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Design of Experimentation on Roll Cage of All Terrain Vehicle

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***Abstract*— A roll cage is a skeleton of an ATV. It forms 3 D shell surrounding the driver to protect from worst case scenario. In the present investigation, design of experimentation is done for stress and displacement of roll cage with weld position of critical element and material of roll cage are deciding factors. We recognize the critical element of the roll cage which comprises of maximum stress when undergo through static force analysis from our previous work in the design development and analysis of roll cage. Further we selected the three commonly used materials for roll cage manufacturing and also give the three different weld positions for the critical element. The weld position and material are used as inputs for Taguchi method and the response factors are find for displacement and stress on the roll cage. ANOVA is used to find the percentage contribution of material and weld position on stress and displacement.**

Keywords*— Critical Element; DOE; Weld Position; Orthogonal Array;

I. INTRODUCTION

In this Era the importance of safer vehicle increased day by day so the automobile industry has changes drastically. The main objective of this paper was to test the ATV Roll Cage against the collision and to find how the material and position of weld of critical element contribute in maximum displacement and stress in the roll cage. Roll cage takes charge of mountings of all vehicle's subsystems with the advantage of taking care of the driver safety at all time. The chassis design need to be considered for impacts generated in any certain crash or rollover. It must be strong and durable taking always in account the weight distribution for a better performance.

During actual road test, any vehicle is withstands to loads that cause stresses, vibrations and noise in the different components of its structure. To sustain against this load it requires appropriate strength, stiffness and fatigue properties of the components. On other side quality of a vehicle, as a system includes efficient fuel consumption, safety, riding dampness and provision of comfort to the driver is highly desired. Roll Cage is the structural basis of an All-terrain vehicle.

The critical element is the component of roll cage which take maximum stress so as the chances of failure of that element is more. Due to this reason it is selected as a critical element of the roll cage. Changes in design are done according to the position of the critical element of the roll cage. Analysis for stress and displacement is done for the combination of weld position and material which is obtained from an orthogonal array. Taguchi is new method of conducting the design of experiments which are based on well defined guidelines. This method uses a special set of arrays called orthogonal array. This standard array stipulates the way of conducting the minimum number of experiment which could give the full information of all the factors that affect the performance parameter. Displacement and stress analysis are done using Altair HyperWorks v12.0 software. Following paper outlines the design of experimentation (DOE) for stress and displacement of roll cage in front impact.

II. SELECTION OF CRITICAL ELEMENT

Critical element is the element which can make change in parameters like stress & displacement of the other elements by changing its position or the weaker element of the roll cage. From the previous analysis[1] we select the critical element for the front impact analysis which is having the maximum displacement in it for the worst case scenario and also the stress value is maximum in it.

The element with maximum stress value is shown in the following fig.1 which is considered as critical element of roll cage for front impact analysis.

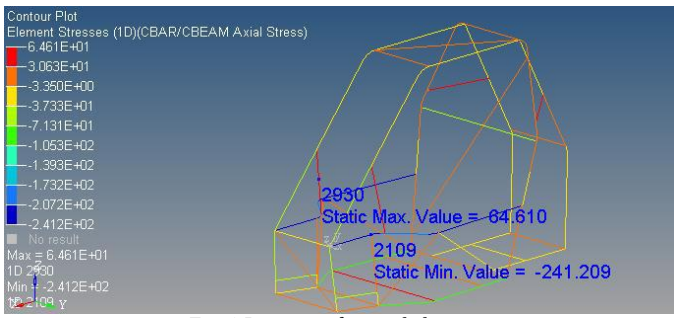

Fig. 1 Location of critical element

III. DESIGN OF EXPERIMENTATION

DOE techniques enable designers to get attention simultaneously on the individuals and interactive effects of many factors that could affect the output results in any design. DOE also provides a full insight of interaction between design elements; it is helpful to turn any standard design into robust one. Simply does helps to determine the sensitive parts and sensitive areas in designs that cause problems in response variable. We are then able to fix these problems and produce vigorous results.

A. Taguchi Method

Taguchi's parameter design provides a systematic approach for optimization of various parameters with regard to performance, quality and cost. Taguchi method consist of a plan of experiments with the objective of acquiring data in a

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controlled way, executing these experiments and analyzing data. Taguchi method also helps to reduce no of experiments and gives maximum information about the results with minimum experimentation. L9 orthogonal array is employed to analyze experimental results of stress and displacement obtained from 9 experiments by varying two parameters viz. weld position and material. The array gives 9 combinations as shown in Table I.

TABLE I. Array of Material and Weld Position

Combination	Variable Parameters	
	Material	Weld Position
1	Matrerial 1	1
2	Matrerial 1	2
3	Matrerial 1	3
4	Matrerial 2	1
5	Matrerial 2	2
6	Matrerial 2	3
7	Matrerial 3	1
8	Matrerial 3	2
9	Matrerial 3	3

B. Analysis of Variance (ANOVA)

ANOVA is a collection of statistical models, and their associated procedures, in which the observed variance in a particular variable is partitioned into components attributable to different sources of variation. In its simplest form, ANOVA provides a statistical test of whether or not the means of several groups are all equal, and therefore generalizes *t*-test to more than two groups. Doing multiple two-sample t-tests would result in an increased chance of committing a error. For this reason, ANOVAs are useful in comparing two, three, or more means

C. Experimentation

The roll cage is used for the experimentation with 3 different materials. Selection of material is done as per the SAE standards and the materials selected are used commonly to manufacture roll cage and are easily available in market. Materials selected are Aluminum alloy 4043,AISI 1018 & AISI 4130. Density is the factor which is mainly differs in all the 3 materials selected.

Also the weld position is changed such as considering the SAE standards as initially the critical element is welded on bend. Position 1, position 2 and position 3 are shown in the Fig. 2, Fig. 3 and Fig. 4 respectively. The properties of materials selected are given in the Table II

TABLE II. Properties of Materials Selected

Properties	Materials Selected		
	Material 1	*Material 2*	*Material 3*
	Al alloy 4043	*AISI 4130*	*AISI 1018*
Density(Kg/m^3)	2690	7850	7878
Yield Strength(MPa)	70	460	370
Tensile Strength(MPa)	145	731	440
Poisson's Ratio	0.34	0.32	0.30
Modulus of Elasticity(MPa)	70	190	210

IV. RESULTS

Based on the combinations obtained from the L9 array, Table I, in the Taguchi method analysis is done and the results for the stress and displacement are obtained for the same combinations of weld positions and the material. Following fig. 2, fig. 3 and fig.4 shows some of the results.

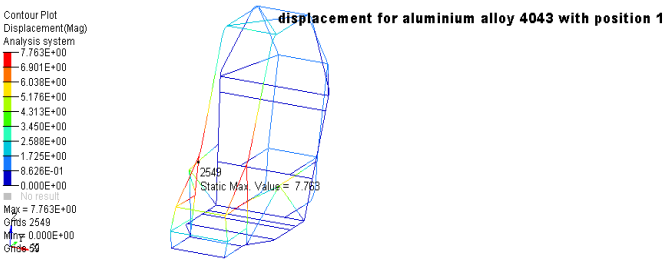

Fig. 2 Displacement for Al alloy 4043 with weld position 1

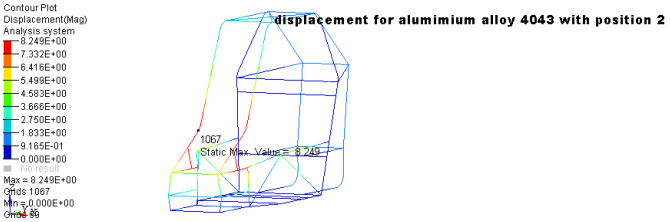

Fig. 3 Displacement for Al alloy 4043 with weld position 2

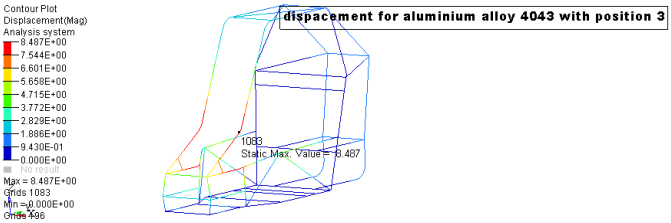

Fig. 4 Displacement for Al alloy 4043 with weld position 3

The results obtained by performing analysis done in Altair HyperWorks 12.0 for 3 separate designs of weld positions are done in Catia V5 and there combination with 3 different materials used. All the nine results for stress and displacement as response factors are tabulated in following Table III.

TABLE III. Response Factors For Combination of Material & Weld Position

Combination Array		Response Factors	
Material	*Weld Position*	*Stress(MPa)*	*Displacement(mm)*
Al alloy 4043	1	37.08	7.63
Al alloy 4043	2	36.48	8.09
Al alloy 4043	3	36.23	8.48
AISI4130	1	37.11	2.85
AISI4130	2	36.47	3.02
AISI4130	3	36.25	3.12
AISI 1018	1	37.13	2.57
AISI 1018	2	36.5	2.74
AISI 1018	3	36.27	2.81

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A. *Taguchi Results forDisplacement and Stress*

Results obtained for displacement and stress obtained from Taguchi method are shown in the following figures. Fig. 5 shows the effect of material and weld position on maximum displacement using the criteria of smaller is better and fig. 6 shows effect of weld position and material on stress using the criteria larger is better.

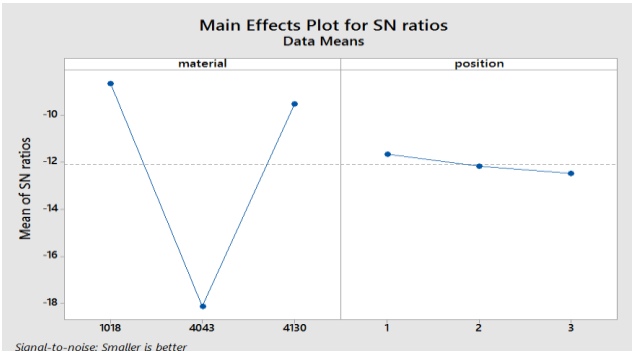

Fig. 5 Effect of material and weld position on displacement

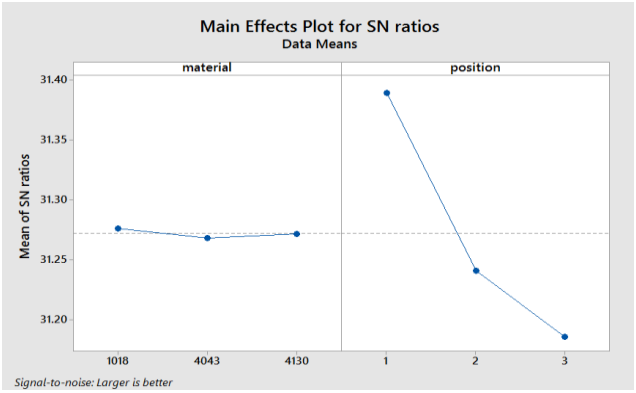

Fig. 6 Effect of material and weld position on stress

B. *Resuts from ANOVA*

Taguchi method cannot judge and determine effect of individual parameters on entire process while percentage contribution of individual parameter can be well determined using ANOVA. MINITAB software of ANOVA MODULE was employed to investigate effect of parameters Material and weld position.

The ANOVA gives us the percentage contribution of material and weld position for stress and displacement in the roll cage. Fig. 7 and fig. 8 gives the percentage contribution of weld position and material on displacement and stress respectively.

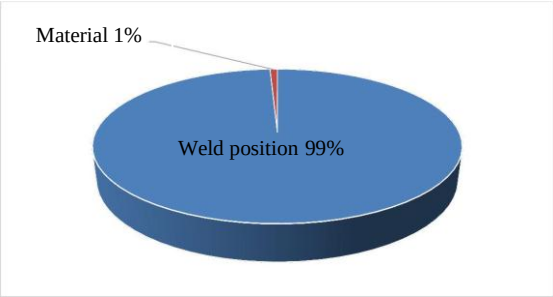

Fig. 7 Percentage contribution Material & Weld position on displacement

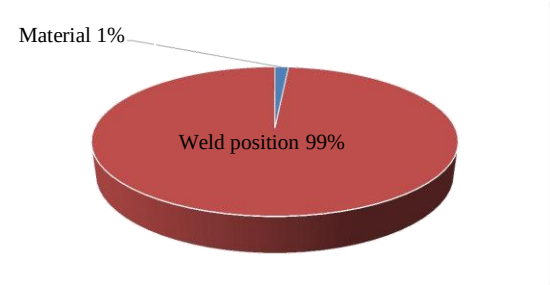

Fig. 8 Percentage contribution Material & Weld position on stress

V. CONCLUSION

Safety is the most important factor in every aspect rather it is driver or any crew member. For that design is made in consideration of all the safety aspects and also as per SAE regulations. After the analysis critical member of roll cage maximum displacement and stress is selected which may harmful to the driver. As the function of roll cage is to keep the driver safe at worst condition the displacement of the members of roll cage should be less. For that we should give more importance to the material selection as its contribution in the displacement is more than the triangulation or weld position of critical element. Similarly when we consider the stress as response factor to have good strength to weight ratio of roll cage we should give importance to the weld position of critical element or the triangulation of the small members instead of material.

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