Available online at www.sciencedirect.com
ScienceDirect
Materials Letters 61 (2007) 1288–1291
materials letters
www.elsevier.com/locate/matlet

Microstructure characteristics in TIG welded joint of Mg/Al dissimilar materials

Peng Liu [a,*], Yajiang Li [a], Haoran Geng [b], Juan Wang [a]

[a] *Key Lab of Liquid Structure and Heredity of Materials, Ministry of Education, School of Materials Science and Engineering, Shandong University (South Campus), Jinan 250061, Jing Shi Road 73, Shandong, PR China*
[b] *School of Materials Science and Engineering, Jinan University, Jinan 250022, PR China*

Received 3 July 2005; accepted 4 July 2006
Available online 21 July 2006

Abstract

The microstructure performance of Mg/Al TIG welded joint was studied by means of metallography, micro-hardness test and SEM. The test results indicate that the structure close to weld metal is columnar crystals, which grow into the weld metal. The weld metal was mainly composed of dendrite crystal. The micro-hardness near the fusion zone of Mg side is about HM 275–300. The brittleness phase with high hardness may be formed near the fusion zone. The fracture surface of Mg side shows a river pattern, which is a typical cleavage morphology. There are some hydrogen (H_2) air holes in the fracture of Mg side.

Keywords: Metals and alloys; Microstructure; Hardness; Fracture

1. Introduction

Mg alloys are the best and lightest metal materials which are used in high technology fields such as automotive, electron and aerospace industries. However, the welding technology between Mg alloys and other metals has been an important research field at present. For example, the fusion welding problem of Mg alloys and steel or Al alloys can exist in automotive manufacture. Welding of Mg and Al to form a compound structure can reduce the weight of the structure and the cost of the component [1,2]. The refractory oxide film of Mg and Al forms inclusions in the heat affected zone and since Mg has obvious thermal brittleness, the fusion welding of dissimilar materials Mg/Al is difficult. The test results indicate that distortion and crack in the heat affected zone of Mg can be produced [3,4]. Gas Tungsten Arc (GTA) and Electron Beam (EB) welding techniques have been used to study the weldability of Al-6063 to different casts of Mg alloys (AM50 and AZ31) [5]. Four different electrodes (Al-1050, Al-4043, Al-10 wt.% Sr, and AZ92) were used as the filler metal. A eutectic structure was observed near the fusion zone, so the β-Mg_{17} (Al, $Zn)_{12}$ close to the fusion zone center became dominant. Resistance spot welding was applied to welding both Mg alloy AZ31B plate and commercially pure Al plate [6]. In recent years, with the development and application of friction-stir welded (FSW) and vacuum diffusion bonding, Mg/Al dissimilar materials were welded successfully [7,8]. So it is necessary to study the welding technology and microstructure of Mg/Al diffusion bonded joint.

In this paper, the Mg/Al dissimilar materials were welded together by Gas Tungsten Arc welding (GTAW). The microstructure, micro-hardness distribution and fracture morphology were observed and analyzed by means of metallography, scanning electron microscope (SEM) and micro-hardness test. This is a helpful move to study and improve the microstructure performance of Mg/Al TIG welded joint, and open a new way to apply Mg/Al dissimilar materials.

2. Experimental

The test materials are magnesium (Mg1) and aluminum (1060) used in navigation. The dimension of the test plate was 100 mm × 40 mm in the test. The thickness of the test plate was 3 mm. The Mg/Al butting joint added welding wire SAl-3 was welded by means of some welding technology. The welding equipment was TIG welding machine of WSJ-500 type. The

* Corresponding author. Tel.: +86 531 8392924; fax: +86 531 2609496.
E-mail address: liupeng1286@mail.sdu.edu.cn (P. Liu).

0167-577X/$ - see front matter © 2006 Elsevier B.V. All rights reserved.
doi:10.1016/j.matlet.2006.07.010

Table 1
Chemical composition and thermo-physical performance of test materials

Materials	Chemical composition (wt.%)							
	Mg	Al	Cu	Fe	Si	Zn	Mn	Other
Mg1	99.50	–	–	–	–	–	–	0.5
Al 1060	0.03	99.6	0.05	0.35	0.25	0.05	0.03	
SAl-3		99.5		≤0.3	≤0.3			

Thermo-physical performance

Materials	Melting point (°C)	Boiling point (°C)	Density (g cm^{-3})	Average specific heat volume (J kg^{-1} K^{-1})	Heat conductivity (W m^{-1} K^{-1})	Resistivity (μ^{-1} Ω^{-1} cm^{-1})
Mg1	649	1090	1.74	1038	155.5	4.2
Al 1060	658	2494	2.70	934.8	217.7	2.66

Table 2
Welding technological parameters used in test

Welding current I/A	Welding voltage U/V	Welding velocity v/(mm s^{-1})	Gas flow (Ar)/(L min^{-1})
120	25	1.5	12

chemical composition and thermo-physical performance of the test plate and filler material were shown in Table 1.

The oxide film (Al_2O_3, MgO) at the welding location must be removed by chemical method before TIG welding. The surface oxide and contamination at the welding wire must be also removed. Then the workpieces welded were fixed at the welding table, and were welded by means of TIG welding. The welding technological parameters were shown in Table 2. During the welding the welding velocity and wire feed velocity should be balanced. The dimension of the welding plate and the shape of the weld bead were shown in Fig. 1.

A series of specimens was cut along the longitudinal direction of the TIG welded joint by a lining cutting machine. These specimens were made into metallographic samples, and then the samples were etched using 10% HNO_3 alcohol solution. The microstructure and fracture morphology near the fusion zone of the TIG welded joint were observed and analyzed by metallography and scanning electron microscope (SEM). The micro-hardness distribution of the fusion zone was measured by means of the micro-hardness test.

3. Results and analysis

3.1. Microstructure in the fusion zone of TIG welded joint

The microstructure in the fusion zone of Mg side for Mg/Al TIG welded joint was observed by means of metallography and SEM. The microstructure near the fusion zone was shown in Fig. 2. According to Fig. 2a, there is an obvious boundary between the Mg substrate and the weld metal. This is composed of Mg–Al structure formed in the processing of weld metal solidification. The structure close to the weld metal is columnar crystals, which grow into the weld metal. In Fig. 2b, the microstructure near the fusion zone is obviously different from the weld metal and Mg substrate. The columnar crystals close to the weld metal were shown regularly, and the length of the crystals is almost a half of fusion zone width.

The microstructure of the heat affect zone (HAZ) and weld metal for Mg/Al TIG welded joint was observed by SEM. Fig. 3a shows the microstructure between the Mg substrate and fusion zone. The Mg substrate close to the fusion zone was largely affected by the welding thermal cycle, and the crystals were small. However, the effect of the welding thermal cycle on Mg substrate far from the fusion line was lesser, and the microstructure was invariant by and large. The microstructure in the weld

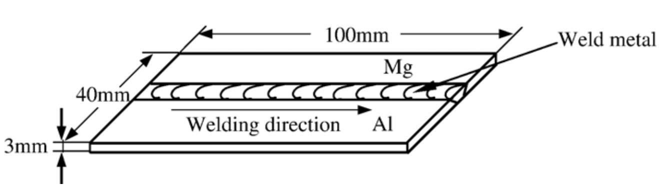

Fig. 1. Schematic diagram of the welding test plate.

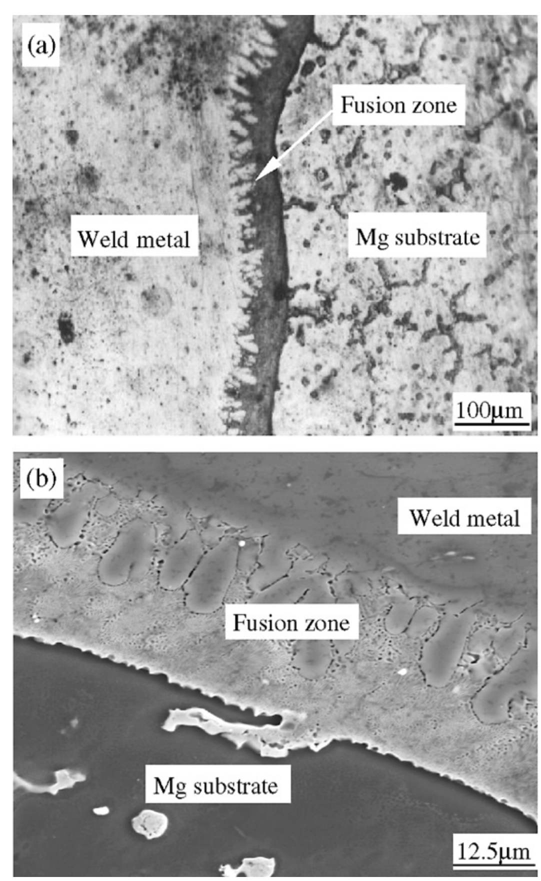

Fig. 2. The microstructure near the fusion zone of Mg side for Mg/Al TIG welded joint. (a) Metallography structure. (b) SEM structure.