ANNALS OF THE ORADEA UNIVERSITY
Fascicle of Management and Technological Engineering
ISSUE #1, MAY 2013, http://www.imtuoradea.ro/auo.fmte/

THE CMT BRAZE-WELDED DIFFUSION LAYER STUDY ON GALVANIZED ALUMINIUM SHEETS

Elena Stela MUNCUT[1], Lavinia Ioana CULDA[2], Gheorghe SIMA[3], Doina MORTOIU[4]
[1]University "Aurel Vlaicu" of Arad, muncutstela@yahoo.com
[2]University "Aurel Vlaicu" of Arad, lavyy_99@yahoo.com
[3]University "Aurel Vlaicu" of Arad, gheorghe.sima@klastorf.ro
[4]University "Aurel Vlaicu" of Arad, doina.mortoiu@gmail.com.ro

***Abstract*—** This paper presents a comparative study on braze-welding of aluminum with galvanized carbon steel using CMT (cold metal transfer) and CMTP (cold metal transfer pulse) methods. The aim is to determine the influence of linear energy on diffused zinc layer thickness in aluminum. This paper presents a two-level factorial experiment (given by transfer types) having the welding current and welding speed as parameters. Finally we determined the influence of linear energy on the thickness of the diffusion of zinc.

***Keywords*—** braze-welding of galvanized steel with aluminum, factorial experiment, intermetallic layer

I. INTRODUCTION

CMT MAG welding is a process derived from MAG short arc welding process.

On this method, at the time of producing the short circuit, a mechanical withdrawal of wire is ordered, which has the effect of interrupting the arc.

The mechanical interruption of welding current leads to the producing of induction current which helps to reignite the arc.

On this method, when short circuit occurs, the current intensity is reduced that's why splashes do not appear, [1].

The source we used enables a combination of CMT transfer and a pulse transfer having a digital control of source, resulting in a special type of transfer i.e. cold metal transfer pulse CMTP.

The source delivers a pulsed current in the moment of interrupting the short circuit current.

In figure 1 is shown the influence of overlapping pulses (from 1 to 7 pulses) on the joint's shape, [2].

As a result of current pulses, changes occurs which increases penetration and allow the joint making possible without using a support at root, [3].

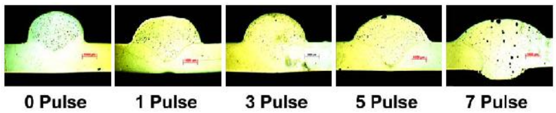


Fig. 1. Changing penetration by alternating pulsed CMTP and transfer [3]

In fact, during the braze-welding of galvanized steel with aluminum the filler material and base material are melted and deposited on the surface of galvanized steel. The link between aluminum and steel sheet is mainly mechanical, due to sudden contraction by cooling of the aluminum in contact with the surface of not melted steel [4].

It should be noted that this combination of heterogeneous zinc present in the material behaves as an etching agent in the joint, supporting the joint. Another positive factor introduced by zinc is the increased surface roughness in the base material where the joint is done. The presence of zinc has a negative effect by favoring pore production in the joint.

Joining by welding the combination of steel and aluminum base materials is difficult, due to metallurgical incompatibility issues and physical characteristics of the two materials. In metallurgical terms, aluminum with iron is forming solid solutions, intermediate phases and eutectic intermetallic compounds. The solubility of iron in aluminum is insignificant. At low content of iron in aluminum an intermediate compound Fe_3Al appears, containing approximately 34% Fe. At higher levels of aluminum $FeAl_2$ (66% Fe), Fe_2Al_5 (70,2% Fe), $FeAl_3$ (74,5% Fe), intermediary compounds appears [5].

The presence of these intermetallic compounds makes difficult to do a welded joint.

A second difficulty in combining steel and aluminum by welding is due to the large difference between the

melting temperature of steel (1536^{0}C) and melting temperature of aluminum (660^{0}C). By using of a fusion welding process is difficult to melt the two basic materials in a single welding bath, [6].

The reasons described above makes it extremely difficult to use welding procedures to achieve this type of dissimilar joints. Joining methods that do not produce the melting of the materials (pressure welding processes or ultrasound), [7] or processes that brought the welding energy to be minimized are preferred For this reason, using a braze-welding process may be a favorable alternative against using a conventional fusion welding process [8]. During the jointing just the material with the lower melting temperature is melted, in this case the aluminum. The filler material is chosen according to the characteristics of aluminum.

II. Equipment used in experiments

Weld brazing experimental program by CMT process was accomplished using a welding station consists of the following elements, (figure 2):

- Power MIG / MAG welding torch and CMT Fronius with buffer device for wire feed speed variation with maximum rated current of 270 A;
- Welding tractor equipped with running path (mechanized welding);
- Table positioning and welding device;
- Device for monitoring parameters;
- Electron Microscope.

Fig. 2. Equipment used in experiments

III. The experimental

Performing the experiment program were used the following materials: galvanized steel sheet DX51D+Z150-N-A-C(SR EN 10327:2004) and aluminum alloy sheet EN AW 1200 (SR EN 1706: 2000), both having a thickness of 1mm.

The main mechanical characteristics of base materials are shown in table I.

TABLE I
MAIN MECHANICAL PROPERTY OF BASE MATERIALS

Basic material	$R_{p0,2}\left(N/mm^2\right)$	$R_m\left(N/mm^2\right)$
Galvanized steel sheet (DX51D+Z150-N-A-C)	348-395	min 405
Aluminum alloy sheet (EN AW 1200)	150-165	min 205

TABLE II
CHEMICAL COMPOSITION OF DEPOSITED METAL WIRE ELECTRODE ALSI5

Filler material	Chemical composition, %			
	Si	Mn	Fe	Al
$AlSi_5$	4,5-5,0	<0,5	<0,5	rest

As filler material for weld brazing was used AlSi5 alloy electrode wire diameter 1.2 mm [9], the chemical composition of the material deposited with the wire according to DIN 1732 are shown in table II and mechanical characteristics of the material AlSi5 wire are shown in the table III.

TABLE III
MECHANICAL CHARACTERISTICS OF THE MATERIAL ALSI5 WIRE

Yield $Rp_{0,2}$ N/mm^2	Hardness HB	Tensile Rm N/mm^2	Elongation at break A_{10}%
70-90	48-60	110-160	min. 15

Technical Argon (Ar 100%) as shielding gas was used this being the recommended gas for welding aluminum alloys [10]. The braze-welding was done mechanized.

The experimental program included a factorial experiment type 2^3 having the following parameters: the speed of welding, dynamic correction factor welding methods – CMT (continuous) or CMTP (pulse)-, each factor was regulated on two levels. The implementation plan of this experiment is shown in table 4. Experiments were performed on sheet size 150x250x1mm.

The braze-welded samples were microscopically analyzed being subjected to shear breaking test.

On microstructure samples the thickness of zinc diffusion was measured whit electron microscope (figure 3).

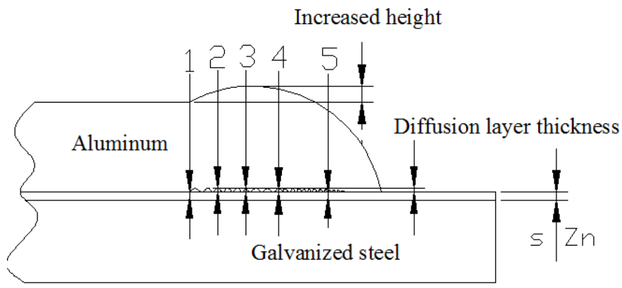


Fig. 3. The thickness of zinc diffusion measuring procedure

Microstructures of the taken samples are shown in figures 4 and 5.

Microscopic examinations were performed in specific areas of dissimilar braze-welded joints (SUD= jointing, MB= basic material, ZIT= heat affected zone) according to EN 1321:2000, disclosing the microstructures shown in figure 4 and figure 5, the sample attack was made with

Nital 2% + NaOH 5%.

Fig. 4. Braze-welded version 0, 100x

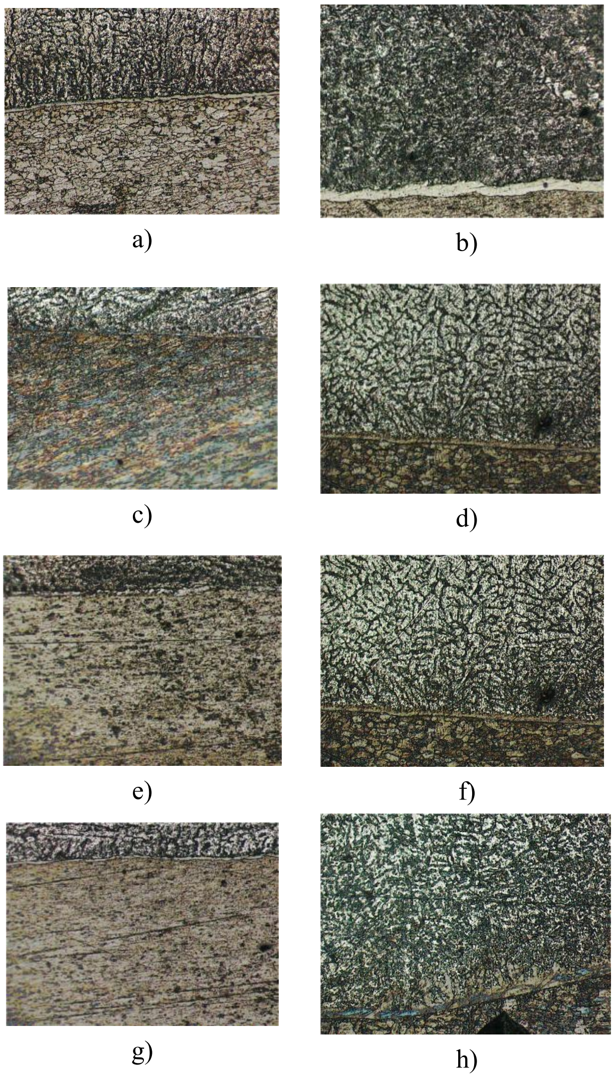


Fig. 5. Micrographic analysis of aluminum- galvanized steel dissimilar joints 100x a) sample 1, b) sample 2; c) sample 5; d) sample 6; e) sample 4; f) sample 3; g) sample 8; h) sample7

On the heat affected zones (HAZ) in the aluminum alloy, α(Al) structures with fine aluminum-silicon-zinc intermetallic compound particles, are observed (figure 5).

TABLE IV
PARAMETER VALUES USED TO MAKE JOINTS AND THE ZINC DIFFUSION LAYER THICKNESS

Nr. Braze welding CMT	vs [cm/min]	Ina	Is [A]	Ua [V]	x El[J/cm]	y [μm] experimental
1	80	5	67.2	11.7	509,79	62
5	80	-5	61	11.3	439,42	40
4	100	5	67.6	11.6	410,26	50
8	100	-5	62.6	11.3	360,76	25
Nr. Braze welding CMTP	vs [cm/min]	Ina	Is[A]	U a[V]	xEl[J/cm]	y [μm] experimental
2	80	5	68,6	12,2	533.53	82
6	80	-5	61,3	11,3	441.58	33
3	100	5	68,6	12,2	426.82	81
7	100	-5	60,1	11,5	352.48	31

Where: CMT – Cold Metal Transfer; CMTP – Cold Metal Transfer Puls; v_s - braze-welding speed; I_S - Braze-welding current; I_{na}- boost current; E_l - linear energy;

On the microstructural probes the thickness of the zinc diffusion produced in the aluminum joining interface was measured. Figure 6 shows how these measurements were performed. For each kind of welded joints 5 measurements were performed, the averaged values were retained.

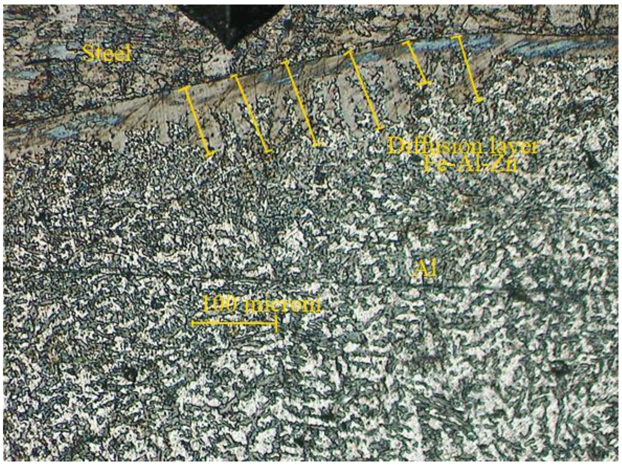


Fig. 6. The diffusion layer of zinc measurement mode

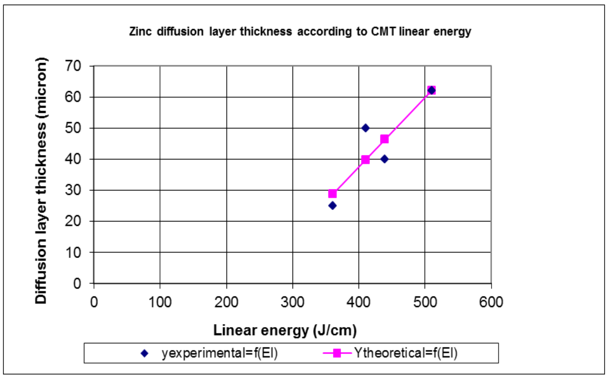
The results of measurements are presented in table IV.

Based on the obtained data, the correlation between the thickness of the diffusion of zinc $s_i[\mu m]$ and linear energy used $E_l[J/cm]$ was determined.

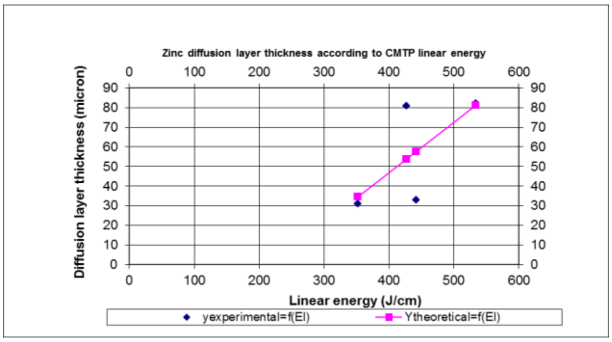
Revealed the following regression:

$$s_i = -51,65 + 0,22 \cdot E_l \text{ for CMT (1)}$$

$$s_i = -55,92 + 0,25 \cdot E_l \text{ for CMTP (2)}$$



a)



b)

Fig. 7 Linear energy influence on zinc diffusion layer thickness, a) CMT, b) CMTP

The obtained relations are presented graphically in figure 7 and the experimental data on which the regression calculation was made, are in table IV.

The intensity correlation coefficients for these regressions are R= 0,84 for CMT, respective R= 0,82 for CMTP, values showing that the determined regressions expresses admissibly the correlation between these values.

The specimens breaking was held in base metal (aluminum) with the exception of two samples from variants 7 and 8 which breaks occurred in welds.

The shear strength do not depends significantly of joint process - CMT or CMTP. It was noted, however, values of about 10-15% higher at CMT process than those typical for CMTP process.

This difference can be explained by more pronounced burning of zinc at the impulse variant and zinc oxide formation.

IV. CONCLUSION

Macroscopic examination of trials comparing the results with the two methods combined is showing that the increased height on joints made continuously (CMT) is higher by about 10-30% than the one made by pulse welding (CMTP). This can be explained by the additional current introduced by the CMTP process in the moment of the droplet detachment. This makes the drop to be further heated on the CMTP process comparing to CMT process. At the same time, we notice a significant influence on the dynamic correction factor profile (convexity) joint. Lowering the value of this factor the joint becomes more convex.

Pulse process is, therefore, preferable, if a lower increased height is desirable. Using a negative dynamic correction factor has an opposite effect leading to an increased height.

The analysis of the results leads to the conclusion that the diffusion layer thickness depends in fact linear by the linear energy used, the process variant significantly affecting the dependency.

At the same linear energy, the diffusion layer thickness of zinc is significantly higher for CMTP variant (pulses) compared with CMT version (continuous).

REFERENCES

[1] Himmelbauer, K. The CMT-Process-a revolution in welding technology XII-1845-05 - Fronius International GmbH.

[2] *** Cold metal transfer MIG welding is spatter-free Edited by the Manufacturingtalk editorial team **Sep 23, 2005**

[3] Trommer, G. Cold Metal Transfer and pulsed arc welding processes separately used or in combination, in order to obtain an wide power range, Sudura XX 1/2010, pp 25-29.

[4] Wilden, J. s.a: Cladding (surfacing) of aluminium substrates with nanocrystalline soldifying wear resistant iron based materials, International Thermal Spray Conference, Surface & Coatings Technology 202 - 2008, pp. 4509–4514.

[5] Staubach, M.: Joinig of steel-aluminium mixed joints with energy reduced GMA processes and filler materials on an aluminium and zinc basis, Welding and Cutting, 2008, vol 7, nr1, pp 30-34.

[6] Zhang, H.T. Feng, J.C. He, P. Zhang, B.B.. Chen, J.M Wang, L. The arc characteristic and metal transfer behaviour of cold metal transfer and its use i joining aluminium to zinc-coated steel, Materials Science and Engineering A499, 2009 pp 111-113.

[7] Tsujino, J.; Hidai, K.; Hasegawa, A.; Kanai, R.; Matsuura, H.; Matsushima, K.; Ueoka, T. Ultrasonic butt welding of aluminum, aluminum alloy and stainless steel plate specimens. Ultrasonics, 2002, vol.40, pp 371-374.

[8] Staubach, M.: Joinig of steel-aluminium dissimilar joints with low energy GMA processes and filler materials based on an aluminium and zinc, Schweissen und schneiden, 2007, vol 59, nr. 6, pp. 302-313.

[9] Kodoma, S. Ishida, Y. Asai, K. Mizumoto, M. Namekata, T. Nagasaki, H. Development of stainless steel welding wire for galvanized steel sheets, Welding in the World, 2010, vol. 54, nr. ½,pp 328-336.

[10] Zhang, H.T. Feng, J.C.He, P.,Zhang, B.B.,Chen, J.M.,Wang, L., The arc characteristics and metal transfer behaviour of cold metal transfer and its use in joining aluminium to zinc-coated steel, Materials Science and Engineering A 499 - 2009, pp 111–113.