



Segregation in fusion weld of 2219 aluminum alloy and its influence on mechanical properties of weld



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Abstract: Three kinds of welds were made using low frequency pulse current variable polarity tungsten inter gas (LPVPTIG) with argon shielding, direct current TIG (DCTIG) with helium shielding and high frequency pulse current variable polarity TIG (HPVPTIG) with argon shielding, respectively. It was found that macrosegregation bands with large amount of thick continuous eutectics and microporosities formed in the LPVPTIG weld due to the fluctuation of the pulse varied heat input. Only microsegregation existed in the DCTIG weld and HPVPTIG weld. However, the HPVPTIG weld had lower extent of Cu microsegregation since its welding speed was slower. The tensile results indicated that the mechanical properties of the weld decreased with the increase of the segregation extent of Cu and porosities, and LPVPTIG weld had lower tensile properties in the longitudinal direction than those in the transverse direction due to the macrosegregation bands.

Key words: 2219 aluminum alloy; fusion welding; macrosegregation; microsegregation; mechanical behavior

1 Introduction

The 2219 (Al–Cu) heat treatable aluminum alloy has outstanding mechanical properties at low temperature and the most readily weldability among 2000 series aluminum alloys [1]. Because of these characteristics, 2219 aluminum alloy is widely used for the fabrication of liquid cryogenic rocket fuel tanks. Although friction stir welding (FSW) [2,3] and variable polarity plasma arc welding (VPPA) [4,5] methods have superiority on the welding of 2219 aluminum alloy, tungsten inert gas arc welding (TIG) [6–8] is still necessary on the welding of complex structure due to its good flexibility. Owing to the low mechanical properties of the TIG weld, it is usually the weakness region of the welded structure. Solidifying segregation is one important factor that affects the mechanical properties of the TIG weld.

2219 aluminum alloy contains 5.8%–6.8% Cu exceeding the maximum Cu content (5.65%) in $\alpha(\text{Al})$ at the temperature of Al–Cu eutectic reaction. According to the Al–Cu binary phase diagram [9], there will be about 2.36% $\alpha(\text{Al})+\theta(\text{Al}_2\text{Cu})$ of eutectic generated under the equilibrium solidification condition. As is well known, the solidification process in the fusion weld is usually nonequilibrium, which results in the microsegregation of Cu. Thus, the amount of eutectic in the weld is higher than 2.36% and the Cu content in the $\alpha(\text{Al})$ matrix is lower than 5.65%. For heat treatable aluminum alloys, the weld metal strength mainly depends on the solute supersaturation since it determines the subsequent aging response and the yield strength [10]. Besides microsegregation, macrosegregation may also exist in the fusion weld and affect the solute redistribution. Pulse varied heat input during welding is one of the acknowledged causes for macrosegregation. Although TIG technique is frequently used for the welding of 2219

aluminum alloy, the segregation behavior in the weld and its influence on the mechanical properties of the weld are lack of systematically study.

In this study, three kinds of welds were made using low frequency pulse current variable polarity TIG (LPVPTIG) with argon shielding, direct current TIG (DCTIG) with helium shielding and high frequency pulse current variable polarity TIG (HPVPTIG) with argon shielding, respectively. Macrosegregation and microsegregation in the welds and their influence on the mechanical properties of the welds were quantitatively investigated. Temperature contours in different welding processes were acquired by numerical simulation. The advancing processes of the solidification front and the solidus interface in the welding process were extracted according to the evolution of temperature contours. Based on these data, the segregation behavior in different welding processes was analyzed.

2 Experimental

2.1 Materials and welding

The base material used in this study was 2219-T8 aluminum alloy. T8 stands for solution heat treating, cold working and artificial aging. The filler metal was 2325 aluminum alloy. The standard chemical compositions of the base material [11] and the filler metal are listed in Table 1. The chemical compositions of the main alloy elements measured by inductively coupled plasma-

atomic emission spectrometer are in the standard range. Since the filler metal almost had the same Cu content with the base material, the average Cu content in the welds was considered to be the same. Three kinds of joints were welded using different welding processes. The first one was butt welded using LPVPTIG with filler metal automatically fed into the singe-V groove. The second one was butt welded using DCTIG without filler metal. The third one was butt welded using HPVPTIG with filler metal manually fed intermittently. The dimensions of the weld plates are shown in Fig. 1. The power source for the first two welding processes was Miller Dynasty 700. The power source for HPVPTIG weld was developed by CONG et al [12]. The welding parameters for different welding processes are listed in Table 2. The pulse frequency for LPVPTIG was 0.8 Hz, while it was 40000 Hz for HPVPTIG. Figure 2(a) shows the schematic diagram of the current waveform for LPVPTIG, of which the variable polarity frequency was higher than the pulse frequency. The current waveform of the HPVPTIG was quite different from that of the LPVPTIG as shown in Fig. 2(b). The high frequency pulsed current was on the direct current electrode negative (DCEN) polarity of HPVPTIG.

2.2 Microstructure examination

The weld samples were cut from the welded plates using electro-discharge cutting machine. Then, the samples were ground by SiC paper from 400 to 2000 grift,

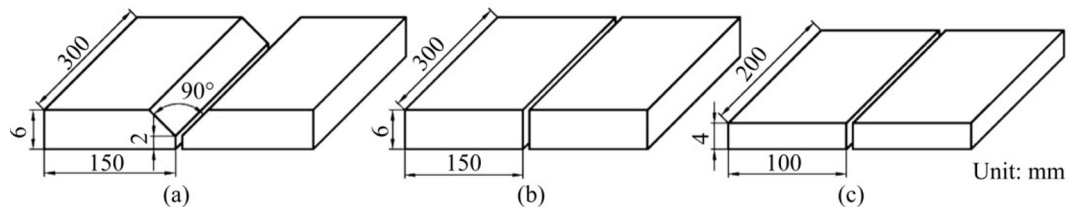


Fig. 1 Dimensions of weld plate and weld groove for different welding processes: (a) LPVPTIG; (b) DCTIG; (c) HPVPTIG

Table 1 Chemical compositions of 2219 and 2325 aluminum alloys (mass fraction, %) [11]

Alloy		Si	Fe	Cu	Mn	Mg	Zn	Ti	Zr	V	Al
2219	Standard	0.2	0.3	5.8–6.8	0.2–0.4	0.02	0.1	0.02–0.1	0.10–0.25	0.05–0.15	Bal.
	Actual	–	0.18	6.18	0.31	–	–	–	–	–	–
2325	Standard	–	–	6.0–6.8	0.2–0.4	–	–	0.1–0.2	–	–	Bal.
	Actual	–	–	6.32	0.34	–	–	–	–	–	–

Table 2 Welding parameters for different welding processes

Welding process	Peak/base arc current I/A	Peak/base arc voltage U/V	Welding speed $v_w/(\text{mm}\cdot\text{s}^{-1})$	Flow rate of shielding gas $v_g/(\text{L}\cdot\text{min}^{-1})$	Pulse time ratio δ	Variable polarity frequency f_v/Hz	Pulse frequency f_p/Hz
LPVPTIG	320/165	23.8/17.5	2	10 (Ar)	0.63	55	0.8
HPVPTIG	220/165	19.5	2	10 (Ar)	0.5	100	40000
DCTIG	170	17.2	4.3	10 (He)	–	–	–

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