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Study of Effect of Weld Length Configuration on the Performance of Wheel Disc for Passenger Car

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ABSTRACT

Uniformity and fatigue life are the main performance parameters for any type of wheel. Weld length is generally considered as a secondary parameter during the design stage. Thus, it is directly selected based on the past experience at the time of designing of the wheel. In the present work an attempt has been made to study the effect of weld length configuration on the performance of the disc wheel. There are basically two weld length configurations considered for this purpose. The number of weld seams can be either 4 or 8. Different weld length configurations can be obtained by varying the weld length for these two basic configurations. Generally, during the FEA analysis of wheel, weld seam is not modelled and the wheel is analyzed directly by assuming bonded contact between the rim and the disc. But, to study the effect of weld length configuration, weld seams need to be modelled. We have used R1MS concept of weld modelling for modelling of the weld seams at the rim disc interface. The weld and other auxiliary parts are modelled by using the modelling software CATIA V5.

Radial fatigue test and Cornering fatigue test are the two most important tests for predicting the fatigue life of the disc wheel. These two tests are simulated by using Ansys 12. The static results are then validated by comparing them with already existing results. After validation of the FEA model, static analysis results are evaluated for different weld lengths and fatigue life cycles are also calculated.

*Keywords— **Disc Wheel, RFT and CFT, Weld Modelling, Finite element analysis, Fatigue life.***

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I. INTRODUCTION

Disc type Wheels are widely used for mass-produced cars and trucks. This type of Wheels represents optimum design in terms of economy, serviceability and safety. Disc wheel basically consists of two parts – the rim and the disc. These two part are welded together to produce a disc wheel. Discs and rims are first manufactured separately. Disc wheels are assembled by carrying out welding at rim-disc interface either at 4 locations or at 8 locations. The length of weld decided at the time of designing is generally based on the past experience of the designer.

The project aims to compare the effect of two weld length configurations as follows-

Configuration No.1 (Total no of weld seams = 4) - In this configuration, Single weld seam of specified length is deposited between each pair of notches. As there are total 4 notches, the total no of weld seams in this configuration are 4.

Configuration No. 2 (Total no of weld seams =8) – In this configuration the total length of weld seam is split into two halves. Thus, the no of weld seams between each pair of notches becomes 2 and the total no of weld seam becomes 8.

Effects of these two weld length configurations on run-out values, strength and fatigue life will be observed by carrying-out Finite Element Analysis and experimental trials.

A. Disc Wheel:

Disc Wheels are used for mass-produced cars and trucks. This type of Wheels represents optimum design in terms of economy, serviceability and safety.

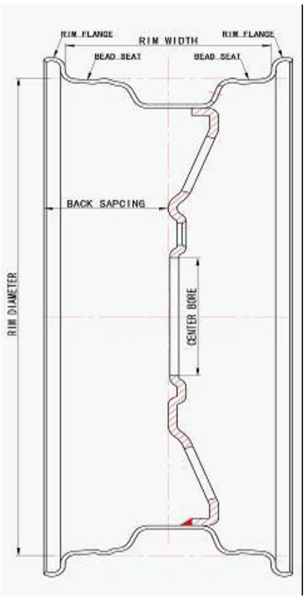
Disc wheel consists of two parts-

1. The Disc
2. The Rim

These two parts are manufactured separately and then welded together.

These are steel Wheels and the material generally used is high strength low alloy (HSLA) steel.

Fig 1. Disk Wheel



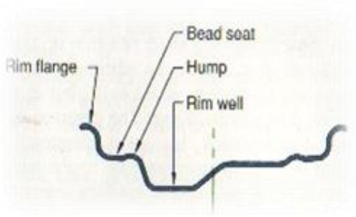


Fig2.Rim

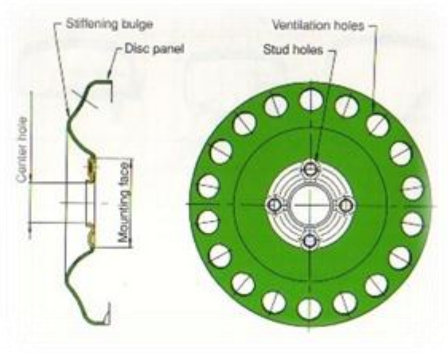


Fig 3. Disk

B. Wheel Designation:

For 5Jx14 H2 disc wheel

“5” is the rim width in inches, measured from bead seat to bead seat not edge to edge.

“J” represents the type and the height of the rim flange.

“x” sign indicates that the wheel is a drop centre wheel.

“14” is the overall diameter of the wheel's bead seat, not the diameter of the rim edge.

“H2” signifies a double round hump.

Table 1: Details of the Given Wheel

Wheel size	5Jx14” H2
Rim Thickness	2.3 mm
Disc Thickness	3.7 mm
Wheel load	460 kg
Radial load	11.28 kN
Fatigue life	500,000 cycles
Bending Moment	2.81 kNm
Fatigue Life	20,000 cycles
Bending Moment	1.65 kNm
Fatigue life	400,000 cycles

II. LITERATURE REVIEW

The paper recommends the critical areas in wheel geometry from design point of view [1] also, the use of local strain approach and SWT mean stress consideration for the estimation of fatigue life. The paper also suggests the use of pseudo von Mises stresses for fatigue life calculation. The guidelines for the FEA simulation of CFT presented in this paper [2]. They have simulated CFT by using FEA software and compared the results with those of static experimental stress analysis. Fatigue analysis of welded assembly by using Ansys Workbench is discussed in detail [3]. They have presented R1MS concept for modelling the weld seam. In this paper, they used local stress concept [4] for the Fatigue Life Analysis of Aluminium Wheels. Also they have presented guidelines for meshing and boundary conditions. Loads are applied at different angles to get the stress values at critical locations. The practical way of computer modelling of radial fatigue test have presented in this paper [6]. This paper mentioned the stress analysis of wheel rim [8]. The main objective of this paper is to analyze the causes of failure of wheel rim. This paper discusses about the various failures, which may arise in the rim.

III. DYNAMIC RADIAL FATIGUE TEST

This test simulates the rolling action of the wheel on a road by bringing it into contact with a rotating drum (fig.4.3). With this it is also possible to make the wheel (with tire) camber or skew to create an extra axial load, such as occurs in cornering.

After a set period of running time, the wheel is inspected for possible cracks. The test specimen can be evaluated in accordance with the position, length, type and number of cracks. In general, failure occurs as a result of the gradual loss of air through cracks at the welded joint between the disc and the rim. Other typical fracture sites occur at the ventilation holes and stud holes. A disadvantage of this test is that the tire suffers extreme wear through the heating caused by overloading. Prolonged testing periods are required, since the heating doesn't allow high speed testing.

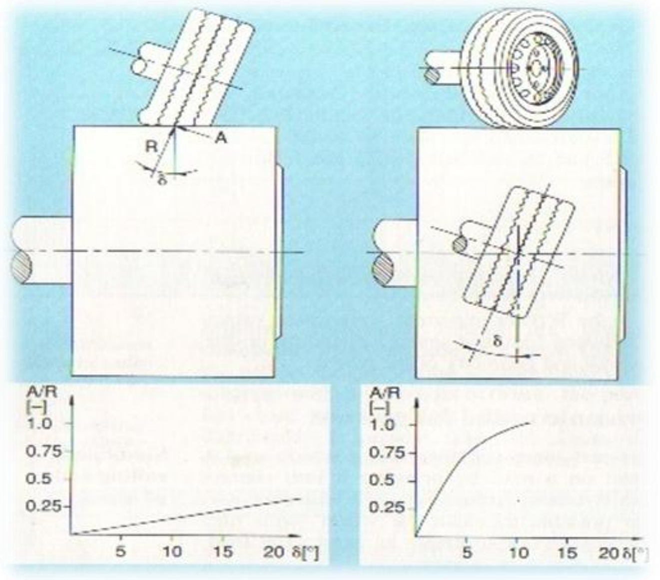


Fig. 4. Radial Fatigue Test

IV. DYNAMIC CORNERING FATIGUE TEST

The dynamic cornering fatigue test is a standard SAE test, which simulates cornering induced loads to the wheel. 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.

This test simulates the load which acts on the wheel during cornering. By exerting radial force outside the centre of the wheel, the test machine essentially generates a rotating bending moment which acts on the wheel by way of a lever arm.

The advantage of this method compared to the dynamic radial fatigue test is that testing can take place without tires, allowing the use of higher speeds and substantially shorter testing times. The disadvantage is that only the wheel disc can be tested. Radial force is less than that developed in the dynamic radial fatigue test and it diminishes at a constant bending moment with the increasing length of the lever arm.

The bending moment M_b acting on the wheel disc in the test is calculated from the load when cornering (wheel and tire) as follows:

$$M_b = F_{rad} \cdot e + F_{ax} \cdot F_{dyn}$$

i.e. this is the sum of bending moments resulting from the radial contact force of the wheel F_{rad} and the axial force on the side of the wheel Fax with the lever arms of the offset e and the dynamic rolling radius r_{dyn} of the tire. The offset e is the distance from the centre of the rim to the attachment face, which is the reference point for the bending moment.

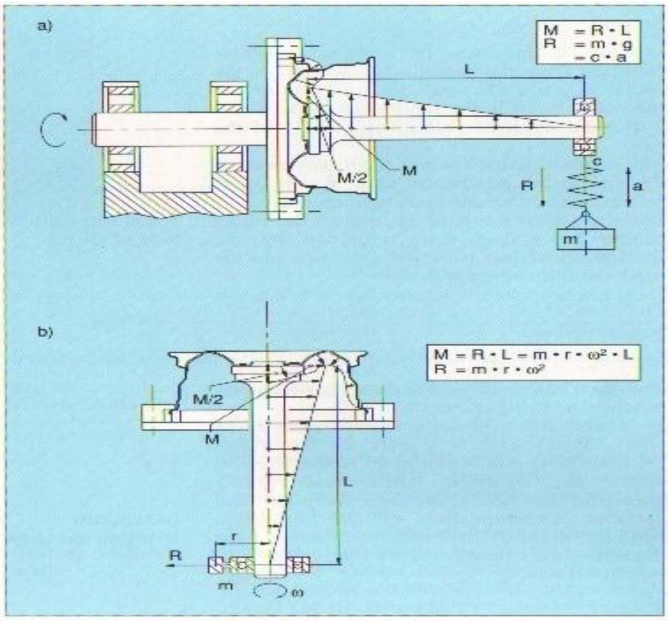


Fig.5. Cornering Fatigue Test

Since the axial force on the side of the wheel cannot be greater than permitted by the friction coefficient between the tire and the road, the following applies:

The coefficient of friction is generally assumed as being around 0.9. F_{rad} is accepted as being at least as great as the static contact force F_{stat}, which is determined from the weight of the vehicle. To this must be added the dynamic wheel load during cornering and shock loadings on poor road surfaces. Determination of the maximum bending moment is based on the highest possible forces incorporated in the formula as overload factor K.

Depending on the vehicle manufacturer and test experience, different values are assumed for the overload factor and the friction coefficient for which certain fatigue life values are expected on the Wohler graph.

V. WELD MODELLING

The Weld Modelling is based on the R1MS concept which is explained in [6].The Fillet Weld is modelled in CATIA V5 as shown in the Figure below.

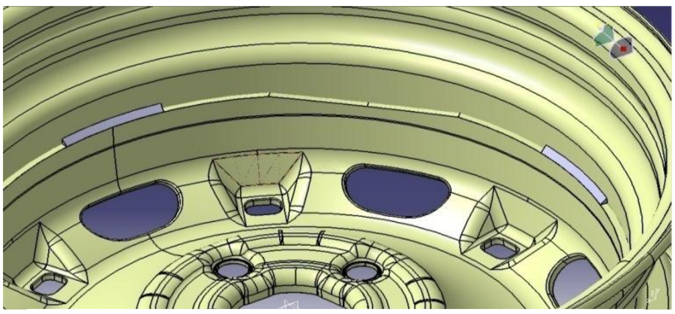


Fig.6. Weld model in CATIA using R1MS Concept

VI. MATERIAL PROPERTIES

The Material Properties which are Important with respect to the Radial Fatigue Test Simulation are displayed below.

Table 2: Properties of the Material of the Wheel

	Rim	Disc
Material	HSLA Steel	HSLA Steel
Density	7860 kg m^-3	7860 kg m^-3
Young's Modulus	2e+11 Pa	2e+11 Pa
Poisson's Ratio	0.3	0.3
Tensile Yield Strength	3.05e+008 Pa	3.55e+008 Pa
Tensile Ultimate Strength	4.4e+008 Pa	4.4e+008 Pa

VII. MESHING

The Meshing is done by using different Mesh Control tools in ANSYS 12.The The Disc having a thickness of 3.9mm is meshed using Solid elements whereas the Rim which has a comparatively less thickness of 2.3mm is modelled using shell elements. The Mesh properties are stated in detail in the following tables:

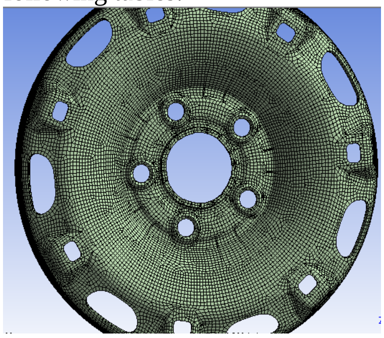


Fig.7 Disc Meshing (View I)

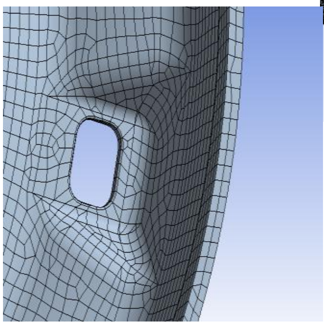


Fig. 8 Disc Meshing (View II)

Table 3: Meshing Details

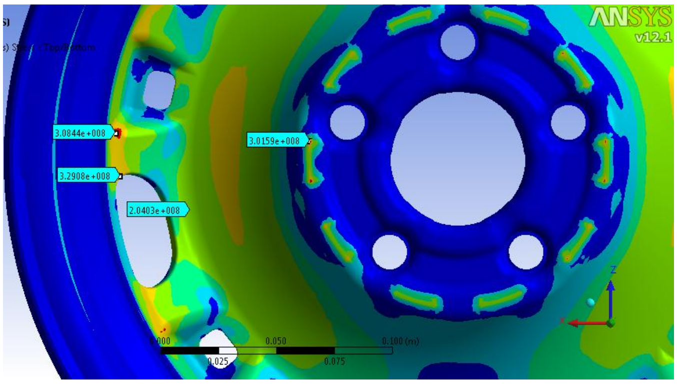
Feature	Property	
Smoothing	Medium	
Transition	Fast	
Span Angle Center	Coarse	
Nodes	236555	
Elements	80282	
	DISC	RIM
Mesh Method	HEX-DOMINANT (3D Elements)	QUADRILATERAL-DOMINANT(2D-Elements)
Free Face Mesh Type	Quad/Tri	All Quad
Element Sizing	3mm	10mm

Fig.9. Rim Meshing

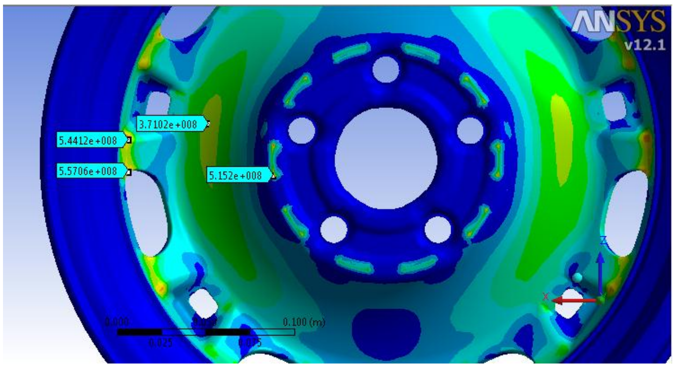
VIII. FEA RESULTS

Cornering Fatigue Test

Vent holes, Balcony, Stiffening bulge, stud holes and weld are the five critical locations as observed by Liangmo Wang[4]. Thus, the stress results are tabulated for these five critical locations.



(a)

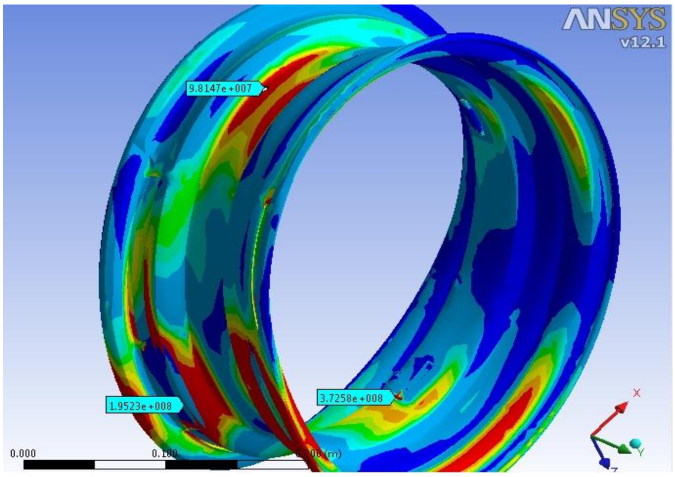


(b)

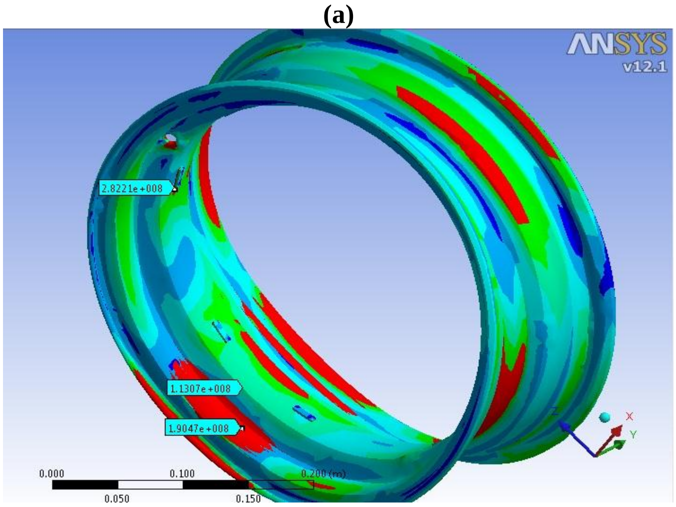
Fig.10. Stress Distribution at Critical Points for Bending Moment
(a) 1.65kNm (b) 2.81kNm

b. Radial Fatigue Test

The critical locations for RFT are Rim well, weld and bead seat. Thus, the stress results are tabulated for these three critical locations.



(a)



(b)

Fig.11. Stresses At Critical Areas for Radial Force = 11.2 KN
(a) for 4 weld (b) for 8 weld

c. Fatigue Analysis

The Fatigue Analysis in Ansys 12 allows the fatigue analysis by both the methods viz. The Stress-Life method and The Strain-Life method. The Fatigue Analysis is based on the Strain-Life phenomenon is more suitable in our case.

Table 4: Material Properties Required For Fatigue Analysis

Strength Coefficient	1067 MPa
Strength Exponent	-0.145
Ductility Coefficient	0.384
Ductility Exponent	-0.531
Cyclic Strength Coefficient	885 MPa
Cyclic Strain Hardening Exponent	0.198

IX. RESULTS OF ANALYSIS

To study the effect of the length of weld on the stress values, CFT and RFT were simulated for different weld lengths. The stress results obtained after carrying out these iterations are as follows-

Table 5: Stress results for wheel with different weld lengths for (a) CFT (b) RFT

		CFT		RFT
No of welds	Length (mm)	1.65 kNm Stress (MPa)	2.81 kNm Stress (MPa)	11.2 KN Stress (MPa)
8 welds	40	341.81	555.47	209.10
	35	344.59	557.48	219.59
	30	347.34	567.72	238.30
	25	348.25	578.82	270.04
	20	349.54	587.43	282.21
4 welds	80	331.47	581.73	235.34
	70	333.35	583.80	272.69
	60	338.15	584.27	300.06
	50	343.43	589.38	331.55
	40	347.15	592.39	372.58

The above analysis shows that, variation of weld length has extremely small impact on the stresses produced in CFT. There is slight decrease in stresses with increase in weld length.

But, in case of RFT there is considerable variation in stresses with change in weld length. It can be easily observed that stresses are increasing quite rapidly with decrease in weld length.

X. FATIGUE RESULTS

Table 6: Fatigue life predicted by FEA for (a) CFT (b) RFT

		CFT		RFT
No Of Welds	**Length (Mm)**	**1.65 Knm**	**2.81 Knm**	**11.2KN**
		Fatigue Cycles	**Fatigue Cycles**	**Fatigue Cycles**
8 welds	40	1.1653x10^{6}	70803	9.5390X10^{5}
	35	1.1472x10^{6}	68742	8.7707X10^{5}
	30	1.0554x10^{6}	67687	8.5847X10^{5}
	25	9.9214x10^{5}	66856	8.2080X10^{5}
	20	9.7809x10^{5}	65193	7.9848X10^{5}
4 welds	80	1.1544x10^{6}	69066	9.1275X10^{5}
	70	1.1309x10^{6}	68313	8.9692X10^{5}
	60	1.0340x10^{6}	66777	8.6888X10^{5}
	50	9.8916x10^{5}	65070	8.1738X10^{5}
	40	9.4230x10^{5}	64893	8.1411X10^{5}

The fatigue results reflect the same thing as that observed in case of static results.

XI. CONCLUSION

This was an attempt has been made to analyze the effects of weld length configuration on the strength and the fatigue life of the disc wheel. It was observed that, values are within limit for both the configurations wheels. This shows that the effect of weld configuration has very small impact at lower speeds (<80 kmph). Configuration with no. of weld=4 gives comparatively better values. Thus, this configuration is recommended for low speed applications, particularly for Indian road conditions.

As we move towards higher harmonics, wheels with 8 welds give better values. Thus we can say that wheels with 8 welds give better performance at higher speeds (>80 kmph).

The variation of weld length has a small impact on the fatigue life predicted by CFT and RFT. There is slight decrease in fatigue life with decrease in weld length. The rate of decrease of fatigue life is comparatively more in case of RFT than that in case of CFT. Also the chances of failure at weld seam are more in case of RFT.

The wheel didn't fail in RFT even after reducing the total weld length to the half of the current weld length. Thus, Effect of weld length has a very small impact on the fatigue life predicted by CFT and RFT.

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