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Author(s)	Ogino, Yosuke; Hirata, Yoshinori; Nomura, Kazufumi
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Numerical analysis on heat source characteristics of two-electrodes TIG arc†

OGINO Yosuke*, HIRATA Yoshinori*, NOMURA Kazufumi*

KEY WORDS: (Arc welding process) (Two-Electrodes TIG Arc) (3D numerical model) (Heat input density) (Arc pressure) (Total heat input)

1. Introduction

Various kinds of multi-electrodes welding processes have been applied to manufacturing fields such as shipbuilding, automobile and piping. However, their welding phenomena are very complex and it is hard to find and select optimum welding condition, because there are many particular parameters; electrodes distance, polarity and current ratio of each electrode, which do not need to be taken care for conventional single-electrode welding process. Some work has been done to understand such complicated phenomena with experiments [1, 2].

In this research, we picked the two-electrodes TIG arc process as an example of the multi-electrodes welding process, and numerically investigated it with a 3D arc plasma model. In the case of two-electrodes welding with same polarities, two arc plasmas attract each other. Therefore electrode distance is very important parameter. We numerically investigated the influence of the electrode distance on heat source characteristics of arc plasma focusing on heat input density, arc pressure and total heat input into the base metal.

2. Numerical Model

Under the LTE (local thermo-dynamical equilibrium) approximation, the arc plasma can be treated as an electromagnetic viscous fluid. Schematic explanations of the 3D numerical model of TIG arc and analysis condition are shown in **Fig. 1**. Each electrode is the same shape;

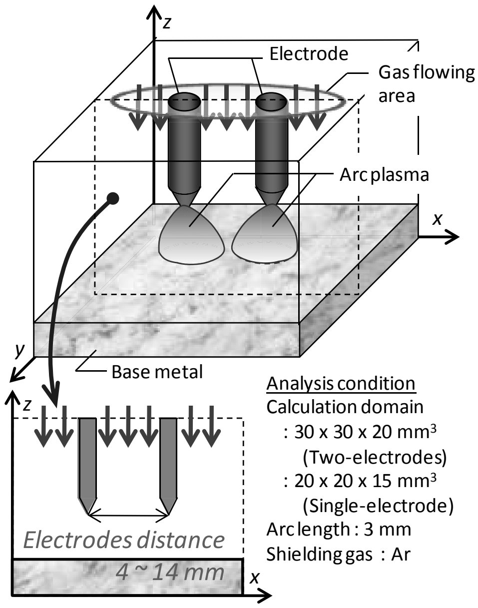
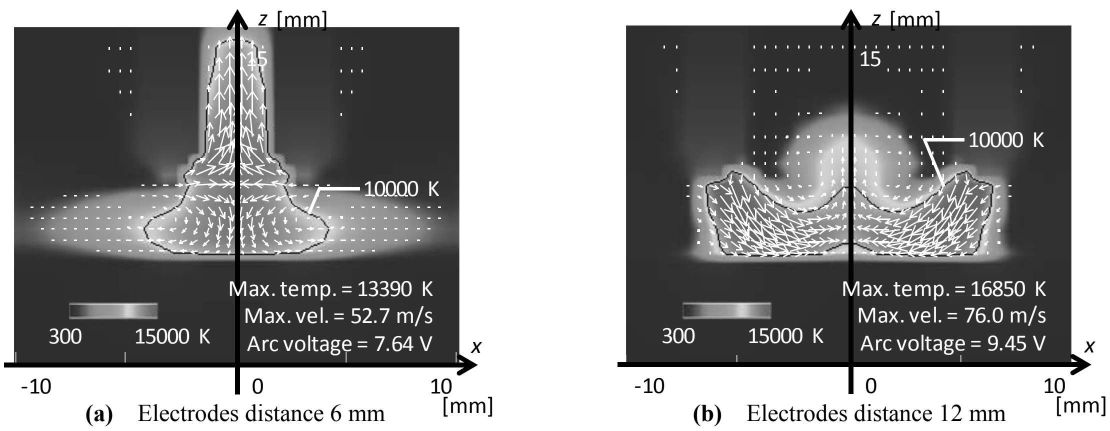


Fig. 1 Schematic image of 3D numerical model of two-electrode TIG arc



(a) Electrodes distance 6 mm **(b)** Electrodes distance 12 mm

Fig. 2 Influence of electrodes distance on temperature and velocity field of arc plasma

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* Division of Materials and Manufacturing Science, Graduate School of Engineering, Osaka University, Japan

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diameter is 3 mm and vertex angle is 90 degrees, set up vertically to anode plate. The arc current of 100 A is supplied for each electrode. Numerical analysis on single-electrode arc is also carried out for comparison. In the case of single-electrode, arc current is 200 A. Electrode distance is defined as distance between both electrodes' tips. In this calculation, anode plate is assumed to be not melted nor deformed. TIG torch is stationary. Shielding gas is Ar and flow from the gas flowing area shown in Fig. 1, which includes space between electrodes.

3. Calculation Results

Figure 2 shows temperature distributions of arc plasma calculated in the case of electrode distances of 6 mm and 12 mm. It shows the *xz* surface across the two electrodes tips. In the figures the isothermal line shows a temperature of 10,000K and the white arrows show flow vectors. As seen, the arc plasma generated from each electrode is drawn each other by the electromagnetic force. Arc plasma shapes are clearly changed as electrode distance is changed. As seen, in the case of short electrodes distance, two arc plasmas are combined as one large arc plasma.

Next, the heat source characteristics of the two-electrode TIG arc were compared with those of single-electrode TIG arc. When the arc current of 100 A is supplied to each of the two-electrodes, the electrode distance is changed. Then, the two-electrode distance decreases and ideally becomes zero. We regarded it to be 200 A single-electrode TIG arc.

Figure 3 shows the relationship between the electrode distance and the peak value of the heat input density. In this research, heat input into base metal from TIG arc is assumed to be provided by heat conduction and current carrying electrons. **Figure 4** shows the relationship between the electrode distance and the peak value of the arc pressure. These peak values of two-electrode TIG with various electrode distances are much smaller than those of single-electrode TIG. The figures of Fig. 3 and Fig. 4 show common characteristic trend clearly. Heat input and arc pressure of two-electrodes TIG arc significantly changed depending on electrode distance, and take minimum values at the electrode distance of 7-8 mm.

Figure 5 shows the relationship between the electrodes distance and the total heat input. As seen, the total heat input doesn't change so much even if the electrodes distance changes. Moreover, there is not so large a difference among total heat inputs of two-electrode with various distances and 200 A single-electrode.

In this way, in the two-electrode TIG arc, the heat input density and the arc pressure change significantly, but the total heat input does not change so much even if the electrode distances changes. These heat source characteristics of the two-electrode TIG arc is useful for controlling heat input distribution with low arc pressure. So, these calculation results show the possibility of the "soft" heat source with high heat input by using the two-electrode TIG arc.

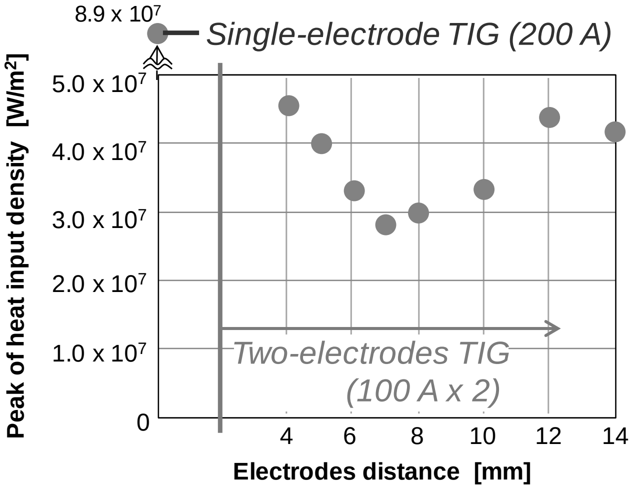

Fig. 3 Influence of electrodes distance on peak value of heat input density

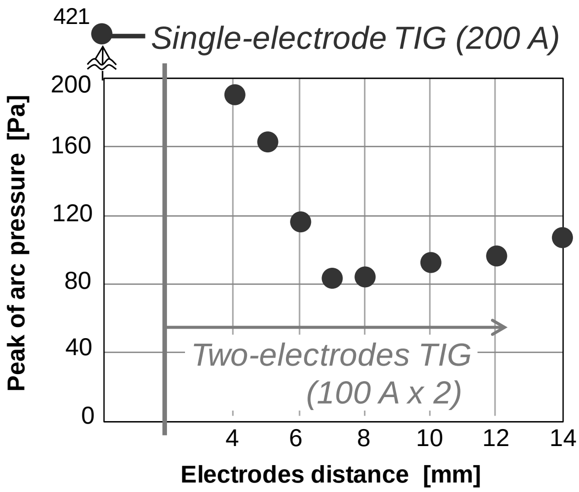

Fig. 4 Influence of electrodes distance on peak value of arc pressure

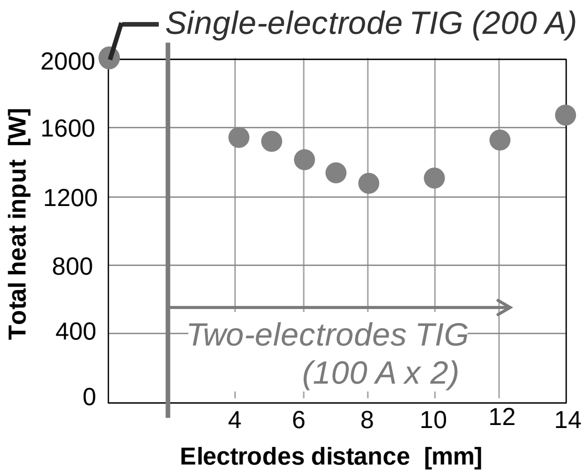

Fig. 5 Influence of electrodes distance on peak value of total heat input

4. Conclusion

In this work the heat source characteristics of two-electrode TIG are numerically investigated with three-dimensional TIG arc model. Results obtained are summarized as follows:

(1) In the two-electrode TIG arc, both distributions of heat input density and arc pressure significantly change depending on electrode distance.

(2) The total heat input of the two electrode TIG arc does not change so much even if the electrodes distance changes.

(3) The two-electrode TIG arc with appropriate electrodes distance serves as a "soft" heat source with high heat input.

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