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A study on variation of shielding gas in GTA welding using finite element method

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Analysis and modelling

ABSTRACT

Purpose: Generally discrete alternate supply of shielding gas is a new technology which alternately supplies the different kinds of shielding gases in weld zone. In this study, welding characteristics under variation of alternate supply method of shielding gases in austenite stainless steel using a GTA welding process have been investigated and found the relationship between welding distortions and welding speed and different types of shielding gas and shielding gas supply.

Design/methodology/approach: 2-D axisymmetric heat and fluid mathematical model about welding arc and weld pool has been developed for verifying the effect of alternate supply of shielding gas. The developed models were solved using a general thermofluid-mechanics computer program, PHOEINCS code, which is based on SIMPLE algorithm.

Findings: The computed results showed that the developed computational models are very adequate to predict in the weld pool and bead geometry, and the technique of alternate supply of shielding gas should be useful to increase higher productivity, cost savings and better quality in arc welding.

Research limitations/implications: The effect of alternate supply of shielding gas should be useful to apply for a narrow -gap welding process.

Originality/value: The range of molten metal at the top of weld pool for supply of He shielding gas became wider than that for supply of Ar shielding gas. The developed computational models are very adequate to predict in the weld pool and bead geometry.

Keywords: Manufacturing and processing; Welding; Finite element method; Shielding gas

1. Introduction

The extensive use of the GTA welding in industry applications has been limited due to the difficulty for choosing the optimal process parameters. Until now, only limited information on optimum welding conditions was available in the related literatures [1-7]. In case of thin plate square-butt configuration, the GTA welding process is usually run autogenously without the addition of filler metal. Furthermore, these conditions which required multi-pass welding and inter-pass grinding may be significantly important related to joint complete times. Thus, despite the high quality of joints produced by a conventional GTA welding, it does not find wide application in the fabrication of thicker materials due to its poor productivity.

A alternate supply of shielding gas is a new technology that supplies the different kinds of shielding gases in weld zone discretely. Several researchers [8-12] reported a new technology capable of achieving better quality and high efficiency using the physical properties of welding arc which was produced by the periodical alternate supply of shielding gases in weld zone. Novikov et al. [8-10] suggested for the first time an advanced technology related to alternate supply of shielding gases in GMA(Gas Metal Arc) and GTA welding processes. They insisted that the defect incidence (porosity and crack) using alternate supply of Ar and He in 1420 and 1460 aluminum alloys have been decreased. Nsbarabokhin et al. [11] found the increased strength and improved ductility properties of welded joints of 1460 aluminum alloy has been carried out as alternate supply of Ar and He using the AC(alternate current) GTA welding machine. Yeo [12] has employed a low heat input by Ar shielding gas technique for first pass and a high heat input by He gas technique for second pass for joining the end plugs and cladding tube in order to avoid various types of weld defects, such as cracking, porosity, distortion. Furthermore, Nakamura et al. [13] reported a GMA welding process that periodically controls shielding gas composition, and a new welding torch that introduces locally and periodically CO_2 into Ar + 2%O_2 mixture to achieve high efficient welding were designed.

The purpose of this study is to investigate welding characteristics according to alternate supply of shielding gases in austenite stainless steel using a GTA welding process, and to find the variations in welding distortions and welding speed with different types of shielding gas and shielding gas supply. Finally, the comparison between the calculated and measured results has been carried out to verify the developed system.

2. Theoretical model

Fig.1. is shown a schematic diagram of the GTA welding process. The flow of welding current from Anode (base metal) to Cathode (tungsten electrode) causes the self-induced magnetic field and plasma arc force as shown in Fig.1. A plasma arc force acts as a distributed source of heat and electric current, impinges onto the base metal. This provides an incident flux of current and thermal energy at the free surface of the weld pool. The thermal energy generated in the arc causes the base metal to melt. Where the arc is maintained after the starting of arc, the supplied shielding gas is continuously ionized, and the ionized gas can be thought of as gaseous conductor, which allows the welding current to flow continuously. Mathematical model for weld pool has been developed to confirm the effect of alternate supply of shielding gas in the GTA welding. The governing equation aand boundary condition for the GTA welding process has been mentioned [14].

In order to enhance the accuracy of calculation in weld pool area and to reduce the time of analysis, grid of variable spacing were employed. Fine grids were utilized near the current source at the welding arc model and the heat source at the weld pool model, while further away from it, a relatively coarse grid was employed. Magnitude of weld pool zone was estimated as approximated 10mm. Numerical calculations for weld pool were performed for the STS304 stainless steel plate.

To numerically solve the governing equations with the associated source terms, a general thermo-fluid mechanics computer program, PHOENICS code was employed[15]. Convergence is completed when the spot values of temperature, pressure and velocities at the critical location remain uncharged(<0.1%) while the residuals of the governing equations continue to decrease. The residuals must generally decrease by at least 3 orders of magnitude with respect to the first sweep before the run is terminated. The time step used is 10^{-3} s. The number of sweeps needed material properties, fine turning of the relaxation parameters. The reference residual employed as a stopping criterion to determine when the calculations should advance to the next step, was assumed to be 10^{-9} for radial velocities, axial velocities, temperature and pressure.

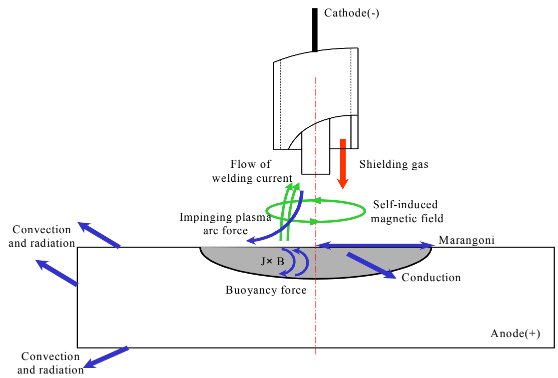

Fig. 1. A schematic diagram of the GTA welding process

3. Results and discussions

In order to analyze the alternate supply of Ar and He shielding gas, additional input conditions were employed as shown in Table 1. For the alternate supply of shielding gas, supply of shielding was assumed to change at 0.3s Ar into the He. The simulations at 0.5s has been carried out.

Fig.2. shows the temperature distributions for alternate supply of shielding gas. When He supplied at the end of the supply of Ar shielding, range of heat transfer the welding arc become wider than Ar shielding, but the heat intensity at the weldment surface is deeper because of the different physical characteristics of Ar and He induced the arc intensity. Fig.3. represents the variations of arc pressure on the weldment surface for Ar and He. Arc pressure distributions on the weldment surface are similar the Gaussian distribution. When the distance from electrode tip center increased, the arc pressure decreased in different types of gas. But, arc pressure of Ar is higher than He about 3 times due to the different input gas flow rate and ionization potential of shielding gas. These results can be shown that the periodic change of gas and arc pressure will be increased fluidity of weld pool and the reduction of surface tension of molten metal.

Table 1.
Input conditions employed in simulation

Gas supply	Frequency (Hz)	Gas flow rate (L/min)	CTWD (mm)	Wire feed rate (m/min)	Welding voltage (V)	Arc current (A)
Ar:He	5:5	16:4	15	7.5	12	140

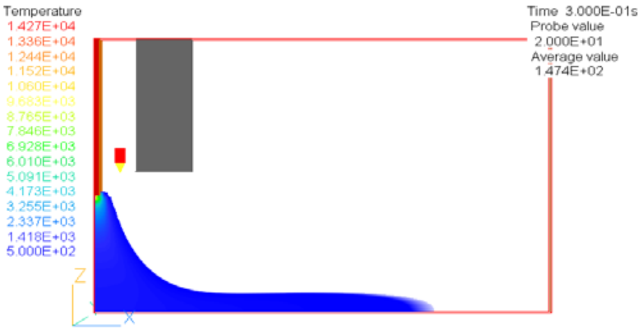

Fig. 2a. t = 0.30 sec

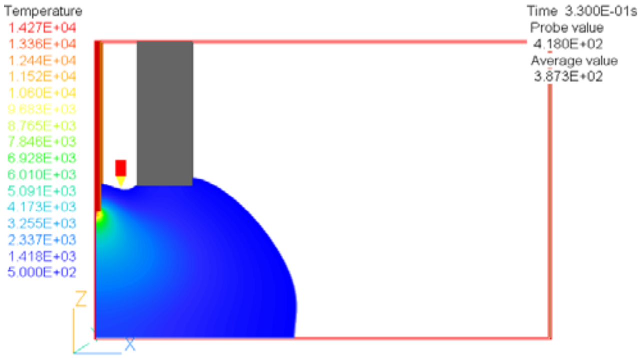

Fig. 2b. t = 0.33 sec

Fig. 2. Temperature distribution of Ar and He with alternate supply

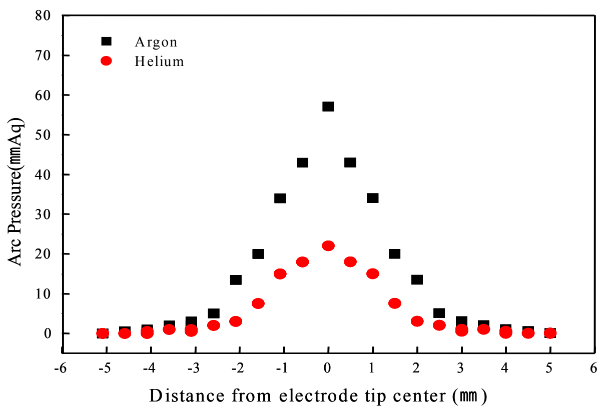

Fig. 3. The calculated results of the arc pressure on weldment surface for different types of shielding gas

The basic understanding of GTA welding process by a computational model requires the knowledge for the effect of various process parameters included type of shielding gas and interrelationship between process parameters and welding quality. In order to verify the developed mathematical models, the comparison between the calculated and measured results has been carried out. Experimental conditions were employed 200×100×12mm STS304 steel plates using the butt welding, and the types of gas and gas supply were chosen Ar + 67%He and alternate supply of Ar and He as a ratio of 5Hz.

Fig.4. shows comparison of the experimental and simulated results in a weld pool for the Ar + 67%He shielding gas. According to Fig.4., the bead geometry for alternate supply of Ar and He has bigger bead width and deeper bead penetration. It can be illustrated from Fig.4 that the developed computational models are very adequate to predict in the weld pool and bead geometry.

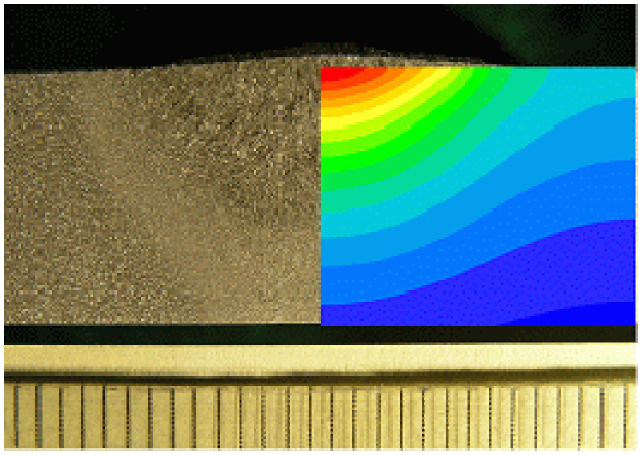

Fig. 4. Comparison of experimental and simulated results for Ar + 67% He shielding gas

4. Conclusions

The experimental and a numerical research to find an interrelationship between alternate supply of shielding gas and weld quality in a GTA welding process has been carried out to check out the welding characteristics according to the variation of alternate supply of shielding gas. A two-dimensional axisymmetric heat and fluid mathematical models for a welding arc and weld pool was developed to verify the effect of alternate supply of shielding gas. The computed results showed that the range of molten metal at the top of weld pool for supply of He shielding gas became wider than that for supply of Ar shielding gas. However, the arc pressure of supply of Ar shielding gas was higher than that of He shielding gas about three times. The comparison between the calculated and measured results has been performed in order to verify the developed mathematical models The calculated bead width and bead penetration are in good agreement with the experimental results with about 5% relative error. These results showed that the developed computational models are very adequate to predict in the weld pool and bead geometry. It is also concluded that the effect of alternate supply of shielding gas should be useful to apply for a narrow -gap welding process.

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