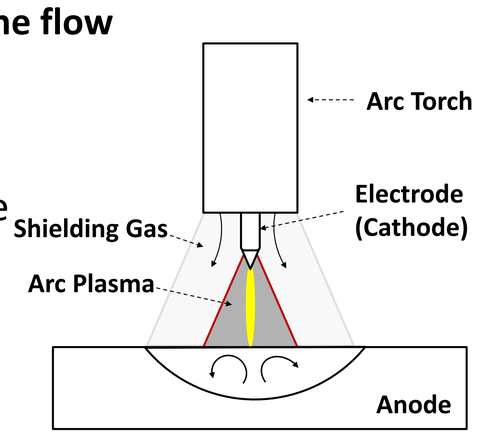
The Effect of Aluminum Content on Convective Flow of Molten Metal Generated by Arc Plasma

Young Tae Cho[1], Chan Kyu Kim[1] , Hyun Uk Hong[1]
[1] Changwon National University, Republic of Korea

INTRODUCTION: By the modeling of molten metal flow generated by arc plasma, the effect of aluminum content of the base material on the flow was analyzed through COMSOL simulation. This physics was governed by mass, momentum conservation and energy equation conducted by heat transfer module, CFD module and AC/DC module in COMSOL.

➢ **Forces acting on the flow**

- ✓Buoyancy force
- ✓Marangoni force
- ✓Lorentz force
- ✓Arc drag force

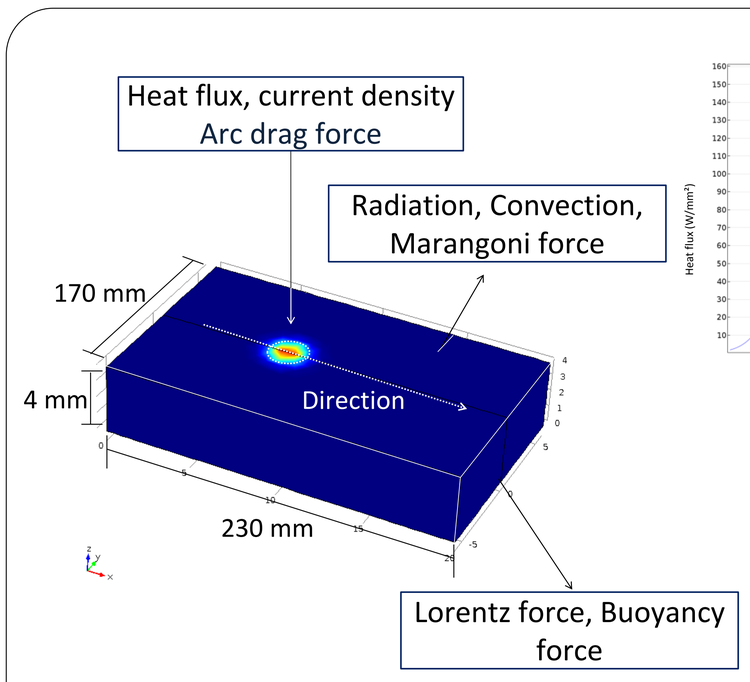


➢ **Parameters**

- ✓Heat input
- ✓Material properties
- ✓Welding speed
- ✓Arc length
- ✓Shielding gas
- ✓Arc spot size

Figure 1. Principle of molten metal flow by arc plasma

COMPUTATIONAL METHODS



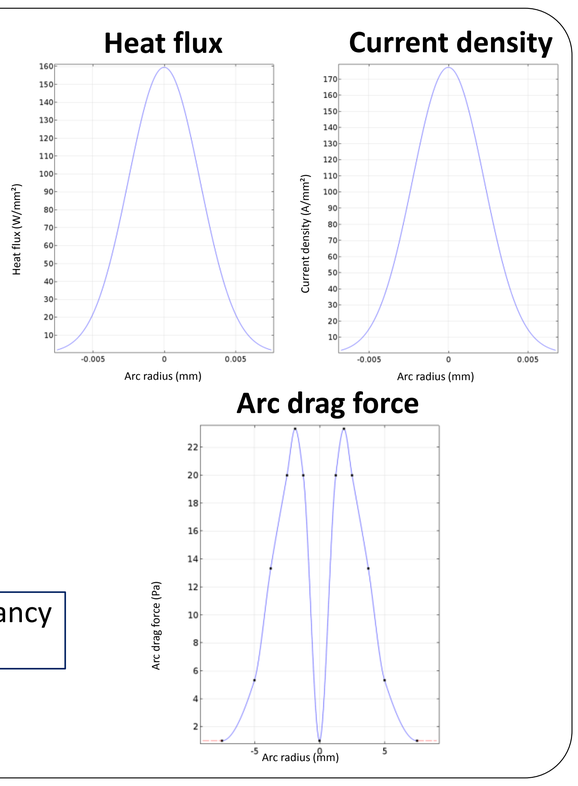


Figure 2. Modeling and boundary conditions

➢ **Surface tension coefficient (Al 50ppm, 500ppm)**

$$\frac{\partial \gamma}{\partial T} = -A_r - R\Gamma_o \ln(1 + k_1 a_o \exp(-\Delta H_0 - RT)) - \frac{k_1 a_o \Gamma_o \Delta H_0 \exp(-\Delta H_0 - RT)}{(1 + k_1 a_o \exp(-\Delta H_0 - RT))T}$$

Ref) Sahoo, P., T. DebRoy, and M. J. McNallan. "Surface tension of binary metal—surface active solute systems under conditions relevant to welding metallurgy." Metallurgical and Materials Transactions B 19.3 (1988): 483-491.

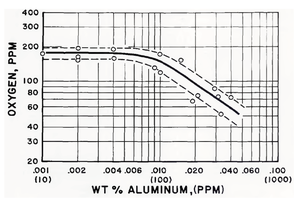
k_1: entropy factor

a_o: Activity of species O in solution

A: Negative of $d\gamma/dT$ for pure metal

ΔH^0: Standard heat of adsorption

Γ_O : Surface excess at saturation



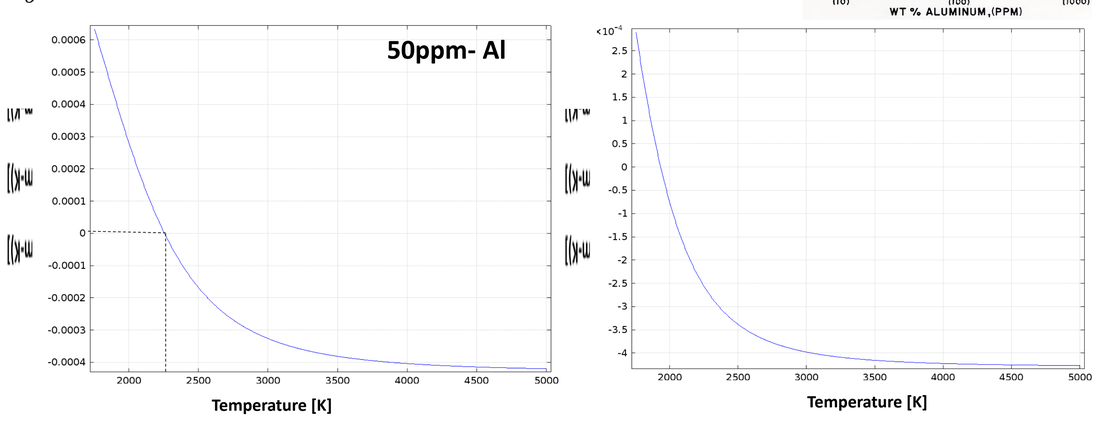
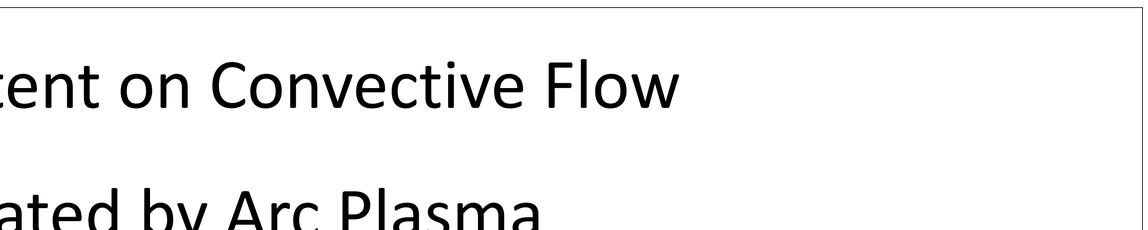


Figure 3. Surface tension coefficient according to aluminum content

RESULTS

➢ **Comparison of experiment and simulation according to Al ppm**

1. Al 50ppm (High-surface tension) : In a high speed camera, the actual molten pool moves from arc center to F.L. Based on the analysis results, this cause is due to the Inward flow.



2. Al 500ppm (Low-surface tension) : In a high speed camera, the actual molten pool moves from arc center to F.L. Based on the analysis results, this cause is due to the Outward flow.

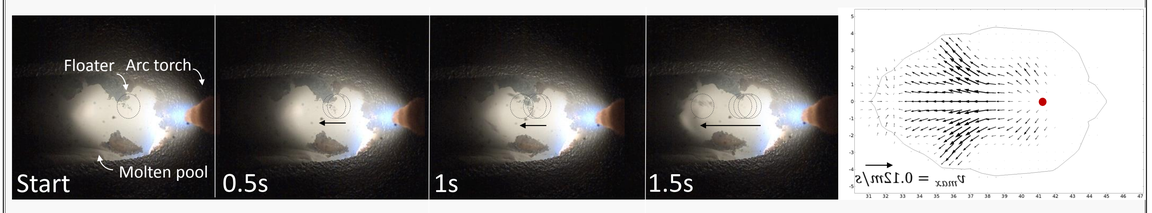
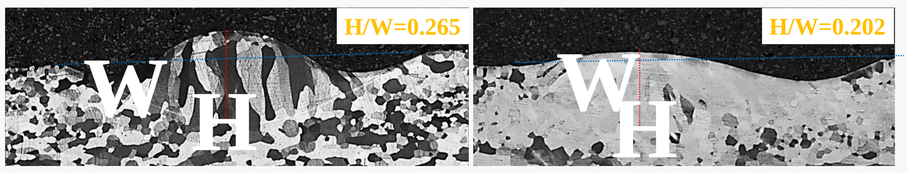


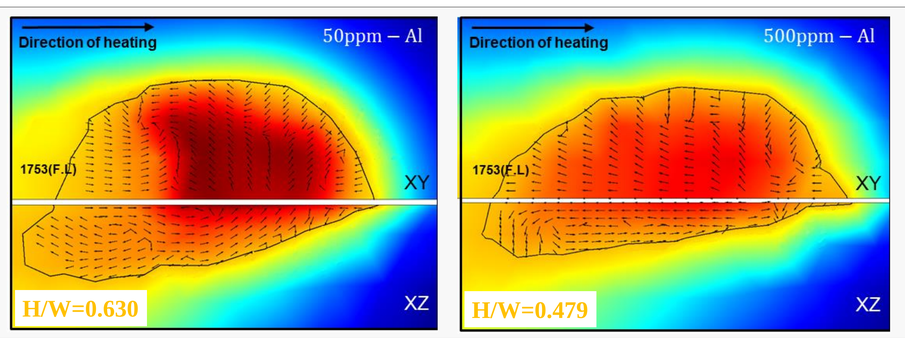
Figure 4. Observation of molten metal flow with high speed camera

➢ **Comparison of experiment and simulation for fusion zone**

- **The inward flow due to the aluminum content affects the bead shape.**
- **Al 50ppm having strong inward flow is higher in H/W value than Al 500ppm**
- **Also, the lower aluminum content, the greater the melting depth**



Al 50 ppm : W=3.77mm, H=1.00mm Al -500 ppm : W=4.16mm, H=0.84mm



50 ppm-Al : W=4.20mm, H=2.65mm 500 ppm-Al : W=4.38mm, H=2.10mm

Figure 5. Comparison of experiment and simulation for Al content

CONCLUSIONS

1. Molten metal flow in arc welding can be 3 dimensionally simulated by COMSOL Multiphysics using heat transter, fluid flow and AC/DC modules.
2. As the aluminum content increases, since surface tension changes Marangoni flow, the strength of inward stream decreases and it can affects the shape of weld bead to be wide and shallow.

REFERENCES:

1. McNallan, M. J., and T. Debroy. "Effect of temperature and composition on surface tension in Fe-Ni-Cr alloys containing sulfur." Metallurgical and Materials Transactions B 22.4, 557-560,(1991)
2. Mukai, Kusuhiro, Zushu Li, and Masafumi Zeze. "Surface tension and wettability of liquid Fe-16 mass% Cr-O alloy with alumina." Materials Transactions 43.7, 1724-1731,(2002)