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Analysis and Optimization of Automobile Wheel Rim

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Abstract: Manufacturing of wheel in automotive industries demands no flaw wheels.This component must not fail. However, the process also as a material deficiency in varying ratios of influence has been counteracting factors in producing flawless wheel rims. The wheels are loaded in a complex manner, understanding these loading conditions are important for efficient wheel design. The wheel must be durable enough to tolerate significant loads and harsh environmental effects. In this project work, the experimentation and Optimization analysis of Automobile Wheel Rim using Finite Element Analysis will be done. Finite Element Analysis Models will be developed for the tests mentioned. Experiments of some tests will be carried out. FEA results and Experimental results will be compared for the best combinations of selected parameters and materials. We are studying Fatigue analysis of an Automobile rim using FEA software on DCFT, the data which will be used to optimize the wheel on weight or mass base criteria with different materials. We use two materials, magnesium alloy and aluminum alloy in this work.

Keywords: Automobile wheel Rim, FEA software. Magnesium alloy, aluminum alloy

1. INTRODUCTION

Automotive wheels have much-complicated profile shape and geometry. It must satisfy manifold design criteria for good style, less weight, good manufacturability, and better performance. Cracking of Automobile Wheel Rims is a major problem observed. Ensuring the reliability and safety of the wheel is very important. [1]

So, we are studying Fatigue analysis of an Automobile rim using FEA software on DCFT, the data which will be used to optimize the wheel on weight or mass base criteria with different materials. Here we have used Aluminum alloy and Magnesium alloy to replace the steel wheels. Analysis of the rims consists of numerically analyzing the stress levels that rims experience during operating conditions. The magnitude of the static load and pressure contributes to increasing the stresses on the rim components. [2]

During the manufacturing and forming of the strips into wheel profile, cracking of Wheel Rims is a major problem observed. Hot rolled of low carbon steel strips with or without micro-alloying are used in manufacturing Wheel Rims for light and medium commercial vehicles. Cold forming necessitates formability as the major parameter in Wheel Rim manufacturing which needs meticulous designing of the chemistry of the parent steel as well as the mechanical properties in the parent strip to be imparted during hot rolling. The major application for Wheel Rims is either for tube wheels or tubeless wheels. [3]

Propose a multi-objective topology optimization methodology for the steel wheel, in which both the compliance and Eigen frequencies are regarded as static and dynamic optimization objectives. Compromise programming method is employed to define the objectives of multi-objective and multi-stiffness topology optimizations, whereas mean-frequency formulation is adopted to settle Eigen frequencies of free vibration optimization. To obtain a transparent and useful topology optimization result, cyclical symmetry and manufacturing constraints are set, the influences of which on the outcomes also are discussed.

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2. OBJECTIVES OF INESTIGATION

1. Develop the FEA model for dynamic cornering fatigue test and radial fatigue test for the two designs provided.
2. Estimate the life cycle period of the automobile wheel rim.
3. Study failure in automobile wheel rim by FEA software and experimentation.

3. PARAMETERS CONSIDERED FOR STUDY

The parameters for the investigation are as follows;

1. Design No.1-D1
2. Design No.2-D2

The materials available for the automobile wheel rim are as follows:

1. Aluminum alloy-M1
2. Magnesium alloy-M2

4.GEOMETRIC MODELLING

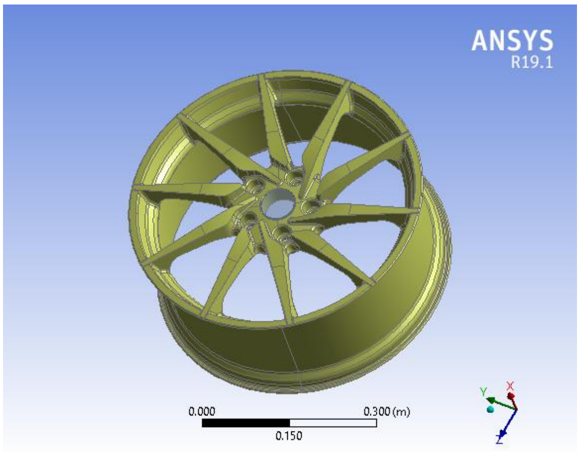

Figure 1 Geometric Model Design 1

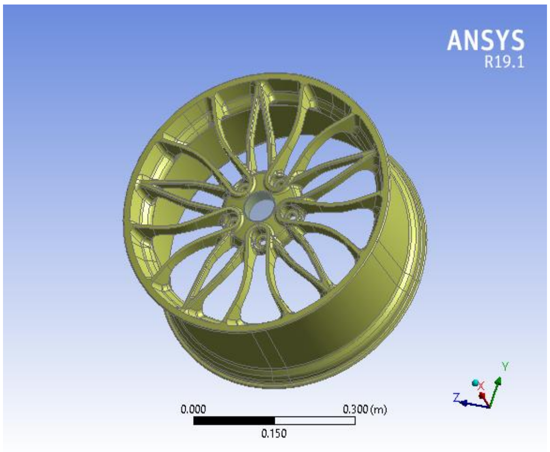

Figure 2 Geometric Model Design 2

5.VALIDATION FOR CORNERING FATIGUE TEST

For the validation, the strain gauges are mounted on the rim at four different locations. These results are compared with the FEA results. Physical mentioned as cornering fatigue test is run and discussed below. After completion of the test, the test specimen is far away from the found out. 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. The Cornering fatigue test machine performs testing on wheels, under rotating condition, with the bending moment applied at 90 degrees to the test wheel.
The stresses calculated within each element with the help of FEA describe the strain distribution of material that may be determined. To evaluate the effect we have to do a failure analysis of Wheel Rims from the comparison.

Figure 3 Photograph of Wheel Rim during Testing

So for Validation purposes, we have two Experiments- Experiment No.3 and Experiment No.7

Table 1 Cases for Validation

Expt. No.	Design No.	Material	Mass (Kg.)	Case/Condition	Remark
3	D1	Mg Alloy	6.39	C1	For Validation
7	D1	Mg Alloy	6.39	C2	For Validation

6. EXPERIMENTAL RESULTS

Experiment No. 03: The strain gauge readings for C1

Table2 Experimental Results for DCFT Experiment No.3

Strain Gauge Position	Strain Values (X10^{-4})				
	Sample(1)	**Sample(2)**	**Sample(3)**	**Sample(4)**	**Average**
1	3.021	2.961	3.112	2.981	3.094
2	0.141	0.138	0.137	0.139	0.139
3	8.864	8.992	9.121	9.420	9.099

Experiment No. 07: The strain gauge readings for C2

Table 3 Experimental Results for DCFT Experiment No.7

Strain Gauge Position	Strain Values (X10^{-4})				
	Sample(1)	**Sample(2)**	**Sample(3)**	**Sample(4)**	**Average**
1	1.239	1.122	1.292	1.276	1.307
2	0.131	0.139	0.129	0.136	0.134
3	10.12	9.851	9.676	10.42	10.01

7.FEA STRAIN GAUGE PLOTS

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A. Experiment No. 03: The FEA strain gauge readings for C1

Figure 4 Strain Gauge at Location 1 for Checking Condition C1

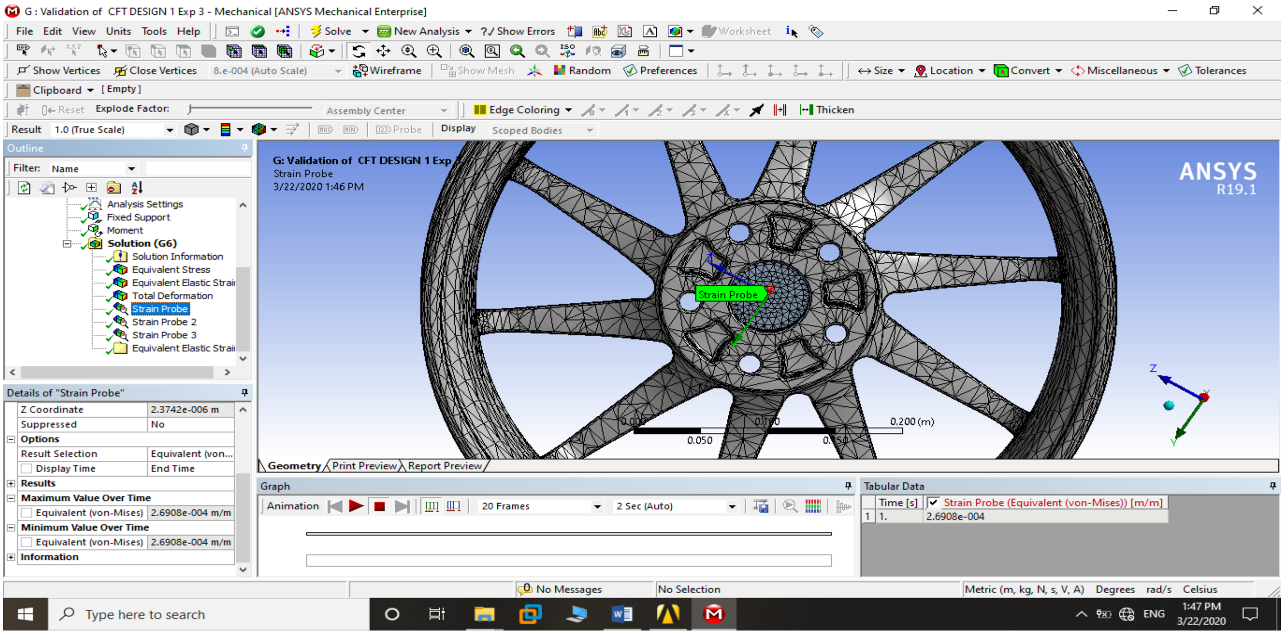


Figure 5 Strain Gauge at Location 2 Checking Condition C1

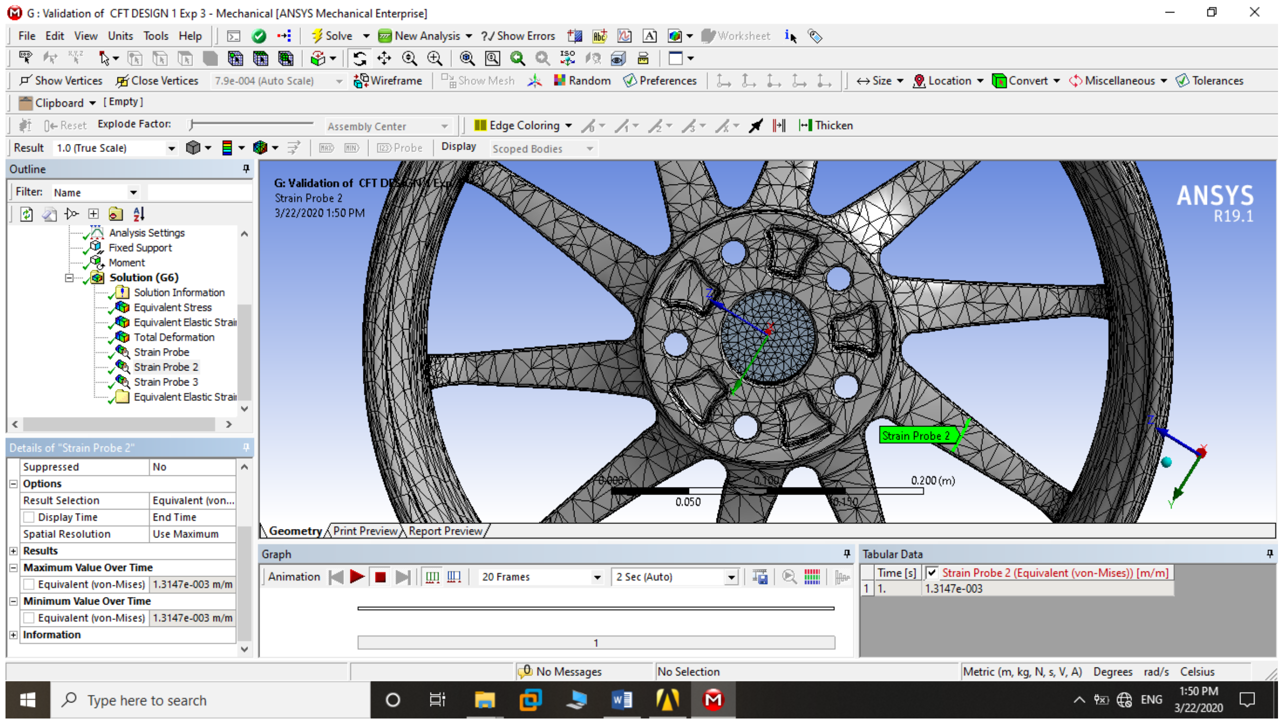
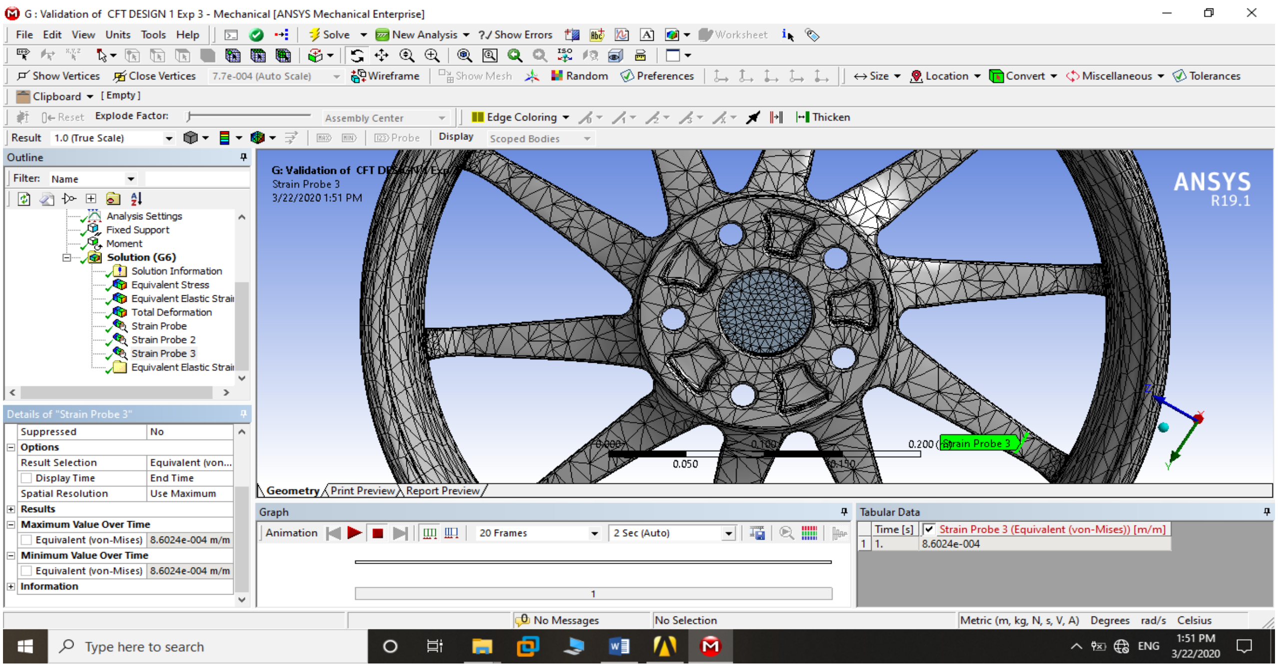


Figure 6 Strain Gauge at Location 3 Checking Condition C1



B. Experiment No. 07: The FEA strain gauge readings for C2

Figure 7 Strain Gauge at Location 1 for Condition C2

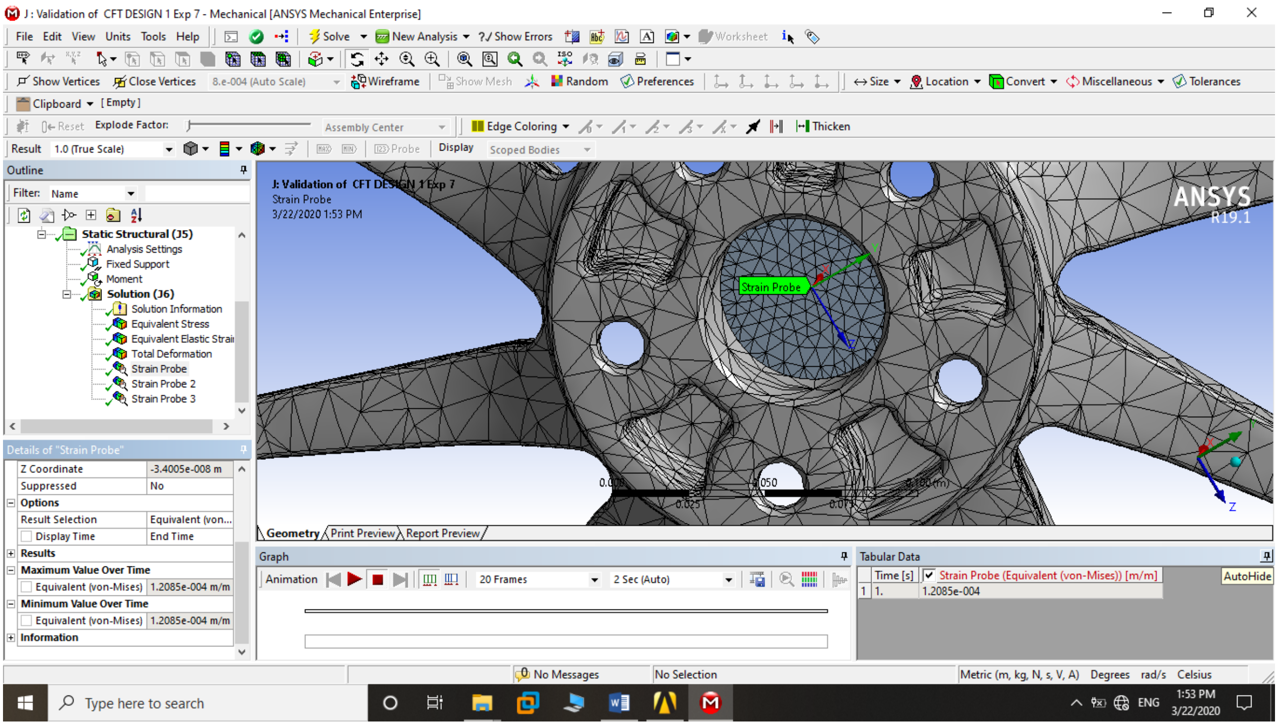


Figure 8 Strain Gauge at Location 2 for Condition C2

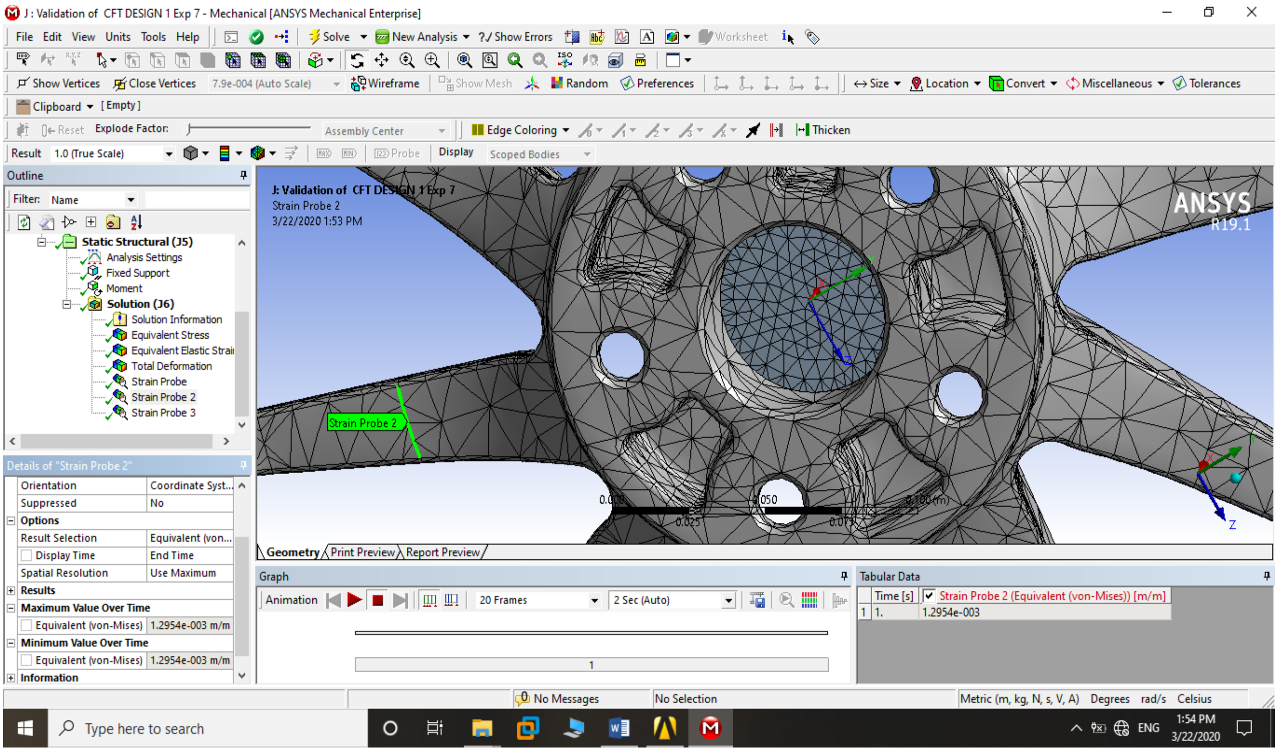
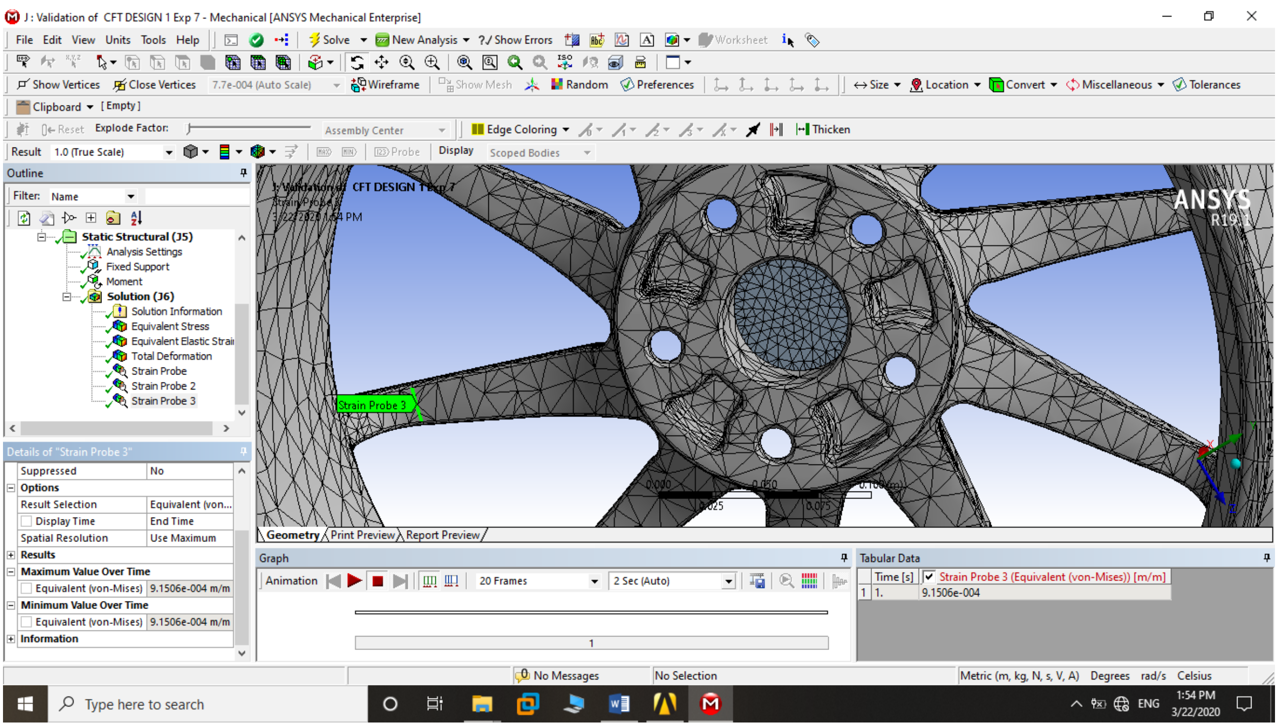


Figure 9 Strain Gauge at Location 3 for Condition C2



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8. COMPARISON OF RESULTS

A. Experiment No. 03: The strain gauge readings for C1

Table. Comparison of the strain gauge readings with FEA for C1

Strain Gauge Position	Strain Values ($X10^{-4}$)					FEA RESULTS ($X10^{-4}$)	Difference
	Sample 1	Sample 2	Sample 3	Sample 4	Average		%
1	3.021	2.961	3.112	2.981	3.094	2.69	13.96
2	0.141	0.138	0.137	0.139	0.139	0.13	6.69
3	8.864	8.992	9.121	9.420	9.099	8.60	5.64

B. Experiment No. 07: The strain gauge readings for C2

Table: Comparison of the strain gauge readings with FEA for C2

Strain Gauge Position	Strain Values ($X10^{-4}$)					FEA RESULTS ($X10^{-4}$)	Difference
	Sample 1	Sample 2	Sample 3	Sample 4	Average		%
1	1.239	1.122	1.292	1.276	1.307	1.2	8.54
2	0.131	0.139	0.129	0.136	0.134	0.12	11.02
3	10.12	9.851	9.676	10.42	10.01	9.15	8.98

The results from the steel Wheel Rim dynamic cornering fatigue test of Case 2 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. The variation in FEA and actual Experimentation is below 15 %, which validates the CFT test. So it indicated that the moment is applied to the hub also.

8. CONCLUSIONS:

A Multi-objective analysis concept is administered to optimize the weight of the Rim. Also, to work out whether the moment is applied at mounting holes or at Hub also. Work is carried out in steps by step manner. We tried to attenuate the number of Experiments and levels of Experiments. All experiments were considered at First Test, then proper Finite Element Analysis is completed. Then Experimentation for an equivalent test is completed and compared. During this way, a filter is applied to extensive Experimentation. For the safe combinations, we carried DCFT with FEA as well as Experimentation. Here we got the final optimized result. Experimental results were compared to finite element results for validating the methods adopted. The experimental results and the modifications and identification of the proper methods for applying the moment on the rim. We found that Magnesium alloy is suitable with Design 1and it weighs only 6.39 Kgs. So a reduction in weight is 8.91 Kg.

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