Numerical Simulation of a 3-D Transient GMA Weld Pool

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Introduction

Gas metal arc (GMA) welding is one of the most widely-used welding processes in industries because of its high productivity and process robustness. However, it is difficult to simulate GMA welding process, mainly due to the addition of filler metal material impact and the large flow and temperature gradients associated with this process. It has been realized that a better understanding of droplet impact effects on weld heat flow and fluid flow is critical to determine welding procedures and to predict weld profiles.

Thus far, the existing GMAW modeling attempts are either 2-D models with stationary arc, or 3-D models without realistic droplet involvement. Therefore, it is difficult to use these kinds of models to predict weld profiles.

Model Description

In this work, a 3-D transient numerical model is presented for GMA weld pool with free surface and droplet impact. This effort predicts a moving GMA weld pool by considering not only the heat transfer and fluid flow with surface tension, electromagnetic force, and buoyancy, but also detailed information about droplet flow effects on weld pool, weld pool solidification and weld bead shape.

The governing equations, including continuity, momentum, and energy equations, are discretized using the control volume method. The regular rectangle meshes are used in the whole domain, and volume of fraction (VOF) method is employed to treat free surfaces. The Gaussian-distributed arc heat and droplet heat content are included as heat input in the pool. Convection, radiation, and evaporation are incorporated as thermal boundary conditions. Both droplet travel speed and arc pressure are involved to determine fluid flow field and free surfaces. Furthermore, latent heat of fusion is considered in the model.

Result and Discussion

Simulations are carried out for the steel material with 1.6 mm diameter electrode and 6mm thick plate. The globular and spray metal transfer modes are selected in the simulation. Effects of droplet size and speed on weld pool shapes are analyzed. It is indicated that larger and slower droplets tend to produce shallower penetration. Bigger droplets and slower torch travel speeds generate higher weld reinforcement. Simulated results of temperature distribution and fluid flow field are shown in the figure 1.

Surface tension effects on weld pool shapes are also obtained. It shows that the larger surface tension coefficient, the higher weld reinforcement. The fluid flow patterns are no longer dominated by surface tension gradient force. They are controlled primarily by droplet incoming velocity. So fluid in GMA weld pool flows inward and downward, which produces a deeper penetration.

Simulations are conducted on both bead-on-plate and T-fillet welds with different weld positions. This demonstrates that the model is capable of simulating real-life situations in productions. Experimental measurements have been performed to validate the model. A good agreement has been achieved between calculation and measurement.

Conclusion

A 3-D transient numerical model is proposed to simulate heat and fluid flows in a moving GMA weld pool. The model is capable of simulating bead-on-plate and T-fillet joints with different weld positions. It is able to predict not only the pool shapes, but also the weld bead profile. It is found that droplet involvement increases weld penetration and forces fluid to flow inward and downward. Higher surface tension coefficient gives higher weld reinforcement.

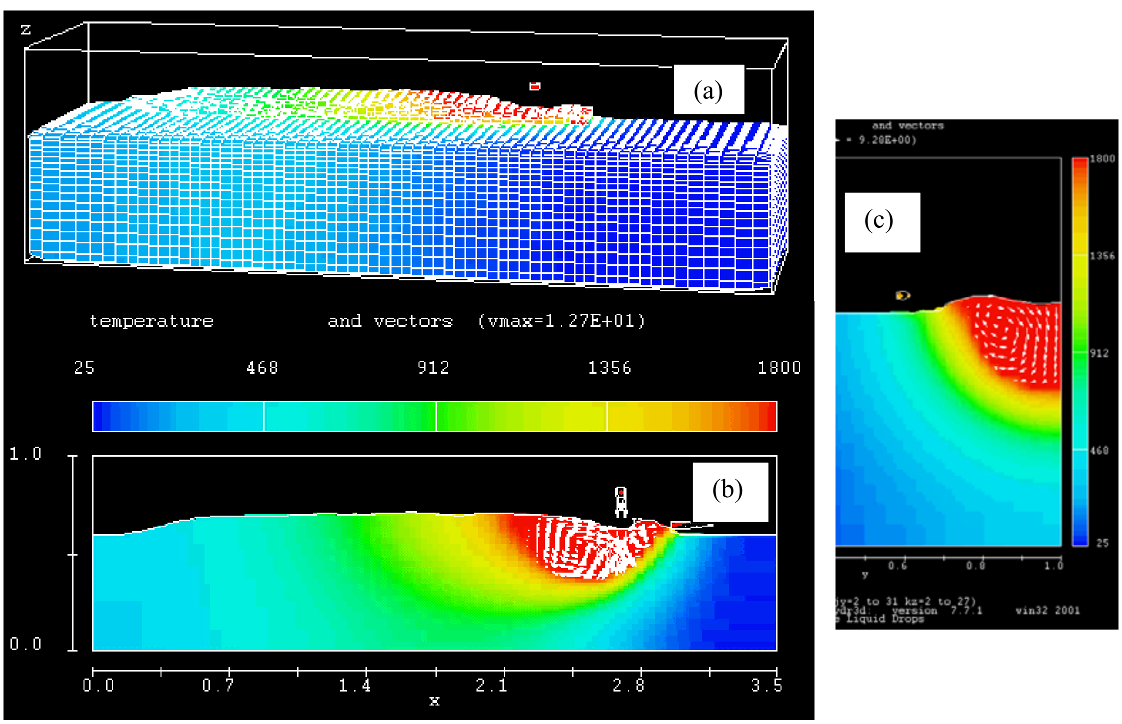

Figure 1 Simulated temperature distribution and fluid flow field during GMA welding: (a) 3D view; (b) longitudinal cross section; (c) transverse cross section