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Materials Science and Engineering A 404 (2005) 227–234

MATERIALS SCIENCE & ENGINEERING A

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Grain refinement through arc manipulation techniques in Al–Cu alloy GTA welds

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Received in revised form 19 May 2005; accepted 19 May 2005

Abstract

Effect of three arc manipulation processes pulsed current welding, magnetic arc oscillation and the simultaneous application of pulsed current and arc oscillation, on the weld metal grain structure and tensile properties of the welds were investigated. Initial studies were conducted on autogenous welds made on 3.5 mm thick 2219-T6 plates, to identify and optimize, welding parameters resulting in fine equiaxed grains in the weld metal. Welds were made on 8.5 mm thick 2219-T87 plates using the optimized parameters and tested for tensile properties. All three techniques resulted in fine equiaxed grains in weld metals and optimum parameters were suggested based on the extent of refinement. Fine-grained weld metals exhibited better yield and ultimate tensile strengths and significant improvement in percent elongation. The reasons for the same were explained with the help of TEM and EPMA studies.

Keywords: Pulsed current welding; Magnetic arc oscillation; Grain refinement; AA2219

1. Introduction

The aluminum alloy 2219 contains copper as the major alloying element and contains small amounts of manganese, iron, titanium, zirconium and vanadium. This alloy is commonly used for cryogenic applications due to its good strength and fracture properties between −200 and +200 °C. The alloy also offers high strength (Y.S −300 to 370 MPa in the aged condition) and good resistance to stress corrosion cracking. The alloy 2219 is considered to possess good weldability in the sense it is not prone to solidification cracking and can be easily welded using all conventional welding processes. However, the joint efficiencies are as low as 30–40%, mainly in thicker T87 plate welds. This fact is of concern in aerospace applications, because, use of thicker plates due to low strength of the weld metal results in heavier structures. If the yield strength of the weld metal can be increased by some means it will be of use in increasing the payload.

In general, the severity of a number of weld defects can be reduced if the solidification structure is refined. Certain novel welding techniques like dc pulsed current welding and magnetic arc oscillation have been employed to improve hot cracking resistance and mechanical properties in the late seventies [1–4]. It was shown by earlier Russian work [5] that the tensile, impact and corrosion properties of OT4-1 titanium alloy weld metal could be improved to the level of the base metal by applying electromagnetic stirring and encouraging heterogeneous nucleation. In other titanium alloys significant grain refinement was obtained using electromagnetic stirring while adding small amounts of Zr, which in turn resulted in improvement of mechanical properties [6,7]. AC pulsed current (PC) welding resulted in substantial grain refinement and increase in yield strength of aluminium–lithium alloy 1441 weld metal [8]. It has also been reported that a further increase in the Y.S could be obtained by the simultaneous application of AC pulsing and arc oscillation (AO). Other investiga-

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doi:10.1016/j.msea.2005.05.080

Table 1
Welding parameters used to make bead on plate welds on 2219-T6, 3.5 mm plates

S.No.	Welding process	Peak current (A)	Base current (A)	Pulsing frequency (Hz)	Oscillation frequency (Hz)	Arc oscillation model
1	Continuous current (CC)	120	–	–	–	–
2	Pulsed current (PC)	180	60	2,4,6,8,10	–	–
3	Magnetic arc oscillation (AO)	120	–	–	2,4,6,8,10	Linear and elliptical
4	PC + AO	180	60	2,4,6,8,10	2,4,6,8,10	Linear and elliptical

Welding speed = 140 mm/min.

tors [9–11] have reported the beneficial effects of welding with arc manipulation techniques, such as better corrosion resistance, resistance to stress corrosion cracking, higher UTS and ductility, lower segregation and higher resistance to hot cracking. The majority of the materials investigated have responded favorably and among them were aluminum alloys [12,13], steels, stainless steels [14–16] and titanium alloys [5–7,17,18]. More recently Janaki Ram et al. [19,20] have reported significant grain refinement and improvement tensile properties in type 2090 Al–Li alloy and type 7020 Al–Zn–Mg alloy due to pulsed current GTA welding. Significantly large amount of work was conducted on the issue of changing the fusion zone solidification structure from epitaxial columnar grains to fine equaxed grains and reviews on this subject were given by Kou [21] and David and Vitek [22].

In the present study, an attempt was made to evaluate the effect of AC current pulsing, magnetic arc oscillation and the simultaneous application of pulsed current and magnetic arc oscillation, on the solidification structure and mechanical properties of alloy 2219 weld metal.

2. Experimental details

Autogenous welds on a 3.5 mm thick 2219 alloy plate (T6 condition) were made using alternating current (AC) Gas Tungsten Arc Welding. Welding current and welding speed have been chosen in such a way that the heat input is approximately same (for 3.5 mm plates it was ∼920 J/mm and for 8.4 mm plates it was ∼1440 J/mm) and also results in through thickness melting of the plate. The parameters used to make bead on plate welds on 2219-T6 plates of 3.5 mm thickness are given in Table 1. Frequency of pulsing and frequency of oscillation are the parameters varied extensively to identify optimum parameters that would result in grain refinement. Schematic illustration of the arc manipulation techniques are given in Fig. 1. Electromagnetic oscillation of the arc was achieved using a Cyclomatic 90 A, controller, manufactured by Celecsco, USA. The oscillation equipment consists of a control panel and a magnetizing coil having four probes, which surround the tungsten electrode when fitted to the torch. The probe creates an electromagnetic field, which interacts with the electromagnetic field of the arc and makes the arc to deflect in a chosen pattern. The control unit allows the operator to apply different patterns of arc oscillation such as linear, circular or elliptical. The arc can also be oscillated either across the seam or along the seam. For this study arc has been magnetically oscillated in two different formats: linear and elliptical across the seam. Miller Syncrowave350

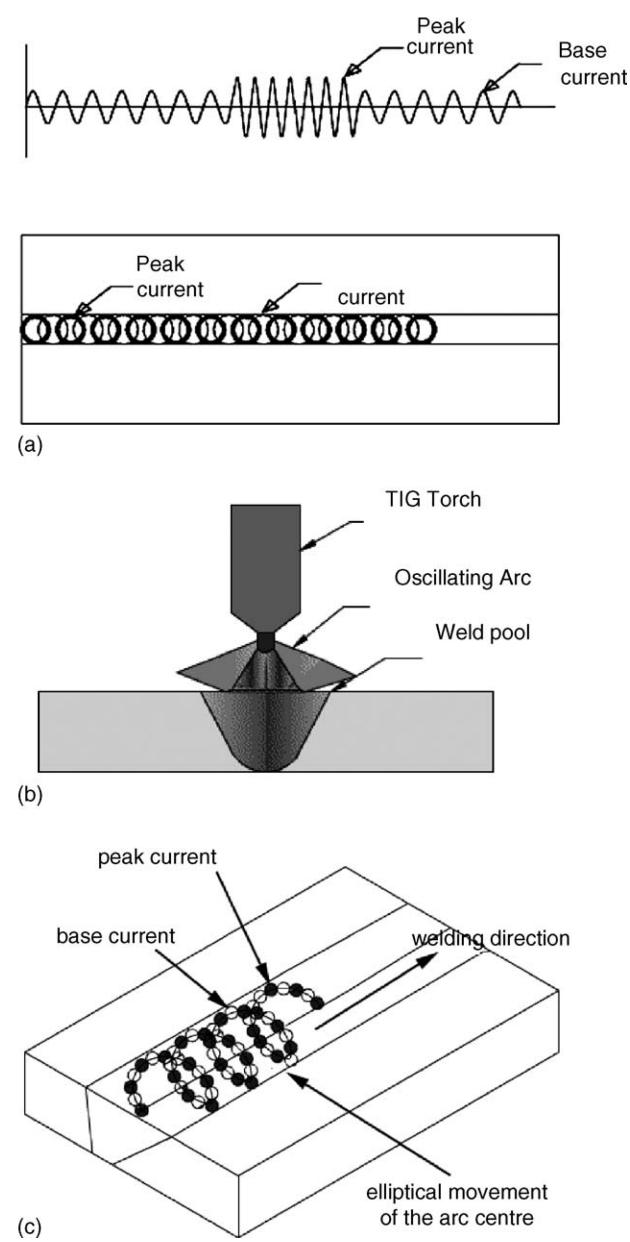

Fig. 1. GTAW arc manipulation techniques: (a) AC pulsed current welding, (b) magnetic arc oscillation and (c) pulsed current arc oscillation (elliptical mode).