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Modeling of molten pool flow simulation for Zr tube GTAW process

Dae Won Cho[a*], Tae Hyung Na[b]
[a]*Korea Institute of Machinery and Materials, Busan, Republic of Korea*
[a]*KEPCO Nuclear Fuel Co. ltd, Daejeon, Republic of Korea*

[*]*Corresponding author: dwcho@kimm.re.kr*

1. Introduction

Fabrication process of nuclear fuel is normally conducted by welding technology. Until now, many researchers optimized the welding conditions by experiment without considering the physical phenomena for the molten pool flow patterns in Zr tube gas tungsten arc welding (GTAW) process. Therefore, it is required to consume lots of time as well as materials cost to optimize the welding conditions for GTAW process. This research firstly makes the computational fluid dynamics (CFD) models to analyze the molten pool flow patterns for Zr tube GTAW and validates various models by comparing the experimental result.

2. Simulation models

In this section, several simulation models for CFD are described to analyze Zr tube GTAW molten pool flow patterns.

2.1 Material shape and mesh size

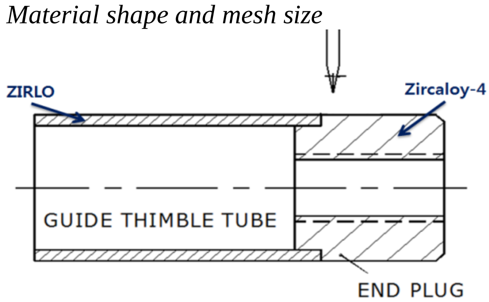

Fig.1. Material shape of Zr tube

The target of Zr tube is described in Fig. 1. The tube rotates 5.2 rpm and the tungsten electrode is fixed. Instead of rotating tube, this study tries to make a model for GTAW bead on plate (BOP) with a welding speed which considers Zr tube rpm. The welding signal such as current and voltage are 68A and 9V, respectively. The mesh density used in the simulation is 0.1mm/mesh.

2.2 Governing equation

Momentum, energy, mass conservation and VOF equation are used as governing equation in this simulation [1-5].

2.3 GTAW modeling

Arc heat flux, arc pressure, electromagnetic force (EMF), surface tension, buoyancy, drag force models are used in the simulation to analyze the molten pool flow in the welding process[1-5]. Among the various arc welding models, arc heat flux, arc pressure and EMF models are Gaussian-distributed model and these models induce a inward molten pool flow pattern and forms a deep penetration when the current is high

- Arc heat source-

$$q_A(x,y) = \eta_A \frac{VI}{2\pi\sigma_r^2} \exp\left(-\frac{r^2}{2\sigma_r^2}\right) \quad (1)$$

- Arc pressure -

$$p_A = \frac{\mu_0 I^2}{4\pi^2 \sigma_r^2} \exp\left(-\frac{r^2}{2\sigma_r^2}\right) \quad (2)$$

- EMF -

$$J_z = \frac{I}{2\pi}\int_0^\infty \lambda J_0(\lambda r)\exp(-\lambda^2\sigma_r^2/2)\frac{\sinh[\lambda(c-z)]}{\sinh(\lambda c)}d\lambda \quad (3)$$

$$J_r = \frac{I}{2\pi}\int_0^\infty \lambda J_1(\lambda r)\exp(-\lambda^2\sigma_r^2/2)\frac{\cosh[\lambda(c-z)]}{\sinh(\lambda c)}d\lambda \quad (4)$$

$$B_\theta = \frac{\mu_m I}{2\pi}\int_0^\infty J_1(\lambda r)\exp(-\lambda^2\sigma_r^2/12)\frac{\sinh[\lambda(c-z)]}{\sinh(\lambda c)}d\lambda \quad (5)$$

$$F = J \times B \quad (6)$$

3. Simulation models

As the current and voltage are smaller than normally used GTAW welding conditions (I>150, V>20) the arc forces such as arc pressure and EMF cannot strongly affect the molten pool behaviors. On the contrary, the effect of surface tension and drag force which induce outward flow on the top surface are relatively stronger than arc force models

Fig. 2 and 3 described the molten pool behaviors on the top surface and the longitudinal section where the molten pool flows outward on the top surfaces. Fig. 4 shows the temperature distribution and the molten pool flow patterns for different time on the transverse section. Even though the arc center approaches, the molten pool maintains the outward flow patterns on the top surface due to surface tension and drag force, the resultant weld bead shape shows a wide and shallow penetrated weld bead as shown in Fig. 5. The models used in the simulation can be validated by comparing the simulation results.

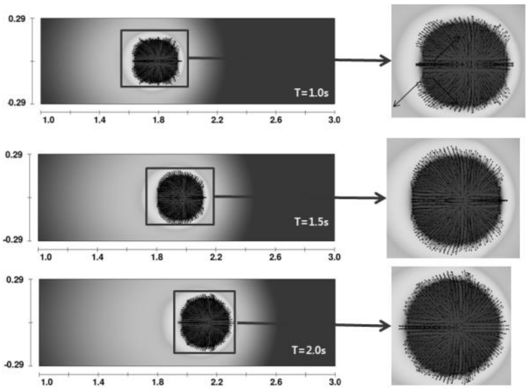

Fig.2. Molten pool behaviors and flow patterns on the top surface

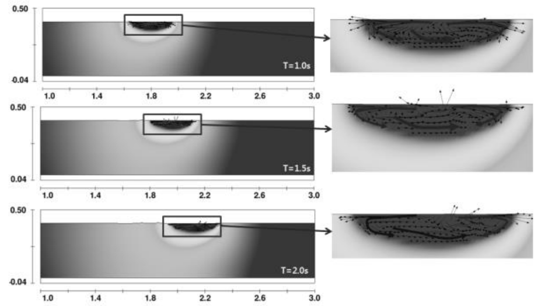

Fig.3. Molten pool behaviors and flow patterns on the longitudinal section

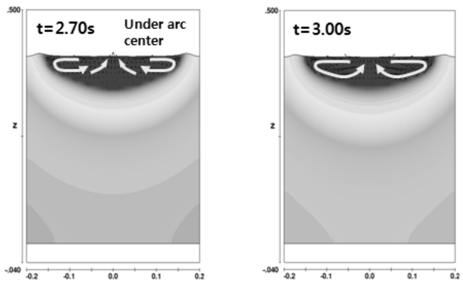

Fig.4. Molten pool behaviors and flow patterns on the transverse section

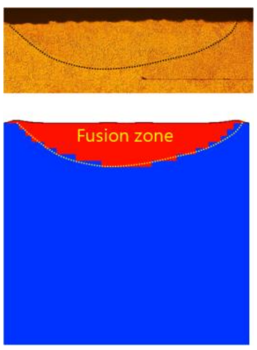

Fig.5. Comparisons of results from experiment and simulation

4. Conclusions

This study firstly conducts the numerical simulation of molten pool behaviors for Zr tube GTAW process. It is possible to understand the mechanism of weld bead formation by transient CFD simulation. The simulation results show a good agreement with a experimental one.

REFERENCES

[1] D. W. Cho, S. H. Lee, and S. J. Na. Characterization of welding arc and weld pool formation in vacuum gas hollow tungsten arc welding, Journal of Materials Processing Technology Vol.140, pp.143-152, 2013

[2] D. W. Cho, D. V. Kiran, W. H. Song and S. J. Na, Molten pool behavior in the tandem submerged arc welding process, Journal of Materials Processing Technology, Vol.214, pp.2233-2247, 2014

[3] D. W. Cho, S. J. Na, M. H. Cho, and J. S. Lee, A study on V-groove GMAW for various welding positions. Journal of Materials Processing Technology, Vol.213, pp.1640-1652, 2013

[4] D. W. Cho, W. H. Song, M. H. Cho and S. J. Na, Analysis of submerged arc welding process by three-dimensional computational fluid dynamics simulations. Journal of Materials Processing Technology, Vol.213, pp.2278-2291, 2013

[5] D. W. Cho, S. J. Na, M. H. Cho, and J. S. Lee, Simulations of weld pool dynamics in V-groove GTA and GMA welding, Welding in the world, Vol.57, pp.223-233, 2013