Effect of Surface Roughness on Adhesive Bonding of Aluminum AA3105-H12 with oxygen-free High conductivity Copper C10200

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Abstract:

The effect of 4 different surface roughnesses with 4 different assembling cases on shear bond strength of bonding Aluminum AA3105-H12 with oxygen-free High Conductivity Copper C10200 was examined. The results demonstrated that the highest shear bond strengths with the highest surface roughness were obtained, and then decreases with the increasing of the value of emery paper grade. The result of bonding similar specimens shows that the Aluminum specimens recoded the highest shear bond strength (13.8 MPa at emery paper grade ASTM 400) than the OFHC Copper specimens (10.33 MPa at emery paper grade ASTM 400). The result of bonding dissimilar specimens recoded that the group (Al-Cu-Al) has the highest shear bond strength (12.33 MPa at emery paper grade ASTM 400) than the group (Cu-Al-Cu) which has (6.02 MPa at emery paper grade ASTM 400). And that shows that the shear bond strength varied with the metals used. However, the shear bond strength value varied with the type of metals used and the surface roughness.

Key words: Adhesive bonding, Surface roughness, Shear bond strength.

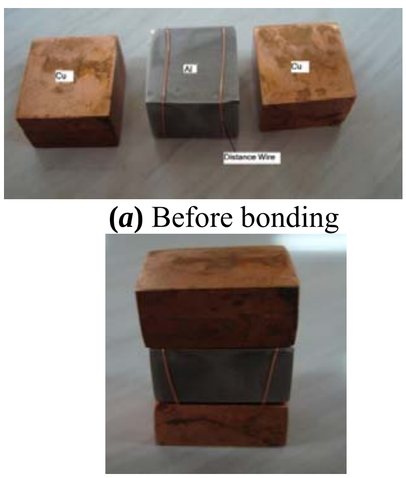
Introduction:

Adhesive bonding Technology has been increasingly applied in primary productions, It is used in aircraft, automotive, and repairing industry because of its functional advantages. The adhesive bonding technology saves costs, in critical metallic materials and the decrease of the joint weight too. In recent years the adhesive bonding technology has shown a capability of replacing conventional methods such as riveting, and welding in a variety of applications [1]. This fact emphasizes the importance of this technology, which influence is essential for the quality, reliability, and necessarily the use of bonded joints [2]. The fracture resistance between the bonded joints is strongly affected by the properties of materials used, surface cleanness, surface roughness, and adhesive consistency [3]. A widespread agreement in the literature that surface roughening is a prerequisite for achieving sufficient bracket-to-alloy bonding. [4, 5]. Micromechanical bonding systems involve sandblasting and result in improved retention between alloy and resin by cleaning oxides or greasy materials from metal surfaces, this treatment creates a very fine roughness, increasing surface area and thus enhancing mechanical and chemical bonding [6, 7]. Thus, the bond strengths obtained from sandblasting alone might be insufficient, especially after thermal conditioning [8, 9]. The roughness and the bond strength values of the metal brackets varied with the type of alloys used and the conditioning systems applied, and showed that the bond strength increases when increasing pre-heat and plastic deformation [10, 11]. Epoxy adhesive have a good affinity for aluminum alloy surfaces, and the oxide layers produced during surface preparation [12]. Copper has been used for its wide applications in electrical supplements. Recently aluminum is widely used for automotive head engine, aircraft and computer components [13].

The objectives of this study were to compare the effect of surface roughness of two metals type Aluminum AA3105-H12 (Al) and OFHC Copper C10200 (Cu) on the shear bond strengths of metals bonded by adhesive epoxy.

Materials and Methods:

Total of (48) square specimens with dimensions (15mm) length, (15mm) height and (10mm) thick, were used twenty four from AA3105-H12 Aluminum and the balance from OFHC Copper. Three specimens assembled for testing similar and dissimilar metals as shown in Figure (1).



(***a***) Before bonding

(**b**) After bonding

Figure 1: Assembly for epoxy bonding.

The specimens were employed consecutively for testing four different surfaces roughness using emery paper grade size (400, 600, 800, and 1000) according to ASTM (Table 1).

Table1: Specimens group and emery paper grade.

G	Condition	ASTM emery paper grade			
A	Al-Al-Al	400	600	800	1000
B	Al-Cu-Al	400	600	800	1000
C	Cu-Al-Cu	400	600	800	1000
D	Cu-Cu-Cu	400	600	800	1000

Table (2) shows the mechanical and the physical properties of AA3105-H12 Aluminum and OFHC Copper.

Table2: Mechanical and physical properties of bonded materials

Metal	Tensile Strength (MPa)	Yield Strength (MPa)	Thermal conduct. W/m.k	Density g/cm3
Al	120	85	173	2.7
Cu	221-455	69-365	94	8.9

And the specimens have been examined at Mechanical Engineering. Dep., Sulymaniah Technical College, and it started in 11/5/2011 and completed in 17/9/2011, the specimens were bonded by using epoxy and hardener with ratio 3:1 respectively, demonstrated its specifications on Table (3),

Table3: Characteristics of used adhesive.

Compr. strength MPa	Tensile strength MPa	Bond shear strength MPa	Shear modulus GPa	Density (Mixed) g/cc	Shear modulus GPa
60	12	50	1.38	1.75	1.38

After grinding the specimens were rinsed in acetone. Three tested specimens used for each case. The adhesive layer had thickness of (250µm). Two distance wires of requisite (250µm) diameter were fixed to control the epoxy layer thickness as shown in Figure (2).

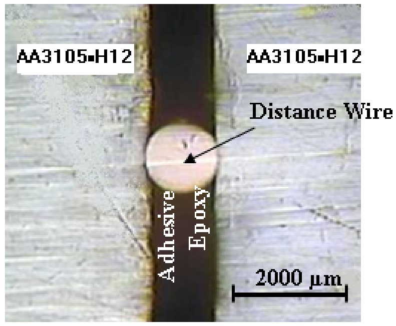


Figure 2: Microscopic bonded joint section.

All the bonding specimens were left at the room temperature for twenty four hours as accruing time.

The shear load test was carried out using double shear fixture has been manufactured specially for this work as shown in Figure (3).

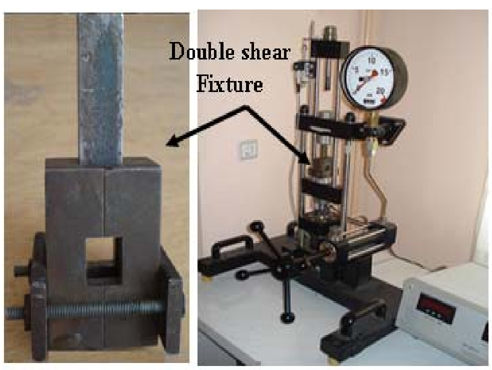


Figure 3: The universal tensile-strength testing machine with double shear Fixture.

After the failure of the bonding specimens the highest force was recorded and the shear force was determined according to:

$$\tau = \frac{F}{2A}$$

Where: τ – Double shear strength (MPa),

F – Highest force (N),

A – Bonded surface area (mm^2).

Results:

The present work is focused on experimental investigation of the influence of surface roughness on adhesive bonding strength by direct experimental measurement and all the tests were run at room temperature.

1. Bonding similar specimens of Aluminum AA3105-H12:
Figure (4) shows the abrasive emery paper grade and shear bond strength values.
Figure (5) shows the microscopic graph of bonding similar specimens of Al.

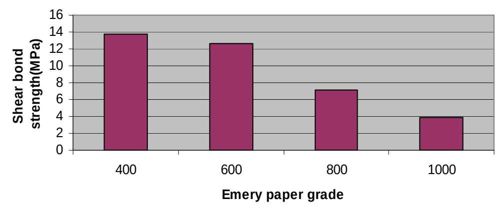


Figure 4: Relation between shear bond strength and emery paper grade using group (Al-Al-Al).

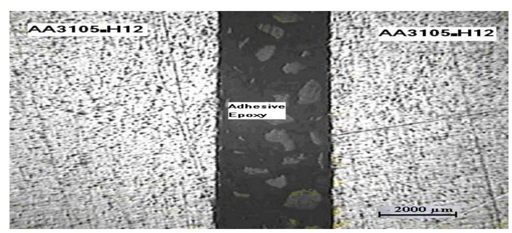


Figure 5: Microscopic bonded joint after using emery paper (ASTM 1000) of group (Al-Al-Al).

2. Bonding similar specimens of oxygen-free high conductivity Copper C10200:
Figure (6) shows the abrasive emery paper grade and shear bond strength values.
Figure (7) shows the microscopic graph of bonding similar specimens of Cu

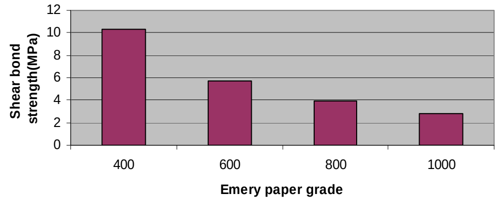


Figure 6: Relation between shear bond strength and emery paper grade using group (Cu-Cu-Cu).

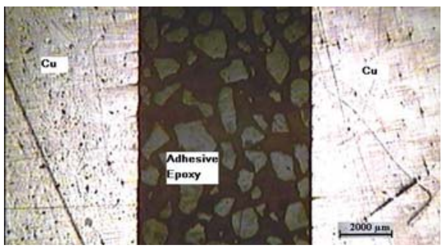


Figure 7: Microscopic bonded joint after grinding using emery paper (ASTM 1000) of group (Cu-Cu-Cu).

3. Bonding dissimilar specimens:

a. Bonding (Cu-Al-Cu) specimens:
Figure (8) shows the abrasive emery paper grade and shear bond strength values.

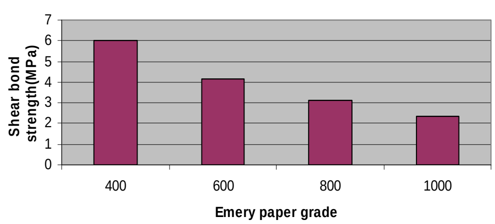


Figure 8: Relation between shear bond strength and emery paper grade using group (Cu-Al-Cu).

b. Bonding (Al-Cu-Al) specimens Figure (9) shows the abrasive emery paper grade and shear bond strength values.
Figure (10) shows the microscopic graph of bonding dissimilar specimens of Cu-Al.

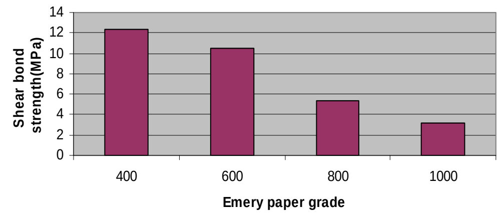


Figure 9: Relation between shear bond strength and emery paper grade using group (Al-Cu-Al).

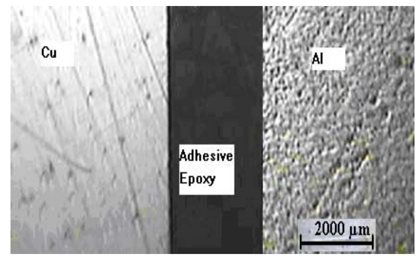


Figure10: Microscopic bonded joint for dissimilar specimens after grinding using emery paper grade (ASTM 1000).

Discussion:

All cases revealed significant differences between groups depending on the combination of emery paper grade and metals type showing that all relations nonlinear.

The results demonstrate that the increase of surface roughness increasing the shear bond strength. The highest shear bond strength for similar specimens of Al is (13.8 MPa) and the lowest is (3.93 MPa) as shown in figure (4), and the highest similar specimens of Cu is (10.33 MPa) and the lowest is (2.77 MPa) as shown in figure (6).The highest shear bond strength of dissimilar specimens of (Cu-Al-Cu) is (6.02 MPa) and the lowest is (2.37 MPa) as shown in figure (8), and the highest of dissimilar specimens is (12.33 MPa) and the lowest (5.37 MPa) as shown in figure (9).

All the results above shows that the highest shear bond strength values were achieved by grinding the contact surface with the lowest emery paper grade

(ASTM 400), whereas the lowest values with the highest emery paper grade (ASTM 1000). These values prove that the emery paper has the main effect on shear bond strength.

Among conditioning groups, the shear bond strength values of similar specimens of Al (the highest 13.8 MPa and lowest 3.93 MPa) are higher than the values of similar specimens of Cu (the highest 10.33 MPa and lowest 2.77 MPa), because higher roughness diverse range could be reached in the case of similar specimens of Al. this confirmed that the properties of materials used affect on shear bond strength.

The result values in figures (8, and 9) shows that the arrangement of dissimilar metals during bonding has significant effect on shear bond strength and depends on the amount of metal's area used in bonding.

The microscopic graphs demonstrated these reasons and revealed the significant influence of surface roughness on shear bond strength. Figure (5, 7, and 10) shows when Using emery paper grade has main effect on Aluminum than Copper and indicated that the emery paper grade removes more amount of metal and made more waves on the

Aluminum surface than Copper surface. So that the cavities are decrease on its surface and the penetration amount of epoxy adhesive became less than on the Copper surface. For this reason the amount of shear bond strength decreases in the case of Copper than Aluminum.

Conclusions:

Within the limitations of the present study, the following conclusions can be considered:

1. the highest shear bond strength was obtained in bonding similar Aluminum specimens (13.8 MPa at ASTM 400) due to its structure and the epoxy adhesive has a good affinity for Aluminum surfaces than Copper surfaces (10.33 MPa at ASTM 400).
2. The highest shear bond strength in bonding dissimilar specimens was obtained in the group (Al-Cu-Al) which has (12.33 MPa at ASTM 400) than in the group Cu-Al-Cu) which has (6.02 MPa at ASTM 400).
3. The shear bond strength value varied with the emery paper grade and it recorded maximum value at emery paper grade (ASTM 400) and decreased when emery paper grade increased from this value because the epoxy adhesive area changes with the changing of the cavities and the vacancies of the surface.

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پوختە

کاریگەری (چوار) نمرەی جیاوازی زبری و(چوار) دۆخی جیاواز پێکەوە بەستن لەسەر بەرگری دادڕانی بۆنـــدی ئەلەمنیۆمی (AA3105-H12) وەلەگەڵ کانزای مس oxygen-free High Conductivity copper C10200 تاقیکرایەوە.ئە نجامەکان دەریان خست کە بەرزترین بەرگری دادڕان لەگەڵ بەرزترین زبری وە نزم ئەبێتەوە بە بەراوردی تا نزمترین زبری. دەرکەوت کەبەرزترین بەرگری دادڕاندن لەکاتی بەستنی یەکەکانی ئەلەمنیۆمی هاوشیوە کە گەیشتە 13.8 MPa لە کاتی بەکار هینانی کاغزی ساف کردن جۆری ASTM 400 بە بەراوورد لەگەڵ بەستنی یەکەکانی مسی هاوشیوە کە کەیشتە 10.33 MPa بە هەمان جۆرە کاغزی ساف کردن. ئە نجامەکان دەریان خست کە بەرزترین بەرگری دادراندن لە کاتی بەستنی یەکەکانی جۆراوجۆر بۆ کومەلەی Al-Cu-Al کە کەیشتە 12.33 MPa بەهەمان جۆرە کاغەزی ساف کردن بە بەراوورد لەگەڵ بەستنی یەکەکانی جۆراوجۆر بۆکۆمەلەی Cu-Al-Cu کە کەیشتە 6.02 MPa بەهەمان جۆرە کاغەزی ساف کردنەوە. هەرچەندەبەهای بەرگری دادڕانی بۆند دەگۆڕێت بە پێی جۆری کانزای بەکارهێنراوو زبری.