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Modeling of temperature distribution with metal vapour in pulsed TIG including influence of radiative absorption†

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1. Introduction

Most reports to date have addressed the case of a constant arc current. However, pulsed arc currents are widely used in high-speed welding, and in general to control the heat input and droplet transfer in arc welding. In the case of TIG welding, in which the electrode rod does not melt and no droplet transfer occurs, pulsed currents are used to control the heat input to the arc and weld pool, and to facilitate high-speed welding. There are few if any cases in which the time variation of the metal vapour distribution has been discussed for pulsed TIG welding. It is important to understand the time dependence of the metal vapour distribution, since the mixing of metal vapour with the shielding gas affects fundamental properties such as the arc temperature and the radiative emission. Furthermore, because the self-absorption of the radiation strongly influences the arc temperature and the heat transfer to the weld pool [1]-[4], it is necessary to take into account the self-absorption of the arc radiation.

In this paper, the time dependence of the distribution of temperature with vapour from the anode is analyzed using an electromagnetohydrodynamic simulation that includes the influence of self-absorption of radiation. Iron is the main component of stainless steel, which is often welded using TIG welding. Using plasma thermophysical data that take into account the iron vapour concentration, the effects to the temperature distribution are investigated, with the influence of self-absorption included.

2. Method of Calculation

Electromagnetohydrodynamic simulations of arcs are performed using a two-dimensional cylindrical coordinate system. However, it is difficult to treat radiative transfer in the cylindrical coordinate system, because the circular grid does not conform to the linear propagation paths of light. To solve this problem, a three-dimensional Cartesian coordinate system is introduced to calculate the radiation power distribution while considering self-absorption. A two-dimensional axisymmetric cylindrical coordinate system is used for all other aspects of the electromagnetohydrodynamic model. It is also important to note that the iron vapour concentration, the arc temperature and the radiative properties of the arc all affect each other.

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Electromagnetohydrodynamic model. Absorption is calculated only within the control volume in which emission occurs, and depends only on the temperature and the radial dimension of the control volume (the absorption length). In the full self-absorption model case, the calculation domain is divided into a three-dimensional Cartesian grid. Incident radiation entering a control volume from all three adjacent control volumes is considered. The flux of incident radiation from each direction is normalized to the area of the interface relative to the control volume’s total surface area. With each passage through the control volume, the incident radiation intensity decreases because of self-absorption and increases according to the influence of the radiative emission from within the control volume.

3. Temperature Distribution with Changing Current Including Influence of Self-absorption

Figure 1 and 2 show the distribution of the arc temperature and radiation, for the simple model that takes account of one control volume and directions, and full self-absorption model that takes account of all three adjacent control volumes and directions.

The results show that the iron vapour diffuses upwards toward the cathode at the time of the peak-to-base current transition. Furthermore, it diffuses during the period in which the base current is constant. The concentration near the anode is low. At the time of the base-to-peak current transition, the increase in the downward convective flow in the arc, driven by the magnetic pinch force, causes the iron vapour to be transported in the direction of the anode. This continues during the period in which the peak current is constant.

When self-absorption is considered, its effects are expected to be more pronounced in the low-temperature region than in the high-temperature region. Therefore, the absorption is greatest at locations where a large amount of metal vapour is present at low temperatures. This corresponds to the regions in the periphery of the arc near the anode, and it is therefore these regions whose temperature is increased. The temperature gradient is also important; a high gradient favours localized absorption, since low-temperature absorbing regions are closer to high-temperature emitting regions.

4. Conclusions

A time-dependent electromagnetohydrodynamic simulation of pulsed TIG arc welding was performed, with the electrodes and arc included in the computational domain. The distribution of temperature with vapour generated from the anode was calculated, using...
thermophysical properties that take into account the iron vapour concentration. The influence of self-absorption of radiation was calculated using a Cartesian grid, allowing radiation from all three adjacent control volumes and directions to be taken into account. Arc temperature distribution was calculated self-consistently.

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References