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WELDING-BRAZING CMT AND PLASMA ARC BRAZING OF THIN SHEET GALVANIZED STEEL WITH ALUMINUM SOLDERS

In this work, a series of experimental studies of MIG / CMT welding-brazing and Plasma arc brazing of thin-sheet galvanized steel with Al-5Si, Al-12Si and Al-6Cu-Mn-Zr-Ti solders were carried out. The obtained samples were tested for strength and corrosion resistance. The results showed that the samples obtained using MIG / CMT welding-brazing were characterized by the absence of adhesive bonding between galvanized steel and aluminum solder. In turn to brazing by plasma arc allowed obtaining joints with a strength of 110–270 MPa and high anti-corrosion properties. To further improve the joining process of galvanized steel with aluminum solders, recommendations were given on the composition of the filler material and joining methods. [dx.doi.org/10.29010/087.8]

Keywords: *galvanized steel; aluminum solder; MIG / CMT welding-brazing; Plasma arc brazing.*

Introduction

Modern requirements for the protection of materials from corrosion in such fields as automotive, installation of ventilation, air conditioning and cooling systems, production of light metal constructions, elements of facades, chimneys and electrical components can be provided by using the materials with coatings. New technologies allow to apply coatings with a thickness 1-60 μm that can serve for decades and save their properties even with mechanical damages (anodic protection) [1].

In the manufacture of galvanized steel structures, two types of welding were used: spot welding and arc welding in shielding gas (MIG / MAG). These welding methods solve the problem of joining materials, but there are difficulties with saving of anti-corrosion coating in the heat affected zone, which lead to deterioration of the mechanical properties and external appearance of the joint. The difference in the physical properties of the base metal and the coating causes the evaporation of zinc, that leads to the instability of the welding arc, the formation of pores, cracks and other defects [2].

The modern way to solve this problem is the use of MIG/MAG, CMT (Cold Metal Transfer) welding-brazing with copper-based wires. The innovative CMT technology allows to control the process of transfer of the electrode metal, which helps reduce the heat input into the base metal. Therefore, the level of destruction of the zinc coating is significantly reduced [2].

Currently, galvanized steel can be joined by an aluminum-based filler metal. This is possible due to the preservation of the zinc layer, which improves the wetting of steel by Al-alloys and decreases the thickness of the Fe-Al IMC layer. For this reason, it is necessary to use the joining methods with low heat input and a filler materials with a melting point below the evaporation temperature of Zn (906°C) and as close as possible to its melting temperature (420°C) [3-14].

In our study, CMT welding-brazing and plasma arc brazing were used. Al5Si, Al12Si and Al6CuMnZrTi were used as solders.

Experimental procedure

For research, samples were prepared from galvanized sheet steel DX56D + Z with the following geometrical parameters: length 120 mm, width 120 mm, thickness 0.7 mm. The chemical composition and mechanical properties of the steel is shown in Table 1. The thickness of the zinc coating is 40 μm.

Al-5Si, Al-12Si and Al-6Cu-Mn-Zr-Ti wires were used as solders. The diameter of the wires was 1.2 mm. The chemical composition and melting point of these materials are given in Table 2.

AL-Flux 726 flux was used to remove oxide films from samples surfaces. The temperature of activation of the flux is 515-630 C [15].

MIG/CMT welding-brazing was performed on the basis of Fronius Ukraine welding equipment. For the experiment, the installation was completed from: welding current sources TPS 5000 CMT R; remote control unit with RCU 5000i display; VR 7000 CMT wire feed; cooling unit FK 4000R; special stand; gas cylinder with argon; buffer compensator; welding table;

Table 1

Chemical composition mechanical properties of steel DX56D + Z [EN10346: 2015]

DX56D	C (max%)	Si (max%)	Mn (max%)	P (max%)	S (max%)	Ti (max%)
	0,12	0,5	0,6	0,1	0,045	0,3
Yield strength, MPa				120-180		
Tensile strength, MPa				260-350		
Relative extension, % min.				39		
Deformation coefficient, r min.				1,9		

Table 2

Chemical composition and melting point of solders

Solders	ΔT*, °C	The chemical composition, %							Standard
		Al	Si	Cu	Zn	Mn	Mg	Ti	
AlSi5	573-625	94	5	-	0,2	0,2	0,1	0,15	DIN 1732: SG-AlSi5 Alloy-No.: 3.2245
AlSi12	575-585	87	12	-	0,1	0,3	0,05	0,15	DIN 1732: SG - AlSi12 Alloy-No.: 3.2585
AlCu6MnZrTi	530-550	93	0,2	6	-	0,3	0,02	0,15	DIN 18273

*$\Delta T = T_L - T_s$. *T_s indicates the solidus temperatures of the solders. T_L indicates the liquidus temperatures of the solders.*

welding torch Robacta Drive CMT; Mobile SuperClean rdax 100 exhaust smoke system.

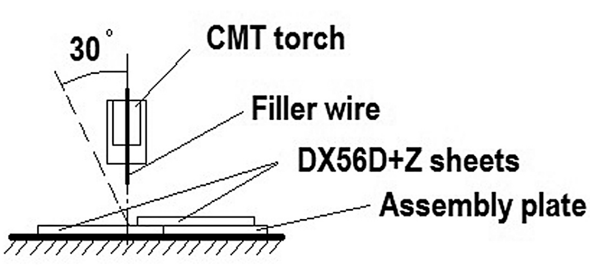


Fig.1. Scheme of plates assembly

Welding-soldering was performed on a special welding table with clamps mounted into it, which fixed the plates during the process. The overlap (inlet) of the plates in the joint was 15 ... 20 mm. To ensure an assemblege without a gap, an assembly plate of the same thickness was placed under the top plate (fig. 1). The flux was applied to the surface of the galvanized steel sheets in the form of a powder.

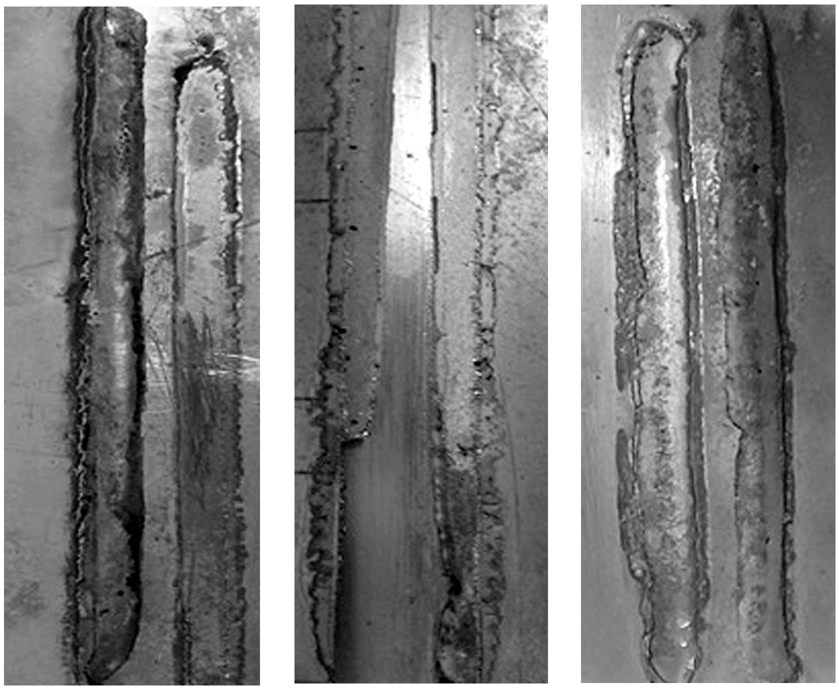
The parameters of MIG / CMT welding-brazing are presented in Table 3.

The results of experimental researches with different parameters of the process MIG / CMT welding- brazing method using wires of AlSi5, AlSi12, AlCu6MnZrTi showed the absence of the adhesive bonding in the interfacial layer of the obtained samples (Fig. 2). It allowed to make an assumption that a result of joining process was

Table 3

The parameters of MIG / CMT welding-brazing

Current *I*, A	30-75
Voltsge *U*, B	8-19
Wire Feeding Speed, mm/min	50-100
Welding-brazing Speed, mm/min	600-1300

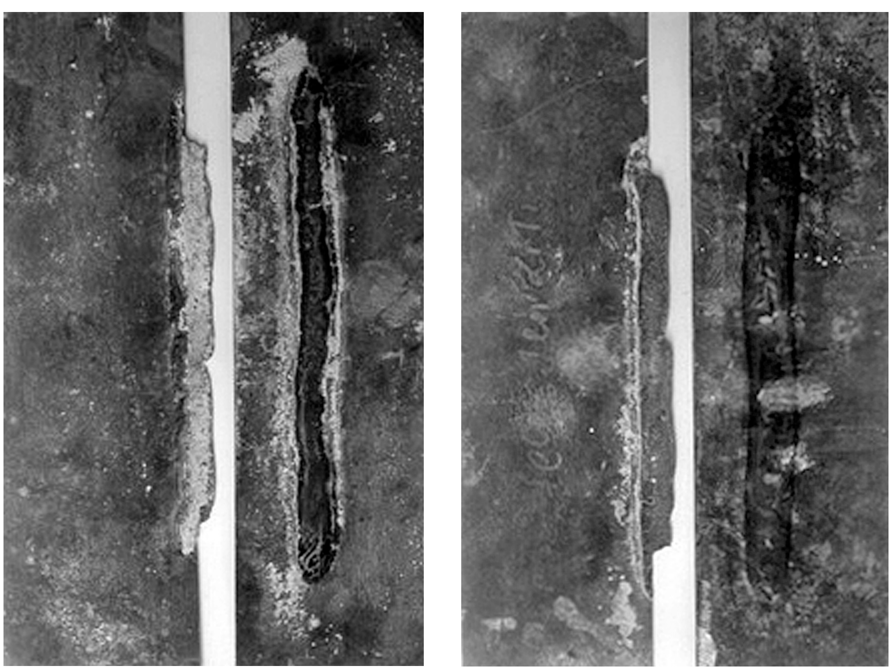


AlSi5 AlSi12 AlCu6MnZrTi

Fig.2. Samples were made by MIG / CMT welding-brazing

the destruction of the layer of zinc coating between the liquid solder and the base metal.

To confirm this assumption, DX56D + Z steel samples were immersed in a bath with 2% copper sulphate solution for 5 minutes, which led to the appearance of corrosion traces along the line of the temperature effect of the arc on the surface of the aluminum solder and the surface of the base metal (Fig. 3). These traces are evidence of the destruction of the zinc coating and the penrtration of a significant part of the base metal (Fe) to the composition of the interfacial layer.



Front side Back side

Fig.3. View of samples after immersion in a bath with 2% solution of copper sulphate for 5 min

Table 4

The parameters of MIG / CMT welding-brazing

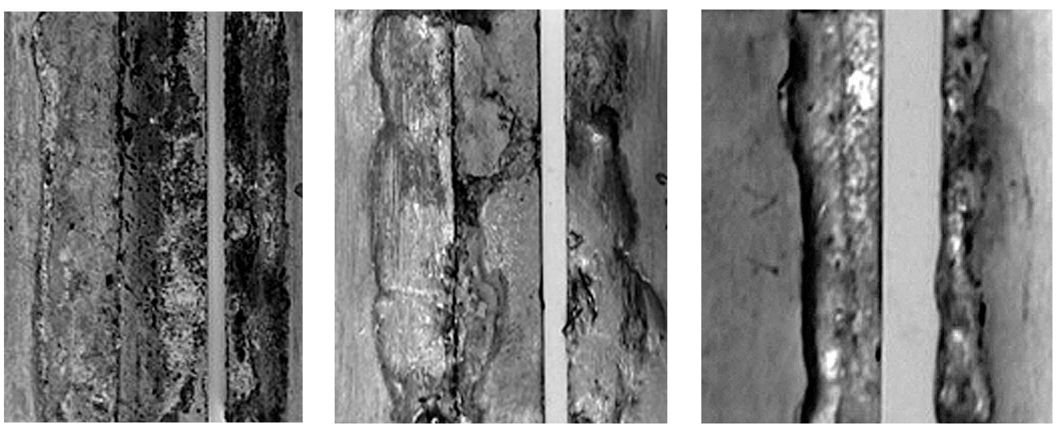
Current *I*, A	30-75
Voltsge *U*, B	8-19
Wire Feeding Speed, mm/min	Manual
Welding-brazing Speed, mm/min	600-1300

Thus, the MIG / CMT welding-brazing process has a low heat input but a highly concentrated arc lead to damage zinc coating and its mixing with the base metal (Fe). The next stage of research was an application of the micro plasma arc brazing with a defocused heat source.

Micro plasmic arc brazing was carried out on the basis of the MPU-4 installation. For the experiment, the installation was equipped with: power source; plasma torch USDS.R-45; balloon with argon. The parameters of the microplasma arc brazing process are presented in Table 4.

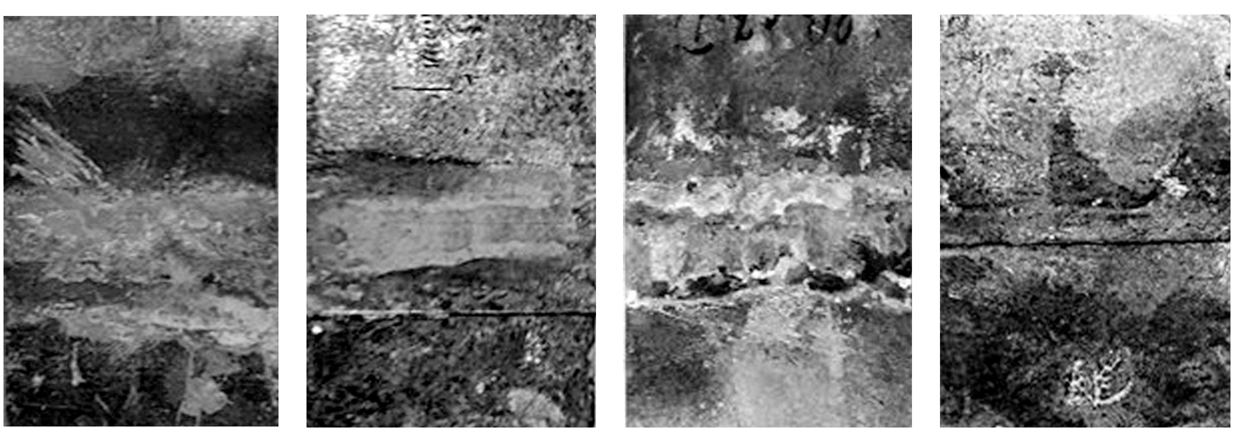
The tensile tests were done by a Tira test 2300. The results showed the tensile strength in the range from 110 to 270 MPa (Fig. 4.). At the same time, the greatest tensile strength was achieved when using the AlCu6MnZrTi solder.

The high corrosion resistance was achieved both in the joint and the heat-affected zone (Fig. 4).



AlSi5 AlSi12 AlCu6MnZrTi

Fig. 4. Samples after mechanical testing



Face side Back side Face side Back side

AlSi5 AlCu6MnZrTi

Fig. 5. Samples were made by microplasma arc brazing after testing for corrosion resistance

Experiments have shown that microplasma arc brazing significantly differ from CMT welding-brazing by the nature of heat input. Plasma arc brazing allows more uniform heating of the surface of the samples, which promotes the activation of the surface, spreading and wetting of the galvanized steel with Al-solder. In the case of CMT welding-brazing, electric arc is more concentrated, as a result, samples have not an adhesive bonding between the base metal and solder.

Conclusion

The mechanical properties of the joints made by plasma brazing have a tensile strength in the range of 110-270 MPa. The highest strength of samples (270 MPa) were achieved using AlCu6MnZrTi solder. The anti-corrosion properties of the joint were at the level of the base metal.

Thus, the preservation of a zinc coating layer between aluminum solder and steel plays an important role in the qualitative formation of the joint. This is possible due to:

- useing of brazing methods that have a low heat input and defocused heat source which allows to activate the surface of the base metal, without destroying the zinc coating;

- using of preheating;

- using solders, the melting point of which is significantly lower than the evaporation temperature of zinc.

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ЕЛЕКТРОДУГОВЕ СМТ ТА ПЛАЗМОВЕ ПАЯННЯ АЛЮМІНІЄВИМИ ПРИПОЯМИ ТОНКОЛИСТОВОЇ ОЦИНКОВАНОЇ СТАЛІ

В даній роботі було проведено ряд експериментальних досліджень зварювання-паяння MIG/CMT і паяння плазмовою дугою тонколистової оцинкованої сталі припоями Al-5Si, Al-12Si і Al-6Cu-Mn-Zr-Ti. Отриманні зразки були випробуванні на міцність та корозійну стійкість. Результати показали, що зразки, отриманні з використанням зварювання-паяння MIG/CMT характеризуються відсутністю формування зчеплення між оцинкованою сталлю і алюмінієвим припоєм. В свою чергу, паяння плазмовою дугою дозволило отримати з'єднання з міцністю 110-270 МПа і високими антикорозійними властивостями. Для подальшого покращення процесу паяння оцинкованих сталей алюмінієвими припоями були наведені рекомендації, щодо оптимізації складу присадкового матеріалу та способів паяння. [dx.doi.org/10.29010/087.8]

Ключеві слова: *оцинкована сталь; алюмінієві припої; зварювання-паяння MIG/CMT; паяння плазмовою дугою.*

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