Aluminium alloys reconditioning by using new filler materials

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Abstract. Even for those experienced in welding steels, welding aluminum alloys can present quite a challenge. Higher thermal conductivity and low melting point of aluminum alloys can easily lead to burn through unless welders follow prescribed procedures. Brazing of aluminum needs to be performed "hot and fast".

The main advantages that the paper presents are: the use of non-specialized brazing equipment, the production of a stronger joint than the base material, brazing can be done without flux material, the environment and the operator are protected because no toxic fumes and working temperature is low.

The most widely used rod on the market for welding zinc base metals - white - die cast - pot metal. Alloyed from pure virgin metals. Welds made with rod are clean and free from slag and produces a sound joint that is stronger than the parent metal. Brazing aluminum without the use of flux, sound and free from porosity, solders galvanized, also used as a rub-on solder, use a slightly carburizing flame (excess of acetylene), with small tip for most work.

1. Introduction
In all industrial fields, aluminum and its alloys are increasingly spreading due to their characteristics.

It can be deinterlaced by the known arc welding processes with W electrode in Ar-controlled atmosphere using a joint in I since 1942. Modern technologies use protective gas containing higher He, which requires a higher arc voltage [1].

The low temperatures of aluminum alloy heating 350°C-450°C do not allow the use of unconventional welding technologies that have been designed to be superior to classical technologies. Thus, since 1985, other technologies have been developed to unbundle aluminum and its alloys by brazing.

This technology, more efficient in terms of energy efficiency and quality of assemblies, is widely used in the aviation, chemical, medical and food industry. On a large scale, an Ag-based filler material and an oxyacetylene flame, preferably made of high purity acetylene (acetylene spectral), are used [2].

Conventional brazing technologies can be used for alloys of the 1xxx, 3xxx and 5xxx series, with low magnesium content.

Alloys containing a higher amount of magnesium and silicon are much harder to brazing with the usual flow methods due to poor wetting and excessive penetration of the filler material. Thus, new brazing technologies have been developed, which use a much higher calorific gas, so with a much shorter time of maintaining the heat source on the parts, and especially the filler materials which melt below the melting temperature of basic materials.

When using classical filler materials, there are several disadvantages:
- preparing the surfaces to be brazed. Industrial pickling is done in special Aloclene 100 or Deoxidizer baths, but the gauge of the parts is however limited by the size of the tanks;
- another disadvantage is the cost of building these tanks and the maintenance system that is imposed, on one hand, and, on the other hand, the price for the purchase of reagents [3].

The present paper does not propose the development of a new filler material used for brazing aluminum 6061 with high content of magnesium and silicon. DuraFix is newly introduced in the industrial market. We used this material in brazing refurbishment as a filler. The paper focuses on two distinct directions: highlighting the mechanical properties of DuraFix material in aluminum brazing and optimizing brazing refurbishing technology by depositing the additive onto the base material.

DuraFix is an aluminum-based brazing rod designed to braze brass, copper, aluminum and zinc based metals without any special tools or a dedicated brazing machine. This product truly shines not only because of its ease of use, but the fact that it can easily braze dissimilar metals without any problems. DuraFix is easily machined and is actually stronger than the based metal. Its use is limited to the previously mentioned materials and will not adhere to stainless or ferrous materials with the exception of galvanized steel.

The brazing process using the new DuraFix is a two-stage process: the first step is to prepare the surfaces by cleaning with a stainless steel brush and then heating the surface to a minimum of 388°C. It is important to heat the base material sufficiently to melt the filler when they come in contact. The difference between the melting point of the DuraFix alloy and that of the base material is high and there is no risk of defects due to overheating of the base material.

The difference is from the melting point at 388°C of the filler material to the melting temperature of the base material that varies from 540°C to 650°C depending on the type of alloy from T0 to T6.

The direct heating of DuraFix material should be avoided because it will break due to thermal shock.

The brazing process is very much like soldering where you heat the working pieces then touch the solder to the pieces and flow it into place. If you apply direct heat to the rod it will simply crumble from the thermal shock.

Using the new DuraFix material in brazing technology has the following advantages:
- emissions of pollutants in the atmosphere in much smaller quantities;
- the use of brazing technology without the financially expensive preparation of the surfaces to be brazed;
- the technology of preparation specific to the new filler materials is not limited by the gauge of the parts;
- higher energy efficiency than oxyacetylene welding, which involves a much lower cost of consumables due to the low melting temperature of the filler material.

2. Materials used
The materials used for the samples to be brazed with the DuraFix filler material are made of Aluminum Alloy 6061. We will use this aluminum group due to the diversity of industries where it is used and because of the relatively high concentration of magnesium and silicon which makes it difficult to apply classic brazing refurbishment.

Samples were cut using a pneumatic guillotine scissors to obtain straight edges. Dimensions are 115×22 mm.

DuraFix electrodes will be used as filler materials. They have the following advantages:
- there is no need for a system of oxygen and gas cylinders like the classic brazing technology;
- no flux material is required for the pickling operation;
- no toxic vapors are released into the atmosphere;
- has a low working temperature.

The technical specifications of DuraFix electrodes are shown in table 1 [4].
Table 1. Specification of DuraFix electrodes.

| Characteristic                        | Value          |
|--------------------------------------|----------------|
| Resistance to elongation [MPa]       | 324            |
| Compression strength [MPa]            | 411.8±514.8    |
| Shear resistance [MPa]                | 234.3          |
| Hardness Brinell [HB]                | 100            |
| Ductility                            | Good           |
| Density [kg/m³]                      | 6920           |
| Elongation for 5cm                   | 3 %            |
| Electrical conductivity [W/(m×K)]    | 100.48         |

3. Brazing technology used

It is worth mentioning that the manufacturer recommends a mechanical cleaning with a stainless steel wire brush before surface heating, but also during heating as surface preparation technology to be brazed with DuraFix electrodes. Thus, the oxides that are formed are removed.

The brazing technology consists of three distinct steps:
- heating the surfaces in contact without melting the base material. The filler material should not come into direct contact with the flame but should be brought into contact with the base material. It will flow without the help of flame, evenly covering the surfaces;
- hot surfaces brushing to fill any pores in the material and to obtain a smooth and glossy surface;
- melting a quantity of DuraFix electrode required to fill the joint. The material deposited at this stage must be alloyed with the previously deposited superficial layer without melting the base material.

4. Experimental results

It should be noted that all the pieces to be assembled are taken from the same aluminum alloy sheet 6061 and the operations were performed by the same operator. This is how human errors were removed.

The pieces were brazed in several samples presented in table 2:

Table 2. Brazed samples.

| Denotation | Specifications                                      |
|------------|---------------------------------------------------|
| D1         | Single side brazing                               |
| D2         | Side brazing on both surfaces                     |
| E1         | Overlay brazing by depositing the DuraFix electrode on one of the base materials |
| E2         | Overlay brazing by depositing the DuraFix electrode on both base materials |

The surface which is in contact with both the sample D1 and D2 and the overlapping surface of samples E1 and E2 is 25 mm in length from the 115 mm total length at which the pieces were cut.

Figure 1 shows one of the samples D1, and in figure 2 one of the samples with the symbol D2.
Figure 1. Sample D1 after brazing:
a. surface with DuraFix deposition by brazing;
b. surface on which no DuraFix material has been deposited.

Figure 2. Sample D2 after brazing – both surfaces were brazed.

Figure 3 shows one of the E1 samples and one of the samples with the E2 symbol.

Figure 3. Samples E1 and E2 after brazing.

Samples were subjected to detachment tests (exfoliation), specific to the brazing process. For this destructive test, the INSTRON 8801 universal testing machine took into consideration the following
parameters: the loading speed was 1mm / min, the tightening torque of the busses was 10% of the load applied to the specimens [5].

Figure 4a and 4b shows a sample D1 after breaking.

![Figure 4. Sample D1 after breaking.](image)

By analyzing figure 4a, it can be seen that the filler material deposited on one side of the base materials remained alloyed on it, and the breakage occurred in the gap created between the two base materials during the action of the forces.

Using a blank, figure 4b, one can notice the uneven elongation of the two parts of the base material during breakage, elongation due to the malleability of the aluminum alloy.

Destructive tests may be necessary to determine the effects of the brazing process or any subsequent heat treatment on the joint characteristics [6].

In order to observe the alloying of the DuraFix filler material on the base material, a metallographic study of the D1 sample shown in figure 5 was made. It can be seen that the joint is only made in the area of the DuraFix material deposition in zone I, the rest of the thickness of the assembly has no filler material - zone II. This phenomenon is caused by the low melting temperature of the filler material.

This is the cause of the break in sample D1.

![Figure 5. Metallographic study of sample D1: I – the area between DuraFix and aluminum, II – the area without DuraFix.](image)

Figure 6a and 6b show a sample D2 after breaking.
It can be seen that in the case of the sample D2 in which brazing was performed on both surfaces, tearing occurs in the base material, the joint remaining intact. This proves that the DuraFix electrodes brazing technology is viable and the strength of the cord obtained is higher than that of the base material.

Figure 7 shows the D2 sample after brazing with DuraFix as filler material that has been deposited on both sides of the base materials. This action improves the performance of the joint, but there may still be areas that are not filled with filler material.

By analyzing the samples E1 and E2 shown in figures 8a and 8b, it can be seen that both samples broke into the base material and not in the filler material, which also means that the DuraFix electrodes brazing process gives the joint a higher resistance than that of the base material.
Figure 9 shows the metallographic study of sample E1. It can be noticed that in the brazing process the initial sintering between DuraFix and the base material is not defective - zone I. In the final brazing there are isolated defects between DuraFix and the second base material - zone II.

![Figure 9. Metallographic study of sample E1](image)

- I – area without defects between DuraFix and aluminum,
- II – area with defects between DuraFix and aluminum.

Figure 10 shows a defect-free structure at the brazing joint between DuraFix and aluminum. This assembly is done in 4 distinct stages:
- the first stage: the placement of DuraFix material on both base materials. At this stage, there are joints without defects between the base material and the filler material.
- second stage: cooling the formed assemblies,
- third stage: bringing together the two DuraFix brazed materials in the first stage,
- fourth stage: heating the new assembly at 388°C. At this stage, strong bonding takes place in DuraFix material without defects.

![Figure 10. Metallographic study of sample E2 without defects.](image)

The results of the maximum breaking forces for the samples D1, D2, E1 and E2 are shown in table 3:

**Table 3. Maximum load force values.**

| Sample set | Force [MPa] |
|------------|-------------|
| D1         | 78          |
| D2         | 132         |
| E1         | 148         |
| E2         | 152         |
5. Conclusions
It can be noticed that reconditioning by brazing the brazing technology of aluminum alloys 6061 can be performed with remarkable results in terms of joint strength using DuraFix electrodes.

Analyzing the samples subjected to tests on sets D2, E1 and E2, breakage takes place in the base material and not in the filler material. The values obtained in these sample sets exceed the maximum tensile strength of 125 MPa of 6061 T1 aluminum used for making the samples.

The brazing refurbishing technology does not work well for side joints because the melting temperature of the DuraFix material is small and it does not fill the joint. This is also repeated when the filler material is deposited on both sides of the samples.

The optimal brazing refurbishing technology using DuraFix electrodes is to deposit them on both surfaces of the base material in the first phase. After the solidification, the pieces are brought into contact and are tangled up to the melting point of the filler materials which are joined together, thus obtaining a smooth structure without defects.

Because of the low melting temperature of the DuraFix electrode, the base material does not have a thermally and mechanically affected area as in the case of oxyacetylene flame welding or brazing.

From the point of view of the surface preparation technology to be contacted, this is very simple and inexpensive, requiring a stainless-steel wire brush, so preparation is not limited by the size of the gauge. So we do not have sources of environmental pollution as in the case of classical brazing where the removal of oxides is done with pollutants.

We can conclude that Aluminum Alloy 6061 which has a large amount of magnesium and silicon is hard to recondition with classical brazing technologies. The use of DuraFix filler material has a very good mechanical performance and, at microstructural level, does not show any defects.

6. References
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