PARTICULARITIES OF CMT/CMTP BRAZE - WELDING PROCESS BETWEEN GALVANIZED STEEL AND ALUMINIUM ALLOY

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Abstract

The CMT/CMTP braze-welding process is characterized by interruption of a short-arc at low welding current values, which is controlled by an invertor source. Thereby, the used energy is lowered by short time (about 1 µs) before reignition of the electric arc. Because of the offered benefits (joining of thin materials, the possibility of using large diameter wire electrode by low welding current, low heat input values, etc.) is facilitated the achievement of butt, corner and overlap welded joints, between dissimilar materials that have a low welding metallurgical behavior. In this paper is analysed the opportunity to produce heterogeneous braze-welded joints (galvanized steel - aluminum alloy) starting from a factorial experiment which considers three sets of technological parameters. Welded joints quality is evaluated by metallographic examinations and mechanical testing.

Keywords: CMT/CMTP process, galvanized steel, aluminium alloy

1. INTRODUCTION

The process of braze - welding CMT/CMTP derives from the MIG/MAG welding process, particularly using the assisted droplet detachment technique [1, 2]. In terms of establishing optimum process, with every controlled touch of the base metal by the electrode wire should take place a separation of a single droplet of filler material. Therefore, the result can be called „drop by drop welding” [3].

Movement with high frequency of the electrode wire back and forth to the base metal, makes the transfer of the droplet occur at low values of welding current. This allows the joining of dissimilar materials with small thickness (under 0.8 mm), the reduction of the linear energy with approximately 30 % from MIG/MAG welding and application of new joining techniques e.g. CMT - laser [4], [5].

This paper deals with the possibility of achieving joints of dissimilar materials delivered in the form of thin sheets by CMT/CMTP braze - welding, which are incompatible from the metallurgical point of view.

2. EXPERIMENTAL PROCEDURE

The base materials used for the realization of experimental program were:

- galvanized steel sheet DX51D+Z150-N-A-C (SR EN 10327:2004), with dimensions of 150x250x1mm;
- alluminium alloy sheet EN AW 1200 (SR EN 1706 : 2000), with dimensions of 150 x 250 x 1 mm.

In (**Table 1** and **2**) is shown the chemical composition of these, and **Table 3** presents the guaranteed values for mechanical strength characteristics.

As filler material was selected a electrode wire alloy AlSi5 with a diameter of 1.2 mm, using cc$^+$ polarity. The chemical composition of the wire electrode EL-AlSi5, according to DIN 1732, is presented in **(Table 4),** and the guaranteed mechanical characteristics for the deposited metal are given in (**Table 5).**

Table 1 The chemical composition of the galvanized steel sheet

Galvanized steel DX51D+Z150-N-A-C	Chemical elements, % mass										
	Al	Fe	Zn	Zr	Mo	W	Pb	Bi	Si	Mn	Co
Actual values	0.42	29.06	69.69	0.03	0.16	1.18	0.07	0.10	0.28	0.06	0.19
Values according to SR EN 10327:2004	max. 0.60	max 32.0	max 70.0	max 0.03	max 0.18	max 1.50	max 0.10	-	max 0.30	max 0.1	max 0.30

Table 2 The chemical composition of the aluminium alloy sheet

Aluminium alloy	Chemical elements, % mass			
EN AW 1200	Al	Si	Fe	Cu
Actual values	98.96	0.78	0.21	0.03
Values according to SR EN 1706:2000	Max. 99 %	Si +Fe <1 %		< 0.0 5%

Table 3 Guaranteed mechanical properties

Base material	$Rp_{0.2}$, MPa	R_m, MPa
Galvanized steel sheet (DX51D+Z150-N-A-C)	348-395	max. 405
Aluminium alloy sheet (EN AW 1200)	150-165	max. 205

Table 4 The chemical composition of the filler material

The filler material	Chemical elements, % mass			
	Si	Mn	Fe	Al
AlSi5	4.5-5.0	<0.5	<0.5	balanced

Table 5 The chemical composition of the electrode wire -AlSi5, according to DIN 1732

Yield strength, $Rp_{0.2}$, MPa	Hardness, HB	Tensile strength, R_m, MPa	Elongation at break As [%]
70-90	48-60	110-160	min 15

Due to numerous applications that can be found in the automotive field, the type of joint selected for experiments was „lap joint".

For welding was used a welding source - FRONIUS Trans Puls Synergic 2700 CMT, with pulsed arc with integrated/separate wire feeder with 4 rolls system, with a working distance of maximum 6 m. The maximum current (270 A) is provided by an inverter working at a 100 kHz frequency, allowing consumption at idling by only 50 W. As a shielding gas pure argon was used (Ar 100 %), this being recommended for welding aluminium-based alloys.

The test plan was based on a factorial experiment on two levels simultaneously that aims to study the main technological parameters used at CMT and CMTP braze - welding: welding current, I_S , arc voltage, U_a , arc length correction factor, l_o , droplet detachment correction, I_{na} , welding speed v_s determined by the welding cart, wire feed speed, v_{as} ,transfer mode CMT/CMTP, way of achieving the pulled/pushed cord; the angle of the welding gun, distance from the nozzle to the base material;

In preliminary experiments it was decided a choice of three technological entry parameters, which strongly influence the geometrical characteristics of the joint. These are:

- welding speed v_s driven by the tractor welding;
- droplet detachment correction / dynamics I_{na};
- CMT/CMTP transfer mode.

Objective functions were considered: shear strength of the joints, and the characteristics of the intermetallic layer formed at the interface of the joint.

2.1. The establishment of the welding technological regime

The programme of work has been designed on the basis of a factorial experiment which consists in carrying out a number of heterogeneous joints by determining a central point (0 - adequate joining) then choices are made on two levels, resulting in 10 types of braze - welded joints.

In **(Table 6)** are shown the values of the parameters used to form the heterogeneous joints galvanized steel - aluminium alloy.

Table 6 The parameter values of the technological

Weld brazing version number	$I_S[A]$	$U_a[V]$	$v_{as}[m/\min]$	CMT* sau CMTP**	$v_s[mm/\min]$	I_{na}
0	70.0	12.9	3.80	CMT	1000	+5
1	67.2	11.7	3.70	CMT	800	+5
2	88.6	15.2	4.37	CMTP	800	+5
3	88.6	15.2	4.35	CMTP	1000	+5
4a	62.6	11.3	3.64	CMT	1000	+5
4b	62.6	11.3	3.64	CMT	1000	+5
5	61.0	11.3	3.47	CMT	800	-5
6	69.3	14.3	4.35	CMTP	800	-5
7	70.1	14.5	4.39	CMTP	1000	-5
8a	63.6	11.6	3.69	CMT	1000	-5

*CMT Cold Metal Transfer ** CMTP Cold Metal Transfer Pulse

3. EVALUATION OF EXPERIMENTAL RESULTS

3.1. Metallographic examinations

In order to assess the quality of joints that were made it was appealed to macroscopic analysis and detailed microscopic analysis.

(Figure 1a) and **1b)** exemplifies the visual image of the braze - welded joints free of surface defects and also with discontinuities. Such defects were seen in joints with 5 and 7 technological regimes.

Research on macroscopic cross sections of braze - welded sections shows that with the exception of technological regime 5 and 7, that led to the appearance of pores in the weld, having a maximum diameter of 0.3 mm **(Figure 2a),** in other cases there was obtained a corresponding geometry , without metallic continuity defects **(Figure 2b).**

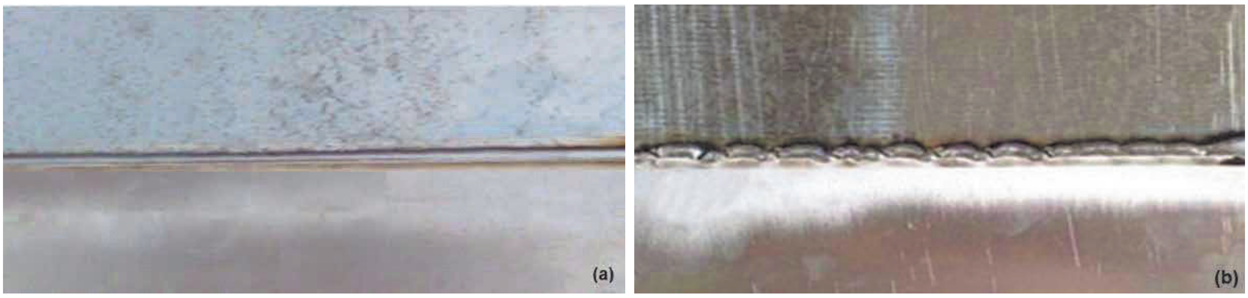

Figure 1 The visual appearance of the surface of braze-welded joints:
(a) - without defects; (b) - with discontinuities

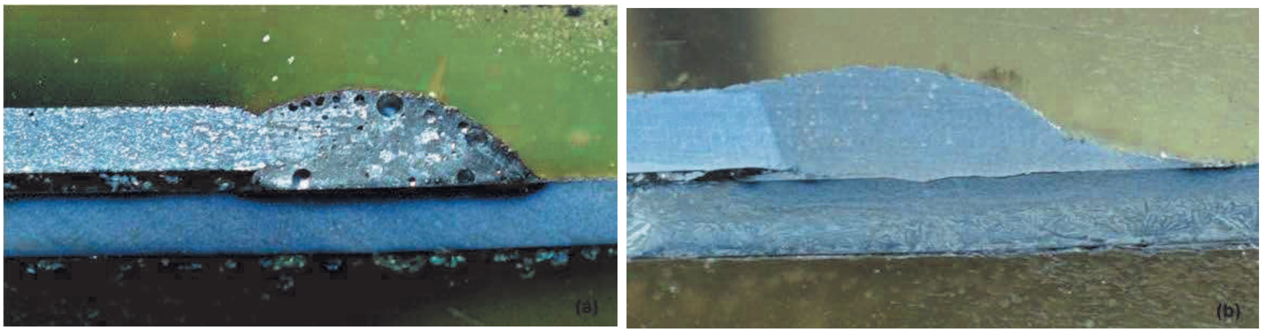

Figure 2 Macrographic image of the cross section of braze-welded joints:
(a) - with porosity; (b) - without defects; Chemical reagent, 10 % Nital

The microscopic examination was carried out in characteristic areas of weld brazed heterogeneous joints (WELD, BM, HAZ) according to SR EN 1321:2006 carrying forth the following characteristic structures:

- a eutectic (α + Si) finely dispersed in a matrix of solid solution α (**Figure 3**) in the aluminium base alloy
- a mixture of ferrite and pearlite (**Figure 4**), specific to non-alloyed steels with low carbon content, to which the pearlite is in small amount and disposed at the intersection of ferritic grains (**Figure 4**);
- a new metallic alloy, created in the connection area of the two base metals by melting the filler material and diffusion of chemical elements from and to the weld (**Figure 5**).

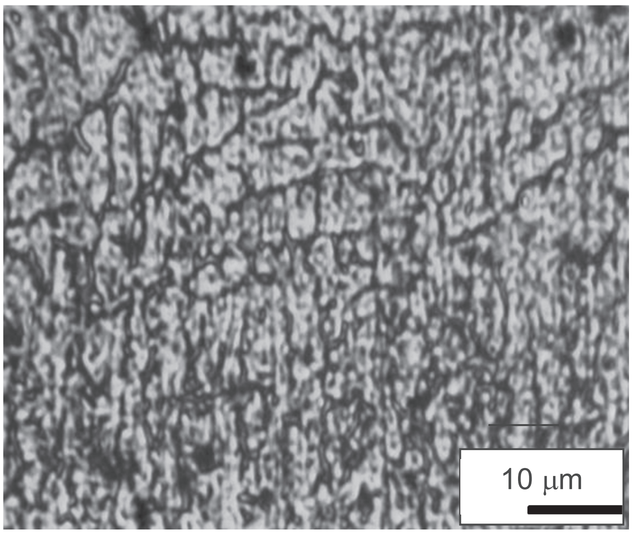

Figure 3 Microstructure of Al alloy

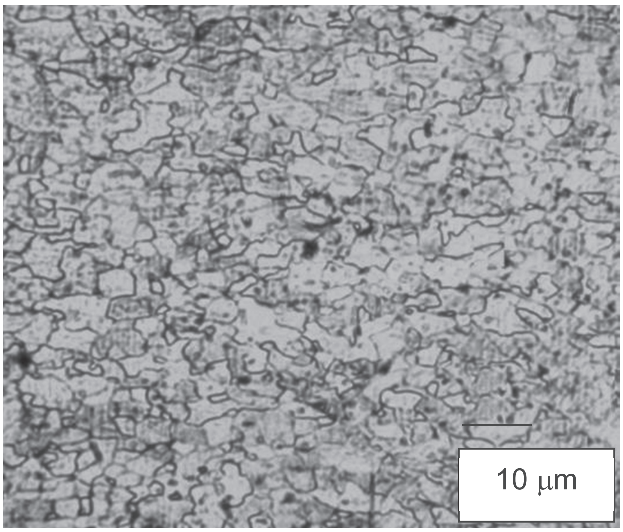

Figure 4 Galvanized steel microstructure

Chemical reagent: 2 % Nital

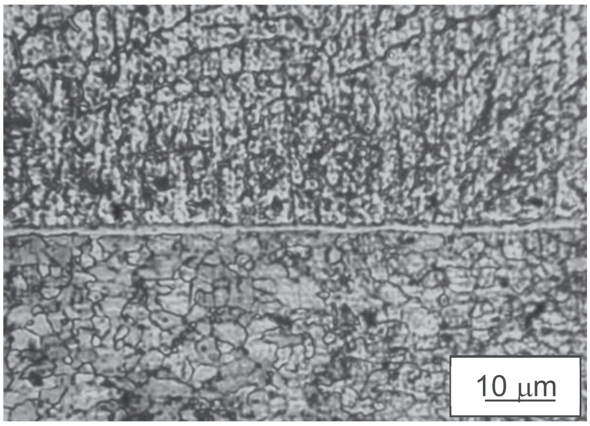

Figure 5 Galvanized steel interface microstructure - Al alloy (2 % Nital)

3.2. Hardness testing

After hardness measurements, were calculated the estimator values of structural hardening ΔHV1 (eq. 1):

$$\Delta HV1 = \frac{HV1_{max} - HV1_{min}}{HV1_{max}} \cdot 100 \quad [\%] \tag{1}$$

In which:

- $HV1_{max}$ maximum hardness HV1 in an area of heterogeneous joints;
- $HV1_{min}$ is the minimum hardness HV1 determined in another area of heterogeneous joint;

It is considered that, if ΔHV1 ≥ 50 %, in the analysed areas have developed accented phenomena of structural hardening-embrittlement, with high risks of fragile breakage.

Figure 6 shows the estimator variations of local hardening ΔHV1 according to braze-welded variants used for the realisation of heterogeneous galvanized steel-aluminium alloy joints.

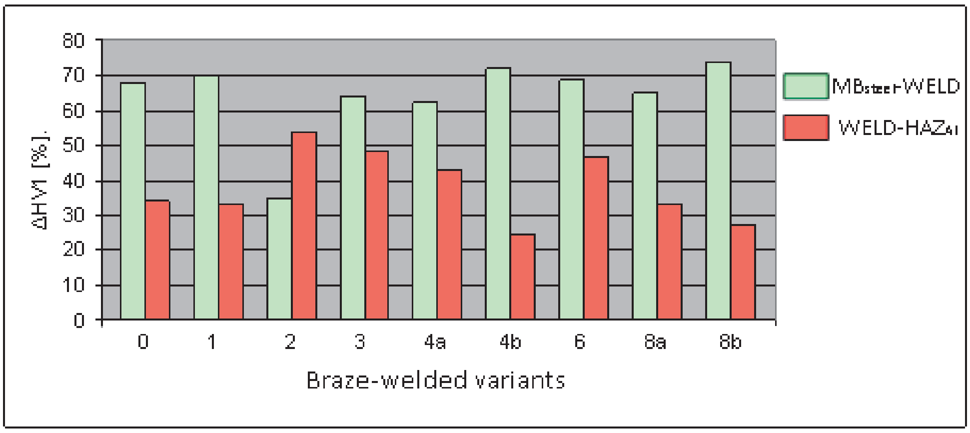

Figure 6 Histogram estimators of hardness values

By analysing these data, it is noted that the ΔHV1 estimator calculated between areas BM_{steel}-WELD (represented with green colour) generally presents higher values, over 50 %, at analysed variants (with the exception of variant 2) attesting development between these areas of some structural hardening phenomena.

3.3. Static testing of traction

These tests were carried out on flat specimens according to SR EN 12797:2002.

Variation of shear strength, R_f calculated for heterogeneous overlapping braze-welded joints with CMT or CMTP process based on maximum breaking force, F determined by the tensile test is shown in **Figure 7**.

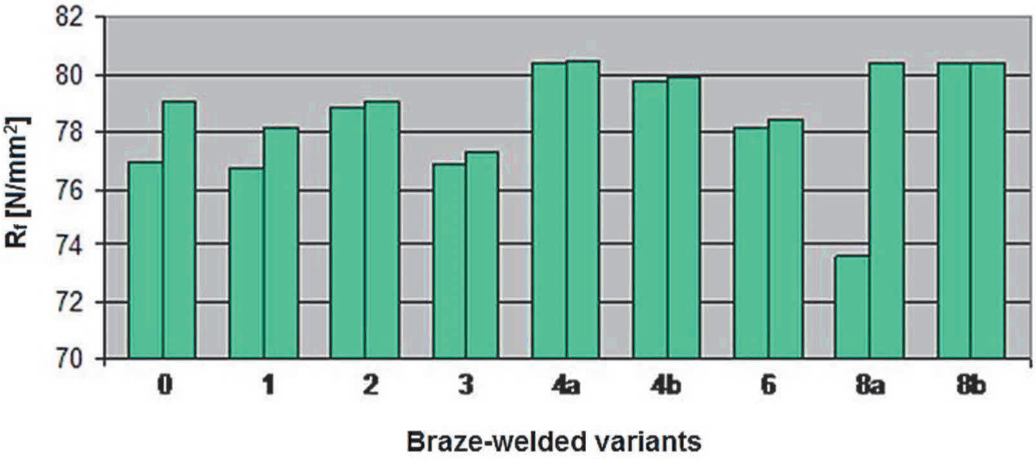

Figure 7 The histogram of shear strength values

Analysing the variation R_f = (braze-welded variation) it is observed that the highest values of the shear strength occur in variant's 4a and 8b, over 80 MPa, and the lowest values occur in variants 1 and 3 (under 78 MPa). In variation 8a there is a big difference between the minimum value, of 73 MPa and the maximum, of 80.5 MPa.

4. CONCLUSION

The designed factorial experiment allowed the defining of optimal process parameters in order to achieve heterogeneous braze-welded joints of galvanized steel - Al alloy with thickness of 1 mm.

Macro and micrographic examinations have demonstrated that joints made at optimum process parameters have an appropriate geometry, without metallic continuity defects.

The estimator values of hardening and shear strength attest that the brittle fracture of the CMT/CMTP braze-welded joints is reduced.

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