A Study on the macro-micro physical properties in pulsed arc plasma†

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KEY WORDS: (Pulsed arc) (High frequency) (Diffusing mode) (TIG welding) (Physical properties)

1. Introduction

Extensive research has been reported on pulsed arc welding and its effects over the past decades. The advantage of the pulsed arc summing-up in the literature, however, mostly concerns weld metallurgy, including refinement of fusion zone grain size and substructure, reduced width of HAZ and so on [1]. Mechanical property improvement of welding joint always was explained as an evidence of the effects. To deepen the understanding of pulsed arc physical properties, a study on the effects of pulsed TIG welding arc is made from lower frequency to higher frequency up to 80 kHz in both electric and thermal respects.

2. Macro View of Pulsed TIG Arc

Welding is carried out using a TIG welding machine (EWM Tetrix 500) as base current source (BCS). A high frequency current producing device is used as peak current source (PCS), and it works with BCS synchronously for generating square current waveform. Welding conditions are as follows: Φ3.0 mm, 2% Ce-tungsten electrode with 60º tip angle; Argon shielding gas 10l/min and 4 mm arc length. Welding parameter setting : I_p = 100A, I_b = 50A. **Figure 1** shows the arc profiles changing in the "electric-thermal transfer" mode from a diffuse to a lift-up attachment with pulse frequency increasing [2], and a ball-like arc column contracting towards tungsten cathode can be observed in the higher pulse frequency region. **Figure 2** shows a trend of the arc voltage U_p and U_b with frequency changing respectively. The phenomena of U_p going up with the increase of pulse frequency and strong oscillation appearing and taking 30% of the U_b period during the changing from I_p to I_b are rather noticeable.

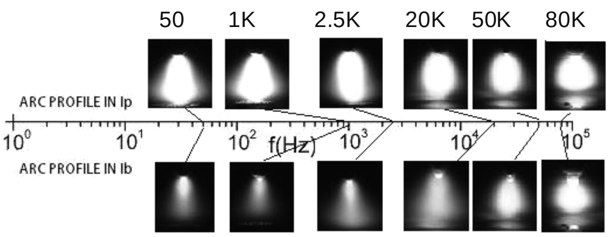

Fig. 1 A map of the arc profiles in different pulse frequancies

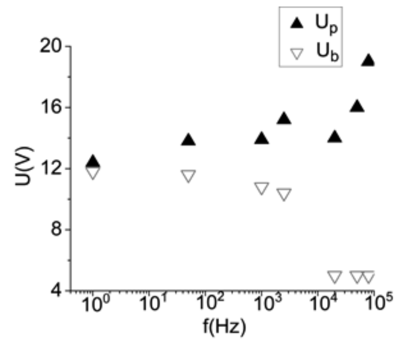

Fig. 2 Arc voltage *vs* pulse frequency

3. Micro View of Pulsed TIG Arc

Electron density in arc column is observed by Stark broadening spectrum and can be calculated using Stark broadening of the 656.3nm Hα emission line [3]. **Figure 3** shows a trend of the electron densities in the I_p period with frequency changing. The electron density goes down at higher frequencies though the input energy from power source to arc is increasing. It may indicate that arc column diffusing near the tungsten cathode instead of continually lift-up constriction at higher frequency in order to realise energy balance.

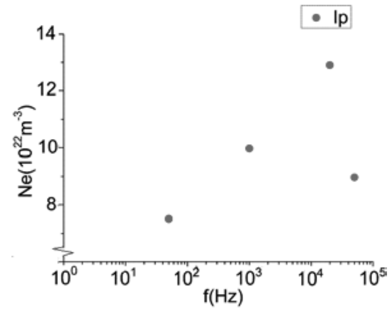

Fig. 3 Electron density N_e *vs* pulse frequency

4. Discussion

While energy frequency inputting to the arc near or reaching to the order of the critical time of energy transfer based on electron-collision mode[3], a positive potential drop would be needed in order to transport the energy from

† 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

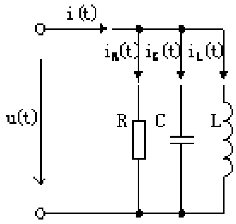

Fig. 4 Arc dynamic impedance model

the arc column into the anode. It would be a reason to explain the phenomena of U_p going up with increase of pulse frequencies.

According to the experimental result, the TIG arc may be not the first-order inertial link under the higher frequency condition, but a second-order link with the obvious oscillation phenomenon in the view of electricity. An arc dynamic impedance model may be shown in **Fig. 4**, and the corresponding arc dynamic impedance transfer function may be expressed by:

$$Z(s)=\frac{U(s)}{I(s)}=\frac{s}{Cs^2+\frac{1}{R}s+\frac{1}{L}} \qquad (1)$$

According to the model, the inductance feature may play a main role at lower frequency region, and the capacitance feature may play a main role at higher frequency region. It would be a reason to explain the phenomena of U_b going down.

5. Conclusions

Based on the above discussion, the following results may be concluded:

(1) With the increase of pulse frequency, there are 2 diffusing modes in TIG arcs, that is, diffusing attachment towards anode at lower frequency region and ball-like diffusing near cathod at higher frequency region. The phenomenon of continual constriction with the frequency increasing is not as expectation, only a slight constriction of the arc at the lower frequency region can be identified.

(2) The electron density distribution with frequency changing may support the profiles of pulsed arc in some diffusing modes. It may be helpful to understand the physical properties of free burning TIG arcs.

Acknowledgement

This work is financially supported by the Chinese NSF, project no. 50375005.

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