Influence of Preheating on Oxygen Plasma Cutting Process*  

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This study aims to develop a new oxygen plasma cutting process for a thick steel plate. In this process, the oxidation reaction is enhanced by preheating the cut surface near the bottom by an additional heat source to realize cutting of the thick plate. In this paper, influence of the preheating process on cutting performance was discussed. Consequently, it was found that the maximum cutting velocity increased with the assistance of the preheating, because the oxidation reaction increased also near the bottom surface. However, in order to decrease the surface roughness and the taper angle, the preheating temperature and the preheating method should be improved in the future.

Key Words: Oxygen plasma cutting, Oxidation reaction, Preheating

1. Introduction

In plasma cutting process, a base metal is melted using the concentrated arc energy produced by a restraint nozzle of a plasma torch and the cutting is achieved by removing the molten metal with high speed plasma jet1-3. An oxygen plasma cutting process realizes higher cutting efficiency with the assistance of oxidation reaction by employing oxygen as the working gas4,5.

This study aims to develop a new oxygen plasma cutting process for a thick steel plate. It is pointed out that in a conventional oxygen plasma cutting process, the temperature on the cut surface near the bottom decreases due to insufficient heat input from the arc. As a result, it makes the cutting of the thick steel plate difficult because of decrease in oxidation reaction. In this process, the oxidation reaction is enhanced by preheating the cut surface near the bottom by an additional heat source to realize cutting of the thick plate. In this paper, influence of the preheating process on cutting performance is discussed.

2. Experimental method

In this cutting process, it is supposed to preheat the cut surface near the bottom of the base metal by an additional heat source during cutting as explained above. However, the bottom of the base metal was preheated in advance before cutting in this experiment due to difficulty to set the additional heat source under the base metal in the cutting machine.  

Fig.1 shows a photograph of the experimental setup. The cutting machine was employed. The cutting current was 300A. The main gas and the twister gas were O2+10%N2 and air. They were introduced at the flow rate of 32L/min and 40L/min, respectively. The standoff was 5mm. The base metal was mild steel with thickness of 25mm or 36mm. The cutting appearance was recorded with the color high speed video camera at the frame rate of 2,000fps.

In this experiment, influence of the preheating temperature (non-preheating, 300℃, 500℃ and 800℃) on cutting characteristics are discussed. The base metal was heated by a gas burner in advance. The temperatures of the top surface and the bottom surface were measured by a thermocouple and a radiation thermometer as shown in Fig.2. It was confirmed that the temperatures measured by both methods approximately agreed and the temperature increased uniformly over the both surfaces.

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3. Results and discussion

First, the cutting characteristics in thickness of 25mm are discussed. The cutting velocity was set to be 2800mm/min.

Fig. 3 shows appearances of plasma cutting arc in cases of non-preheating and preheating temperatures of 300°C, 500°C, 800°C, respectively. In non-preheating case, it was seen that the cutting front near the bottom surface was delayed compared with that near the top surface due to decrease in the heating by the oxidation reaction caused by oxygen, because the temperature on the cut surface near the bottom decreased due to insufficient heat input from the arc. Consequently, the plasma jet from the top surface outflowed backward under the bottom surface. With increase in the preheating temperature, the delay of the cutting front near the bottom surface decreased gradually and the plasma jet outflowed downward more vertically.

Fig. 4 shows dependence of outflow angle of plasma jet under the bottom surface. The outflow angle increased with the preheating temperature especially above 500°C. It means that the cutting front near the bottom surface caught up with that near the top surface. For a reason, it is considered that the formation rate of the oxide of iron largely increases above 570°C.

Fig. 5 and 6 show cutting appearances of the top surface and bottom surface in each preheating temperature. It is seen that the cutting appearances of both surfaces are good. Furthermore, an amount of the dross on the bottom surface decreased with increase in the preheating temperature.

Fig. 7 shows cross sections in each preheating temperature. The base metals were cut sharply also in higher preheating temperature.

Table 1 shows surface roughness and taper angles in each preheating temperature. The surface roughness was measured at 2mm from the top surface, the center (middle height) and 2mm from the bottom surface. It was found that the surface roughness was gradually increased with the preheating temperature especially near the top surface, On the other hand it was almost the same near the bottom surface. It is considered that increase in surface roughness was caused by excessive melting volume of the base metal due to rise in the temperature near the top surface through higher heat input. The taper angles were nearly within 1 degree independent of the preheating temperature.
Second, influence of the preheating on the maximum cutting velocity is discussed.

Fig. 8 shows appearances of plasma cutting arc in cases of non-preheating and the preheating temperature of 800 °C, respectively. In case of non-preheating, the plasma jet coming from the top surface couldn’t penetrate the base metal and outflowed backward from the top surface. On the other hand, in the preheating temperature of 800 °C, the plasma jet penetrated it completely and the cutting was achieved.

Fig. 9 and 10 show cutting appearances of the top surface and bottom surface in each preheating temperature. Fig. 11 shows cross sections in each preheating temperature. It is seen that the cutting was achieved in the preheating temperature of 800 °C, although the bottom side of the base metal was not penetrated by the plasma jet in the non-preheating case.

Table 2 shows surface roughness and taper angles in each preheating temperature. The surface roughness was measured at three points as same as Table 1. It was seen that the surface roughness was increased especially near the top surface and the taper angle increased in the preheating temperature of 800 °C.

Consequently, it was found that the maximum cutting velocity increased with the assistance of the preheating, because the oxidation reaction increased also near the bottom surface. However, in order to decrease the surface roughness and the taper angle, the preheating temperature and the preheating method should be improved in the future.
This study aims to develop a new oxygen plasma cutting process for a thick steel plate. In this process, the oxidation reaction is enhanced by preheating the cut surface near the bottom by an additional heat source to realize cutting of the thick plate. In this paper, influence of the preheating process on cutting performance was discussed.

Consequently, it was found that the maximum cutting velocity increased with the assistance of the preheating, because the oxidation reaction increased also near the bottom surface. However, in order to decrease the surface roughness and the taper angle, the preheating temperature and the preheating method should be improved in the future.

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