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WELDED JOINTS STUDIES ON THE DEVELOPMENT OF BRAZED ALUMINUM SHEETS

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Abstract: Currently, the joints of different steel and aluminum materials are widely used for the manufacture of hybrid structures in the automotive field, in various naval constructions and transports mainly due to the need to reduce weight and achieve energy savings. The joining of aluminum sheets by welding or brazing means that two pieces are connected to each other through certain processes to form a whole and the structure thus created is of high performance. The materials chosen to make this type of welding-brazing are the result of laboratory analyses, they must be properly joined to be able to ensure the required strength of these joints. This work aims to study the realization of MIG welded-brazed joints of aluminum alloys with steel, which are complex joint structures that require high strength connections. The materials to be joined were chosen, a morphological analysis of the joint was carried out with the help of electronic microscopy, as well as various tensile tests to confirm the resistance of these joints.
Key words: welding, brazing, joint, alunimun, sheet.

1. INTRODUCTION

According to the specialized literature, the ways in which two metal sheets can be well joined include welding, brazing, adhesive bonding, and other joining technologies such as riveting, crimping, and others. Adhesive bonding is a process that uses the mechanical bonding force, physical adsorption force and chemical bonding force generated by the interaction between the structural adhesive and the connected material to achieve an effective connection [1-7].
Bonded joints made by this method exhibit uniform stress distribution, excellent sealing performance and vibration resistance performance. Completely different from adhesive bonding, the self-pierce, riveting and clinching technology mainly depends on plastic deformation to join light alloys such as aluminum alloys and magnesium alloys. Welding or brazing is a technology for joining metals or non-metallic materials by simple heating, using high temperatures or high pressures [8].
Welding of aluminium sheets can be made by three different technologies: fusion welding, pressure welding and brazing. The sheets are of small thickness and for making the correct joints, the soldering temperature and soldering time have a great importance on how the base materials are diffused with the filler material, resulting in a good homogeneity, composition and microstructure [9-12].
When discussing the brazing or welding of aluminum sheets, the following steps must be taken: initially, the surface of the aluminum sheets must be cleaned with the help of a special cleaning solution in the soup to remove any grease or even possible impurities that could affect the soldering process; then the aluminum sheets are fixed with the help of clamping pliers; at the end, a glue flux is applied to the surface of the aluminum sheets in order to join them. This flux will help remove the aluminum oxide from the surface and allow the filler metal to spread evenly. At the same time, it must be compatible with aluminum and have a lower melting point than aluminum sheets. Through a specific brazing process, the joined areas are heated until the filler metal melts and spreads evenly. The joint areas must be over-melted, as this could affect the mechanical properties of the aluminum sheets. After cooling them to room temperature, they are cleaned with a brush to remove the excess bran flux [13].
The joining of various aluminum alloys with steel types presents a huge challenge due to the significant differences in their thermophysical properties, which can inevitably lead to the generation of brittle intermetallics if high temperatures are used [14].
This fragility that can appear after the joining process also compromises the safety of the final products. So it is essential to inhibit the thickness and segregation behavior of the component elements for different welding or brazing processes to improve the performance of the bimetallic joint.
These conventional MIG welding-brazing methods generally improve the mechanical performance of the joint,

the thicknesses of the materials to be joined must be optimized relative to the thickness of the flux layer used, which greatly limits the large-scale application of Al/steel bimetallic structures. This optimization of the welding process is absolutely necessary to achieve the adhesion of aluminum to steel; this is achieved by choosing an appropriate welding technique.

2. MATERIALS AND METHODS

Figure 1 shows the brazing process and the arrangement of the brazing flow and the flow according to the position of the brazed sheets. The 2 mm aluminum alloy sheet was regularly placed over the steel sheet and the overlapping distance between them was about 20 mm in the experiments. The precast samples were fixed tightly on the welding workbench with the help of clamping hooks. The forces applied by the four devices must be exerted on the samples as evenly as possible. Before welding, the welded surface had to be completely cleaned with alcohol and after that the weld-braze seam is made with Hitbox MIG200II torch.

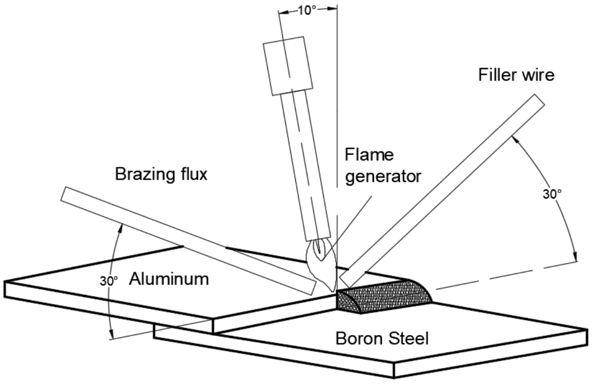

Fig. 1. Welding-brazing joint.

The base materials used in this study were Al-Si coated boron steel and 5052 aluminum plates with the same dimensions of 100 mm × 60 mm × 2 mm. Al-5Si wire (ER4043) with a diameter of 1.2 mm was used as the filler material. The chemical compositions of the materials to be joined can be found in Table 1.

Table 1. Chemical compositions of materials (mass fraction, %).

Materials	C	Si	Mg	Mn	Zn	B	Fe	Al
Boron steel	0.21	0.26	-	1.31	0.01	0.002	Bal.	0.02
Aluminum	-	0.19	2.58	0.04	0.02	-	0.1	Bal.
ER4043	-	4.5-6	0.05	0.05	0.1	-	0.8	Bal.

To carry out the tests, a number of three samples were cut from a larger brazed sheet. The samples were cut so that they were from different areas. The welded sheets have a size of 200 x 500 mm, from which the samples were taken. The first two is taken at 100 mm close to the edges of the board and one from the middle of it.
The dimensions and shape of these samples being exemplified in figure 2, as we can see, they are 100 mm long, 12 mm at the ends and 6 mm in the part where they are joined.

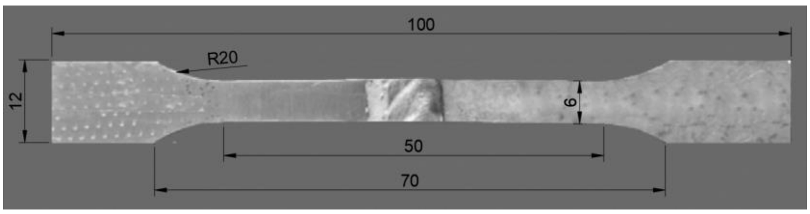

Fig. 2. The geometry of the brazed sample.

Tensile tests indicated that the yield strength and tensile strength were approximately 400 MPa and 600 MPa, respectively. After going through the press hardening process, fully martensitic steel with an ultra-high strength of over 1500 MPa can be obtained.
The composition and surface energy of liquid and solid are assumed to be constant, in real systems sometimes

interactions occur, such as: formation of the alloy between the liquid and the base material; the diffusion of the base metal and bonding with the filler material; the diffusion of the filler metal in the structure of the base material; penetration of the filler material along the particle boundaries and the formation of intermetallic compounds.
Since the samples were taken from the same sheet, they behaved similarly regardless of their cutting area. It can be seen that the average stress is around 1.7 kN along the length of 5. The differences between all 3 specimens being minimal, they break in about the same way.

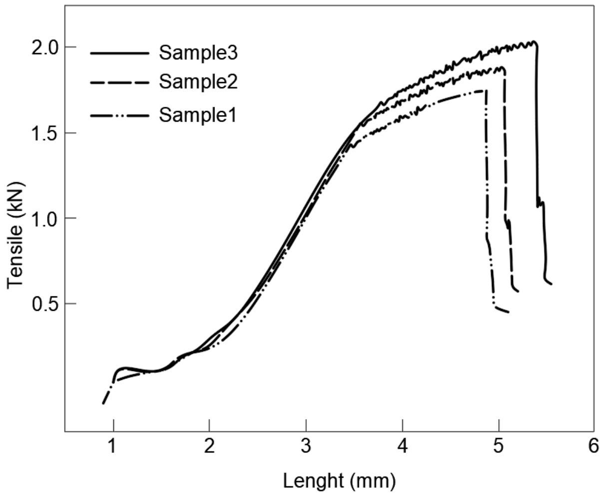

Fig. 3. The breaking tests of the three samples.

Tensile tests were performed on three types of welded specimens using a universal testing machine at a constant speed of 1 mm/min, with the specimens at room temperature. For the weld joint obtained in conventional MIG brazing, the maximum load force was approximately 1,000 kN. Rupture occurred for these specimens at the bond interface following these tests.
Conventional welding procedures also present a series of disadvantages, namely: the appearance of internal stresses, structural changes in the joint area, as well as the influence of multiple factors on the quality of the joint. These factors are given by the nature of the base materials, the choice of the filler material, the welding conditions, the qualification of the welder, etc., making welded or brazed bimetallic joints can amplify these factors.

3. RESULTS AND DISCUSSION

For the samples made on thin sheets, the electron microscopy image was followed and how the additive material wetted the walls. In figure 4, is analyzed the cross-sectional morphologies of the brazed-welded joint by tracking the wettability and spreading ability of the molten filler wire.

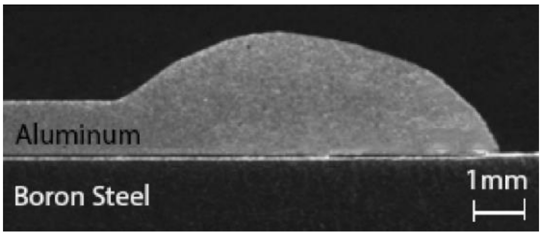

Fig. 4. Cross section of the welding-brazing joint.

A contact at a small angle, which involves wetting, is also a particular necessary but not sufficient condition for flow, viscosity being also important. Fillers with limited melting ranges that aim for a eutectic composition generally have low viscosities with extended melting ranges. Thus, a high surface tension of the filler metal in the liquid state, a small contact angle and a low viscosity are all desirable. Benchtop Scanning Electron Microscope (JCM-6000 PLUS) was used in this case.
From the analysis of the fracture behavior of the brazed bimetallic sheets, the conclusion can be drawn that they have a suitable behavior, and the welding seam is well made along the entire length of the sheets.
The three repeated tensile tests for each joint were evaluated and their average value was taken according to Eq.

(1). The behavior of the fracture was then analyzed by scanning Electron Microscope (Zeiss EVO LS15 SEM).

$$S = \frac{F_{max}}{l} \tag{1}$$

where S is the joint strength (N/mm), F_{max} is the ultimate strength (N) and l is the width of the tensile shear specimen at failure (mm).
If we were to perform the comparative thermal analysis, we notice that it can be written in the form:

$$f = \frac{1}{T} = \frac{1}{T_1+T_2} \tag{2}$$

where f is the current frequency, T (K) is a thermal period, this being equal to the sum of the thermal peak phase times T_1 and the thermal base phase T_2.
By choosing the brazing flux, this connection could be made in good conditions, and the cleaning conditions of these materials were respected in order to be able to properly make this connection between the two materials with different properties.
A flux with small particles is more active and leaves less residual flux. It is true that a flux with small particle sizes covers the assembly surfaces much more completely than the same amount of flux with larger particles. Smaller flux grains will thus adhere better to these surfaces, assuming that the two fluxes can be compared showing the difference in particle distribution.
If the particle size decreases, the total surface area of the flow increases. This allows for a larger surface area of the flux in contact with the components to be joined. During the process of increasing the temperature, they will be able to transfer the energy of the flow much more efficiently with particles having smaller sizes. The net result is that it can affect the melting kinetics – how fast the flux melts – but it cannot affect the melting temperature range.
As seen from Figure 5, it appears that the weld bead has formed quite regularly between the fusion zone and the steel matrix. Through these examinations, defects were searched for, and it was concluded that no defects were discovered at the Al/steel interface. Achieving a good welded or soldered bond is related to the chemical elements found in the filler metal. If we analyze the welding process, we notice that the presence of chemical elements in the weld bead in the fusion zone with the steel greatly improves the wettability of liquid metals on the steel surface.

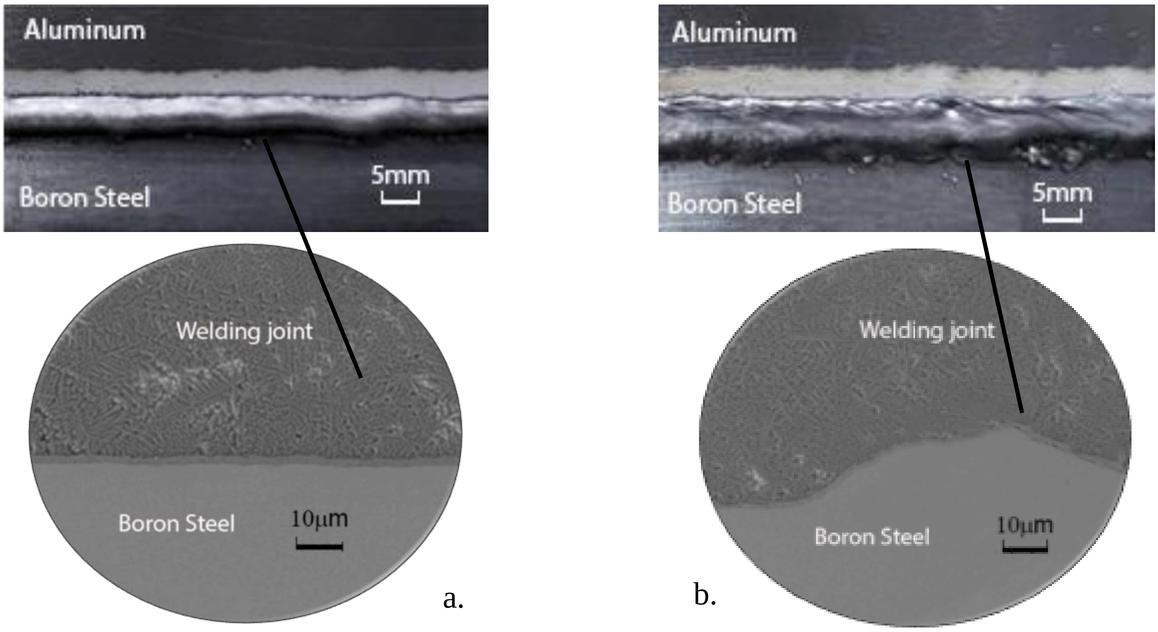

Fig. 5. Weld seam analysis.
a. the middle area; b. end zone.

Figure 5 shows us in detail this bond between the two base materials and so we can see more closely how it was created and what the fusion zone between the weld bead and the base materials looks like, especially in the area where it is with the steel.

The liquid metal was completely spread over the steel surface due to the evaporation of the elements found in the blast flux, they could prevent the oxidation of the steel surface and absorb the excessive heat input. All this causes the steel to expose the fresh metal surface for brazing, the bead being constantly arranged and well made throughout its length [15].

Deep penetration welding-brazing is generally one of the most used methods for making joints of thick aluminum and steel sheets. In this process, using the difference between the melting points of aluminum alloy and steel, we observe that a fusion welded joint on the aluminum side and a brazed joint on the steel side are formed simultaneously. The flux layer can be effectively suppressed because very little melted steel edge. The heat source provides a large amount of heat input, which is beneficial for making these Al/steel bimetallic welds.

Diffusion processes in combination with the partial dissolution of the base metal can modify both the composition and the chemical and physical properties of the boundary zone formed between the base metal and the filler metal, usually affecting the entire joint.

The microstructural samples were mechanically ground and polished. The microstructure of the interface was examined by a scanning electron microscope (SEM). Phase identification was performed using micro-X-ray diffraction technique. The scan region was approximately a circle with a diameter of 100 μm. The fracture behavior was then examined by SEM, figure 6.

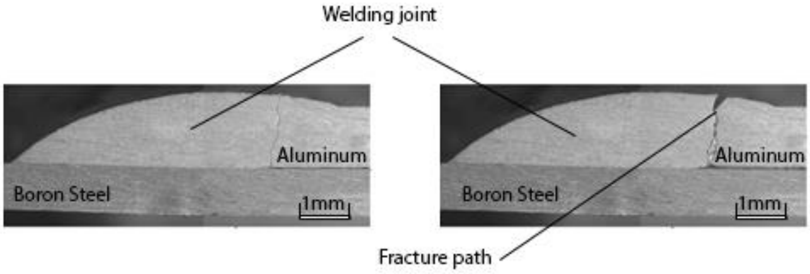

Fig. 6. Fracture behavior.

As can be seen in the figure, we can see that the structure of the weld bead is regular between the fusion zone and the steel matrix. No defects were observed at the Al/steel interface. The good formation of the interface is explained by the Zn elements existing in the filler metal.

The heat source used in the joining process has a great influence on the joining process. When the MIG flame generator it is not well optimized, incomplete penetration of the filler material into the base material is observed, indicating that the molten metal does not have proper wetting and is not properly distributed on the steel side. This is mainly because the values for the heat source are inadequate, the heat transferred from the MIG arc is insufficient, and the Al base material is not completely melted, resulting in a poor joint. If the MIG flame generator is chosen appropriately a uniform weld bead is formed, their joining continues on both sides of the base metals, and the molten metal is completely spread over the front and back of the steel.

This is attributed to the increased surface temperature on the steel side as the heat input increases.

During the MIG welding process, the arc and the droplet can oscillate over the entire width of the weld bead under the effect of electromagnetic force, all this to improve the wetting of the molten aluminum on the steel surface.

However, by raising the power of the heat source to high values, cracks may appear on the surface of the welded joint and the steel may melt due to excessive energy. These are correlated and studied experimentally and the different behavior of the materials subjected to joining can be correctly determined.

Microstructural analyzes were performed to highlight the texturing of the base and additive material as well as the microstructural distribution of compounds in composite images using backscattered electrons.

4. CONCLUSIONS

Through the experiments carried out in this work, it can be observed that a glued joint is generally not a homogeneous body, but rather heterogeneous, composed of different phases with different physical and chemical properties. From what can be seen is that the partial dissolution of the base metal from the diffusion process can have an influence on the chemical and physical properties of the boundary zone that forms at the contact zone between the base metal and the filler metal.

The brazing process must initially have a cleaning operation, after which it proceeds to the addition of filler metal that must be compatible with the base metal and through heating and cooling cycles.

Through the microscopic analysis of the adhesion of the melt to the aluminum sheet by microblast analysis by electron microscopy, it was found that the chosen brazing material has a weak differentiation between the base

metal and the filler metal, which means that the brazing is of very good quality.
The resistance tests carried out in this work following the bonding of the two different base materials led to the conclusion that this whole process was well done, the addition material as well as the flow chosen being appropriate for the proposed purpose.
Through this work, a knowledge of the industrial problems related to the requirements for aluminum-based bonding materials and used as materials with industrial potential for development and in the multifunctional field is proven: reinforced composite matrices, aluminum-based cellular metallic materials, etc., they can be extended to many industrial applications.

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