Finite Element Analysis of Residual Stress in Butt Welding of Two Similar Plates

P.Pavani[1] Mr. P. Sivasankar[2] Mr. P. Lokanadham[3] Mr. P. Uma Mhahesh[4]

[1] PG Scholar, Mechanical Engineering, Chadalawada Ramanamma Engineering college of Engineering,Tirupati, Andhra Pradesh, India
[2] Asst.Professor, Mechanical Engineering, Chadalawada Ramanamma Engineering college of Engineering,Tirupati, Andhra Pradesh, India
[3] Professor & Hod, Mechanical Engineering, Chadalawada Ramanamma Engineering college of Engineering,Tirupati, Andhra Pradesh, India
[4] Asst.Professor, Mechanical Engineering, Chadalawada Ramanamma Engineering college of Engineering,Tirupati, Andhra Pradesh, India

ABSTRACT:

In this paper, Manual Metal Arc Welding of carbon steel plates was studied. The finite element analysis of residual stresses in butt welding of two similar plates is performed with the ANSYS software. This analysis includes a finite element model for the thermal and mechanical welding simulation. It also includes a moving heat source, material deposit, temperature dependent material properties, metal plasticity and elasticity, transient heat transfer and mechanical analysis. The welding simulation was considered as a sequential coupled thermo-mechanical analysis and the element birth and death technique was employed for the simulation of filler metal deposition. The residual stress distribution and magnitude in the axial direction is to be obtained. A good agreement between the computation and experimental results is to be obtained. Key words: welding, welding joint, plate, residual stresses, stress analysis, finite element method.

Key Words: *welding , materials , analysis, etc…*

INTRODUCTION:

WELDING is widely used in automotive industries to assemble various products. It is well known that the welding process relies on an intensely localized heat input, which tends to generate undesired residual stresses and deformations in welded structures, especially in the case of thin plates. Therefore, estimating the magnitude of welding deformations and characterizing the effects of the welding conditions are deemed necessary. With modern computing facilities, the finite element (FE) technique has become an effective method for prediction and assessment of welding residual stress and distortions(1). However, the welding deformations are various with production variations such as dimension, welding materials and welding process parameters. Therefore, rapidly and accurately predicting welding induced distortion for real engineering applications is more challenging. In many high temperature applications, it is necessary to join together components of same or different chemical, physical and mechanical characteristics.

LITERATURE REVIEW:

There are many experimental approaches available (e.g. X-ray diffraction) to measure residual stresses, however, most of them are expensive and destructive(3). Therefore, a general trend is to use numerical methods. Since the heat generated during a welding process is dissipated through convection, conduction and radiation, a severe temperature gradient would exist around the welding point.
Rybicki et al. presented a finite element study for girth welding of pipes.
Free and Goff, developed a finite element model to calculate the residual stresses in complex multi-pass weld mends.
Dissimilar butt-welded plates were studied by authors, Lee and Chang.IMurugan et al. modeled a multi pass weld and showed that the patterns of the residual stresses change in each welding pass. This has been confirmed by using the experimental measurements for welded plates with different thickness(2).

Sattari-Far and Farahani used a finite element technique to analyze the thermo-mechanical behavior and residual stresses in butt-welded pipes.

METHODOLOGY:

Welding is a science of joining the metals by the application of heat.Conventional Arc welding process has been used for the present work. The material composition is as shown in the table given below(5).

Comp	C	Mn	P	S	Si	Cr	Ni	Fe
Type 304 (%)	0.08 max	2.00 max	0.045 max	0.03 max	0.03 max	0.75 max	18.00 – 20.00	8.00 – 12.00

CATIA has been used for the design of the weld plates.
The Main Modules are:
Part Design, Assembly, Generative Drafting, Wireframe and Surface Design.

Then, FEA SOFTWARE – ANSYS

The procedure for ANSYS analysis consists of three main steps:

1. Build the model.
2. Obtain the solution.
3. Review the results.

ASSUMPTIONS AND RESTRICTIONS:

1. The structure is linear (i.e. constant stiffness and mass).
2. There is no damping.

FATIGUE ANALYSIS:

While many parts may work well initially, these often fail in service due to fatigue failure caused by repeated cyclic loading. Characterizing the capability of a material to survive the many cycles a component may experience during its lifetime is the aim of fatigue analysis. Three different types of fatigue analysis namely Strain Life, Stress Life andFracture Mechanics were done to analyse the residual stresses in the welded joint(6).

RESULTS :

THERMAL RESULTS

THERMAL	MAXIMUM	MINIMUM
Total Heat Flux	18.174 W/mm2	5.7533e-14 W/mm2
Directional Heat Flux x axis	18.095 W/mm2	-18.099 W/mm2
Directional Heat Flux y axis	3.9805 W/mm2	-3.9748 W/mm2
Directional Heat Flux z axis	0.18337 W/mm2	-0.14702 W/mm2

(THERMAL + STATIC) COUPLED FIELD RESULTS

STATIC	MAXIMUM	MINIMUM
Equivalent Stress	458.06 Mpa	0.10642 Mpa
Normal stress in X- Axis	103.66 Mpa	-141.93 Mpa
Normal stress in Y- Axis	428.69 Mpa	-32.524 Mpa
Normal stress in Z- Axis	98.478 Mpa	-132.8 Mpa
Shear stress in XY Plane	86.039 Mpa	-96.958 Mpa
Shear stress in YZ Plane	79.86 Mpa	-85.842 Mpa
Shear stress in XZ Plane	18.555 Mpa	-18.357 Mpa
Total Deformation	0.019461 mm	3.0681e-5mm
Directional deformation in X- axis	0.019441 mm	-0.019441 mm
Directional deformation in Y-axis	0.0097307 mm	-0.009731 mm
Directional deformation in Z-axis	0.0018541 mm	-0.0018539 mm
Equivalent stress	375.34 Mpa	375.34 Mpa

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 02 Issue: 07 | October-2015 www.irjet.net p-ISSN: 2395-0072

STATIC IN DUE TO PATH WELDING

STATIC	MAXIMUM	MINIMUM
Total Deformation	0.019236 mm	0.0020228 mm
Normal stress In X- Axis	103.66 Mpa	-104.35 Mpa
Normal stress In Y- Axis	290.9 Mpa	-13.397 Mpa
Normal stress In Z- Axis	24.53 Mpa	-58.711 Mpa

NORMAL STRESS AT END DISTANCE WELDING PATH DISTANCE

Thermal Strain

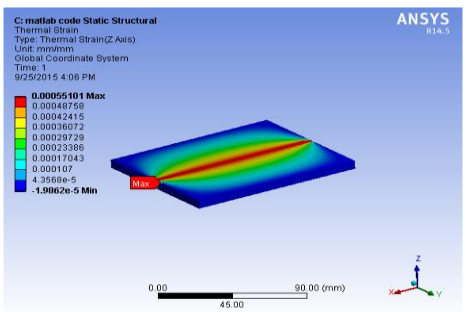

FIGURE 1 Thermal strain having in**Z- Axis** having Maximum of 0.00055101 mm/mm and Minimum of –1.986e-5 mm/mm

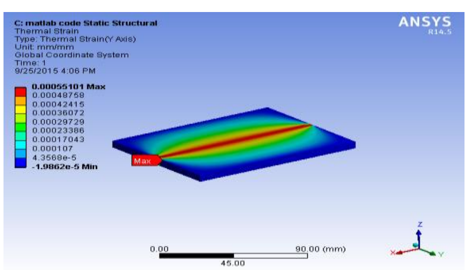

FIGURE 2 Thermal strain having in y- Axis Having Maximum of 0.00055101 mm/mm and Minimum of –1.986e-5 mm/mm

Thermal Strain

STATIC	MAXIMUM	MINIMUM
Normal stress In X- Axis	72.595 Mpa	-0.78417 Mpa
Normal stress In Y- Axis	0.082714 Mpa	-0.1728 Mpa
Normal stress In Z- Axis	0.00096549 Mpa	-0.030926 Mpa

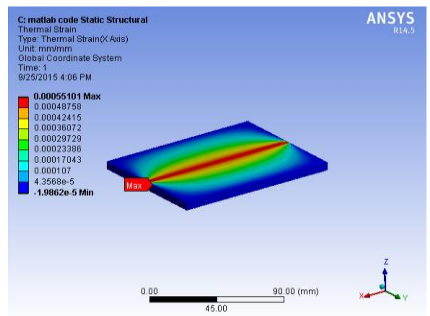

FIGURE 3 Thermal strain having inx- Axis Having Maximum of 0.00055101 mm/mm and Minimum of –1.986e-5 mm/mm

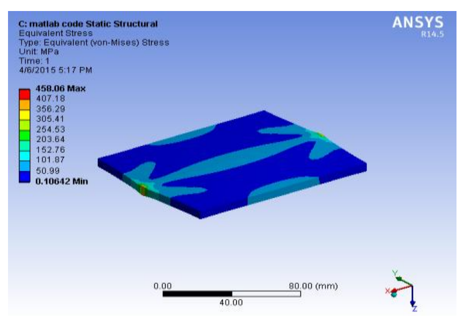

Figure 4 residual Equivalent Stress Having Maximum of 458.06 Mpa and Minimum of 0.10642 Mpa .

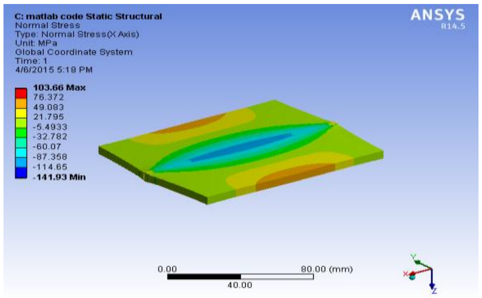

Figure 5 residual Normal stresses in X- Axis Having Maximum of 103.66 Mpa and Minimum of -141.93 Mpa

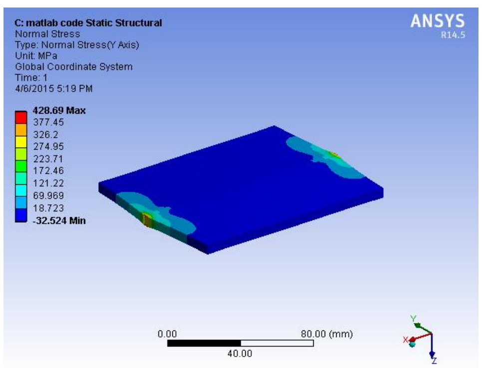

Figure 6 residual Normal stress in Y- Axis Having Maximum of 428.69 Mpa and Minimum of -32.524 Mpa

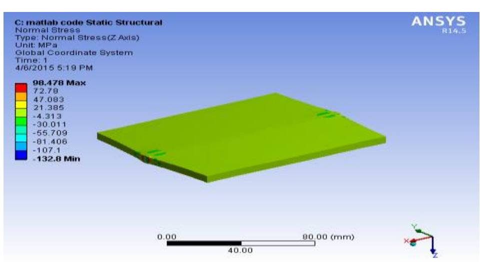

Figure 7 residual Normal stress in Z- Axis Having Maximum of 98.478 Mpa and Minimum of -132.8 Mpa

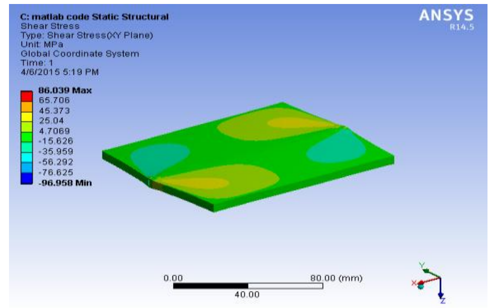

Figure 8 residual Shear stress in XY Plane Having Maximum of 86.039 Mpa and Minimum of -96.958 Mpa

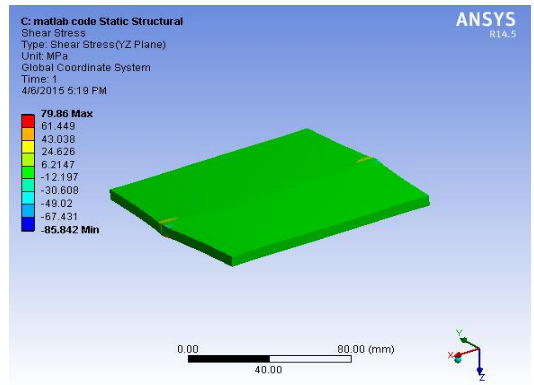

Figure 9 residual Shear stress in YZ Plane Having Maximum of 79.86 Mpa and Minimum of -85.842 Mpa

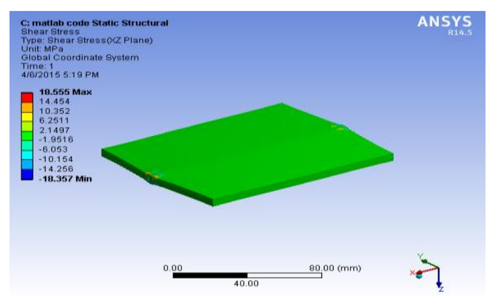

Figure 10 residual Shear stress in XZ Plane Having Maximum of 18.555 Mpa and Minimum of -18.357 Mpa

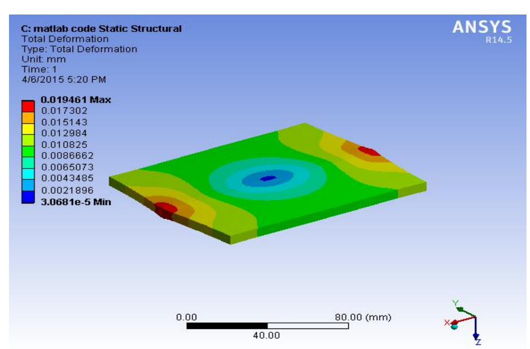

Figure 11 residual Total Deformation Having Maximum of 0.019461 mm and Minimum of 3.0681e-5mm .

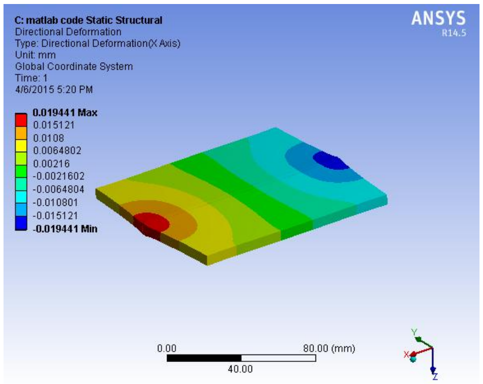

Figure 12 residual Directional deformation in X- axis Having Maximum of 0.019441 mm and Minimum of -0.019441 mm .

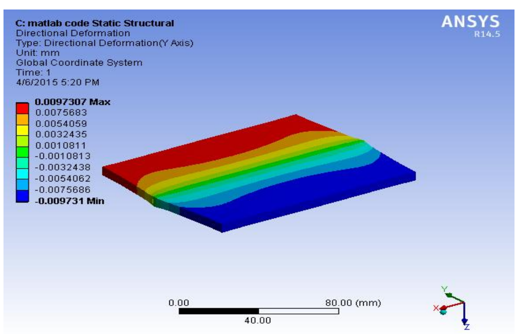

Figure 13 residual Directional deformations in Y- axis having Maximum of 0.0097307 mm and Minimum of 0.009731 mm.

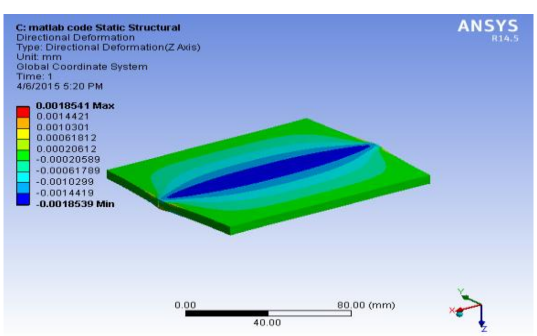

Figure 14 residual Directional deformation in Z- axis having Maximum of 0.0018541 mm and Minimum of -0.0018539 mm.

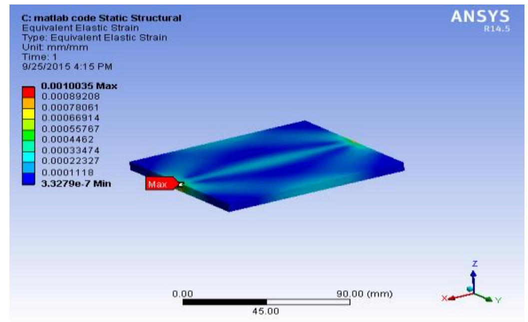

Figure 14.1 residual equivalent elastic strain having Maximum of 0.0010035 mm/mm and Minimum of 3.329e-7 mm/mm

Stress Vs distance along weld path

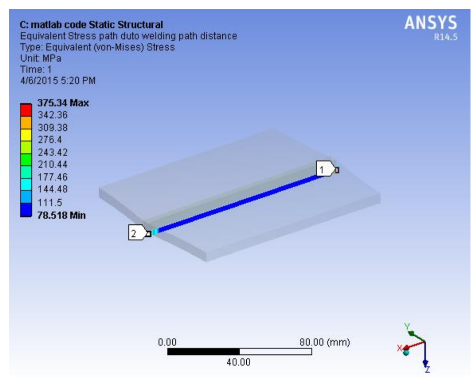

Figure 15 residual Equivalent stress along 1—2 path having Maximum of 375.34 Mpa and Minimum of 78.518 Mpa .

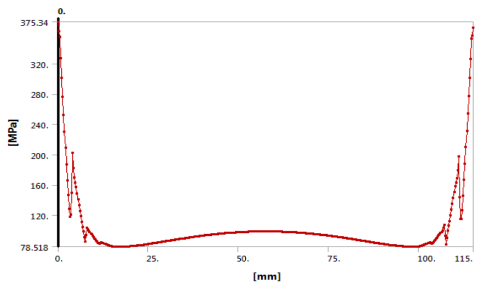

FIGURE 15.1
Model (C4) > Static Structural (C5) > Solution (C6) > Equivalent Stress path duto welding path distance
The above graph shows along the weld path distance and obtained residual stress at the weld bed of the top edges shows the maximum residual stress values are 375.34 MPA of the initial and final edge offset distance of the 15 mm.

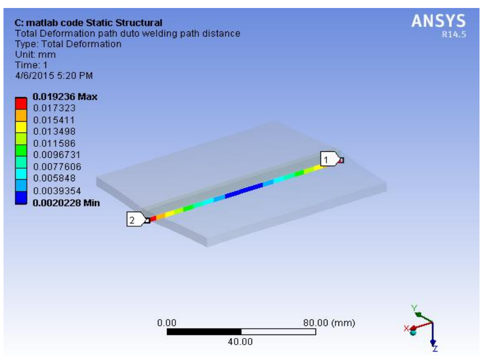

Figure 16 residual Static Structural of total deformation along 1—2 path having Maximum of 0.019236 mm and Minimum of 0.0020228 mm .

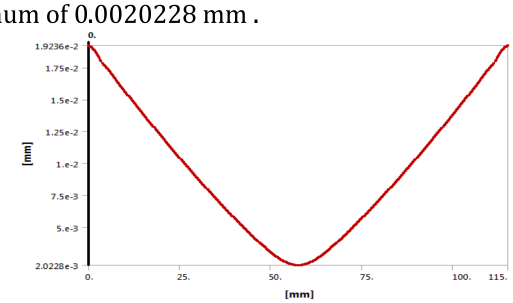

FIGURE 16.1
Model (C4) > Static Structural (C5) > Solution (C6) > Total Deformation path duto welding path distance

The above graph shows along the weld path distance and obtained total deformation at the weld bed of the top edges shows the maximum total deformation values are 0.019236 mm at initial and final edges.

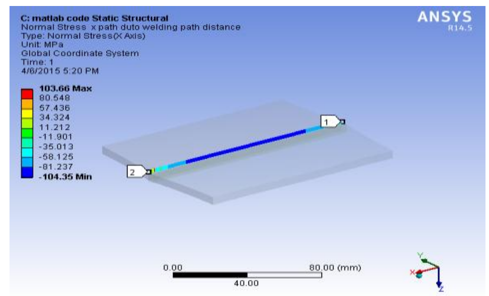

Figure 17 residual Normal stress In X- Axis having Maximum of 103.66 Mpa and Minimum of -104.35 Mpa .

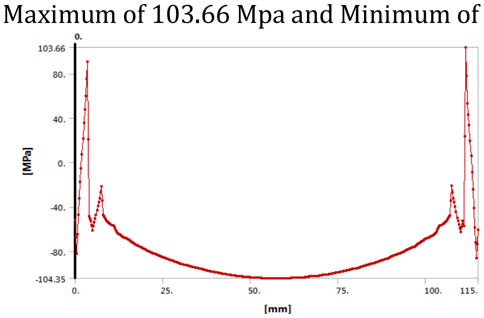

FIGURE 17.1
Model (C4) > Static Structural (C5) > Solution (C6) > Normal Stress x path duto welding path distance
The above graph shows along the weld path distance and obtained residual stress at the weld bed of the top edges shows the maximum residual Normal stress along x axis values are **103.66 Mpa**of the initial and final edge offset distance of 5mm.

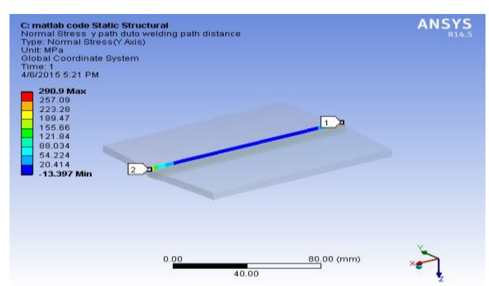

Figure18 residual Normal stress In Y- Axis having Maximum of 290.9 Mpa and Minimum of -13.397 Mpa

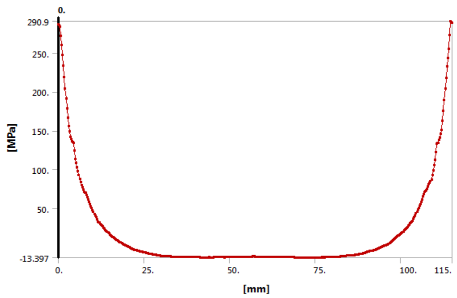

FIGURE 18.1
Model (C4) > Static Structural (C5) > Solution (C6) > Normal Stress y path duto welding path distance

The above graph shows along the weld path distance and obtained residual stress at the weld bed of the top edges shows the maximum residual Normal stress along y axis values are **290.9 Mpa**of the initial and final edge points.

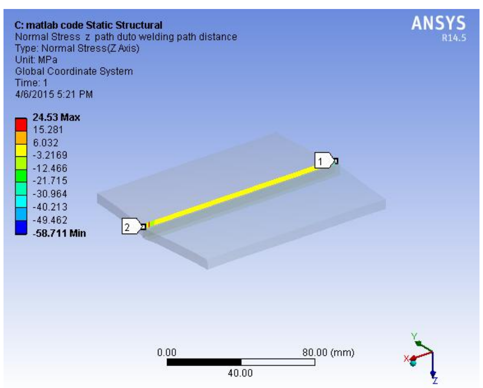

Figure 19 residual static structural Normal stress In Z-Axis having Maximum of 24.53 Mpa and Minimum of -58.711 Mpa

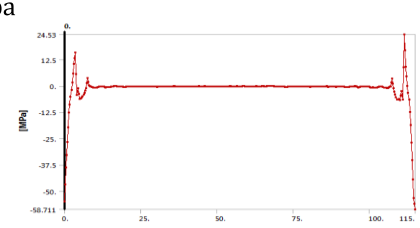

FIGURE 19.1 Model (C4) > Static Structural (C5) > Solution (C6) > Normal Stress z path duto welding path distance

The above graph shows along the weld path distance and obtained residual stress at the weld bed of the top edges shows the maximum residual Normal stress along z axis values are **24.53 Mpa**of the initial and final edge offset distance of 5mm

CONCLUSIONS

Conclusions this work presents the FE model for numerical simulation of welding residual stresses in high strength carbon steel butt welds.

The finite element method is an efficient technique in analyzing residual stresses in welding processes. A three-dimensional finite element welding simulation was carried out on a one-pass Manual Metal Arc Welding plain joint structure.

The welding simulation was considered as a sequential coupled thermostructural analysis and the element birth and death technique was employed for the simulation of filler metal deposition.

The finite element analysis results of the residual stress distributions of two butt welded plates in the axial directions are presented in Fig.5, Fig.6, and Fig.7 are Normal stress along x, y and z directions. Thus the values are 103.66 Mpa, 428.69 Mpa, and 98.47 Mpa the axial residual stresses calculated by the finite element method the maximum value obtained along y axis

The distribution of the residual stress in the weld zone of ASME steel, was determined using ANSYS finite element software. It is seen that the stress, in the direction of the width of test plate has highest influence on the formation of cold cracks.

In this study finite element analysis of residual stresses in two dissimilar plates was performed with the commercial software ANSYS. For computing residual stresses a sequentially coupled thermo-mechanical analysis conducted. In this analysis after temperature distribution and its history in the welding model, computed by the heat conduction analysis, the temperature history was employed as a thermal load in the subsequent mechanical analysis and longitudinal and transverse residual stresses obtained.

In graphs FIG 15.1 , FIG 16.1, FIG 17.1, FIG 18.1 and FIG 19.1, the distributions of longitudinal residual stresses were plotted vs. the distance from weld center line.

The instantaneous stress on the weld surface is 800–1000 MPa and below the weld is 500–600 MPa. This gradient is high near the fusion zone and this is one of the reasons for the formation of cracks in the fusion zone in high strength steels.

REFERENCES

1. M. SeyyedianChoobi, M. Haghpanahi and M. Sedighi, “Investigation of the effect of clamping on residual stress and distortion inbutt-welded plate,” Journal of ScientiaIranica Transaction B: Mechanical Engineering, vol. 17, no. 5, pp. 387-394, 2010.
2. X.K. Zhu, and Y.J. Chao, “Effect of temperature-dependent material properties on welding simulation,” Journal of Computers and Structures, vol. 80, pp. 967-976, 2002.
3. K. Deng and H. Murakawa, “Prediction of welding distortion and residual stress in a thin plate butt-welded joint,” Journal of Computational Material Science,vol. 43, pp. 353-365, 2008.
4. D. Deng, “FEM prediction of welding residual stress and distortion in carbon steel considering phase transformation effect,” Journal of Materials & Design, vol. 30, pp. 359-366, 2009.
5. E.M. Quresh, A.M. Malik and N.U. Dar, “Residual stress field due to varying tack welds orientation in circumferentially welded thin-walled cylinder,” Journal of Advance in Mechanical Engineering,vol. 2009, pp. 1-9, 2009.
6. Nguyen, N. T., Ohta, A., Matsuoka, K., Suzuki, N. and Maeda, Y. “Analytical solutions for transient temperature of semi-infinite body subjected to 3-D moving heat sources,” Welding Journal Research Supplement, pp. 265-274, 1999.
7. J. Goldak, A. Chakravarti and M. Bibby, “A new finite-element model for welding heat,” Journal of Metallurgical and Material, Transaction B,vol. 15, pp. 299-305, 1984.