Modeling of molten pool behavior in plasma cutting process for nuclear decommissioning

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1. Introduction

Plasma cutting process is widely used in manufacturing process such as shipbuilding industry, plant industry and automobile industry due to the cheaper price of the facility than laser cutting. However, the plasma cutting process brings more secondary waste such as spatter, dross volume, and larger kerf; therefore the process parameter should be optimized first. To conduct the plasma cutting process with a physical understanding, it is necessary to simulate the cutting process with various physical models. This study introduce the physical model for plasma cutting process and analyze the molten pool fluid behavior using computational fluid dynamics (CFD) simulation as well as high speed camera.

2. Experimental set up

Fig. 1 shows the schematic of experiment where the high speed camera recorded the various images to capture the moving plasma arc. The materials used in the experiment are carbon steel with 10mm and the welding speed is 5mm/s

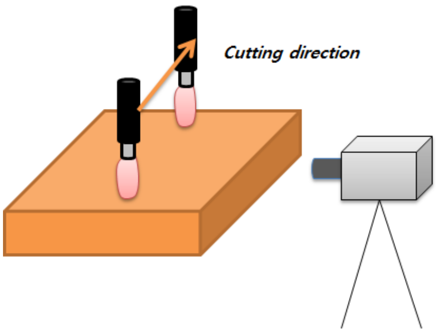

Fig. 1. Experimental setup for plasma cutting

With a high speed camera, it is possible to know the plasma arc is bended during the cutting process as shown in Fig. 2. It means that the cutting speed is relatively higher with a given cutting condition (80A, 500mm/min) or cutting nozzle to form the smooth cutting surface.

Fig. 2. High speed images with a bended plasma arc

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3. Simulation modelling

This study used the commercial software, Flow-3D to solve the momentum, energy, mass conservation and VOF equation. Moreover, this study model the plasma cutting models such as arc heat source, arc pressure, electromagnetic force and drag force which can also be used in arc welding process [1-3] Moreover, vaporization model and nozzle pressure are applied in equation (1) and (2) because the parameters used in the cutting process such as nozzle pressure, side wall drag are far from the welding condition.

$$J_v = \frac{\lambda P_v}{\sqrt{2\pi M k_B T}} \quad (1)$$

$$P_{nozzle} = \frac{1}{2}\rho v^2 \quad (2)$$

Finally, this study can simulation three dimensional numerical simulation to describe the molten pool behaviors.

4. Results and discussion

Fig. 3(a) to (c) show the transient simulation results of plasma cutting process in the longitudinal section. In the beginning of the cutting, the material start to melts at the edge section as shown in Fig. 3(a). Moreover, the molten pool flows to bottom surface due to nozzle pressure while the main arc heat source is applied to the top surface. Therefore, the molten pool shape is inclined during the cutting process in Fig. 3(b) and (c) and it is very similar tendency to high speed images in Fig. 2. Therefore, the nozzle pressure and the arc heat sources are the main force of molten pool cutting process. Fig. 4 is three dimensional simulation results.

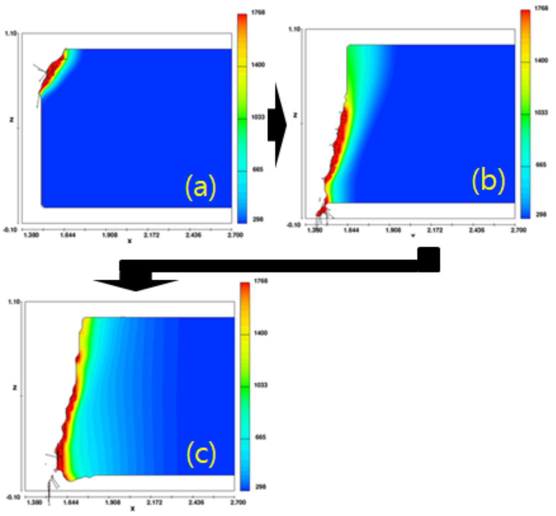

Fig. 3. Transient molten pool behavior of edge start plasma cutting process in the longitudinal section.

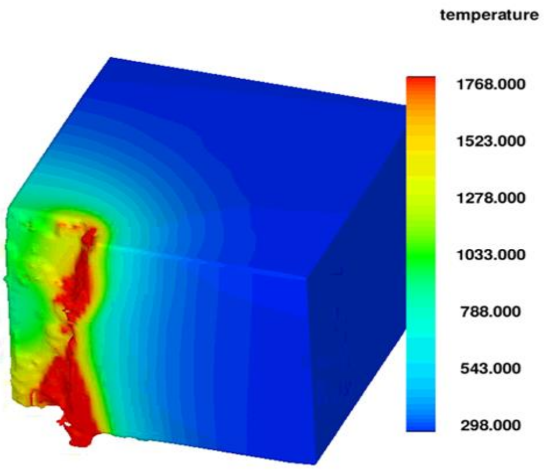

Fig. 4. Three dimensional simulation of plasma cutting process with edge start.

5. Conclusions

This study model the plasma cutting process with various physical models and it is possible to describe inclined cutting profile which also can be extracted from the high speed camera. The formation of molten dross is very important and it shall be conducted soon

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