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Liquid Phase Diffusion Bonding of AC2C/ADC12 Aluminum Casting Alloy by Using Metal Salt Coated Zn Sheet

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Abstract

Currently, the common way of bonding aluminum together is brazing. However, brazing creates problem when the high brazing temperature causes the formation of brittle intermetallic compound in between the joints prompting the need to circumvent this difficulty by considering transient liquid phase diffusion bonding method as a possible alternative. Being considered as a possible alternative solution, transient liquid phase diffusion bonding is not without problems that need to be overcome. One of these problems is the presence of oxide film on the insert material surface (Zn) necessitating the need to remove or destroy the oxide film without using high temperature and high load. Hence, in this study, the aim is to treat the bonding surface with formic acid for the removal of oxide film and substitution to a metal salt to determine the effectiveness of such treatment by performing tensile test and observation on the fractured surface of samples. From this study, it is found out that the tensile strength of the joint increased with the rise in bonding temperature with or without metal salt generation processing. However, it is understood that with metal salt generation processing, high strength joint can be obtained with lower bonding temperature compared with unmodified joints. It is hypothesized that this is because metallic zinc is generated as a result of surface modification and thermal decomposition of formate in the bond interface at low bonding temperatures.

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Keywords: Metal salt generation bonding; Tensile strength; Fracture; Aluminum alloy; Zn; Formic acid

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1. Introduction

Aluminum alloy is used in various parts of the car such as the engine, transmission system and wheel and is easy to recycle due to its low melting point. In the past, methods such as brazing and friction stir welding have been used as ways to bond aluminum alloy [1, 2]. However, the adverse effect of halogen in the flux has on the environment is also something need to be concerned [3]. Besides that, aluminum is also excellent at radiating heat and conducting electricity therefore making it difficult to be bonded together using other welding methods [4]. Because of the limitations, transient liquid phase diffusion bonding is considered to be the most suitable method to connect materials at low bonding temperature. However, the oxide film on the bonding surface prevented the atoms from different bonding surfaces from contacting with each other thus lowering the bonding strength [5]. Therefore, it is necessary to treat the bonding surface to remove the oxide film before transient liquid phase diffusion bonding.

In this study, transient liquid phase diffusion bonding between aluminum alloys and zinc is carried out on zinc surfaces treated for metal salt generation processing using formic acid. After that, examinations are carried out to determine the effectiveness of the metal salt generation processing. The soundness of the joint is tested by carrying out the tensile test. Afterwards, the observation of the fractures surfaces after tensile test is performed followed by FT-IR analysis on the product produced after metal salt generation processing.

2. Experimental details

As shown in Fig. 1(a), the Al alloy specimen is a cylindrical bar cut from AC2C and ADC12 aluminum casting alloy (refer Table 1, Table 2). The rounded part of the specimen provided it to avoid stress concentration. The bonding surface is polished with a #1200 emery paper. As shown in Fig. 1(b), the pure Zn sheet specimen (thickness: 0.2, 0.8, 2.0 mm, 99.9%) with dimensions of 10 mm × 10 mm were used in this study. Transient liquid phase diffusion bonding is performed under a N_2 gas atmosphere using the following conditions; 20 MPa for bonding pressure, 15 min for bonding time and 673~733 K for bonding temperature. As for the bonding pressure, it is applied to the sample before the start of the heating process until the end of the heating process. The heating rate is fixed at 0.5 K/s. Zn sheet surfaces were modified by boiling in formic acid for predetermined time for metal salt generation on the bonding surface. In addition, the surface modified Zn sheet specimen is readied for transient liquid phase diffusion bonding in a N_2 gas atmosphere chamber within 3 min after metal salt generation processing to avoid oxidation or changes to the bonding surface due to moisture absorption. Accordingly, the effect of the thickness and the modification time of the Zn filler metal on the tensile strength of joint is investigated. After transient liquid phase diffusion bonding, the strength of the joint is evaluated using a tensile test. The tensile test is performed using INSTRON 5567 universal test machine at room temperature using a displacement speed of 0.017 mm/s. To identify the compound that is produced on the bonding surface after metal salt generation processing, the Zn sheet surface is inspected using grazing-angle incidence reflection-absorption infrared (GIRAS-IR) spectroscopy to obtain IR spectra at a nanometer-scale depth from the modified Zn surface. The spectra were obtained by a FTIR spectra (Thermo Fisher Inc. Magna-750) equipped with an MCT detector using a single reflection accessory (Harrick Inc. Seagull) at an incident angle of 80° using a mercury-cadmium-telluride detector. An Au-coated mirror surface was used as the reflection reference and measurements were carried out at a wavenumber resolution of 8 cm^{-1}.

Table 1. Chemical composition of AC2C used in this study.

Elements	Cu	Si	Mg	Zn	Mn	Ni	Sn	Al
mass%	0.5~1.1	6.5~7.5	0.2~0.4	<0.1	<0.1	<0.1	<0.1	Bal.

Table 2. Chemical composition of ADC12 used in this study.

Elements	Cu	Si	Mg	Zn	Mn	Ni	Sn	Al
mass%	1.5~3.5	9.6~12	<0.3	<3.0	<0.5	<0.5	<0.3	Bal.