Stress Analysis in Wheel Rim by using Dynamic Cornering Fatigue Test Under Different Conditions

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ABSTRACT

Abstract—The wheel rim being critical component in the vehicle has to meet strict requirements of driving safety. Also it should meet the styling appearance and required engineering functions. The wheel rim also must be withstand the various loading environments.To achieve better performance and quality, the wheel rim designer and producers use a number of tests (rotating bending test, radial fatigue test, and rim impact test) to insure it meets the standards.The wheel rim tests are time much expensive and consumes lot of time. Computer simulation and Finite Element analysis of these tests can reduce the time and cost required to perform a wheel rim design at significant level.In this paper we discussed the simulation and Finite Element Analysis of wheel rim using Dynamic Cornering Fatigue test and compared to the experimental results.

Keywords: Wheel rim, Simulation, finite element analysis, dynamic cornering fatigue test

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1. INTRODUCTION

Wheels rim should not fail during its working. From design point of view the strength and fatigue life of rim are critical issues. 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. Under test conditions, these high levels of stress alter the mean stress level which in turn, alters the fatigue life and critical stress area of the components as well. The inclusion of clamp load improves the prediction of the critical stress area and fatigue life of aluminum wheels For a new wheel, the failure probability of the dynamic radial fatigue test can be read directly from this probability contour drawn from the test data. A bi-axial load-notch strain approximation for proportional loading to estimate the fatigue life of a passenger car wheel during the cornering fatigue test. The elasto-plastic strain components were calculated analytically using the total deformation theory of plasticity.[7] Wheel is generally composed of rim and disc. Rim is a part where the tyre is installed. Disc is a part of the rim where it is fixed to the axle hub. Offset is a distance between wheel mounting surface where it is bolted to hub and the centerline of rim. The flange is a part of rim, which holds the both beads of the tyre. Bead seat comes in contact with the bead face and is a part of rim, which holds the tyre in a radial direction. Hump is bump what was put on the bead seat for the bead to prevent the tyre from sliding off the rim while the vehicle is moving. Well is a part of rim with depth and width to facilitate tyre mounting and removal from the rim. [8]. The randomness of fatigue prediction owing to theinherent uncertainties in loading, manufacturingvariability, and material properties has been commonly recognized [1].

1.1 Objective

1. Measurement of stresses in to rim under dynamic conditions using FEA
2. Development of finite element analysis model of wheel rim,
3. Study failures in wheel rims and estimate life cycle period of rim using FEA software(ansys)
4. Find out better Method for FEA

2. LITERATURE REVIEW TITLE-2

Chang and Yang (2008) studied the nonlinear dynamic finite element is used to simulate the SAE wheel impact test. The dynamic response of a wheel during the impact test is highly nonlinear. Nonlinear dynamic finite element with a considerable mesh size and time step can calculate the dynamic response properly and acurately. The simulated results in this work show that the total plastic work can be effectively employed as a fracture criterion to predict a wheel fracture of forged aluminum wheel during impact test. [3]

Firat et al. (2008) concentrated on computational strategy is proposed for exhaustion harm appraisal of metallic car segments and its application is given numerical reproductions of wheel outspread weariness tests. The system depends on the neighborhood strain approach in conjunction with direct flexible FE stress examinations. The stress–strain reaction at a material point is figured with a cyclic versatility model combined with an indent stress–strain guess plan.[4]

Wanga and Zhang (2009) studied a practical and comprehensive method for simulating the dynamic cornering fatigue test of wheel rim. The test of a steel car wheel rim is simulated by use of the linear transient dynamic finite element analysis and the local strain approach. A rotating force of constant magnitude is applied to the moment arm end to simulate the bending rotating effect on the wheel rim, with the wheel stationary. It is observed that a radial component of the rotating moment is needed to obtain the accurate radial .The strain on the elements whose local stress–strain characteristic keeps linear and closest to the critical element is applied to know the fatigue life of the critical element with Neuber's rule and local strain approach, which is near to the test results.[6]

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3. DYNAMIC CORNERING FATIGUE TEST TITLE-3

A. **Test Equipment:**

The test equipment shall be designed to produce a constant bending moment on the center of the light-alloy wheel which rotates with a constant velocity. An example of such equipment is shown in figure.

Fig1.Dynamic Cornering Fatigue Test

B. **Equipment Details / Features:**

The Dynamic Wheel Cornering Fatigue test machine (90º loading method) manufactured by M/s MTS Systems Corp., USA.

C. **Testing Conducted:**

It is a unique facility for testing of wheel rims, hubs and other similar component on which cornering forces are exerted in dynamic condition. A rotating bending moment is applied to a stationary wheel through 800 mm long arm. Test wheel rims from 10 to 24 inches in diameter with offsets up to 15 inches (375 mm) can be accommodated on the machine. Bending moment up to 3000 Kg-cm can be applied according to the size of the rim. 2) Evaluating load deflection value in static condition

D. **Procedure:**

a) Preparation - The rim flange is clamped securely to the test fixture. The mounting on the testing machine should have the same fixing characteristics as the face of the hub used. Check all the attachments properly. These wheel bolt should be tightened at the beginning of the test to the vehicle/wheel manufacturer's specified torque values. The bending moment shall be maintained within ± 2.5 percent. [8]

b) Bending moment- To apply bending moment to the wheel rim, a force may be applied either perpendicular or parallel to the plane of the mounting surface of the wheel at a specified distance (moment arm).[8]

E. **Test Conditions: Bending Moment:**

The bending moment M, in Nm applied in accordance with shall be determined by the following equation:

$$M = Sm./\ p\ .\ \boldsymbol{W}.\ r$$

Where

Sm = coefficient equal to ***0'7;***

p = the friction coefficient between tyre and road, equal to o-7;

W **=** is the maximum design load marked on the wheel, in decanewtons; and

r **=** maximum static loaded radius among those tyres that can be fitted to the wheel, in meters.[2]

F. **Failure criteria:**

a) For three wheeled vehicles:

i) Inability of the wheel rim to sustain load

ii) A fatigue crack penetrating through a section of the wheel rim.

iii) The wheel rim shall withstand a minimum of 18000 load cycles without failure.[8]

b) For two wheeled vehicles

After being subjected to 10^6 cycles according to the rotation bending fatigue test specified above, there shall be no evidence of harmful cracks, significant deformation or any abnormal looseness at joints[8].

G. **Finite Element Analysis of Wheel Rim under Dynamic Cornering fatigue test:**

The existence of two zones with high stresses, disposed in the central area of the disk. These stresses are responsible for the fatigue breaks of the rim.The finite element analyses have identified the likely failure locations in the wheel bolt holes, ventilation holes and welding seam. Stress distribution on rims varies from one region to another. Based on this type of FEM analysis, one can decide as to which parts are critical, then, can strengthen those zones. On the other hand, stress distribution may not be that high on some other parts, hence, excess can be removed from these regions to prevent material extravagance. Furthermore, if the residual stresses remain in the critical zones of the rim, it should be taken into consideration that these parts will be more enduring, hence safer. For FEA of wheel rim we considered following two cases of dynamic load or moment applied:

Case I: Moment applied at mounting holes

Case II: Moment applied on mounting holes and disc

During experimentation of strain gauges were used to know the strain developed at various positions.These strain gauge readings were compared with FEA results of both cases.The scheme with minimum error will be considered for study of stresses developed in rim and future failure analysis.

Case I:Strain Developed due to Moment applied at mounting holes

Table I:Strain Developed due to Moment applied at mounting holes

Strain Gauge Position	**Experimental Results**						**FEA Results ($x10^{-2}$)**	Error (%)	Average % Error
	Sample 1 **($x10^{-2}$)**	Sample 2 **($x10^{-2}$)**	Sample 3 **($x10^{-2}$)**	Sample 4 **($x10^{-2}$)**	Sample 5 **($x10^{-2}$)**	Average **($x10^{-2}$)**			
1	1.8230	1.8590	1.8610	1.8510	1.8210	1.8430	1.8331	0.99	5.27
2	1.8660	1.8690	1.8540	1.839	1.8270	1.8510	1.7953	5.57	
3	1.8590	1.8720	1.8440	1.8510	1.8500	1.8530	1.7249	13.01	
4	1.8740	1.8600	1.8860	1.8530	1.8320	1.8610	1.8761	1.51	

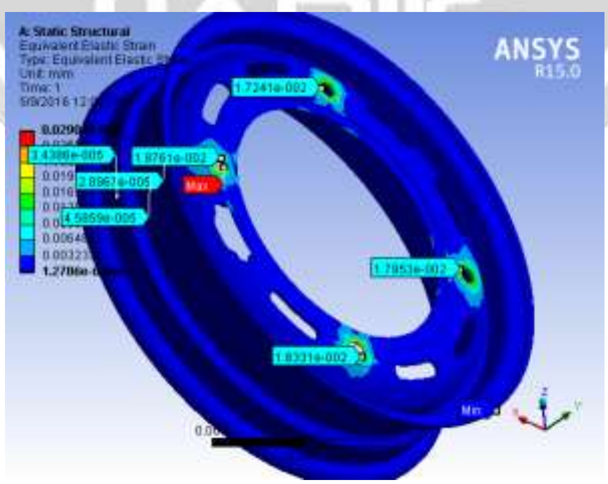
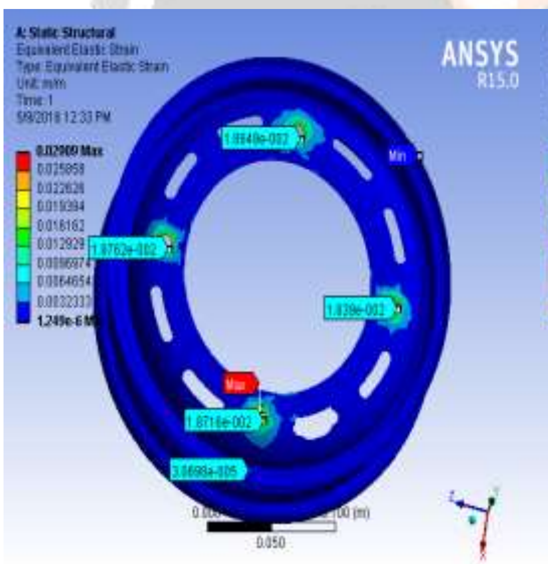


Fig.2 Strain Developed due to Moment applied at mounting holes

Case II:Moment applied on mounting holes and disc

Table 2: Strain Developed due to Moment applied at mounting holes and disc

Strain Gauge Position	**Experimental Results**						**FEA Results** ($x10^{-2}$)	Error (%)	Average % Error
	Sample 1 ($x10^{-2}$)	Sample 2 ($x10^{-2}$)	Sample 3 ($x10^{-2}$)	Sample 4 ($x10^{-2}$)	Sample 5 ($x10^{-2}$)	Average ($x10^{-2}$)			
1	1.8230	1.8590	1.8610	1.8510	1.8210	1.8430	1.8390	0.4	
2	1.8660	1.8690	1.8540	1.839	1.8270	1.8510	1.8649	1.39	1.2425
3	1.8590	1.8720	1.8440	1.8510	1.8500	1.8530	1.8762	2.12	
4	1.8740	1.8600	1.8860	1.8530	1.8320	1.8610	1.8716	1.06	



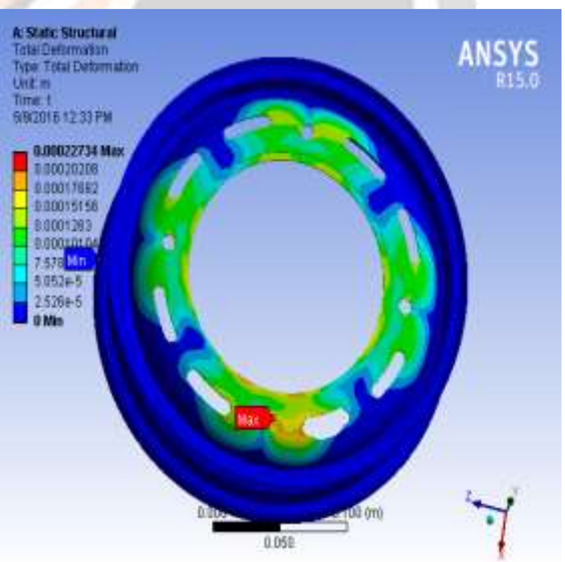


Fig.3 Moment applied at Disc **Fig.4 Moment applied mounting holes and Disc**

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4. RESULTS

The fatigue life of steel wheel rims was predicted by using the equivalent stress amplitude and steel alloy wheel rim S-N curve. The results from the steel wheel rim dynamic cornering fatigue test showed that the baseline wheel rim 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 rim life cycle was improved to over 1.0×10^{6} 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 steel

5. CONCLUSION

As shown in results the case II have more accurate results than that of case I. So we can consider that there is effect of dynamic forces or moment on the disc as well as on the mounting holes. The simulation resultsare nearly equal to the experimental results.So we can consider the case II for FEA of the Rim.

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