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P Diffusion welding of commercial Aluminum to Carbon Steel

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***Abstract*— This research is aimed to study the effect of using insert materials on the strength of the diffusion welding joints between commercial–grade Aluminum(AL200) and carbon steel (S20C).**

In this experiment as well as clarifying the mutual relation between the insert materials and welding conditions, the relation between the strength of a joint and the formation of compound layer also investigated. Besides the study of metallurgical effects of insert materials using by accurate microstructure examination. it was found that the insert materials when used in a thin layered form, had important role in enhancing of the diffusion to weld materials which differ in their melting point. The result also showed the deformation rate of the joints is decreased when using insert materials with low yield stress at constant welding conditions.

***Index Terms*— welding, diffusion, joint, temperature**

I. Introduction

The diffusion welding is one of the methods used to joint two different metals, jointed permanently, there are many advantages to this method as the welding in this way does not leave a mark on the two pieces welding and to joint the region[1], and the connecting force between the two pieces are very large and because it is caused by the spread of atoms as a result of raising the temperature, its entered invasive in many areas of manufacturing and production of precision instruments that need to be great sensitivity, such as electrical transistors industry as well as small parts of electronic computers [2].

Several experiments have been conducted in this area was where the welding different metals multi-most famously made by Kaukato group of Japanese were diffusion welding between pure aluminum AL100 and Mild steel using intermediate compounds such as Ti-Ni alloy, these experiments and studies included to identify some properties mechanical such as tensile strength and shock when you change different welding conditions as these studies showed that the effectiveness of the use of intermediate compounds depends on the quality of the thermal treatment performed on the mother of two pieces and on the nature of welding where if welding was one dip or more, and the results also showed that the conditions of welding (temperature, time, pressure) used an active role and a large effect on the mechanical strength of the welding connection[3].

In this research, conducted a study of the possibility of obtaining the maximum tensile strength of the connection welding through the use of intermediate compounds are (Ni, 2024 alloy, Ag), study and investigate the correlation between the output of the use of intermediate compounds and conditions of the welding process impact, as well as shed light on the relationship between the strength of the link and the formation of metal compounds described during obtain diffusion.

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II. THEORETICAL BASIS

The study of diffusion in important minerals in practice it happens as a result of the relative movement of atoms, as the atom moves from place to another within the crystal lattice of the metal and oscillate about its balanced, altering atoms site is the cause of diffusion in the material [4], and deployment is happening inside grained only, but on a grain boundary surfaces free, proving laboratory experiences that spread the granular border faster than it is inside the beloved and spread on the free surfaces faster of the two, and is attributable to the lack of agglutination granular border installation and surfaces free[2], and spread via the free surfaces and borders granular important because the grain boundary occupy much space and be a network covering the mineral sample, and the diffusion coefficient depends on the composition and temperature as the following equation describes the diffusion process[5].

$$D = D_o \exp(-Q/RT) \qquad \text{……………..........…..(1)}$$

whereas :

D: Propagation coefficient
Do: frequency coefficient
Q: The activation energy for the diffusion
R: gas constant
T: Temperature

Practical experience has shown that different metals are not spread evenly rate, element which melts at low thermal grade spreads faster, for example, in the alpha Brass (a mixture of copper and zinc) zinc atoms spread faster than the copper atoms, but in a couple of diffusible composed of copper and nickel, the atoms copper spread faster [6], and as a result this is happening dilation and contraction of the surface interval expansion that occurs in the vertical direction on the surface interval (interface) have not disabled the contraction and expansion winning the direction parallel to the surface shall be disabled by a pair diffusion that does not spread it occurs parts Vicu the first part in the event stresses Hdih and the other in the case of stresses Pressure where displace atoms, and lead these stresses to the formation of thermoplastic (plastic deformation) [7], and accompanies this configuration are quasi-grained (sub grain) and Recrystallization and the growth of the grains.

There are several ways to spread are:

A. *Interstitial diffusion:*

Corn moving in this way from the site of Benny to the nearest site interface another without the occurrence of permanent original atoms change (matrix atom), that this transition jump or be accompanied by spillover or deformation (distortion) and this distortion in the crystal is a barrier to proliferation, and this kind of commonly spread in alloys in which the atom occupies interface locations, it is a distortion and a small deployment does not need to voids (vacancies) [2].

And it expresses its interface diffusion coefficient as follows:

$$D = \alpha\, a^2 ZV \exp(-\Delta F/RT) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

whereas:

α : Geometric factor

a: Constant of crystalline

Z: Number associated with

V: Frequency

F: Energy needed to deploy

B. *Ring diffusion:*

The self-diffusion in metals and alloys are not caused by the direct exchange of atoms, because this method leads to the formation of large deformations in the crystal inappropriate in terms of energy stimulant, so the spread gets another way is ring diffusion where rotation of several atoms at the same time, this type adequate to explain some unusual phenomena coefficient diffusion in metals with body-centered crystal structure (B.C.C) [5].

C. *Vacancy mechanism:*

A winning spread because corn moved to the empty sites in crystals as the distortion in this case a little, so the energy that few are also needed, and this method is the most predominant in metals and alloys with different crystalline structures (BCC, FCC, HCP), and Vacancy mechanism also increases with rising temperature [8].

III. THE PRACTICAL SIDE

A. *The method of the experiment*

Chemical composition of the samples used are shown in table {1} and the basic materials used are AL200, S20C. The geometry of samples welding is cylindrical dimensions of the form (14×20) mm for the purpose of tensile test and (20×28) mm) for the purpose of Impact test and (10×14) mm for the purpose of the crystal structure using a microscope examination, the welding device diffusion, it was use measuring crawling device creep of metals for this purpose has been on the tensile stress to the stress put pressure on the welding samples, and use of electric resistance furnace for the purpose of the samples heated with thermocouple to set the temperature of welding, is welding in a vicious room air so as to prevent air leakage into the welding strictly prohibited , also used the hydraulic piston for use in welding some samples, and the time of the welding process to be determined with the arrival of the temperature to the desired degree and pre-set, also used a range of different intermediate materials, which were clarified thickness and the amount of purity in table{2}, where installed temperature and pressure and welding time with the change of use of the type of intermediate materials, and note the impact on the durability of the mechanical link and this is the second part of the practical aspect related to mechanical tests after the welding process the samples.

Table{1}: The chemical compositions of samples used

S20C	C	Mn	Si	S	P	AL	Fe			
	0.19	0.72	0.07	0.032	0.026	<0.005	Bal.			
AL200	Fe	Si	Cu	Zn	Ti	Mg	Mn	Cr	Pb	AL
	0.560	0.099	0.050	0.017	0.017	0.005	0.004	0.002	0.001	Bal.
A2024alloy	0.18	0.186	4.036	0.060	0.035	1.556	0.060	0.012	0.013	Bal.

Table{2}: The thickness and purity interfaces used

Insert material	Ni	2024alloy	Ag	Ti
Thickness (mm)	0.01	0.05	0.03	1.03
Purity (%)	>99.5		>99.9	>99.5

B. *Mechanical tests*

Conducted tensile tests using tensile testing device as calculated value of the tensile strength when the speed of the top cross head device and the amount of 0.5mm / min, and calculated the maximum tensile strength of the connection welding direction vertical to the line connecting the two samples connected, and the test was conducted using Charpy device to see how much carry link welding stresses shock by using the weight of 5kg so put piece in the examination to be the edge of a rock fall on the welding area of the welded samples during the examination, And make microscopic examination of samples welded near the dividing line between the welded samples at temperatures of various welding (500,520,540,600)^{o}C, having been assigned to the hot and conducted by gradually smoothing (110,420,500,1200)^{o}C and then refined by Alalmunya then Manifesting process conducted by Olnayatl 4% for a period of 6 seconds after the sample is washed with alcohol and dried to become a sample ready for microscopy and imaging.

IV. RESULTS AND DISCUSSION

When using metal sheets of alloy aluminum 2024 Al and raise the temperature initially at 513^{o}C at a rate of 2.5^{o}C/min, and to check heating of the change in the amount of the liquid phase, which arise from heating it after heating the ingot and auditing at different temperatures for 30 min. is galvanization in water iced, and then measure the amount of liquid phase. This can be seen in fig.(1), which shows the relationship between the amount of the liquid phase VL and temperature where we note that the size of 3.5VL of the liquid phase occurs at a temperature of 600^{o}C, also note that the number of crystalline granules which is calculated in a manner calculate the distance at least rapidly with temperature rise. Based on this result, the use of Ni, AL2024, Ag, Ti as material interfaces between S20C temperature welding fixed 600^{o}C and pressure welding equal to 20.065kg/m, is illustrated in fig.(2), which shows that when using Ni as a feedstock, the robustness of the link obtained be so that breakage occurs in the sample during the examination Turning works and using these four interfaces materials note that the use of Ag gives maximum durability of the link and then come (2024 alloy) while giving Ti less solid connection to welding.

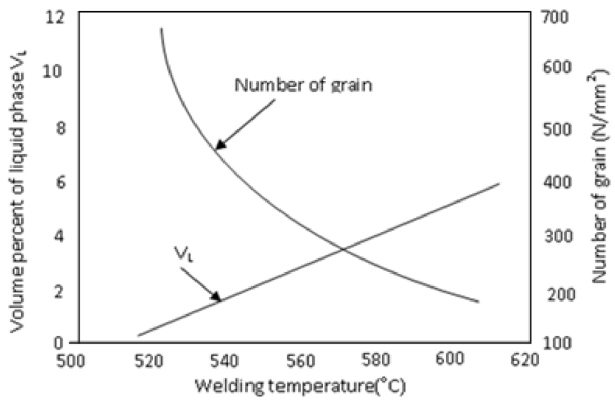

Fig.(1): The effect welding temperature on the amount of illustrates the liquid phase and the number of grains of the alloy

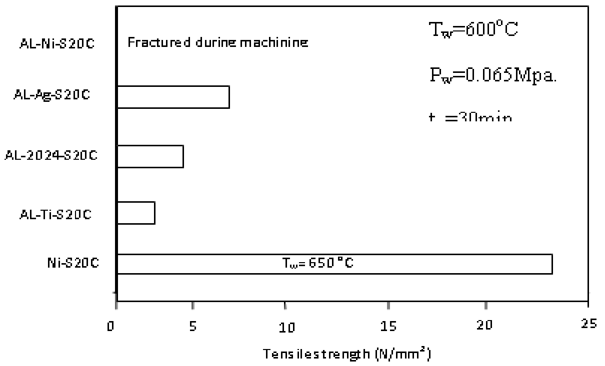

Fig.(2): the effect of interface materials on the tensile strength of the welding connection when welding conditions (pressure, temperature, time)

by fig.(3) can be observed ultrastructure next to the welding area for Ni with S20C obtained in this way, as well as the presence of a small concavity and convexity of the boundary between the two pieces and that such a movement of the line dividing believed it improved the robustness of the connected.

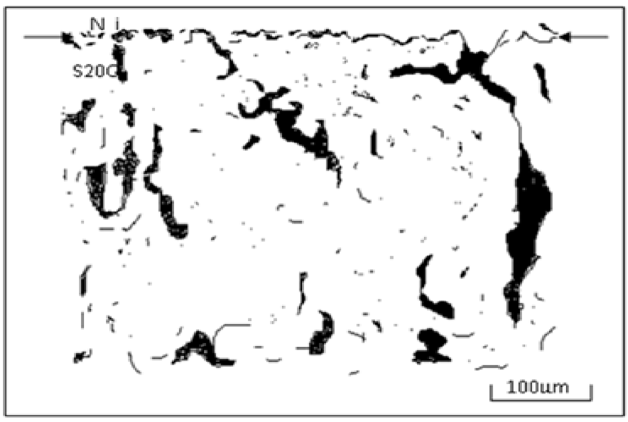

Fig.(3): Welding zone connection Ni-S20C when welding conditions

As fig.(4) explains the effect of temperature welding T_w the screwing of the link AL-Ni in the temperature 610°C, 650°C, the tensile strength of the link be equal to 4.7 kg/mm^2 using compression welding equal to 20.045 kg/mm. And it increases the tensile strength increased slightly when increasing the temperature of 640°C to 650°C.

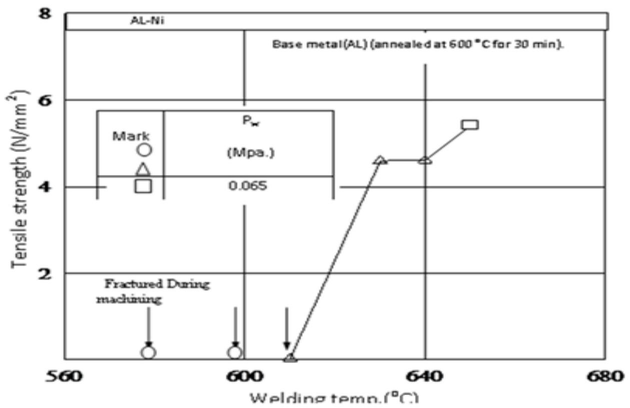

Fig.(4): The effect of the temperature of the welding on the tensile strength of the joint (AL-Ni) at a different pressure welding values (Pw)

The exact composition of the compounds interfaces formed at the boundary between the AL, Ni for the welding can be seen in fig.(5), when raising the temperature of 610°C to 650°C gets growth volumetric of these compounds, as shown in fig.(5).

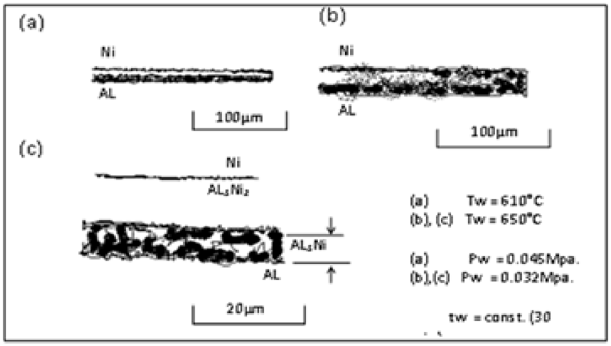

Fig.(5): Welding of the connection (AL-Ni) when the conditions welding for different pressure, temperature.

And fig.(6) shows the effect of the temperature of welding on the strength tensile connection welding AL - S20C note of the figure the amount of durability welding pieces conducted by thermal treatment (annealing) at 600°C for 30min, we find that the strength of the joint be close to the durability that happen by breakage of a piece examination during the boot process. We find that durability in connection welding AL-S20C be larger as you can in the temperature 520°C, with an increased temperature of welding as strong connected Welding, note that the feedstock used is alloy 2024 in the party AL and Ni in the party S20C, this result represents an indication of the fact that that T_w while increasing growth in the volumetric crystal boundary phases formed, which leads to increased Brittleness.

In fig.(7), which illustrates the impact resistance of the connection welding (AL-S20C), we find at a temperature of 600°C The impact resistance of a piece examination was almost equal to the amount which the fraction obtained during surface operation, and at a temperature of 520°C we get the maximum impact resistance manner and with increasing temperature less impact resistance.

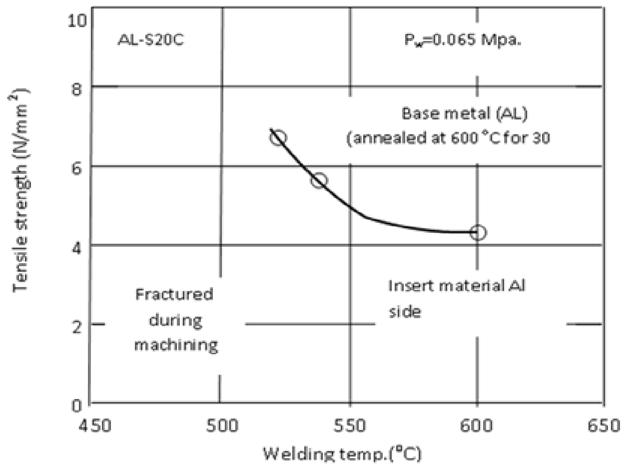

Fig.(6): The effect of the welding temperature on the tensile strength of the connection (AL-S20C)

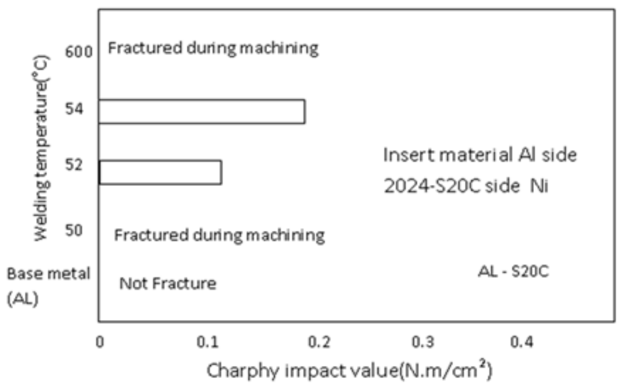

Fig.(7): The effect of the welding temperature on the impact resistance of the connection (AL- S20C)

V. CONCLUSIONS

1. durability connection welding depends on the type of intra-feedstock used in the welding process.
2. during diffusion welding for Ni-S20C must reach the temperature T_w at least above the temperature of any AL turned over 723°C.
3. conclude from mechanical tests that breakage occurs between the interface and S20C in each case of the four cases, from above, we can prove that the temperature used 600°C be inappropriate to get spread between the interface used and the S20C, if the temperature is raised over the diffusion will accelerate but gets deformation in a piece of aluminum which leads to sacrifice the most important feature is characterized by a trickle-down welding deformation of metals curb pain. In diffusion welding of metals, which vary greatly in degrees of melting as is the case in our experience, and when you do not get the durability required using the pre one layer of the feedstock with the metal with a high degree of fusion gives tremendous results, when welding nickel with S20C at a temperature 850 °C, the durability shall be equal to 772kg/mm^2 which is greater than the value of the metal is much pain.
4. high temperature of welding T_w increases volumetric growth interfaces used in diffusion welding, also lead to reduced tensile durability and impact resistance.

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