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Thermo-Mechanical Simulation of Residual Stress Estimations in the Butt Welds using Finite Element Simulation

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ABSTRACT

Thermal Stresses plays important role in the engineering applications. Welding is one type of manufacturing process which finds wide usage in permanent assembly process which constitutes a thermal process by melting the region of joining and solidification after cooling. The joints are stronger compared to other joining process like soldiering, brazing etc. In the present work, the effect of heat flux is analysed on temperature generation and corresponding residual stresses after cooling process. Also analysed for the effect of thickness on the welding process. Further the effect of convection or cooling process on residual stress formation in the joint.

Keywords *– Submerged Arc Welding, High Strength Structural Steels, Newton Raphson methodology.*

1. INTRODUCTION

Welding is a process of joining similar or dissimilar metals by the application of heat with or without the application of pressure and addition of filler material. The result is a continuity of homogenous material of the composition and characteristics of two parts which are being joined together. The application of welding are so varied and extensive that it would be no exaggeration to say that there is no metal industry and there is no branch of engineering that does not make use of welding in one form or another. In fact, the future of any new metal may depend on how far it would lend itself to fabrication by welding. The type of welding under investigation is Submerged Arc Welding butt joint of Mild Steel. The specimen, which is to be welded, is having a thickness of 6mm for studies. Two weld plates each of 50mm length and 25mm breadth is to be joined by butt joint with the help of submerged Arc Welding. The diameter of the electrode considered is 6mm.

2. LITERATURE REVIEW

Residual stresses are stresses that remain after the original cause of the stresses has been removed. They remain along a cross section of the component, even without the external load. Residual stresses occur for a various reasons, including inelastic deformations and heat treatment. Heat from welding may create localized expansion, which is taken up during welding by either the molten metal or the placement of parts being welded. When the finished weldment cools, certain areas cool and contract more than others, leaving residual stresses. The stresses will vary through a stack of thin film materials can be very complex and can vary between compressive and tensile stresses from layer to layer. Over the past decades [1], High Strength Structural Steels (HSSS) have been used in many welded steel constructions and are facing the problem of hydrogen concentration and residual stresses.. In order to solve such failure cases, techniques are used to reduce hydrogen input, pre- and post-heating and heat input consideration. Certain techniques can be used to remove some critical factors, i.e. hydrogen concentration and susceptible microstructure, but the interaction of the thermal cycle with the components reaction in terms of stress build up has not been completely solved. The fatigue resistance of a welded joint [2] is inferior to that of base material. In low carbon steel the fatigue limit is 50% for butt joints and 15- 25% for lap joints. This phenomenon deals mainly with the combined effect of stress concentration, the higher the mechanical properties - the higher the level of harmful tensile residual stresses. One of the ways to increase the fatigue strength of welded structure is the application of improvement treatments of welded joints during fabrication, repairs and service life.

The effect of thermal properties and weld efficiency on residual stresses in welding [3] has been done using birth and death of elements to simulate the welding process. Cladding process, a thermal procedure is implemented through element birth and death through Newton Raphson methodology.

Measurement of Residual Stress Distributions in Welded Joints [4] has discussed about measurement techniques for residual stress measurement like X-Ray diffraction, Neutron diffraction etc. The data available on thick welds states that several characteristics of the residual stresses make their determination difficult to either numerically or experimentally.

Effect of residual stresses due to laser welding on the Stress Intensity Factors of adjacent crack [5] has discussed about welding deflections and crack growth rates. Many studies have indicated by experimental proof that the weld type residual stresses can significantly affect the fatigue crack growth rates in welded joints. The studies comprise analytical, two dimensional and three-dimensional numerical models predicting the effect of residual stresses field on the SIF (Stress Intensity Factor) values.

In the article, "Fatigue Life Evaluation of Welded Joints Based on Nominal Stress and Finite Element Analysis" [6] has discussed about stress relaxation in during the welding process and reheating process. Fatigue life evaluation methods of welded joints taking into account residual stress has been discussed with mathematical formulae. They used local strain approaches along with equations governing temperature and cooling rates.

3. RESULTS AND DISCUSSIONS

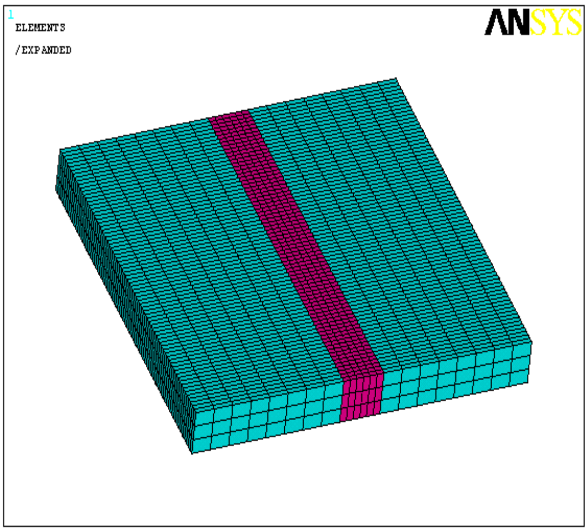
3.1 Methodology and FE Modeling

Geometry of the plate are considered as 50X100X6mm.The geometry is created using Ansys mixed approach and the geometry is split into 25 segments for virtual simulation of thermal welding process. The geometry is brick meshed with Solid70 element for better results.

3.2 Boundary Conditions

Both thermal and structural boundary conditions are applied to find the temperature distribution and structural stress estimations. Solid45 element is used for structural stress estimations. Components are created so as to apply heat on the particular surface during which other outer geometry is applied with convection process. Due symmetry insulation conditions are applied at the center. The analysis is carried out in the transient domain for applying heating cycle and cooling cycle. Further thickness of the plates is defined to find the effect on thermal and structural conditions.

Case 1: Results for Heat flux of 1e7 w/m^2.



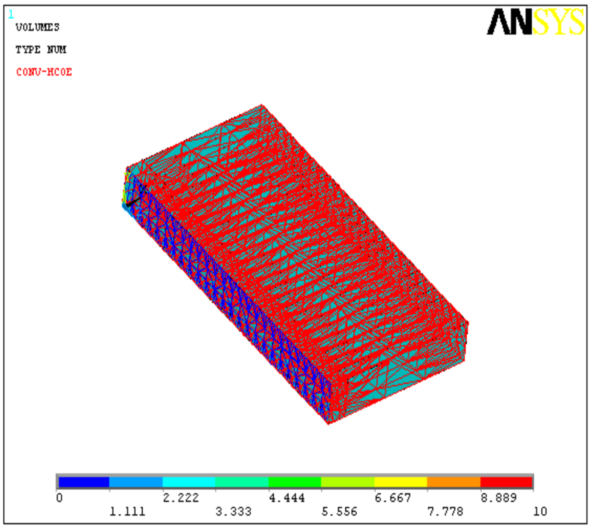


Fig 1: Mesh and Boundary Conditions.

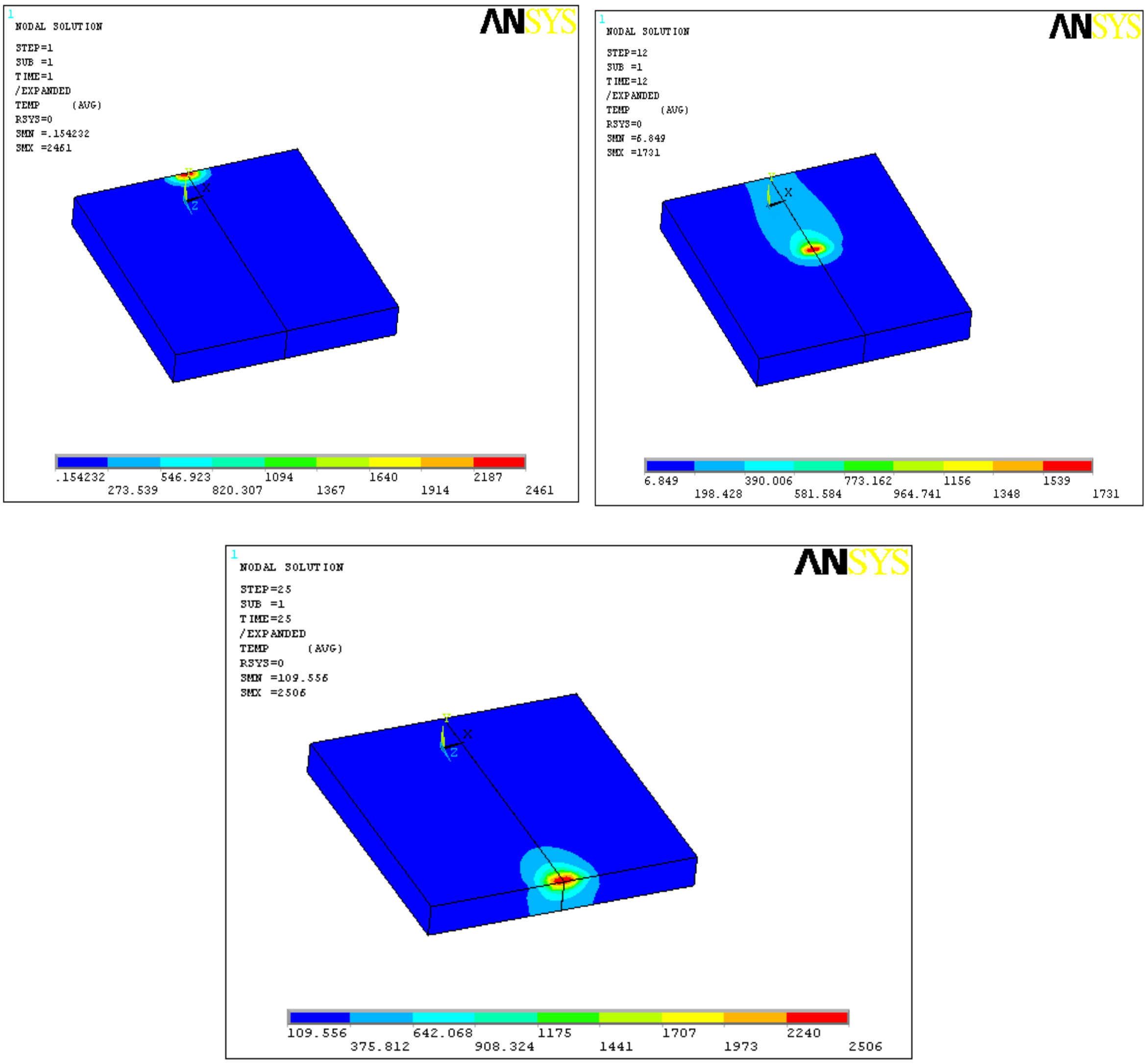


Fig 2: Temperature at Start, Middle and End due to Welding Process.

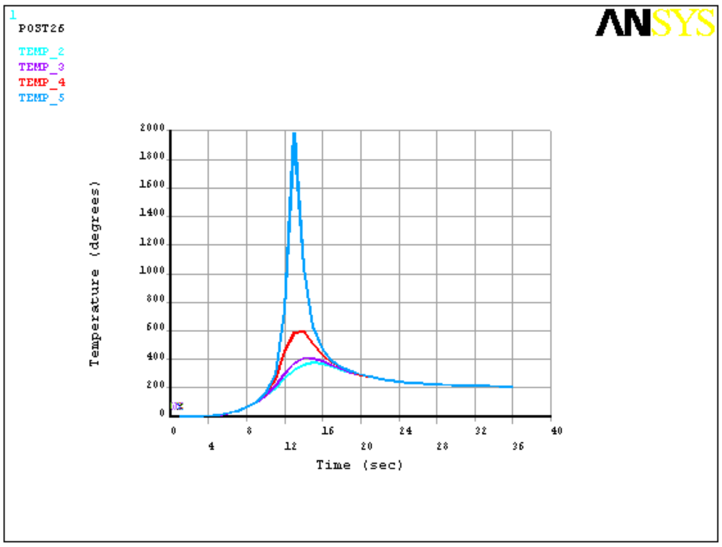


Fig 3: Temperature variation at the center during thermal process.

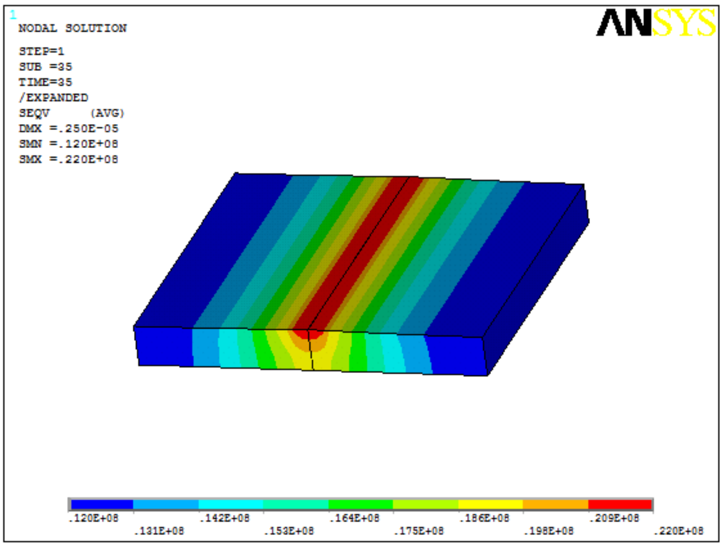


Fig 4: Structural Results for given Heat flux of 4e7w/m^2.

Heat Flux Input (w/m^2)	**Temperature (^{0}C)**	**Von-Mises Stress (Mpa)**
4e7	2506	22
4.5e7	2802	24.7
5e7	3106	27.5
5.5e7	3382	30.2

Table 1: Temperature and von-Mises Development with Different Heat Inputs.

Cooling Time (sec)	**Von-Mises Stress (Mpa)**
25	22
30	20
35	17.8
40	15.6

Table 2: Von-Mises Stress Development with Reference to Cooling Times.

4. CONCLUSION

The two plates to be joined are created using Ansys top approach and overlapped to create the connectivity between the members. Due to symmetry, only half the model is created and meshed using Solid70, a thermal element. The convection and heat flux are applied on the surface and load steps are represented. The results shows higher heat input is creating more stress. From the study, it can be observed that with 5.5e6 w/m^2 heat input, stress developed is 51Mpa and with 4e6 w/m^2 heat input, the stress is only 46Mpa. Totally 4 iterations are carried out to check the effect of heat flux on stress generation. The results shows a linear increase can be observed with the increase in heat flux. Similarly the weld cycle time effect is also studied which shows there is dependency of residual stress on total cycle time. The stresses are reducing with reduced weld cycle times. Even cooling rate on the surface is also having minor effect on reducing the residual stresses.

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