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"Deformation and Stress Optimization of Lap Joint Utilizing Taguchi & Anova Method"

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ABSTRACT

Welding is used extensively in a number of sectors, including the aviation industry, the automobile industry, and the construction industry. Consequently, the optimization of mechanical qualities is deemed crucial for the welding qualities or reactions. For the experiment's factorial design, the Taguchi technique is used, which is a suitable statistical approach. In addition to the fact that there are several conventional ways for measuring the tensile strength of a material, it is important to create novel approaches for getting the tensile strength of welding joints. In the current work, an efficient method is employed to analyze and optimize welding processes for Lap Joint with increased tensile strength. Taguchi technique is chosen for investigation of lap-welding joints. The Taguchi technique is used to optimize the results. In addition to the Taguchi approach, the ANOVA method is employed for accurate outcome evaluation. The programme ANSYS is used to compute the stress and deformation.

Keywords: TAGUCHI METHOD, ANALYSIS OF VARIANCE, EQUIVALENT STRESS, TOTAL DEFORMATION

1. INTRODUCTION

1.1 WELDING TECHNIQUE

Welding is the most frequent technique for attaching machine components and structures permanently. Welding is a manufacturing procedure that unites materials -metals or thermoplastics by mixing them together. The use of heat or pressure, with or without the inclusion of filler material, is used in the welding process to unite materials. Various auxiliary materials, including as shielding gases, flux, and pastes, may be used to make the process feasible or to facilitate it. The necessary energy for welding comes from external sources. Welding is well-defined low-temperature metal joining procedures, including soldering and brazing, since welding is a permanent joining process that does not need melting the base metal[1].

1.2 LAP JOINT WELD

"Lap welding joints" are regarded as the modified form of the butt joint. Typically, lap wilding joints are created when two metal parts are positioned such that they overlap. Generally, lap joint welding is used to connect two components of differing thicknesses. One or both sides of an object may be welded. Generally, lap joints are used for thin materials and are seldom utilized for larger materials. The most typical usage of lap joint welding is for sheet metal. The possible downsides of various forms of Lap Joint Welding include lamellar ripping and corrosion. On the other hand, such downsides may be avoided by using the proper approach and also by altering variables according to the need.

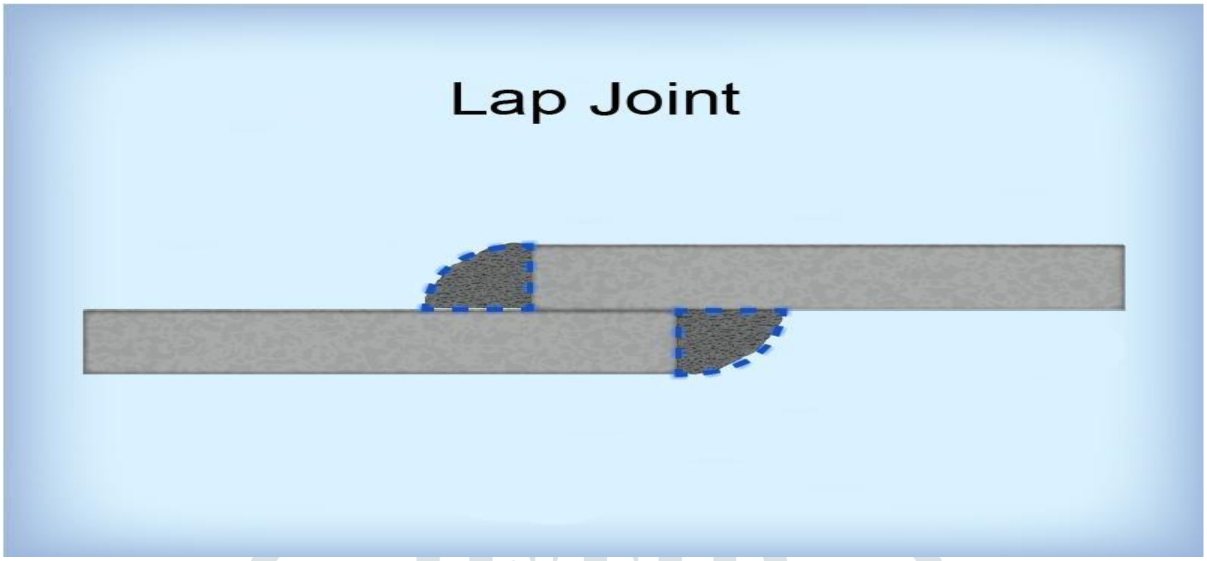

FIG1. LAP JOINT WELDS

2. LITERATURE REVIEW

REVIEW OF PAST STUDIES:

M. B. RAUT AND S. N. SHELKE [1], paper looks at a case study to figure out how to optimize the design for a special MIG welding job. The most important things that affect the quality, speed, and cost of welding are the MIG Welding parameters. This paper shows how MIG welding is affected by things like welding current, welding voltage, welding speed, gas flow rate, work piece rotation speed, and filler wire feed rate. Based on the Taguchi Method, experiments are done to get the needed data. The welding features and optimization parameters are found by using an orthogonal array, the signal-to-noise ratio (S/N), and analysis of variance (ANOVA). Finally, the confirmation tests have been done to compare the values that were predicted with the values that were actually found.

LOUREIRO et al. [2] explained that in recent years, a number of researchers have exerted significant effort to advance information about the behavior of steel joints. Special efforts have been made to acquire the stiffness of the various components of the joints in order to include this stiffness into the component technique in line with EC3. However, the component approach has significant limits; hence it is required to create other techniques for determining the joint stiffness. In this paper, an alternate approach for assessing the stiffness of externally welded 2D haunched joints is described. The authors provide the results of four experiments and their accompanying finite element models. Regarding the stiffening of the column web, four distinct joint types have been examined. In addition, finite element models of the joints have been created and calibrated against the test findings. The condensed stiffness matrices of the joints have been retrieved and evaluated by inserting them into the global analysis of four frames and comparing the resultant findings with those derived from the respective finite element models. The usage of the condensed matrix of the joints yields excellent results and takes into consideration all the interactions between the numerous degrees of freedom of the joint.

DANIEL DAS et al. [3] in his investigation, the rotating speed of the tool was shown to be the most important factor in making stronger joints. In general, AA 7075 is considered an unfabricated metal, and the parent material cannot be fused using the fusion welding technique. AA 7075 was composed of 0.4% silicon, 1.6% copper, 0.6% iron, 0.25% chromium, 0.1% titanium, and the remainder was aluminum. The chemical composition of AA 6063 was 1.38 % Si, 0.64 % Cu, 0.98 % Fe, 0.63 % Zn, 0.49 % Ti, and the rest was aluminum. The ranking procedure reveals that the Feed rate is the most persuasive of the three characteristics that generate efficient weld junctions. According to the levels, the feed rate at the first level is 162.8 mm/min, followed by 153.8 mm/min and 144.7 mm/min at levels 2 and 3, respectively. The differential value at feed rate was about 18.1. Since the welding speed has achieved second place, the maximum value of the welding speed (159.8 mm/min) has reached level 3. Maximum tool rotational speed data mean values were 154.6 rpm. Compared to other variables, the feed rate was the most persuasive. The figures of the SN ratio indicate that the Feed rate was the most compelling of the three criteria that generate efficient weld connections. According to the levels, the feed rate at the first level is 44.23 mm/min, followed by 43.73 mm/min and 43.21 mm/min at levels 2 and 3, respectively.

MANDEEP SINGH et al. [4], the supplied gas is ionized to create an arc between the electrode and the work piece, resulting in a seamless weld. Continuous welding produces a greater metal deposition rate as well as a rapid welding rate. Filler wire is attached to positive polarity, whilst the work item is connected to negative polarity. In 1920, R.A. Fisher introduced the DOE approach. Essentially, it is used to examine the simultaneous impacts of many factors. DOE's partnership with Taguchi is effective in achieving the needed optimization. DOR is also effective for combining components at diverse levels, each with its own range, while ensuring little variance around the optimal outcomes. In MIG welding, the most crucial process parameters are the welding current and voltage, followed by the gas flow rate, wire feed rate, and electrode diameter. In terms of mechanical qualities and the geometry of the weld bead, they determine the quality of the weld. The proportion of welding current to penetration depth is direct. The Taguchi technique is a powerful instrument for enhancing the output response during research and development, resulting in the production of higher-quality goods at a lower cost and in less time.

H.LI et al. [5], Spot welds are often employed to connect thin sheets of metal in the automotive and aerospace sectors. Spot welds fail due to the propagation of fatigue fractures that begin at the weld nugget's perimeter. Fracture mechanics analysis based on stress intensity factors (SIFs) has been implemented to forecast the fatigue life of spot welds, which play an essential role in vehicle durability. Consequently, it is crucial to acquire SIFs with a high level of fidelity in addition to spot-welded edges. Dealing with a realistic industrial-scale structure with thousands of spot welds is made more difficult by a variety of reasons, including a greater number of welds, disparity between the structure's spot welds, complicated geometries, and load scenarios. The assessment of stress intensity factors with high precision depends on discretization methods with high-quality solutions and robust extraction techniques that can calculate correct SIFs from the solutions. This study utilizes the Displacement Correlation Method (DCM). It links stress intensity variables at the fracture front to the jump displacement throughout a crack surface in a straightforward manner.

3. RESEARCH METHODOLOGY

The Taguchi method was chosen for the work of welding joint, and Ansys software was used to do the work. Taguchi method and Ansys software are used to design the structure and figure out how much the material will bend and stretch under stress.

3.1 ANSYS

The finite element analysis (FEA) method is used for structural analysis with Ansys software, which is a dynamic, integrated platform. Ansys gives you a dynamic environment with a full set of analysis tools, from preparing geometry for analysis to adding more physics to make the model even more accurate. Because the user interface is easy to use and can be changed, engineers of all levels can get answers quickly and with confidence. Ansys Workbench makes it easy to connect to commercial CAD tools and update design points with the click of a button. Several studies are done to find out how different things affect the strength of welds. The parameters are the conditions of the load, any flaws in the welding, the effects of the environment, and the mechanical parameters. With the help of ANSYS software, you can get the best results. [16]

3.2 TAGUCHI METHOD

The Taguchi method is a way to improve the quality of an item that can be measured. With the Taguchi procedure, the best way to weld is chosen. Taguchi made an amazing design of orthogonal arrays to look at all of the parameter space with a small number of tests. The Taguchi method works best when "Design of Experiments" and "Optimization of Control Parameters" are used together. "Orthogonal Array" gives you a set of experiments that are well-balanced. "Dr. Taguchi's Signal-to-Noise ratios (S/N)," which are a log function of the desired output, serve as objective functions for "optimization" and help with data analysis and predicting the best results. [17]

The Taguchi Method is made up of four steps:

STEP 1: Figure out what the main functions, side effects, and how it could fail.

STEP 2: Use the Taguchi method to figure out the goal function that needs to be optimized.

STEP 3: Choose "orthogonal array matrix experiment."

STEP 4: Finish the verification experiment and make plans for what to do next.

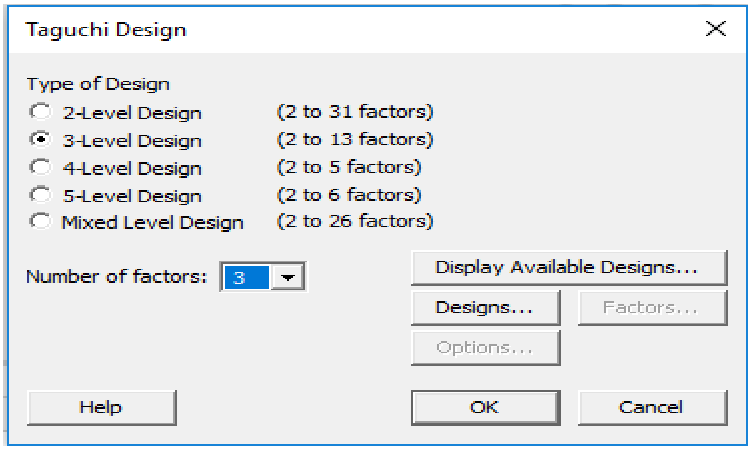

FIG.2 LEVEL OF DESIGN & NO^{0}OF FACTORS

The image above depicts the design level and number of selectable variables. Then, click the "OK" tab.

Below image exhibits the orthogonal array as L9 and L27 & columns to be selected and then press “OK” button.

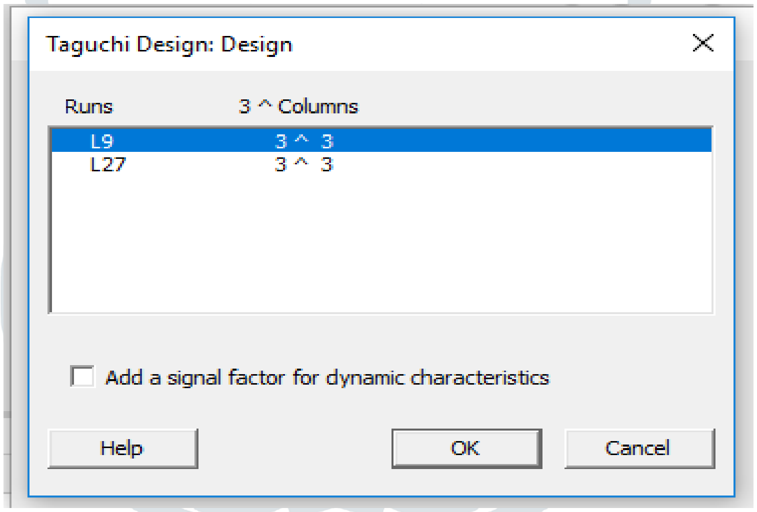

FIG .3 CHOICE OF ORTHOGONAL ARRAY AS L9 AND L27 & COLUMNS

The graphic shown below illustrates the assign factors, which include the column of the array in which the data is input together with the level values.

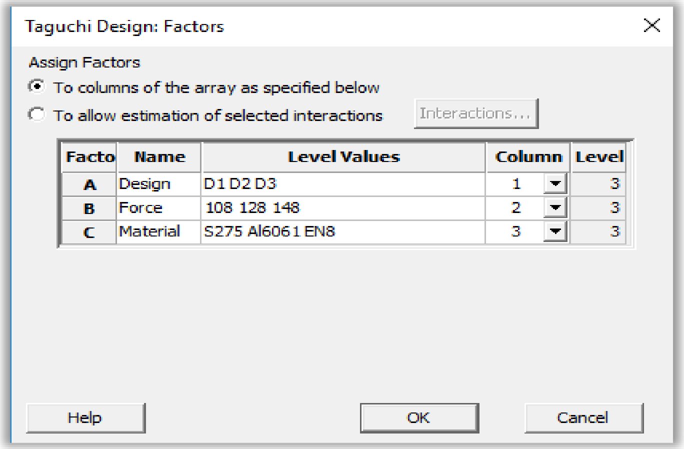

FIG. 4 TAGUCHI DESIGN FACTORS

3.2.1 DESIGN REPRESENTATION FOR WELDING

Using software, a lap welding junction is created, and IPE300 and HEA200 beams are welded perpendicularly using two different beam types. Figure for design 1 demonstrates the perpendicular direct junction of beams, Figure for design 2 demonstrates the perpendicular curve joint, and Figure for design 3 demonstrates the perpendicular rectangular joint.

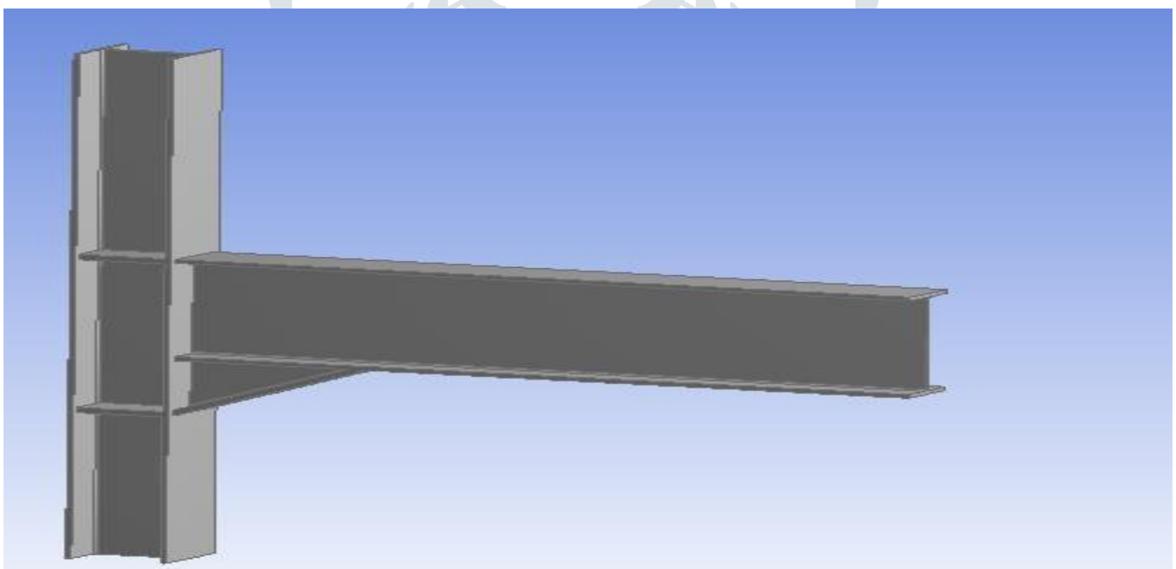

FIG.5 DEPICTS DESIGN 1 WITH PERPENDICULAR BEAMS JOINED DIRECTLY.

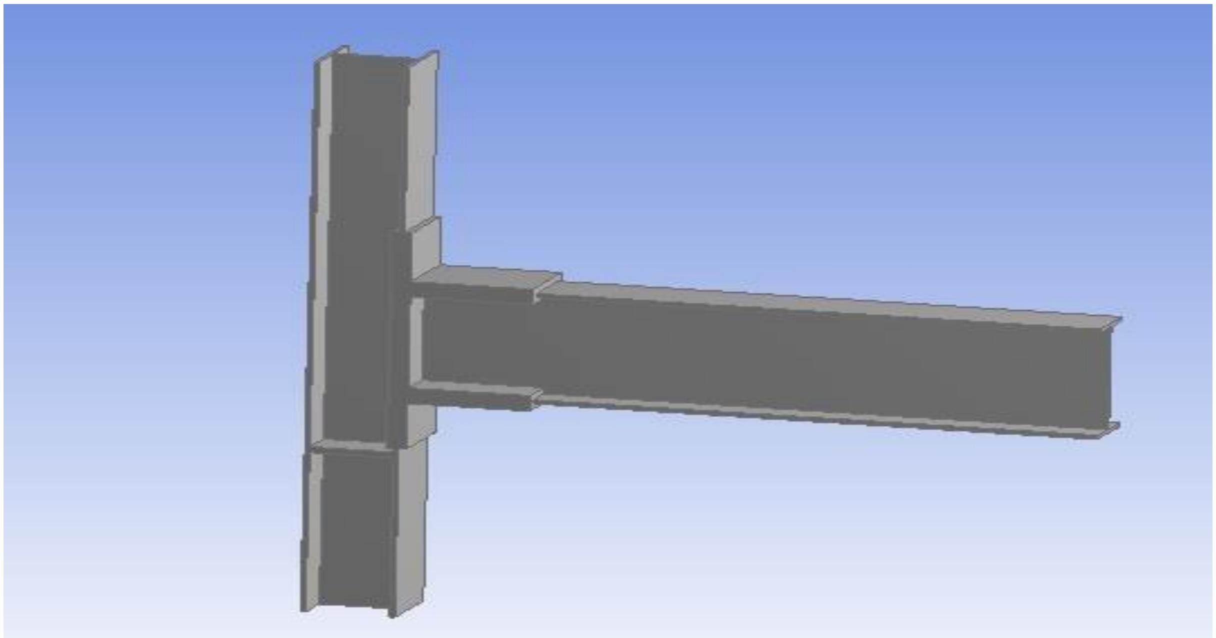

FIG.6 DESIGN 2 DISPLAYING A PERPENDICULAR CURVE JUNCTION

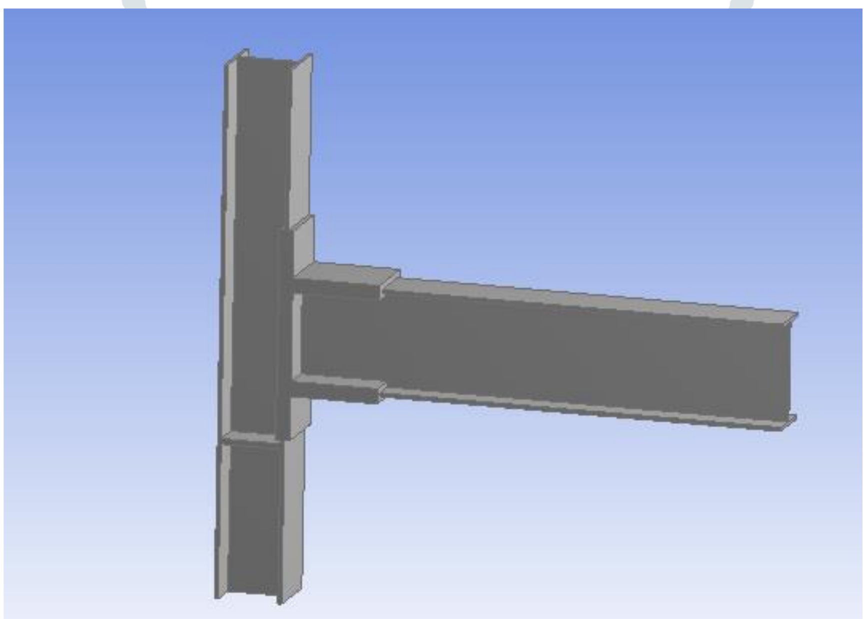

FIG.7 DEPICTS PERPENDICULAR RECTANGULAR JOINTS IN DESIGN 3

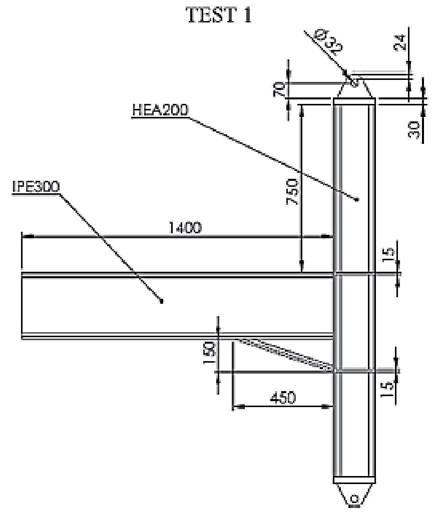

FIG.8 DIAGRAM DEPICTING THE DESIGNS' DIMENSIONS

3.3 MATERIAL CHARACTERISTICS

S275 steel, Al6061 aluminum, and EN8 steel are three different materials that are lap-welded together. Lap welding has been chosen as the analytical setup and method for these materials. The Taguchi method and ANSYS software are used to design the joints and interpret stress and deformation. Steel and aluminum were used as the materials for the project. Additionally, the structural framework of the design is created with these qualities in mind. The programme also takes into account the materials' density, young modulus, and poison's ratio.

TABLE1. MATERIAL CHARACTERISTICS TABLE

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

3.4 REPRESENTATION OF MESH ARCHITECTURE

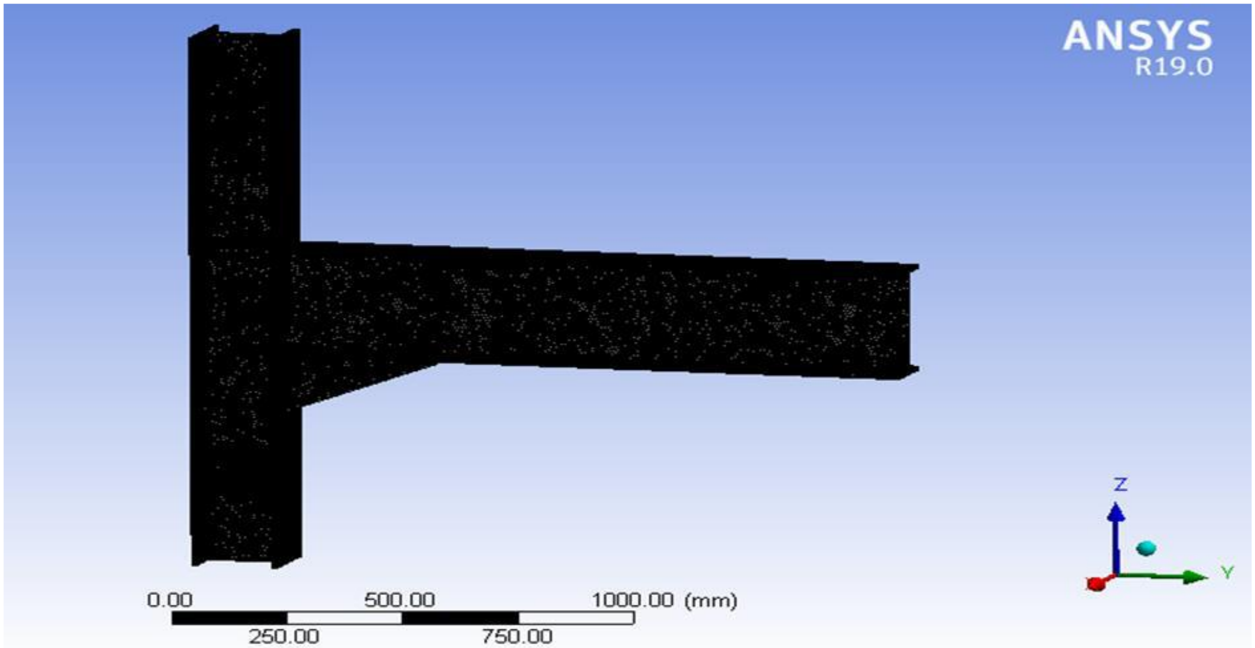

FIG.9 MESH DESIGN REPRESENTATION

Welded mesh is a form of barrier fence that is available in both rectangular and square configurations. They are constructed from welded steel wire at each junction. This kind of fence is superior to chain link fencing since it cannot be cut easily, particularly if the wire is thick. It is an excellent choice for high-security institutions. Nodes identified to be 784563 and Element determined to be 468057 after analysis.

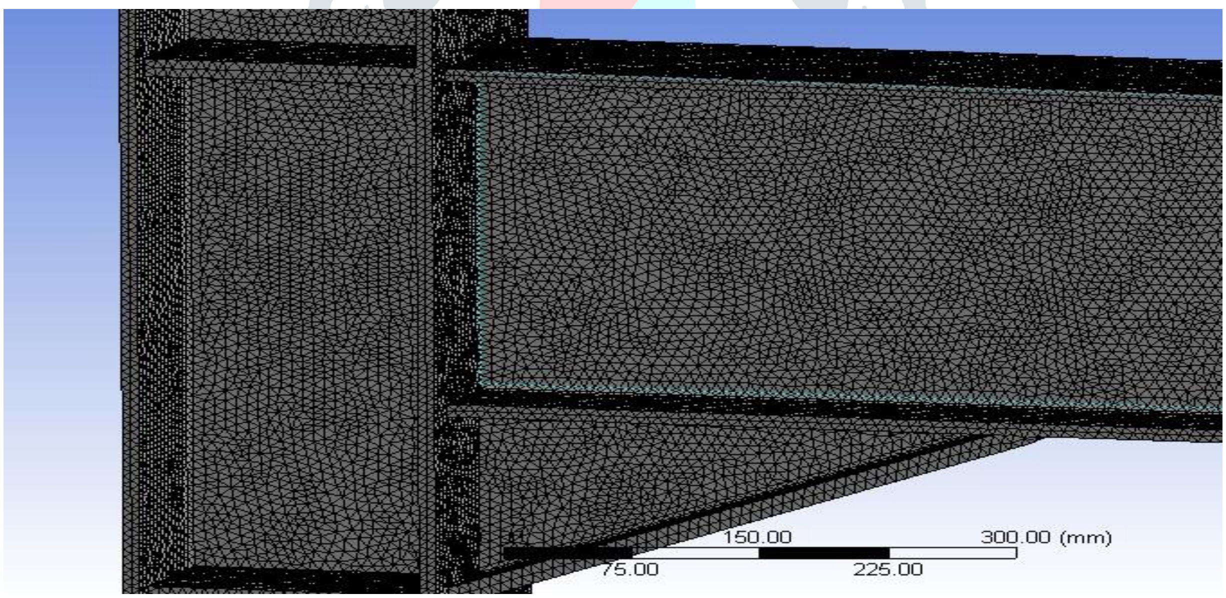

FIG.10 ZOOM VIEW OF MESH

3.5 EXAMPLE OF BOUNDARY CONDITION REPRESENTATION

As shown in the graphic below, the boundary condition is represented by a beam that is fixed at both ends perpendicular to the beam force of 128 KN.

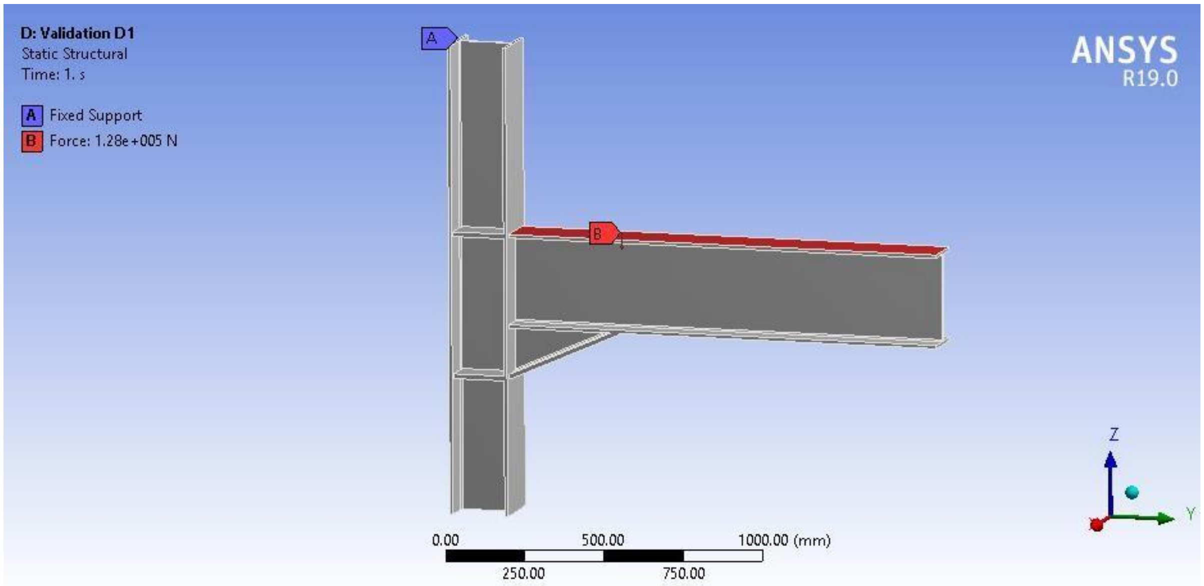

FIG.11 BOUNDARY CONDITION REPRESENTATION

3.6 ANOVA METHOD FOR DATA SETUP

ANOVA is an analysis tool used in statistics that divides the observed variation into two equal parts. The random factor and the systematic factor make up the two parts. Systematic factors have a statistical effect on the given data set, but random factors don't have any statistical effect. Analysts often use the ANOVA test to figure out how one variable affects another variable that isn't part of the test.

3.6.1 Determine the S/N ratio:

In the table below, the average values of how the input parameters were set are shown. Signal-to-noise ratio is used to figure out how the three parameters will respond. The better performance of welding will be shown by smaller values of stress.

TABLE 2. TABULAR REPRESENTATION OF 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

3.7 RESPONSE TABLE

TABLE3. SHOWING THE RESPONSE.(Here, a smaller value is preferred).

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**

3.8 S/N RATIO SHOWN GRAPHICALLY

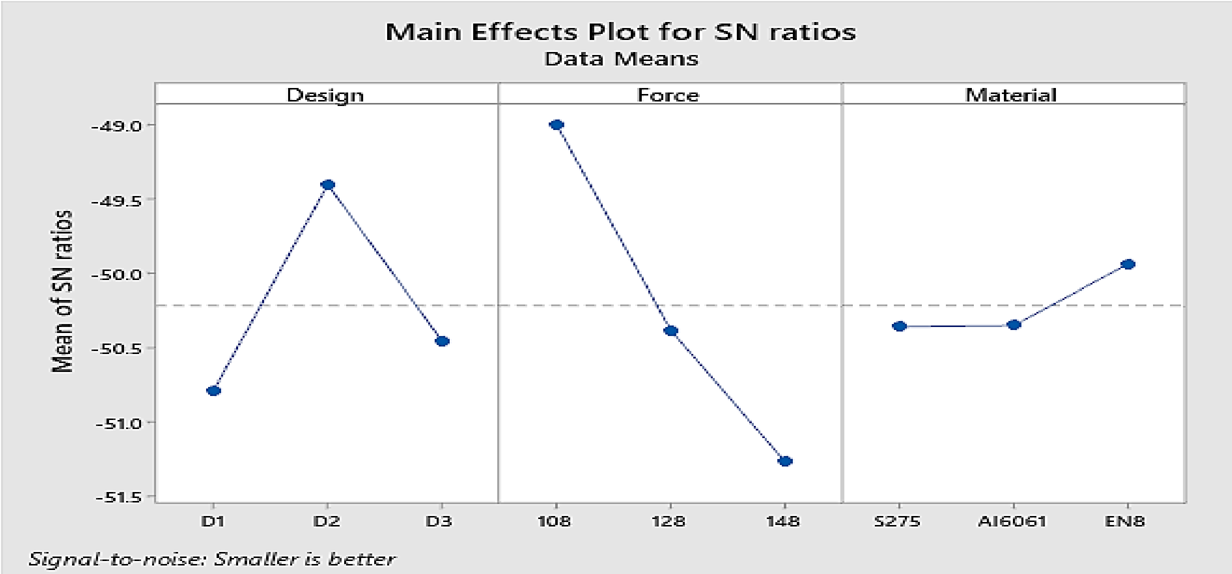

FIG12. S/N RATIO GRAPH

4 .VALIDATION OF RESULT

a. Equivalent Stress-

It is used when there is a multi-axial stress situation with numerous stress components working simultaneously in a structure. In such instances, von-misses stress is taken into account while drafting the structure of the material part.

Case 10's outcome is shown in the following diagram-

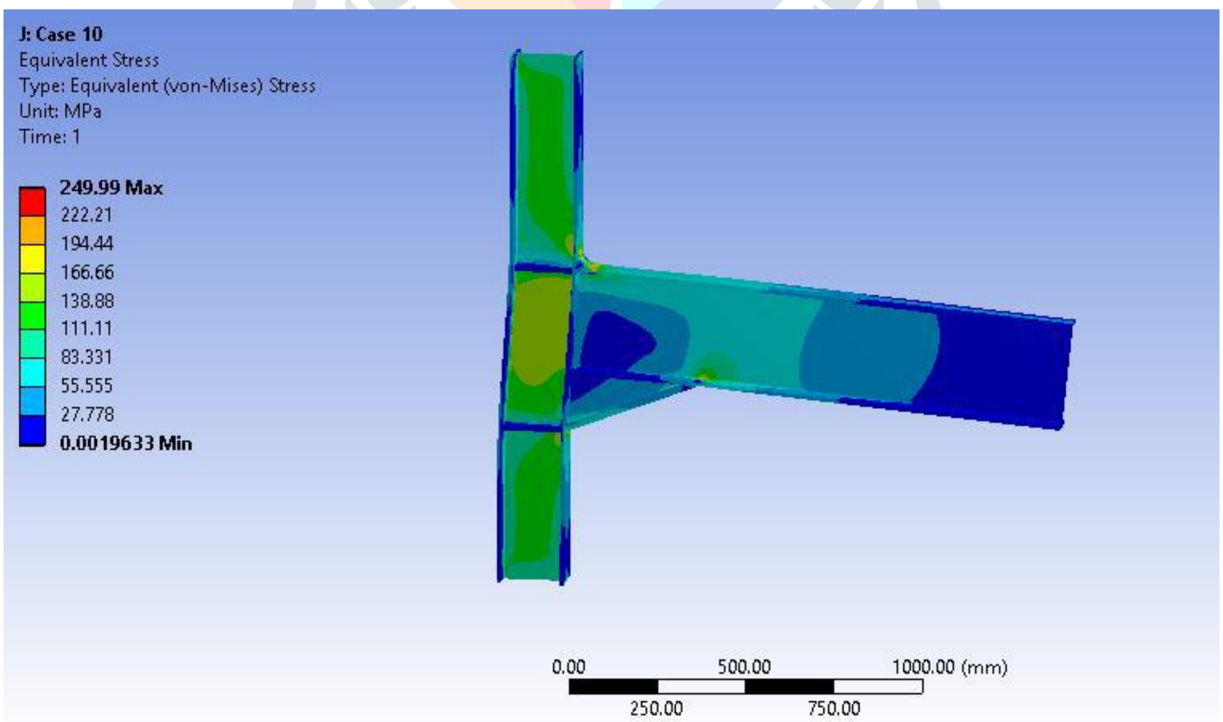

FIG13.TENTH CASE EQUIVALENT STRESS

b. Total Deformation-

The outcome of Case 10 is shown in the following diagram-

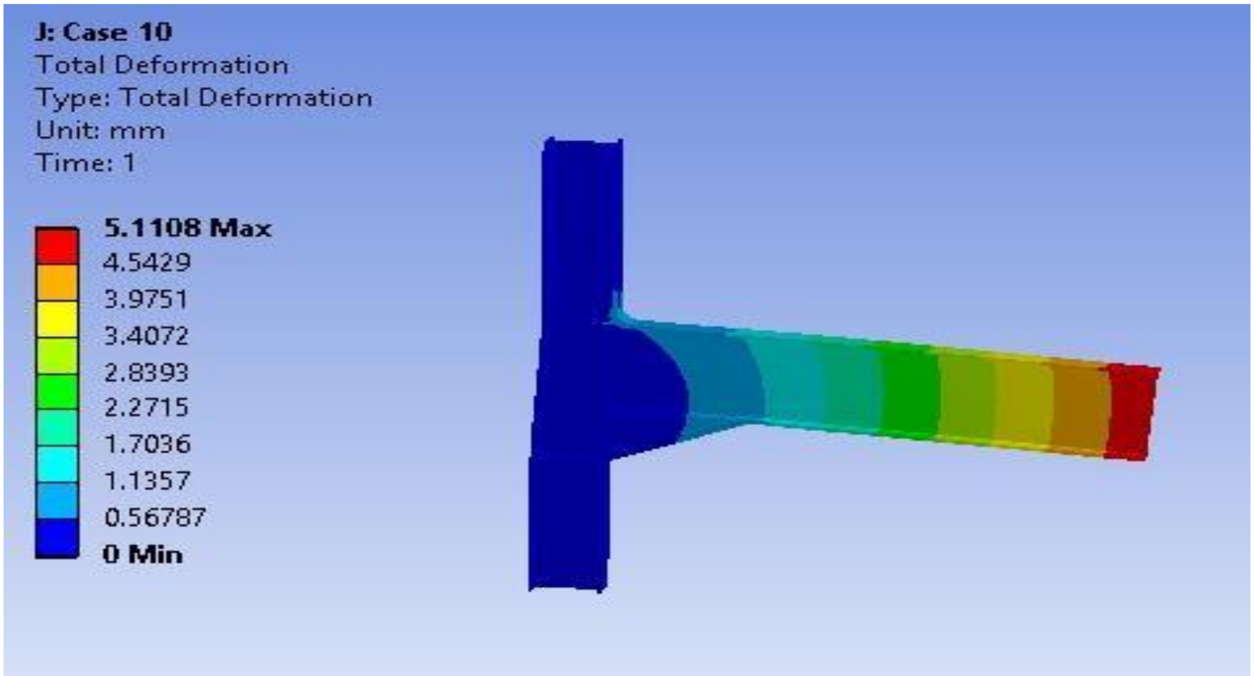

FIG14. TENTH CASE TOTAL DEFORMATION

c. Stress Evaluation

Residual stresses are stresses created during manufacturing operations like cutting, cold work, welding, grinding, shot peening etc. Tensile residual stresses on surfaces are generally undesirable because they reduce fatigue strength. However, compressive surface stresses enhance fatigue resistance. Welding-related stresses are of the highest significance and may be a leading cause of component failure.

i. STRESS V/S CASES

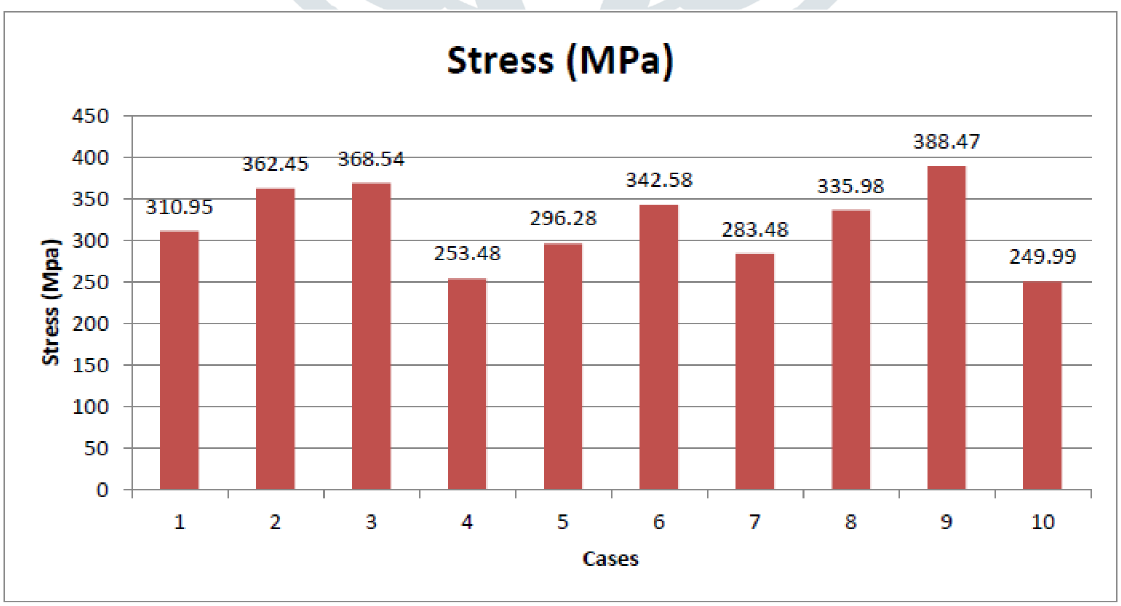

FIG 15.STRESS SHOWN GRAPHICALLY

***ii.* DEFORMATION V/S CASES**

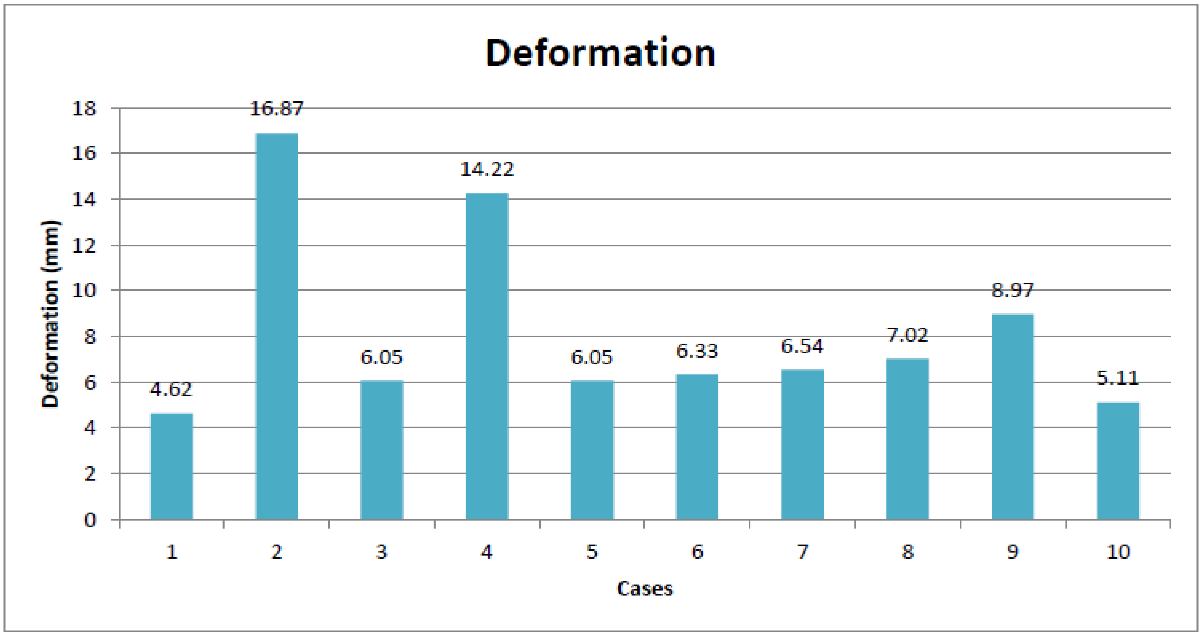

FIG 16.A VISUAL ILLUSTRATION OF THE CASES AND DEFORMATION

d. ANOVA ANALYSIS METHOD

TABLE4. TABLE DISPLAYING ANOVA RESULTS

SOURCE	DF	CONTRIBUTION (%)	P VALUE	F VALUE
design	2	26.31	0.061	15.35
force	2	68.37	0.024	39.89
material	2	3.61	0.322	2.11
error	2	1.71	-	-
total	8	100	-	-

5. CONCLUSION

Following conclusions are drawn from my present research work-

i. Using Finite Element Analysis (ANSYS), it is possible to shorten the length of an experiment.
ii. Using the Taguchi approach, processing quality may be improved and variances can be minimized.
iii. After using the Taguchi technique, it was determined that Force ranks first, followed by Design and then Material.
iv. Taguchi technique may increase the effectiveness of optimization processes.
v. To get a superior outcome, Force of level 1, Design of level 2, and materials of level 3 are used.
vi. The lowest stress value is reached, which is 249.99 MPa, and the corresponding deformation value is 5.11 mm, when the combinations mentioned above are used.
vii. Analysis of variance reveals that the Contribution of Design is 26.31%, the Contribution of Force is 68.37%, and the Contribution of Material is 3.61%.

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