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Authentication in Welded Clad Plate with Similar Material and Thickness

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***Abstract*— This paper continues the research previously done by authors on numerical modelling of the dissimilar welded joints with varying clad thicknesses using a commercial finite element software. The current study simulates the welding conditions of a similar clad plate with a thin thickness. The computer simulated outcome then verified with the measured data of from other researchers. A close match between the numerical models and the experimental data was found.**

***Keywords*— FEA, stress analysis, clad plates, stress authentication, similar-dissimilar material**

I. Introduction

In authors previous papers [1-9] residual stress was introduced as the key advancement in the field of material joining and hybrid programming of material joining concentration technology. Among the various manufacturing methods, the welding a particular type of joining technique in dissimilar materials also poses a contributory factor in the formation of residual stresses within the metal structures. The gas metal arc welding (GMAW) method of joining dissimilar metal plates; stainless steel and mild steel; having different clad thicknesses was carried out in house. In parallel, stress profiles were obtained for the plates using a finite element (FE) modelling. The underlying theory behind this weld research is based on the Gaussian transformation principle and the consequently can be carried out without stretching the plane, folding or tearing it.

The numerical simulation of the similar welded joints with a certain thickness was carried out using Abaqus 2018 (Simulia, US). The computer model was verified using the measured data of from other researchers [3-8]. A close match found between the data obtained from the numerical simulation and those found from the experiment.

To enhance the quality of the study, the residual stress profiles obtained from current study, validated against existing ultrasonic data which was developed practically by other researchers and found close agreement between the outcome of the studies.

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For the surfaces of the plates, it was discovered that the transverse stress profile near the region of weld experienced perturbations and 'crown effects' of the stress whereas farther away towards the end of the plates, no perturbation exists, hence zero effect due to edge tack.

II. Computer simulation

A. *Specimen's geometry*

The below is a typical model of a 2D Plate showing the weld path across the length of a plate with dimension of 30mm by 20mm and thickness of 1mm. The weld axis line in the center of the plate (red line) has been highlighted in Figure 1. Seven welding stages was defined for the model to complete the welding of the plate across line of axis as shown in Figure 1.

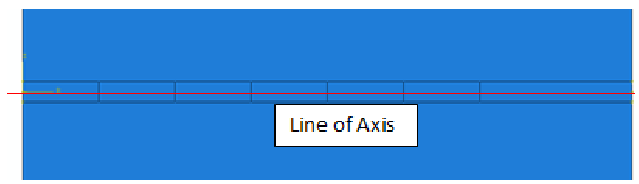

Figure 1. Weld line of a 2D plate model. Seven stage welding was defined for the model to complete the welding of the plate.

B. *FE Meshing*

A mesh convergence analysis was carried out to obtain an optimum element size and type for the model. A 2D stress elements were chosen from the element family, and quadratic elements were used to carry out the meshing in the plate, whereas an 8-node quadratic block was used for the plates. The meshing parameters employed in the stress analysis a stress specific in order to speed up the mapping of the nodal data and elements having same topology in order to improve the convergence during structural analysis. The creation of an element occurs at the solidification temperature, whereas the melting temperature (sink) or ambient temperature is that at which the thermal strains equal zero for thermal expansion coefficients of the base metals and filler metals. The hourglass control used in the meshing element is to enable a single point reduced integration scheme and to regulate convergence, hence preventing unnecessary locking while running the stress analysis in the finite element model.

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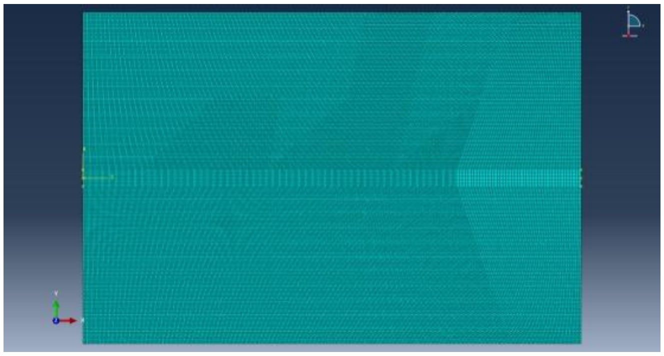

Figure 2. A 2D Plate showing a 4-node bilinear plane stress quadrilateral, reduced integration, hour glass control (CPS4R) was used to mesh the plate. The seeding of the welding stages was different with the seeding of the plate.

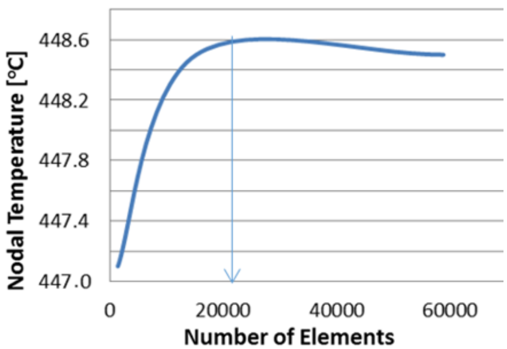

Figure 3. Mesh Convergences using a 2D Plate

A plane stress analysis method along with a linear geometric order was used to generate a total of 59,192 nodes and 58,695 linear quadratic elements of type CPS4R. A second model was created in 3D with lower cost meshing using linear hexahedral elements of type C3D8R having a total number of 14742 elements and 18256 number of nodes. Using a family mesh of 3D stress; the element library was standard and the geometric order set to linear. It was an 88-node linear brick with reduced integration and hourglass control.

C. *Boundary Conditions*

The distortion occurring in the model is accounted for by setting the initial strains to zero at the period of the activation of the element. For the structural analysis, certain conditions applied at the boundaries, which denote the effect of the clamping of the cylinders in place for the welding procedure. This implied that all the nodes at the end of the plate are fixed in the axial direction, as well as two other nodes being fixed and situated at 180 degrees from each other.

Specifically, a boundary conditions was applied at the top and bottom of the plate and likewise the 3D plate. Displacement and rotation were restricted in the X, Y and Z directions – that is displacement U1 = 0; U2= 0 and U3 = 0.

In order to obtain an accurate result, a Newton-Raphson iterative solution technique is utilized incorporating a sparse matrix solver for both thermal and stress analysis. The reason for the choice of the complete Newton-Raphson solver is its ability to incorporate a modified material properties table alongside a stiffness matrix which reformulates after each equilibrium iteration [1-13]. The typical nature of both stress and thermal models is that a huge quantity of temperature dependent data is utilized across the choice of material which changes rapidly during the course of the analysis. As such, the Newton-Raphson scheme generates correct results for the analysis output compared with initial-Newton-schemes or modified-Newton-schemes. For the different weld scenarios considered in this research, the emissivity values were taken to be 0.1 [3-8].

III. Modelling Results

A. *Axial Residual Stress*

Considering the residual stress along x-axis as depicted by the coordinate arrow in Figure4; the axial (longitudinal) stress across the length of the plate after second pass weld is shown in Figure 5. The results clearly show the maximum residual stress occurs at weld zone where the weld meet the parent place from both sides. Interestingly, the stress at the edges of parent plate are in tensile while in the centre of the welding zone the stress is in compression. It means the stress sign in the middle of the welding pass is negative and at the edges of the welding pass where it meets the parental plate are positive.

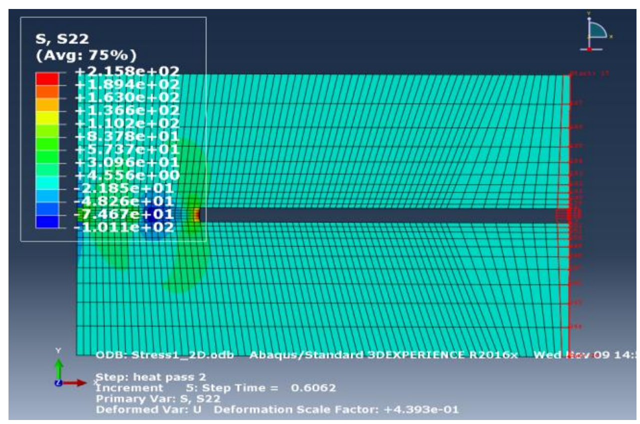

Figure 4. Stress distribution across the weld direction at heat pass 2

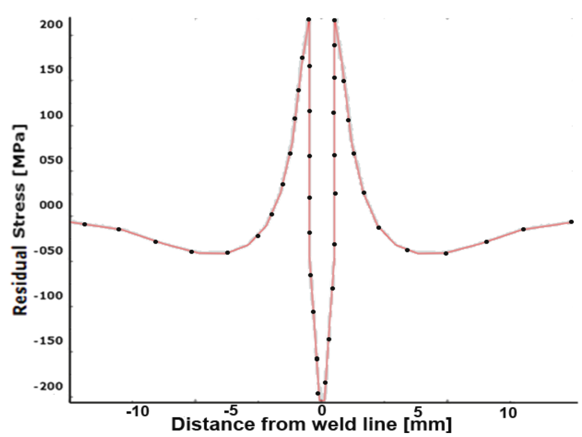

Figure 5. Residual stress at heat pass 2

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Figure 6 shows the stress distribution on the plate across the weld direction at heat pass 7. The graph clearly shows the maximum residual stress occurs at weld zone. Unlike weld pass 2 the stress remains constant and in tensile at weld zoon. The value of the stress immediately after weld pass 7 is lower than what obtained at weld pass 2.

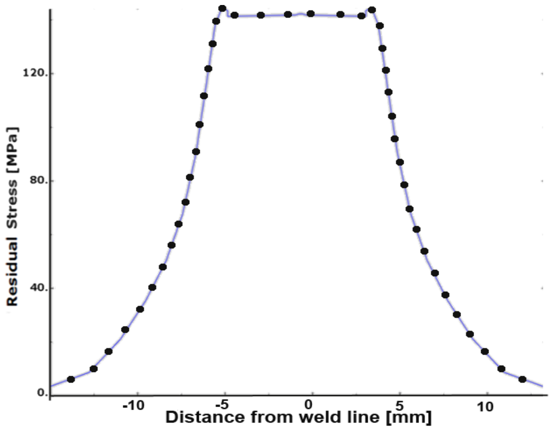

Figure 6. Residual stress at heat pass 7

B. *Validating residual Stress*

To validate the numerical simulation obtained in this study a comparison made with the work carried out by Sinha et. al. [11]. As a result of residual stress a deformation on the plate at the vicinity of the weld zone may appears which the size or appearance of the deformation has a link with the application of energy resulted from the welding heat. It also may appears as a result of a forces (energy) generated during welding process. This force could be sourced for compressive forces or pushing, torsion or bending forces and shear or even tensile forces responsible for pushing. It is cases strain on the specimen.

It is suspected that the displacement of these defects is triggered thermally, hence hindering the rate of atomic diffusion. For deformation to occur, intermolecular forces within an object or body resists such external forces. If the forces within is great, the body assumes a new state of equilibrium and returns back to its original shape. If the applied forces overcome the internal, deformation sets in [3-8].

Tensile stresses which are posiitve are seen in the 2D plate stress distribution in Figures 5 and 6. Compressive stresses in Figure 5 occur in the vicinity of the weld region, whereas farther away from it are the tensile stresses. The stress. There is no failure since the yield stress is not exceeded. Although when temperature rises, the yield stress is redueced, the value of the residual stress for the 2D plate is still within safe value.

The stress results obtained from experimental work and the simulated result have been compared in Figure 7. The simulated result has been computed with butt-welded plate done by Anderson, and Sheng and Sheng & Chen [3-8] results.

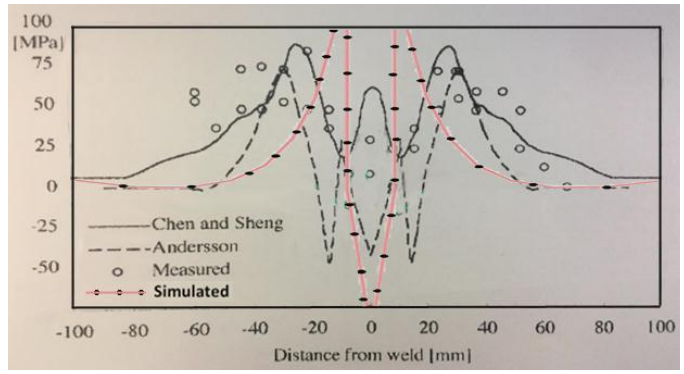

Figure 7. Transverse stress in a Butt-welded plate courtesy of Anderson Sheng and Chen [3-8] and measured transverse stress in a plate.

In order to validate the stress models obtained from simulation, the Anderson and Sheng and Cheng model of residual stress is used as a refernce. From Anderson and Sheng and Cheng model [3-8] of residual stress in a plate, the compressive stresses occur in the vicinity of the weld region whereas farther away from it are the tensile stresses. The maximum value of the tensile stress being 75 MPa and those of the compressive being 50 MPa. The straight lines are the transverse residual stresses simualted by Chen and Sheng, whereas the dotted curves represent those from Anderson's. The measured resisdual stress are those represented by tiny circles. The red-dot line in Figure 7 represents the residual stress simulated in the 2D. It is shaped in distribution like that of the Anderson stress in the sense that the compressive stresses below the weld crown are shaped like a 'W' whereas the tensile stresses above the weld crown are 'M' shaped. Secondly, the value of simulated stress compared with those found by Anderson's shows a difference. The difference in weld modelling parameters, dimension of geometry, and material property (such as yield strength, Young's Modulus) accounts for this difference in stress value. The dimesions of their plate is 100 mm in width compared to the dimension used in this research, 20 mm as depicted by the distance from weld. However, there is no failure since the yield stress of 357 MPa, is not exceeded. Although when the temperature rises, the yield stress is reduced and the value of the residual stress for the 2D plate is still within safe value. When comparing the results of Anderson, Sheng and Cheng with the residual in Figure 7, it can be seen that compressive stresses occur at the vicninty of the weld, whereas at a distance farther away from the weld region, tensile stress occur. This proves the validity of the simualated results.

C. *Summary*

From the results of the Transverse stresses the following can be deduced:

1. Transverse stresses are symmetric in nature as a result of the weld line symmetry
2. Higher values of tensile stresses are observed close to the fusion zone, whereas compressive stresses

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are seen both on the exterior and interior of the pipe away from the Heat Affected Zone (HAZ)

3. The circumferential position of the weld bead from the start of the weld to the finish directly affects the Hoop stresses and determines their distribution. In conclusion, volumetric change and yield strength which occurred under the tensile test curves as a result of martensitic transformation clearly has an effect on the welding residual stress, by increasing the magnitude of the residual stress in the weld zone, as well as changing its sign.

D. Conclusion

With the aid of residual stress and deformation experiments, the validity of the numerical stress models is verified. There is an agreeable similitude between the simulated outputs and those of other authors. The model can be used to predict the stress result on similar weld condition examples.

Acknowledgment

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About Author (s):

"The principle of the Gaussian flat surface having a zero Gaussian curvature at each point the surface of a cylinder is referred to as a Gaussian flat plane; revolved from a piece of paper.) Based on that, the four positions of interest on the pipe circumference can be represented onto the plate"

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