy is 157.44 Mpa. The vibration is generated in the Titanium alloy wheel at maximum Acceleration is [(mm/s²)²/Hz] 5.00E+06. The maximum stress is generated due to random vibration is 1.441e-006 MPa.

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