

# STUDY OF LOADING CONDITIONS FOR THREE PLATE LAP WELDED SPECIMEN USING ANSYS TOOL

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**Abstract** - Welded joint are most common types of joint found in industries & various engineering applications. Numerical simulation is applied in welding technology which is now not just influencing the life of the component but leads to the improvement of overall fabrication process. Present work includes the stress and strain generated at the root and toes of the lap weld with wide amounts of literature study conducted for this work. Present paper focuses on single cover plate butt type of weld. ANSYS which is a Finite Element Analysis (FEA) tool is used to simulate the lap weld. Study of different meshing methods with some necessary variations has been done. Effects of different loading and boundary conditions have been studied in the present paper.

**Key Words:** finite element (FE), ANSYS, meshing, 3D Modeling, Numerical Simulation, Weld Shape, Weld Dimensions

## INTRODUCTION

Welding finds innumerable applications, as a fabrication technique, in manufacturing industries having a direct influence on the life of the components and their thermal and mechanical behavior during service. Because of change in geometry generated during welding any two separate parts and followed by loading of the welded metal, undesirable stresses and deformations are produced in welded components. Therefore, it is of paramount importance to simulate the welded joints to delineate the ensuing stresses and deformations. Because of the inherent complexity of geometry, boundary conditions and nonlinearity of material properties in welding, not too many studies have been conducted in this direction to predict the behavior of welded structures.

Since various welding experiments are rather long and expensive, finite element simulations are widely used in prediction of different optimal parameters in various industrial applications. The drastic growth in computer processor technology and efficient numerical methods have made computational weld mechanics solve a large number of problems that are of interest to diversified industries. Typical applications of such technology include nuclear reactors, defense, micro electronics, automotive, aerospace structures etc.

## Weld Geometry

**Effective throat:** The minimum distance from the root to the face of the weld. It is also known as the effective area of welded joint.

**Face of weld:** The exposed surface left after the weld bead formation. It is the visible side of the weld among the three sides shown in the figure 2.

**Root:** The point where the two plates & the weld meet. It is also the point where weld material end common point of two flanges.

**Toe of weld:** The point where face of the weld, meet the bottom or top base plate.

**Leg size:** The distance between the root of weld to the toe is known as leg size.

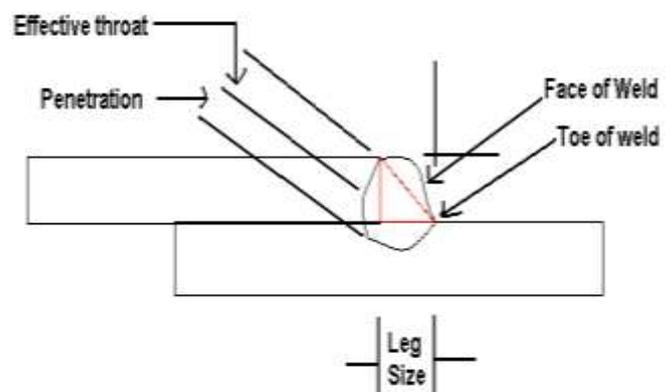


Fig-1. Geometry of a Weld

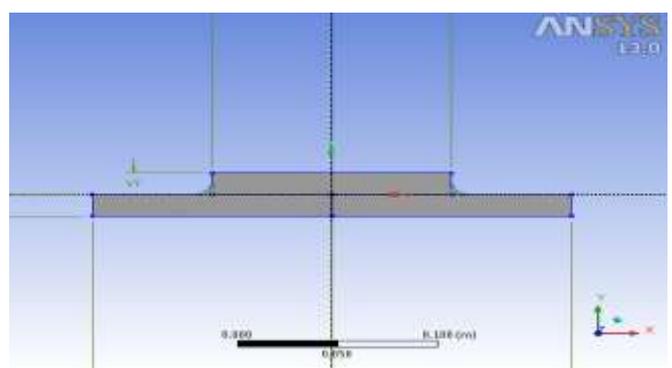
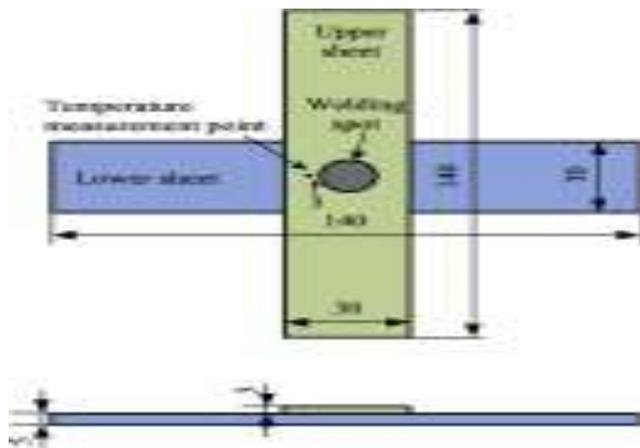


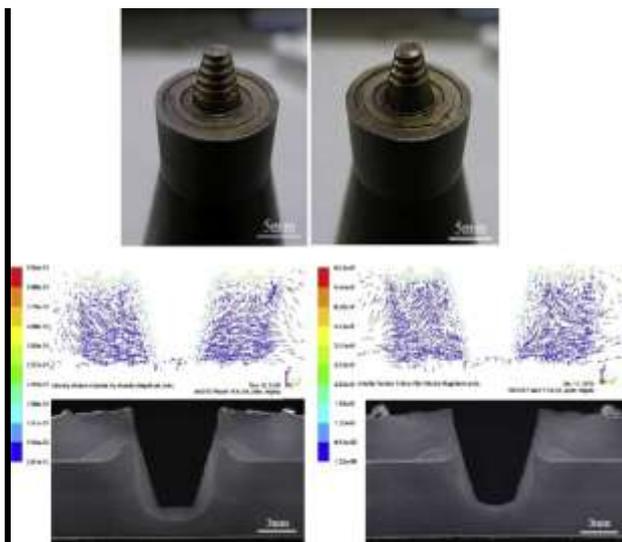
Fig. 2. Figure of a Weld drawn in ANSYS

**LITERATURE REVIEW**

To enhance the material flow at the lap interface which induces lower heat input, [1] analyzed half- & full threaded pin tool of alclad 2A12-T4 aluminum alloy in friction stir spot welding (FSSW), using experiment and simulation methods shown in **fig. 3 (b)**. Tool geometry is the main factor which significantly influences the material flow behavior during friction stir spot welding (FSSW) & weld quality. Peak temperature during welding using the half-threaded pin is lower than that using the full-threaded pin. The higher material flow velocity causes bigger bonding width at the lap interface with the half-threaded pin type tool as desired. Cross tension failure load of the welds shown in **fig. 3 (a)** is bigger using the half-threaded pin than that using the full-threaded pin. This is in agreement with the different bonding widths. Bigger bonding width on the weld is also directly proven by fracture morphologies, is obtained by using the half-threaded pin.

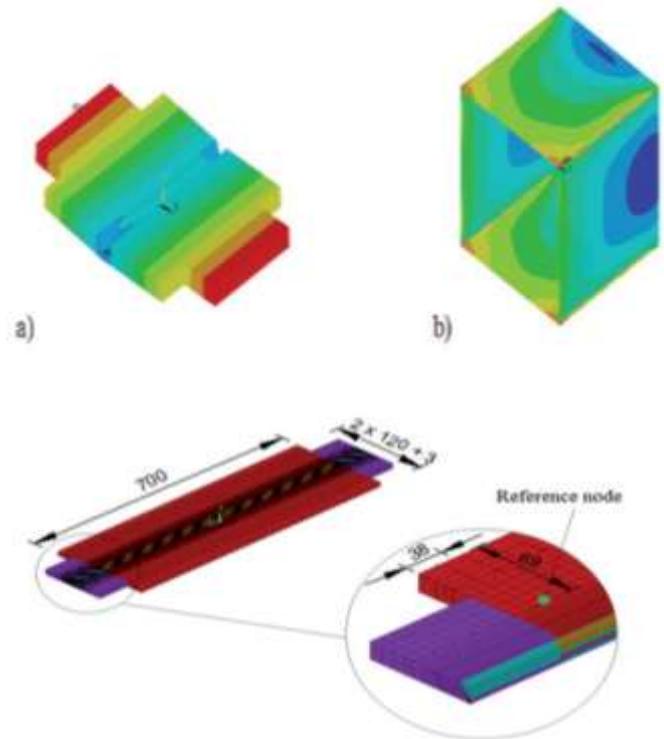


**Fig- 3. (a)** lap weld specimen used by [1]



**Fig- 3. (b)** FSSW tools half & full-threaded pin simulated in ANSYS Fluent 15.0 [1].

SYSWELD & ANSYS 14.5 is utilized by [2] to simulate two type of welded joint specimen shown in **fig. 4. (a), (b) & (c)** made of structural steel S355 as per the recommendation code Eurocode 3 (EC3): EN1993-1-2:2005 & EN1993-1-5 for the design of steel structures for Structural fire design.



**Fig- 4.** Deformed shapes of molded geometries: (a) butt welded plates (b) box section (c) Finite element model for multi-pass butt welded plate with dimension [2]

The objective of [2] is to study the effects of different welding parameters like heat input, welding speed & steel grade etc. on the residual stresses and deformations of the specimen. First Specimen is a butt welded plates with a thickness of 16 mm, width is 120 mm & length 700 mm. The second is having width and height of 400 mm with plate thickness of 8 mm for the investigated butt welded box section constructed by steel material S355 where length of the specimen is set equal to the width. The study include the heat Sources, temperature dependent material properties and the development of an uncoupled thermo-mechanical analysis. The virtually fabricated specimens of structural steel S235, S355, S460 and S700 are further analyzed to investigate the stability behavior. The results show, that heat input has large effect on the maximum tensile residual stresses and on the location of the maximum value but negligible influence on the compressive residual stresses. It is also observed that the size of the heat affected zone is increasing by increasing heat inputs, and the peak stress decreases on the interface of the molten and stiff materials. The buckling resistance of the two methods utilized are compared and discussed.

To investigate the thermal process of large spot laser + MIG arc brazing–fusion welding on Al-steel joint, [3] used finite element model. For this numerical simulation, laser is considered as Gaussian plane heat source for Laser-arc hybrid welding. Modified double ellipse Gaussian plane was assumed to be from MIG arc heat source. Here the arc distortion is taken into consideration. The experimental results found close to the calculations of weld bead geometry and heat-affected width of zinc coating. The brazed interface, showed non-uniform and asymmetric temperature field distribution. The bimodal characteristic of thermal cycles at brazed interface is found at arc center and laser spot center. The introduction of laser beam causes widened high temperature zone at brazed interface which is found to be more than that with conventional MIG brazing–fusion welding. Based on the founded model, a fundamental processing window which satisfies a certain energy condition framed. In this the steel plate was not melted but Al alloy was fully penetrated.

The FEM analysis on dissimilar butt joint of hybrid Al-Ti structures is done by [4] using fiber laser offset welding having 2 mm thickness AA5754 and Ti6Al4V specimen. Butt joints were produced by shifting an YB fiber laser source on the upper surface of the Ti sheet without using any filler wire or groove preparation Unavoidable formation of brittle inter-metallic compounds, mixing of molten phases, and large differences in material properties makes it difficult to join Al-Ti, for its applications aircraft and automotive industries. During this investigation the temperature distribution and thermal cycle in the work-piece were obtained & supported by FEA for which ANSYS parametric design language (APDL) was used to perform calculations. In order to validate the model, the temperature & seam cross section were detected. The modeling & experimental analysis of this joint under different working conditions and seam shapes showed good characteristics and margins for improvement in terms of microstructure, micro-hardness, and tensile behavior. Satisfactory approach of experimental results with numerical outputs was found.

Investigation of micro-structural characteristics & intermediate layers formation mechanism during explosive welding through experimental and numerical analyses at Al/Fe wavy joint interface is conducted by [5]. At an impact velocity of 750 m/s and an impact angle of 15°, two types of intermediate layers were obtained at the wavy joint interface. The layer formed at tail-side includes the area with dendritic structure which contains Al<sub>3</sub>Fe and Al<sub>5</sub>Fe<sub>2</sub> thus shows local melting in the area. On the other hand, no evidence of melting was found on front side layer. Smoothed particle hydrodynamics (SPH) method was applied to simulate the oblique collision at Al/Fe interface to study the formation behavior and temperature change. On the tail-side, a mixture of Al and Fe particles

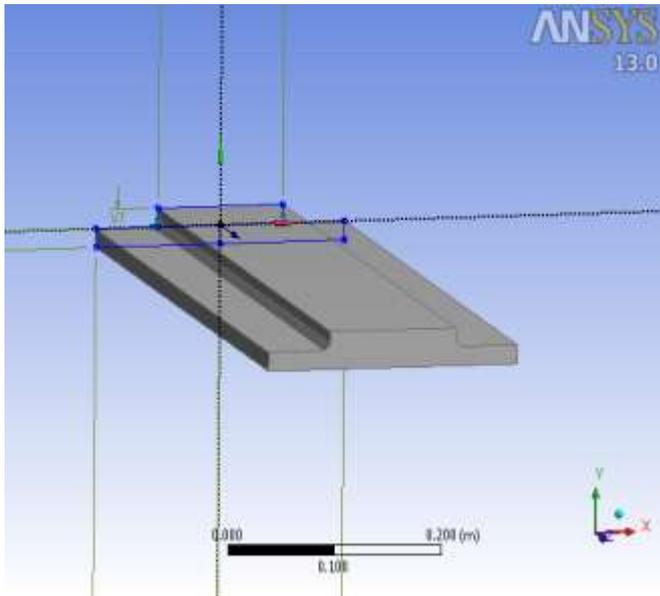
formation was found as the simulation results and a large increase in local temperature exceeding the melting temperature of Fe and Al occurred. Small temperature increase was found at front side. Formation of two types of intermediate layer is plausibly explained by the composition ratio of Al and Fe, and the temperature distribution calculated by the SPH simulation at the joint interface.

Laser-welded triangular corrugated core sandwich panels is compared by [6] with equivalent solid plates under air blast loading using Autodyn simulation as well as practical experiment. Experimental investigations were occurred with three levels of blast loading in an explosion tank where maximum deflection, core web buckling and core compaction were found to be increased as a result, with decrease in stand-off distance. At the stand-off distances of 100 mm and 150 mm, the back face deflections were found to be half for sandwich panels than that of the solid plates. Catastrophic failure & fracture was found at closest stand-off distance i.e 50 mm. The investigation based on fully-coupled numerical simulation using Autodyn for the dynamic response of sandwich panels were found to be in a good agreement with experimental results. Also, the effects of face sheet thickness on the dynamic response along with core web thickness of sandwich panel were discussed.

To join thin 6013 aluminum alloy plate to galvanized steel plate as a lap joint, the process of metal inert gas (MIG) arc brazing-fusion welding was developed by [7], based on the difference in melting point between aluminum alloy and steel. To study its thermal process, finite element modal was formed in which MIG arc was assumed to be double ellipse Gaussian plane heat source was uniform body heat source for this model is overheated metal droplet. Effects of the zinc coating is taken into consideration along with the overlap gap. To validate the calculated results, the brazed seam width as well as the width of heat-affected zinc coating present on the back side of galvanized steel plate were used. The calculations were found to be as per the experiments performed.

In the brazing-fusion welded joint, the calculation results indicate non-uniform distribution of temperature. The reaction temperature and time, at different positions on the brazed interface were found at a great difference. A corresponding relationship must be followed where the welding current and welding speed are synchronized to be increased, to achieve the energy condition that steel plate is not melted and aluminum plate is fully penetrated.

**MODELLING**

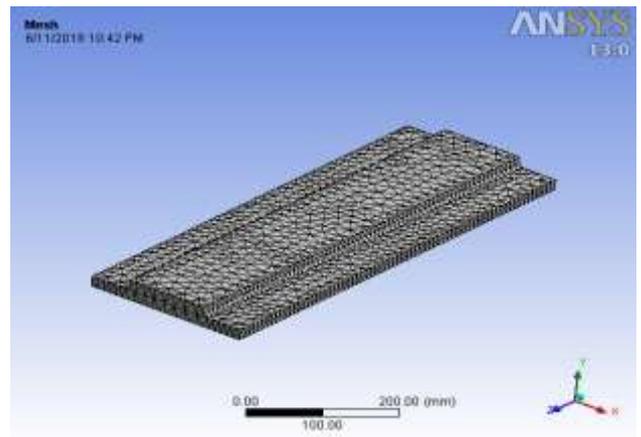


**Fig- 5.** Welded joint in ANSYS

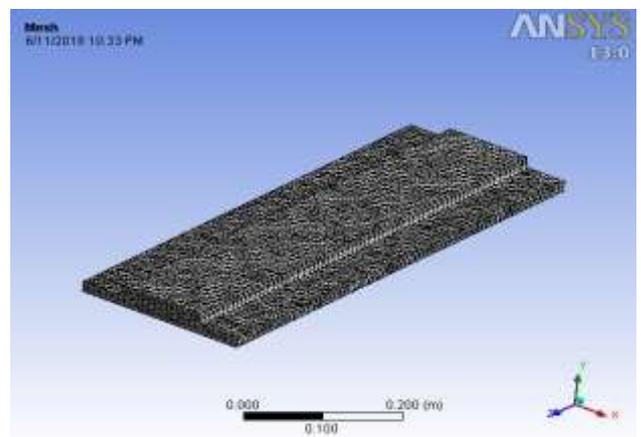
Figure 3 illustrates the butt weld drawn. ISO-metric views in design modeler and multi-physics respectively have been shown in the Figure 5. Table 1 shows the dimensions of the fillet weld. Figure 4 shows the different meshing methods & element size considered. Difference between the methods can be easily observed.

**Table-1:** Dimensions of the welded plates

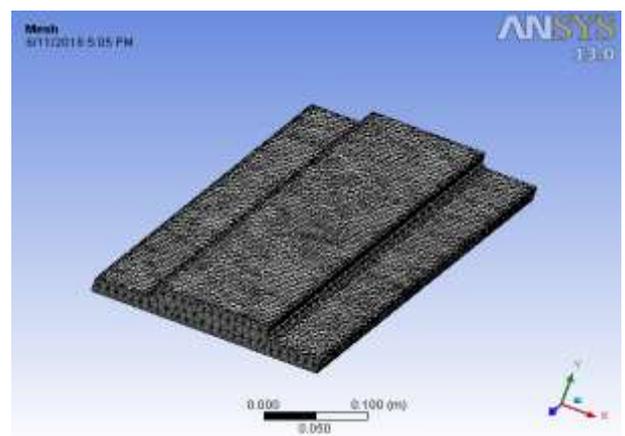
Part name (unit)	Length	Thickness	Width
Two Horizontal plates (mm)	700	16	120
Top Horizontal cover plate (mm)	700	16	120



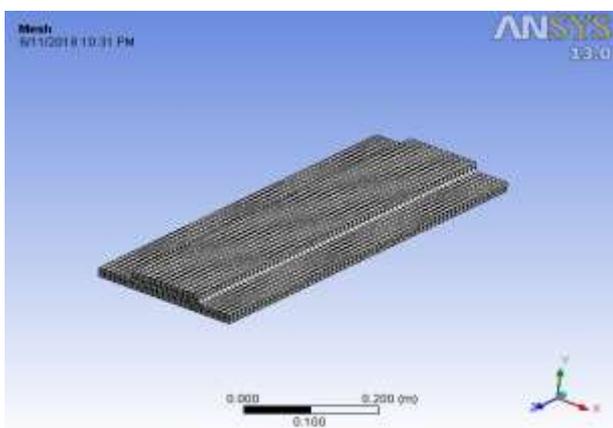
Patch conforming 10mm



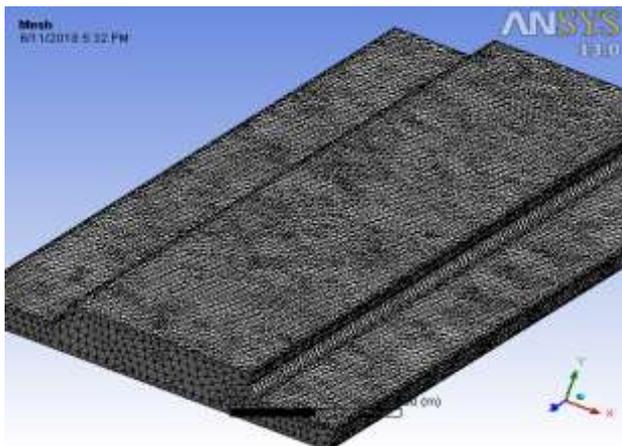
Patch independent 10mm



Patch conforming 5mm



Automatic 10mm



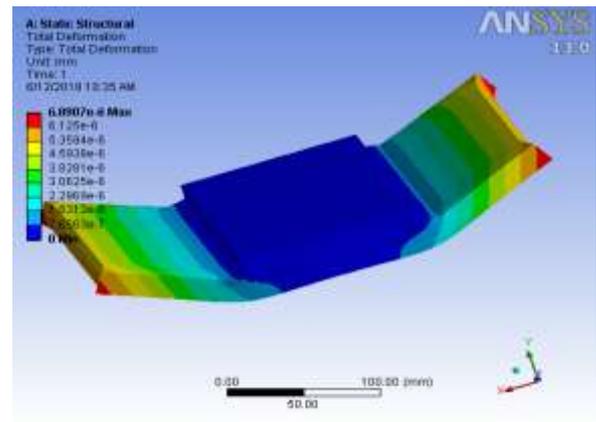
Patch conforming 3mm

Fig- 6. Different meshing methods with element sizes

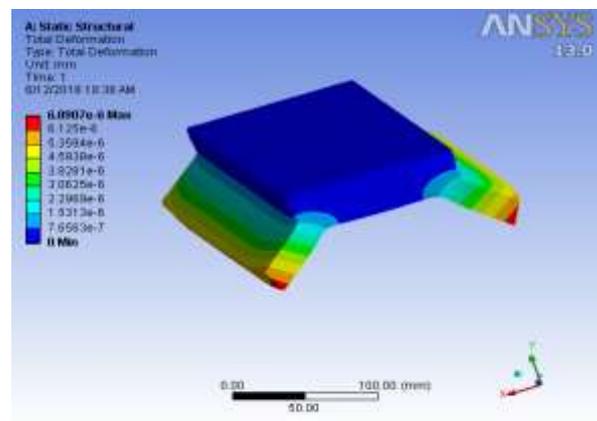
From table 1, it can be noticed that number of nodes and elements varies with meshing methods and element size. Density of mesh increases with increase in nodes & elements. For patch conforming method, with decrease in element size number of nodes and elements increases quickly. But notice that increment in number of nodes and elements fine the meshing but increases the solution time which can go up to days depends on nodes and element numbers.

Table- 2: Meshing methods with number of nodes & elements for different elements sizes.

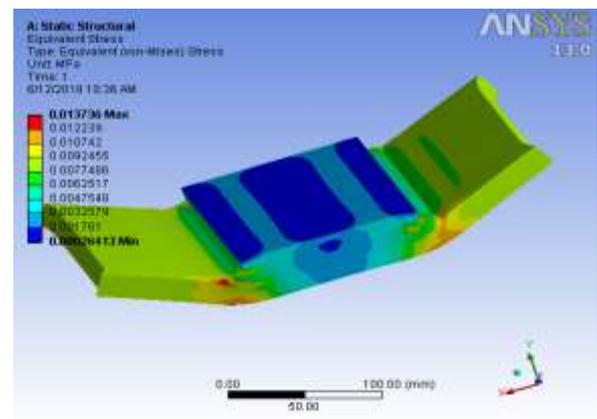
Type of meshing	Element size	Nodes	Elements
Automatic	10mm	24472	4550
Patch conforming	10mm	12403	6587
	5 mm	44967	25026
Patch independent	10mm	77007	51035
	5 mm	665648	472371



(a)



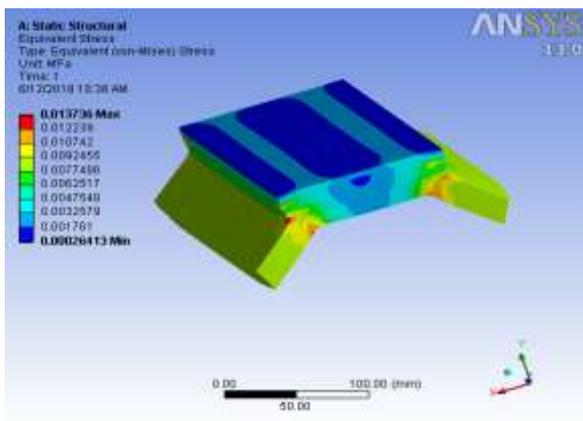
(b)



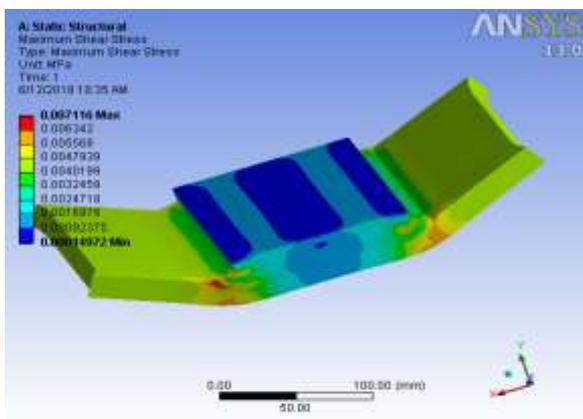
(c)

## RESULTS & DISSCUSSION

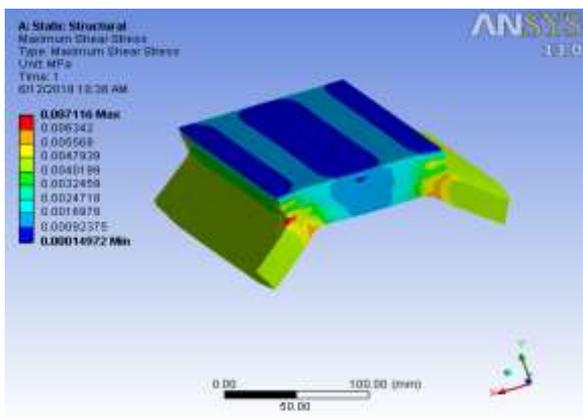
Here in figure 5, the stresses & deformations generated in the butt weld specimen are shown when it is loaded. Figure 5 (a) & (b) shows the results of total deformation, (c) & (d) shows results for von-mises stress while (e) & (f) results for Maximum shear stress theory.



(d)



(e)



(f)

Fig-7. Results Generated in the Butt Weld.

Two different types of boundary conditions of the force have been considered in the present study i.e. expansion & compression. Results in column first of Figure 5 are for the case when both bottom plate's has been subjected to expansion load from 1 N to 100 N. While results in the second column of Figure 5, are for the case when both

bottom plates have been subjected to compression load i.e. from -1 N to -100 N.

It can be noticed that stress and strain have been generated near the weld toes on both the sides as shown by the red & orange colour in the specimen in (c), (d), (e) & (f) parts of the figure 5. So here we can conclude that weld toes between top cover plate & the two bottom plates are the portion where the chances of failure of single cover plate butt weld are maximum. Weld toes are the portion where stress concentration may occur, and while manufacturing they should be designed considering this fact in mind. Further rise in load may increase the stresses generated in the butt weld specimen.

### CONCLUSIONS

1. In a single cover plate butt weld, the toes between top cover plate & bottom plates are the areas where maximum stress and distortion occurs.
2. FE tool like ANSYS can predict the approximated results which may help the industries while manufacturing these types' welds.
3. Meshing can affect the results, so a fine meshing should be used if possible as it may increase the time of the solution.

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