SPOT WELD ANALYSIS OF AN AUTOMOBILE RIM

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Abstract: In this thesis the Optimization of Number of Spot welds on Automobile Wheel Rim using Finite Element Analysis is studied. Spot welded rim must pass certain tests like Weld Strength Test (WST), Dynamic Cornering Fatigue Test (DCFT) and Radial Fatigue Test (RFT). In Weld Strength test a shear force is applied on the spot weld using Universal Testing Machine. In dynamic cornering fatigue Test a moment is applied on the rim as specified by the company standards. In Radial Fatigue Test Influence of Tire pressure and vehicle load are studied. We choose three parameters for optimization namely, Number of spots on rim, spot diameter and thickness of rim.

Keywords: Rim, Weld Strength Test, Dynamic Cornering Fatigue Test, Radial Fatigue Test, FEA.

1. INTRODUCTION:

Automotive wheel, as a critical component in the vehicle, has to meet the strict requirements of driving safety. Traditionally, the new designed wheel is tested in the laboratory for its life through an accelerated fatigue test before the actual production starts. However, a physical prototype test time lasts at least 7 days and an average design period is 6 months or more depending on the requirement, so the time to test and inspect wheel during development is very consuming. At the same time, because steel wheel is designed for variation in style and has very complex shape, it is difficult to assess fatigue life by using analytical methods. In the last decade, many scholars and wheel manufacturers have been taking increasing attention to numerical analysis of wheel fatigue life. [9]

2. PROBLEM DEFINITION:

Presently 24 spots are used to join disc and rim on spot weld machine having 3 stations. One cycle of 3 spots requires 6-7 seconds. There are 8 cycles of welding and 7 time indexing. One indexing requires and each indexing takes 4-5 seconds. Loading and unloading time is near about 3 seconds. So for production of one rim will require near about 94 seconds. Other operations need maximum 35 seconds. Now there is a bottle neck at this stage of production, in a shift with other operations 900 to 960 rims are produced but at welding machine 300 to 306 rims are produced. To cope up with this problem 2 Welding machines are installed still the maximum production of rims is 612 rims per shift. So this thesis aims at optimizing the number of spot welds on the rim, which will increase the production rate.

3. METHODOLOGY:

Before starting analysis it is important to understand current process. Literature review was carried out to understand past work carried out in field stress analysis of wheel rim. To validate the solution following methodology was adopted.

1. Experimental Method
2. Finite Element Method
3. Comparison of above two methods

4. PARAMETERS:

The parameters for Experimentation are selected as follows, currently there are 24 spot weld on the rim with plate thickness 2.3 mm and spot weld diameter 7.0 mm

5. EXPERIMENTATION PLAN:

Combining all parameters Experiment Plan is as follows:

Parameters	**1**	**2**	**3**
Number of Spots	21	18	15
Diameter of Spots(in mm)	8.4	7.7	7.0
Plate thickness(in mm)	2.0	2.3	2.6

Table: 1 Parameters considered for optimization

Expt. No.	Spot No.	Diameter Spot(mm)	Thickness Plate(mm)
1	S1=21	D1=8.4	T1
2	S1=21	D2=7.7	
3	S1=21	D3=7.0	
4	S2 =18	D1=8.4	
5	S2 =18	D2=7.7	
6	S2 =18	D3=7.0	
7	S3=15	D1=8.4	
8	S3=15	D2=7.7	
9	S3=15	D3=7.0	
10	S1=21	D1=8.4	T2
11	S1=21	D2=7.7	
12	S1=21	D3=7.0	
13	S2 =18	D1=8.4	
14	S2 =18	D2=7.7	
15	S2 =18	D3=7.0	
16	S3=15	D1=8.4	
17	S3=15	D2=7.7	
18	S3=15	D3=7.0	
19	S1=21	D1=8.4	T3
20	S1=21	D2=7.7	
21	S1=21	D3=7.0	
22	S2 =18	D1=8.4	
23	S2 =18	D2=7.7	
24	S2 =18	D3=7.0	
25	S3=15	D1=8.4	
26	S3=15	D2=7.7	
27	S3=15	D3=7.0	

Table 2 Experimentation Plan

6. WELD ANALYSIS EXPERIMENTATION:

6.1 Finite Element Weld Analysis Results

We will start Analyzing the Rim for Weld strength at minimum thickness(T1=2.0 mm),Maximum thickness(D1 = 8.4 mm) and (Spots numbers=21).If this experiment combination fails all the remaining experiments for T1 will get fail because we are using maximum diameter and maximum number of spots so other combinations will be weaker than above used. So we will directly take next thickness of rim. If passed we will go for the next experiment combination.

Force: As in UTM a force of 237.5 kN is applied. (As specified by Manufacturer)

6.2 Experiment No.1.1: D1=8.4 mm; S1 = 21; T2=2.0 mm

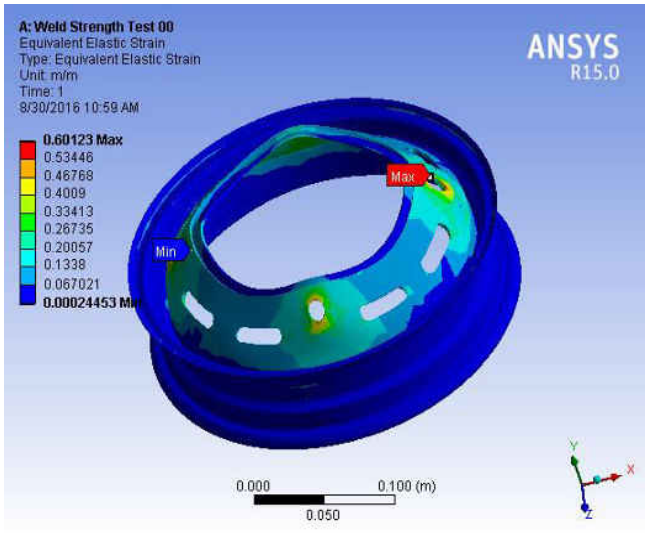

Fig: 1. Equivalent Strain

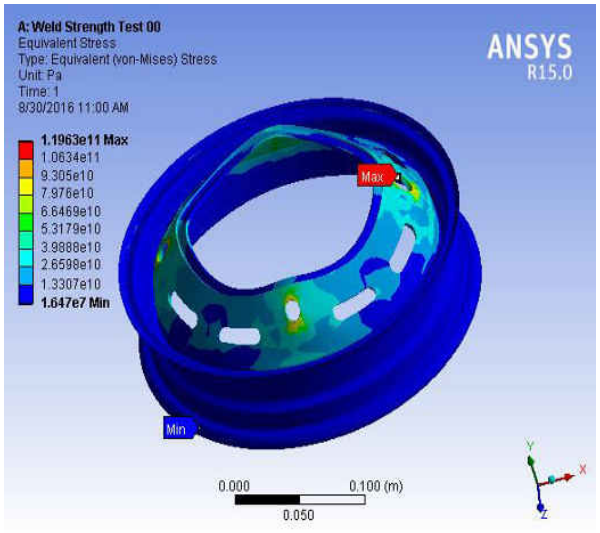

Fig.2 Maximum Equivalent Stress

From above plots Maximum strain is 0.60123; maximum equivalent stress is $1.1963X10^{11}$ N/mm^2 Maximum shear stress is $2.96X10^6$ N/mm^2. This exceeds the minimum limit indicating the failure of rim. As this is the best combination for the thickness selected all other combinations of number of spots and spot diameter will fail. So we go for the next thickness of T2=2.3mm.

The experiments for this thickness are as follows:

1	S1	D1	T2
2	S1	D2	
3	S1	D3	
4	S2	D1	
5	S2	D2	
6	S2	D3	
7	S3	D1	
8	S3	D2	
9	S3	D3	

Table 3 The Experiments for thickness T2=2.3 mm

Now starting with Experiment No.1 for thickness T2=2.3 mm The plots are as follows :

Experiment No.2.1 D1=8.4mm; S1 = 21; T2=2.3 mm

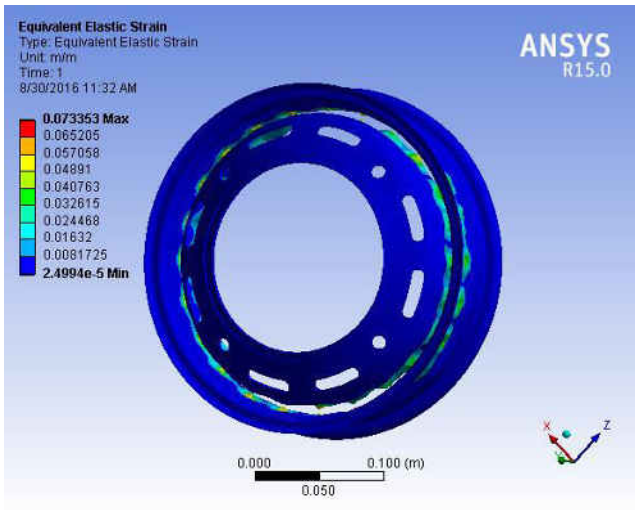

Fig:3 Equivalent Strain

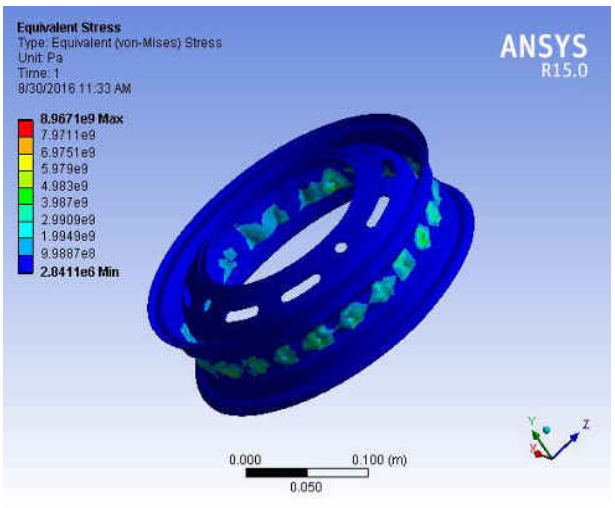

Fig.4 Equivalent Stress

From second experiment Maximum strain is 0.07335; maximum equivalent stress is $8.96X10^9$ N/mm^2. Maximum shear stress $2.72X\ 10^9$ N/mm^2. Which do not exceeds the minimum limit indicating the safety of rim.

From Third experiment Maximum strain is 0.07952; maximum equivalent stress is $9.21\ X10^9$ N/mm^2, Maximum shear stress $3.57X\ 10^9$ N/mm^2. Which do not exceeds the minimum limit indicating the safety of rim.

From fourth experiment Maximum strain is 0.5063; maximum equivalent stress is $1.006X10^{11}$ N/mm^2. Maximum shear stress is $2.31X10^{10}$ N/mm^2. This exceeds the minimum limit indicating the failure of rim. As this is the best combination for the thickness selected all other combinations of number of spots and spot diameter will fail. As this iteration is with 15 spots and D1=8.4 mm the rim will also fail for D2=7.7 mm and D3=7.0mm.So there is no need to conduct experiment number 06 and Experiment number 09.

From fifth experiment Maximum strain is 0.07991; maximum equivalent stress is $9.2098X10^9$ N/mm^2. Maximum shear stress is $3.44X\ 10^9$ N/mm^2. Which do not exceeds the minimum

From seventh Maximum strain is 0.5897; maximum equivalent stress is $1.173X10^{11}$ N/mm^2. Maximum shear stress is $2.6897X10^{10}$ N/mm^2. This exceeds the minimum limit indicating the failure of rim. As this is the best combination for the thickness selected all other combinations of number of spots and spot diameter will fail. This rim is with spot diameter D3=7.0 mm, as it fails for spot number S1=21, it will also fail for spot numbers S2=18 so there is no need to go for experiment number 08.

6.3 Outcome of Weld Strength Test

The Results at Rim thickness T2=2.3 mm are as shown in table,

Sr. No	Expt. No.	Spot No.	Spot Dia.	Rim Thickness	Equivalent Strain	Equivalent Stress	Shear Stress	Result
1.	1.1	S1	D1	T1	0.60123	$1.19X10^{11}$	$2.96X10^{10}$	FAIL
2.	2.1	S1	D1	T2	0.07335	$08.96X10^9$	$2.72X10^9$	**PASS**
3.	2.2	S1	D2		0.07952	$09.21X10^9$	$3.57X10^9$	**PASS**
4.	2.3	S1	D3		0.50603	$01.0X10^{11}$	$2.31X10^{10}$	FAIL
5.	2.4	S2	D1		0.07991	$09.21X10^9$	$3.4\ X10^9$	**PASS**
6.	2.5	S2	D2		0.07994	$09.20X10^9$	$3.44\ X10^9$	**PASS**
7.	2.7	S3	D1		0.58970	$1.17X10^{11}$	$2.68X10^{10}$	FAIL

Table 4 Experiment outcome for Weld Test

6.4 Validation of Rim Weld Test

We took the 05 samples for each combination. According to the tests standard and as specified by company load taken by rim should be near about 200 KN.

Sr.No	**Expt No.**	**Spot No.**	**Spot Dia.**	**Rim th.**	**Load Withstand by rim in KN**						
					1	**2**	**3**	**4**	**5**	**Average**	**Result**
1	1.1	S1=21	D1=8.4 mm	T1	150.35	152.61	153.33	150.3	158.37	152.99	FAIL
2.	2.1	S1=21	D1=8.4 mm	T2	257.35	259.66	257.1	257.48	255.6	257.44	**PASS**
3.	2.2	S1=21	D2=7.7 mm		229.7	228.99	231.44	230.11	232.6	230.51	**PASS**
4.	2.3	S1=21	D3=7.0 mm		170.23	173.33	175.52	176.68	176.88	174.53	FAIL
5.	2.4	S2=18	D1=8.4 mm		215.55	217.48	215.87	213.58	209.91	214.48	**PASS**
6.	2.5	S2=18	D2=7.7 mm		204.98	206.3	199.98	206.6	204.4	204.45	**PASS**
7.	2.7	S3=15	D1=8.4 mm		180.36	185.68	189.4	186.8	191	186.65	FAIL

Table 5. Experiment Trials on Weld Test

The results and outcome of experimentation are as follows:

6.5 Comparison of FEA Result and Experimental Results:

Sr.No	Expt No.	Spot No.	Spot Dia.	Thickness	Experimental Results	FEA Results
1	1.1	S1=21	D1=8.4 mm	T1	FAIL	FAIL
2.	2.1	S1=21	D1=8.4 mm	T2	**PASS**	**PASS**
3.	2.2	S1=21	D2=7.7 mm		**PASS**	**PASS**
4.	2.3	S1=21	D3=7.0 mm		FAIL	FAIL
5.	2.4	S2=18	D1=8.4 mm		**PASS**	**PASS**
6.	2.5	S2=18	D2=7.7 mm		**PASS**	**PASS**
7.	2.7	S3=15	D1=8.4 mm		FAIL	FAIL

Table 6. Comparison of FEA Result and Experimental Results

From the comparison of Experimental Results and FEA Results it is clear that the FEA results confirm the optimization procedure. `From the Weld Strength Test we see that the rim at thickness T1=2.0 fails and for T2=2.3 mm following rims passed.

CONCLUSION:

Finite Element Analysis results and Experimental results show that FEA can be adopted as optimizing the spot welds on Rim. Weld Analysis creates a strong ground for optimization as it filters the experiments and minimizes the iteration to be performed. FEA of weld is easy method for optimization of numbers of spot, now after this analysis we can move to experiment on DCFT and RFT.

REFERENCES:

1. D'Andrea, A., & Tozzo, C. : Interface stress state in the most common shear tests. *Construction and Building Materials*, *107*, 341-355. (2016).
2. Irastorza-Landa, A., Van Swygenhoven, H., Van Petegem, S., Grilli, N., Bollhalder, A., Brandstetter, S., & Grolimund, D. (2016). Following dislocation patterning during fatigue. *Acta Materialia*, *112*, 184-193.
3. Wan, X., Shan, Y., Liu, X., Wang, H., & Wang, J. (2016). Simulation of biaxial wheel test and fatigue life estimation considering the influence of tire and wheel camber. *Advances in Engineering Software*, *92*, 57-64.
4. Fang, G., Gao, W. R., & Zhang, X. G. : Finite element simulation and experiment verification of rolling forming for the truck wheel rim. *International Journal of Precision Engineering and Manufacturing*, *16*(7), 1509-1515. (2015).
5. Kosenko, I., & Gerasimov, K. : Object-oriented approach to the construction of an omni vehicle dynamical model. *Journal of Mechanical Science and Technology*, *29*(7), 2593-2599. (2015).
6. Nejad, R. M., Farhangdoost, K., & Shariati, M. : Numerical study on fatigue crack growth in railway wheels under the influence of residual stresses. *Engineering Failure Analysis*, *52*, 75-89. (2015).
7. Song, W., Woods, J. L., Davis, R. T., Offutt, J. K., Bellis, E. P., Handler, E. S., ... & Stone, T. W. (2015). Failure Analysis and Simulation Evaluation of an Al 6061 Alloy Wheel Hub. *Journal of Failure Analysis and Prevention*, *15*(4), 521-533.
8. Zheng, Z., Yuan, S., Sun, T., & Pan, S. : Fractographic study of fatigue cracks in a steel car wheel. *Engineering Failure Analysis*, *47*, 199-207. (2015).
9. Sharma, S., Sangal, S., & Mondal, K. : Wear behavior of newly developed bainitic wheel steels. *Journal of Materials Engineering and Performance*, *24*(2), 999-1010. (2015).
10. Esmaeili, F., Rahmani, A., Barzegar, S., & Afkar, A. : Prediction of fatigue life for multi-spot welded joints with different arrangements using different multiaxial fatigue criteria. *Materials & Design*, *72*, 21-30. (2015).
11. Alvarez, R. D. A., Ferguson, N. S., & Mace, B. R. : A robust spot weld model for structural vibration analysis. *Finite Elements in Analysis and Design*, *89*, 1-7. (2014).
12. Li, Z., DiCecco, S., Altenhof, W., Thomas, M., Banting, R., & Hu, H. : Stress and fatigue life analyses of a five-piece rim and the proposed optimization with a two-piece rim. *Journal of Terramechanics*, (2014).