AN INVESTIGATION ON STRENGTH AND FRACTURE MECHANICS OF DIFFUSION AND ADHESIVE BONDING

IN AL 6061 AND BRASS 60/40

A.M. Easa & A.M. Khourshid *

Assoc. Prof., Production Engg. & Mech. Design Dept., Faculty of Engg., Menoufia University,
EGYPT.

ABSTRACT

The major parameters which affect the diffusion and adhesive bonding techniques are; surface roughness, temperature, type of aherend, type of adhesive, pressure and time. In the present work these parameters were investigated using AL 6061 and Brass (Br) 60/40 alloys. It is very important to make a comparative study between the two types of bonding techniques which has been nearly ignored in most of the published work.

Different values of loading pressure less than yield pressure (Py) of the metals were used. Different levels of heating temperatures, less than melting temperature (T_m) of the alloys were also used. Then tensile testing was carried out on special tensile machine.

From the test results of diffusion-bonded (DB) joints, the overlap shear test pieces machined from 6mm thick (DB) sheets showed two fracutre zones at the bond interface. Zone 1 at the ends of the overlap showed predominantly intergranular fracture and zone 2 at the center of the overlap showed peel-type fracture. The load appeared to be carried entirely by zone 1. Only zone 1 fracture was obtained in the base metal test piece. The fracture zones were caused by the

MANUSCRIPT RECEIVED FROM DR: A. M. EASA AT:24/4/1996,
ACCEPTED AT:28/5/1996, PP 115 - 133
ENGINEERING RESEARCH BULLETIN, VOL,19,NO. 2, 1996
MENOUFIYA UNIVERSITY, FACULTY OF ENGINEERING,
SHEBINE EL-KOM, EGYPT. ISSN. 1110 - 1180

non-planar stress distribution and by the bending moments associated with this type of test piece. The planar bond interface may accentuate the tendency in this metal towards low ductility and toughness in the short transverse direction.

From the adhesive-bonded(AB) joints results, the adhesive was teared at different points of the contact area and took another form from joint to another. In some points, the adhesive was seperated.The variation of adhesive thickness, contact area, chemical composition of adhesive material and surface roughness had a large effect on the (AB) behaviour.

The adhesive joint has a higher tensile strength in the range of pressure up to 0.7 Py as compared with diffusion bonded joint. Beyond this range (0.7 ~ 0.8 Py), the diffusion bonded joint has a higher tensile strength.

1- INTRODUCTION

Diffusion bonding with its many advantages has found wide applications in industrial production processes, such as; manufacture of forming dies and constructing dies form laminates or segments, .. etc. The reliability of this techniques (DB) is checked by destructive mechanical testing and metallographic examination. For these reasons and for more details of fracture morphology in diffusion-bonded and base metal shear test pieces, this research is carried out.

On the other hand, adhesive bonding techniques have been used more and more for making machine tool elements, some of air craft parts and in aerospace structures.

Diffusion bonding is a solid-state bonding process wherein coalescence of contacting surface is produced with minimum macroscopic deformation by diffusion-controlled processes that are induced by applying that pressure for a finite time interval /1/. The process is applicable to the joining of similar or dissimilar metals, either directly or with a third metal as an interlayer /2/. Typically, the bonding temperature is in the region of 0.5-0.8 T_m where T_m is the absolute melting point of the material being bonded, the pressure is kept below the bulk yield stress at the temperature employed, and the time may vary from minutes to hours /3,4 and 5/.

The two methods of bonding have nearly the same advantage such as; reducing the time and the cost of manufacturing, composite structure (materials with different properties which can be utilized for various parts of structure).

The reliability of adhesive and diffusion joints is usually checked by destructive mechanical testing and metallographic examination /6/. However, the quality of adhesive joints (AB) and diffusion joints (DB) in industrial products is sensitive to many parameters, such as, surface roughness, temperature, type of adherend, type of adhesive, pressure, time, contamination of bonding surfaces and experienc of operator /7, 8 and 9/.

In the present work, the major parameters which have direct effect on (AB) and (DB) joints were studied. These parameters are; surface roughness, applied pressure, heating temperature and type of adherend.

2- Experimental Work

2.1- Types of Specimens

The specimens configurations used in these investigations are shown in Figs. (1-a and 1-b). The adherends were selected to appropriate surface roughness (C.L.A) values for each adherend. The two mating parts of (DB) and (AB) joints were made from AL 6061 or Br 60/40 or combination of them for (AB) joints. The mechanical properties of AL 6061 and Br 60/40 are listed in Appendix (A).

The mating surfaces of the parent are cleaned, then the measurements of surface roughness is formed by using Taly-surf 5-M60 instrument. The surface roughness and degree of flatness are recognized as a significant parameters in these investigations.

2.2- Bonding

2.2.1- Adhesive Joint (AB)

The type of adhesive used in this investigation was super-bonder 415. It has high impact strength, excellent solvent resistance. It also, cures completely and leaves no residue on surface. After preparing the mixture of adhesive and selecting the adherends, the bonded joints were manufactured by applying the bonding agent to the cleaned surface. Then the joint was assembled in simple jig Fig. (2-a), which pressed sections together. After the joint was fully assembled, the adhesive thickness was measured using dial gauge. The bonded joint was removed from the simple jig after about three hours (setting time), then it was left 18 hours (Curing time) in order to be fully cured before the test process. The specifications of the adhesive super-bonder 415 are shown in Appendix (B). After the joint was fully cured, the it was applied in heating furnace. The heating temperatures were varied from 30 to 120°C. The cooling rate for the adhesive joint was rapid under the experimental conditions. The photographes were taken to the contact area after the joint was broken.

2.2.2- Diffusion Joint (DB)

The (DB) joint is shown in Fig. (1-b). The two mating surfaces of the joint have the same surface roughness as adhesive joint. The applied pressures were varied from (0.6:0.8) Py for a duration of 5 min [8]. The heating temperatures are from (0.6:0.8) T_m (melting point temperature).

To produce (DB) joint, the load was applied axially to a pair of metal or metals by means of a manually operated press. Diffusion bonded joints were manufactured as shown in Fig. (2-b). The apparatus consists of an electric furnace, power supply, a 200 ton hydraulic press and pressure die /8/. It is obvious that the die material and its hardness have a profound influence on die life. The important factors considered in selecting the type of steel used for closed die are; uniform hardness, good resistance to the abrasive action of the hot metal being pressured, ability to withstand heavy shock loads and good resistance to chocking and cracking from high temperature.

Diffusion bonded joints were fabricated at different; pressure loads, heating temperature and different surface roughness. Both of heating and pressure application were terminated at the completion of the appropriate time period. The time necessary to heat the joint from ambient to bonding temperature was kept to be within five minutes and the cooling rate for the bonded joint was rapid under the experimental conditions.

The two mating surfaces of joint have the same surface roughness (C.L.A) and the same degree of flatness. The joints of single overlap shear test piece, Fig. (3), were made by diffusion bonding as shown in Fig. (2-b) from two sheets of identical thickness at 560°C under pressure to give a final overall through thickness deformation of 8% to 12%.

After bonding, a 8 mm long x 4 mm deep section was cut from each edge of bonded test-piece to determine the microstructure before and after a post-bonding heat treatment which consisted of solution treatment (15 min, at 530°C water quench) and ageing (4 hr at 185°C and air cool). Surface solts were cut to the depth of the bond line, Fig. (3), to give overlap lengths L=2 to 16 mm. Similar base metal shear test pieces were made by machining slots to half the shear thickness after a thermal cycle of 4 hr at 560°C. Overlap lengths for the base metal test pieces were L=3 to 6 mm. Fracture surfaces were studied in scanning microscope.

3- Results and Discussions

3.1- Fracture mechanics of (DB) and (AB) joints

The sections through a bonded joint in the unrecrystallized sheet is shown in Fig. (4), were the bond interface was indistinguishable from the planar boundries associated with the pancake-shaped grains in the base metal. A similar section through a bonded joint in partially recrystallized sheet is shown also in Fig. (4). The planarity of the bond interface A-A in this section is in marked contrast to the grain boundaries associated with the equiaxed grains in the base metal at B. However, transmission electron microscopy observations have shown that the bond interface is a conventional large-angle boundary. It is clear that the planarity of this interface is a characteristic of interfaces produced in aluminum 6061 by solid state diffusion bonding. Short segments of straight grain boundary are also a common feature in metallographic sections is this case e.g. at C in Fig. (4) and in transmission electron micrographs of AL 6061.

In Fig. (5), macrographs of fracture surface of test pieces with overlap lengths L equal 2,4 and 16 mm are shown. For small overlaps (e.g. L=2 mm) the fracture surface topography appears uniform, but for longer overlap lengths, e.g. L=4 mm two distinct fracture zones, zones 1 and 2, were visible at the ends and at the center of the fractures as shown in the previous figure. The ratio of the length of zone 1 to zone 2 decreased with increase in overlap length; (L=2 mm, zone 1 only =2 mm), (L=4 mm, zone l/ zone 2 = 3/2 mm), (L=16 mm, zone 1/zone 2 = 6/9 mm).

Scanning microscope fractographs confirmed the surface uniformity in zone 1, as shown in Fig. (6) for L=2 mm. The zone 1 fracture for L=16 mm was identical and is shown at higher magnification in Fig. (7a and b). The intergranular fracture surface was very smooth at (A) but ductile cusps occurred at grain boundary steps at (B), and are characteristic of a soft precipitate free zone. Occasional voids were also observed within grains or at grain boundaries, e.g. at (C) in Fig. (7a). These could be associated with coarse Mg-Cr rich insoluble particles in the alloy. Zone 2 was characterized by a much rougher surface topography caused by a mixture of inter and transgranular shear fracture as shown in Fig. (8) and areas of pull-out. It is clear that, the latter were caused by cracks deviating from the bond interface and propagating in both trans and intergranular modes in planes parallel to the bond interface. This led to large depressions or mounds on the fracture surfaces with dimensions in a direction normal to the surface of at least two grain diameters. A typical example associated with extensive shear for the test piece with L=4 mm is shown at (A), Fig. (9a and b) and an example of pull-put with little shear is shown at (B), Fig. (9a and C).

It is clear that, when L>4 mm, tensile failure occurred in the base metal but peel occurred in the bonded joint; this suggests that the peel resistance was greater for the base metal. The shear fracture obtained when L=2 mm is shown in Fig. (10). At low magnification the surface roughness appeared much greater than for the corresponding diffusion-bonded joint when comparing Figs. (6) and (10a), but at higher magnifications smooth fracture areas were apparent with diameters of about 20 to 50 μm at (A) in Fig. (10b), these dimensions correspond to the grain diameters for this metal, Fig. (4). In a section through the bonded shear test piece shown in Fig. (11a) fracture has occurred along the bond interface at A-A and partly through the base metal at the base of the machined notch at B-B. In a similar test piece the base metal crack B-B turned through 90° and intercepted the bond interface fracture plane as shown in Fig. (11b). This enables a direct comparison to be between the fractures in the planar bond interface at (C) and in the base metal at (D). The greater roughness for the fracture in the base metal is apparent.

It is obvious that, in both the (DB) interface and the base metal, intergranular fracture was the dominant failure mode. The difference in fracture surface roughness was related primarily to the grain-boundary surface contour. The mounds and cavities on the zone 2 fracture surfaces were caused by metal pull-out. These results are consistent with parent metal strength and a conventional grain-boundary micro- structure in the bond interface. The intergranular fracture is common in commercial AL 6061 which tends to have well developed pancake-shaped grains with their major axes parallel to the rolling plane. This microstructure led to intergranular delamination, and low tensile ductility and fracture toughness. These results suggest that the mechanical properties of the bonded joints may be limited by the planar boundary oriented normal to the short transverse direction.

Figs. (13a and 13c) for the same type of joint and material, tearing took place in another form at points 1 and 4 from Fig. (13b) and point 3 from Fig (13-c), while a complete seperation of adhesive layer observed Points 2 and 3 from Fig. (13b) and points 1 and 2 from Fig. (13-c). The breaking loads of these joints were 4.444, 4.179 and 4.05 KN respectively.

From Fig. (13b) one can say for Br/Br bonded joint, the tear of adhesive has nearly the same behaviour as was seen in AL bonded joint depending upon adhesive thickness. Decreasing the adhesive thickness results in a complete tearing of the adhesive layer. The breaking load of this joint was 4.2 KN, where the diameter of joint was 30 mm and the adhesive thickness was 150μm. The adhesive of this joint was teared at points 3 and 4 and seperated at points 1 and 2. The effect of joint type on the fracture behaviour was demonistrated in Figs. (14a and 14b). The double butt strap joint was tested under uniaxial tensile loading at room temperature. The dimension of strap was 20 x 20 x 2 mm and the adhesive thickness was 150μm. The breaking load was 31.2 KN. From Figs. (14-a and 14-b) it is obvious that the adhesive is seperated from material at points 1 and 3, while there are tearing in adhesive layer at points 2,4 and 5.

This effect can be attributed to the variation of adhesive thickness and it may be also due to the viration of contact area between the different joints.

3.2. Effect of surface roughness on the strength of joint :

Fig. (15) indicates the relation between the tensile strength and surface roughness (C.L.A) for three adherend materials using adhesive thickness of 200 μm for (AB) joints. From this figure, the tensile strength increases with the increase of surface roughness in the range of machining processes up to 20 μm, then the tensile strength starts to decrease continuously with the increase of C.L.A. value. The range of C.L.A. which gives maximum joint strength are from 15 to 30 μm. The different adherends results indicate the same trend, but the surface roughness which give highest value of tensile strength are from 17 to 30 μm for AL/AL joint. From the analysis of the same figure, it can be concluded that the range of surface roughness which gives good results for different joints are from 15 to 30 μm.

Figs. (16 and 17) show the relation between the tensile strength and surface roughness (C.L.A) for three adherend materilas of (DB) joints. The specimens

From the previous figures, the reduction in the measured "shear" strength with increase in overlap length has been observed for other (DB) AL6061 joints. The stresses are sensitive to the moment factor, which is dependent on the test piece, the shear test and the sheet thickness. However, the stress distribution characteristic of an overlap test piece consists of a very high tensile stress (about 4x applied stress) normal to the bond interface at the ends of the bonded length where the shear stress is zero, a region of high shear and low tensile stress within a distance L<t from the ends of the bond and a region at the center of the bond length where the stresses are zero. In the present tests the constraint imposed by the shear test jig may reduce the tensile component at the ends of the bond.

At the end of the fracture zone 1 the ratio of resolved normal force/bond width values obtained for the measured bend angles of 4° to 6° are 35 to 90 N mm^{-1} for the 4 and 16 mm overlaps. These values are in good agreement with measured 90° peel strength values of 30 to 50 N mm^{-1}. Taking zone 1 bond areas only, shear strength (load/area) values of 200 and 190 MPa are obtained for the 4 and 16 mm over laps, respectively. The values are within the shear strength scatter band obtained in the region for L=2 mm. These results suggest that the central region contributes little to the shear strength of the joint.

For these reasons it can be concluded that the fractures observed in the present tests are consistent with crack nucleation at the ends of the joint caused by the high tensile stress, followed by fast crack growth through zone 1 to relax the shear strains as shown in Figs. (12a and b). The rate of crack growth may fall as the crack centers the region of low stress and plastic bending and an increased normal stress component causes peel-type fracture in zone 2, as shown in Fig. (12c). Even if the high rate of intergranular crack growth in zone 1 is used to explain the lack of deformation on this fracture surface, it is difficult to reconcile the fracture morphology with shear, it is possible that the local crack tip stresses actually give rise to tensile fracture in zone 1.

Fig. (13a) shows the tearing of AL/AL boned butt joint under tesile load, where the diameter of this joint was 30 mm and the adhesive thickness was 150 µm. It is obvious that the adhesive thickness plays a vital role in the fracture mechanics of the bonded joint. As shown in Fig. (13a), the adhesive is teared at points 4,5 and 6 and the adhesive is seperated at points 1,2 and 3. Comparing with were subjected to pressure load as mentioned before which varies for different materials. These pressures were at (0.6-0.8) T_m. From these figures, it can be seen that the tensile strength decrease with the increase of surface roughness (C.L.A). This means that, the bond interface area increase with the decreases of surface roughness (C.L.A). The difference in fracture surface roughness was related primarily to the grain-boundary surface contour. Mounds and cavities on the fracture surfaces were caused by metal pull-out. These results are consistent with parent of the same metal. The reduction in the measured tensile strength with the increase of surface roughness is very clear when two different adherends were used as shown in Fig. (16). The similar pairs of joints give good results as compared with the others. This is due to the increase of adhesion force between the same grains of metal.

3.3- Effect of temperature on the strength of the joint :

Fig. (18) indicates the relation between temperature and tensile strength of (AB) joints for three adherend materials (AL/AL, Br/Br and AL/Br) using adhesive thickness of 200 μm and C.L.A 25 μm. It can be seen that, tensile strength decreases with increasing the temperature for these types of joints. The tensile strength reaches the minimum value when the temperature is nearly 120°C. The experimental results indicate that, room temperature gives higher value of tensile strength for all group of adherends. It is clear that, the increasing of temperature caused degradation of this type of adhesive material.

Fig. (19) indicates the relation between the temperature and the deformation (in diameter) for three types of (DB) joints at constant pressure (0.8) Py for different materials at pressure time=5 minutes. The Br/Br joint gives more deformation in length as compared with the others. The less deformation was at AL/AL joint. This is may be due to the mechanical properties of the metals which are used in these investigations. From Fig. (17), AL/AL (DB) joints give good results as compared with the other types of (DB) joints. But all of these types of (DB) joints give a very small values of tensile strength especially AL/Br-(DB) joints.

3.4- Effect of adherend materials on the strength of the joint :

The experimental results indicate that the difference in tensile strength for all types of adherends (AL/AL, Br/Br and AL/Br) is small as shown in Figs. (15 and 19). This means that, the type of adherend material has a small effect on the tensile strength of (AB) joint. Therefore, different materials of the adherend may be used in the structural adhesive in such a way to take full advantage of their properties. For instance, (AL/AL), which has a Young's modulus more than the other metals can be used for the panels to improve stiffness and/or reduce the weight of structure.

Fig. (17) indicates the relation between three types of joints and tensile strength at these conditions; pressure loads are between 0.6-0.8 Py, different heating temperatures from 200-950°C, the same surface roughness and the same degree of flatness. From this figure, it can be seen that the AL/AL joint gives good results as compared with the others. This is may be due to the following factors; the bonded area in the other joints is very small related to mechanical properties of these metals and the adhesion between the two parts of joint is very small at elastic deformation.

4- CONCLUSIONS

The results and the analysis led to the following :

1- The fracture of overlap shear test-pieces in AL 6061 was similar for both the base metal and the diffusion-bonded joints (DB).

2- Two types of fracture surface were observed as the theoretical elastic stress state changed from that approximating to shear to that characteristic of peel.

3- The planar bond interface may accentuate the tendency in AL 6061 towards low ductility and toughness in short transverse direction.

4- Two types of fracture surface were observed in the contact area of (AB) joint, it was teared in some places and was seperated in the others.

5- The behaviour of (AB) fracture depends upon; degree of surface roughness, canact area and the chemical composition of adhesive material.

6- The surface roughness (C.L.A) plays an important role in the durability of (AB) and (DB) joints. The range of surface roughness which gives good results in tensile tests is from 15-30 μm and 10-25 μm for (AB) and (DB) respectively.

7- The (AB) joints gives good results in tensile tests as compared with (DB) joints specially at low temperatures.

8- The type of adherend has a large effect on the performance of (DB) joint, but it has very small effect in the performance of (AB) joint. AL/AL joint of the two types of bonding gives good tensile strength as compared with other types of adherends.

9- Manufacturing of (DB) joint at 0.8 Py and 0.8 Tm gives more durability but also gives more deformation in joint diameter.

10- Obviously, (AB) technique is more economical bonding method than the (DB) technique.

5- REFERENCES

1- P.G. Partridge, "Diffusion Bonding of Metals" 5 AGARP-L-S, 168, 1988.

2- M.G. Silk, A.M. Stoncham, and J.A.G. Temple "The Reliability of Non-destructive Inspection", pp. 76-84, Hilger Bristol 1987.

3- M.G. Silk, A.M. Stoncham, and J.A.G. Temple, "The Reliability of Non-destructive Inspection", pp.19-25, Hilger, Bristol 1987.

4- Thomas J. Moore, " Practical Method for Diffusion Welding of Steel-Plate in Air", Welding Journal 51 (3).pp. 1063-1065, Mar, 1972.

5- L.J. Hart-Smith, "Delamination and debonding of materials" ASTM, (American Society for Testing Materials, Philadelphia, Pennsylvania, 1985, pp. 238-243.

6- P.M. Brewis " In Durability of Structural " A. J. Kinloch, Applied Science Publishers, London. 1983.

7- B. Chicco, "Diffusion Bonding of AL-SI P20 Tool Steel". Materials Forum, Vol. 16, pp. 105-110, 1992.

8- Nadle, M.A., and Yoshino S.Y., "Adhesive Joint Strength as Function of Geometry and Material Parameters", Society of Automative Eng., Report No. 670856.

9- Xiangfu Zhu and J.G. Byrne, "Effect of Interface Defects on the Mechanical Properties of Autogenous Diffusion Bonded Joints", J. Mater. Eng. Vol.13, pp. 207-211, 1991.

10- D.S. Talor & G. Pollard, "In advance in welding processes", Vol.1, 4th Int. Conf. Harrogate, 9-11 May 1978, The welding Institute, Cambridge, UK, 1978.

11- A.M. Easa and M.M. Sadek. "Effect of Surface Roughness and type of adhesive on the performance of bonded joint" PEDAC 1983. Alex. University, Egypt.

12- A.M. Khourshid and B.M. Badr, "Structure and Mechanical Properties of AL-SiC Alloys Produced By Pressure Casting". Eng. Res., Helwan Univ. Bull., Vol.2, pp. 98-114, April 1993.

13- D.V. Dunford, P.G. Partridge, "Strength and Fracture Behaviour of Diffusion Bonded Joints in AL-Li (8090) Alloy". J. of Mater. Sc., Vol. 26, pp. 2625-2629, 1991.

14- D.M. Bailey, R.S. Salyess, "Effect of Roughness and Sliding Friction on Contact Stresses ", J. of Tribology, Vol. 113, pp. 729-738, October, 1991.

15- A.M. Easa & A.M. Khourshid, " An Investigation on strength and fracture behaviour of (DB) joints In AL 6061" Eng. Res. Bul., Helwan Univ., Vol.1, 1994.

Appendix (A)

The mechanical properties of Br 60/40 and AL 6061 are as follows :

Mechanical Properties	δ_u M Pa	δ_y M Pa	E G Pa	B.H.	% Elongation
Br 60/40	400	175	90	60	50
AL 6061	125	55	60	30	25

Appendix (B)

The Sepcifications of Adhesive "super-bonder 415" are as follows :

Specification at 20°C	Checical name	Colour	Viscosity	Typical Handling strength	Typical Ultimate Strenght	Gap filling	Temp. range	Min. shelf life
	Anearable	Amber	10 CPS	1 min	24 hrs 30 N/mm^2	0.25mm	-55 : 120°C	0 :5°C 1 year

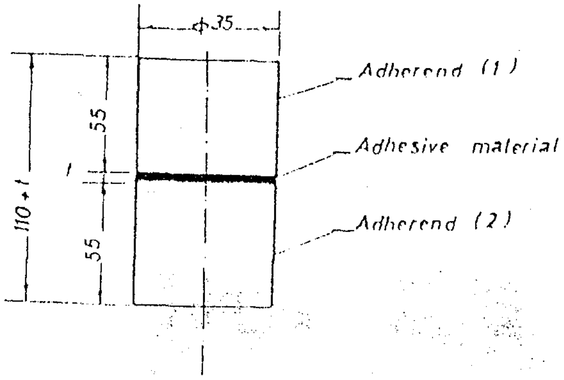


Fig.(1_a) A pair of AB blocks using Br/Br or Al/Al or combination of them.

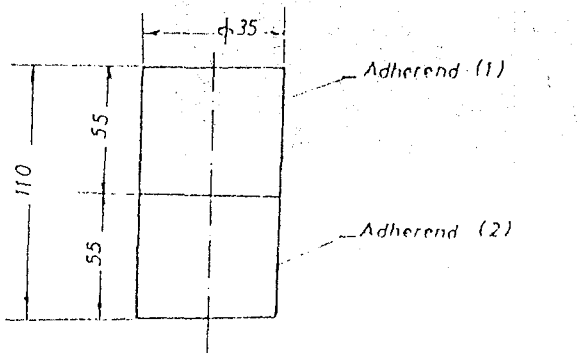
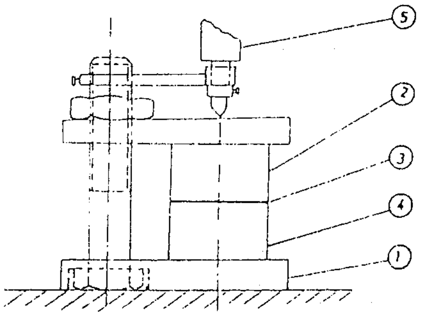
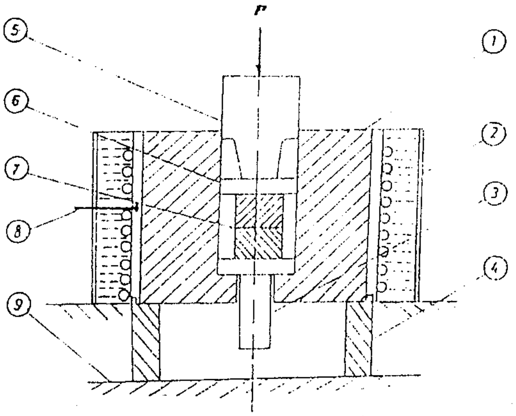


Fig (1_b) A pair of DB blocks using Br/Br or Al/Al or combination of them.



1 _ Base.
2 _ Adherend (2).
3 _ Adhesive material.
4 _ Adherend (1)
5 _ Dial gauge

Fig.(2_a) Adhesive joint fabrication set_up.



1 _ Die.
2 _ Electric furance.
3 _ Ejector
4 _ Stand.
5 _ Press.
6 _ Press stand.
7 _ Joint.
8 _ Thermocouple.
9 _ Press table.

Fig.(2_b) Diffusion joint fabrication set_up.

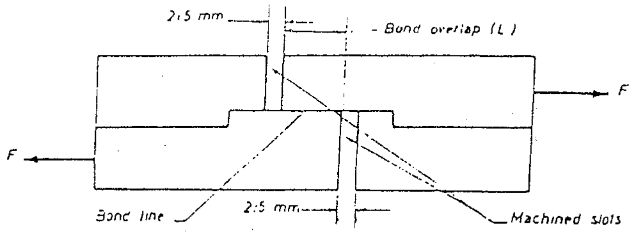


Fig.(3) Diffusion bonded overlap shear test piece.

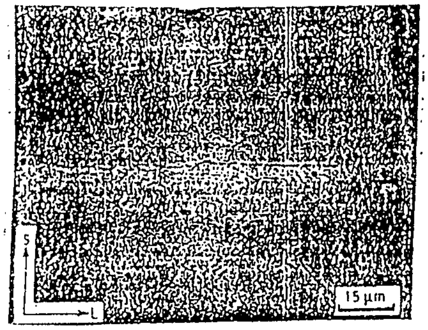


Fig (4) Section Through Diffusion-Bonded Joint
(1mm thick sheet)

a)Overlap length=2mm.
b)Overlap length=4mm.
c)Overlap length=16mm.

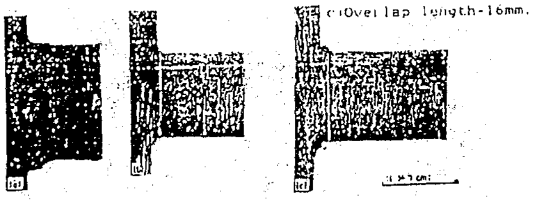


Fig.(5)Shear Fractures Of Diffusion-Bonded Joints.

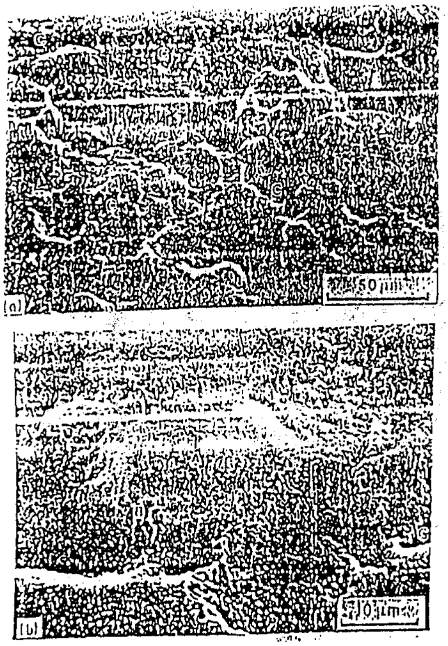


Fig.(7)SEM Of Zone 1 Fracture in (DB)Joint.
(L=16mm)

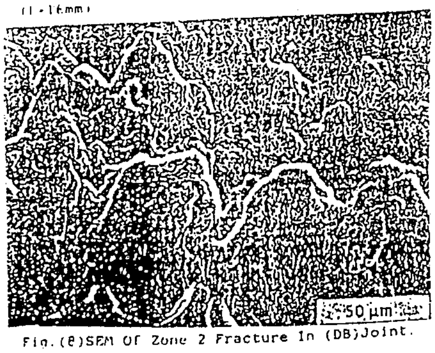


Fig.(8)SEM Of Zone 2 Fracture In (DB)Joint.
(L=15.1).

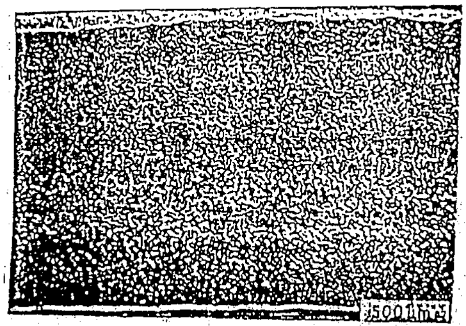


Fig.(6)SEM Of Zone 1 Fracture in (DB)Joint.
(L=2mm).

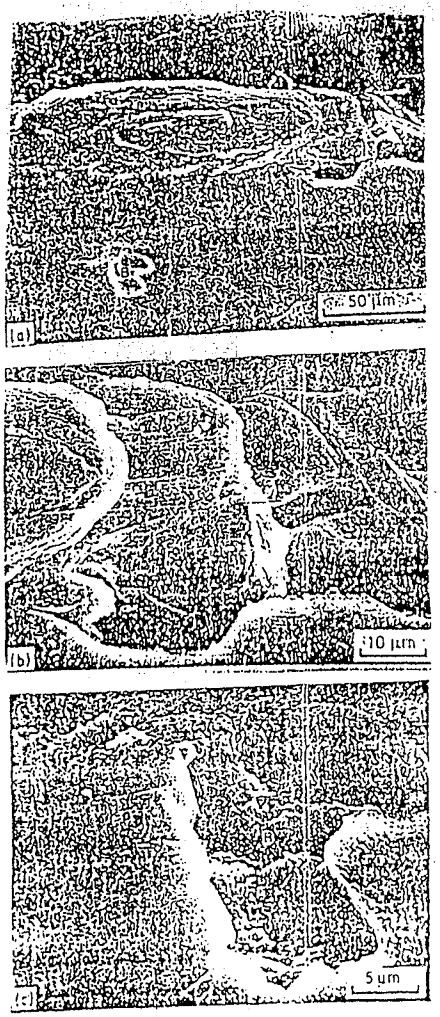


Fig.(9)SEM Of Zone 2 Fracture In (DB)Joint
(Direction of test is from left to right, L=4mm)

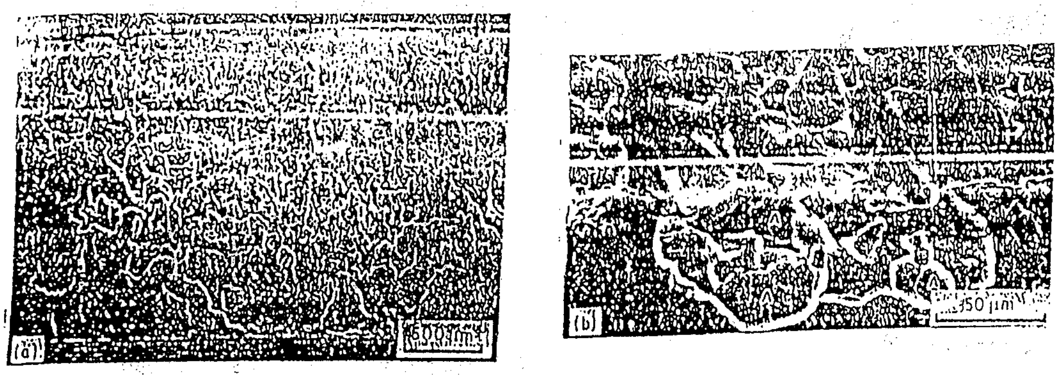
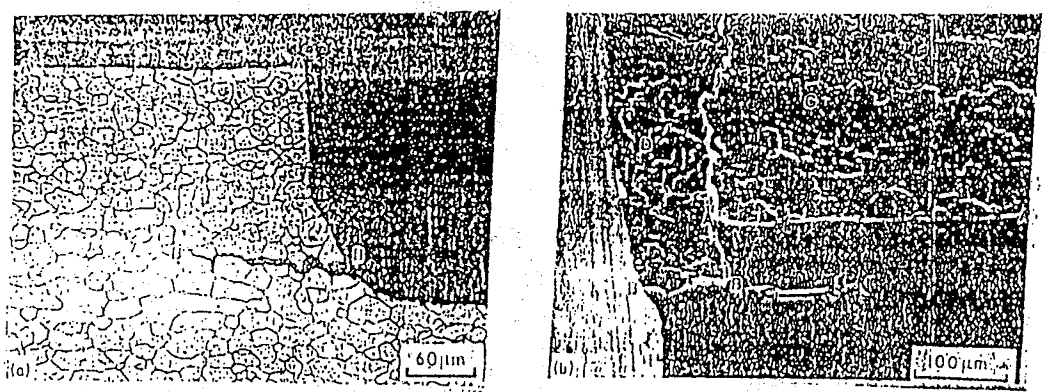


Fig.(10)SEM Of Zone 2 Fracture In Base Metal.
(Direction of test is from top to bottom,t=2mm).



a)Zone 1 bond interface fracture at A-A, base metal fracture at root of slot at B-B.

b)SEM of base metal fracture at root of slot at D. Zone 1 bond interface fracture at C

Fig.(11)Fracture In (DB)Joint,(t=2mm).

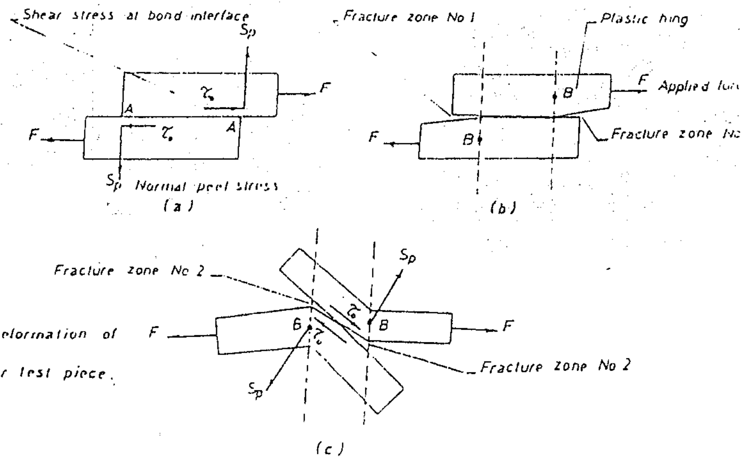
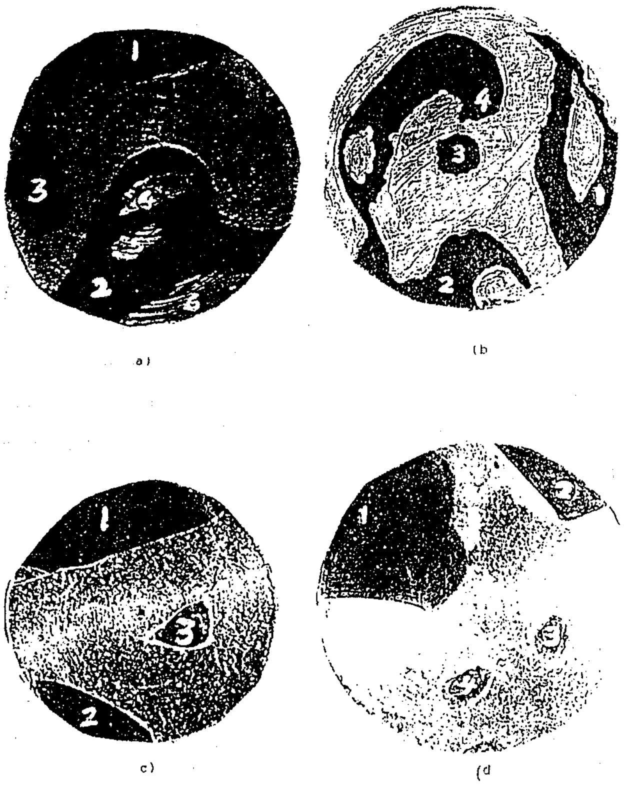


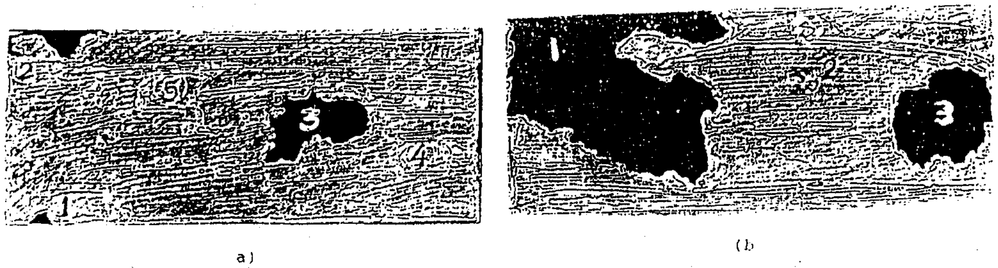
Fig.(12) Fracture and deformation of an overlap shear test piece.



a) (b

c) (d

Fig (13) Fracture Mechanics of
Adhesive butt joints .



a) (b

Fig (14) Fracture Mechanics of
Adhesive double strap joint .

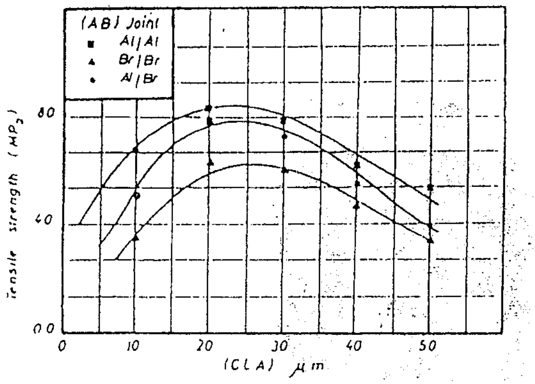
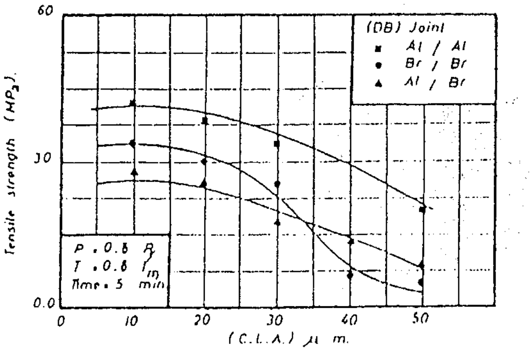


Fig.(15) $[\sigma_f$-C.L.A.$]$ Relations of three adherends and different surface roughness.
(adhesive thickness = 200 μ m.)



Fig(16) $[\sigma_f$-C.L.A.$]$ Relations of three adherends and different surface roughness.

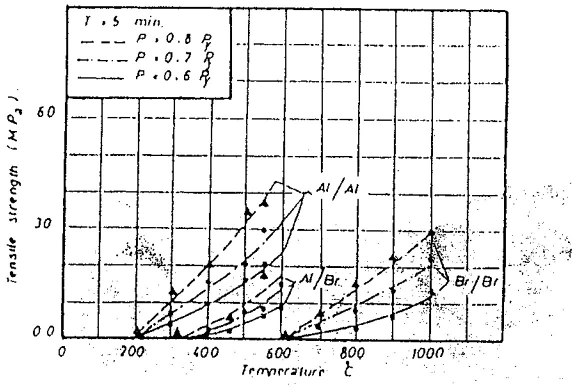


Fig.(17) $[\sigma_f$-T$]$ Relations for (DB) joints at different pressure.

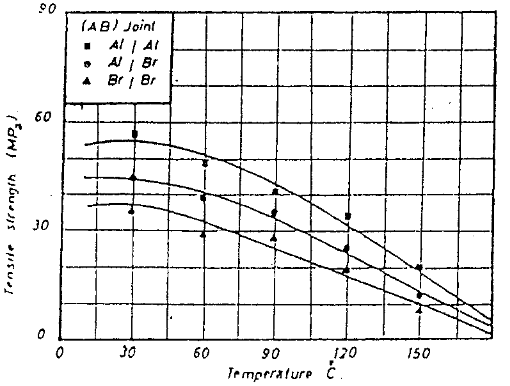
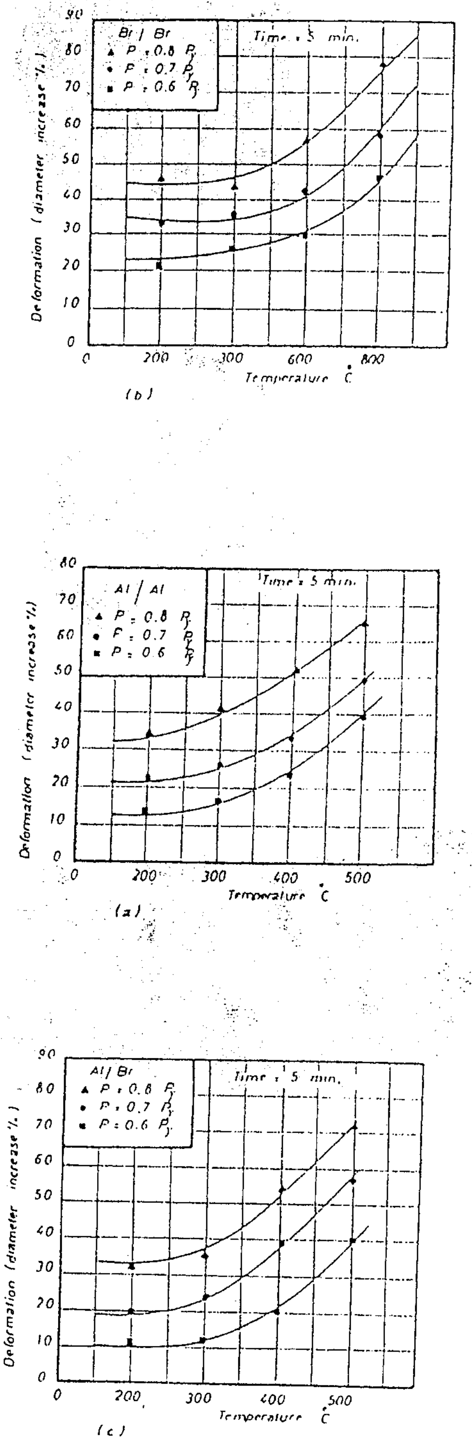


Fig.(18) $[\sigma_f$-Temp.$]$ Relations for three types of adherend materials (adhesive thickness = 200 μ m)



(b)

(a)

(c)

Fig(19)(a,b,c.) Relation between temperature and deformation in diameter at different pressures.

عنوان البحث باللغة العربيه :

دراسة سلوك التحمل والكسر للوصلة الملحومه بالإنتشار واللصق للألومنيوم (٦٠٦١) والنحاس ٦٠/ ٤٠

المشتركون : د./ عبالفتاح خورشيد – أستاذ مساعد بكلية الهندسة بشبين الكوم

ملخص البحث :

إن العناصر الرئيسية التي تؤثر على تقنية كلا من وصل المعادن بالانتشار (DB) ووصلها باللصق (AB) هي : خشونة سطح المعدن ، درجة الحرارة ، نوع المادة اللاصقة ، الضغط والزمن . وفي هذا البحث تمت دراسة هذه العناصر مستخدمين الألومنيوم ٦٠٦١ والنحاس ٦٠/٤٠ ومن الأهمية بمكان مقارنة هذان النوعان من طرق وصل الأجزاء خاصة أن هذه المقارنة قد أهملت في أغلب الأبحاث السابقة .

ولقد تم إستخدام أحمال ضغط مختفة ودرجات حراره مختلفه لكلا المعدنين المستخدمين وذلك أثناء تصنيع وصلات الانتشار – أما وصلات اللصق فقد تم التسخين حتى ١٢٠م بعد تصنيع الوصلة وذلك تمشيا مع التوصيات المرفقة بالمادة اللاصقة . وتم إختبار جميع الوصلات على ماكينة شد خاصة .

ونتائج هذا البحث أظهرت أن عينة الوصلة (Overlap shear test) والتي صنعت من سمك مقدارة ٦ مم من ألواح تم تجهيزها بطريقة اللحام بالإنتشار – أن هناك مجالان للكسر (Zone 1 and Zone 2) في منطقة الإلتحام المجال الأول (Zone 1) يظهر في نهايتي (Over lap) والذي يوضح كسر الحبيبات المتداخلة – والمجال الثاني (Zone 2) ويقع في مركز (Over lap) والذي يوضح أن هناك كسر بالنزع (Peel fracture). ويتضح من التحليل أن الحمل يكون مركزاً غالباً داخلياً على المجال الأول ويهمنا أن نحدد أن المجال الأول هو الذي يظهر في قاعدة المعدن فقط.

ومجالي الكسر يحدثان بسبب الإجهاد الموزع توزيعاً غير افقياً وأيضاً نتيجة لعزوم الإنحناء الناتجة في هذا النوع من الوصلات . ولقد أظهر التحليل أن الإلتصاق الأفقي لعينة يجعل الكسر ذو قابلية للتحرك في إتجاه السحب والمتانة المنخفضة وذلك في الإتجاه العرضي القصير .

وبالنسبة لميكانيكية كسر وصلة اللصق (AB) – ظهر تمزق للصق عند بعض النقاط في منطقة التلامس وأخذ التمزق أشكالاً أخرى في نقاط مختلفه ومن وصلة إلى أخرى . وهناك إنفصال للصق في بعض النقاط ، وإتضح أن سمك اللصق، مساحة التلامس ، التركيب الكيميائي لمادة اللصق لهم تأثير كبير على ميكانيكيه الكسر بهذا النوع من الوصلات .

وقد أظهرت نتائج هذا البحث أيضاً أن وصلة اللصق تعطي نتائج أعلى من وصلة الإنتشار خاصة في درجات الحرارة المنخفضة . ووصلة الانتشار تعطي أحسن نتائجها عند تصنيعها بحمل ضغط يتراوح بين ٧ر – ٨ر من حمل الخضوع . ودرجة الحرارة بين ٧ر – ٨ر من درجة إنصهار المعدنان تعطي نتائج أعلى مقارنة بوصلات الربط الأخرى . وتأثير خشونة أسطح الترابط أو الالتصاق تلعب دوراً هاماً في قيم تحمل الشد الناتج أثناء إختبار (DB) أو (AB) .

مساهمة البحث في الصناعة :

إن تحديد مدى تحمل نوعيات الوصلات للإجهادات وميكانيكية الكسر في كلا النوعين في هذا البحث يوضح بالتالي لمهندسي التصميم مجالات الإختيار لنوع الوصلة عند معرفة ظروف تشغيلها .