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The influence of Annealing heat treatment and layers stiffness on the strength of carbonic steel coated with aluminum bearing alloy through cold roll welding

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ABSTRACT

In the present study, the cold roll welding, bond of aluminum bearing alloy and simple carbonic steel was carried out; it also was achieved the effective processes of temperature and time towards the optimization of the related conditions. Finally, the bond strength of 508 Newton was obtained in this case representing the high effective of the Annealing process between two related alloys. Here, two series of experiments were separately carried out. The first series of the welded samples were annealed in 220 C for 4 hr and in the second experiment the steel sheet was annealed in 650 C for 24 hr in the related furnace before rolling process. Then, they were bonded together by roll welding process. Both experiments of annealed samples showed high bonding strength in this regard.
Key words: *Anneal thermal operation, layers stiffness. carbonic steel bond, aluminum, alloy, roller welding*

INTRODUCTION

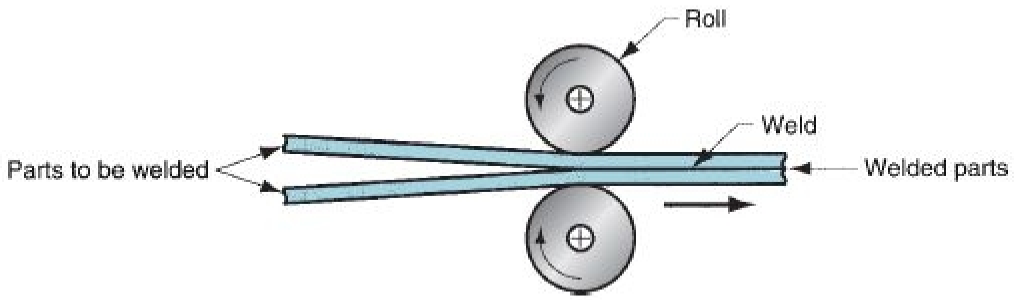
Coated steels with an excellent composite material of aluminum alloys are the most applicable cases in the industry. These binary composites have been highly applying in aviation, automobile and shipbuilding industries efficiently. Steel with aluminum coating and its alloys can be applied to recover the corrosion resistance, deformation, thermal and electrical conductivity [1]. There are two important processes in the construction of these triple and binary steel sheets including the explosive welding being used little due to its high expenses in this case; and cold rolling welding as the most economical method in this process [2]. In the process of rolling welding, the layers will reach to a suitable strength with a suitable deformation [3]. In the construction of these binary alloys with this process, there have been established many different effective parameters. One of these important factors is subjected to the process of levels preparation. When these under welding levels are clean, the penetration and bonding of the atoms will be easily achieved in this pavement [4]. In the process of cold rolling, there will be a little hairline interfacial and cracks between the layers due to the stiffness of the work from the rolling process reducing the strength of the related bond. In addition, there are fragile and cracking combinations between these two layers of the metal; if the size of these layers are higher than 5 micron, the publishing point will make the related crack reducing the strength of the metal harshly; however, the problem will be solved by the process of Annealing potentially[5,6,8]. In the rolling of the layers, if the difference of the stiffness is low between two layers, the strength of the bond will be high in this regard. The application of annealing heat treatment is one of the ways to reduce the steel stiffness in this path. [7]. Due to the above mentioned statements, the most suitable heat treatment has been done on the related welded samples and the strength of the bond was observed along with the layer experimentation in the related research.

Explanation of experimentations:

Used material:

In this welding process, the following work steps have been carried out according to figure 1.

Figure one: schematic display of welding bond steps in the cold rolling process



In this research two alloys were applied. The first one is subjected to a simple steel sheet of carbon St12 annealed according to the standard ASTM D903-93 in rolling with 305*25*1.4 millimeter dimensions. Another one is related to aluminum-zinc-cooper AlSn20Cu1 bearing being cut according to the same above standard. On the experimentation steel the determination of the chemical combination was fulfilled according to publishing spectrometry method according to ASTM E 415-05 standard. The result is given in table 1.

Table1: chemical combination of carbon simple steel based on weight percent

C	Si	Mn	P	S	Cr	Ni	Mo	Cu	V	W
0.06	0.02	0.34	0.011	0.018	0.02	0.04	0.02	0.04	0.004	Trace
Ti	Co	Al	Sn	Pb	As	Sb	Zr	Nb	Fe	
Trace	0.008	0.054	0.003	None	0.002	Trace	None	None	Base	

The chemical combination of cooper, zinc and aluminum alloys was determined by chemical analysis method under the experimental environmental conditions at 23 C and 27% humidity in this research. The result is given in table 2.

Table 2: chemical combination of casted aluminum alloy

Element	Weight percent	Element	Weight percent	Element	Weight percent	Element	Weight percent
Sn	20.3+-0.2	Cu	0.31	Al	78.9+-0.5	-	-

Surface preparation:

One of the most important determinant parameters is subjected to the surface preparation in this process. Here, the under welding surfaces were brushed with acetone tank in two phases and then the surface of the steel sheet was perfectly mirrored and polished with a solar brush made of steel carbon. In this metal, the surface evenness was measured with evenness-measuring instrument and it was reached to 0.5 to 1 micron in this case. In the next phase, the surface of the aluminum was polished by the use of stainless brush and the surface evenness was also measured by the above mentioned method and it was reached to 1 to 1.5 micron in the study[5].

Rolling of sheets:

The cold rolling welding operation was achieved and measured by a roller instrument with 500mm diameter and 30 rpm speed as well as surface evenness. During the process of welding, the entire loadings and vertical pressures were completely registered and recorded that they have been shown in table 3. After the preparation of the surfaces, the sheets will get over together and then packaged under the various loadings as well as the reduction of different cross sections by the same welding roller instrument. This reduction of the cross surface was according to table 4 ranging from 10 to 70%. In this research the highest strength of the layers bond was 400si in vertical loading and the reduction of the surface was obtained 38% in this pavement [3].

Table 3: degrees of achieved force on samples and strength of layers

Necessary force to separate the layers by thermal operation (Newton)	Necessary force to separate the layers (Newton)	Rollers pressure (PSI)
35	31	200
327	272	400
508	410	400 warmed up steel
157	102	600
53	36	800

Table 4: results of vertical pressure and RIDUCTION

Total thickness of layers after rolling (mm)	Reduction (%)			Pressure PSI	Sample
	Total reduction of thickness	Steel	AL		
2.3	10	0%	21%	<200	1
2.07	20	7%	32%	200	2
1.67	38	23%	47%	400	3
1.51	44	27%	55%	600	4
1.31	55	35%	62%	800	5
0.91	71	53%	75%	1000	6
0.3	88	Not measurable	Not measurable	1200	7

Heat treatment:

The main purpose and focus of the study was based on the Heat treatment. Two types of annealing were fulfilled in this related research. In the first experimentation, a series of welding phase of steel sheets were annealed at 650 C for 24 hr in a furnace before welding phase. Then, these annealed steel sheets were coated with bearing alloy. In the second experimentation after the welding phase, a series of bonded sheets were annealed at 220 C for 48 hr in this regard [2].

Peel test:

One of the most famous and well-known experimentations is subjected to the Peel Test for determining the strength of bonds between the layers of binary steel sheets according to standard ASTM-D903; the speed of the whole samples were selected equally 10mm/min.

RESULTS AND DISCUSSION

Relationship between vertical loading and reduction of cross surface with bond strength (bond):

Figures 2 and 3 show these relationships.

The sample of pre-heat with annealing heat treatment after welding

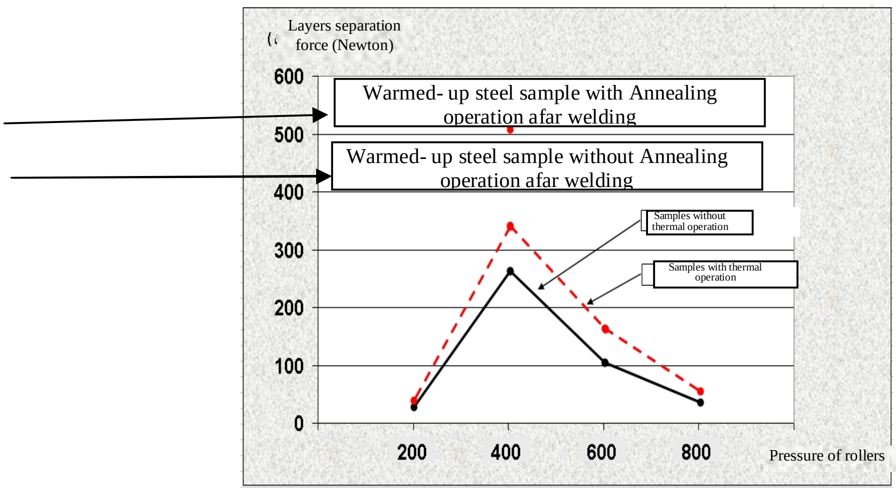


Figure 2: relationship of rollers pressure with bond strength

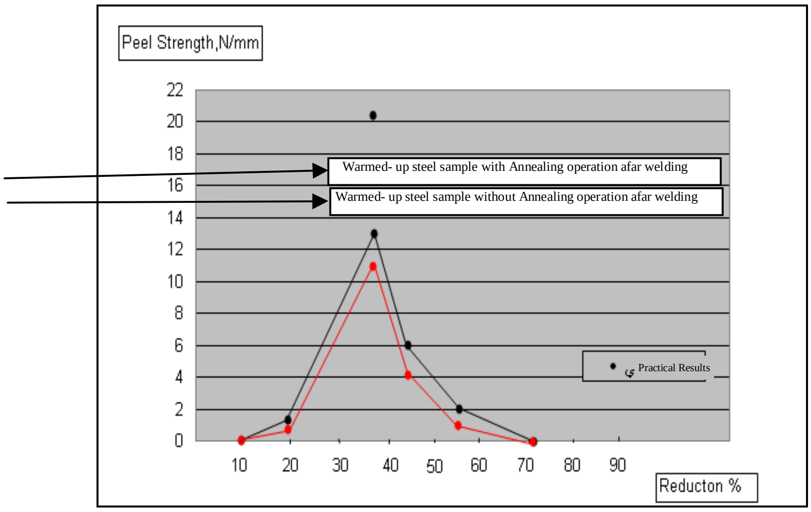


Figure 3: relationship between layers strength and reduction:

As it shown in figure 2, the increase of vertical loading has increased the layers bond strength; after reaching to the maximum strength, it will be reduced by increasing the vertical pressure. The reason may be subjected to the increase of the pressure providing the necessary force in order to break high fragile layers being oxidized between the same layers and extrusion bond of the clean layers of the beneath cases. This makes the penetration of the atoms easily into together. In a one pressure limitation, the increase of the vertical loading does not help to the bond strength. Indeed, it will lead to the slip of the surfaces on together making microscopic crushing on the surfaces. Figure 3 shows the best Reduction is 38% for bonding of these two alloys [1].

The influence of thermal operation on the bond strength:

In figures 2 and 3 two diagrams are seen. The upper diagram is subjected to those samples that they were annealed at 220 C for 48 hr after welding. As it shown, in similar points with non-annealed samples, the necessary force is increased for separating the layers together. This increase is reached to 100 Newton based on 400 Psi pressure. This event may come from the following reasons [7]:

1- The rapid penetrative paths such as beads territory, deformations, free surfaces; these beads territories having high free energy are more susceptible to the penetration direction. When the free energy is high, it will go towards the large bead angle. In a big territory, the areas will be weak including the open structure. The bond of the atoms will be broken or deformed harshly in this regard. As a result, these territories will have high energy; in other words, the conditions will be provided for the penetration process. Here, the bead territory energy for three elements of Al, Sn and Fe at 220 C after rolling and annealing temperature and penetration temperature includes 270 Mj/m2, 164 and 800 representing the fact that the bead territory in Fe has the biggest territory and the penetration of two aluminum and zinc are subjected to the Fe. The main question is which elements of Al and Sn have the highest degree of penetration?

   First the subject is investigated in terms of solubility that it is low in the second element causing the beads of the same second element and its concentration is become intense in this case. Hence, the activity and motion of the bead territory will be lower and the bead penetration will be happened with little intense in a certain duration. Now, the solubility degree of aluminum and zinc in Fe should be compared together, in 220 C as the penetration temperature of the research, the degree of zinc solubility in Fe is 0.08 and 11% in aluminum. That is, the penetration of aluminum is higher than zinc; it will be investigated in 1000 Kelvin as following:

   By the use of Formula: $D = D0\exp(-Q/RT)$, the calculations will be carried out; as a result, the zinc penetration coefficient in Fe equals:

   $Dsn = 1.3*10-16$ and aluminum penetration coefficient is $DAI = 2.9*10-14$

   $DAI/DSn = 220$ represents that the aluminum penetration coefficient in Fe is about 200 times in compare to zinc in Fe. According to the above mentioned table $DSn/DFe = 40$ representing the penetration coefficient of zinc in Fe is 40 times higher than Fe in zinc; in fact, the motion flux of aluminum in Fe is higher than zinc in Fe: JAI>JSn.

   The main point obtained from the analysis of the study is that due to the annealing process, the beads become tiny and the level of these beads territory will be high making the geometrical points and areas susceptible to highly penetration process increasing the bond strength in this case.

Due to the rolling process and hardworking from the hairline interface between the layers will be constructed that these will be also removed through the thermal operation increasing the strength in this regard[8].

Ingredients between the fragile layers are higher than 10 micron causing to the reduction of the strength and the process of Annealing will be disappeared in this path [8].

Impact of stiffness difference reduction between layers on the bond strength:

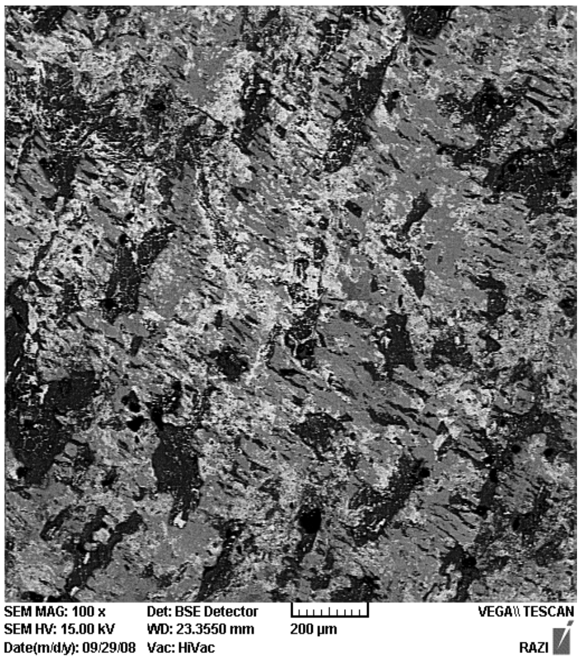
In the process of cold rolling welding, the stiffness and ductility of under welding sheets close together will increase the bond strength. This law was the fundamental and basics of the experimentation. Here, the stiffness of the steel was estimated based on Standard ASTM E384 about 135 Wickers and the stiffness of bearing alloy was also 35 Wickers in the research. Some steel sheets samples were cut before welding in order to reduce the impacts of the stiffness difference for 24hr at 650 C; they were also annealed at the same temperature. Due to the impact of the annealing process, the steel stiffness is reached to 85 Wickers. Indeed, the stiffness difference of these two alloys will be low. In diagrams of figures 2 and 3, two separate points were seen as red and black representing the strength of the bond in the samples that the stiffness of two sheets have been reduced before the welding process. The upper point is subjected to the sample that has been annealed after welding in the furnace according to section 3-2 having the highest bonding strength in this regard. Diagram 4 shows the Peel test on the highest area along with the separation force of layers in 500 Newton [3].

Diagram 4: diagram of layers tension with annealed steel:

In fact, the steel manufactured in a factory as a sheet being entered into the marketplace has been coming along with Annealing treatment but there has been also little cold work left on it yet. Due to the heat treatment carried out on the sheet in this research, the cold work is reduced here; in addition, the beads become more homogeny and their stiffness is reached to 85 Wickers. This homogeny structure and degree of cold work provide little conditions for better penetration of aluminum, zinc in Fe elements [3].

Finally, the bond strength will be recovered in this case. In order to evaluate the highest common point, two moods of SEM were given as following:

The stretched beads show the cold Ferrite



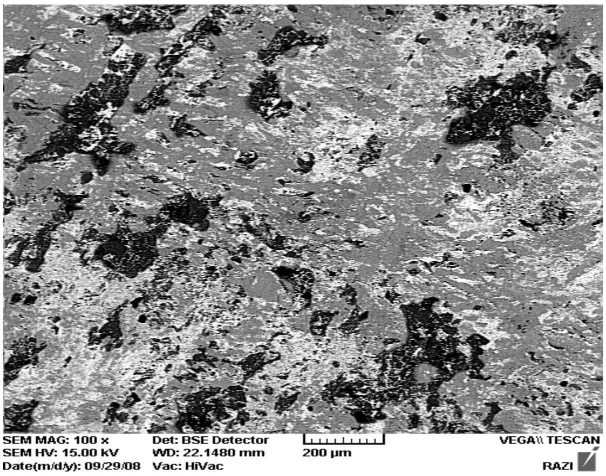


Figure 4: steel St14 microscopic structure

Figure 5: electron images of separated ribbons and strops when the steel is warmed up. Magnification 100*

In figures 5 and 6 the black phase of aluminum, white phase of zinc and gray phase of homogeny combination of Fe, Al, Zc and Co were given. The comparison of two figures shows completely that when the steel is annealed before welding, the gray publishing phase is getting high made of a homogeny elements; that is, the atomic penetration will be easily carried out in this case.

CONCLUSION

Due to the annealing process of the steel, the possibility of Sn and Al atoms penetration will be high increasing the strength in this case. Due to the rolling impact and hardworking from the hairline cracks will be constructed that these will be also disappeared and removed by achieving annealing process and finally it will raise the strength in this regard. The ingredients ranging higher than 10 micron between the related layers will reduce the strength. These ingredients will be reduced due to the impact of thermal annealing operation. By reducing the stiffness difference of two under welding layers, the possibility of deformation of the layers equal and finally the penetration elements will be better together; in the end, the cohesion of the layers will be also recovered in this case.

REFERENCES

1. Kawase, H., Makimoto, M., Takagi,K., Ishida, Y. and Tanaka, T. (1983). Development of aluminum clad steel by roll bonding .Trans ISIJ 23 PP 623-632.View Record in scopus.
2. Hwang , Y.M., Hso, H.H. and Lee, H.J.(1995). Analysis of sandwich sheet rolling by stream function method.int Mech Sci 37 3 . pp 297 .
3. Bay, N.(1986). Cold welding part ii . process variation and application . p.486 .
4. Zang, W and Bay, N.(1887). Cold welding experiment investigstion of surface preparation methods. p.326.
5. Ryabov, V.R. (1985). Aluminum of steel .oxoniane press pvt ltd New Delhi . p17.
6. Yahiro, A., Masui,T.(1991). Development of non- ferrous clad plate and sheet by warm rolling with different temperature of materials ISIJ INT 6 .P 647.
7. Abbasi, M., Karimi Taheri, A., Salehi ,M.T.(2002). An investigation on cold roll bonding of copper to aluminum using electrical resistivity. pp 432-430.
8. Danesh Manesh , H., Karimi Taheri, A. (2003). The effect of annealing treatment on mechanical properties of aluminum clad steel sheet .