Available online at www.sciencedirect.com
ScienceDirect
Trans. Nonferrous Met. Soc. China 21(2011) 278−286

Transactions of Nonferrous Metals Society of China
www.tnmsc.cn

Effect of pulsed current on temperature distribution, weld bead profiles and characteristics of gas tungsten arc welded aluminum alloy joints

N. KARUNAKARAN[1], V. BALASUBRAMANIAN[2]

1. Department of Mechanical Engineering, Annamalai University, Annamalai Nagar 608002, India;
2. Centre for Materials Joining and Research, Department of Manufacturing Engineering,
Annamalai University, Annamalai Nagar 608002, India

Received 23 February 2010; accepted 23 April 2010

Abstract: Temperature distribution and weld bead profiles of constant current and pulsed current gas tungsten arc welded aluminium alloy joints were compared. The effects of pulsed current welding on tensile properties, hardness profiles, microstructural features and residual stress distribution of aluminium alloy joints were reported. The use of pulsed current technique is found to improve the tensile properties of the weld compared with continuous current welding due to grain refinement occurring in the fusion zone.

Key words: aluminium alloy; gas tungsten arc welding; pulsed current; temperature distribution; bead profiles; tensile properties

---

1 Introduction

Reduction of mass is a prime concern for many industries involved in transportation especially the automobile industry, which has become significant because of fuel saving, reduction of emission and recyclability. Hence the focus on light weight materials like aluminium and magnesium has become predominant. Weldability of aluminium alloys has recently been investigated through a variety of processes, such as gas tungsten arc welding (GTAW), gas metal arc welding (GMAW) and friction stir welding[1−2].

In conventional welding, fusion zones typically exhibit coarse columnar grains because of the prevailing thermal conditions during weld metal solidification. This often results in inferior weld mechanical properties and poor resistance to hot cracking. It is thus highly desirable to control solidification structure in welds, but the control is often very difficult because of higher temperatures and higher thermal gradients in welds in relation to castings and the epitaxial nature of the growth process. Nevertheless, several methods for refining weld fusion zones have been tried with some success in the past: inoculation with heterogeneous nucleants, microcooler additions, surface nucleation induced by gas impingement and introduction of physical disturbance through techniques such as torch vibration[3]. In this process, two relatively new techniques, namely, magnetic arc oscillation and current pulsing, have gained wide popularity because of their striking promise and the relative ease and can be applied to actual industrial situations with only minor modifications of the existing welding equipment[4].

Pulsed current GTA welding, developed in 1950s, is a variation of GTA welding which involves cycling of the welding current from a high level to a low level at a selected regular frequency. The high level of the peak current is generally selected to give adequate penetration and bead contour, while the low level of the background current is set at a level sufficient to maintain a stable arc. This permits arc energy to be used efficiently to fuse a spot of controlled dimensions in a short time producing the weld as a series of overlapping nuggets, and limits the wastage of heat by conduction into the adjacent parent material in normal constant current welding. In contrast to constant current welding, the fact that heat energy required to melt the base material is supplied only during peak current pulses for brief intervals of time allows the heat to dissipate into the base material, leading to a narrower heat affected zone (HAZ). The technique has secured a niche for itself in specific applications such

---

Corresponding author: N. KARUNAKARAN; E-mail: cdl.karun28@gmail.com

DOI: 10.1016/S1003-6326(11)60710-3

as in welding of root passes of tubes, and in welding thin sheets, where precise control over penetration and heat input are required to avoid burn through[5].

Extensive research has been performed on this process and reported advantages include improved bead contour, greater tolerance to heat sink variations, lower heat input requirements, reduced residual stresses and distortion[6]. Metallurgical advantages of pulsed current welding frequently reported in literature include refinement of fusion zone grain size and substructure, reduced width of HAZ, control of segregation, etc[7]. All these factors will help to improve mechanical properties. Current pulsing has been used by several investigators to obtain grain refinement in weld fusion zones and improvement in weld mechanical properties[8−9]. However, reported research work on the effect of pulsed current on temperature distribution and bead profiles and their subsequent influence on tensile properties, hardness profiles and microstructure characteristics are very scant. Hence, the present study was carried out to understand the effect of pulsed current welding technique on the peak temperature, the cooling rate, the cross sectional weld bead profile, the microhardness, the residual stress distribution, the microstructure and the tensile properties of gas tungsten arc welded AA6351-T6 aluminium alloy joints.

2 Experimental procedure

In this investigation, plates with 4 mm in thickness were used as the base materials. The chemical compositions and mechanical properties of base metal are presented in Tables 1 and 2. These plates of aluminium alloy were cut to the required size (150 mm × 150 mm) by power hacksaw cutting and grinding. Square butt joint configuration was used to fabricate the welded joints. Single pass, autogenous welding procedure (without filler metal addition) was applied to fabricating the joints. High purity (99.99%) argon gas was used as shielding gas with a flow rate of 9 L/min. 2% thoriated tungsten electrode with 3.2 mm in diameter was used with DC straight polarity (electrode "−" and base plate "+") to carry out the experiments. The power source used in this investigation is capable of delivering pulsed current in DC mode only. The arc length was maintained at 2 mm.

Table 1 Chemical compositions of base metal (mass fraction, %)

Mg	Si	Fe	Cu
0.7	1.2	0.5	0.1
Mn	Zn	Zr	Al
0.6	0.2	0.05	Bal.

Table 2 Mechanical properties of base metal

Yield strength/ MPa	Tensile strength/ MPa	Elongation in 50 mm length /%	Micro hardness at 0.49 N load (HV)
150	250	20	95

The experimental setup is shown in Fig.1. The welding parameters were controlled by the Lincoln Electric TIG welding machine (Precision TIG 375). To measure the temperature during welding, the K type chromel-alumel thermocouple was used[10−12]. The hot end diameter of the thermocouple was 1.5 mm, the cold end was fixed to a thermocouple bank and was in turn connected to the DAQ Labview. Labview was a bundled package on virtual instrumentation having the flexibility to measure the parameter of concern at very short interval. Fig.2 shows the positions on the plate where the thermocouples were glued to a depth of 2 mm, the holes were drilled at the bottom of the plate[13]. The data acquisition system of LABVIEW was used to acquire the temperature during weld from these three locations as well as the room temperature.

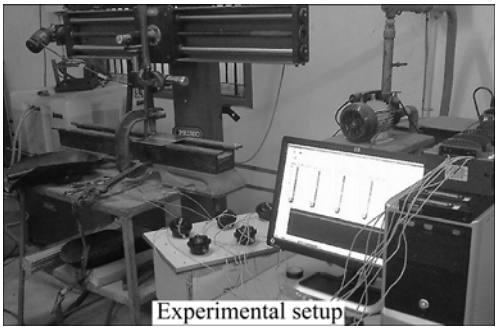

Fig.1 Experimental setup

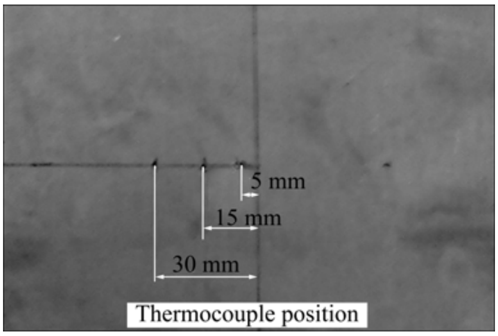

Fig.2 Thermocouple positions on plate

Before welding was performed, the plate was cleaned and thermocouples were incorporated at its appropriate positions. Welding was done by both the constant current (CC) and the pulsed current (PC) process. A number of trial runs on the base material were done to fix the upper and lower heat input levels. The CC higher than 120 A resulted in burning of base metal and in PC process the burning happened above 160 A.