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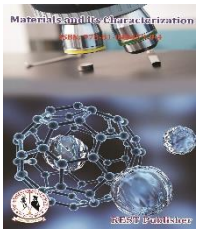

Mechanical And Metallographic Characteristics of Aa6061/Aa7075 Aluminium Alloy Diffusion Bonded Joints

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Abstract: *Diffusion bonding is a solid-state joining technique that is particularly well suited for combining dissimilar alloys. It is highly dependent on the process parameters being optimal in order to achieve high-quality bonding. The extent of atomic diffusion, as expressed by the thickness of the interface layer, has also been shown to be significantly related to the mechanical strength of the joints. AA6061/AA7075 aluminium alloys were used in this work, and the shear strength and ram tensile strength of the diffusion bonded joints were measured and analysed. The joint strength rises with increasing interface thickness up to 6 m and declines with increasing thickness owing to the production of brittle intermetallics when the interface thickness is increased further.*
Key words: *Mechanical strength, Metallographic characteristics.*

1. INTRODUCTION

When it comes to non-ferrous materials, aluminium and its alloys are being used in place of conventional metals in the automotive and structural industries. This is due to their unique characteristics including high strength and corrosive resistant properties. They are also lightweight and have a low density. They also have high reflectivity, ductility, and are proven to be reliable [1]. Traditional welding procedures, on the other hand, are more difficult to use when fusing incompatible grades of aluminium alloys together because of the varying solidification modes of the alloys and filler materials [2]. Furthermore, oxidation of these alloys while they are still in the molten state leads in the development of brittle intermetallic compounds, which reduces the strength of the joint [3]. Incorporating solid state diffusion bonding to join them can help to reduce the occurrence of fracture development, deformation, and segregation of grain boundaries, resulting in increased strength [4]. Derby and colleagues [5] asserted that the most challenging aspect of doing diffusion bonding is keeping the aluminium surface free of oxide development and determining the right process variable for sound bonds. Researchers Kellerer et al. discovered that the surface roughness of the faying surface is proportional to the creep rate of the material, which is dependent on temperature and encourages grain development across the joints [6]. Diffusion bonding process factors such as bonding temperature, pressing load, and pressure duration have been revealed to be the most influential in recent research [7]. According to the literature [8], the process temperature for diffusion bonding was generally kept between 0.5 and 0.8 of the melting temperatures of the materials used. For local plastic flow of the material to the adjacent interface to fill interfacial gaps and disperse surface oxide coatings, the load must be carefully adjusted to ensure that the material flows to the adjacent interface in a controlled manner. The holding time required for the formation of chemical bonds across the contact is maintained to a bare minimum.

2. EXPERIMENTAL PROCEDURE

The different aluminium alloys of grades AA 6061 and AA 7075 were received as plates with thicknesses of 5 mm and 6 mm, respectively, despite the fact that they were made of the same alloy. After that, they were cut into squares measuring 50 mm by 50 mm for use in the studies. Surface EDS analysis was used to determine the chemical composition of both alloys, and the results are shown in Table 1. The oxide layers on the mating surface were removed by polishing with SiC papers of different grits (200#, 400#, and 600#) and cleaning the surface with acetone. The experimental setup for diffusion bonding is shown in another publication, and it includes the capability of heating and keeping the specimen at the intended temperature with an accuracy of +1 °C through the use of a PID controller. The trials were carried out at a vacuum pressure of 29 mm of Hg in order to prevent oxidation from occurring. The hydraulic arrangement, which is fitted with a load cell, is responsible for applying the necessary forces. After holding the specimens at the prescribed conditions for a certain amount of time (holding time), they were cooled to room

temperature in preparation for further investigation. The tests were carried out in triplicate, and the parameter values were determined by the use of design of experiments for crucial locations, which are listed in Table 2 along with the mechanical bond strength. Following the polishing and etching of the surface, an optical microscope (Make: MEIJI, Japan; Model: MIL-7100) was used to examine the microstructure of the diffusion layer under the microscope. It was decided to utilise the 'panasis' programme to measure the thickness of the interface bond using a metallurgical microscope (Make: HUVITZ, Korea; Model: HRM-300M) to measure the thickness of the interface bond. Using energy-dispersive X-ray spectroscopy (EDS) and a scanning electron microscope (SEM), the elemental mapping of the micro-zones surrounding the joints was carried out (Make: ZEISS, Germany; Model: EVO -18). It was determined the phase structure of the joints using X-ray diffraction (XRD) (Make: PANalytical; Model: X'Pert PRO) that the joints had a phase structure. Vickers' micro hardness tester (Make: SHIMADZU, Japan; Model: HMV-T1) with a 0.5 kg load and a dwell duration of 10 s was used to determine the extent of the diffusion layer over the joint, and the results were analysed (normal to the interface region).

This study used a non-standard test procedure from the literature in which the lap shear specimens were machined with an electric spark line cutting machine (Make: ELECTROICA, Japan; model: super cut-734) at a cutting speed of 1.5 mm/sec and those used in the ram tensile test were prepared with a spark erosion machine at a cutting speed of 0.5 mm/sec (Make: ELEKTRA, Japan; model: cut-500). A constant ram speed of 5 millimeters per second was used in the mechanical tests, which were carried out in a servo-controlled Universal Testing Machine (Make: FIE-BLUESTAR, India; Model UNITEK 94100) with a 100 kN capacity. Figure 1 depicts a selection of the test specimens that were created.

TABLE 1. Composition of two aluminium base alloys.

	Al	**Zn**	**Mn**	**Fe**	**Ti**	**Si**	**Cu**	**Ni**	**Cr**	**Mg**
AA 6061	97.29	0.06	0.13	0.40	0.06	0.71	0.23	0.04	0.18	0.90
AA7075	90.02	5.10	0.30	0.50	0.20	0.40	1.20	--	0.18	2.10

FIGURE 1. Bonded specimens were photographed for (a) Lap Shear test (b) Ram Tensile test

3. RESULTS AND DISCUSSION

Experimental Observation: Due to insufficient thermal stimulation for causing the atoms to disperse, satisfactory bonding could not be achieved below the process temperature of 325°C, as demonstrated by trial tests. Additionally, when the process temperature was elevated above 425°C, the thickness of the interface layer increased significantly as a result of the development of additional intermetallic compounds, which reduced the strength of the joint. It was necessary to provide a minimum of 2 MPa pressure to the mating surfaces in order to produce the bare minimum of contact points between them. When applied at a pressure greater than 18 MPa, the specimen deforms plastically, resulting in bulging of the outer margins. The diffusion process required a minimum of 15 minutes, and a prolonged holding period (more than 75 minutes) results in excessive grain formation, which leads to the melting of AA 7075 aluminium alloy. Table 2 shows the thickness of the interface and the binding strength at various design sites for various design points.

Mechanical Characterization: General observations, on the other hand, have shown that welding strength rises with rising temperature up to 375°C and diminishes with increasing temperature beyond that. Similarly, the load must be maintained at a suitable level in relation to the temperature and duration of the load.

TABLE 2. Process variables, interface thickness, and mechanical strength in bonding experiments

Expt. No	Factors				Lap shear strength, MPa			Ram tensile strength, MPa		
	Process Variables			Interface Thickness						
	T, ˚C	P, MPa	H, min	µm	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3
1	325	10	45	0.799 ± 0.004	14.19	13.73	12.79	20.52	22.90	24.11
2	350	5	30	1.552 ± 0.053	23.09	22.76	20.63	29.54	30.12	32.02
3	350	5	60	2.258 ± 0.013	26.22	27.79	31.01	39.50	40.86	40.36
4	350	15	30	2.454 ± 0.013	34.77	36.54	34.32	43.37	44.36	47.15
5	350	15	60	2.776 ± 0.016	34.71	36.52	36.65	44.73	46.21	46.7
6	375	2	45	2.981 ± 0.013	28.45	29.95	29.14	42.70	41.87	41.94
7	375	10	15	3.275 ± 0.085	43.59	42.57	43.32	50.74	51.67	53.53
8	**375**	**10**	**45**	**4.085 ± 0.043**	**56.81**	**54.83**	**53.72**	**70.9**	**73.43**	**72.99**
9	375	10	75	5.726 ± 0.027	49.18	50.91	50.27	60.54	59.76	62.76
10	375	18	45	5.777 ± 0.099	40.42	41.16	44.15	52.79	51.47	55.13
11	400	5	30	5.934 ± 0.019	43.98	45.43	45.98	52.18	55.45	55.12
12	400	5	60	6.364 ± 0.158	48.67	49.23	50.63	62.35	60.29	63.90
13	400	15	30	6.560 ± 0.023	50.76	51.51	48.21	60.59	62.43	60.58
14	400	15	60	8.522 ± 0.281	49.98	50.13	47.28	59.44	58.49	60.78
15	425	10	45	10.822 ± 0.074	48.38	49.57	46.53	55.38	57.84	56.07

Metallographic Characterization

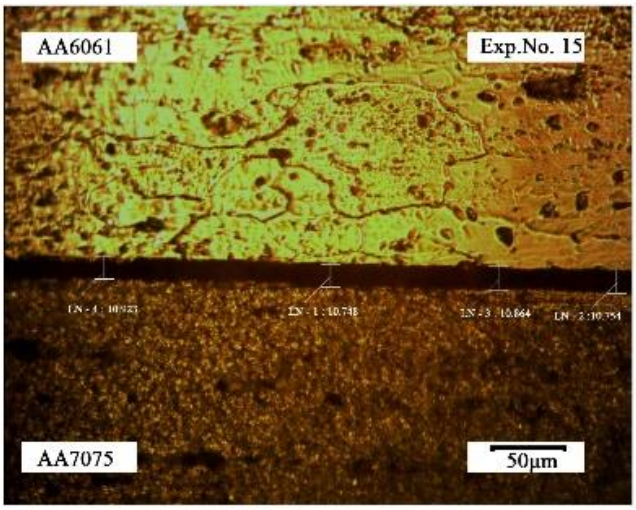

FIGURE 2. Microstructures of diffusion bond showing the variation in interface layer thickness

The interface diffusion layer is a manifestation of the quantum of atomic diffusion that occurs across the bonding layers, and its thickness has a direct relationship with the mechanical characteristics of the bond. This is because the interface layer is typically formed of brittle intermetallics or precipitates, which makes it difficult to work with. Inadequate atomic diffusion results in the production of a very thin interface layer with low mechanical bond strength as a result of insufficient atomic diffusion. Excessive atomic diffusion, on the other hand, results in the creation of a thick interface layer, which in turn leads to a reduction in joint strength and durability.

Figure 2 depicts the microstructure of the various test specimens, as well as the thickness of the interfaces between them. Through the use of software, we were able to calculate the average interface thickness by collecting measurements at several points on each micrograph and averaging the results. Figure 3 depicts the relationship between the thickness of the bond contact and the strength of the connection. It is discovered that the strength improves with increasing contact thickness up to 6 m and decreases with increasing interface thickness beyond that point. The production of precipitates such as Mg_2Si, Al_2MgCu, $MgZn_2$, and Fe_2MnSi, as demonstrated by XRD profile analysis, is responsible for the reduction in strength associated with increased interface thickness (Fig. 4)

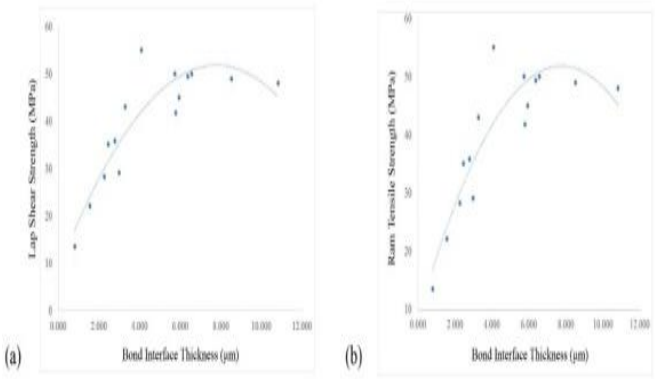

FIGURE 3. Bond interface thickness and correlation trend (a) Lap Shear Strength (b) Ram Tensile Strength

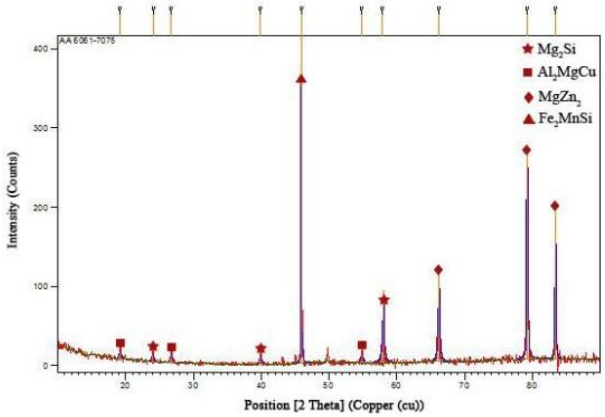

FIGURE 4. The diffusion-bonded sample's XRD pattern.

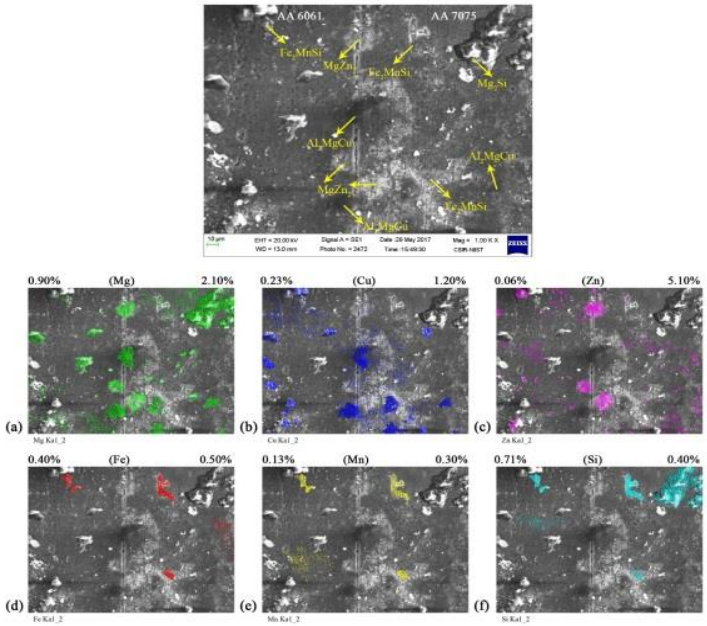

FIGURE 5. SEM picture of diffusion-bonded alloys accompanied by an elemental map (a) Mg, (b) Cu, (c) Zn, (d) Fe, (e) Mn, (f) Si showing diffusion.

It was necessary to conduct a chemical examination of the bonding aluminium alloys prior to bonding, and the amount to which a specific element diffused from one bonding material to another was traced using elemental mapping of the bonded surface (Fig. 5). Prior to bonding, the percentage content of a specific element such as magnesium (Mg), copper (Cu), zinc (Zn), iron (Fe), manganese (Mn), and silicon (Si) was noted above the elemental mapping micrograph in order to understand the extent of diffusion of each element during the diffusion bonding process (Fig. 5). These mappings also allow for the identification of the intermetallic that has developed in conjunction with the examination of the XRD profile (Fig.6). In conjunction with conventional JCPDS data, the X-ray diffraction patterns were evaluated to identify the compounds as Mg_2Si, Al_2MgCu, $MgZn_2$, Fe_2MnSi.

4. CONCLUSION

The elemental mapping confirms the transport phenomena of atoms and the formation of intermetallic compound to disclose the variation of diffusion layer thickness at interface with respect to process variables. The bond strength increases with interface thickness upto6μm and deteriorates thereafter due to the formation of brittle intermetallics. The ideal process variable for maximum shear strength and ram tensile strength are the bonding temperature 375˚C, pressure 10 MPa and holding time 45 min.

REFERENCES

[1] Zaki Ahmad. Recent Trends in Processing and Degradation of Aluminium Alloys.first ed. Croatia: InTech;2011.
[2] Ilangovan M, Rajendra Boopathy S, Balasubramanian V, Microstructure and tensile properties of friction stir welded dissimilar AA6061/AA5086 aluminium alloy joints.Trans. Nonferrous Met. Soc. China 2015; 25:1080-1090.
[3] Anne Sunwoo.Diffusion Bonding of Aluminum Alloy, 8090. Scripta Metallurgica *et* Materialia 1994;31:407-412.
[4] Yiyu Wang, Guoqiang Luo, Jian Zhang, Qiang Shen, Lianmeng Zhang. Effect of silver interlayer on microstructure and mechanical properties of diffusion-bonded Mg–Al joints. Journal of Alloys and Compounds 2012; 541:458–461.
[5] Derby B, Wallach ER. Joining Methods in Space: A Theoretical Model for Diffusion Bonding.Acta Astronautica 1980; 7:685-698.
[6] Kellerer HG, Milacek LH. Determination of Optimum Diffusion Welding temperatures For Ti-6a1-4v.Welding Research Supplement, 1970.
[7] Feng JC, Zhang BG, Qian YY, He P. Microstructure and strength of diffusion bonded joints of Ti Al base alloy to steel. Material characterization 2002; 48 :401–406.
[8] Kazakov NF. Diffusion Bonding of Materials.first ed. Moscow: Mir Publishers;1985.

