Temperature Distribution Analysis in Pulse Gas Metal Arc Welding Process

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Abstract—Welding is the most preferable joining process used in industries. In the arc welding process the thermal cycle leads to residual stresses and displacement. In this paper Gaussian heat distribution model has been used for temperature field analysis and used 5 mm thick AA 5083 plates for experiment model and derived a good agreement between them. The numerical simulation of welding process is complex and takes more computational time, several assumptions are typically used in simulation for simplifying the process and to save the computational time. The complex analysis carried out in two steps first is transient thermal analysis and second is mechanical analysis which, displays the residual stresses and displacement. In this work, thermal analysis with the help of ANSYS tool carried out for Single V, butt joint aluminium base metal (AA5083) using Pulse Gas metal arc welding (GMAW-P) process. In this work we are using Gaussian heat distribution models and temperature dependent material properties for the simulation of filler metal disposition. An experiment was carried out to measure temperature distribution during the single pass GMAW-P process used a k type thermocouple attached to the plate. The results of the experiment compared with finite element analysis to confirm the accuracy of finite element code. In this work moving heat source model develops in ANSYS APDL code for a good agreement between numerical method and experiment results.

Key words: Moving Distributed Heat Source, Transient Thermal Analysis, GMAW, and ANSYS APDL

I. INTRODUCTION

Welding is a most useful manufacturing process in a joining of a metal. Welding has been used in the fabrication, structures of engineering application like Aerospace, Pressure vessels, nuclear reactor, and Shipbuilding industry etc. Due to the nature of welding process involving localized heat generation from moving heat source, rapid heating in the welded structures, and subsequent rapid cooling, problems such as residual stresses and distortions of welded structures remain great challenges to welding practitioners, designers and modeler. The non-uniform heating and cooling cycle, which occurs in the weld and the adjacent base metal, is a distinctive feature of welding heat transfer. Finite element analysis of welding process is complex and computationally expensive as it involves various parameters like the non-linearity of material properties, a moving heat source, complicated boundary conditions and phase transformation effects.

Biswa et al. [1] Study on Elasto-plastic thermo mechanical model developed for predicting the thermal history and measure angular distortion in SMAW. Eagar T W et al. [2] they used the Gaussian heat distribution model and gives the information about the size and shape of weld pool with effect of process variability and material properties. Panwala et al. [3] used Tsai model for modeling heat input in Ansys APDL code and temperature curves obtained from analysis have been validated with experiment. Tailor et al. [4] used Gaussian heat distribution model for modeling heat input in the FORTRAN 95 code. Lindgren [5] provided a useful overview of different aspects of finite element analysis of welding process. Darlesson alves docarmo et al. [6] they study on the formulation of a 2D element with through the thickness parabolic temperature distribution.

II. EXPERIMENTS

The material of the plates selected for the experiments was aluminium-magnesium alloy (AA5083). Single V weld edge is prepared to make a butt joint between two plates having size 250 X 500 mm and 5 mm thickness Welding process selected for the experimental work was Pulse Gas Metal Arc Welding (GMAW-P). K type thermocouples were attached at the distance 25 mm, 50 mm, 100 mm, and 150 mm, away from the weld centerline. The schematic representation of thermocouple attachment for all specimens is shown in Fig. 1.

Fig. 1: Thermocouple location

Welding is executed with the help of approved welding procedure specification (WPS) & qualified welder. Details are given as below:

- Base Metal: As rolled AA5083 H116
- Filler Wire classification & diameter: ER5183, 1.2 mm
- Shielding gas: 99.995% Ar with flow rate: 20-25 LPM
- Welding technique: Single pass/ run multilayer
- Process: GMAW-P
- Welding power source: Fronius make TPS 4000
- Contact tube to work distance: 10-15 mm
- Current (I) =100 Amp
- Voltage (V) =16 volts
- Travel speed (TS) = 5 mm/sec
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Fig. 2: thermocouple attachment during welding

A. Moving Heat Source Model

In the present work consider as a circular disc model which is called as a Gaussian heat distribution model. A moving heat source model is developed to present the heat generated by the torch in the MIG welding process. In Gaussian distribution heat flux model only one constant to be inputted which is called as a heat distribution coefficient. These heat distribution coefficient is equal to half of weld bead width. Hence Gaussian heat distribution model calculate surface and body heat flux distribution as a heat input. The heat source distribution shown in Fig. 3 and heat input calculated below equation.

\[ q(r) = q(0)e^{-cr^2} \]  
\[ q(0) = \frac{Q}{2\pi c^2} \quad \text{and} \quad Q = \eta VI \]  

Fig. 3: Gaussian heat distribution model [8]

B. Thermal Model

The major heat generation source in arc welding is an electric arc. For a welding process the heat conduction through metal body is the major mode of heat transfer and heat convection is less efficient as far as temperature field in weld body is concerned. When a volume is bounded by an arbitrary surface, the differential equation governing heat conduction in a solid body is given by

\[ \nabla^2 T + \frac{\partial T}{\partial t} = \frac{Q}{\rho c} \]  

Fig. 4:Flow chart of Thermal Model Analysis

C. Material Properties

The material used in the present work is AA 5083. Its thermal properties are temperature dependent as shown in figure 5.

Fig. 5: Temperature dependent material properties [7]

D. Finite Element Analysis Model

In above experiments discuss two plates that are joined by a butt weld. The plate size consider as a 250 x 500 x 5 mm. Simulation is carried out of one weld geometry is 45° angle with single pass using commercially available finite element code in ANSYS. Material property of AA 5083 is taken from zhu x k et al. [7] for the simulation of temperature field. The welding parameter used for experiments is described in table 1. In present study two dimensional symmetric plate was designed to calculate the temperature distribution in the plate. In fig. 6 area divided in to the no of parts which derived the weld pool zone, heat affected zone, and rest of the plate for only conduction and after represent the finite element mesh, with refined meshes use at the weld pool zone. Two dimensional solid element PLANE 77 were employed in the model.

The convection boundary condition consider as an analysis and radiative boundary condition is neglected because of difficult phenomena and its effect very small. The convective boundary condition is applied on base metal surfaces which are given by following equation.

\[ \frac{\partial T}{\partial n} = h(T - T_e) \]
$$q = h_f (T - T_\infty)$$  \hspace{1cm} (2)

The amount of heat input divided into two loads, surface load and body load. In the present work we have used a body load which was given by using a finite element code by using ANSYS. For time step we measure actual welding time, this time divided by the node which are along with the weld centre line. And then this value is given on the every node.

E. Result and Discussion

Fig. 7-12 illustrate the temperature field of welded plate at t = 25, 49, 75, 100 and 1000 sec after the start of welding. These figures represent the transient temperature distribution when torch moves away from the start position. Also ellipsoidal temperature distribution shape observed at near the weld bead. The numerical simulations are carried out for heat input conditions as given in Table 1.

<table>
<thead>
<tr>
<th>Serial no</th>
<th>Voltage (v)</th>
<th>Current (amp)</th>
<th>Weld efficiency</th>
<th>Weld velocity (mm/sec)</th>
<th>Half of weld bead width (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>16</td>
<td>80</td>
<td>0.6</td>
<td>4.30</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>16</td>
<td>100</td>
<td>0.6</td>
<td>5</td>
<td>5.5</td>
</tr>
<tr>
<td>3</td>
<td>16</td>
<td>120</td>
<td>0.6</td>
<td>5.45</td>
<td>6</td>
</tr>
</tbody>
</table>

Table 1: Weld heat input data

F. Validation of Thermal Model

The temperature is measured at 25, 50, 100 mm away from the weld center line in experiment as shown in fig. 1. The numerical temperature profile is validated with the experiment result at location 25, 50, 100 mm in fig. 13-15. In this work we have taken heat input as I = 100 A and V = 18 v. Half of Weld bead width is taken as 5.5 mm which was measured by experiments.
III. CONCLUSION

Gaussian heat distribution model has been implemented in to FEM thermal simulation to predict welding temperature distribution. Numerical simulation value has been validate with experiments.

1) In above discussion numerical values of peak temperature is higher than the experiments values. The experiment results accurately and precisely within 3.84% to 10.19%. This error comes due to measurement inaccuracy during experiments, radiation neglected in this work.

2) Based on the above results from present analysis and heat input parametric studies for simulating welding induced residual stresses using a general purpose of finite element package.

IV. NOMENCLATURE

q (r) = Surface flux at radius r
q (0) = Maximum flux at the centre of the heat source
η = Arc efficiency
I = Arc current V = Arc voltage
C = Distribution of width coefficient.
r = radial distance from the centre of the heat source.

REFERENCES


