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Review Study of Automotive Wheel Fatigue Tests

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ABSTRACT: Wheel Rim is a most critical components as it play a vital role in human safety. Automotive wheels have much complicated profile shape and geometry. Rims are now produced in Aluminum Alloy and Magnesium Alloy providing options to steel material which are heavy and difficult to produce due to complex styling. Also, rim should satisfy all the fatigue test criteria according to IS and ARAI standards. There are two important fatigue tests Radial fatigue test and Dynamic cornering fatigue test. In this paper we are studying various research works on Fatigue tests with finite element analysis.

(Keywords: Wheel Rim, radial Fatigue test, cornering fatigue test.)

I. INTRODUCTION

From past decades, wheel producers are using new materials and manufacturing technologies in order to improve the wheel's aesthetic appearance and design. Steel wheels are widely used for wheels due to their excellent properties, such as lightweight, good forge ability, high wear resistance and mechanical strength. Ensuring the reliability and safety of wheel is very important. [1]

Analysis of the rims consists of numerically analyzing the stress levels that rims experience during operating conditions. These stress levels will then serve as input parameters for a fatigue analysis of the rims to evaluate their respective fatigue life. Additionally, the load bearing capacity of the bolt pattern will be evaluated for conditions of severe loading. The finite element (FE) method is implemented for all rim analysis. The reliability of FEA approach is based on their previous experience in fatigue analysis studies .The magnitude of the static load and pressure contributes to increasing the stresses on the rim components. [2]

II. LITERATURE REVIEW

XiaofeiWan (2016) et al The traditional fatigue test of wheel comprising the radial and cornering fatigue tests cannot simulate the real stress state of wheel well. Biaxial wheel fatigue test combining the set traditional tests has become an internationally recognized method that can reproduce the real loading condition of the wheel in service.[1]

Antonio D'Andrea (2016) et al The finite element model (FEM) results of a pavement structure are used to evaluate how stress state at the layer interface varies during the passage of a wheel over the road surface and to qualify the reasonability of existing dynamic tests used to characterize interface shear behavior.[2]

A Irastorza-Landa(2016) et al., Precursors of failure are dislocation mechanisms at the nanoscale and dislocation organization at the mesoscale responsible for long-range internal stresses and lattice rotation. The proposed technique is complementary to 3D x-raymicroscopy using wire techniquesand 3D-EBSD , both restricted to a snapshot in time of the microstructure. Together they have the potential to boost synergies between modelling and experiment.[3]

WeiweiSong(2015)et al This paper details the failure analysis of a wheel hub from a student designed Formula SAE_ race car that fractured at the roots of the rim finger attachment region. The wheel hub was identified to be manufactured from a rolled Al 6061 alloy.The wheel simulation results were consistent with the failure mode determined from the fractography study.[4]

Reza MasoudiNejad(2015)et al, says Accurate prediction of fatigue crack growth on railway wheels and the influence of residual stresses by finite element method (FEM) modeling can affect the maintenance planning. Therefore, investigation of rolling contact fatigue and its effect on rolling members life seem necessary. The objective of this paper is to provide a prediction of

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rolling contact fatigue crack growth in the rail wheel under the influence of stress field from mechanical loads and heat treatment process of a railway wheel. [5]

Gang Fang (2015),et al., investigated general laws of three-pass roll forming of steel wheel rim by finite element simulation. Firstly, finite element models of the rolling process were built on ABAQUS. To ensure the validity of models, some important settings as multistep construction, flexible boundary conditions of side rolls and nonlinear loading curves were considered, which provide the basis for high-accuracy numerical simulation of rim forming. Optimized flaring angle is obtained by the FE simulation of the flaring and three-pass roll forming. [6]

Zhanbiao Li (2014) e al, studies A five-piece rim and a two-piece bolt-connected rim were investigated to examine stress levels and fatigue lives on critical regions. The finite element models of the rim/tire assemblies were developed and validated through tire engineering data and previously validated modelling approaches.[7]

E. R. Weishaupt(2014) et al.,says The right-rear wheel of a full-size pickup truck involved in a single-vehicle accident was alleged to have fractured, leading to loss of vehicle control. The wheel was found fractured and partially separated from the vehicle by a distance of approximately 200 feet from the final resting point of the vehicle. The wheel was manufactured using a common casting procedure utilizing aluminum alloy A356 in the T6 condition. [8]

Zhan-GuangZheng (2014) et al., proposed a computational methodology to simulate wheel dynamic cornering fatigue test and estimate its' multi-axial fatigue life. The technique is based on the critical plane theory and the finite element methods. The prediction of fatigue life is found to be in close agreement with the corresponding experiment. [9]

2.1 Summary of Literature Review

The research papers studied focuses on Finite Element Analysis of Wheel Rim. Along with FEA the simulation of the dynamic cornering fatigue test, Radial Fatigue test and Biaxial Fatigue Tests of the automotive wheels. Also experimentation of all the Wheel Rim test is also studied in those works.

The studied papers focuses on:

1. Investigated to examine stress levels and fatigue lives on critical regions of wheels which are made from different materials by simulating static analysis with cyclic loads is found to converge with experimental results.
2. A computational methodology is proposed for fatigue damage assessment of metallic automotive components and its application is presented with numerical simulations of wheel various fatigue tests.
3. Use of the finite element model (FEM) results of a structure to evaluate the stress state at the layer interface changes during the passage of a wheel over the road the durability performance of wheel evaluated by radial fatigue test and cornering fatigue tests.
4. The study reveals the fatigue failure mechanism of the fractured steel wheel after the fatigue test.
5. Designing for Alloy wheel used in four wheeler by collecting data from reverse engineering process from existing model and evaluating by analyzing the model by taking the constraints as ultimate stresses and variables as two different alloy materials and different loads and goals as maximum outer diameter of the wheel and fitting accessories
6. Study of fatigue lifetime prediction method of alloy wheels was proposed to ensure their durability at the initial design stage.
7. The premature failure of a truck steel wheel prototype that occurs during the course of radial fatigue tests is studied using finite element analysis. Finite element-based stress analysis showed that the crack initiation regions on the wheel disc are subjected to stress concentration

2.2Research Gap

From the papers studied a research gap found is as follows:

1. At the same time, steel wheel which is designed for variation in style and has very complex shape, it is difficult to assess fatigue life by using available methods.
2. Available FEA methods do not concentrate on number of variations of materials on the rim for analysis purpose.
3. The study of effect of variation of material with fatigue tests are not studied.
4. A paper with combined study of RFT and DCFT is not seen.
5. Although FEA of fatigue testing are studied, but procedure to perform these test using FEA software is not mention
6. We do not find any work of weight optimization using RFT and DCFT.

III. WHEEL RIM FATIGUE TESTS

The wheel design and development use three main wheel tests (rotating bending test, radial

fatigue test, and impact test) to test a prototype wheel for various fatigue and durability considerations.
The Wheel Rim has to pass the following fatigue tests:
1. Dynamic Cornering Fatigue Test
2. Radial Fatigue Test
3. Impact test
4. Biaxial Fatigue Test
5. Rim Weld Strength Test

3.3 CORNERING FATIGUE TEST

The dynamic cornering fatigue test is a standard SAE test, which simulates cornering induced loads to the wheel.Fig.1shows the test system in which the test wheel is mounted to the rotating table, the moment arm is fixed to the wheel outer mounting pad with the bolts and a constant force is applied at the tip of the moment arm by the loading actuator and bearing, thus imparting a constant rotating bending moment to the wheel. If the wheel passes the dynamic cornering fatigue test, it has a good chance of passing all other required durability tests.

The Conering Fatigue Testing (CFT) machine allows the simulation of an endurance fatigue test on car/light truck/bus wheels subjecting them to cornering fatigue stress and holding the test conditions constant throughout the test duration. This is the type of stress a wheel experiences during turning.

3.3.1 Working

The Cornering fatigue test machine performs testing on wheels, under rotating condition, with the bending moment applied at 90 degree to the test wheel.The function of the machine is to apply a rotating bending moment to the wheel; the resulting stresses on the wheel are very similar to the stresses created under cornering by a car or truck on the road. The Rotary fatigue test machine applies a force to the wheel central disc. The wheel failures on the machine will be to the center of the test wheel and or in the area of the wheel mounting holes.The machine may be controlled in a manual or fully automatic mode (load, speed) by means of controls mounted on the front of the control panel. The following settings can be adjusted:
1. No. of load cycles
2. Bending moment or speed set point.

The following parameters are displayed on the front of the control panel:
1. Applied Load (force / moment)
2. Speed (moment RPM)
3. Deflection
4. Cycles (Total revolutions of wheel)

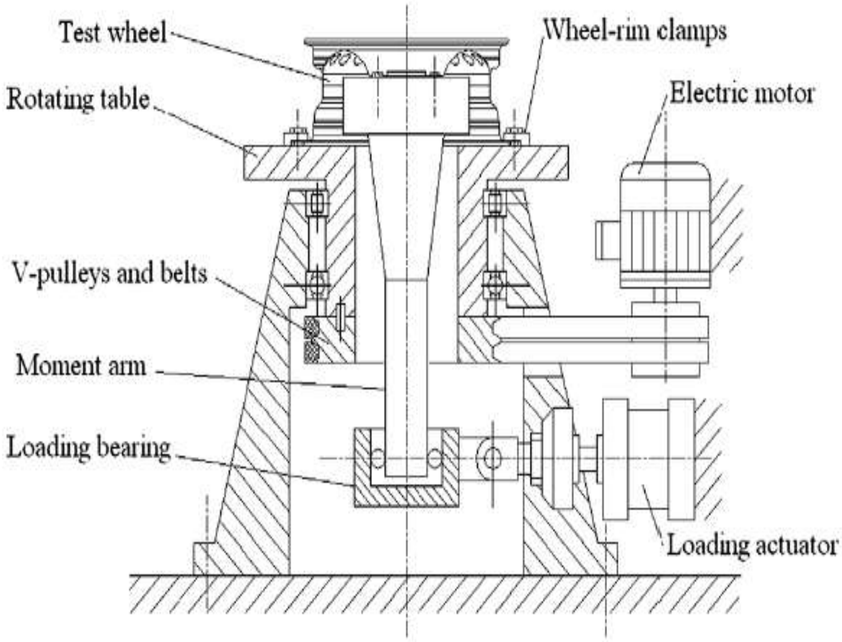

Fig 1.Schematic of Cornering Fatigue Test Rig.

After completion of the test the test specimen is removed from the set up. Then by visual inspection the cracks are observed. If cracks are visually not seen then the dye penetrant test is used to detect the crack.

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Fig.2.Photograph Cornering Fatigue Test Rig.

3.4 Radial Fatigue Test

The steel wheel, which is one of the basic structural elements of motor vehicle tire assemblies, connects the vehicle body and the tire and enables the wheel rotation. It also transmits vertical and lateral tire forces to the axle housing or the axle beam. Because of the position and function in vehicle suspensions, they are categorized as safety components. Therefore, it is necessary to guarantee a predicted durability of this component that should not fail under service loads. The load capacity and fatigue behaviour of a steel wheel under a certain dynamic load is determined by dynamic radial fatigue tests shown in figure. In these tests, the tire-wheel assembly is positionedon a rotating drum. The predicted radial test load is applied to the tire producing contact pressure between the tire and the drum.[10]

3.4.1 Equipment

The test machine shall be equipped with a means of imparting a constant radial load only as the Wheel Rim rotates. The suggested equipment incorporates a driven rotatable drum set which presents a smooth surface wider than the loaded test tire section width. The diameter of the drum is 1700 mm with tolerance of + 1%.[11]

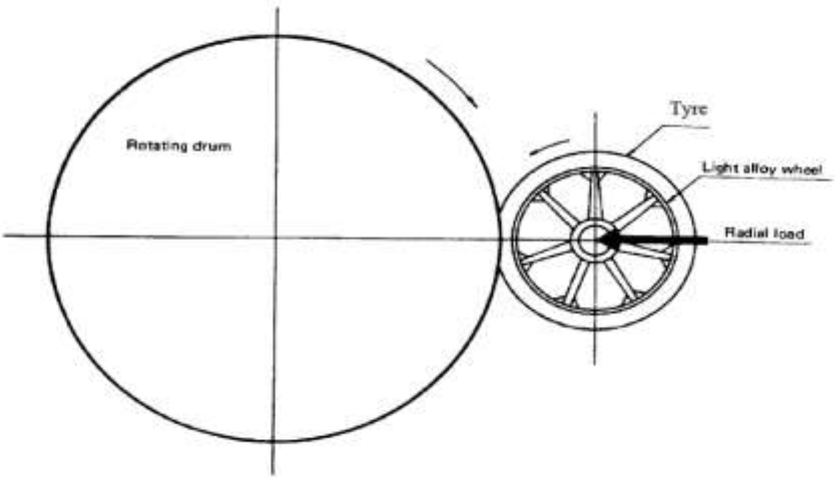

Fig.3 General view of the wheel dynamic radial fatigue test.

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3.4.2 Procedure

The tire selected for this Wheel Rim test shall be representative of the maximum size and type specified by the vehicle/Wheel Rim manufacturer or at the discretion of the testing agency. The cold inflation pressure of the tire will be equal or higher than the maximum recommended.

Figure 4. Photograph of Radial Fatigue Test Setup

3.4.3 Failure criteria

a) Inability of Wheel Rim to sustain load
b) A fatigue crack penetrating through a section of the Wheel Rim
c) The Wheel Rim shall withstand a minimum of 400000 test cycles without failure.[28]

IV. CONCLUSION

We studied various research workson automobile rims which were focusing on various fatigue tests and FEA.Investigated to examine stress levels and fatigue lives on critical regions of wheels which are made from different materials by simulating static analysis with cyclic loads is found to converge with experimental results.The important research gap found are Available FEA methods do not concentrate on number of variations of materials on the rim for analysis purpose.

1. The study of effect of variation of material with fatigue tests are not studied.
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