International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 4 Issue 02, February-2015

Modelling and Simulation of Weld Induced Deformations by using FEM Tool

Altaf Hussain Bagawan, Shriranganath P A, Basavaroodh A B, Shashir S K.
Assistant Professor, Mechanical Department, S.I.E.T- Vijaypur, Karnataka, India-586101

Abstract— **Welding is one of the important and integral parts of the manufacturing process. Due to welding some deformations and residual stresses are induced in the components. The main task, to improve the properties of material is to reduce these two parameters. It is quite clear that the mechanical restraints used to reduce weld induced distortions will increase the values of residual stresses. It has been observed that by making edge preparation of work piece and by increasing the welding speed, can reduce the distortions. In the present paper FEA analysis is done for reduction of distortion by edge preparation and increasing welding speed and compared with the experimental values.**

Keywords— welding, FEA, Chamfer, Angle of Joint.

I. INTRODUCTION

Welding is a fabrication process used to join materials, usually metals or thermoplastics, together. During welding, the work pieces to be joined are melted at the joining interface and usually a filler material is added to form a pool of molten material that solidifies to become a strong joint. Welding generally requires a heat source to produce a high temperature zone to melt the material, though it is possible to weld two metal pieces without much increase in temperature.

In most welding procedures metal is melted to bridge the parts to be joined so that on solidification of the weld metal the parts become united. The common processes of this type are grouped as fusion welding. Heat must be supplied to cause the melting of the filler metal and the way in which this is achieved is the major point of distinction between the different processes. The method of protecting the hot metal from the attack by the atmosphere and the cleaning or fluxing away of contaminating surface films and oxides provide the second important distinguishing feature.

In arc welding processes, due to rapid heating and cooling, the work piece undergoes an uneven expansion and contrast in all the directions. This leads to distortion in different directions of the work piece. Angular distortion or out-of-plane distortion is one such defect that makes the work piece distort in angular directions around the weld interface. Post weld treatment is required to eliminate the distortion so that the work piece is defect free and accepted. During welding with the angular distortion there also occurs welding residual stresses, Stress and deformations are largely opposed, if we attempt to reduce angular distortion by restraining, it will lead to more residual stresses. Providing an initial angular distortion in the negative distortion is a method to eliminate the angular distortion during welding. Hence it will be highly useful to predict the angular distortion. Scientifically proven statistical methods are used to study the effects of various parameters on angular distortion. In this study, Taguchi-methods have been used to develop mathematical models to correlate angular distortion with process variables. The process variables considered are

- Edge preparation angle (ß).
- Current (I).
- Speed (S).

II. LITERATURE REVIEW

Submerged arc welding is one of the major metal fabrication techniques in industry due to its reliability and capability of producing good quality weld. In submerged arc welding, various process parameters interact in a complicated manner, and their interactions influence the bead geometry, bead quality as well as metallurgical characteristics and mechanical properties of the element. In most of the cases, quality of the weld is left to depend on the past experience and working skill of operator. But, with the advent of automation, it is now possible to design a machine capable of selecting optimal process parameters to provide desired yield.

M.Sadat Ali [1] studied the Modeling the effects of preheating on angular distortions in one sided fillet welds, in this work a numerical elasto-plastic thermo mechanical model has been developed for predicting the thermal history and resulting angular distortions of manual metal arc welding in one sided fillet joints. To create a realistic simulation of the single sided fillet welding, a moving distributed heat source is used in finite element model. From the modeling and experiment it was observed as the thickness of the plate increases the distortion decreases. From the experiment and modeling it was also observed that with the increase of power input the distortion also increases. The distortion patterns obtain through finite element modeling and experimental observed patterns matching perfectly. The temperature profile obtained from the finite element modeling compared fairly with the experimental ones.

Hirai and Nakamura [2] investigated angular distortion experimentally for steel fillet welded joints, and provided a graph to predict angular distortion for fillet welded T-joints with different thickness.

Taniguchi [3] applied the same method to aluminium alloy fillet welds. In both results, angular distortion was prescribed as a function of plate thickness, and weight of electrode consumed per weld length, which means that angular distortion is related with the rigidity of joints (plate thickness) and welding parameters (weight of electrode deposited). Results also showed that the maximum angular distortion occurred at a certain thickness range, which means if plates were thinner or thicker than this thickness range, less angular distortion would occur.

Bai-Qiao Chen [4] studied that Prediction of heating induced temperature fields and distortions in steel plates. This work has developed models and techniques for predicting the temperature distributions and the distortions induced in steel plates by the line heating as well as the welding process. Finite element models have been developed. Furthermore, a series of load temperature curves for a bead-on- plate weld steel plate have been calculated with suitable convection boundary conditions and non-linear material properties. The time variant temperature fields obtained have been applied as thermal load into mechanical analyses to predict the plate distortions. Results have been compared to numerical and experimental results obtained from previous research. A complex three dimensional line heating and welding processes phenomenon was simulated using a commercial finite element package ANSYS, in order to compute the distortion pattern and deformation of steel plates. A mathematical model of moving heat source was established in ANSYS to simulate the transient thermal analysis.

Rosenthal [5] was among the first researchers to develop an analytical solution of heat flow during welding based on conduction heat transfer for predicting the shape of the weld pool for two and three-dimensional welds. Using the Fourier partial differential equation (PDE) of heat conduction, he introduced the moving coordinate system to develop solutions for the point and line heat sources and applied this successfully to address a wide range of welding problems. His analytical solutions of the heat flow made possible for the first time the analysis of the process from a consideration of the welding parameters namely the current, voltage, welding speed, and weld geometry.

Goldak et al. [6] derived a mathematical model for welding heat sources based on a Gaussian distribution of power density. They proposed a double ellipsoidal distribution in order to capture the size and shape of the heat source of shallow and deeper penetrations.

Mandal and Sundar [7] performed the work that estimates the welding shrinkage in a welded butt joint by applying a mathematical model approach.

Heinze et al. [8] investigated a single-layer gas metal arc (GMA) weld of 5 mm thick structural steel is experimentally and numerically. The numerical modeling begun with a mesh analysis based on modal analyses. The sensitivity of welding-induced distortion is examined regarding different continuous cooling transformation (CCT) diagrams.

Gunaraj and Murugan [9] have highlighted the use of Response Surface Methodology (RSM) to develop mathematical models and plot contour graphs relating important input parameters namely the open-circuit voltage, wire feed rate, welding speed and nozzle-to-plate distance to some responses namely, the penetration, reinforcement, and width and percentage dilution of the weld bead in SAW of pipes. They demonstrated that all responses decrease with increasing welding speed. Also, when the nozzle-to-plate distance increases all responses de-crease, but reinforcement increases. Moreover, an increase in the wire feed rate results in an increase in all responses but the width remains unchanged.

Murugan and Parmar [10] used a four-factor 5-levels factorial technique to predict the weld bead geometry (penetration, reinforcement, width and dilution %) in the deposition of 316L stainless steel onto structural steel IS2062 using the MIG welding process.

Bipin Kumar Srivastava et al. [11] studied the A review on effect of arc welding parameters on mechanical behaviour of ferrous metals/alloys. This work presents the exhaustive research review on effect of arc welding parameter on quality of welds. It is understood that several process control parameters in SAW influence bead geometry, microstructure as well as weld chemistry. Their combined effect is reflected on the mechanical properties of the weld in terms of weld quality as well as joint performance.

Jun sun [12] studied the Modeling and finite element analysis of welding distortions and residual stresses in large and complex structures. The objective of this research is to develop effective and efficient numerical methods and computational techniques that are capable of performing 3D large scale finite element analysis of material processing problems. This study investigates the deployment of parallel computing and several related modeling and optimization issues used for simulating welding distortion in large structures. The FEA algorithm is also carefully implemented on a large shared memory computer and optimized to achieve the optimal computational performance

III. MODELING AND ANALYSIS

FEA models are used for present study with the solid45 and solid 70 degree elements as shown in figure1 and figure 2. Solid45 element is used in analyzing the 3-D modeling of solid structures. The element is defined by eight nodes having three degrees of freedom at each node: Translations in the nodal x, y and z directions. A Solid70 element shown in Figure 5.2 is used in analyzing the 3D modeling of thermal element. The element has a three-dimensional thermal conduction capability.

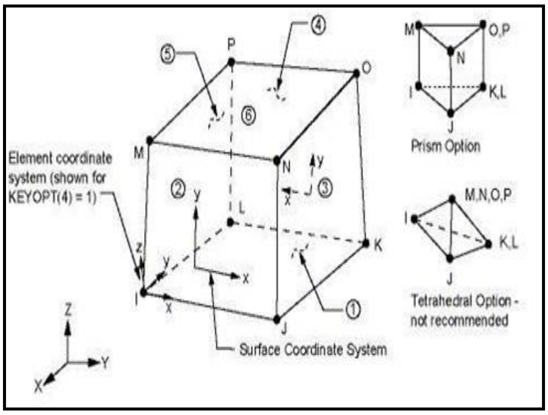

Fig-1 Solid 45^{o} element

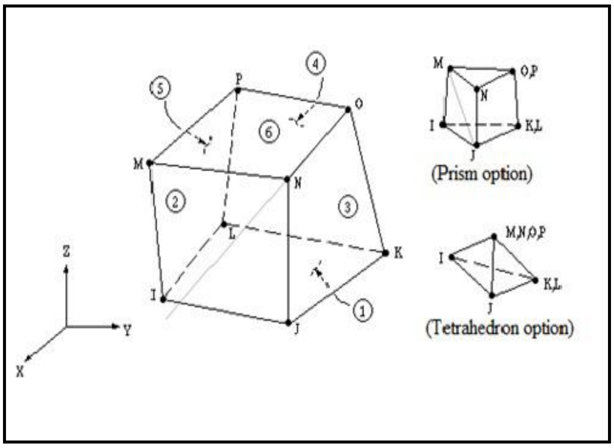

Fig-2 Solid 70^{o} element

<u>Boundary Conditions:</u>

The thermal boundary conditions are set as the nodes exposed to ambient air are applied with the convection with a convection heat transfer coefficient of 15 w/ m2k at 298°K.

The structural Boundary Conditions are set as Model kept on the table is restrained in negative y-direction.

IV. RESULTS

In the present work the temperature distribution on work pieces is studied varying with the different angle of chamfer.

The temperature distribution is changes as the angle of joining of the work pieces to be joined is changed, that further depends on the angle of chamfer of work pieces.

The results of the temperature distribution for different angle of joints are given below.

A. *For joint with 60^{o}.*

The mesh model for the joint with 60^{o} is shown in the figure-3.

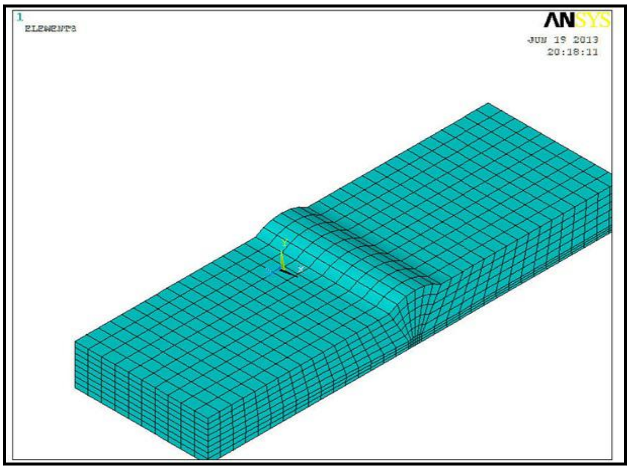

Fig 3: Mesh model for specimen with 60^{o}

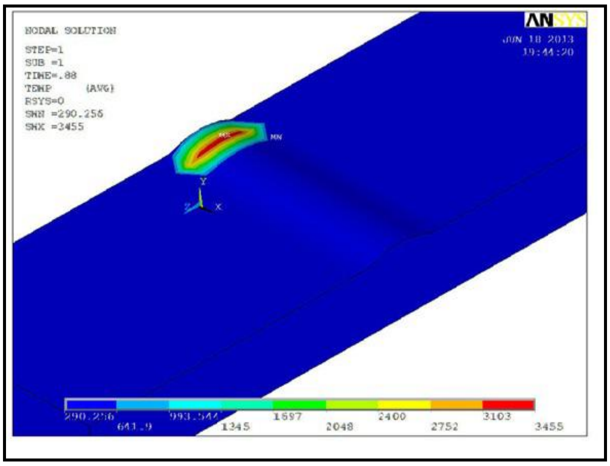

Fig 4: Temperature distribution after 1.25 seconds

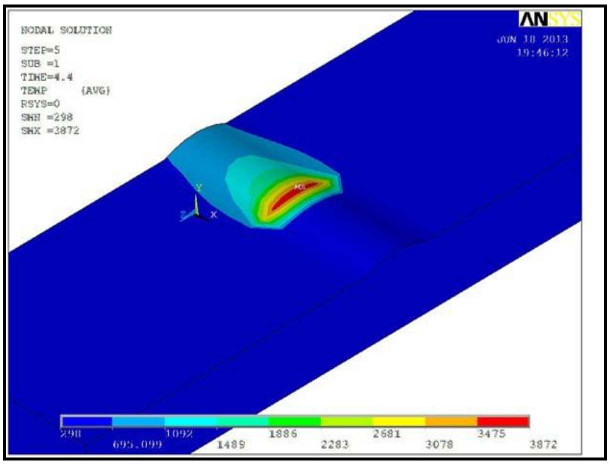

Fig 5: Temperature distribution after 6.25 seconds

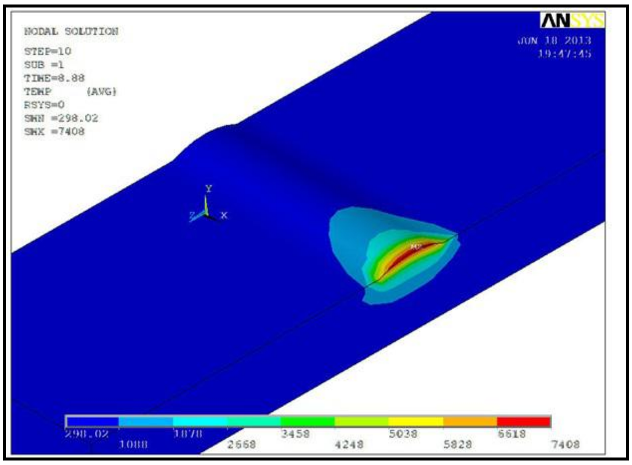

Fig 6: Temperature distribution after 12.5 seconds

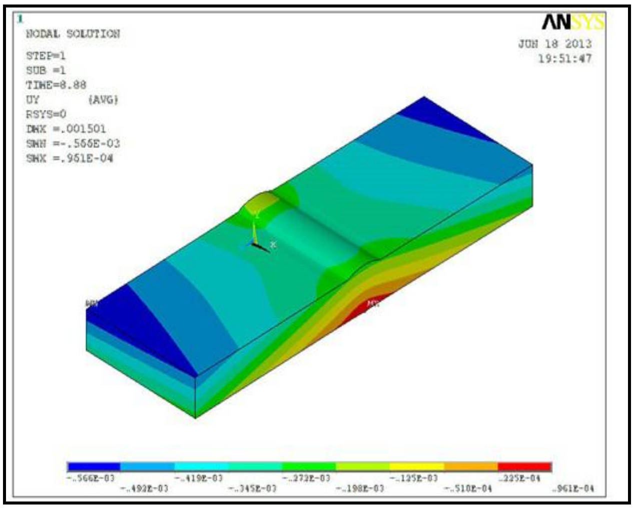

Fig 7: Deflection for specimen with 60°

B. *For Specimen with 75°:*

The mesh model for the joint with 60^o is shown in the figure-8.

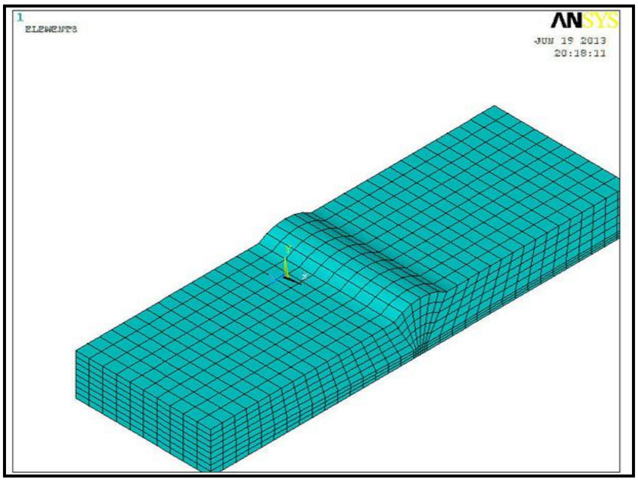

Fig 8: Mesh model of specimen with 75°

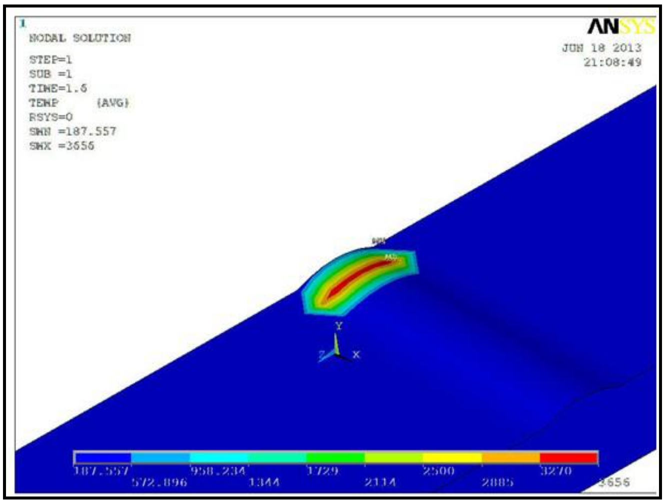

Fig 9: Temperature distribution after 1.25 seconds

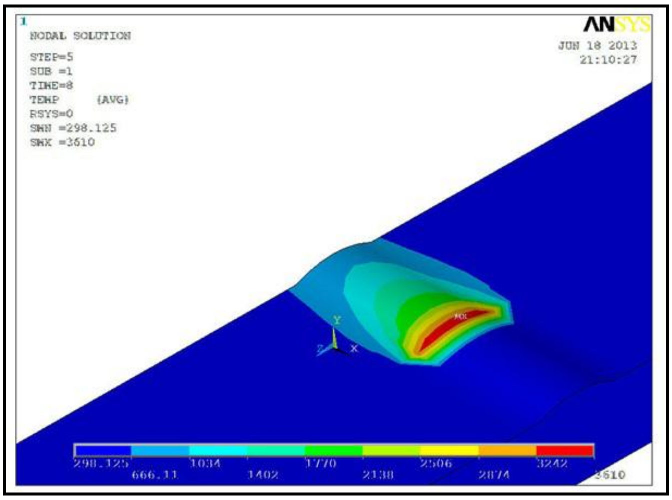

Fig 10: Temperature distribution after 6.25 seconds

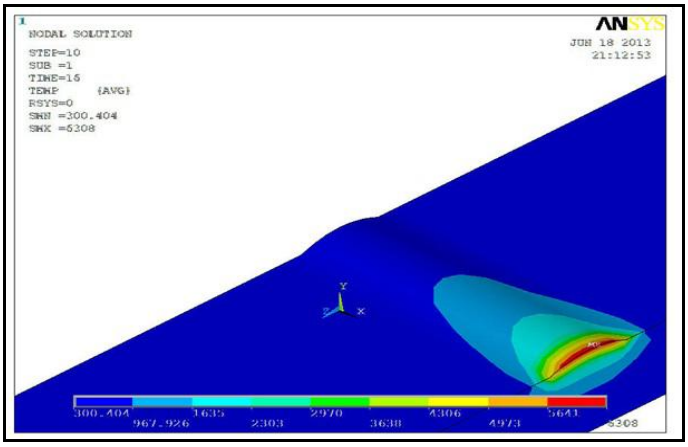

Fig 11: Temperature distribution after 12.5 seconds

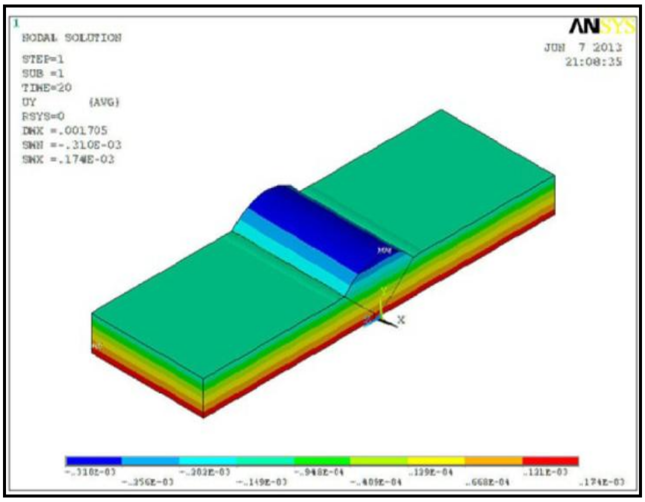

Fig 12: Deflection for specimen with 75°

The results of the distortion of the work pice for deffrent angle of chamfer is shown in the table-1. Table-1 also contains the comparision between FEM analysis and the experimental results for distortions.

Table-1: Comparison of Experimental Distortion and FEM Distortion

Current	Speed	Edge angle	Experimental Distortion	FEM Distortion
100	2.5	15	1.75	1.72
130	4.5	45	0.083	0.081
140	5	60	0.137	0.12
175	4.5	75	0.67	0.672

V. CONCLUSION

The distortions obtained by FEA and experimental are almost equal.

Since the distortions obtained by FEA and experimental method are same, it can be concluded as the temperature history predicted by FEA is almost equal to experimental method due to the fact that distortions depends on temperature. So FEA can be used an effective tool to predict temperature

histories at various instants of time, which is very difficult to measure by temperature measuring devices experimentally.

REFERENCES

[1] M Sadat Ali, 2012. Centurion University of Technology & Management, Gajapati, Odisha, India “Modelling the effects of preheating on angular distortions in one sided fillet welds”.

[2] Hirai, Nakamura, (1955) 59-68. “Research on angular change in fillet welds”, Ishikawajima.

[3] Taniguchi, 1972. “Massachusetts Institute of Technology, Master’s thesis, MIT, Cambridge “Out-of-plane distortion caused by fillet welds in aluminum”.

[4] Bai Qiao Chen, 2011. Dissertation to obtain the degree of Master in Naval Architecture and Marine Engineering, Lisbon “Prediction of Heating Induced Temperature Fields and Distortions in Steel Plates”.

[5] Rosenthal, D. 1946. “The Theory of Moving Sources of Heat and Its Application to Metal Treatment Sadat Ali, 2012. Centurion University of Technology & Management, Gajapati, Orissa, India “Modeling the effects of preheating on angular distortions in one sided fillet welds”, Trans. A.S.M.E 68: 849-866.

[6] Goldak, J.A., Chakravarti, A. & Bibby, M.J. 1984. “A New Finite Element Model for Welding Heat Sources”. Metallurgical Transactions B 15B: 229-305.

[7] Michaleris, P. & Sun, X. 1997. “Finite Element Analysis of Thermal Tensioning Techniques Mitigating Weld Buckling Distortion”. Welding Journal, 76(11): 451–457.

[8] Heinze, C., Schwenk, C. & Rethmeier, M. 2011. “Influences of Mesh Density and Transformation Behavior on the Result Quality of Numerical Calculation of Welding Induced Distortion”. Simulation Modelling Practice and Theory 19(9): 1847–1859.

[9] Gunaraj, V., and Murugan, N. 1999. “Application of response surface methodology for predicting weld bead quality in submerged arc welding of pipes”. Journal of Materials Processing Technology 88: 266–275.

[10] Murugan, N., and Parmar, R. S. 1994. “Effects of MIG process parameters on the surfacing of stainless steel”. Journal of Materials Processing Technology 41: 381–398.

[11] Bipin Kumar Srivastava, 2010. Mechanical engineering department Institute Of Technology, Banaras Hindu University, Varanasi, India “A review on effect of arc welding parameters on mechanical behaviour of ferrous metals/alloys”.

[12] Jun Sun, 2005. The Pennsylvania State University the Graduate School Department of Mechanical Engineering, “Modeling and finite element analysis of welding distortions and residual stresses in large and complex structures”.