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BY USING TAGUCHI AND ANOVA METHODS FOR OPTIMIZATION OF STRESS AND DEFORMATION FOR LAP JOINT

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Abstract

In several industries, welding is significantly used; aviation industry, automotive industry and construction industry are some of the industries which widely use welding. Therefore, for the welding characteristics or responses, optimization of mechanical properties is considered important. For the factorial design of the experiment, Taguchi method is used that is an appropriate statistical method. Moreover, there are several standard methods for evaluating tensile strength of the material, it's necessary to develop new ideas for obtaining tensile strength of welding joints. In this present study, the effective way is used to evaluate and optimise the welding techniques with better tensile strength for Lap Joint. The method opts for analysis of Lap welding joint is Taguchi method. Taguchi method is used for the purpose of result optimization. ANOVA method is used for proper judgement of result along with Taguchi method. The stress and deformation is calculated on the ANSYS software.

Keywords: ANSYS, Joints, Lap joint, Taguchi, Tensile strength, welding.

1. INTRODUCTION

When it comes to securing machine components and structures, welding is the most popular method. Blending occurs when two different materials (metals or thermoplastics) are brought together by welding. With or without filler material, welding is a procedure in which heat or pressure is used to fuse

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two or more metals together. [1] There are several auxiliary materials that may be employed to facilitate the process, such as shielding gases, flux, and pastes. Welding requires an external source of energy. As a permanent connecting procedure without melting the base metal, welding is one of the "well-defined low temperature metal joining methods", including soldering and brazing.[2]

1.1. Types of material used

S275 Steel: Standard cross-sectional forms (or "sections") are used to create structural steel, a fundamental building material constructed from particular grades of steel. Chemical and mechanical qualities are tailored for particular purposes in structural steel grades. Most of the industrial construction, includes bridges, trains, and ships, uses structural S275 steel plates. Because of this, establishing the S-N curve, which measures the fatigue strength of a material based on the number of cycles it takes to fail and the stress it is subjected to, is critical in industrial building. [3]

Steel structural may be employed in a wide variety of ways and for a wide range of purposes. The unique combination of outstanding welding qualities and guaranteed strength makes them especially valuable. Engineers who want to reduce weight and increase structural strength often turn to structural steel, which has a wide range of applications. [4]

Al6061: Magnesium and silicon are the primary alloying constituents of 6061 (Unified Numbering System (UNS) designation A96061), an aluminium alloy that is precipitation hardened. It was first referred to as "Alloy 61S" in 1935. High mechanical qualities, good weld ability and widespread extrusion make it a popular choice. For general-purpose application, it is one of the most common aluminium alloys Tempered 6061-T6 and 6061-T651 grades are widely available, as are 6061-O (solutionized, stress-relieved stretched and artificially aged).[5]

6061 is commonly used for the following:

- Construction of aircraft structures, such as wings and fuselages, more commonly in homebuilt aircraft than commercial or military aircraft.
- Yacht construction, including small utility boats.
- Automotive parts, such as the chassis of the Audi A8 and the Plymouth Prowler.
- Flashlights
- Aluminum cans for the packaging of food and beverages.
- Scuba tanks and other high pressure gas storage cylinders.

EN8 Steel: Steel having increased strength and through-hardening properties, EN8 carbon steel is a popular medium carbon and medium tensile steel. Additionally, EN8 carbon steel may be machined in any state.[6]

The untreated state of EN8 steels is the most common usage for these metals. However, induction methods allow for further surface hardening of EN8 steels, resulting in components with improved wear resistance. Steel EN8 has excellent homogeneous metallurgical structures in its heat-treated forms, resulting in consistent machining qualities.

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All general engineering applications needing a greater strength than mild steel may use EN8 steel, including the following:

i. general-purpose axles
ii. shafts,
iii. gears,
iv. Bolts and studs.
v. spindles,
vi. automotive and general engineering components,
vii. Other general engineering parts etc.

1.2. Objectives of the Study

1. From the above studies, it is observed that different materials like S275, AL6061 and EN8 have not been used in earlier studies. So these materials are used in our study for external welded Lap haunched joints.
2. By varying the length of External welded Lap haunched joints, the design is modified for further studies.
3. In previous studies, the effect of force is not studied. So, investigation can be performed on effect of force in External welded Lap haunched joints.
4. In External welded Lap haunched joints, for analyzing the value of stress and deformation, Finite Element Method will be used.

2. LITERATURE REVIEW

Loureiro et al. [7] A number of academics have recently worked hard to increase their understanding of the behaviour of steel joints. In order to meet the requirements of the EC3, special attention has been paid to acquiring the stiffness of the various components of the joints. However, the component technique has significant limits, hence new methods for determining the stiffness of joints must be developed. An alternate approach for assessing the stiffness of 2D external welded haunched joints is described in the current study. There are four tests in all, each with a finite element model to go along with the findings. The stiffening of the column web has been evaluated with four distinct types of joints. Furthermore, finite element models of the joints have been built and calibrated using the results of the testing.

Daniel Das et al. [8] In his investigation, tool rotational speed was shown to be the most important factor in enhancing the strength of the joint. When it comes to fusion welding, AA 7075 is considered to be an unfabricated metal, and the parent metal can't be weld. When it comes to feeding rates, there are three distinct levels: 162.8, 153.8 and 144.7 mm/min, respectively, for the feed rate. At the feed rate, the delta was about 18.1... As a result, the maximum welding speed (159.8 mm/min) has been increased to level 3 (second place). The tool's rotating speed was measured at 154.6 rpm. Compared to tool speed and

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welding speed, feed rate proved to be the most compelling metric in this case. There is no doubt that Feed rate is the most effective parameter among the three that generate efficient weld joints, according to SN ratio values There is a first level of 44.23 mm/min feed rate, followed by 43.73 mm/min and 43.21 mm/min at levels two and three, respectively.

Mandeep Singh et al. [9] Smooth welding is achieved by ionising the supplied gas and creating an arc between the electrode and the workpiece. Welding speed and metal deposition are both boosted when welding is done in continuous mode. A positive polarity filler wire is used, and a negative polarity work piece. R.A. Fisher created the DOE method in 1920. Multiple variables may be analysed concurrently using this method. In order to achieve the needed optimization, DOE's partnership with Taguchi has shown to be effective. For example, combining components at different levels, each with its own range, and yet ensuring little variance around ideal outcomes is also possible using DOR. MIG welding process characteristics include welding current, voltage, gas flow rate; wire feed rate, electrode diameter, and more. Welding voltage and current are the most critical.

H.Li et al. [10] Spot welds are widely utilised in the automotive and aerospace sectors to attach thin metallic sheets. The most common cause of spot weld failure is the formation of fatigue fractures around the weld nugget's edge. Stress intensity factors (SIFs) are used to forecast the fatigue life of spot weld joints, which are critical to the durability of vehicles. The spot weld edges and high fidelity SIFs are consequently essential. When dealing with a real industrial-scale structure including thousands of spot welds, the quantity of welds, the disparity between the structure welds, complicated geometries, and load situations make it even more difficult to do the necessary welding.

Stalin et al. [11] One of the fastest-growing prospects in production engineering is welding technology. Welding is essential in many construction, erecting, ship-building, and body-building projects nowadays. Although welding technology offers numerous advantages, it also has certain drawbacks that must be taken into account when doing this research. If welding technology's flaws could be fixed, many dangers and accidents may be averted. A large number of persons involved in welding projects are unable to determine the precise loading and boundary conditions for the matching weld, which is to be made utilising the “design of experiment (DOE)”.

Asif Ahmad et al. [12] "tungsten inert gas welding" is a popular method for welding "ferrous and non-ferrous" metals. "Stainless steel grade 3HQ (S30430)" is a specialty wire grade in the production of stainless steel. Grades 384 and 305 have been superseded by it for heading use. Consequently, it exhibits outstanding toughness at temperatures even lower than cryogenic. Utilizing Taguchi's design of experiments (DOE), studies were carried out and a mathematical model built using variables such as voltage, depth, current, or speed.

Marcello Lepore et al. [13] Multiple three-dimensional fracture propagation in a welded structure may be modelled numerically using a finite element technique. An AA2024-T3 butt joint subjected to process-induced residual stress develops cracks during friction stir welding. Temperature dependent elastic-plastic material characteristics, softening and isotropic hardening were taken into account in a thermo-mechanical FEM simulation of the process to estimate the residual stress field. After that, fractures are added in the FEM computational domain that enable stress redistribution and fatigue crack

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propagation.. Comparison of numerical results obtained by a combined FEM-DBEM process, accessible in literature, has verified the suggested approach.

3. METHODOLOGY

3.1. Step of Method

1. Design of Experiment table by using L9 Orthogonal array table.
2. Further converting the File in .step format for importing it in Ansys Fluent work bench.
3. Assigning the Material property in parts.
4. Meshing for performing the simulation process.
5. Provide the suitable boundary conditions according to the decided objective.
6. Evaluating the results after the finish of simulation work.
7. After simulation the result is analysis in Taguchi method by using Minitab software

3.2. Material Property:

Three different materials as S275 steel, Al6061 aluminum, EN8 steel that are joined by Lap welding. The analytical setup and procedure opted is Lap welding for these material. The joints are designed with the help of Taguchi method and ANSYS software for stress and deformation interpretation.

The materials opted for the work is aluminum and steel. And their density, young modulus, poisson's ratio is taken in account by using the software and the structural frame work of the design is crafted with these characteristics.

Table 1: Table Representing Material Property:

Material	**Density Kg/m^3**	**Young's Modulus (MPa)**	**Poisson's Ratio**
S275	7850	210x10^3	0.30
Al6061	2700	68.9x10^3	0.33
EN8	7800	190x10^3	0.3

3.3. Table showing Orthogonal L9:

Table 2: Table representing Orthogonal L9:

Case	**Design**	**Force (KN)**	**Material**
1	D1	108	S275
2	D1	128	Al6061
3	D1	148	EN8
4	D2	108	Al6061
5	D2	128	EN8
6	D2	148	S275
7	D3	108	EN8

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8	D3	128	S275
9	D3	148	Al6061

4. RESULTS AND DISCUSSION

4.1. Calculation of S/N Ratio :

Table 3: Table representing S/N Calculation Ratio:

Case	Design	Force	Material	Stress (MPa)	Deformation	S/N Ratio
1	D1	108	S275	310.95	4.62	-49.8538
2	D1	128	Al6061	362.45	16.87	-51.185
3	D1	148	E8	368.54	6.05	-51.3297
4	D2	108	Al6061	253.48	14.22	-48.0789
5	D2	128	E8	296.28	6.05	-49.434
6	D2	148	S275	342.58	6.33	-50.6952
7	D3	108	E8	283.48	6.54	-49.0504
8	D3	128	S275	335.98	7.02	-50.5263
9	D3	148	Al6061	388.47	8.97	-51.7871

4.2. Response Table:

Table 4: Representing Response Table
(Smaller value is considered better here)

Level	Design	Force	Material
1	-50.79	-48.99	-50.36
2	-49.40	-50.38	-50.35
3	-50.45	-51.27	-49.24
Delta	1.39	2.28	0.42
Rank	2	1	3

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4.3. S/N Ratio Graph:

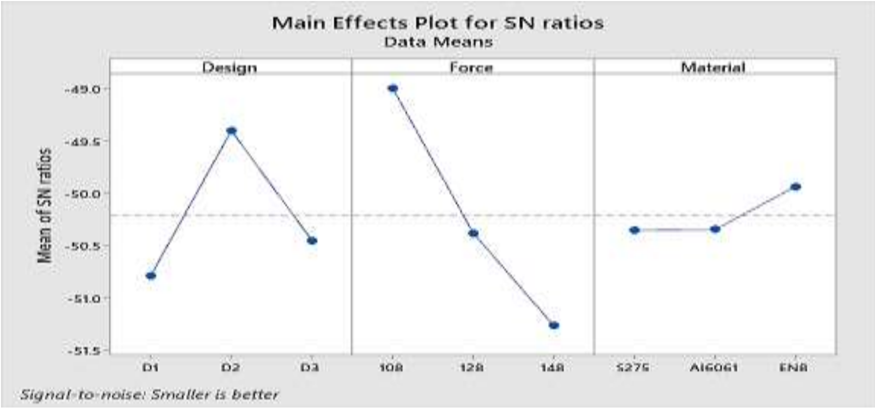

Figure 1: Graphical representation of S/N ratio

4.4. Result Validation:

Equivalent Stress: Using equivalent stress when there is a multiaxial stress condition with numerous stress components working simultaneously in the structure is a common practise. In such cases von-mises stress is considered while drawing the structure of the material component.

In the figure given below, the result of Case 10 is shown. The result shows the maximum 249.99MPa as well as minimum value 0.0019633MPa of equivalent stress.

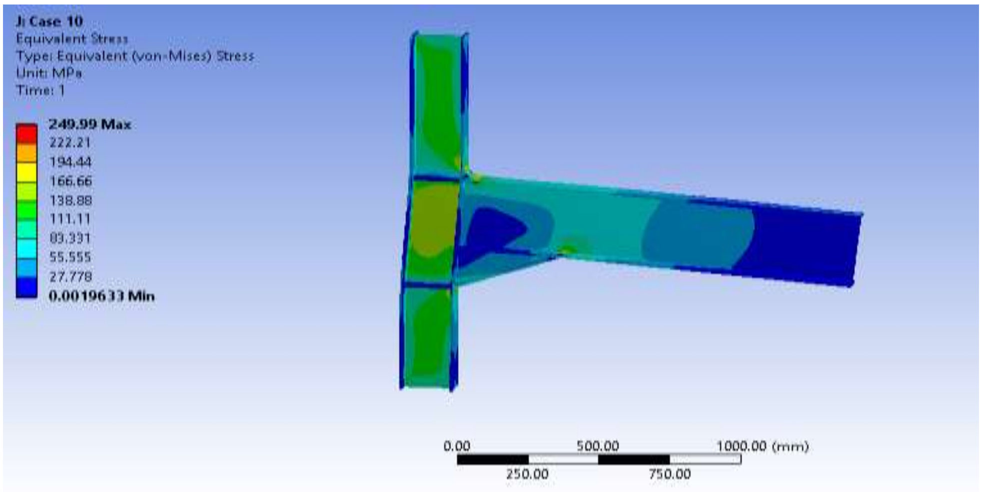

Figure 2: Equivalent stress for Case 10

Total Deformation: In the ANSYS Work Bench, deformation data are often shown as either total or directional deformation. Both of them are used to measure stress-induced displacement.

In the figure given below, the result of Case 10 is shown. The result shows the maximum 5.1108mm as well as minimum “0”mm value of total deformation.

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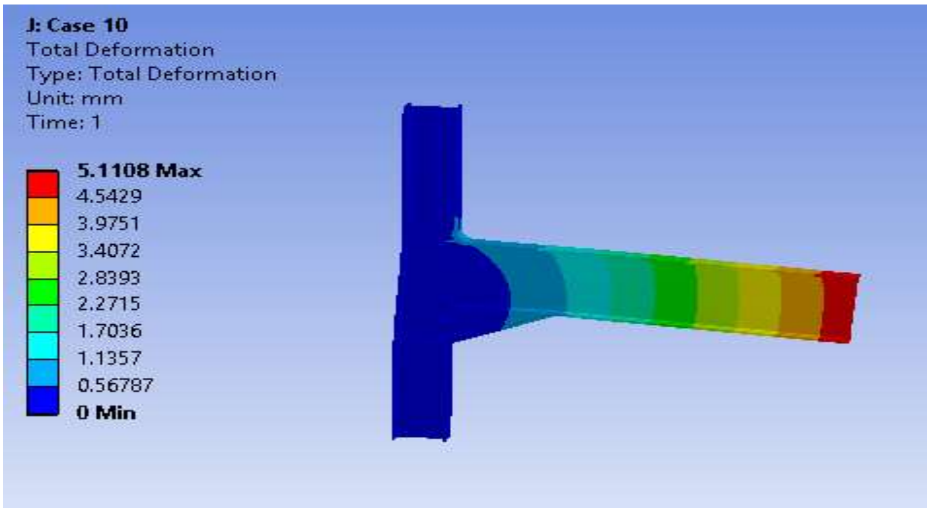

Figure 3: Total deformation for Case 10

4.5. Stress Comparison:

Stresses created during manufacturing operations such as cutting, cold work, welding, grinding, shot peening and so on are known as residual stresses (RS). Residual tensile stress on a surface is generally undesirable, since it reduces fatigue resistance. Therefore, compressive pressures on the surface boost the fatigue strength. Component failure may be attributed to welding-related stresses, which are critical to consider.

Stress v/s Cases:

The graph shown below represents the value of stress in particular cases from Case 1 to Case 10. In case 9, the maximum value of stress is observed and Case 4 shows the minimum value for stress.

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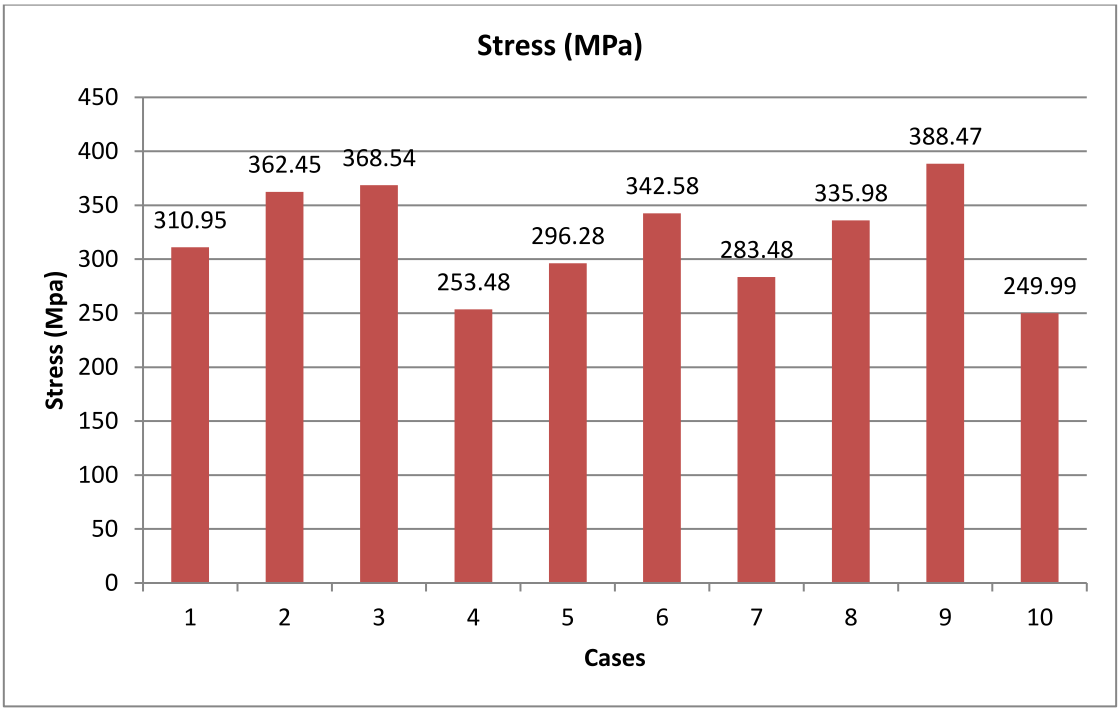

Figure 4: Graphical representation of Stress

Deformation v/s Cases:

The graph shown below represents the value of deformation in particular cases from Case 1 to Case 10. In case 2, the maximum value of deformation is observed and Case 1 shows the minimum value for deformation.

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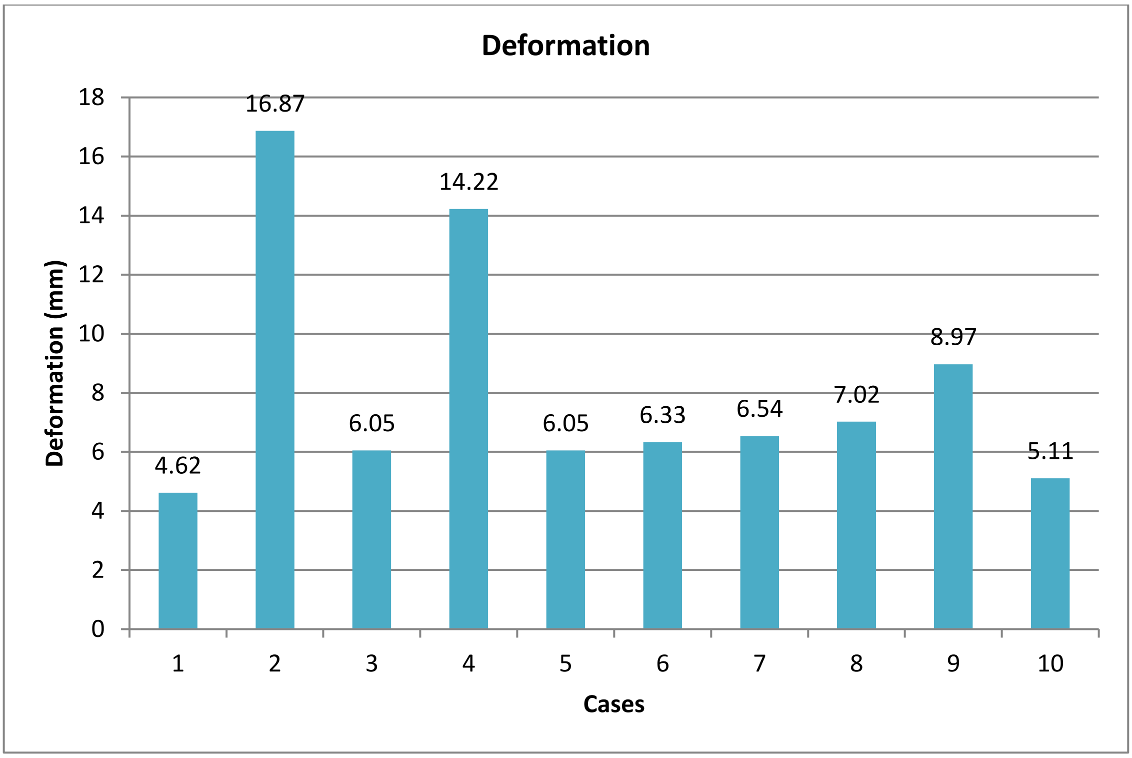

Figure 5: Graphical representation of Deformation v/s Cases

4.6. ANOVA Method for Analysis

In order to determine the relative relevance of different components, the statistical S/N analysis must be followed by an ANOVA analysis. Experiment standard errors or level modifications may have caused the observed response variation, according to ANOVA. Analyzing the outcomes of the studies on reaction is also done using ANOVA, which is a standard statistical technique. Consideration of the chamfer on a vertical plate may also be used in the FE analysis process. When welding Lap-joint weldments with varying throat thickness and gap variation, maximum von-misses stresses are measured, and the corresponding Maximum Breaking Stress is calculated.

Table 5: Table Representing ANOVA Analysis:

Source	**DF**	**Contribution**	**F-Value**	**P-Value**
Design	2	26.31%	15.35	0.061
Force	2	68.37%	39.89	0.024
Material	2	3.61%	2.11	0.322
Error	2	1.71%	----	----
Total	8	100.00%	-----	----

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5. CONCLUSION

A study of the deformation breaking stress of the welding joint is employed in this work to limit the risk of welding failure (using low carbon steel as a base metal and copper filler material). The maximum von-misses stress in the welding under tensile load was determined by doing a static stress study on the welding using ANSYS. Welded lap joint design and analysis has been completed satisfactorily.

1. By applying Finite element analysis (ANSYS), the duration of experimentation can be reduced.
2. The processing quality can be enhanced by using Taguchi method and the processing variations can be reduced.
3. After applying Taguchi method it was observed that Force is placed at first rank, Design at second and Material at third.
4. The efficiency of optimization process can be enhanced by using taguchi method.
5. For obtaining better result, Force of level 1, Design of Level 2 and material of level 3 is taken.
6. The lowest stress value is achieved which is 249.99 Mpa and the corresponding deformation value is 5.11 mm after applying the above shown combinations.
7. ANOVA analysis show that Contribution of Design is 26.31%, contribution of force is 68.37% and contribution of material is 3.61%.

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