Title	Fundamental research on micro discharge process : Research on discharge of sub-millimeter size process
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Citation	Transactions of JWRI. 2010, 39(2), p. 207-208
Version Type	VoR
URL	https://doi.org/10.18910/7438
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Fundamental research on micro discharge process †

— Research on discharge of sub-millimeter size process —

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KEY WORDS: (Precise materials processing) (Glow discharge) (Arc discharge) (Glow-arc transition)

1. Introduction

Arc welding processes have been widely used as the indispensable joining technologies for various manufacturing fields because of low process cost with high efficiency and reliability. Plasma arc welding process, which is one of the arc welding processes, has been applied to one pass welding with low distortion for sheet and/or thin thickness plate up to 6 mm. But conventional plasma arc is not suitable for the precise materials processing of sub-millimeter sizes. In conventional plasma arc process, the arc temperature increases with decrease of constricted nozzle diameter. Then the nozzle is burn out eventually when the nozzle diameter is less than 1mm.

Therefore, micro sized and/or sub-millimeter sized welding is normally carried out with a laser beam or electron beam because it is possible to reduce the beam diameter less than 0.1mm. Recently micro sized discharge process at atmospheric pressure is strongly demanded because in laser beam process and/or electron beam process there are several problems such as high cost, big size of processing machine, low energy efficiency, and so on.

In this research, the possibility of precise materials processing by electrical discharge energy at glow region or glow-arc transition region, which consists of low temperature plasma, was experimentally investigated using a new type of nozzle which was designed to establish very small diameter plasmas and an experimental power source which can supply wide range of voltage.

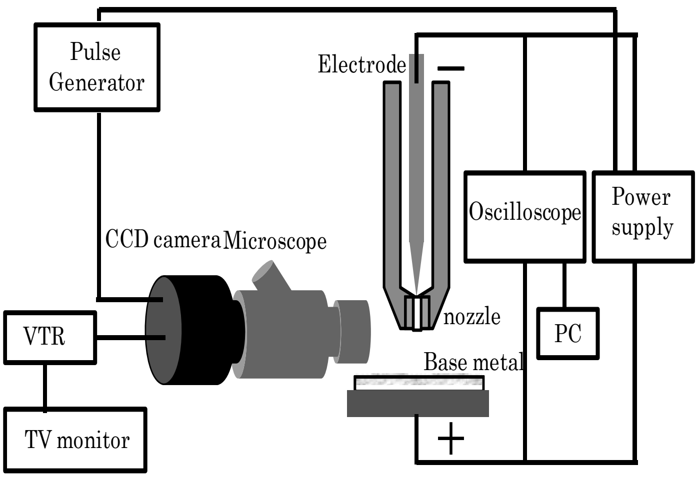

Fig. 1 Schematic illustration of the experimental setup.

2. Experimental procedure

The schematic illustration of the experimental setup is shown in **Fig. 1**. The electrode (W-2%ThO_2) of 1mm diameter is used and placed inside the torch. The nozzle diameter is 0.3mm. The argon gas is used as plasma gas for this experiment (0.2~0.5l/min). The current-voltage waveform was measured by means of an oscilloscope. The appearance of plasma discharge was observed using an optical microscope set with a high-speed CCD camera. The size of melting spot on base metal surface was also evaluated by using optical microscope.

3. Experimental results and discussion

Figure 2 shows an example of waveforms of current and voltage of electrical discharge using the new type of nozzle with the experimental power source. Nozzle diameter and discharge gap was fixed at 0.3mm and 5mm, respectively. The electrode vertex angle was 30 degree. As seen in Fig. 2, the waveform of voltage was almost constant at 800V, but
some instances of high-voltage of around 1100V were observed. This phenomenon is considered to occur as transition from normal glow to abnormal glow, that is, the electric discharge is in glow-arc transition region. The discharge appearance is shown in **Fig. 3**. It is noted that the plasma diameter increased at the area of base metal then directly under nozzle.

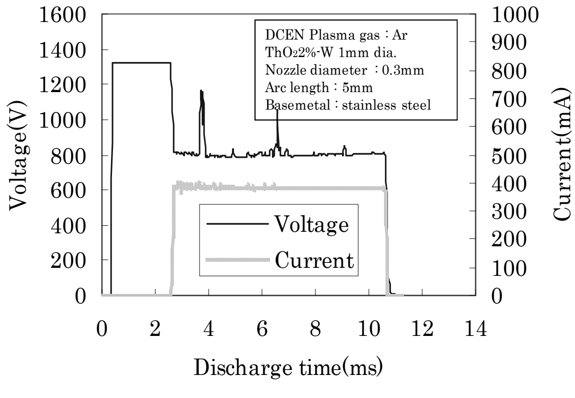

Fig. 2 Current and voltage waveforms of the electrical discharge with the experimental torch and power source.

† Received on 30 September 2010
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Transactions of JWRI is published by Joining and Welding Research Institute, Osaka University, Ibaraki, Osaka 567-0047, Japan

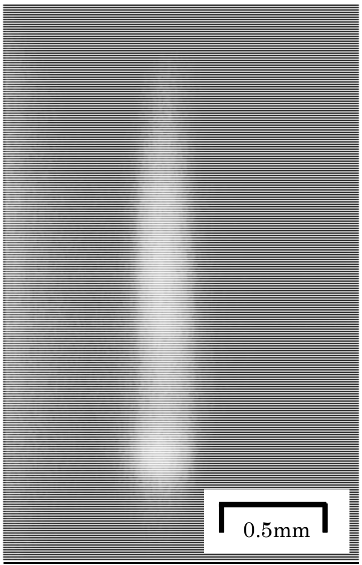

Fig. 3 Appearance of Ar DC discharge-plasma constricted by the nozzle of diameter of 0.3 mm. （Gap length 5mm, Discharge current 390mA, Discharge voltage 800V）

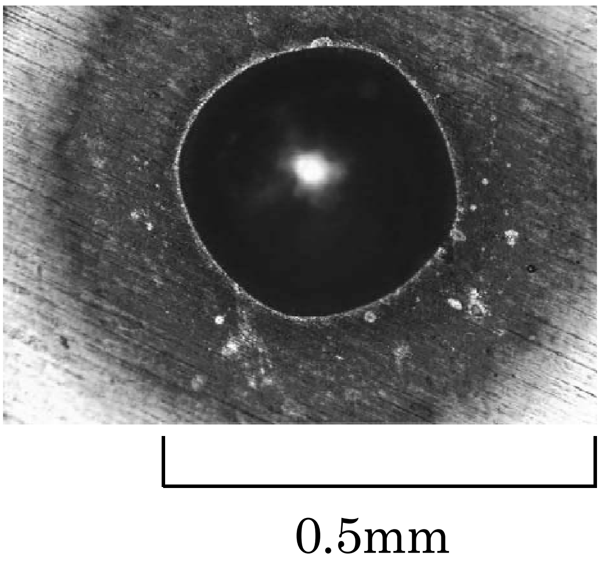

Fig. 4 Photograph of melting spot at a stainless steel plate formed by the nozzle of diameter of 0.3 mm. （Gap length 4mm, Discharge current 390mA, Discharge voltage 800V）

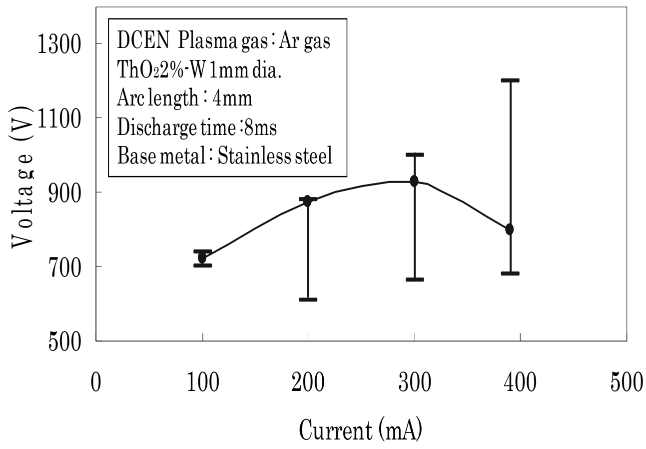

Fig. 5 Relationship between current and voltage of the discharge in atmospheric pressure (nozzle diameter: 0.3mm)

Figure 4 indicates the melting spot at a base metal surface formed with use of the nozzle of diameter of 0.3 mm. The size of melting spot was formed with about 0.3mm diameter. The center of melting spot is seen with small dimple shape as seen in Fig. 4. This phenomenon mainly occurred due to the high-current density at the center of the melting spot, high arc-pressure, and local evaporation of melting metal.

Figure 5 shows a relationship between current and voltage of the discharge at atmospheric pressure. In the figure average voltage and range of voltage fluctuation are indicated. The average voltage gradually decreases with increase of current beyond around 300mA. This is considered to be arc-glow transition region.

4. Conclusion

The possibility of precise materials processing by electrical discharge energy at glow region or glow-arc transition region was experimentally investigated using a new type nozzle which was designed to establish very small diameter plasmas and an experimental power source which can supply a wide range of voltage. The results obtained are summarized as follows:

(1) When discharge current increases, discharge mode changes from normal glow to abnormal glow, that is, glow-arc transition region.
(2) Sub-millimeter sized melting spots were formed at the base metal surface using the constricted nozzle of 0.3 mm in diameter.

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