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Evaluation of Long Straight Arc Stability with Arc Voltage Measurement
アーク電圧計測による直線状長アークの安定性評価

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Long straight arc column changes its style as arc gas flow rate increases. Measurement of arc voltage indicates a small change of its DC component and a large variation in fluctuating component with increase of the gas flow rate. These results are expected to depend on the change of not only the arc behavior but also anode spots.

1. Introduction

Authors have developed a novel heat treatment system for steel products using a magnetically driven arc [1,2]. It has been confirmed that this equipment is able to raise a steel plate surface hardness up to 2-3 times higher than that of original surface. However, the optimum arc forming gas flow rates for the applied torch nozzle diameter to treat the steel surfaces have never been reported in the literature [3]. This misunderstanding often engenders cratered surfaces on the heat-treated steel plates.

In the present study, relation between arc behaviors and arc voltages for various arc gas flow rates are investigated in order to use for evaluation of the optimum gas flow rate in heat treatment application.

2. Experimental Method

Figure 1 presents an experimental arrangement for a long straight arc generation.

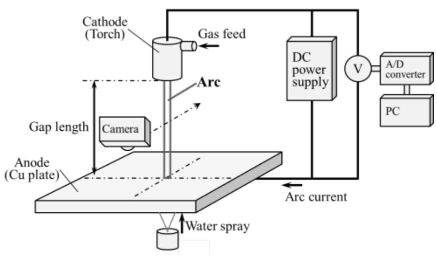


Fig.1. Schematic illustration of experimental equipment.

A DC power supply, which operates with constant current mode, is connected to a torch and an anode. Arc forming gas is argon, whose flow rate supplied to the torch is between 3 NL/min and 12 NL/min. An arc is generated between the torch and the anode, which are separated by a gap of 50 mm. The torch, whose nozzle diameter is 5 mm, is commercially available to use for TIG welding. The anode, which is a copper plate of 5 mm in thickness, is cooled by water sprayed onto the lower side. The arc current is fixed to 60 A. The arc voltage is measured by a voltage meter connected in parallel to the power supply and continuously recorded on a linked PC through an A/D converter.

3. Results

3.1 *Arc profile transitions*

Figure 2 shows arc profile variation caused by the gas flow rate increment from 3 NL/min to 12 NL/min.

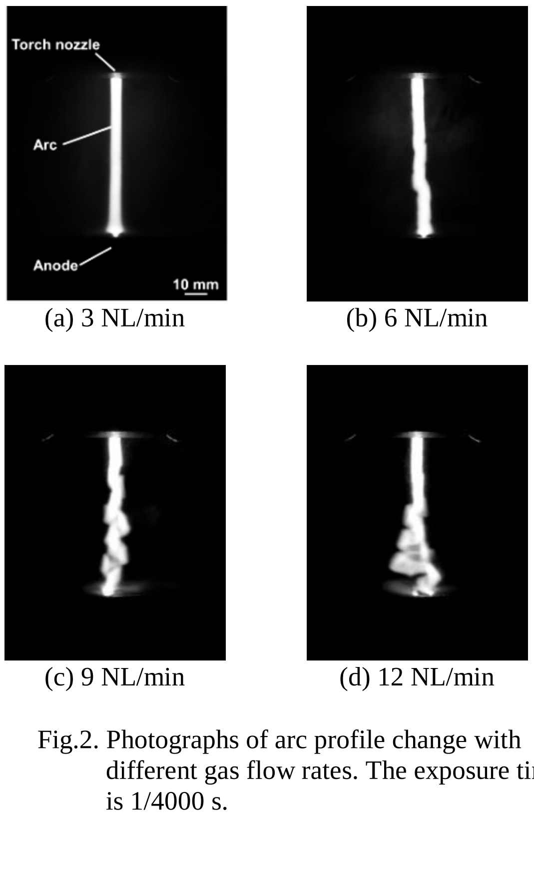


Fig.2. Photographs of arc profile change with different gas flow rates. The exposure time is 1/4000 s.

As shown in Figs. 2(a) and (b), the arc column is almost straight form when the gas flow rate is small. However, as the gas flow rate increases, it turns to the right and the left as shown in Figs. 2(c) and (d). Hereafter, we refer to the arc profiles of (a) and (b) as “Laminar flow arc”, (c) and (d) as “Turbulent flow arc”, respectively.

Figure 2 also shows that total length of the arc column increases as the gas flow rate increases. Therefore, it can be expected that the arc voltage increases due to this arc column extension. The averages of measured arc voltage values, which are considered as DC components of the arc voltages, are almost constant at about 90 V between 3 NL/min and 5 NL/min. On the other hand, the arc voltage increases linearly to 125 V with the gas flow rate more than 6 NL/min. These results agree with the arc profiles in straight and distorted forms depicted in Fig. 2.

3.2 *Measurement of arc voltage fluctuation*

We calculate root-mean-square (RMS) value of the obtained arc voltage fluctuation for each gas flow rate. Figure 3 presents the variation of the RMS values of the arc voltage fluctuation for the various gas flow rates. The RMS values of the laminar flow arc are almost constant at about 0.5 V. On the contrary, they slightly increase from 7.1 V to 9.5 V about turbulent flow arc.

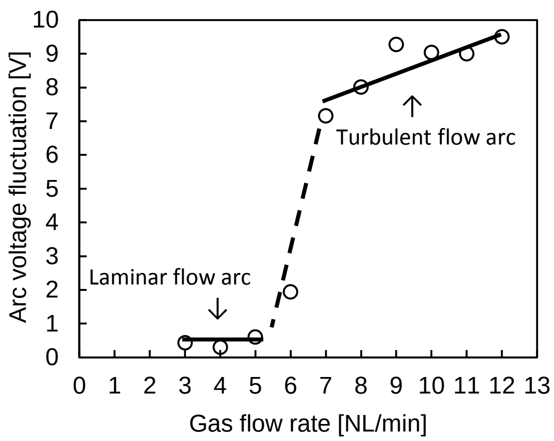
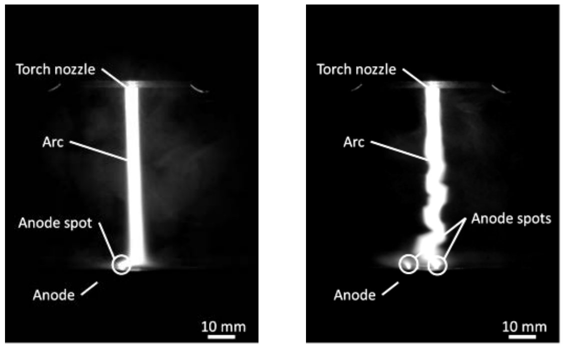


Fig.3. Variation of RMS values of arc voltage fluctuation for various gas flow rates.

In this experiment, several anode spots are observed. Figure 4 shows the anode spots for laminar and turbulent flow arcs. Because the anode is made of copper, they are bright green spots. In the case of laminar flow arc, one or two anode spots appear and they are stable for a long time. In contrast, several anode spots appear and disappear repeatedly in a short time about the turbulent flow arc. In addition, they move very quickly, which possibly causes the slight increase of the arc voltage fluctuation level shown in Fig. 3.



(a) Laminar flow arc (b) Turbulent flow arc

Fig.4. Photographs of anode spots of laminar flow arc (a) and turbulent flow arc (b), respectively.

However, the most interesting feature of Fig. 3 is that the RMS value of arc voltage fluctuation drastically increases between 5 NL/min and 7 NL/min. It is expected that the change of these anode spot behaviors, leads to the arc voltage fluctuation increase from laminar flow arc to turbulent one. More detailed research about this steep increment is necessary and more experiments are going on now.

4. Conclusion

We have investigated relations between arc behavior and arc voltage. Followings are the obtained conclusions.

(1) The arc profile changes steeply from a laminar flow arc to a turbulent one as the gas flow rate increases.

(2) The DC components of arc voltage increase linearly with the gas flow rates in the turbulent flow arc, while they are almost constant in the laminar one.

(3) A large change of the arc voltage fluctuation within small gas flow rate variation is observed, which corresponds to the arc profile change.

(4) The increase of the fluctuation level in turbulent flow arc is probably caused by the quick motion of the anode spot.

References

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