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"PARAMETRIC FINITE ELEMENT ANALYSIS AND OPTIMIZATION OF STRESS CONCENTRATION AND DEFORMATION IN A LAP JOINT"

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ABSTRACT

Welding is extensively employed across several industries, including the aviation, automotive, and construction sectors, due to its reliability and structural efficiency. Consequently, the optimization of mechanical properties associated with welding characteristics is of significant importance. For the factorial design of experiments, the Taguchi method is adopted, as it is an effective and robust statistical optimization technique. Although several standardized methods exist for evaluating the tensile strength of materials, there remains a need to develop improved approaches for accurately assessing the tensile performance of welded joints. In the present study, an effective methodology is implemented to evaluate and optimize welding parameters in order to achieve enhanced tensile strength in lap joints. The Taguchi method is employed to systematically analyze the influence of welding parameters and to identify the optimal combination for improved joint performance. Furthermore, the Analysis of Variance (ANOVA) technique is used in conjunction with the Taguchi method to statistically validate the results and to determine the significance of each parameter. The stress distribution and deformation behavior of the lap welded joint are numerically analyzed using ANSYS finite element software.

Key Words: *Analysis of Variance , Tensile Performance, Joint Performance , Welded Joint, Strength , Optomize.*

I. INTRODUCTION

Welding is the most commonly used process for permanent joining of machine parts and structures. Welding is a fabrication process which joins materials (metals) or thermoplastics, by causing blending. In the joining process of welding application uses heat or pressure, with or without the addition of filler material. Various auxiliary materials, e.g. shielding gases, flux or pastes, may be used to make the process possible or to make it easier. The energy required for welding is supplied from outside sources. Welding is the well-defined low temperature metal joining techniques including soldering and brazing as welding is permanent joining method without melting the base metal. [1]

1.1 MIG Welding:

It"s a metal inert gas welding. It uses the wire feed techniques as idealistic for robotic techniques. The usage of various coil capacities will be depending upon the welder size. The joining of the metals together with the help of joining materials, welding wire should be the same as the material to be welded. The power consumption and power must be throughout the process of welding.

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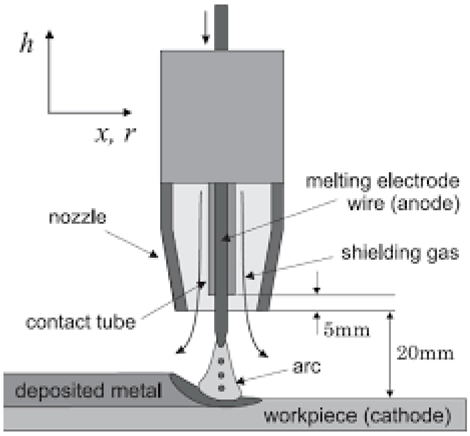

Figure 1.1: Diagrammatic representation of MIG Welding

1.2 TIG Welding:

Tungsten inert gas welding is also like a gas welding which usually uses tungsten electrode in-order to produce arc in-order to weld. There are various larger welders that runs between 400 to 500 A. TIG Welding needs skilled carrying capacity embrace the effectiveness of the welding basically for the non- ferrous metals includes copper, aluminium and magnesium.

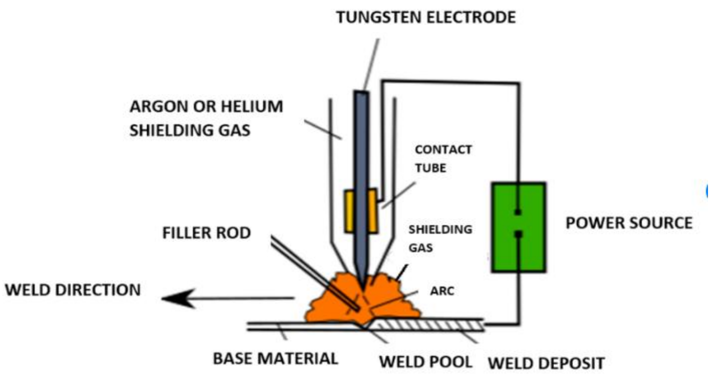

Figure 1.2: Diagrammatic representation of TIG Welding

1.3.1 Lap Joint Welding:

Lap wilding joints are generally formed when 2 pieces of metal are kept on each other in an overlapping way. Lap joint welding is mainly used for joining the two pieces together of different thicknesses. Welding can be done on either one side or on both sides.

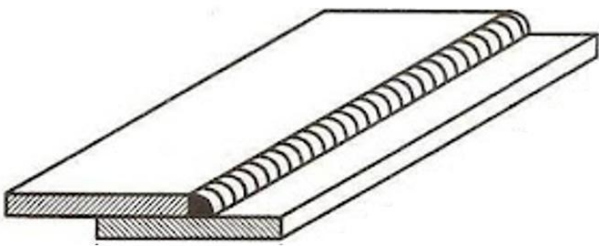

Figure 1.8: Diagrammatic Representation of Lap Joint

1.3 Types of material used

S275 Steel

Structural steel is a basic construction material, made from specific grades of steel and manufactured in a variety of industry

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standard cross-sectional shapes (or „sections‟). Structural steel grades are engineered with specific chemical compositions and mechanical properties formulated for specific applications. Structural S275 steel plates are commonly used in most industrial construction, such as bridges, railways and ships etc. Consequently.

Al6061

6061 (Unified Numbering System (UNS) designation A96061) is a precipitation-hardened aluminium alloy, containing magnesium and silicon as its major alloying elements. Originally called "Alloy 61S", it was developed in 1935. It has good mechanical properties, exhibits good weld abilityEN8 Steel

EN8 carbon steel is a common medium carbon and medium tensile steel, with improved strength over mild steel, through-hardening medium carbon steel. EN8 carbon steel is also readily machinable in any condition.

EN8 steels are generally used in the as supplied untreated condition. But EN8 steels can be further surface-hardened by induction processes, producing components with enhanced wear resistance. Steel EN8 materials in its heat treated forms possess good homogenous metallurgical structures, giving consistent machining properties.

II. Literature Review

Shah Mohamad rashi Rashid et al [1] The present study isconcentrated on the effect of the kind of joint used for lap joint like the adhesive joint, riveted joints, andbolted join Four different typologies of joints have been tested, in regards to the stiffening of the column web. Additionally, finite element models of the joints have been developed.

Loureiro et al. [2] In recent years, several researchers have been working hard to improve the knowledge with respect to steel joints behaviour. Special effort has been made for obtaining the stiffness of the different components of the joints, with the aim of introducing this stiffness in the component method in accordance with the EC3. Nevertheless, the component method has important limitations and therefore it is necessary to develop new methods for obtaining the stiffness of joints. In the present work, an alternative method of evaluating the stiffness of 2D external welded haunched joints is presented. The authors show the results of 4 tests and their corresponding finite element models.

Daniel Das et al. [3] In his research work, tool rotational speed was identified as the most influencing parameter in producing better joining strength. Generally, AA 7075 is concluded as an unfabricated metal and also the parent metal can‟t be welded using fusion welding process. The chemical composition of AA 7075 was 0.4 % Si; 1.6 % Cu; 0.6 % Fe; 0.25 % Cr; 0.1 % Ti and balance of Aluminium base metal. The chemical composition of AA 6063 was 1.38% Si; 0.64% Cu; 0.98% Fe; 0.63% Zn; 0.49% Ti and balance of Aluminium base metal. The ranking process shows that the Feed rate was the most convincing parameter among three parameters that produces effective weld joints. According the levels, the feed rate secures 162.8 mm/min at its first level followed by 153.8 mm/min and 144.7 mm/min at level 2 and level 3 means values respectively.

Mandeep Singh et al. [4] The gas supplied gets ionized to form an arc between electrode and work piece, resulting in smooth welding. Continuous welding results in higher metal deposition rate as well as high welding speed. The filler wire is connected to positive polarity while work piece is connected to negative polarity. DOE is a technique introduced by R.A. Fisher in 1920. It is basically used to study the effects of multiple variables simultaneously.

H.Li et al. [5] Spot welds are broadly used to join thin metallic sheets in the automotive and aerospace industries. The basic failure of the spot welds is propogation of fatigue cracks that nucleate around the edge of weld nugget. Fracture mechanics analysis which is based on stress intensity factors (SIFs) has been adopted to predict the fatigue life of spot welds which plays a important role in vehicle durability. It is therefore critical to obtain high fiedility SIFs

Stalin et al. [6] Welding technology is one of the fastest growing opportunities in the field of manufacturing engineering. Today, many construction, erection, ship building and body building works are not possible without welding. Although welding technology has many positive features, there are some negative features which are to be taken under consideration of this work. Many risks and accidents could be avoided, if the negative features of welding technology have been rectified. Many people involving in welding works are not able to identify the exact loading and boundary conditions for the corresponding weld, which is to be created by using design of experiment (DOE).

Asif Ahmad et al. [7] For “ferrous and non-ferrous”, a famous welding technique is the “tungsten inert gas welding”. In the manufacturing of stainless steel, “Stainless steel grade 3HQ (S30430)” is a specialized wire grade. For heading usage, it has replaced more than Grade 384 and 305. As a result, it shows excellent toughness which is even less than cryogenic temperature.

Marcello Lepore et al. [8] In this work a numerical procedure, based on a finite element approach, is proposed to simulate

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multiple three-dimensional crack propagation in a welded structure. Cracks are introduced in a friction stir welded AA2024-T3 butt joint, affected by a process-induced residual stress scenario. The residual stress field was inferred by a thermo-mechanical FEM simulation of the process, considering temperature dependent elastic-plastic.

S. Kannan et al. [9]the various welding parameters such as tool rotating speed (rpm), projection of tube (mm) and depth of cut (mm) are determined according to the Taguchi L9 orthogonal array. The two conditions were considered in this process to examine this experiment; where condition 1 is flat plate with plain tube Without holes [WOH] on the circumference of the surface and condition 2 is flat plate with plane tube has holes on its circumference of the surface

S. P. Kondapalli et al. [10] Design of Experiment (DOE) is an experimental or analytical method that is commonly used to statistically signify the relationship between input parameters to output responses, where by a systematic way of planning of experiments, collection and analysis of data is executed. DOE has wide applications especially in the field of science and engineering for the purpose of process optimization and development.

III. RESEARCH GAP

1. From the literature review, it is observed that materials such as S275 structural steel, AL6061 aluminum alloy, and EN8 steel have not been extensively investigated in earlier studies. Therefore, these materials are selected in the present work for the analysis of external welded lap haunched joints.
2. The geometric configuration of the external welded lap haunched joint is modified by varying the haunch length, and its influence on joint behavior is examined through further parametric studies.
3. Previous investigations have not adequately addressed the effect of applied load on the performance of external welded lap haunched joints. Hence, the present study focuses on evaluating the influence of varying force levels on stress distribution and deformation characteristics.
4. The Finite Element Method (FEM) is employed to numerically analyze the stress distribution and deformation response of external welded lap haunched joints under different material, geometric, and loading conditions.

VI. METHODOLOGY

4.1 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

4.2 Software Used

4.2.1 ANSYS

Ansys software is a dynamic, integrated platform that uses finite element analysis (FEA) for structural analysis. Ansys provides a dynamic environment that has a complete range of analysis tools from preparing geometry for analysis to connecting additional physics for even greater fidelity. The intuitive and customizable user interface enables engineers of all levels to get answers fast and with confidence. Ansys Workbench enables robust connection to commercial CAD tools, providing click button design point updates. Several researches are carried out to find out the varying effect on the strength of welded joints. The parameters are loading conditions, welding defects, environmental effects and mechanical parameters. Maximum results are obtained with the help of ANSYS software. [23]

4.2.2 Minitab

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Minitab helps companies and institutions to spot trends, solve problems and discover valuable insights in data by delivering a comprehensive and best-in-class suite of machine learning, statistical analysis and process improvement tools. Combined with unparalleled ease-of-use, Minitab makes it simpler than ever to get deep insights from data. In this work, this software is brought in use for analysis of Taguchi method and ANOVA method.

4.3 Taguchi Method

Taguchi strategy was made by Dr. Genichi Taguchi. This strategy incorporates three stages: framework outline, parameter plan, and resistance outline. The Taguchi method is a measurable method used to enhance the item quality. The Taguchi procedure chooses or decides the ideal cutting conditions for turning procedure. Taguchi built up an extraordinary design of orthogonal arrays to examine the whole parameter space with few experiments as it were. The trial results are then changed into a solitary to commotion (S/N) proportion. It utilizes the S/N ratio as a proportion of value characteristics going amiss from or nearing to the coveted values.

Figure 4.1: Flow chart representing Taguchi methodology

4.3.1 Steps representing Taguchi Design:

Below figure exhibits the level of design and number of factors to be selected. Then press "OK" tab.

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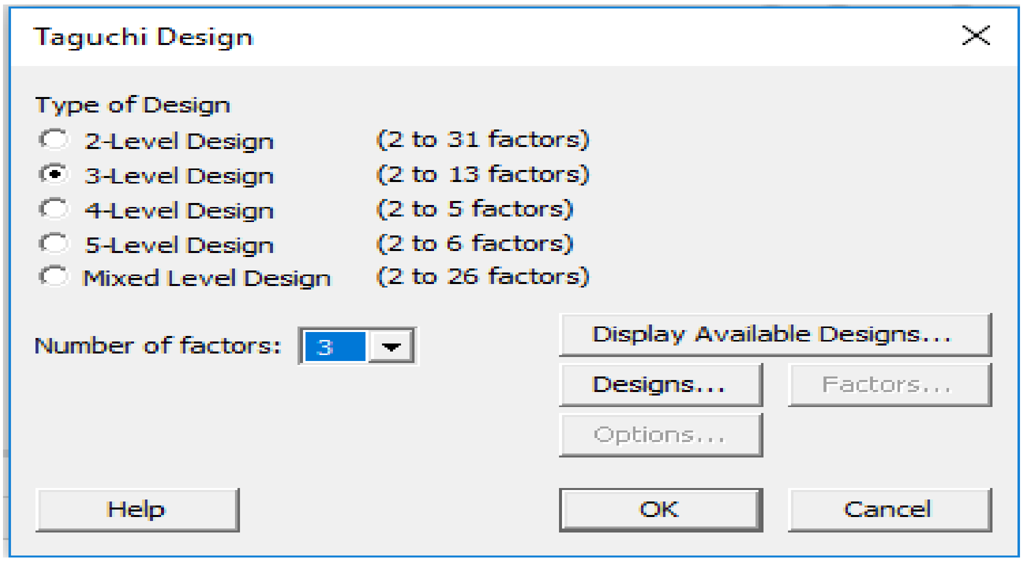

Figure 4.2: Level of design and number of factors

Below figure exhibits the orthogonal array as L9 and L27 and columns to be selected and then press "OK" button.

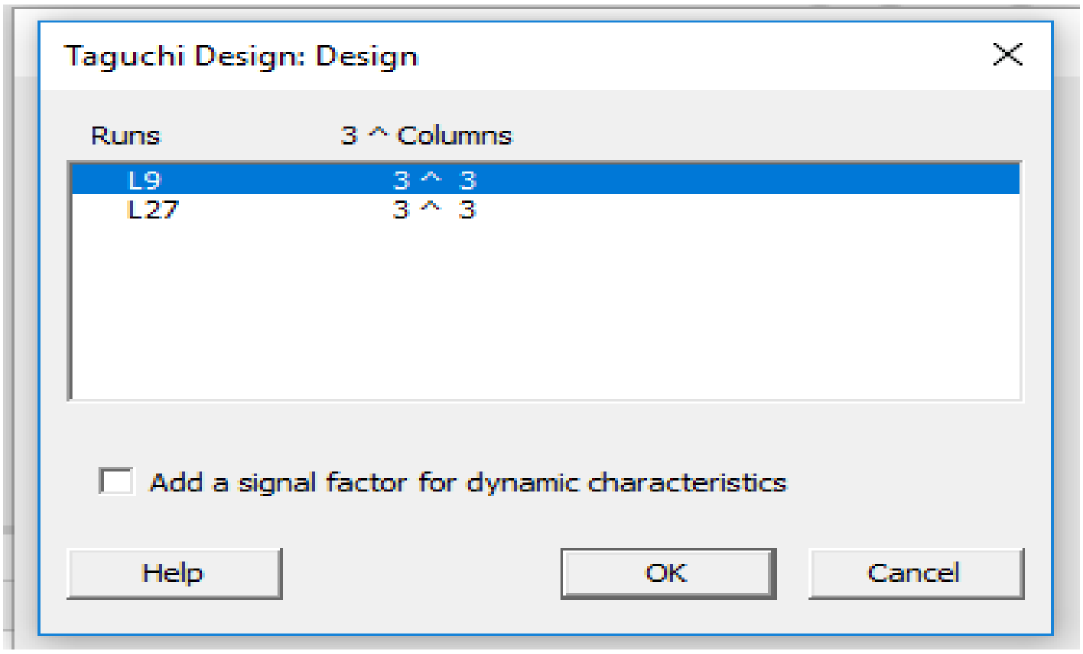

Figure 4.3: Selection of Orthogonal array as L9 and L27 and columns

Below figure exhibits the assign factors which includes the column of the array and the data is entered along with level values.

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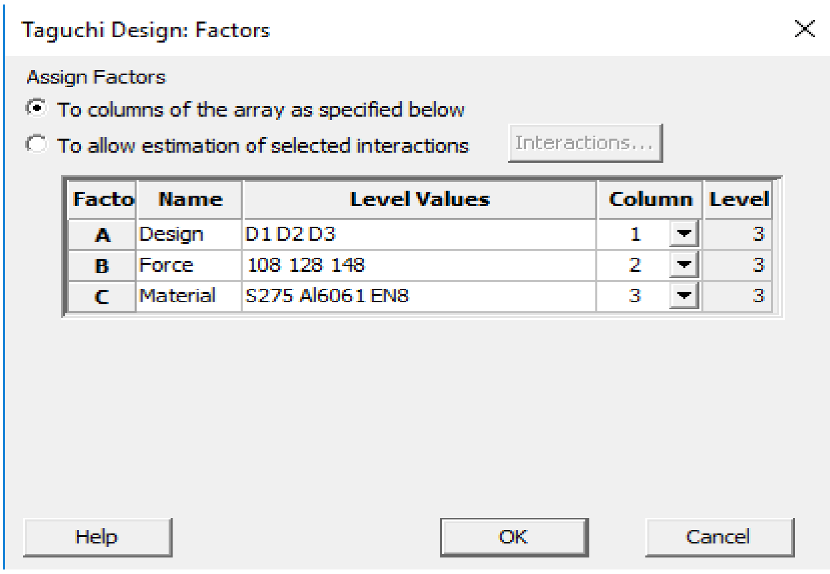

Figure 4.4: Insert Taguchi design factor

4.3.2 Table showing Orthogonal L9:

Table 4.1: 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
8	D3	128	S275
9	D3	148	Al6061

4.3.3 Representation of Welding Design:

Lap welding joint is drawn with the help of software and two types of beam are used as IPE300 and HEA200 and joined together perpendicularly using software. Lap welding joint is presented here in three images, Figure for design 1 showing direct joint of beams perpendicularly, figure for design 2 showing curve joint perpendicularly, figure for design 3 showing rectangular joint perpendicularly.

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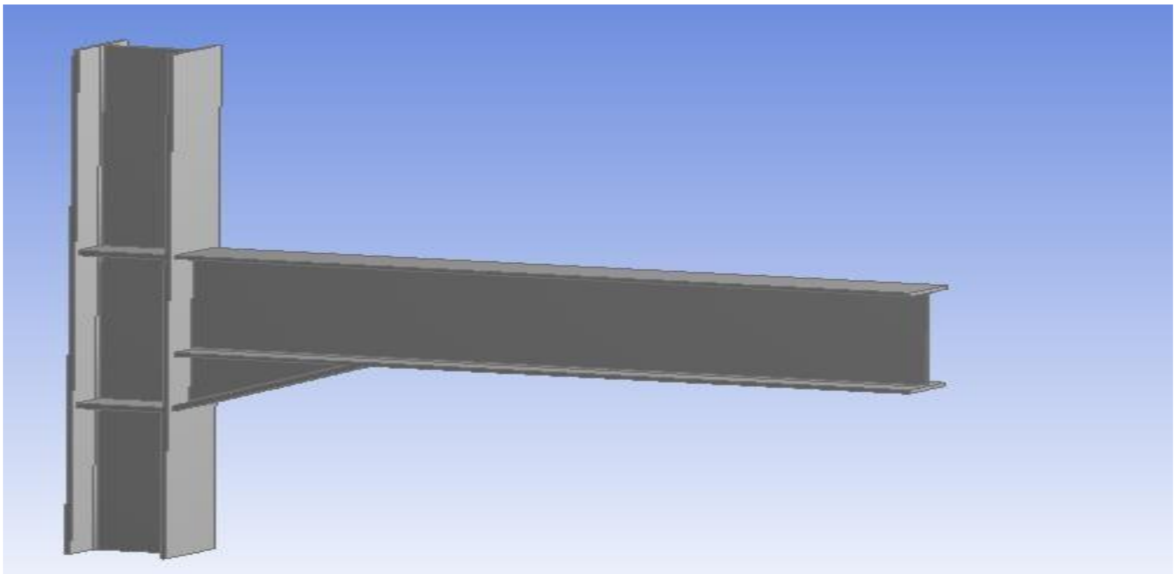

Figure 4.5: Design 1 showing direct joint of beams perpendicularly

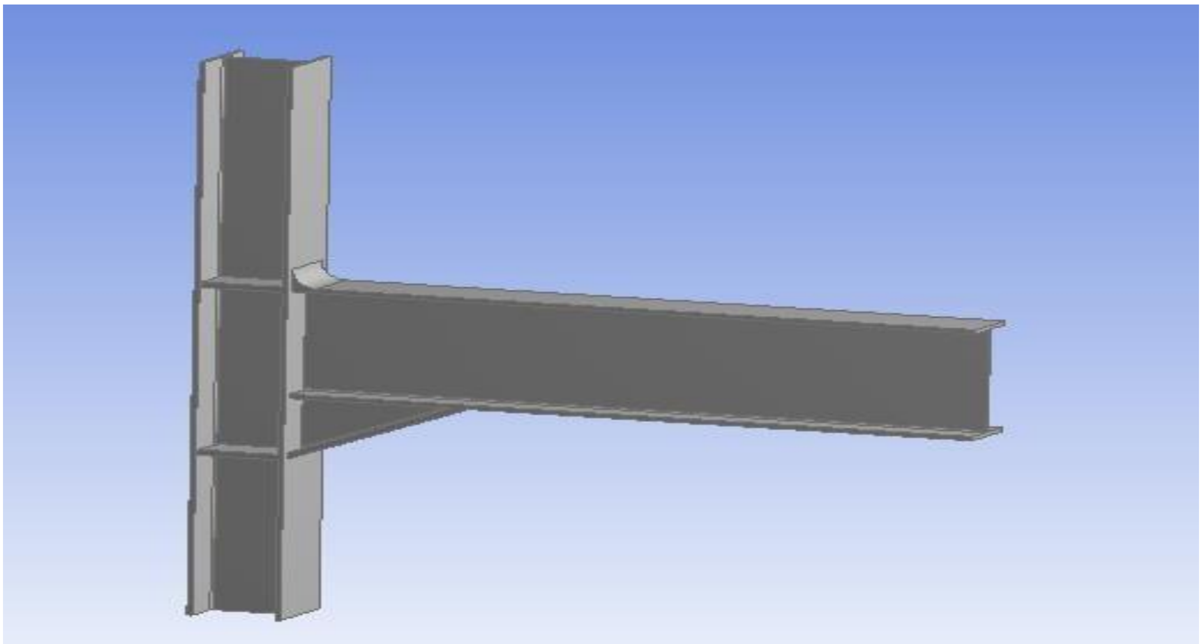

Figure 4.6: Design 2 showing curve joint perpendicularly

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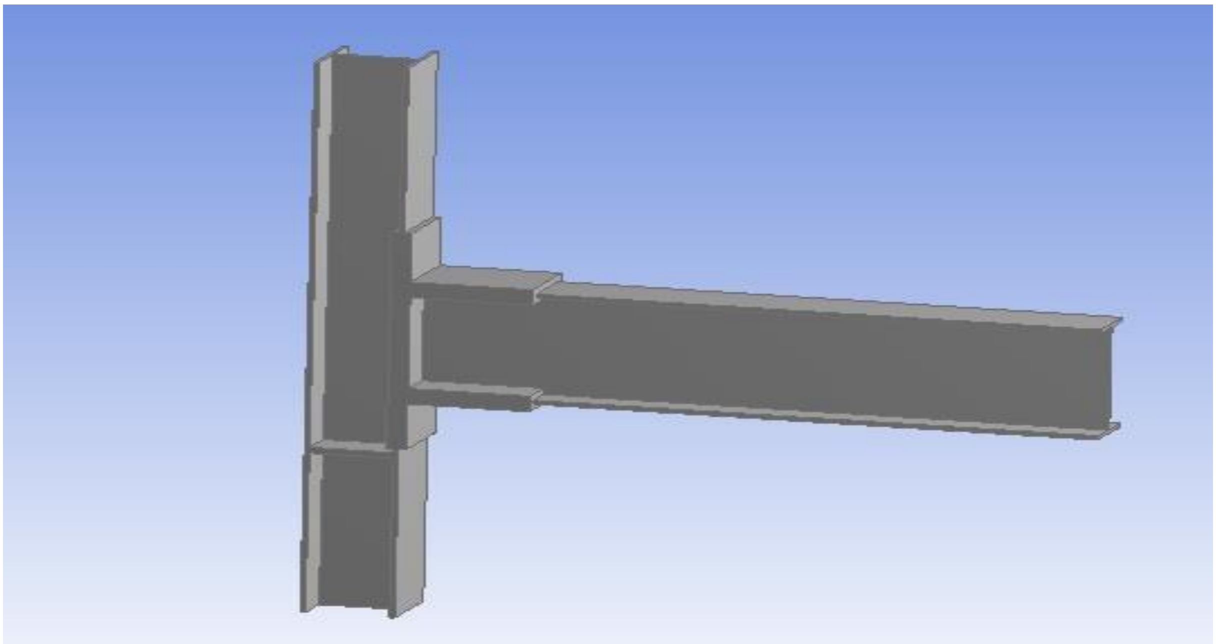

Figure 4.7: Design 3 showing rectangular joints perpendicularly

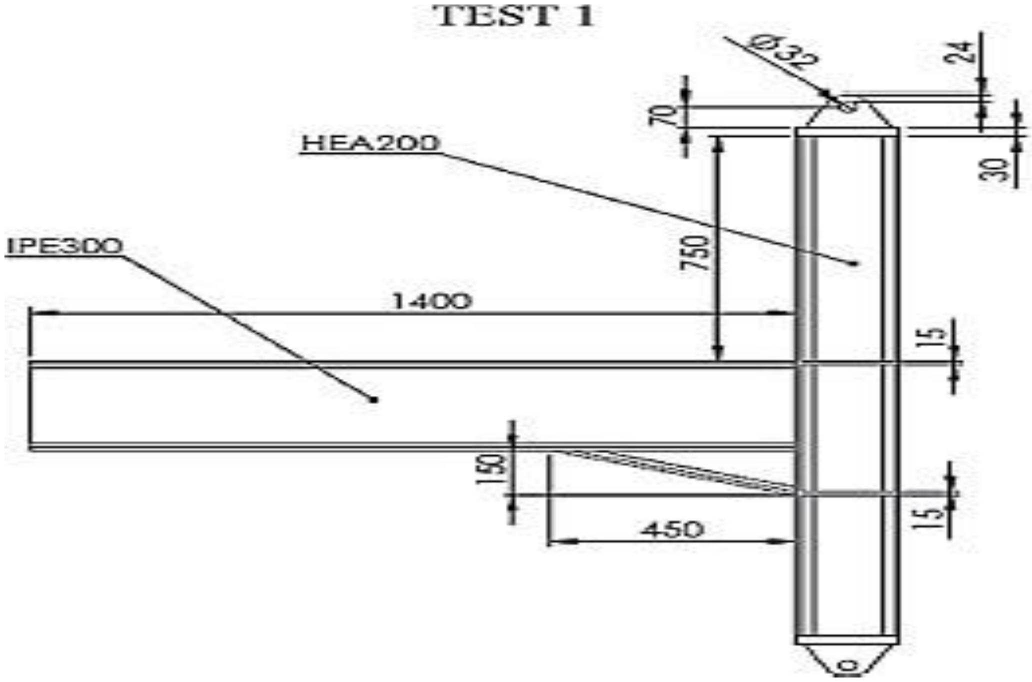

Figure 4.8: Figure representing the dimensions of the designs

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V. Research Gap

5.1 Case 1 (D1, 108 and S275):

The 310.95 MPa of equivalent stress for case 1 is exhibited in the below mentioned image and deformation is exhibited of 4.6255 mm. The blue colour represents the minimum equivalent stress value and deformation value and red colour represents the maximum equivalent stress value and deformation value.

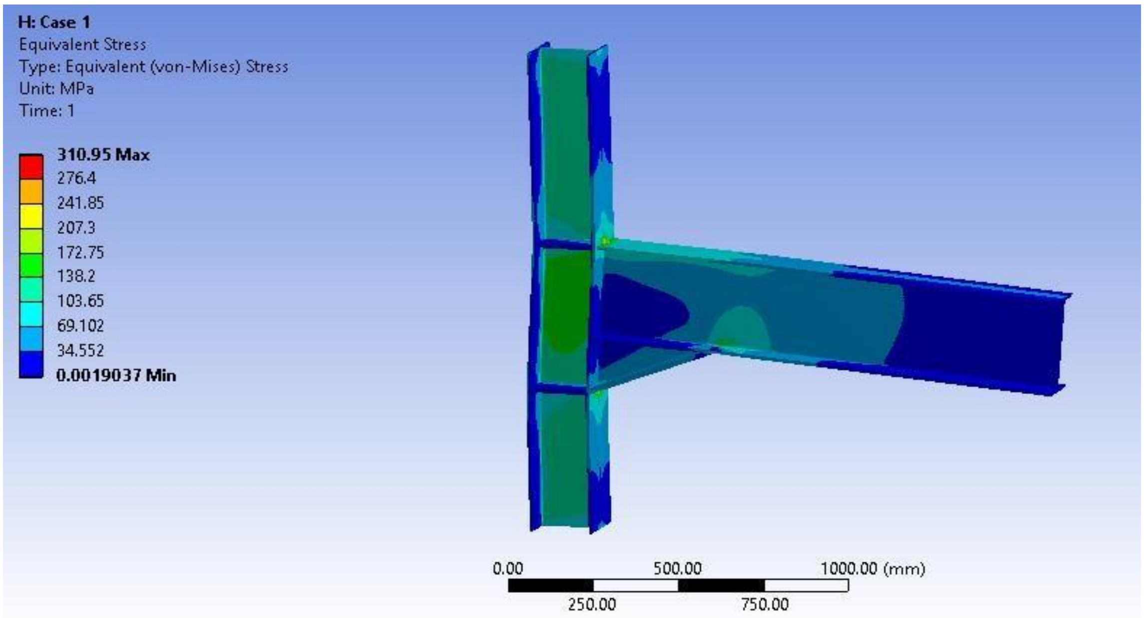

Figure 5.1: Equivalent stress for Case 1

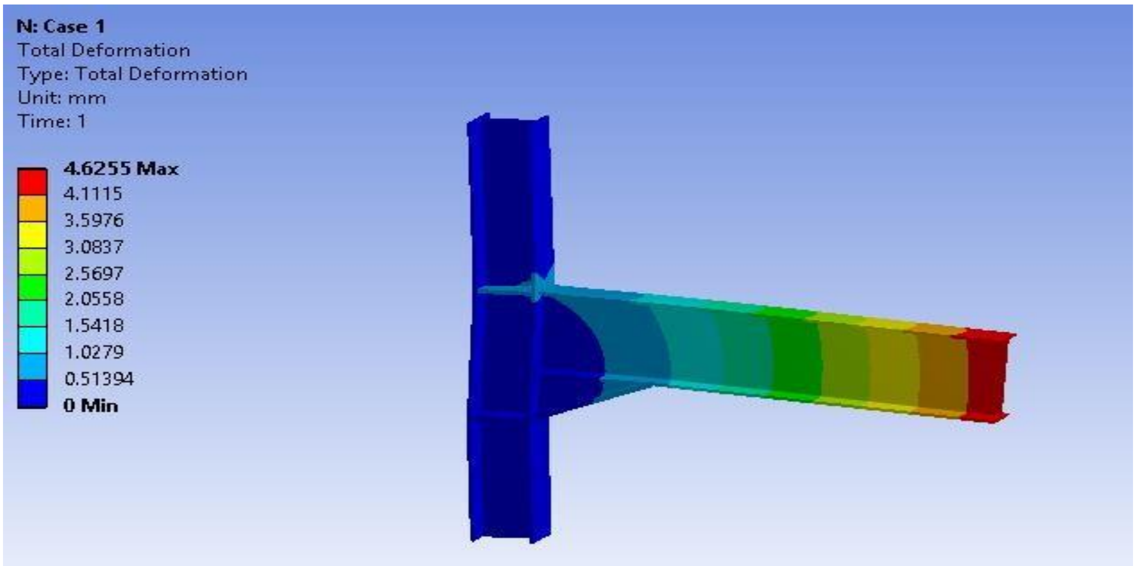

Figure 5.2: Total deformation for Case 1

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5.2 Case 2 (D1, 128 and Al6061)

Case 2 exhibits an equivalent stress of 362.45 MPa and deformation of 16.872mm. The blue colour represents the minimum equivalent stress value and deformation value and red colour represents the maximum equivalent stress value and deformation value.

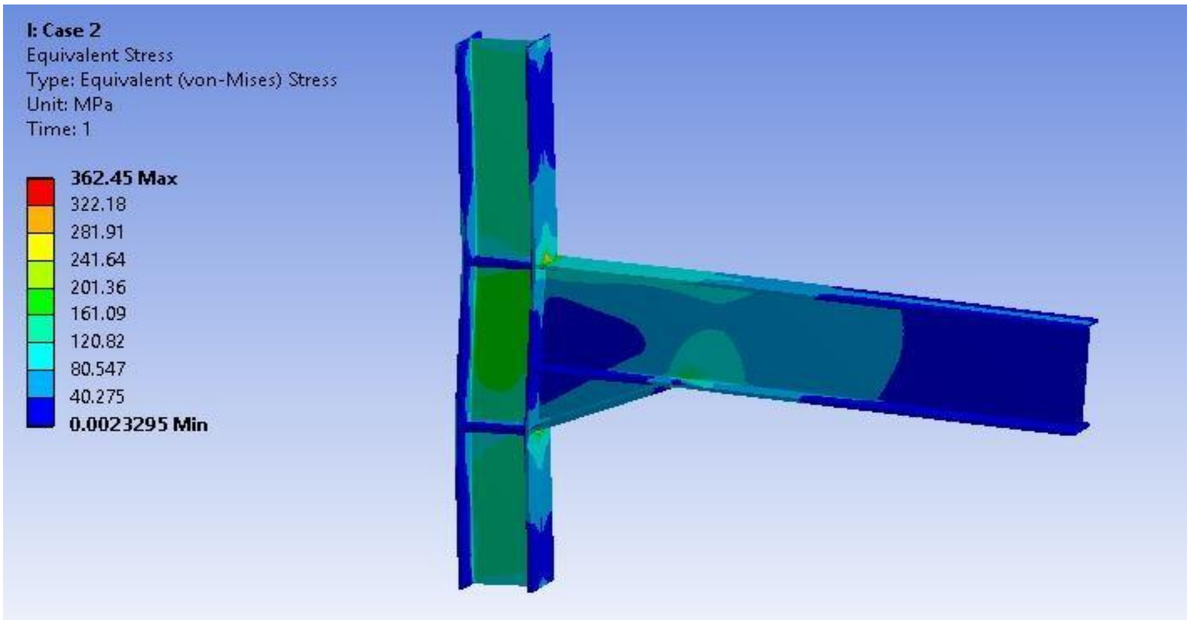

Figure 5.3: Equivalent stress for Case 2

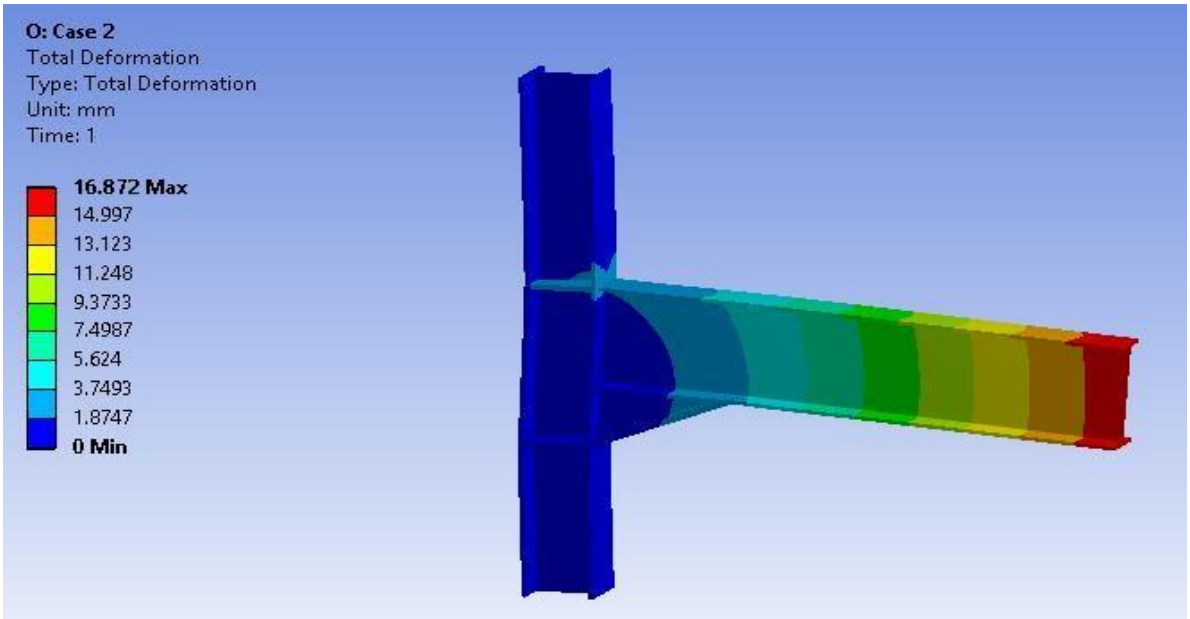

Figure 5.4: Total deformation for Case 2

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5.3 Case 3 (D1, 148 and EN8):

Case 3 exhibits an equivalent stress of 368.54 MPa and the deformation is of 6.0591 mm. The blue colour represents the minimum equivalent stress value and deformation value and red colour represents the maximum equivalent stress value and deformation value.

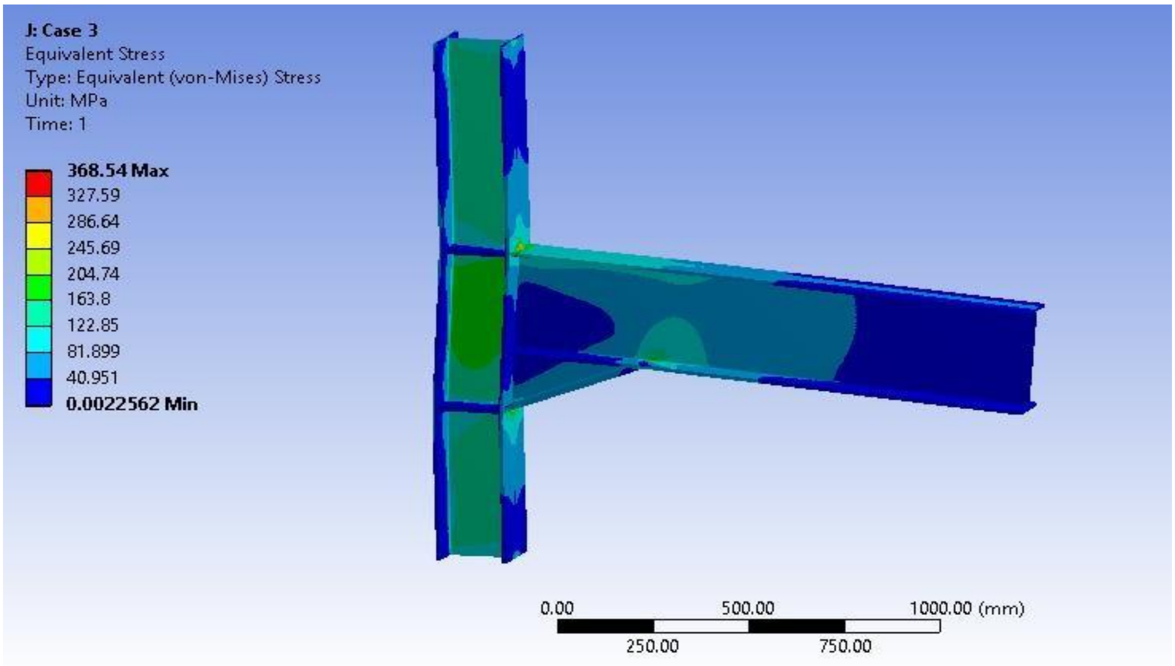

Figure 5.5 Equivalent stress for Case 3

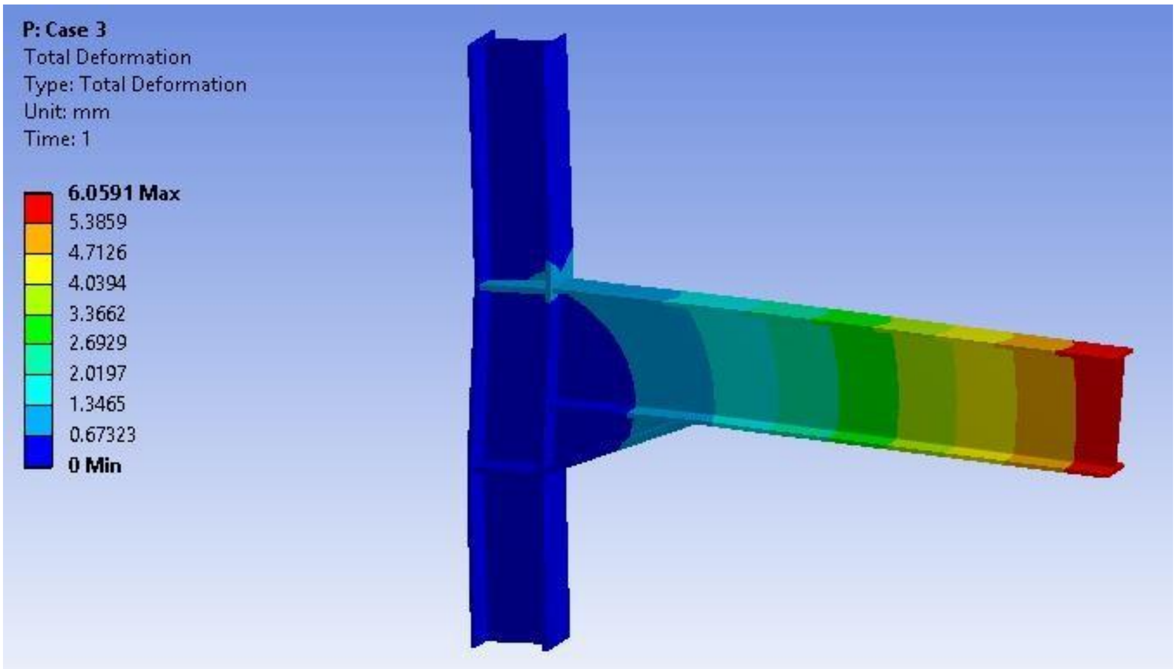

Figure 5.6: Total deformation for Case 3

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5.4 Case 4 (D2, 108 and Al6061)

Case 4 exhibits an equivalent stress of 253.48 MPa and the deformation is of 14.228 mm. The blue colour represents the minimum equivalent stress value and deformation value and red colour represents the maximum equivalent stress value and deformation value.

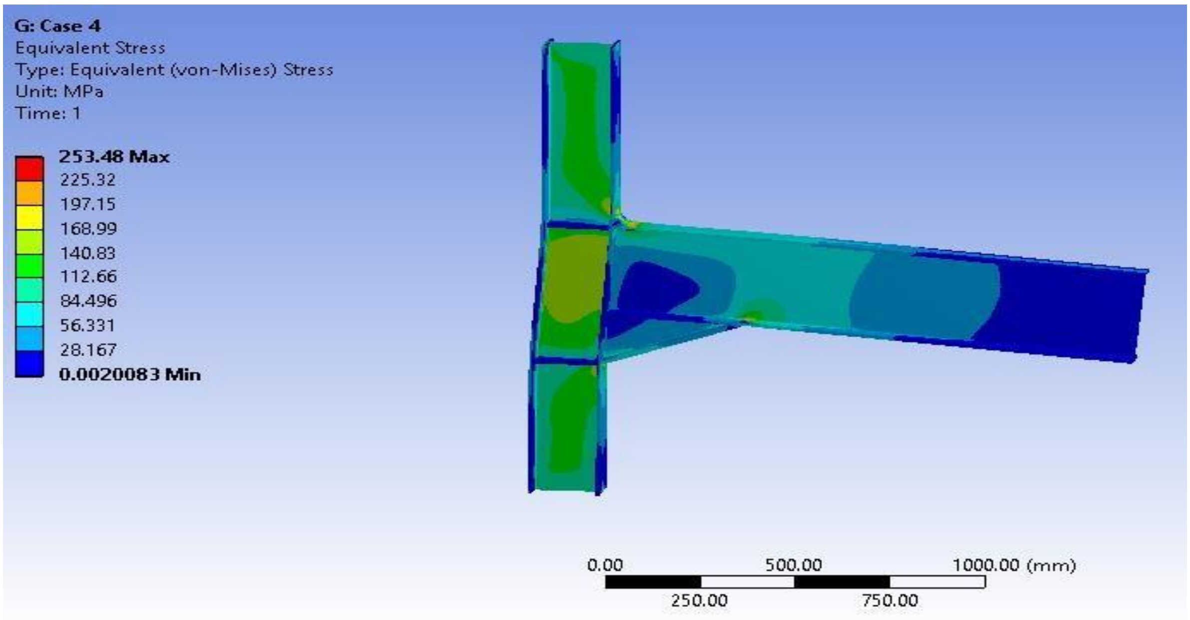

Figure 5.7: Equivalent stress for Case 4

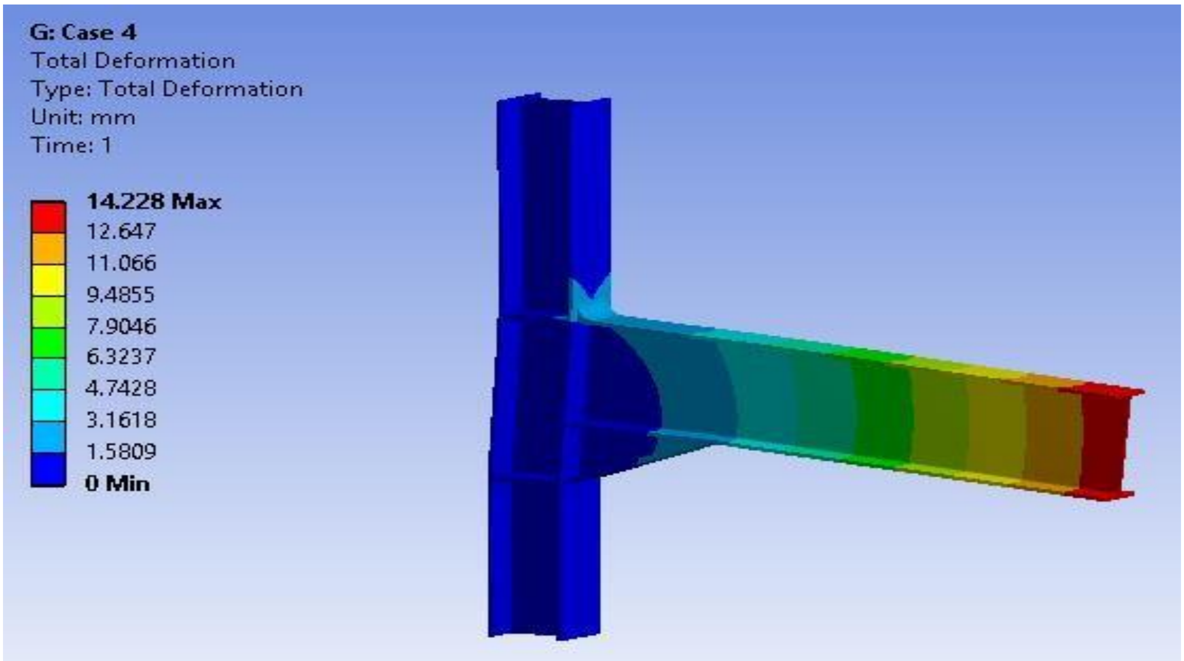

Figure 5.8: Total deformation for Case 4

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5.5 Case 5 (D2, 128 and E8)

Case 5 exhibits an equivalent stress of 296.28 MPa and the deformation is of 6.0572 mm. The blue colour represents the minimum equivalent stress value and deformation value and red colour represents the maximum equivalent stress value and deformation value.

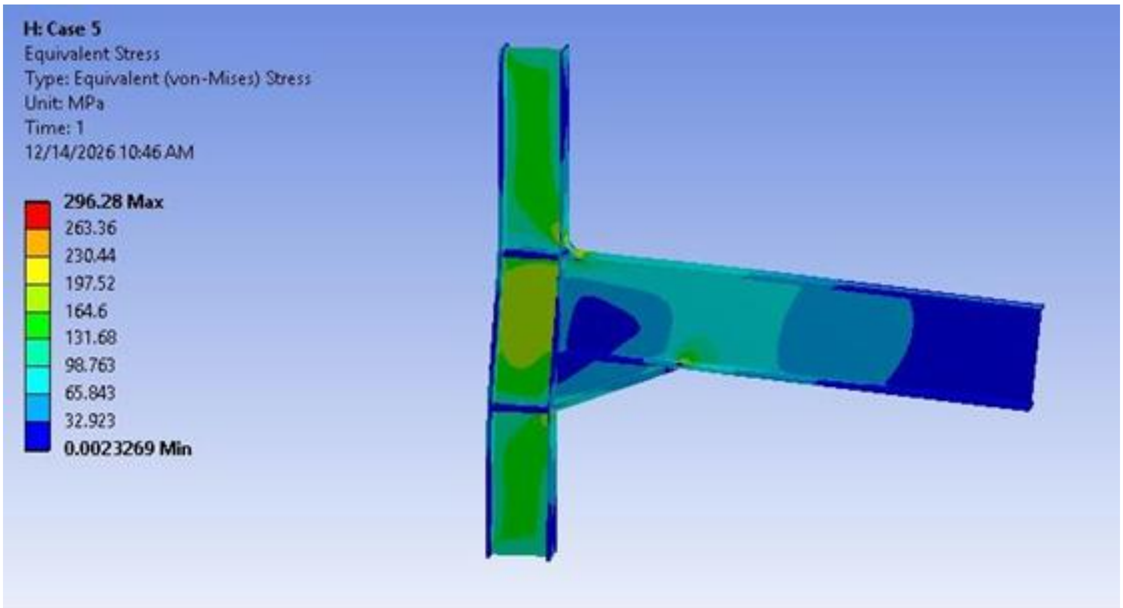

Figure 5.9: Equivalent Stress for Case 5

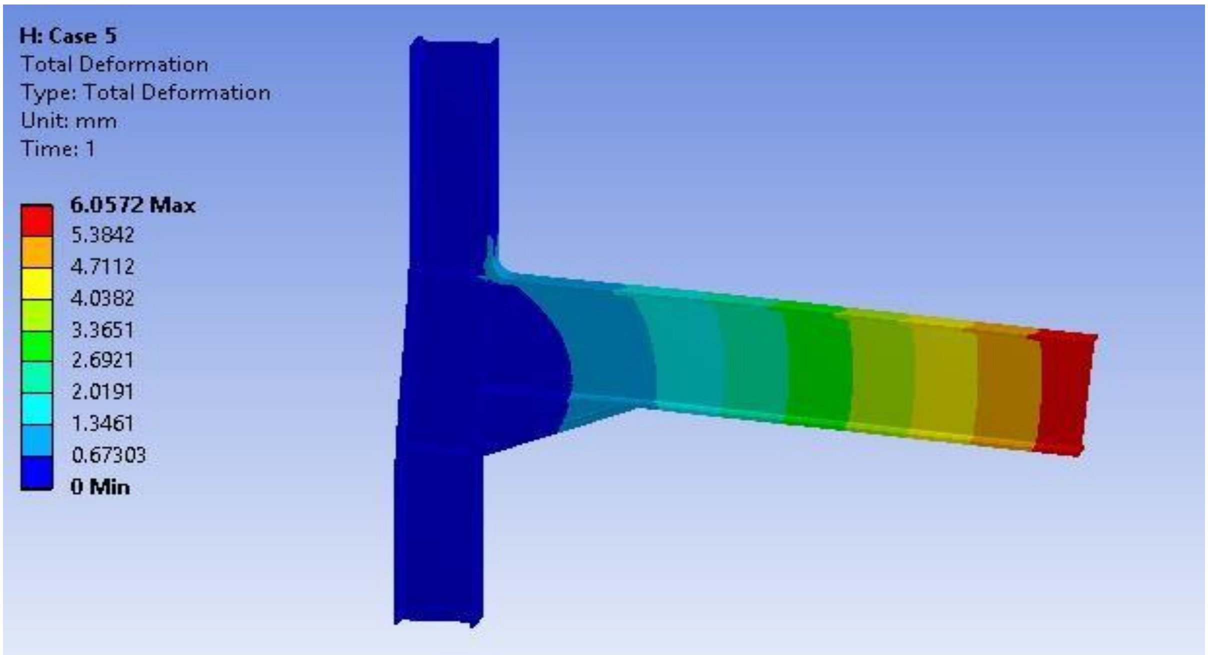

Figure 5.10: Total deformation for Case 5

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VI. CONCLUSION

The finite element analysis is used in this work to evaluate the deformation breaking stress of welding joint to restrict the welding failure (using low carbon steel as a base metal and copper filler material). Static stress analysis performed on the welding under tensile load revealed the maximum von-misses stress with respect to the gap between parent plates using ANSYS. The design and analysis of welded lap joint has been done successfully.

i. By applying Finite element analysis (ANSYS), the duration of experimentation can be reduced.
ii. The processing quality can be enhanced by using Taguchi method and the processing variations can be reduced.
iii. After applying Taguchi method it was observed that Force is placed at first rank, Design at second and Material at third.
iv. The efficiency of optimization process can be enhanced by using taguchi method.
v. For obtaining better result, Force of level 1, Design of Level 2 and material of level 3 is taken.
vi. 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.
vii. 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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