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Discharge Characteristics of Multi-Phase AC Arc for In-Flight Processing
インフライト処理に用いる多相交流アークの放電特性

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Multi-phase AC arc is suitable for the in-flight melting treatment of the granulated glass raw materials because of its large plasma volume, low gas velocity and high energy efficiency. The discharge mechanism of the multi-phase AC arc plasma was investigated by a high-speed video camera observations synchronized with voltage measurements and an image analyses of high temperature distributions were carried out. Uniform high temperature distributions are broadened with increasing the number of the phase.

1. Introduction

The concept of controlled generation of an arc by rotated magnetic field or by multiple electrodes has already been studied [1]. These power sources for arc generation are accomplished by DC power supply, although it takes more cost in the apparatus for converting AC to DC. The conventional single-phase and three-phase AC power supplies have a characteristic of intermittent discharge which limits the application of arc systems [2]. To obtain a more effective arc reactor, a multi-phase AC power supply has been developed [3]. The important advantage of this system is larger number of discharging paths among the electrodes. Therefore, discharges among the electrodes always exist to realize smooth arc re-ignition. Consequently, the multi-phase AC arc have been attracted to be applied to waste treatment, synthesis of nano-sized materials, and in-flight glass melting processes [4].

Only few researches about the characterization of the discharge mechanism of the multi-phase AC arc, however, have been reported. In order to enhance the performance of the in-flight treatment, the discharge mechanism of the multi-phase AC arc should be understood. The objective of this study is to investigate the discharge mechanism of the multi-phase AC arc.

2. Experimental

Figure 1 shows the schematic diagram of the experimental setup of the multi-phase AC arc. It consisted of twelve electrodes, reaction chamber and AC power supply. Twelve electrodes were symmetrically arranged by the angle of 30 degree and were divided into two layers, upper six electrodes and lower six electrodes. The details about the experimental setup can be shown in our previous work [4]. In this study, a high-speed video camera was installed on the top of the reactor to observe the behavior of the multi-phase AC arc. Voltage measurements were also conducted with synchronizing the camera observations. Three types of the electrode configuration, clockwise (CW), flip-flop (FF), knight connection (KC), were applied to control the arc region, which corresponds to the high-temperature region.

3. Results and Discussion

Figure 2 shows the representative of the high-speed video images of the multi-phase AC arc for different types of the electrode configurations. The sinusoidal waves of voltages were applied as indicated in the expression in Fig. 2.

The luminance area is cyclically distributed with fluctuation caused by phase shifting in the multi-phase AC arc. Then the fluctuation of the

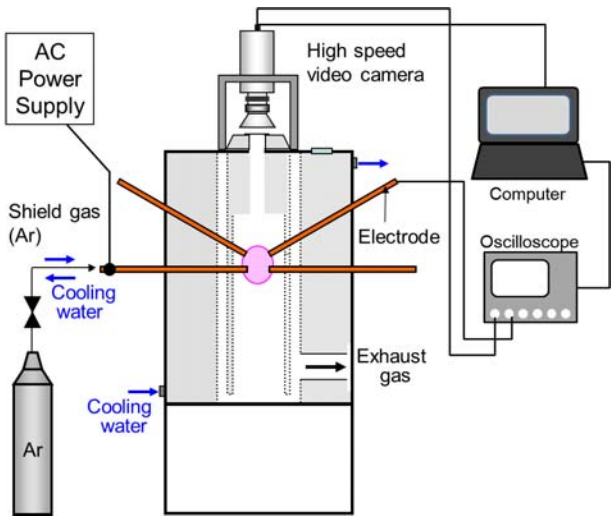

Fig.1. Schematic of multi-phase AC arc reactor.

luminance area was evaluated from high-speed video images. Figure 3 shows the fluctuation of the luminance area of the FF patterned 12-phase arc, and its result of fast Fourier transfer (FFT) analysis. Here, the strongest peak of 100 Hz is observed. This is originated from the power source.

The behavior of the multi-phase AC arc is complicated and fluctuated as indicated in previous section because of its complex effects of rotating electro-magnetic fields and the Lorentz forces between the arcs. In order to evaluate the high-temperature region near the electrodes tip as well as the area among the electrodes, the high-speed video images were analyzed by the image processing. The analyzed images by accumulating the high-temperature region during a cycle (20 ms) are shown in Fig. 4. As indicated in Fig. 4, the high-temperature regions for three types of the electrode configurations are compared. The results indicate that the more uniform high-temperature region can be obtained in CW pattern than others. This is because the opposite side of voltages (For example, V_1 *and* V_7) are applied to the opposite side of the electrodes, resulting in the longer arc passing through the center of the electrode region. In contrast, the high-temperature region of the arc in FF pattern shows the doughnut-shaped. This is because the arcs exist only near the electrodes. These results indicated the controllability of the multi-phase AC arc

4. Conclusion

Multi-phase AC arcs were characterized by high-speed video observations and its image analysis. Obtained results indicated that the controllability of the high temperature region by changing the electrode configuration, which would be useful for various plasma processes.

Acknowledgements

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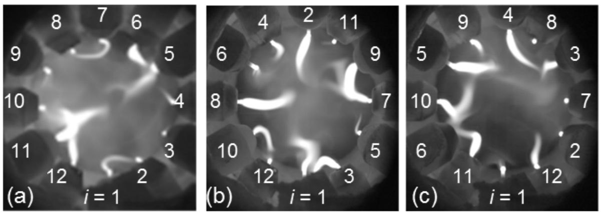

Applied Voltage: $V_i = V_m \sin\left(\omega t - \frac{i-1}{6}\pi\right)$, i=1, 12

Fig.2. Representatives of the high-speed video images of the multi-phase AC arcs; (a) CW, (b) FF, (c) KC pattern.

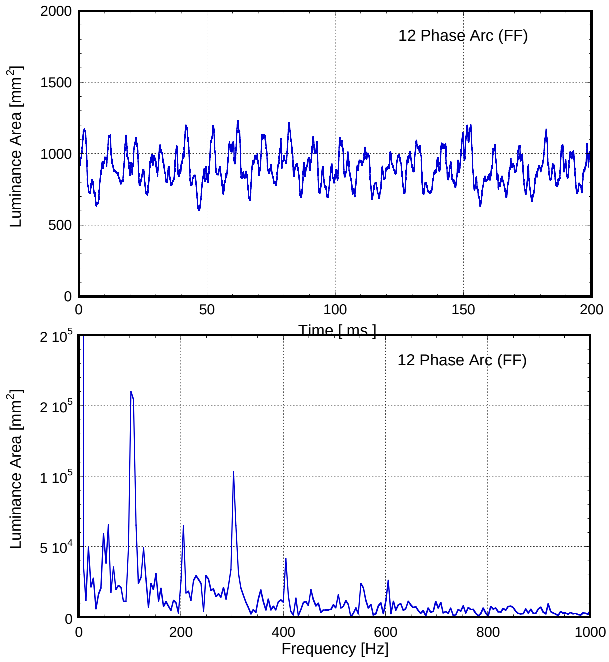

Fig.3. (a) Fluctuation of luminance area and (b) FFT analysis of the luminance area for multi-phase AC arc in FF pattern.

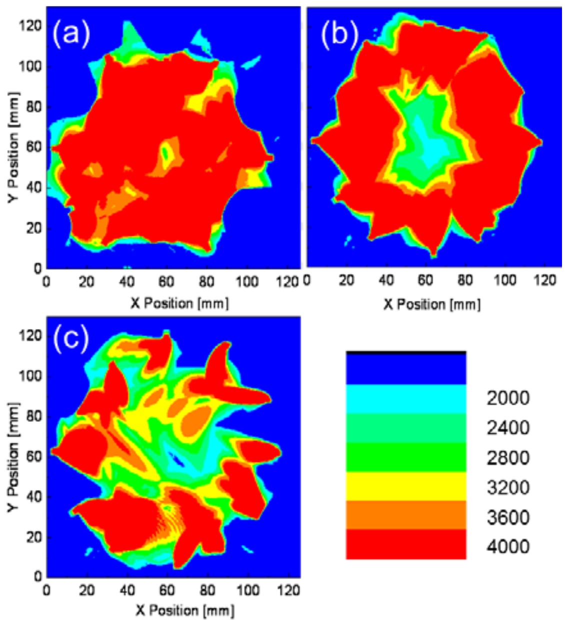

Fig.4. Contour maps of the arc existence frequency of the multi-phase AC arcs; (a) CW, (b) FF, (c) KC pattern.