

Physical characteristics of twin-wire indirect arc plasma



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ABSTRACT

In this study, the behavior of arc in a twin-wire indirect arc welding is simulated for arc lengths of 5.2 mm, 6.2 mm and 7.2 mm. The plasma temperature is measured by spectrometric method. The results showed that increase in arc length increase the arc parameters (plasma temperature, current density, plasma velocity, heat flux and arc voltage) of twin-wire indirect arc (TWIA). The change in arc length was found to have little influence on the distribution and the variation in trend of arc parameters in the whole arc region. As the arc length increases, the arc parameters in cathode region increase at a slower rate than those of anode region. This probably is the reason for self-adjustment of TWIA and for the arc stability in a certain range of arc lengths. The temperature of anode region is slightly higher than that in the cathode region and other arc parameters have similar trends. The isotherms are displaced toward the anode side and the shape of TWIA is similar to an inclined and inverted bell. The displacement increases with increasing arc length. The experimental results of plasma temperatures are in good agreement with calculated results which verifies the accuracy of the calculated results.

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1. Introduction

With the development of welding technology, the production efficiency of arc welding and the welding quality have improved, the scope of application of welding is broadened and this subject now is an intense area of research. Traditional welding methods are limited in application to low base metal melting rate and high wire melting rate. So a novel technology to redistribute the energy between welding wires and the base metal is necessary. Argon shielded twin-wire indirect arc welding is a novel method with twin wires connected to negative and positive electrodes of the direct current power source and base metal as an independent unit, as is shown in Fig. 1. The TWIA welding has low base metal melting rate and high welding wire melting rate and can be used for special applications [1].

The matching of wire melting and feeding rates is necessary for stability of TWIA [2]. In their previous studies the authors found that melting rate of the wires can be made self-adjusting according to the length of arc. As most of the energy is used for the melting wires, this novel welding technology has high melting rate and welding efficiency, low welding deformation and penetration ratio and low penetration depth of weld joint. So this welding technology can achieve a high welding efficiency and have a wide

developmental foreground. In TWIA welding process, the characteristics of arc have an important effect on the welding parameters, such as heat input, deposition coefficient etc. However, this study placed a focus on the characteristics with different arc lengths of TWIA. Understanding the nature of TWIA is essential to make practical use of this novel welding technology.

Understanding of the TWIA requires simultaneous solutions to a set of conservation equations for mass, momentum, energy and current. The solutions of the conservation equations are presented for the TWIA excluding the cathode and anode. Calculated temperature in the arc region is compared with the spectrometric measurements. It should be noted that the arc length of TWIA changes during the welding process, arc length (the distance between the centers of cathode and anode surfaces) is an important factor

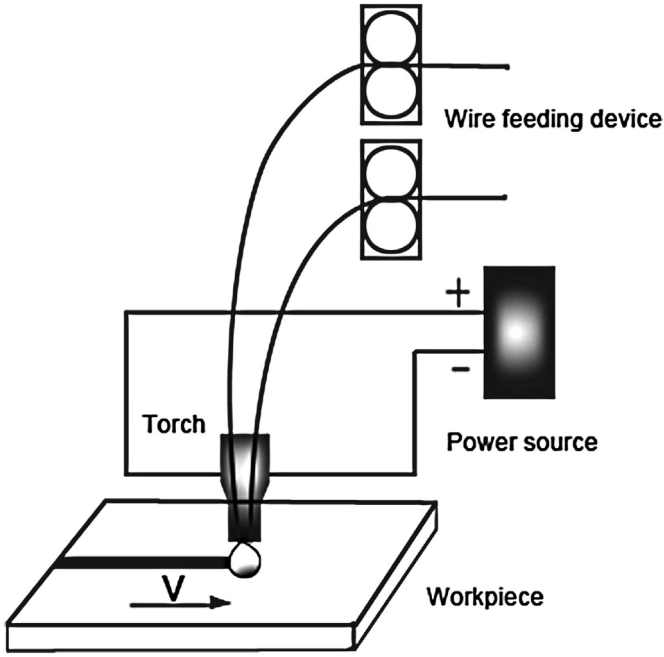


Fig. 1. Schematic diagram of TWIA welding.

of simulation technology, the model for welding arc are mainly 2D [4] model or 3D [5] model. Researchers are mainly focus on TIG welding arc and plasma arc which the arc is axial symmetry. The shape of TIG welding arc and plasma arc are typically a bell shaped. Some researchers establish unified model of arc and weld pool, and study the interaction between them [6]. Recently researchers modeling the arc of gas metal arc welding and established the unified model for arc, droplet and weld pool [7], this is an important direction of welding arc simulation. TWIA is not axial symmetry, but has symmetry about the plane which contains the central axis of cathode and anode. The studies on the arc behavior for different arc lengths of TWIA are still limited. However, this study placed a focus on the characteristics of TWIA with different arc lengths.

2.2. Assumptions

The model proposed for this study is based on the following assumptions [8]:

- (1) The arc is in a local thermodynamic equilibrium (LTE).
- (2) The arc is steady, the flow is laminar, and the plasma is optically thin and incompressible.
- (3) The droplet formed by melting feed wire is negligible in size and the surfaces of the cathode and anode are flat.
- (4) Gravity and heat dissipation due to viscosity effects are negligible.

2.3. Conservation equations

Based on these assumptions, the conservation equations can be written as:

Mass conservation equation:

$$\frac{\partial \rho}{\partial t} + \nabla(\rho v) = 0 \quad (1)$$

Momentum conservation equation:

$$\rho \frac{dv}{dt} = -\nabla p + \mu \nabla^2 + J \times B \quad (2)$$

Energy conservation equation:

$$\rho \frac{dH}{dt} = \frac{d\rho}{dt} + \nabla \cdot \left(\frac{k}{C_p} \nabla H \right) + \Phi - S_R + \frac{J^2}{\sigma} \quad (3)$$

In these equations, ρ , v , p , μ , H , C_p , K , S_R , Φ , B , σ , and J are the mass density, the velocity vector, the pressure, the viscosity coefficient, the enthalpy, the specific heat capacity, the thermal conductivity, the radiation flux density, the power dissipation, the magnetic induction strength, the electric conductivity, and the current density, respectively.

Current continuity equation:

$$\nabla \times J = 0 \quad (4)$$

Ohm's Law:

$$J = -\sigma \nabla \phi \quad (5)$$

Ampere's law:

$$\nabla \times B = \mu_0 J \quad (6)$$

In these equations, J is the current density, ϕ is the electrical potential and μ_0 is the permeability of vacuum.

2.4. Boundary conditions

TWIA is not axial symmetry, but has symmetry about the plane which contains the central axis of cathode and anode. So half model is established and the calculation domains for this analysis are shown in Fig. 2. Fig. 2(a) is the schematic of three dimension model for the TWIA and Fig. 2(b) is the schematic of symmetry plane (ABCD). The angle between the twin wires can be adjusted in welding process, in previous experiments, it to be found that the angle between twin wires between 20 and 40°, the TWIA burning stably and can achieve satisfied welding quality. The experimental results of different angle between twin wires are mentioned in a Ph.D. Thesis named "Study on arc characteristics and metal transfer of twin-wire indirect arc welding" write by Shunshan Zhang who is graduated from our laboratory.

The changing of the angles between twin wires not

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