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EXPERIMENTAL RESEARCH REGARDING WIG WELDING OF CERTAIN ALSI 5 ALUMINUM ALLOY COMPONENTS DESTINED TO WATER CANONS FOR FIRE EXTINGUISHERS

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Abstract. The paper presents the results of experimental research of WIG welding of some pipe-type components with a diameter of 100 mm and the wall thickness of 5 mm, made of Aluminum-Silicon alloy, AlSi5 brand, destined to water canons for fire extinguishers.

1. INTRODUCTION

Aluminum and its alloys are materials that are more and more frequently used in making welded structures. The world production of Aluminum currently represents about 2.5% of the world steel production. At world level, there are currently more than 400 types of laminated (forged) Aluminum types and over 200 Al alloys as molten product and ingots, registered by The International Aluminum Association, IAA.

The classification of Al alloys is mainly done by the following two criteria:

a. the chemical composition: takes into consideration the main alloying element, so we distinguish the following 8 series, table 1.

Table 1. Classification of Alluminum alloy according to their chemical composition

SERIES OF THE ALLOY	MAIN ALLOYING ELEMENT
1XXX	MINIMUM 99% AL
2XXX	COPPER
3XXX	MANGANESE
4XXX	SILICON
5XXX	MAGNESIUM
6XXX	MAGNESIUM + SILICON
7XXX	ZINC
8XXX	OTHER ELEMENTS

Thermal treatment: takes into consideration the evolution under a thermal treatment, so we distinguish the following 2 groups:

- Thermally treatable alloys:
  - series 2xxx, 6xxx and 7xxx (laminated);
- Thermally non-treatable alloys:
  - series 1xxx, 3xxx and 5xxx

Note: Alloys from the 4xxx series, depending on their chemical composition, may be thermally treatable or non-treatable.

The use of Aluminum and its alloys in product making, as an alternative to steel, is more and more frequent in fields like spatial industry, automobile industry, naval constructions, railroad vehicles, civil and industrial constructions, urban design, household tools etc.

2. TECHNOLOGICAL ASPECTS IN ALUMINUM AND ALLOY WELDING

Compared with steel, aluminum has a unit weight that is three times lower, a thermal conductance that is six times higher, a liniar expansivity that is twice as big and a melting temperature of 658° C. From a chemical point of view, Aluminum has a great preference for Oxygen. The Al_20_3 layer, thin and adherent to surfaces, prevents oxygen from getting deep into it and thus confers the material a very good resistance to atmosphere corrosion.

The technological problems that appear when welding aluminum and its alloys are:

- its great need for oxygen: the formation of the Al_2O_3 layer is problematic when welding because:
  - its welding temperature, which is higher than that of the aluminum, 2050°C as compared to 658°C, makes it impossible for the layer to melt when welding;
  - it is a bad current conductor (having an insulation action), making it difficult to start the electric arc;
  - it prevents the metal baths of the two components to be mixed with the added material and the formation of a common bath makes it difficult to achieve the respective joining (this is the most serious problem that occurs in welding);
  - aluminum oxide is hygroscopic (absorbs humidity), which leads to the danger of pore formation, due to the H_2 that results from the decomposing of water.
  - Al_2O_3 is heavier than aluminum (having a density of 3,7 gr/cm^3 as compared to 2,7 gr/cm^3), which makes the welding to remain in the welded joining or to sink to the bottom of the metal bath (at its root), as Al_2O_3 metal inclusion.

These problems - that the presence of Al_2O_3 creates - require welding to be made under special protection conditions that prevent gases to enter the electric arc, as well as the Al_2O_3 layer to come off the surface of the components before welding, in a mechanical, chemical way or by micro-sanding.

- *High thermal conductivity:* determines a rapid dissipation of the heat of the electric arc from the place of welding into the components, making it difficult for the base material to melt, which imposes the compensation of heat losses by the pre-heating of components before the welding, at temperatures between 100 – 300°C, depending on the welding procedure and the thickness of the components;
- *High expansively:* leads to the introduction of deformations and high internal tensions in components, which requires welding to be avoided in the devices, as well as components to be made rigid when welding.
- *High capacity to dissolve gases that are in a melted state*, especially H_2: when the metal bath becomes solid, the solvability of hydrogen tends to 0 (0.05 cm^3/100gr deposited metal, as compared to steel, which can dissolve 8 cm^3/100 gr of deposited metal); this leads to pore formation, a danger also increased by the high hardening speed of the bath;
- *The alloys of aluminum that are plastically deformed when cold or alloys that can be chilled lose their mechanical properties:* under the action of the heat introduced when welding, the characteristics of the base metal are diminished in ZIT; in the case of alloys that are not thermally treatable, another phenomenon occurs – one of re-baking of the hammer-hardened material (in its elaboration phase), while in the case of thermally treatable alloys, a degradation of the initially applied thermal treatment takes place. In the first case, in order to re-make the mechanical characteristics of the joining, it is recommended to hammer the joint, while in the second it is recommended that the thermal treatment is re – applied after welding. The fact that aluminum has different

properties than steel makes the welding of aluminum to be much more different than that of steel. If we know the technological problems that appear when welding aluminum, then we can do it relatively easily.

3. EXPERIMENTAL RESEARCH

Experimental research have followed the choice of the welding procedure for the execution of the joining, the establishment of a constructive solution for the parting, establishment of the welding technology, the analysis of the quality of the welded joint

3.1. SELECTING THE WELDING PROCEDURE.

For welding aluminum and its alloys, one can use several procedures: manual welding with covered electrodes (more and more seldom used), WIG welding, MIG welding, welding with electrode fascicle, plasma welding, LASER welding. The choice of the welding procedure depends on the level of quality imposed to the welded joining, the geometrical characteristics of the joining, the volume of production, fabrication cost etc. The more practically used procedures are WIG and MIG welding. The choice mainly depends on the thickness of the welded material. Starting from the analysis of the welded joining, figure 1 (head-to-head joining upon periphery, pipe with d = 100 mm and wall thickness t = 5mm, small series production) and of imposed conditions (a universal, accessible procedure), the WIG welding procedure has been proposed. This one ensures a very good quality of the welded joining, with low expenses.

3.2. THE CONSTRUCTIVE SOLUTION FOR THE PARTING.

When choosing the constructive solution for the parting, the joining requirements were considered, namely avoiding to block the inner pipe diameter by material drains to the root, as well as ensuring the quality and resistance conditions for the welded joining, by guaranteeing a safe piercing. In this respect, the base layer is supported by a non-fusible support that can later on be easily taken away, as in figure 2.

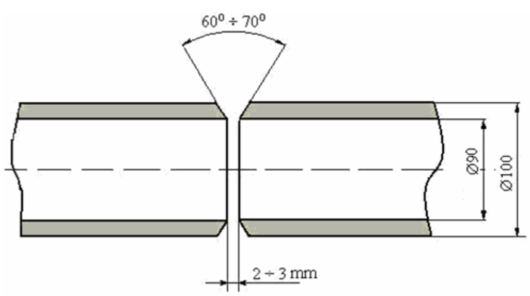

Figure 1. Geometry of the joining

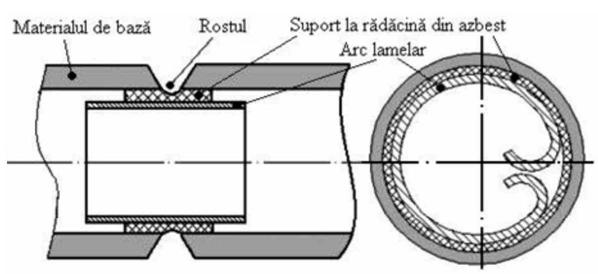

Figure 2. Root support

The support is made by a non-fusible ring made from asbestos, which has a gap for the correct formation of the root, pressed on the inside with a plated arc. Taking out the arc allows the ring to be easily taken away.

3.3. THE WELDING INSTALLATION.

A modern welding source with an inverter was proposed for the WIG welding, namely MAGIC WAVE 300 (Fronius), while for moving the part in order to mechanize the welding speed, the positioning and rotating table MPR 20 (IMPS Oradea) was proposed,

as in figure 3.
The premises for the execution of welded joining on periphery, in a continuous manner and without interrupting the welding process are thus created. This will re-position the part or will pass from one welding layer to the other, with benefic effects on the quality of the joining and the welding productivity, by the possibility ot increase the welding speed and why not, to simplify the mode of operating.

3.4. THE WELDING TECHNOLOGY.

The basic metal for the components is an aluminum and silicon alloy from the 4000 series, namely AlSi 5 alloy. The chemical composition of the basic metal is presented in table 2. For welding we need to use an additional material that is compatible with the basic material, ER 4043 rod, table 2. The protection gas that was used was Ar 100%, cf. SR EN 439/96 and the non-fusible electrode was from pure EWP Wolfram, cf. SR EN 26848/93.

The preparation of components for welding consisted of mounting the support on the root, temporarily fixing it and placing it into the universal chuck of the positioning and rotating table MPR 20, as in figure 4.

Table 2. Chemical composition of the base metal and the additional material

Material type		Chemical composition (%) – maximum values							
		Si	Mn	Cu	Mg	Fe	Zn	Ti	Al
Basic material	4643	3,6-4,6	0,05	0,1	0,1-0,3	0,8	0,1	0,15	The rest
Additional material	ER 4043	*4,5-6,0*	*0,05*	0,3	*0,05*	*0,8*	*0,1*	0,20	The rest

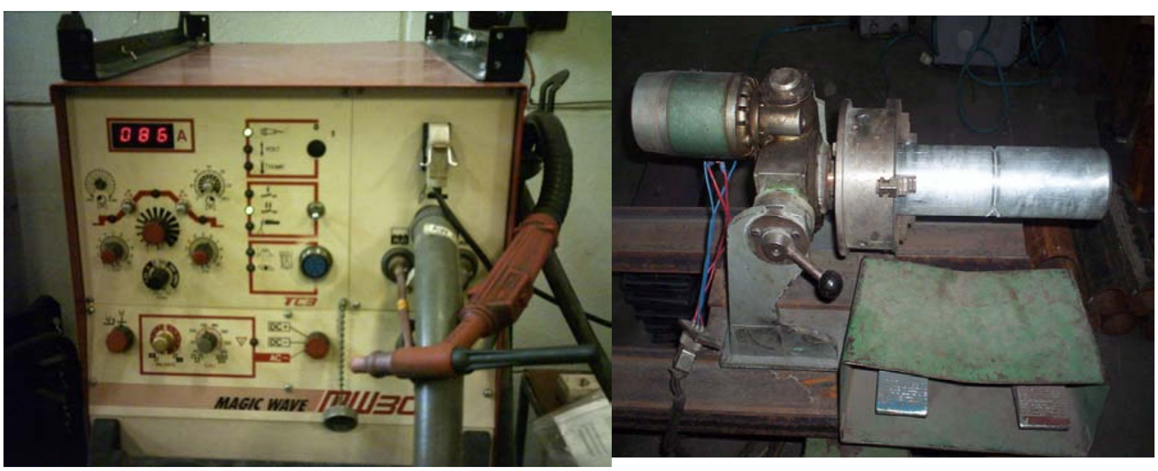

Figure 3. The welding installation
Figure 4. Welding preparations

In order to establish the best welding technology three tests were prepared. Welding was done in two overlaying layers, one as root and one as filling. The external aspect of the welding is presented in figure 5. The used technological parameters are presented in table 3.

Figure 5. External aspect of the welding

Table 3. Technological welding parameters

Test 1		
Technological parameters	**Root layer**	**Filling layer**
Welding current	I_s = 150A	I_s = 160A
Electric arc voltage	U_a = 16V	U_a = 16,5V
Type of non-fusible electrode	EWP	EWP
W Electrode diameter	d_{el} =3,2 mm	d_{el} =3,2 mm
Type of additional material	ER 4043 (rods)	ER 4043 (rods)
Diameter of rod	d_s = 2,4mm	d_s = 2,4mm
Type of gas	Argon 100%	Argon 100%
Gas debit	Q_{gaz} =9l/min.	Q_{gaz} =9l/min.
Welding speed	V_s=12 cm/min	V_s=12 cm/min
Test 2		
Technological parameters	**Root layer**	**Filling layer**
Welding current	I_s =160A	I_s =180A
Electric arc voltage	U_a = 16,4V	U_a = 17,2V
Type of non-fusible electrode	EWP	EWP
W Electrode diameter	d_{el} =3,2 mm	d_{el} =3,2 mm
Type of additional material	ER 4043 (rods)	ER 4043 (rods)
Diameter of rod	d_s = 2,4 mm	d_s =2,4 mm
Type of gas	Argon 100%	Argon 100%
Gas debit	Q_{gaz} =9l/min.	Q_{gaz} =9l/min.
Welding speed	V_s=12 cm/min	V_s=16 cm/min
Test 3 (Best welding technology)		
Technological parameters	**Root layer**	**Filling layer**
Welding current	I_s =150A	I_s =160A
Electric arc voltage	U_a = 16V	U_a = 16,5V
Type of non-fusible electrode	EWP	EWP
W Electrode diameter	d_{el} =3,2 mm	d_{el} =3,2 mm
Type of additional material	ER 4043 (rods)	ER 4043 (rods)
Diameter of rod	d_s =3,2 mm	d_s =3,2 mm
Type of gas	Argon 100%	Argon 100%
Gas debit	Q_{gaz} =9l/min.	Q_{gaz} =9l/min.
Welding speed	V_s=15 cm/min	V_s=16 cm/min
Macroscopic aspect		
Test 1	**Test 2**	**Test 3**

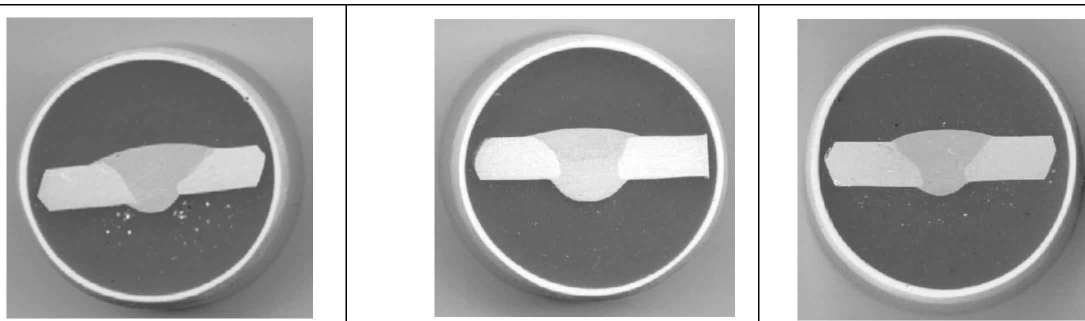

Figure 6. Macroscopic aspect of weldings

From the analysis of the geometry of joints on the macroscopic tests in figure 6 we come to the following conclusions:

- in the first test we notice a defect in the alignment of the two components, with an asymmetric deposit, a large width of the welding and a relatively big dilution of the basic metal;
- in the second test the dilution is even more intense and there is also a tendency of over melting observed in the strong over-raising of the root;
- the third test has the best geometry and the welding technology is considered the best for the execution of the joining.

3.4. ANALYSIS OF THE WELDING QUALITY.

It has been done by the macro and microscopic metallographic analysis, by measurements with the sclerometer. The macroscopic analysis followed to underline the geometry of the welding and of the possible macro-defects in the welded joint – cracks, lack of melting, lack of penetration, pores, inclusions – for the best considered welding technology, in test 3. No defects of any kind have been noticed in the areas of welded joints, which confirms the justness of the proposed constructive solution.

In order to make a microscopic analysis of a joining that would underline the structural constituents, we need to analyze the balance diagram Al-Si, figure 7. This one shows that the alloys in this category can be structurally hardened. The diagram shows an eutectic transformation at 580^{o}C and 17.7%Si. It also has a 1.65 solvability at this temperature, while in the normal environmental temperature it is zero. The decrease of the Si solvability favors the structural hardening of the AlSi alloy. Structural hardening is made because of the eutectic ($\propto$+Si).

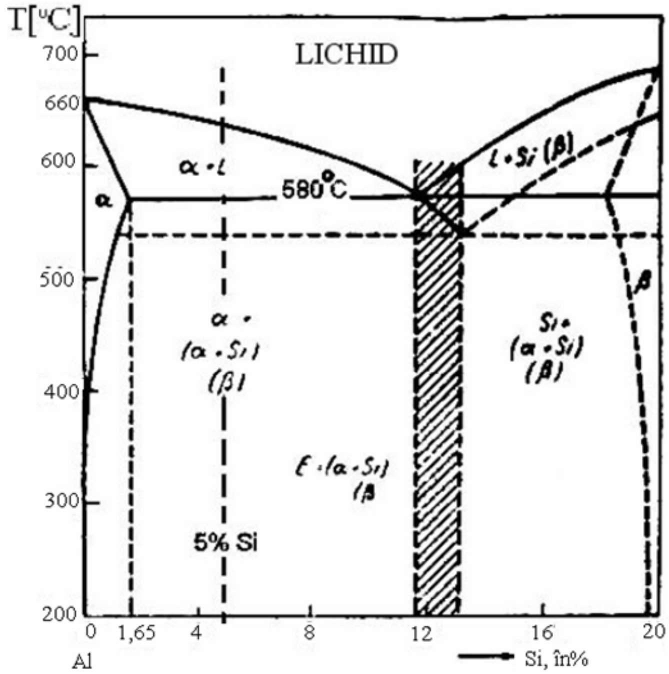

Figure 7. Al-Si balance diagram

In figure 8 we can see the structural constituents in the area of the welded joints:

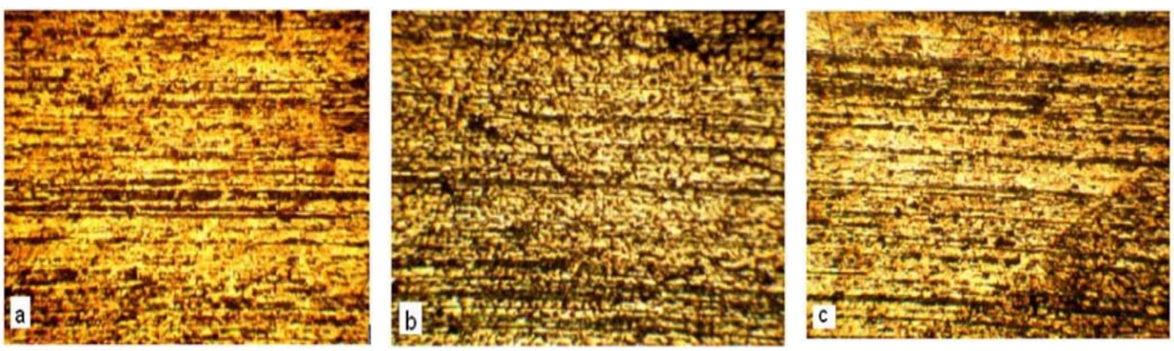

Figure 8. Structural constitutents in the area of welded joints

- basic metal, figure 81: solid α solution and the Al – Si eutectic in laminating rows;
- welding, figure 8b: α solid solution and fine Al-Si eutectic precipitations;
- ZIT, figure 8c: the diffusion area is very small, so it cannot be rendered obvious even with this zoom.

The hardening measurements have followed to underline the tendency of hardening the welding material by the Vickers HV5 method.

The arrangement of hardness prints is presented in figure 9.

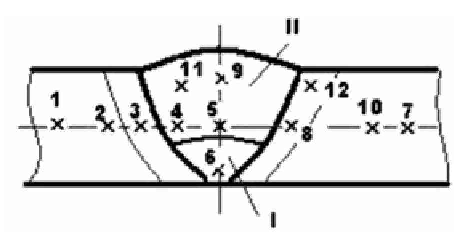

Figura 9. Arrangement of hardness prints

Table 4 shows the values of hardness measurements.

Table 4. Values of hardness measurements

No. of trial	Analyzed area	Value of **VH5** hardness
1	Basic material	29,7
2	Basic material	29,9
3	Z.I.T.	45,2
4	Seam	50,2
5	Seam	51,6
6	Seam	51,6
7	Basic material	29,5
8	Z.I.T.	55,4
9	**Seam**	**56.0**
10	Basic material	28,5
11	Seam	49,0
12	Z.I.T.	40,0

From an analysis of the obtained results we notice that the maximum hardness is obtained in the seam – trial 9 – having the value of 56,0 HV5 in ZIT respectively, trial 8 having 55,4HV5, which proves the tendency of hardening when welded. The results of mechanical trials will confirm once more the fulfilling of the exploitation requirements of this product.

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