Title	Numerical Study of Stationary TIG Welding Process(Physics, Processes, Instruments & Measurements, INTERNATIONAL SYMPOSIUM OF JWRI 30TH ANNIVERSARY)
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Citation	Transactions of JWRI. 2003, 32(1), p. 33-34
Version Type	VoR
URL	https://doi.org/10.18910/11096
rights	
Note	

Numerical Study of Stationary TIG Welding Process †

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Abstract

The whole region of tungsten inert gas (TIG) arc welding, namely, tungsten cathode, arc plasma and weld pool is treated in a unified numerical model. Calculations have been made for stationary TIG welding in an argon atmosphere at a current of 150 A. The two-dimensional distribution of temperature and the geometry of the weld penetration is predicted.

KEY WORDS: (Numerical model) (Calculation) (TIG) (Welding) (Arc) (Electrode) (Weld pool)

1. Introduction

Modeling the arc welding process has been tried by a number of researchers[1-5]. However, almost every numerical model has treated either only the arc plasma[1)] or only the weld pool[2-4)]. The calculated predictions, for example for the weld pool, require distributions of heat flux and current density to be specified at the anode surface. Recently, modelling the combined arc plasma and the weld pool phenomena has been tried for the stationary welding[5)], but the calculated results of the arc plasma and the weld pool were made separately, without interaction between the plasma and the weld-pool.

In the present paper, we use a unified numerical model of a stationary TIG arc welding. The basic model and procedure is that of Sansonnens et al[6)], but expanded to include melting of the anode, with inclusion of convection effects in the weld pool. We give a prediction of the two-dimensional distribution of temperature in the whole region of the TIG welding process and its quantitative values of the energy balance for the various regions of the whole TIG welding process.

2. Arc Model and Calculation Results

The tungsten cathode, arc plasma and anode are described relative to cylindrical coordinates, assuming rotational symmetry around the arc axis. The governing equations, boundary conditions, assumptions and numerical method are given in Sansonnens et al[6)].

Figure 1 represents a two-dimensional distribution of temperature in the whole region of the stationary TIG welding. The maximum temperatures of tungsten cathode, arc plasma and weld pool are 3500 K at the tip of the cathode, 17000 K on the arc axis close to the cathode tip, and 2000 K at the center of the anode surface, respectively. In our model, we assumed that the anode was a stainless steel SUS304 and its melting point was 1750 K. **Figure 2** shows results for calculation of energy balances with quantitative values in the case of the same conditions as Fig. 1. Ohmic heatings of 47 W, 1183 W and 1 W occur in the cathode, arc plasma and anode, respectively. The ohmic heating in the arc plasma reaches 97 % of total heating in TIG arc welding. Most of the generated thermal energy by the ohmic heating in arc column is transferred to the cathode and anode, with the remaining energy disappearing as energy loss by radiation.

The energy loss by radiation and conduction from the arc plasma is 276 W and 5 W, respectively. The energy loss from the cathode consists of the thermionic emission of electrons 678 W, thermal conduction 33 W and radiation 47 W, and it balances against the energy input from the arc plasma by thermal conduction 478 W and ion flux 156 W. The energy loss from the anode consists of the conduction

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Transactions of JWRI is published by Joining and Welding Research Institute of Osaka University, Ibaraki, Osaka 567-0047, Japan

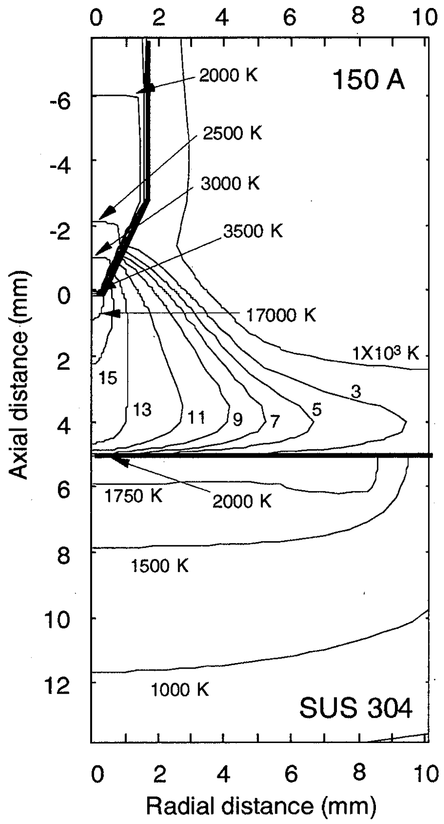

Fig. 1 Calculated temperature contours.

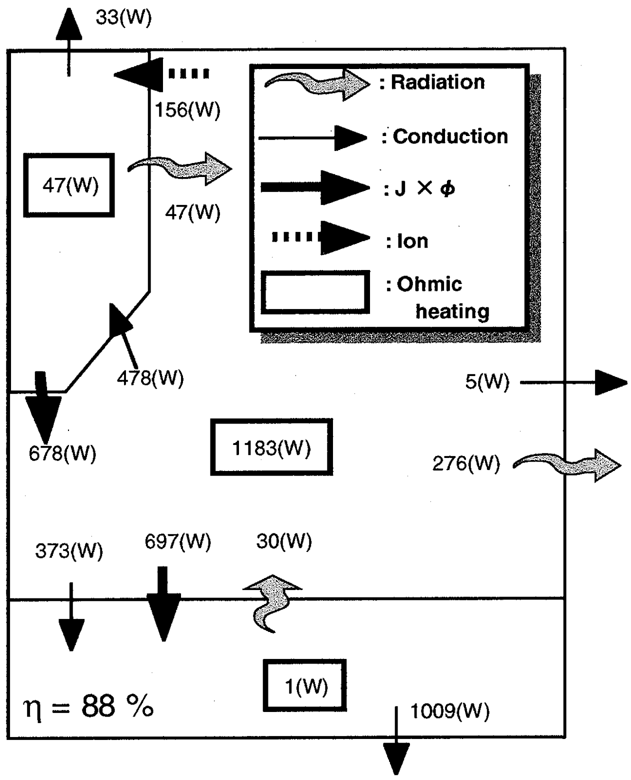

Fig. 2 Calculated quantitative values of energy balance for various plasma and electrode regions in Fig. 1.

copper boundary of 1009 W and radiation 30 W. This loss is balanced by energy input from the arc plasma which consists of the electron absorption at the anode surface 697 W and thermal conduction 373 W. The calculated arc efficiency for heating the anode is 88 %, which is in good agreement with previous measurements[7].

3. Conclusion

The whole region of TIG arc welding, namely, tungsten cathode, arc plasma and weld pool has been treated in a unified numerical model. The predicted two-dimensional distribution of temperature is shown, together with the predicted shape of the weld for a 150 A arc in argon. The quantitative energy balance is calculated between the various regions of TIG welding process.

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