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ARTICLE

Influence of Cold Metal Transfer Process and Its Heat Input on Weld Bead Geometry and Porosity of Aluminum-Copper Alloy Welds

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Abstract: The weld bead geometry and the porosity of AA2219-T851 high strength aluminum alloy welds with ER2319 wire produced by different cold metal transfer (CMT) processes and heat inputs were investigated. The results show that a narrow finger-shaped geometry is observed using the conventional CMT process and a large number of gas pores exist in the lower and upper parts of welds. Compared to results of above mentioned CMT process, the weld melting area is increased using CMT-pulse (CMT-P) process, and it is beneficial to reduce the porosity effectively with an appropriate heat input. The finger-shaped geometry with lower melting depth using CMT-advanced (CMT-ADV) process and the spherical-shaped bead geometry with lower dilution using CMT-pulse advanced (CMT-PADV) process are achieved. The gas pore is reduced predominantly and even eliminated due to the lower heat input and the effective oxide cleanliness of wire ends for the two processes.

Key words: aluminum alloy; cold metal transfer; heat input; weld bead geometry; porosity

Cold metal transfer (CMT) process is a relatively novel welding technique which is characterized by its low heat input, no-spatter and high deposition rate[1]. Recently CMT has been developed into different droplet transfer modes which are conventional CMT, CMT pulse (CMT-P), CMT advanced (CMT-ADV) and CMT pulse advanced (CMT-PADV). At present, CMT has been employed in the welding fabrication of Al alloy thin plates[2,3], Al/steel alloys[4] and Al/Mg dissimilar alloys[5,6], etc. It has been observed that this process exhibits greater control of weld dilution which is beneficial in thin plates welding. In the actual welding fabrication of Al alloys, weld bead geometry as a significant impact and porosity as one of the most important defects, effectively affect and restrict the weld quality of Al alloys. However, in the previous research, few literatures have been published on the characteristics of weld bead geometry and porosity in Al alloy welds produced by these CMT processes. In the present paper, the aforementioned four different CMT processes with the variation of heat input were employed in the welding of Al-Cu alloy with ER2319 wire, their influences on the weld bead geometry and porosity were investigated, and the mechanism of porosity generation was also discussed, so as to provide a theoretical reference and practical experience for the welding fabrication of Al alloys and wire arc additive manufacturing (WAAM) of Al alloys with no porosity.

1 Experiment

The wrought AA2219 (temper T851) 19 mm thick plates with a chemical composition of Cu 6.3, Mn 0.3, Si 0.2, Fe 0.3, Zr 0.18 and Al balance (all in wt%) were used as substrates. ER2319 wire with 1.2 mm in diameter with a chemical composition of Cu 6.3, Mn 0.3, Zr 0.175, Ti 0.15, V 0.1 and Al balance (all in wt%) supplied by VBC group was used in its as-received condition. All the substrates were cleaned shortly before being used, by degreasing with acetone and linishing afterward.

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In the present study, all the experiments were carried out in an open atmosphere with torch shielding only. Fronius CMT Advanced 4000 R was employed as the power source. A single-pass welding process was performed and single bead welds of 100 mm in length were obtained using the aforementioned four CMT processes. Arc current and voltage of these four different CMT processes are shown in Fig.1, and the wire feed speed (WFS) was 7.5 m/min. In order to control the variation of heat input (HI), constant WFS=7.5 m/min and variable welding speed (WS) were used and the parameter details are given in Table 1. HI for different trials were calculated using the formula HI=$\eta(\sum U_i I_i)$/WS[7], where U_i and I_i are arc voltage and current for each sample, respectively, and η is the arc thermal efficiency of CMT process that was set to 0.8[8,9]. For all the trails, standard pure argon (99.99%) was used as shielding gas with a constant flow rate of 25 L/min, and the contact tip to work distance was kept to 15 mm.

The melting width B, melting depth H and weld reinforcement dH were used to describe the weld bead geometry as shown in Fig.2. The penetration R was calculated using the formula $R=H/B\times100\%$.

All samples were cut by a Discotom-60 automatic machining along the longitudinal and transverse directions. They were polished using a standard metallographic procedure, which consisted of grinding followed by polishing and etching. Specimens were etched with the standard Kroll's reagent solution (6 mL HNO_3, 2 mL HF, 92 mL H_2O). Porosity and microstructure examinations were carried out using an OPTIPHOT optical microscope. Pore size and weld bead geometry were measured using the Axio Vision SE64 software.

2 Results and Discussion

2.1 Weld bead geometry

Fig.3 illustrates the correlations between the geometry and WS and Fig.4 shows the transverse sections of each sample. It is observed that, for the conventional CMT, CMT-P and CMT-ADV processes, B and dH are reduced with the increase of WS corresponding to the decrease of HI (Fig.3a and 3c). H is stabilized with higher HI as shown in Fig.3b, which denotes that H is about 2.2, 2.1 and 1.5 mm, respectively, corresponding to HI variation in 207.3~331.6 J/mm for CMT process, 305.7~366.8 J/mm for CMT-P process and 273.4~341.6 J/mm

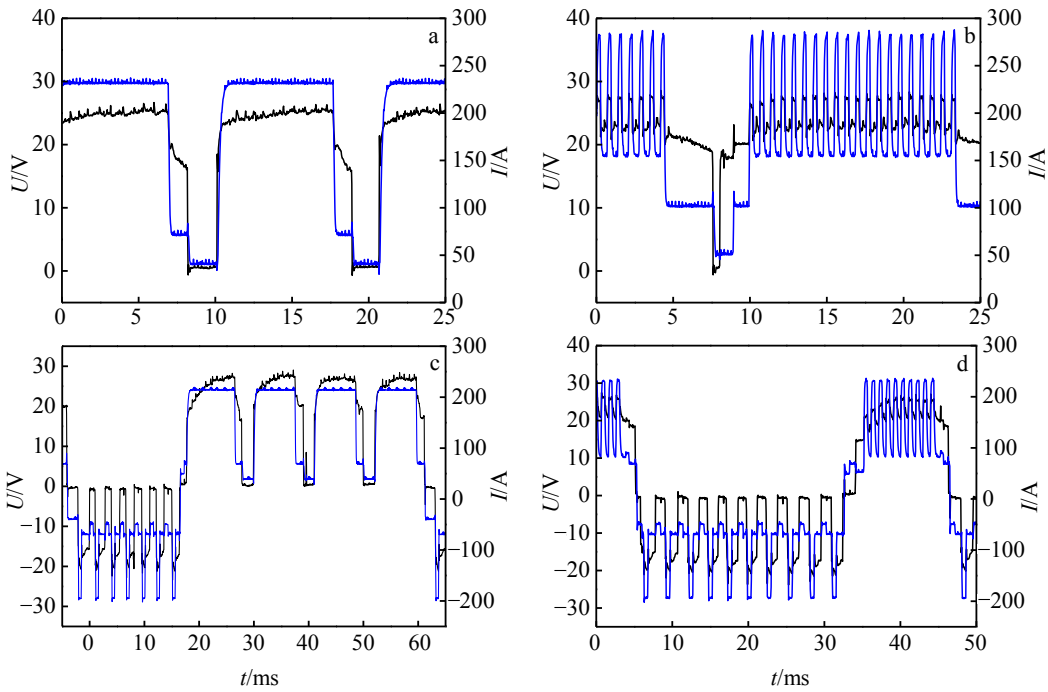

Fig.1 Arc voltage and current waveforms: (a) conventional CMT, (b) CMT-P, (c) CMT-ADV, and (d) CMT-PADV (WFS=7.5 m/min)

Table 1 Welding speed setting and the calculation of heat input

Serial No.	CMT		CMT-P		CMT-ADV		CMT-PADV	
	WS/m·min^{-1}	HI/J·mm^{-1}	WS/m·min^{-1}	HI/J·mm^{-1}	WS/m·min^{-1}	HI/J·mm^{-1}	WS/m·min^{-1}	HI/J·mm^{-1}
1	1.0	165.8	1.0	183.4	0.8	170.8	0.5	135.4
2	0.8	207.3	0.8	229.3	0.6	227.8	0.4	169.3
3	0.6	276.3	0.6	305.7	0.5	273.4		
4	0.5	331.6	0.5	366.8	0.4	341.6		