International Journal of Applied Engineering Research
ISSN 0973-4562 Volume 10, Number 9 (2015) pp. 24659-24669

http://www.ripublication.com

Corrosion Studies on Diffusion Bonded Aluminium Alloys

Venugopal. S[1]
Research Scholar, Sathyabama University,
Chennai - 600119, India. venu.siva.1956@gmail.com
Mahendran.G [2]
IFET College of Engineering, Villupuram – 605108, India.
mahe1967@yahoo.com

Abstract

The aim of this work is to study the effects of corrosion behavior on diffusion bonded AA5083, AA6082 and AA7075 aluminum alloys, the samples are subjected to potentiodynamic polarization resistance measurements in NaCl solution. It is observed that the parent metal wrought aluminum alloy AA7075 found to corrode higher than the corresponding welded region of joints. Similarly the corrosion current and corrosion rates are higher for the AA7075 compared to the AA6082 and AA5083. The corrosion rates observed were 2.47, 9.93 and 12.14 mm/year for AA6082, AA5083 and AA7075 respectively at diffusion bonded zones. Microstructure study was conducted by optical microscope to validate the results of the weld joints.

Keywords: Diffusion Bonding, Tensile strength, Corrosion rate, Optical microscope, I_{corr}.

Introduction

Diffusion bonding is one of the promising techniques to join alloys as there is no melting occurs during bonding and absence of contamination at the weld joints . The metals are brought in close proximity to each other with heating and the metal surface is subjected to compressive pressure to near plastic state and by giving upset pressure to get the diffusion bonding [1]. Diffusion bonding has exhibited superior joint strength when joining dissimilar materials [2]. In recent years nonferrous metal aluminum alloys drawn more attention in application to marine, aerospace and automobile industries due to high strength to weight ratio, together with its natural ageing characteristics. Diffusion bonding process involves application of different parameters like bonding Temperature, bonding pressure, holding time to get the formation of the bonding of the samples. It is carried out at high pressure, shorter processing time and temperature below melting point [3]. Three wrought aluminum alloys AA6082, AA5083, and AA7075 were selected to study the corrosion behavior at the diffusion bonded zone. Out of the three alloys selected two namely AA6082 and AA 7075 are heat treatable and AA5083 is not heat treatable. Presence of Si and Mg forms Mg2Si equal to or approaching that of non-heat treatable alloys [4]. On the other hand AA5083 is more prone to inter granular corrosion on the grain boundaries [5]. The AA7075 wrought alloy containing copper & zinc has the highest strength used primarily in aerospace applications [6,7]. All the three alloys have unique differences in its processing, and applications. the corrosion studies carried out at the diffusion bonded zone might be useful & appropriate. The corrosion evaluations were carried out by electro chemical method. Polarization resistance measurements are done to measure the general corrosion rate.

Experimental Work

The chemical composition of base metals selected for corrosion studies of the study are presented in TABLE I. . The joints are fabricated as per Taguchi L9 orthogonal array technique at three levels and four parameters as shown in TABLE II. Square shaped specimens (50mmx50mm) were machined from rolled plates of 5mm thickness aluminum alloys AA5083, AA6082 and AA7075, shown in *Fig.1*. The polished and chemically treated specimens were stacked one over the other in a die made of H-13 AISI Tool Steel and the entire diffusion bonding setup, shown in *Fig.2*, and inserted into a vacuum chamber (vacuum pressure of 29 mm of Hg was maintained). The specimens were heated up to the bonding temperature using induction furnace with a heating rate of 25°C/min. Identical soaking timings were given for all the pairs of the alloy subjected to diffusion bonding. After the completion of process, the samples were cooled to room temperature before removal from the chamber. By this procedure, 27 joints were fabricated with different parameters of bonding temperature, bonding pressure and holding/soaking time which are displayed in Table-II. Microstructure studies were carried out to evaluate the diffusion bonded layer and subsequent microstructures at the interface after etching using Kellar's Reagent soln. In order to evaluate the joint strength, suitable test was conceived to measure the shear strength(SS) is shown in *Fig 3*. The specimens for bonding strength(BS) as shown in Fig.4, were prepared from the diffusion bonded joints by electrode discharge machining process. Test was carried out in 50 kN capacity servo controlled Universal Testing Machine and the results are presented in TABLE II. Similarly Ram tensile test was conducted by using specimen shown in *Fig 4*. The results of the test conducted for the specimen are given in TABLE II. Based on the tested values three samples from each alloy were selected for further corrosion studies.

Table 1: Chemcial Composition of base metal AA5083, AA6082 &AA7075

Alloy	Chemical Composition Of Aluminum Alloys									
	Si	***Fe***	***Cu***	***Mn***	***Mg***	***Cr***	***Zn***	***Tin***	***others***	***Balance***
AA5083	0.26	0.35	0.05	0.60	4.74	0.11	0.05	0.06	0.01	Al
AA6082	0.7-1.3	0.5	1.2-2	0.4-0.10	0.6-1.2	0.25	0.2	0.1	0.15	Al
AA7075	0.4	0.5	0.1	0.3	2.5	0.21	5.6	0.2	0.05	Al

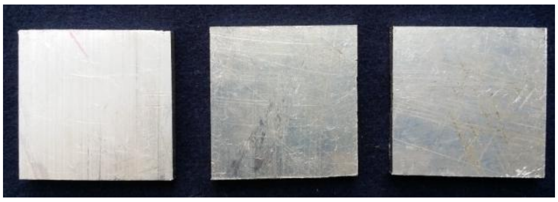

Figure 1: Sample Before Diffusion Bonding

Figure 2a: Diffusion Bonding Machine

Figure 2b: Vacuum Furnace

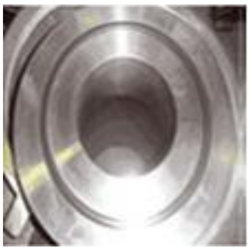

Figure 2c: Vacuum Furnace

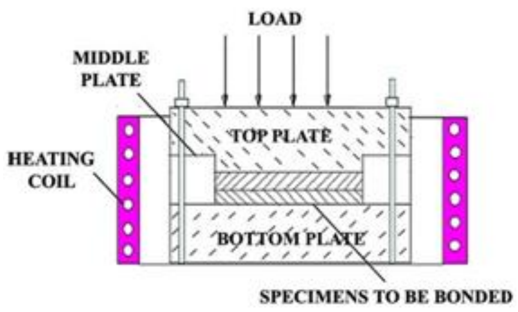

Figure 2d: Diffusion Bonding Setup

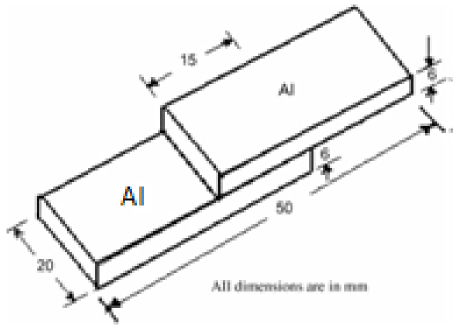

Figure 3: Lap Shear Sample

Figure 4: Ram Tensile Sample

Table 2: Diffusion Bonding Parameters Used For Bonding

Parameters	***DL(μm)***	***HV***	***SS(Mpa)***	***BS(Mpa)***
(AA5083)				
450ºc/3Mpa/45mini.	3.8	79.6	14	33
475ºc/4Mpa/30mini.	9.35	83.9	13	36
500ºc/2Mpa/15mini.	6.3	79.5	10.5	33
(AA6082)				
450ºc/3Mpa/45mini.	5.0	41	16	22
475ºc/4Mpa/30mini.	6.54	43.2	17	23
500ºc/2Mpa/15mini.	5.9	40.8	16	22
(AA7075)				
450ºc/3Mpa/45mini.	3.96	62.1	13	38
475ºc/4Mpa/30mini.	5.90	40.8	16	22
500ºc/2Mpa/15mini.	4.11	58.1	13	38

Results and Discssion

A. Corrosion Test analysis sample for corrosion studies

Diffusion bonded samples of size 10 mm x 10mm having two regions namely base metal and the diffusion bonded zones were sectioned from the square specimen by wire EDM processes with the thickness of 1.5mm. In this study 3.5% (by weight) of Sodium chloride was used as an electrolyte. The samples were initially polished and prepared to identical surface finish using metallographic techniques. Polarization resistance measurements are an accurate and rapid way to measure the general corrosion rate[8,9]. Electrochemical polarization test methods are extremely pertinent for understanding and evaluating the corrosion behavior of materials with changes in the exposed corrosive environment. The results of potentiodynamic corrosion studies would throw light on suitability of alloys for anodic or cathodic protection and susceptibility to several forms of corrosion. Venugopal Et. al [10] and srinivasarao Et.al[11]studied micro-structural and pitting corrosion properties of friction stir weld of AA7075 Al alloy in 3.5% NaCl solution. It is observed that corrosion resistance of weld metal is better than that of TMAZ (Thermo mechanical affected zone) and base metal. Samples of base alloy AA5083, AA6082 and AA7075 and Diffusion bonded samples were subjected to electrochemical corrosion in sodium chloride solution of 3.5% to determine corrosion parameters such as corrosion potential (Ecorr.) and corrosion current (Icorr.) as shown in TABLE III.

Aluminum alloy, AA7075 is susceptible to galvanic attack near precipitates of MgZn2 MgAlCu. Srinivasan et.al [12] reported that the general corrosion resistance of the AA6082 parent material is better than the AA7075 parent material due to content of copper. The zinc rich precipitates in the AA7075 alloy causes the formation of micro galvanic cells, leading to higher rates of dissolution. Further, zinc is active when compared to aluminum alloy matrix, hence can enhance the corrosion rate. The potentiodynamic polarization curves for alloys under study are shown in *Fig. 5, Fig. 6 &Fig. 7* in 3.5% NaCl at temperature 29◦C. It is observed that the diffusion bonded AA7075 shows higher corrosion rate of 12.142mm/year followed by AA5083 parent metal imparts 9.9274 mm/year while AA6082 parent metal imparts 2.4749 mm/year with better corrosion resistant properties. This result indicate that the sample AA6082 of the diffusion bond joint act as a cathode and give better resistance to corrosion when compared to samples AA7075& AA5083.

Table 3: Results of Corrosion Tests

Sample I.D.	I_{corr} **(Corrosion current in Mamps/Cm^2)**	**Corrosion rate mm per year**
AA5083	0.9116132	9.9274
AA6082	0.2272643	2.4749
AA7075	1.115	12.142

B.Corrosion Chart

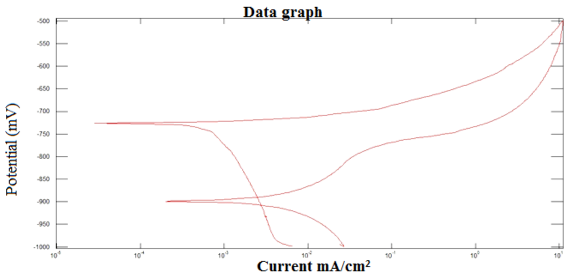

Figure 5: Corrosion Graph ofAA5083

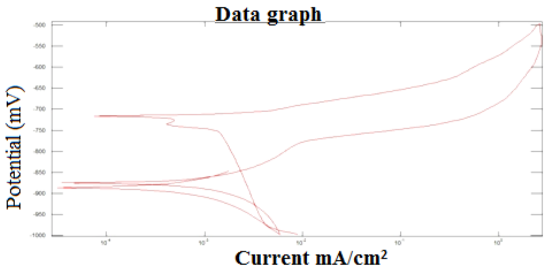

Figure 6: Corrosion Graph of AA6082

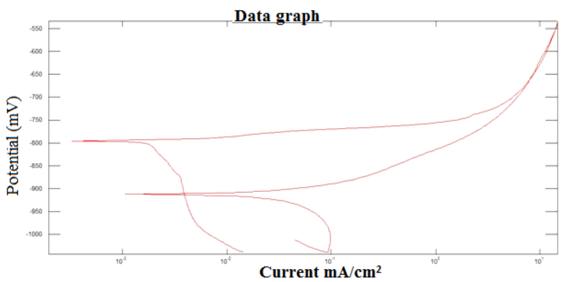

Figure 7: Corrosion Graph ofAA7075

Microstructure

A. Parent Metal

Optical microscopy studies were conducted to the Diffusion bonded samples of AA5083, AA6082 & AA7075. The microstructure of parent metal, diffusion zone and HAZ were imaged. The microstructure of all the alloys showed the precipitation of the respective phases based on the alloy content. This is due to soaking and slow cooling of the specimen after diffusion bonding. The microstructure of the parent metal *Fig. 8a, Fig. 8b & Fig. 8c* and the diffusion bonded zones are shown in *Fig. 9a, Fig. 9b & Fig.9c*. The effect of polarization leads to the formation of large corrosion pits. These pits are shown in black color cylindrical shape and occurred in close proximity. In addition the grains boundaries are ditched and nowhere the surface of the metal is free from corrosion pits. The *Fig. 9d, Fig. 9e & Fig. 9f* shows the micro structure of alloys after potential-dynamic polarization. As stated above the corrosion pits are in the same order of corrosion rate. The effect of polarization leads to the formation of corrosion pits of different gravity

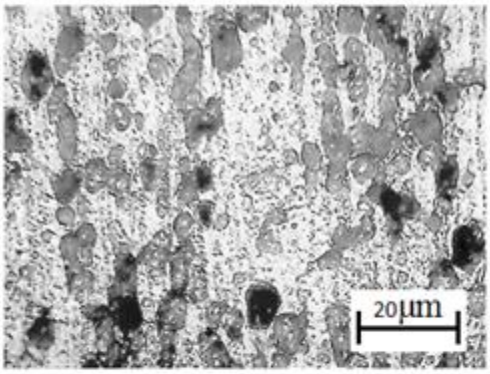

Figure 8a: Microstructure of Parent Metal AA5083

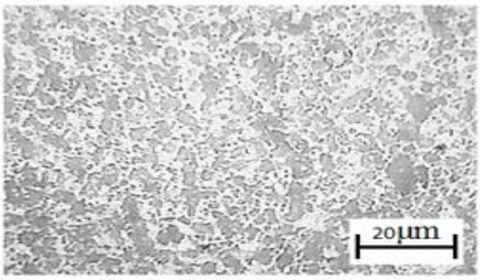

Figure 8b: Microstructure of Parent Metal AA6082

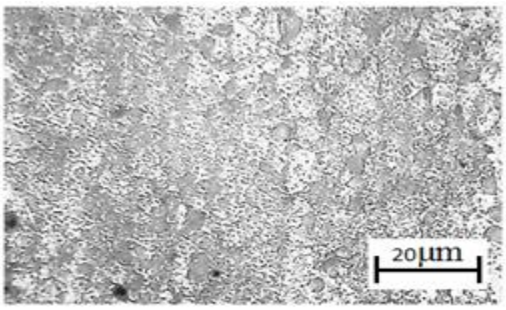

Figure 8c: Microstructure of Parent Metal AA7075

The three corrosion surface images are taken from the fusion zone. *Fig.9[a,b,c]* image is taken from the core of the fusion zone which shows better resistant to corrosion but it shows inter granular corrosion by polarization method. G. Elatharasan et.al also reveals that the affected zone of the weld exhibited highest susceptibility to inter-granular corrosion [13, 14]. This zone does not show the presence of deep pits instead, the grain boundaries are marginally ditched. The *Fig. 9c* is taken from the fusion zone which is closer to the AA7075 side. The constituents of the fusion zone are more diluted with AA7075alloy. Hence the corrosion behavior is more and follows the pattern of AA7075. *Fig. 9a.* Shows the fusion zone more diluted with AA5083 and least affected. However the corrosion rate is the consolidated effect of the entire three zones as the corrosion cell covers all the three zones. In AA7075parameter the effect of polarization leads to the formation of corrosion pits of different gravity. The three corrosion surface images are taken from the fusion zone. All the three images shows *Fig. 9a,b,c* severe corrosion pits as well as grain boundary ditches but there is more resistance to corrosion while compare to other zones. It is evident that this surface should have shown more corrosion and the experimental values confirm the same. Moreover fusion zone is more diluted with AA7075 alloy constituents. *Fig.9c*

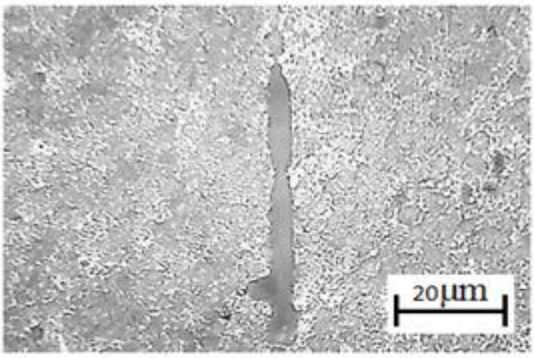

Figure 9a: Microstructure of Diffusion Bonded AA5083

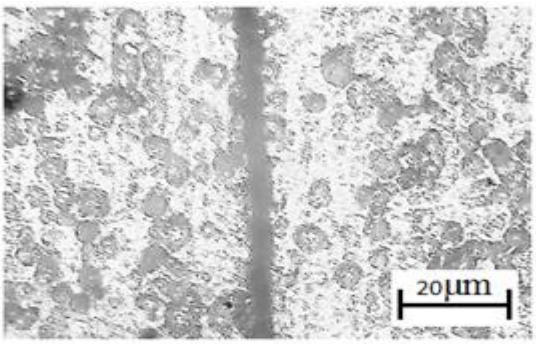

Figure 9b: Microstructure of Diffusion Bonded AA6082

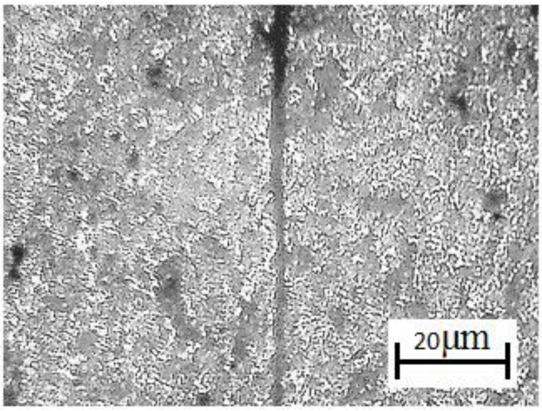

Figure 9c: Microstructure of Diffusion Bonded AA7075

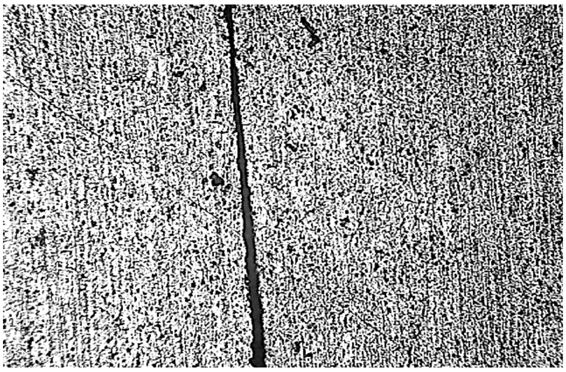

Figure 9d: Microstructure after Corrosion test AA5083

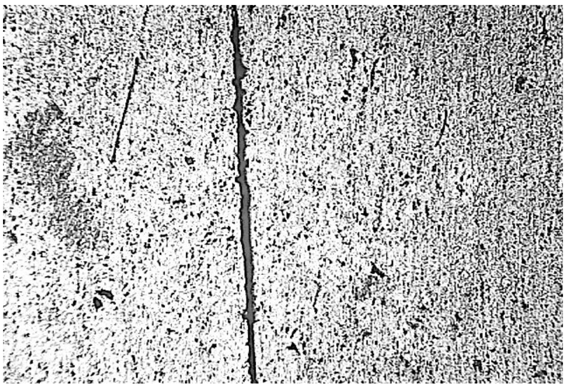

Figure 9e: Microstructure after Corrosion test AA6082

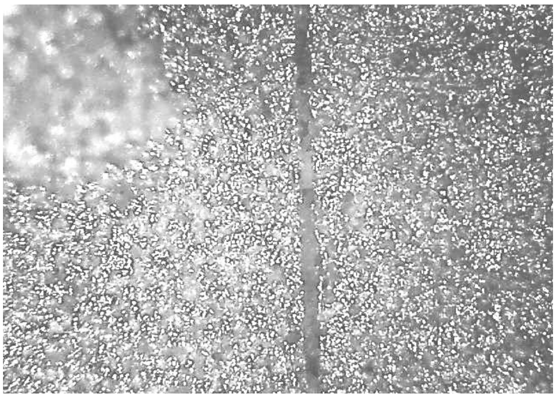

Figure 9f: Microstructure after Corrosion test AA7075

Conclusion

The present work investigated the corrosion behavior of diffusion bonded AA5083,AA6082,AA7075 aluminum alloys. The findings made by the experimental work are given below.

- The maximum strength obtained is 38 Mpa for the diffusion bonding of similar alloy namelyAA 7075
- Out of the three alloy bonding experimented the AA7075 showed higher deformation after diffusion bonding.
- Out of the diffusion bonded alloys, AA6082 showed low corrosion rate of 2.47 mm per year. AA5083 diffusion bonded zone showed 9.92 mm per year followed by AA7075 with high corrosion rate of 12.142mm per year with least corrosion resistance.
- The rest potential vary in the order AA7075 > AA5083 > AA6082.
- Comparison of microstructure before and after potentiodynamic polarization corrosion pits in the order AA7075 > AA5083 > AA6082.
- The corrosion rate of the three diffusion bonded similar alloys are in the order AA7075 > AA5083 > AA6082

Acknowledgment

The authors express their gratitude to SATHYABAMA UNIVERSITY, Chennai-600119, Dr. B. RAVISANKAR, NIT, TRICHY & METMECH ENGINEERS, CHENNAI-83. for their Constant encouragement while carrying out this work.

References

[1] G.Mahendan, S.Babu and V.Balasubramanian, Analyzing the Effect of Diffusion Bonding Process Parameters on Bond Characteristics of Mg-Al Dissimilar Joints,j.Materr.Eng.Perform,2010,19,p657-665

[2] G.Mahendran,V.Balasubramanian,T.Senthilvelan,Influences of diffusion bonding process parameters on bond characteristics of Mg-Cu dissimilar joints, Trans.Nonferrous Met.Soc.China,2010,20,p997-1005

[3] *M.JosephFernandus,T.Senthilkumar,V.Balasubramanian,S.Rajkumaroptimizing Diffusion Bonding Parameters to Maximize the Strength of AA6061Aluminium andAZ61A Magnesium Alloy Jointssociety for Experimental Mecanics*.(10.1111/1747-1567.2012.00815x)

[4] G.Mahendran,V.Balasubramanian,T.Senthilvelan,Mechanical and metallurgical properties of diffusion bonded AA2024 aluminium alloy and commercial grade copper,ElixerMech.Engg.38(2011)4283-4289

[5] J.B. Lumsden, M.W. Mahoney, G. Pollock, C.G. Rhodes, *Corrosion* 55 (12) (1999) 1127

[6] J. G. Kaufman and E. L. Rooy, Corrosion Test and Standards, Application and Interpretation, 2nd edition, edited by R. Baboian. ASM International, Materials Park, OH, (2005) 1–8

[7] J. G. Kaufman, in ASM Handbook, Volume 13B, Corrosion: Materials, edited by S. D. Cramer andB. S. Covino Jr. ASM International, Materials Park, OH, (2005) 95–124.

[8] David Talbot and James Talbot, *Corrosion Science and Technology*, CRC Press LLC, 1998.

[9] R. Kenneth, Trethewey and J. Chamberlain, *Corrosion for Science and Engineering*, LongmanGroup Limited, 2nd Edition, 1996.

[10] T. Venugopal, K. SrinivasaRao, and K. Prasad Rao, *Trans. Indian Inst. Met*als, 57 (2004) 659-663

[11] K. SrinivasaRao, and K. Prasad Rao, *Transaction of Indian Institute of Metals, 57* (2004) 503-610

[12] P.B. Srinivasan, W. Dietzel, R. Zettler, J. dos Santos, V. Sivan, *Corrosion Engineering Scienceand Technology* 42 (2007) 161-167

[13] G.Elatharasan and V.S.Senthil Kumar, *Journal of Mechanical Engineering*, 60 (2014) 29.

[14] R. Sathish, V. Seshagiri Rao, Corrosion Studies on Friction Welded Dissimilar Aluminium Alloys of AA7075-T6 and aa6061-T6 Int. J. Electrochem. Sci., 9(2014) 4104-4113