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EFFECT OF BONDING PRESSURE ON MECHANICAL AND METALLURGICAL CHARACTERISTICS OF POWDER METALLURGICALLY PRODUCED PURE ALUMINIUM AND PURE COPPER JOINTS

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ABSTRACT

In this investigation, pure aluminium (Al) and pure copper plates manufactured by powder metallurgy (P/M) technique were bonded by diffusion bonding process. The selection of diffusion bonding process variables that influence interfacial structure, morphology and compound is critical to obtain the quality of bonds. The experiments were conducted by varying the pressure between 2-20 MPa and the bonding temperature and the holding time were kept constant. The bonding quality was checked by microstructure analysis near the diffusion bonding interface using optical microscope (OM). The shear strength and bonding strength of the bonds were evaluated by conducting lap shear test and ram tensile test respectively. These strengths of the bonds are getting enhanced by applying process parameters. However, the effect of bonding pressure on diffusion bonding of powder metallurgically produced pure aluminium and pure copper was analysed in details.

Key words*: Pure Aluminium, Pure copper, Powder Metallurgy, Diffusion bonding*

1. Introduction

Aluminium is used in the field of aerospace, automotive industries because of their high strength; corrosion and wear resistance [1,2]. Copper has good features such as high electrical conductivity, thermal conductivity and machinability and therefore, applied in electronic and electrical power industries, electrical appliances, machinery and automobile industries [3]. Joining dissimilar materials by conventional fusion welding technique causes severe thermal cracking and easy formation of brittle intermettllic compounds in the bond region[4]. Therefore, welding of these dissimilar materials by fusion welding technique is difficult Hence the diffusion bonding technique is used to join these materials. The bonding pressure, bonding temperature and holding time are the predominant process parameters of diffusion bonding [5].

Diffusion is promoted by high temperature since adhesion necessary for the bonding process [6]. The excessive heating decreases the bonding strength. The bonding pressure has to be enough tight contact between the joining surfaces of the materials and it should be sufficient to aid the deformation of surface and fill the void in the weld zone. Also the bonding time could be sufficient for intimate contact between the materials [7,8,12]. However, the effect of bonding pressure on diffusion bonding of pure aluminium and pure copper were analysed and the details are presented in this paper

2. Experimental work

Square shaped specimens (50 mmx50 mm) were manufactured from pure Al and pure Cu by powder metallurgical technique. The prepared specimen thickness of Cu was 3 mm and Al was 5mm. The specimens prepared by P/M technique were displayed in Fig. 1(a), 1(b) and these were machined to make flat surfaces by milling and then polished and cleaned in acetone just before diffusion bonding.

The polished and chemically treated specimens were stacked in the die which was made by 316 L stainless steel. The diffusion bonding set up was shown in Fig. 2. The specimens were heated up to the bonding temperature by induction furnace. The heating rate of furnace was 10 ^{0}C/minutes. The required pressure was simultaneously applied to the certain time.

Thus, the bonding was completed and then the bonding samples were cooled to the room temperature before removal from the chamber of diffusion bonding machine. By this procedure 34 joints were fabricated by

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using various combination of bonding temperature, bonding pressure and holding time and they are displayed in fig. 3. The microstructure analysis was carried out to reveal the formation of diffusion layer and to measure its thickness at the interface of the joints by using a optical microscope.

The copper side was etched by a solution containing ethanol, $FeCl_3$ concentrated HCL, whereas the aluminum side was etched by using keller's solution to reveal the microstructure. The different conditions of process parameters used to fabricate the diffusion bonds were presented in Table 1

Fig. 1(a) P/M Pure Copper plates

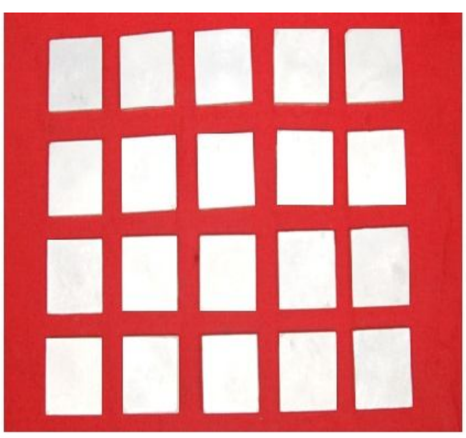


Fig. 1(b) P/M Pure Aluminum plates

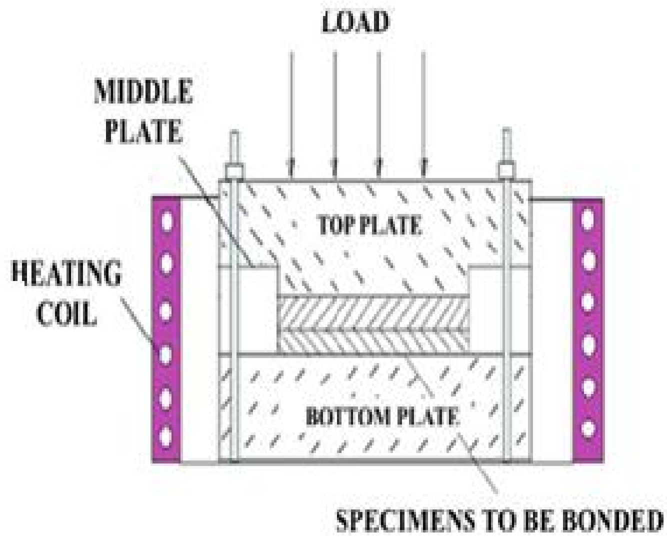


Fig. 2 Configuration of the diffusion bonding set up

Fig. 3 some of the fabricated diffusion bonds

Table 1: Experimental Results

Joint No	Bonding Temperature (°C)	Bonding Pressure (MPa)	Holding Time (min)	Bonding (Yes or No)	shear strength (MPa)
1	200	10	30	No	-
2	200	20	60	No	
3	250	10	30	Yes	16
4	300	10	30	Yes	24
5	325	10	30	Yes	25
6	350	10	30	Yes	30
7	375	10	30	Yes	31
8	400	10	30	Yes	25
9	425	10	30	Yes	24
10	450	10	30	Yes	18
11	300	10	15	Yes	20
12	300	10	90	Yes	22
13	300	5	120	Yes	14
14	350	2	30	No	-
15	350	5	30	Yes	16
16	350	15	30	Yes	27
17	350	20	30	Yes	23
18	350	10	15	Yes	25
19	350	10	45	Yes	35
20	350	10	60	Yes	38
21	350	10	75	Yes	35
22	350	5	15	Yes	14
23	400	5	60	Yes	15
24	400	15	75	Yes	13
25	400	20	5	Yes	9
26	450	5	90	Yes	15
27	450	10	15	Yes	14
28	450	15	60	Yes	17
29	450	10	75	Yes	26
30	450	20	75	No	-
31	475	10	30	No	-
32	500	10	30	No	-
33	500	10	15	No	-
34	550	10	10	No	-

3. Result and Discussion

3.1 Effect of pressure on shear strength and bonding strength

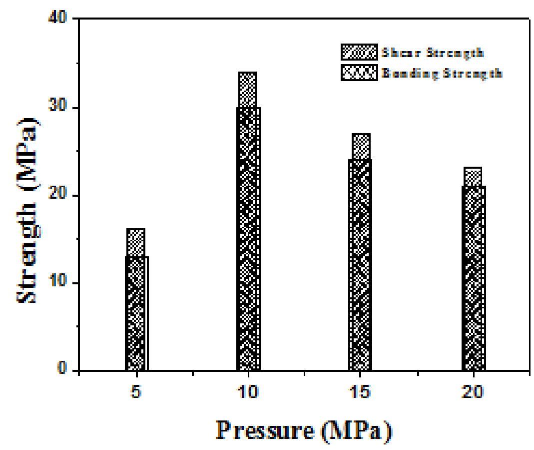


Fig 4.

From the Fig. 4 It is understood that shear strength and bonding strength of the bonds increase with increasing of bonding pressure, irrespective of bonding temperature and holding time. At low bonding pressure of 5 Mpa, shear strength and bonding strength are minimum, because at low bonding pressure, the voids are present in the interface region and the contact rates between the materials is low. When the bonding pressure is increased to 10 MPa, plastic deformation develops at contact sites to increase the contact areas of surfaces and therefore these strengths of joints increase.

Further increase of pressure to 20 Mpa, that will obviously increase the rate of interface contact and more diffusion paths are created due to moments of atoms which reduce the strength of bonds.

Table 2: Properties of Al/ Cu bonds

Bonding pressure (MPa)	Diffusion layer thickness (µm)	Interface hardness (Hv)	Shear strength (MPa)	Bonding strength (MPa)
5	14	66	16	13
10	17	73	34	30
15	27	86	27	24
20	30	106	23	21

The mechanical and physical properties are presented in the above table 2. From which it is inferred that the bonding pressure is directly proportional relationship with interface hardness and diffusion layer thickness. The shear strength and bonding strength increase up to the bonding pressure of 10 MPa at bonding temperature of 350 ^{0}C and holding time 30 min. after which these strengths decrease up to the bonding preesure of 20 MPa.

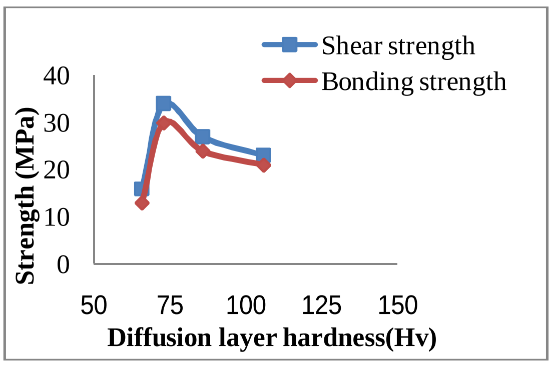


Fig. 5

From the fig. 5 it is inferred that the shear strength and bonding strength increase till the diffusion layer hardness 73 (Hv) after which these strengths decrease because of the higher hardness to lead the weak joints

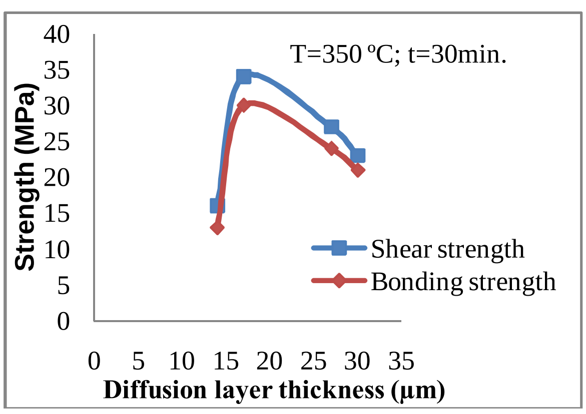
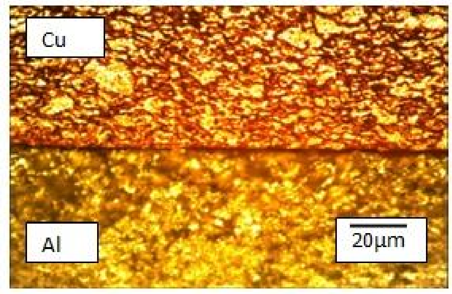
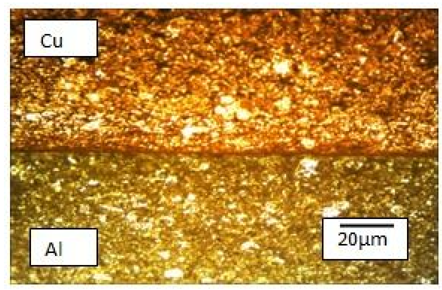


Fig. 6

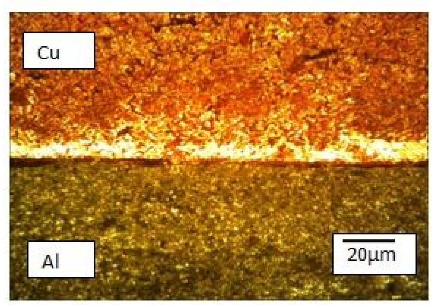
From the fig. 6 it is understood that the diffusion layer thickness plays an important role for shear strength and bonding strength. When the diffusion layer thickness is 14µm, it has lower shear strength and bonding strength. The diffusion layer thickness is 30µm which lead to the lower shear strength. However, the diffusion layer thickness is 17µm that lead to obtain the higher shear strength.



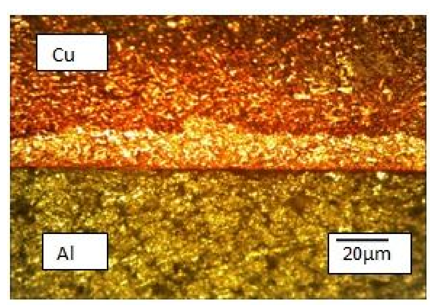
(a) P= 5 MPa



(b) P=15 MPa



(c) P=15 MPa



(d) P=20 MPa

Fig. 7 Optical micrograph of interface region of pure Al/Cu diffusion bonds

4. Characterisation of diffusion bonded joints

When diffusion bonding occurs between two dissimilar materials, the brittle intermetallic compounds formed in the interface of diffusion layer which could weaken the joints strength and hence, it is important to analyses the formation of the intermetallic compounds at the interface region. The optical micrographs (OM) were taken at interface region of Al/Cu bonds to understand the effect of diffusion bonding pressure on the formation of diffusion layer and they are presented in the Fig.5 (a -d).

5. Conclusions

From this investigation, the following conclusions are obtained

(i) Diffusion layer thickness is having directly proportional relationship with bonding pressure
(ii) Diffusion layer hardness is having directly proportional relationship with bonding pressure
(iii) Diffusion layer hardness is having directly proportional relationship with Diffusion layer thickness.
(iv) the shear strength and bonding strength increase up to the bonding pressure of 10 MPa at bonding temperature of 350 ^{0}C and holding time 30 min. after which these strengths decrease
(v) The maximum bonding strength of 35 MPa and shear strength of 38 MPa were obtained under bonding temperature 350 ^{0}C, bonding pressure of 10 MPa and holding time of 60 minutes

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