Studying the Effect of Friction Welding Parameters on the Hardness Values Distribution of Al-Cu Joint

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ABSTRACT

This research depends on studying the connected of similar metals (Al-Al, Cu-Cu) and dissimilar metals (Al-Cu) by friction welding. Welding friction parameters that studied were friction time at range (3-31) sec, friction pressure at range (20, 40, 60) MPa ,forging pressure at range (70,100,130) MPa and constant revolution of (2000) r.p.m.were studied by (17) samples. The welded parts were tested by tensile strength test, hardness (HV) test and liquid penetration test. The results showed that the hardness of welding zone was higher in values than both of (HAZ) zone and base metal zone due to the occur of recrystallization process due to the generated heat during welding process, also the tensile strength of welded zone was higher (500 MPa) due to the activation of diffusion process at welding zone which depends on the heating generated during welding process, It is also found that the decreasing in the length (ΔL) of aluminum is more than that of copper because the hardness of aluminum (32Hv) is less than that of copper (60Hv). Also from the results, it was found that weldabilty of similar metal (Al-Al), (Cu-Cu), were improved using the friction welding process due to a good tensile strength.

Keywords: friction pressure, forging pressure, recrystallization.

1-Introduction

Friction welding is a class of solid state welding which generates heat through the mechanical friction between the moving part and the fixed part to be welded as well as the friction and compression forces, which transform the contact area between the weld parts into the elastic zone. The friction welding is perhaps the least sensitive of the other welding methods as long as the heat produces directly upon welding [2].

Conductive welding can achieve high production ratios, so it is an economical welding in applications as it replaces other bonding processes. It is used to connect various ferrous and non-ferrous alloys, which have circular and non-circular sections and different temperatures as well as various mechanical properties as well [11].

In this welding, the heat is generated from mechanical power generation to thermal energy at the interface of the welded parts during the rotation of the moving part and by pressing the fixed and moving parts together. [8] The variables controlled in the welding process are friction pressure, friction time, Pressure Forming, Forming Pressure [13].

The factors affecting friction pressure, compressive pressure, friction time and pressing time were applied to determine the stability of rotational velocity and friction coefficient to find optimal conditions for similar and non-similar metals according to the method of single variable and evaluated based on tensile strength [14].

The study of tensile strength, and microscopic structure of the friction welding of non-similar metals between the stainless steel SF2507 and soft steel and the change of the pressure and the pressure of the formation of three cases and the time and rotational velocity and concluded that the efficiency of the joints decreases with the increase of both the pressure and the pressure of formation [7].

The influence factors (operating time, operating pressure, compressing time, compression pressure) were examined on morphological properties of Al / Cu welding joints and rotational velocity. The search results in a change in the shape and properties of the contact surface between the two metals as we move away from the axis of rotation. The pressure of the formation of 48 MPa and the compression pressure of 160 MPa resulted in morphological changes. The effect of the pressing time with the effect of the pressure group was evident in changing the shape of the seam for a very narrow period exceeding a few seconds [12].

The study investigated the effect of friction pressure, friction time and speed on mechanical properties such as tensile strength, hardness and cuff resistance of the 6061-T6 aluminum alloy using statistical method of design and optimization of practical experiments. It has concluded that the effect of friction pressure and rotation speed comes first then the second friction time and the hardness and tensile strength and cuffing shall be less in the area of the link than the base metal area as well as the effect of these factors and their interactions between them [4].

The study examined mechanical properties (hardness distribution -

tensile resistance - static torsion and dynamic twisting) of the Yok-Tube [3]. In this paper, we will study the effect of friction pressure and pressure time on the distribution of hardness values in welded works of similar and similar metals as well as tensile strength and other mechanical and metallurgical properties.

2- Experimental

The practical aspect that shows the preparation of the samples and welding them (welding friction) within the variables, and then conduct mechanical tests used hardness test and test tensile and permeability.

2-1 materials selection

Aluminum and copper were used as raw materials for the preparation of the samples used in the welding process and the chemical composition of the used metals was examined as shown in the table.1

Table.1 chemical composites for Aluminum and Copper

	Fe	Cu	Ti	V	Mn	Mg	Cr	Si	Zn
Al	0.2	0.15	0.05	0.07	0.1	0.04	0.01	0.2	0.04
Cu	0.15	0.1	0.06	0.02	0.1	0.03	0.01	0.1	0.1

2-2 Preparation of samples

Samples used in the welding process from the above materials are equipped with the dimensions shown in Table .2

Table .2 Sample dimensions

Samples	Diameter (mm)	Length (mm)	Number
Al	8	80	17
Cu	8	90	17

2-3 Samples welding (with frictional welding)

The specimens were manufactured using mechanical machining, then the friction welding were performed using the machine shown in fig .1

Fig .1 the welding machine

Where the welding process was conducted as shown in Table .3, which also includes the conditions of the welding process and the welding, was on three groups depending on the friction pressure and compression.

Table .3 Conditions of the welding process

1	1	3	60	130	2000
	2	5	60	130	2000
	3	7	60	130	2000
	4	9	60	130	2000
	5	11	60	130	2000
2	6	13	40	100	2000
	7	15	40	100	2000
	8	17	40	100	2000
	9	19	40	100	2000
	10	21	40	100	2000
3	11	23	20	70	2000
	12	25	20	70	2000
	13	27	20	70	2000
	14	29	20	70	2000
	15	31	20	70	2000
4	16	(Al-Al) 9	60	90	2000
	17	(Cu-Cu) 31	60	130	2000

2-4 Change in weld sample length(ΔL)

The table below shows the change in the length of the samples with the change in the conditions of the welding process of

Different metals (Al-Cu).

Table .4 Change in sample length (Al-Cu)

No.	$Al(\Delta\mathrm{L})(\mathrm{mm})$	$Cu(\Delta L)(mm)$
1	80-71=9	90-87=3
2	80-68=12	90-81=9
3	80-66.1=13.9	90-88.8=1.2
4	80-65.4=14.6	90-88.5=1.5
5	80-65.2=14.8	90-88.4=1.6
6	80-73=7	90-89.6=0.4
7	80-71=9	90-89.3=0.7
8	80-69=11	90-88.8=0.2
9	80-67=13	90-88.4=0.6
10	80-66=14	90-88.1=0.9
11	80-77.2=2.8	90-89.7=0.3
12	80-76.4=3.6	90-89.3=0.7
13	80-75.7=4.3	90-89.1=0.9
14	80-74.3=5.7	90-88.79=1.21
15	80-73.1=6.9	90-88.7=0.3

Table.5 shows the change in sample lengths with the change of the friction welding zones of similar metals (Al-Al), (Cu-Cu).

Table .5 Changes in sample lengths (Al-Al), (Cu-Cu)

No.	ΔL, Al(mm)	ΔL, Al(mm)
16	80-77=3	80-76.5=3.5
No.	ΔL, Cu(mm)	ΔL, Cu(mm)
17	90-89.3=0.7	90-89.2=0.8

3-Mechanical tests

3-1 permeability test

The quality of the samples was examined through the liquid penetrant test, consisting of three bottles, the first used for cleaning and the second for the dye, where the welding area is sprayed with the paint, left for five minutes, and then cleaned. The third stage is used as a liquid substance called the developer. Welding .

3.2 Hardness Test

The hardness of the welded models was measured by using the Vickers method where readings were taken from the three regions (welding area, heat affected area and metal base area).

Where the readings shown in Table.6 were recorded indicating the hardness values of the three groups.

Table .6 Hardness values for Al-Al, Cu-Cu and Al-Cu,

Group No.	Sample No.	Base (Al-	H.A.Z (Al-Cu)	W.Z (Al-Cu)
1	1-5	33-61	40-71	85
2	6-10	37-59	56-66	82
3	11-15	39-59	55-63	80
4	(Al-Al) 16	39	41	60
	(Cu-Cu) 17	60	66	74

3-3 Tensile test

Tensile testing is one of the most important tests in the resistance of welding, where the device shown in Fig. 2 is used.

Fig .2 tensile testing apparatus

The readings shown in Table.7 were recorded.

Table .7: tensile strength values of similar metals (Al-Al, Cu-Cu, Al-Cu)

Group No.	Sample No.	Tensile strength(MPa)
1	1-5	476
2	6-10	467
3	11-15	457
4	16	490
5	17	500

4- Results and discussion

The results were discussed through the variable conditions of the welding process as well as the mechanical properties tests which were performed on the weld after welding.

4-1 Tensile strength relationship with friction pressure.

Figure .3 shows the relationship between tensile strength, friction pressure and behavior. The increase in tensile strength is shown with increased friction pressure. The reason is that the friction pressure works to clean the two surfaces of the welding metal. The friction pressure also raises the temperature of the metal which activates the subsequent phase of the welding process (the pressing phase) where the greater the pressure of friction the greater the temperature of the welding area and raise the metal's ability to recrystallize and thus improve the micro structure of the weld area and improve the tensile strength

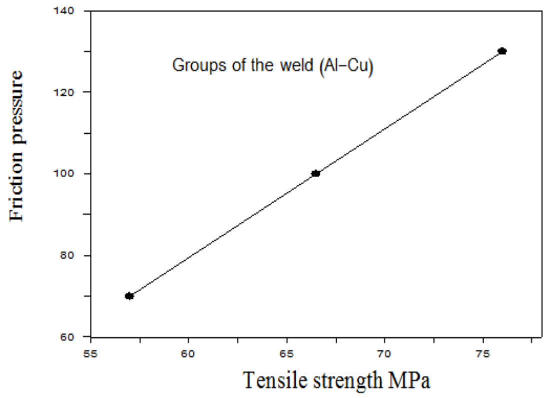

Fig .3 the relationship between tensile strength and friction pressure.

4-2 Tensile strength relationship with friction time.

Figure .4 shows the relationship between tensile strength and friction time. We observe a decrease in tensile strength with increasing friction time, because increasing friction time increases heat generated, allowing for oxidation process as well as increasing hardness in welding area, which reduces tensile strength values.

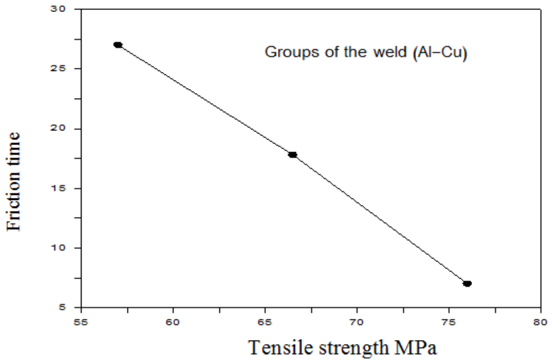

Fig .4 Relation of tensile strength with friction time

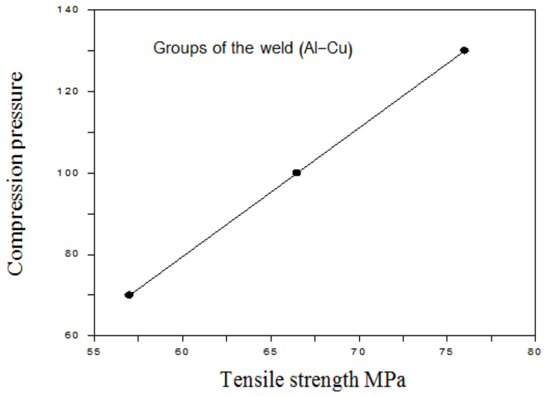

Fig .5 the relationship of tensile strength and compression pressure.

4-3 Tensile strength and compression ratio

Figure .5 shows the relationship between tensile strength and compression pressure where we note the increase in tensile strength with increased compression pressure due to the improved welding between the metals (Al, Cu) with increased compression of the capsule, which increases the process of overlap between welded metals and reduce the gaps that occur Usually during the conventional welding process, which is opposite to the friction pressure as we mentioned earlier.

4-4 Relationship of tensile strength with hardness.

Figure.6 illustrates the relationship between tensile strength and hardness. We observe the higher hardness values at the welding area than the hardness in the heat affected area and base metal. The scientific justification for this is that the welding zone was subjected to both friction pressure and compression pressure, The temperature of the metal to a temperature higher than the temperature of recrystallization and cooling after air, which increased the value of the hardness of this area in addition to the process of settling resulting from the process of interference between aluminum and copper during the welding process in addition to the softness of the crystals formed in this region resulting from the crystallization process.

The area affected by heat (HAZ) has increased the value of hardness slightly compared to the base metal for its impact on the heat transferred to it during the welding process affected by the process.

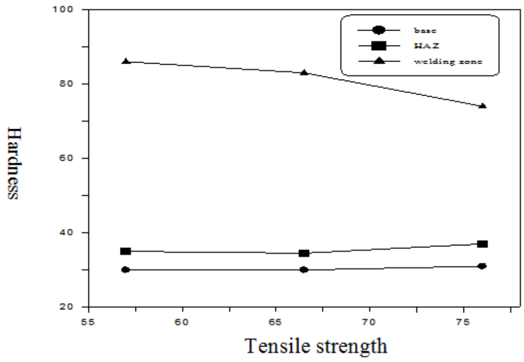

Fig .6 Tensile strength relationship with hardness

4-5 Testing permeability

The welding area was examined using the three permeable liquids and the defects (usually defined in the conventional welding) were not shown. The weld area was above the flange, which was later removed by the lathe.

5- Conclusions

1- The length of the coaxial combustion, the length of the welding process (L), is greater for the aluminum than the copper, because the hardness of the copper is higher than the hardness of the aluminum.

2-The welding area is more rigid than the base metal (aluminum and copper) because of the friction between the surface of the metal, which raises the temperature to higher than the degree of recrystallization.

3- The hardness of the welded area (HAZ) for both aluminum and copper has increased due to the spread of the heat generated by the welding process to that area, increasing its strength.

4-The tensile strength has increased with increased friction pressure and the reason for the recombination process is almost homogenous.

5-Tensile strength decreased with increased friction time.

6.-The length of the common metal in the welding process (Burn-off Length) of both metals increased with the time of friction and friction pressure and compression.

7-Through the results it can be show that the use welding process of welding of both aluminum and copper.

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دراسة تأثير معامل احتكاك اللحام على توزيع قيم الصلابة على مفصل الالمنيوم-النحاس

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الـخلاصـــة

يعتمد موضوع البحث على دراسة تأثير متغيرات اللحام الاحتكاكي على قابلية اللحام للمعادن المتشابهة (الالومنيوم-الالومنيوم) و(النحاس-النحاس) والمختلفة (الالومنيوم-النحاس) حيث تم اجراء التجارب العملية على عينات من النحاس والالومنيوم وشملت المتغيرات ضغط الاحتكاك (Friction pressure), ضغط الكبس (Forging pressure) وزمن الاحتكاك (Friction time) مع ثبوت السرعة الدورانية (2000 دورة / دقيقة) وتم اجراء التجارب على(17) عينة لكل من (الالومنيوم والنحاس) وعينتين (نحاس-نحاس) و(ألومنيوم-ألومنيوم) حيث كان زمن الاحتكاك (3-31) ثانية وضغط الاحتكاك (60,40,20) ميكا باسكال وضغط الكــبس عنــــــــد (70,100,130) ميكاباسكال وبعد انجاز عملية لحامهما تم اجراء فحوصات النفاذية , متانة الشد والصلادة (فيكرز) وتبين زيادة الصلادة في منطقة اللحام والمنطقة المتأثرة باللحام اكثر من المعدن الاساس بسبب الحرارة المتولدة من عملية اللحام وحدوث عملية اعادة التبلور (Recrystallization) اثناء فترة الاحتكاك والكبس, كما ارتفعت متانة الشد لمنطقة اللحام اكثر من متانة الشد للمعدن الاساس ويعود ذلك الى عملية التجانس في منطقة اللحام لكلا المعدنين وحصول ظاهرة الانتشار التي تعتمد على درجة الحرارة والضغط , وقلة مركبات الاكسدة الناتجة من اللحام, كما وجدنا ان نقص الطول (ΔL) الذي يحدث للالومنيوم اكثر من النحاس لكون صلادة الالومنيوم ($32H_v$) اقل من صلادة النحاس ($60H_v$).ومن النتائج لاحظنا تحسن اللحامية للمعادن المتشابهة (ألومنيوم-ألومنيوم) ,(نحاس- نحاس).