Studies and research on the microstructure of brazed aluminum alloys in the repair process

A Dimitescu¹, Gh Amza¹, D F Nîţoi¹, C Gh Amza¹ and Z Apostolescu¹
¹Univ. Politehnica of Bucharest, Splaiul Independenei no. 313, sect 6. Bucharest, Romania
E-mail: andrei_dimitrescu@yahoo.com

Abstract. In aeronautical industry, in recent years, brazing joints got a growing spread. Therefore, it is necessary a detailed study on the microstructure of the assembly base and filler material brazed in conditions of reconditioning operation [1]. The methods of destructive examination are not associated with any particular type of test piece but lay down the general principles of the types of testing described. It is emphasized that a satisfactory examination method can only be developed and used after taking into account all the relevant factors regarding the equipment to be used and the characteristics of the test pieces being examined. [1, 2]. Brazing joints are most often systematically designed to be resistant to shearing, and the size of the joint influences the shear strength more than the tensile strength. Studies and researches on the microstructure may be necessary to determine the effects of brazing process or of any subsequent heat treatment on the characteristics of the joint.

1. Introduction
The majority of brazed joints are designed was the component parts in a lap configuration. Because of the capillary nature of a brazed joint, most imperfections will be contained within the joint region, with the principal axes parallel to the plane of the joint [3].

The experiments to be carried out must comply with prescribed guidelines in technology and also carried out on the same types of material. All samples will be submitted to nondestructive testing such as penetrated testing, ultrasonic testing for aluminum alloys and a series of destructive tests such as tensile test, fatigue tests or metallographic structure examination.

According to SR EN 12797 [6] “The quality of brazed joints and fundamental information about parent material/filler metal reactions, diffusion characteristics and other aspects can be investigated by macro- and micro-examination of the brazed joint”. Consideration should be given to the manufacture of test pieces specifically intended to assist metallographic examination.

2. Materials and methods
For this study, it was used as base material 3L59 aluminum alloy and as filler material L103 aluminum alloy.

To perform the microstructure examination following steps should be followed:
-Cutting, performed on an automatic cutting machine with speed 3000rot / min, feed 5mm / min, cooling with cold water figure 1.
- Operation of embedding specimens figure 2 using a temperature of 423 ÷ 443K, pressure 4 atm for 8 ÷ 10min.

- Polishing was performed figure 3 using the following parameters of the technological process: grinding with water, 20N force, speed 300rpm, grinding time 3min, discs grain 400/600/800/1000/1200/2500, grinding with alumina cloth Topol 2 0.7μm suspended in water, 20N force, speed 50rpm, grinding time 6min, grinding with alumina cloth 0.25μm Topol 3 suspension in water, 20N force, speed 50rpm, grinding time 6min.

- The chemical etching was carried out with the reagents 3, 2, 6, whose chemical composition is as indicated in Table 1.

| Reagent | Composition | Application data |
|---------|-------------|------------------|
| 2       | 1g NaOH, 100ml water | - Buffering 10 seconds to highlight the overall structure.  
- Immersion 10 ÷ 20 seconds, wash in water for 10 min for film formation that varies with grain orientation. |
3 | 2ml HF  
   3ml HCl  
   5ml HNO₃  
   150ml water | - Immersion 10÷20 seconds. Washing in warm water stream.  
   Highlighting general structure.  
   - Dilution with 4 portions water. Staining constituents.  

6 | 25ml HNO₃  
   75ml water | - Immersion 40seconds at 343K. Rinse with cold water.  

- Heating the specimens at 343K and introducing in heated reagent:

![Heat treatment furnace](image)

**Figure 4.** Heat treatment furnace.

- Registration of the experimental specimens microstructures was performed using the OLYMPUS GX 51 figure 5 inverted metallurgical microscope with the following characteristics: UIS 2 optical system, magnification: 50X - 1000X, specialized image analysis software – AnalySIS, digital camera DP25- 2-5.

![Inverted metallurgical microscope Olympus GX 51.](image)

**Figure 5.** Inverted metallurgical microscope Olympus GX 51.
Further analyzed samples belong to representative brazing technologies brazing and come from samples brazed in work conditions specific for aerospace fuselages refurbishment [7].

– First technological process for surface preparation:
  - Degrease surface with acetone;
  - Pickling in DEOXIDIZER 30min;
  - Wash in warm water bath;
  - Wash in cold water bath;
  - Clarifying 5 min in nitric acid;
  - Wash in warm water bath;
  - Wash in cold water bath;

– Second technological process for surface preparation:
  - Degrease surface with acetone;
  - Chemical alkaline degreasing (soda) 30min;
  - Wash in warm water bath;
  - Wash in cold water bath;
  - Pickling in ALOCLENE 100 12min;
  - Wash in warm water bath;
  - Wash in cold water bath;
  - Clarifying in nitric acid 5min;
  - Wash in warm water bath;
  - Wash in cold water bath.

3. Experimental researches

After brazing through technology 49 (A₁B₂C₂D₃) figure 6: degreasing with acetone, filler material deposition on one surface of the base material, high purity acetylene 2.6, reducing flame (neutral), we see again minor damages at the first sintering and at the final brazing appears a continuous damage and an surface impurity migration in the brazed layer.

![Figure 6. Technology 49, specimen 43.](image)
When using technology 50 (A:B:C:D) figure 7: the technological process I for surface preparation, deposition of filler on one surface of the base material, high purity acetylene 2.6, reducing flame (neutral), can be observed isolated defects at the interface between the base material and the sintered layer, but comparing with the witness specimen, there are multiple inclusions at the interface between the second material and the sintered layer.

![Figure 7. Technology 50, specimen 103.](image)

When using technology 51 (A:B:C:D) figure 8: technological process II for surface preparation, deposition of filler on one surface of the base material, high purity acetylene 2.6, reducing flame (neutral), the initially sintered bonding doesn’t show any defects and on the final brazing isolated there can be seen isolated defects in the interface between the filler material and the base material, and that certain impurities migrated to the filler material.

![Figure 8. Technology 51, specimen 108.](image)
When using technology 52 (A\textsubscript{1}B\textsubscript{1}C\textsubscript{2}D\textsubscript{3}) figure 9: degreasing with acetone, deposition of filler material on both surfaces of the base material, high purity acetylene 2.6, reducing flame (neutral), major defects are found at both interfaces and the appearance of major impurity in the filler material due to oxides migration caused by improper cleaning of surfaces.

![Figure 9. Technology 52, specimen 12.](image)

When using technology 53 (A\textsubscript{3}B\textsubscript{3}C\textsubscript{2}D\textsubscript{3}) figure 10: the technological process I for surface preparation, deposition of filler material on both surfaces of the base material, high purity acetylene 2.6, reducing flame (neutral), the brazing shows insulated defects at interfaces due to a not complete removal of the existing oxide layer on the surface of the base material.

![Figure 10. Technology 53, specimen 24.](image)
When using technology 54 (A\(\text{I}\)B\(\text{II}\)C\(\text{III}\)D\(\text{IV}\)) figure 11: technological process II for surface preparation, deposition of filler material on both surfaces of the base material, high purity acetylene 2.6, reducing flame (neutral), the assembly shows normal brazing aspects without defects on the interfaces or oxides migration to the filler material interior.

![Image](image.png)

**Figure 11.** Technology 54, specimen 29.

4. Conclusion

To obtain the normal brazing structure without defects on the interfaces or oxides migration to the filler material interior, it is recommended use the second technical process for surfaces preparation. This technology was used because, in this situation, oxidation of Al alloy is not possible till the brazing process starts.

The second conclusion recommends a filler material using because filler material deposition is done on both surfaces of the base material. In the case of tensile testing, material failure occurs only in the filler material.

A very important criterion for a homogenous structure is using high purity spectral acetylene 2.6 that means a short heating time and impossible oxidation process. Using a reducing flame (neutral) implies a sufficient acetylene quantity that means a high calorific power comparing with the other two flame type.

5. References

[1] Pablo de Greife 2006 *Handbook of Reparations*, Oxford University Press, pp 68-90, USA.
[2] Minford J D 1993 *Handbook of Aluminium Bonding Technology and Data* (New York, Ed. Marcel Dekker Inc.), pp. 56.
[3] American Welding Society *Brazing Handbook 5th Edition* 2007 pp 23-27
[4] Dimitrescu A 2013 *The Influence of Brazing Temperature on the Metallographic Microstructure of the Bonded Weld*, Constantin Brancusi Publishing House, pp 103-108, Tg. Jiu.
[5] Dimitrescu A 2013 *The Distribution of Filler Material on Base Metals During Brazing of Aluminum Alloys*, Constantin Brancusi Publishing House, pp 517-522, Tg. Jiu.
[6] SR EN 12797:2002 *Încercări distructive ale îmbinărilor lipite tare*, ASRO Publishing House, Bucharest.
[7] Dimitrescu A, Nițoi D F, Dobrotă D, Apostolescu Z. 2015 *Researches and studies regarding brazed aluminium alloys microstructure used in aeronautic industry*, Croatian Metallurgical Society, vol.54/2, pp 383-386.