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Thermo-Mechanical Analysis of Effect of Weld Preparation on Residual Stress Formation Using Finite Element Analysis

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ABSTRACT

Welding is the major manufacturing process in engineering applications. Proper welding process helps in safety and longer life to the components. In the present work, finite element analysis has been carried out to find the residual stress formation due to various welding process. Edge weld, smooth weld, V-type weld and U-type weld analysis has been carried out to find the temperature distribution and residual stress formation. The variation of material properties has been considered for change the temperature.

Keywords *- Arc welding, Butt joint, weldment, Newton Raphson Method, Ansys.*

1. INTRODUCTION

The increased globalization of industry is accelerating the pace of product change. Shorter product development time with Excellency in functionality, quality and cost competitiveness is the order of the day. This trend is forcing the Design Engineers to respond with products that have increasingly lower costs, better quality and shorter development times.

Welding is a process of joining similar or dissimilar metals by the application of heat (fusion) 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 with small changes in strength.

The applications of welding are so varied and extensive. 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 adjusts to fabrication by welding.

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 formulas. They used local strain approaches along with equations governing temperature and cooling rates.

3. METHODOLOGY

Geometry of the plate are considered as 100X100X5mm, various weld geometries are created using Ansys Mixed approach. The geometry initially created in the two dimensional space and a final model is modeled in the three dimensional space. The structure is map meshed by splitting the geometry using work plane options. For two dimensional problems plane55 element is used for thermal simulation and Plane42 element for structural simulation. For the dimensional problem solid70 element for thermal and solid45 element for structural residual stress estimations. For all the configurations, same heat flux are applied to virtual simulate the problem in the coupled filed domain. The methodology is followed to reduce the solution time along with the intension obtaining better results.

The two plates of 100mm by 100mm size with 5mm thickness 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 thermal elements (plane55 and solid70).

Different approaches like weld edge formation smooth edge formation, V-shape and ‘U’ shape welds are analyzed for residual stresses. The convection and heat are applied on the surface and load steps are represented to simulate virtually using finite element software ‘Ansys’. The results of temperature at the end of loading process and temperature at the end of cooling process and resulting stresses are represented in the problem.

Von-Mises stress is also called as equivalent stress and represents failure stress for most of the ductile materials. So Von-Mises stress is captured for every result and a comparison is done for different process. Both two dimensional and three dimensional studies are carried out and results are represented (planar elements and brick elements).

Edge Weld Results:

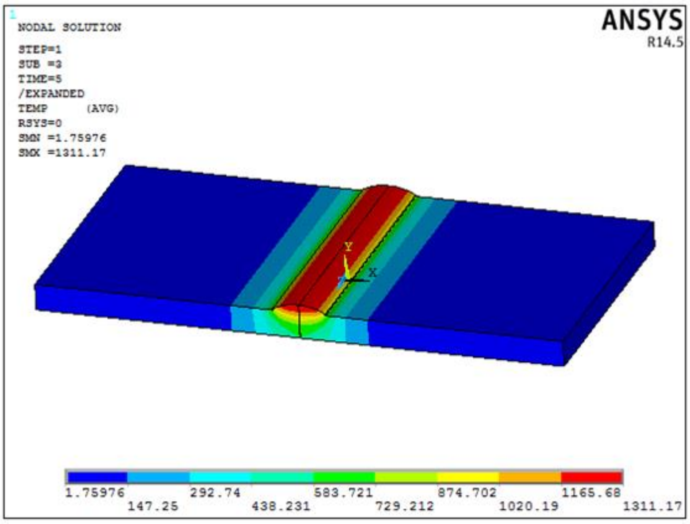

Fig 1: Temperature Distributions after Temperature Input.

The fig 1 shows temperature distribution on the butt joint and maximum temperature is around 1312.17^{0}C. Maximum temperature distributed at the center top region. This can be attributed to direct melting of filler material which is at high temperature. Remaining region is relatively at lesser temperature.

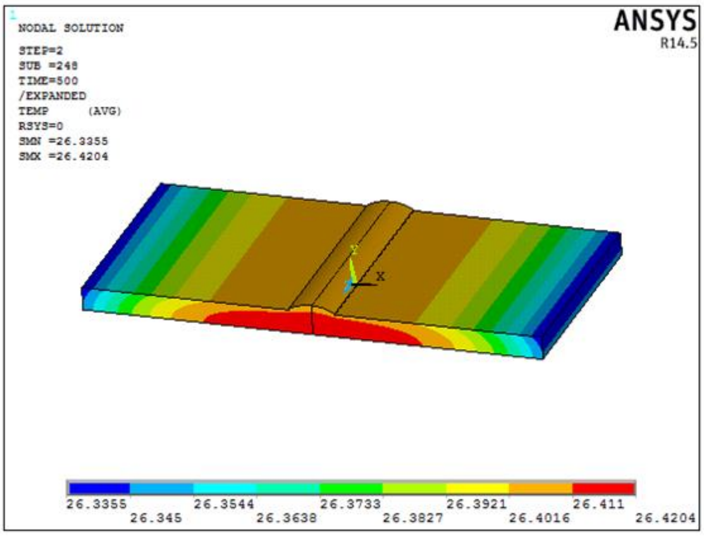

Fig 2: Final Temperature after Cooling for 500 sec.

The fig 2 shows, temperature distribution after 500 seconds. Constant cooling rate is provided for all the models. The final temperature is reaching to room temperature of 26^{0}C. The status bar represents variation of temperature with reference to colored bar.

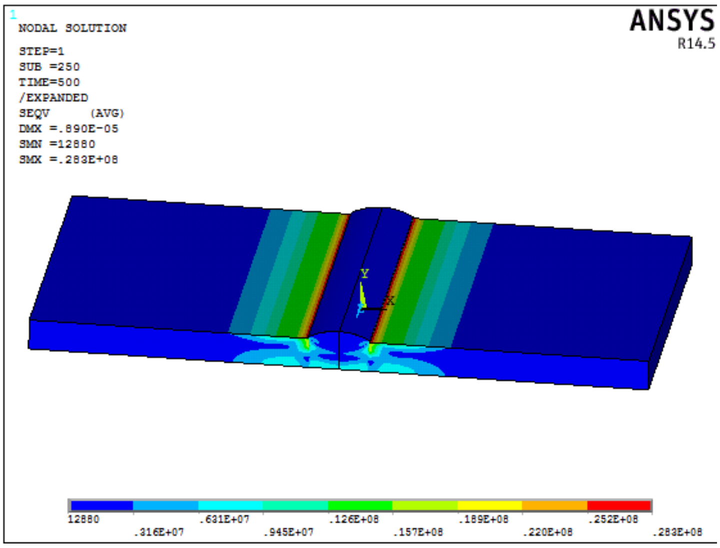

Fig 3: Final Residual Stress with Cooling Process.

The stress distribution is shown in the figure. The stress is concentrated at the edge region and the maximum value is around 28. 3Mpa the stress is retained mainly at the welding region shown by different color other than the blue color.

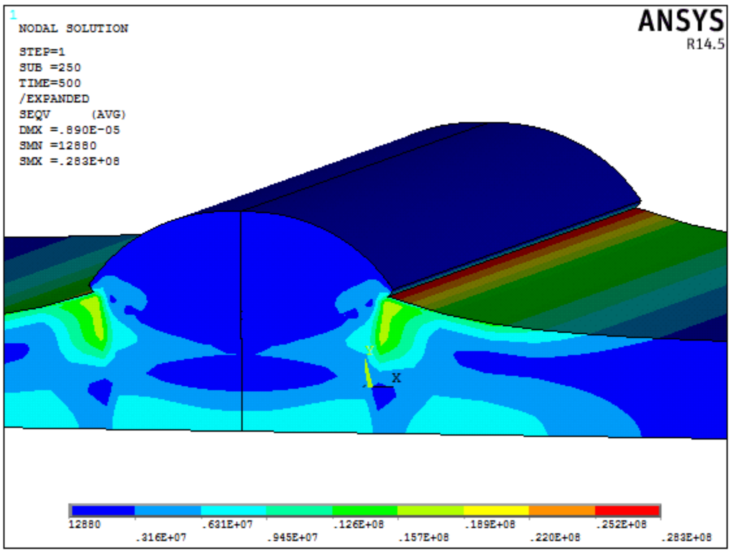

Fig 4: Stress Concentration with the Edge Weld.

Similarly other case has been carried out and results are as follows.

Method	Residual Stress (Mpa)
Edge Weld	28.3
Smooth Weld	19
V- Type Weld	17.3
U-Type Weld	15.1
3 Dimensional weld – Mild Steel	28
3 Dimensional weld – Mild Steel	36

Table 1: Results Comparison for Residual Stresses.

4. CONCLUSION

The results with steel and stainless shows higher stress with stainless steel. This can be mainly attributed to higher thermal expansion coefficient of the stainless steel (18e-6mm/^{0}c).

The results shows ‘U’ type weld has lesser residual stress formation compared to the other arrangements. This can be mainly attributed to higher surface area of distribution either during loading or cooling.

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