Particle simulation of metal transfer using inertia force in gas metal arc welding

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Abstract: Numerical simulation was conducted to clarify the mechanism of the metal transfer phenomena using inertia force by a wire feed control process in gas metal arc welding. As a result, one droplet per swing, as in the actual welding was successfully simulated. Moreover, it was suggested that the velocity difference between molten metal and solid wire was necessary to achieve the metal transfer.

1. Introduction

Gas Metal Arc Welding (GMAW) is an arc welding process that uses metal wire as an electrode and is used in various manufacturing applications. This process involves a series of metal transfer phenomena in which molten metal forms droplets at the tip of the wire and they are eventually detached from it and transported through the arc plasma to the molten pool. Depending on metal transfer mode, spatters are generated and adhere to the surrounding area. In such cases, the spatters should be peeled off, resulting in higher manufacturing costs. Therefore, various methods have been developed to suppress the generation of spatter [1,2]. Recently, GMAW using a wire feed control process incorporating inertia force generated by changing the wire feed direction and speed over time as a droplet control factor developed [3]. Compared with the conventional wire feed control process, this process enables low amount of spatter and fume over a wide range of conditions from low to high currents. It also allows high deposition and high-speed welding while maintaining deep penetration. However, the mechanism of how the inertia force created by this wire feed control process affects the droplet transfer morphology and the achievement of droplet detachment is still unclear. Therefore, the purpose of this study is to clarify the mechanism of the metal transfer phenomena using inertia force by numerical simulation.

2. Computational Method

A hybrid model using smoothed particle hydrodynamics (SPH) method [4] and grid-based model [5] is developed to simulate arc behavior and molten metal behavior with phase change and large deformation. The velocity of molten metal is determined by the Navier-Stokes equation, which considers Lorentz force, arc pressure, shearing force caused by plasma flow, Marangoni effect, and surface tension force in the normal direction. The temperature of all particles is determined by the energy transfer equation, which considers Joule heating and energy balance on the anode surface. Arc plasma behavior is simulated by an magnetohydrodynamic (MHD) model assuming a 2D axisymmetric and steady state.

In the particle simulation, a 25 mm long wire that consists of particles with a diameter of 0.1 mm, for which the material properties of mild steel are given, is used to simulate the shapes of the wire and the molten metal are passed to the MHD simulation. The MHD simulation calculates the wire-arc-base metal and passes the physical quantities in the computational domain to the particle simulation. In this simulation, the shielding gas was pure CO_2, the gas flow rate was set to 20 L/min.

3. Results and Discussion

Figure 1 shows the velocity distribution in the *z* direction in the longitudinal section along the central axis of the wire. The hybrid model developed in this study simulated one droplet per swing, as in the actual welding. At t = 7.6 ms, the velocity difference is confirmed between the molten metal below about z = 8 mm and the solid wire above it. It is suggested that the formed neck grows by this velocity difference, leading to the detachment of the droplet.

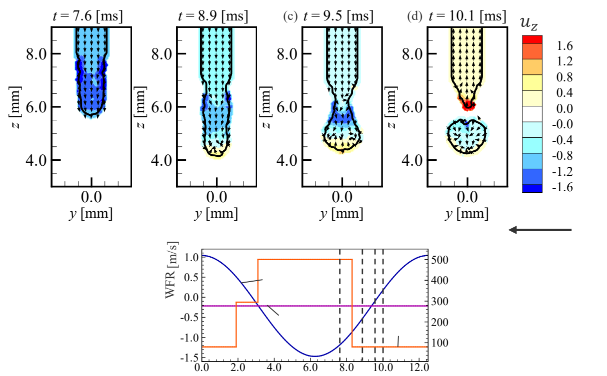

Fig. 1. Velocity distribution in the *z* direction in the longitudinal section along the central axis of the wire.

4. Summary

In this study, numerical simulation was conducted by the hybrid model using SPH method and grid-based model to simulate metal transfer using the inertia force by a wire feed control process in GMAW. As a result, one droplet per swing, as in the actual process was successfully simulated. Moreover, it was suggested that the velocity difference between molten metal and solid wire was necessary to achieve one droplet per swing.

References

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