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Effects of Current Pulsation on Weld Solidification Structure of Aluminum Alloys †

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In order to produce the grain refinement of solidification structure of weld, some techniques have been developed, such as the arc vibration and weaving, the ultrasonic vibration and the weld pool stirring by electromagnetic force. The essence of these methods is the generation of dendrite fragmentation at the growing solid-liquid interface by forced thermal fluctuations[1].

Despite that pulsed arc welding is seemed to be an established process to generate these fluctuations by varying the energy input into the weld pool, pulse conditions which are suitable to generate effective grain and substructure are less provided.

In this note, the simplified pulsing condition of current of GTA welding to be effective in introducing the grain refinement of aluminum alloys are described and discussed.

Chemical compositions of alloys used in the experiment are shown in **Table 1**. Experimental procedure is schematically illustrated in **Fig. 1**. A testing specimen which is 200 mm in length, 100 mm in width and 8 mm in thickness, is put on a thick copper plate. The plate is fixed on the carriage which is smoothly movable with a constant speed of 300 mm/min. GTA bead-on-plate welding of d.c. straight polarity with He-gas shielding of 35 liters/min in flow rate has been carried out with a distance of 2 mm between the tungsten electrode and the specimen. The averaged value of welding current is 220A, and the rectangular pulse current whose amplitude is I_A is superposed to the d.c. current, shown in **Fig. 2**.

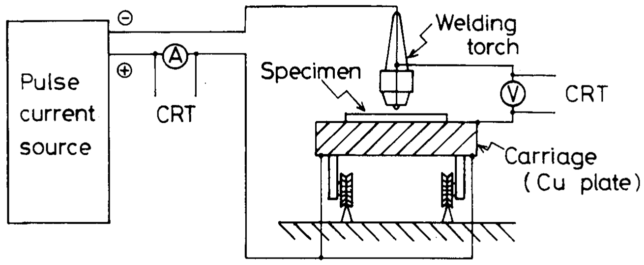

Fig. 1 Schematic illustration of experimental apparatus.

The macrostructure of bead surface in various cases of pulse condition are shown in Fig. 2. It is found that the refinment occurs only over a limited range of pulse condition. The frequency range suitable to effective refinement is below about 10 Hz. With current modulation of above about 20 Hz, the refinement is appreciable only in the region near the fusion boundary and the continuous columnar growth re-established in the central region of the bead. In the case that modulation amplitude I_A is lower than 80 A, the effect of current modulation on the macrostructure is not remarkable.

In **Fig. 3**, typical wave-forms of current and voltage of

Table 1 Chemical composition of materials used

Material	Chemical composition (wt.%)								
	Cu	Si	Fe	Mn	Mg	Zn	Cr	TI	B
1070-0	<0.01	0.05	0.13	<0.01	<0.01	0.01	–	0.004	<0.002
5052-0	0.02	0.10	0.27	<0.01	2.36	0.01	0.19	0.009	<0.002
5083-0	0.01	0.14	0.18	0.65	4.60	0.01	0.10	0.008	<0.002

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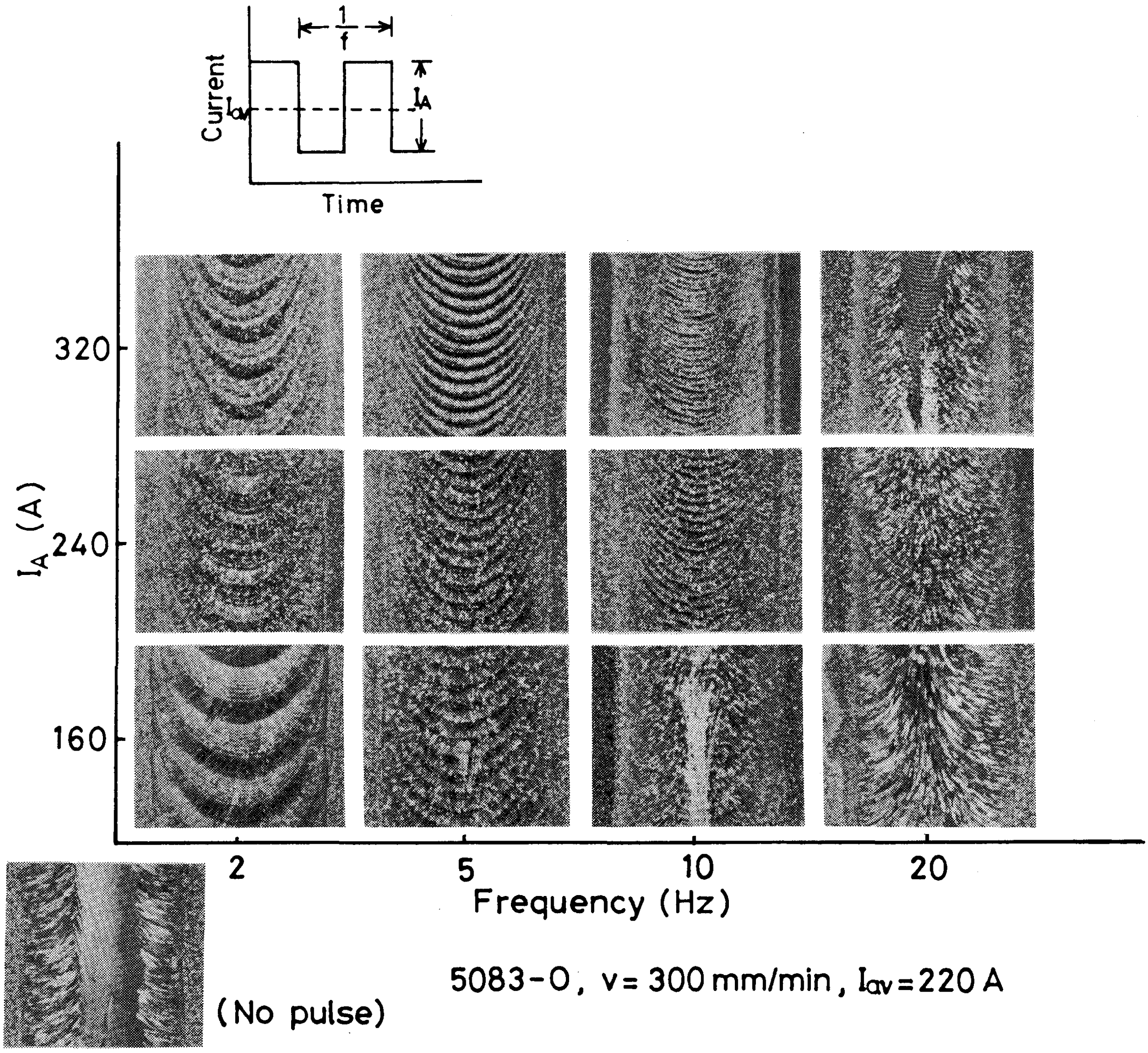

Fig. 2 Pulse current wave-form and macrostructure of bead surface in various case of pulse conditions. Material: 5083, f: frequency, I_A: modulation amplitude of current.

the arc are displayed. Small fluctuations appeared in the voltage wave-form are identical with the surface ripple lines in number. In the duration of higher voltage, it is damped oscillation and the frequency is lower than that in the lower voltage duration. It is considered that these fluctuations are due to the oscillations of the molten metal in the pool excited by the physical disturbance by pulsation of arc pressure. These fluctuations, however, seem to have no correlation to the refinement of structure. In **Fig. 4**, micro- and macro-structures of the longitudinal cross section in the case that the frequency is 2 Hz, the welding speed is 300 mm/min and the modulation amplitude I_A is 360 A are shown. It is clearly evident that the banding in which very effective grain refinement is produced, is associated with the front of current pulse. Very rapid change in the arc force caused by that of the current generates vigorous movement of the molten metal which fragments to supply the nuclei.

Two other types of material are used in order to observe the effect of the difference in material compositions. 1070 and 5052 alloys are both of very lower susceptibility to grain refinement by the electromagnetic stirring and especially with 1070 alloy is given no evidence of the refinement[2), 3)]. Shown in **Fig. 5**, the interface of banded zone in which grain multiplication produced by fragmentation of dendrites resulting from the forced washing of the liquid metal by impulsive arc pressure at the pulse front can be observed in 5052 alloy. In 1070

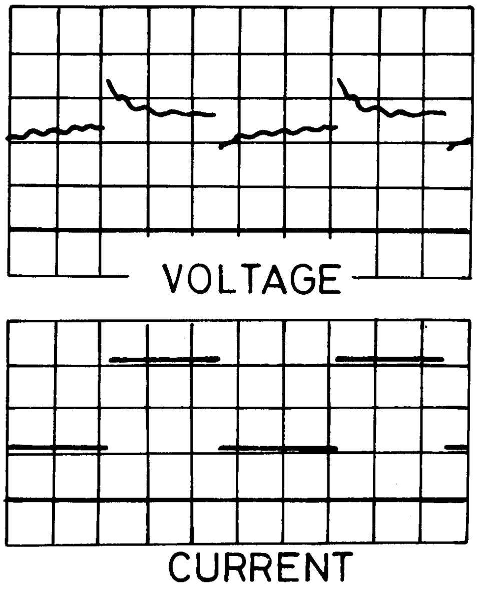

Fig. 3 Typical current and voltage wave-forms in case of f = 10 Hz, I_{av} = 220 A and I_A = 200A.

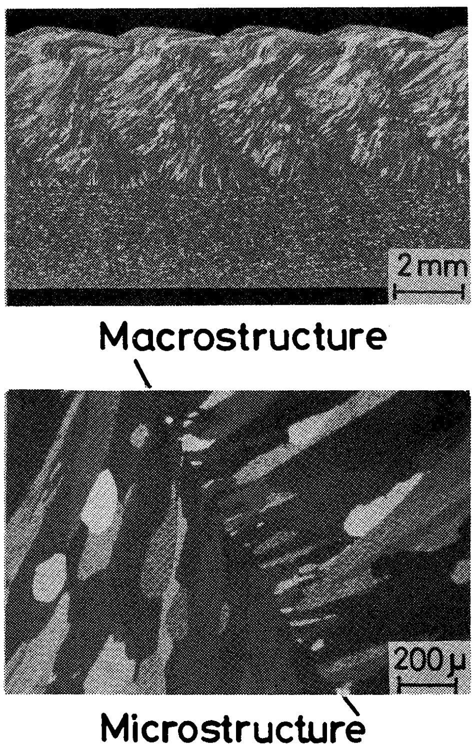

Fig. 4 A longitudinal cross section of 5052 weld bead in case of f = 2 Hz, I_{av} = 220A and I_A = 360 A.

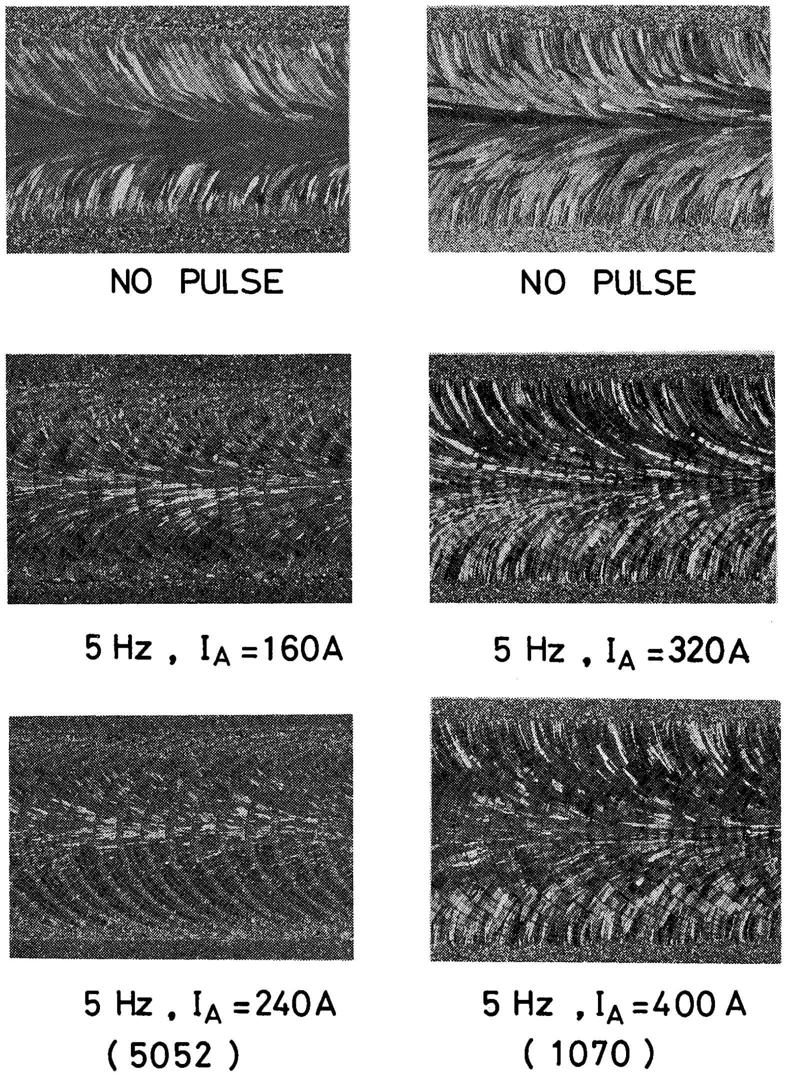

Fig. 5 Application of current pulsing to 5052 and 1070 alloys.

alloy, the grain multiplication in its region is not so remarkable as that in 5052 alloy, especially below the surface region. These results are almost similar to those of electromagnetic stirring with thick plate[3].

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