Materials and Design 32 (2011) 3957–3965

Contents lists available at ScienceDirect

Materials and Design

journal homepage: www.elsevier.com/locate/matdes

Transient liquid phase diffusion bonding of Al/Mg_2Si metal matrix composite

H. Nami, A. Halvaee *, H. Adgi

School of Metallurgy and Materials Engineering, University of Tehran, Tehran, Iran

ARTICLE INFO

Article history:
Received 10 September 2010
Accepted 2 February 2011
Available online 8 February 2011

Keywords:
D. Diffusion bonding
E. Mechanical properties
F. Microstructure

ABSTRACT

As-cast Al/Mg_2Si metal matrix composite was joined by transient liquid phase diffusion bonding using Cu interlayer at various bonding temperatures and durations. This metal matrix composite contained 15% Mg_2Si and was produced through in situ technique by gravity casting. Specific diffusion bonding process was applied as a low vacuum technique. The microstructure of joints consisted of Al-α, $CuAl_2$ and Mg_2Si or Al-α and Mg_2Si depending on bonding temperature and duration. The maximum shear strength was achieved when samples were bonded at 580 °C for 120 min. Micro-hardness and compositional homogeneity of joints across the bonded interface were improved with increasing the bonding duration at 560 °C and had no significant changes at 580 °C.

1. Introduction

Aluminum metal matrix composites (MMCs) possess considerable advantages over aluminum alloys and are becoming more popular in industrial applications [1]. The growing demand for more fuel-efficient vehicles in order to reduce energy consumption and air pollution is a challenge for the automotive industry. Recently, Al/Mg_2Si metal matrix composites have been developed for high-performance applications in automotive industries [2]. Al- and Mg-based composites, reinforced with particulates of Mg_2Si have been recently introduced as a new group of particulate metal matrix composites which offer attractive advantages such as low density, good wear resistance and good castability. Al/Mg_2Si metal matrix composites are good replacement for Al–Si alloys used in aerospace and engine applications [3]. Application of any advanced material depends mostly on the development of processing technology. Joining of Al/Mg_2Si metal matrix composites has been a critical factor promoting their application as industrial components.

Fusion welding processes are inefficient for joining of composites due to poor flowability of the liquid welding pool, undesirable interfacial reaction between the matrix and reinforcement and defects such as porosity [4–6]. Solid state diffusion bonding of Al/Mg_2Si metal matrix composites using Cu interlayer has been evaluated in our previous work [7]. Transient liquid phase (TLP) diffusion bonding has been widely used for joining of Al metal matrix composites [8,9], in this work, the authors have preliminarily evaluated the TLP diffusion bonding feasibility for joining of Al/Mg_2Si metal matrix composites using Cu interlayer.

TLP diffusion bonding is a joining process which involves formation of a metallurgical bond. A liquid layer forms and isothermal solidification takes place due to inter-diffusion of atoms at a constant bonding temperature [10–13]. It is generally considered that TLP diffusion bonding consists of four different stages:

1. Dissolution of the interlayer.
2. Widening and homogenization of the interlayer.
3. Isothermal solidification.
4. Homogenization of the bond region.

Early two stages are controlled by liquid diffusion and may last from less than a minute to few minutes. However, last two stages are controlled by solid diffusion and may need several hours for completion. Diffusion occurs some 100–1000 times faster in liquid than in the solid state. The third stage is completed when the whole joint area solidifies isothermally. Effective parameters on this stage are bonding time and temperature. The solid–liquid interface moves towards the bond centerline. If conditions for completion of isothermal solidification are not satisfied, residual liquid at the bond centerline solidifies during cooling [14,15].

TLP diffusion bonding of Al metal matrix composites is commonly performed under a high vacuum or high pressure inert gas environment. The process presented in this research recommends a low vacuum technique using active coal particles. It is known that TLP diffusion bonding is carried out under low bonding pressure. Applying high pressure in TLP diffusion bonding of Al metal matrix composites involves with the aggregation of particles at the interface. Applying a high pressure may have an interesting effect on expulsion of aggregated particles–liquid from the interface. In this research, TLP diffusion bonding was performed under a relatively high pressure (6 MPa).

* Corresponding author. Address: School of Metallurgy and Materials, Faculty of Engineering, University of Tehran, North Kargar Avenue, Tehran, Iran. Tel.: +98 21 61114104; fax: +98 21 88006076.
E-mail address: halvaee@ut.ac.ir (A. Halvaee).

0261-3069/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.matdes.2011.02.003