Brown band characteristics of aluminum cladding alloys

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Abstract. Clad materials are a variant of the typical composites, which consist of two or more materials joined on their interface surfaces. Clad materials as metallic composite materials are developed for the needs of user because the single metal often cannot satisfy it application conditions. That is, the advantage of clad materials is that the combination of different properties of materials can satisfy both the need of good mechanical properties and the demand of users such as industrial consumer. The purpose of this study is to study structural aspects in aluminium 3003 clad material with 4343 alloy, after different cladding time. Generally, Al 3003 material is Al−Mn alloy which has superior ductility, but the strength and hardness are low. Aluminium series 4xxx material is Al−Si alloy with high strength and hardness, but low ductility. In our paper we determine the grain sizes of the coated aluminium alloys, before and after cladding, and also the corrosion potentials of these aluminium cladding alloys.

1. Introduction
Aluminium is the most used material for different applications such as: the automotive field, especially for heat exchangers because it offers many advantages such as production cost, plasticity, low weight, good corrosion resistance and easy processing [1,2].

The heat exchanger industry is subject to continued pressure from the automotive industry to produce as low, light, efficient and inexpensive heat exchangers. As the thickness of the material used decreases, materials are increasingly sensitive to pitting corrosion. The structure of a shifter can be protected using a specific anticorrosive design, such as the use of high Zn material for fins that are part of the exchangers.

Increased corrosion protection can be achieved by introducing long life alloys. These are so produced so that at the surface of the material we have a much lower corrosion potential than the basic alloy [3-5].

In order to obtain such a gradient of corrosion potential, it is necessary to keep the manganese content in the solid solution as follows: maintaining the silicon content at the lowest level in the base alloy; the material is not homogenized; preheating at a lower temperature for hot rolling; intermediate treatments should be avoided and, if necessary, they should be done at a lower temperature.

Also, the copper content has a very important role in improving the mechanical post-brazing properties and because high content leads to an increase in corrosion potential.

Thus, through careful control of the chemical composition and processing conditions, a material with a lower corrosion potential on the surface of the centre can be produced, with a much higher corrosion resistance.
2. Materials and experimental procedure

The elemental composition of the investigated samples was determined using an ARL sputter optical emission spectrometer. Table 1 shows the chemical compositions for the investigated samples.

| Alloy | Chemical Composition, %wt. |
|-------|-----------------------------|
| Si    | Fe  | Cu  | Mg  | Mn  | Zr  | Al  |
| 3003  | 0.2 | 0.53 | 0.075 | 0.021 | 1.15 | 0.01 | Balance |
| 4343  | 10.37 | 0.54 | 0.006 | 1.25 | 0.06 | 0.01 | Balance |
| Recommended 3003 | 0.4-0.6 | <0.5 | 0.6-0.8 | <0.02 | 1.2-1.5 | <0.01 | Balance |
| Recommended 4343 | 4.5-6 | <0.8 | <0.3 | 0.05 | 0.05 | <0.01 | Balance |

The experimental samples were obtained within the SC ALRO SA company following the milling, plating, preheating, hot rolling, cold rolling, heat treatment stabilization, straightening, cutting or fastening process. The experimental samples were made of alloy 3003 plated alloys 4343, subjected to the above-mentioned technological processes.

The two metals, both the base plate and the plate, are prepared to be welded with a longitudinal cord on one of the ends of the sleeve in the direction of rolling, and on the other end the plate platen the area. Then secure with steel strips to avoid loosening the base plate at the time of insertion into the deep furnace. After the milling and cladding operation, the billets are placed in the preheating furnaces (fixed furnace furnaces) for lamination. The working temperature or theme to which the jellies are preheated depends on the nature of the alloy of origin. In the case of plated alloys, the theme is 20-40° C lower than the melting temperature. From the metal obtained from the above production flow, samples of EN-AW 3003 alloys were taken with EN-AW 4004 alloy; EN-AW 4045; EN-AW 4343; EN-AW 1150, which have undergone a composite, morphological and mechanical investigation.

Before performing the microstructural analysis and determining the degree of contamination, the samples were prepared metallographically. The metallographic preparation of the samples was carried out following the following operations: cutting, embossing, grinding, and polishing, in order to research the structure of the material by optical and electronic microscopy. Optical microscopy images were acquired using an Olympus BX60M metallographic microscope with the KP-M1 camera.

3. Results and discussions

Knowing the structure of the material is essential in the evaluation of aluminum and aluminum alloys. The macroscopic examination highlights the inhomogeneities in the analyzed material, its compactness and the breakage mode. Depending on the shape of the mold, the surface analyzed provides information on the casting techniques used and the casting quality. Surface examination often reveals casting defects such as: macroporosities, shrinkage, oxides, macro-inclusions, grain size differences, cracks, cracks, etc. Such an analysis makes it possible to identify defects, helping to eliminate the causes and to improve the properties of the material. The metallographic analysis was performed on samples of 3003 plated with 4343 plated samples. The total thickness of the cladding layer for all the samples were 8.5%±1.5%, as is recommended by the specification.

The analysis of the images in Figure 1 (on longitudinal cross section) and Figure 2 (on transversal cross section) indicates that the analyzed samples showed a uniform distribution of the MnAl₆ and α (AlMnSi) phases. The precipitates are fine, spheroidal shape and uniformly distributed. The MnAl₆ precipitate is generally fine and uniform distributed on the cross section of the sample.

For the determination of the grain size in the experimental samples, in both states: before (Figure 3) and after the cladding (Figure 4), the sample were electrolytic attacked in according with Behr specification. Alloy 3003 have a structure with elongated grains, wrought formed in two directions,
having diffused boundaries grains. One may remark that by cladding of the aluminum alloy, the average grain size increases both at longitudinal cross section (from 45µm to 50 µm), or at transversal cross section (from 38 µm to 39 µm).

![Image](image1.png)

**Figure 1.** Optical microscopy for 3003 aluminum alloy coated with 4343 aluminum alloy (on longitudinal cross section): a- 100x, b- 500x.

![Image](image2.png)

**Figure 2.** Optical microscopy for 3003 aluminum alloy coated with 4343 aluminum alloy (on transversal cross section): a- 100x, b- 500x.

In order to identify the "brown band" area, there are applied the heat treatments parameters illustrated in Table 2.

| Temperature –Time regime | Heating phase | Brazing phase | Cooling phase |
|--------------------------|--------------|---------------|---------------|
| RT-300°C                 | 300-577°C    | T<sub>max</sub> 577°C | T<sub>max</sub>-RT |
| 10<sup>±2</sup> min.     | 9<sup>±2</sup> min. | 6<sup>±2</sup> min. | 600<sup>±5</sup> °C | 12<sup>±2</sup> min. |

The dimension of the brown band of the samples were about 27.37µm up to 49.25 µm, with an average size of 38.43 µm. This size is corresponding to approximatively 13% from the total thickness of the sheet. Also, the analyzed samples revealed an elongated grain texture with "pancake" diffuse grain boundaries which induced mechanical properties improved to a standard 3003 alloy. This type of grain gives the material a mechanical strength and tear strength with 20 MPa units higher than the
standard material. It also gives the structure a uniform distribution and good protection against intergranular corrosion.

**Figure 3.** Grain size measurement 3003/4343 clad alloys (M=200X) before cladding: a) longitudinal cross section; b) transversal cross section.

**Figure 4.** Grain size measurement 3003/4343 clad alloys (M=200X) after cladding: a) longitudinal cross section; b) transversal cross section.
Figure 5. Optical microscopy for brown band of the 3003 aluminum alloy coated with 4343 aluminum alloy: a), b), c), longitudinal cross section, d) 100x, e) 200x, f) 500x.

Table 3. Corrosion potential of the cladding aluminum alloys.

| No. | Sample          | Thickness, (mm) | E corr, average, (mV) | E corr min. (mV) | E corr max. (mV) |
|-----|-----------------|-----------------|-----------------------|------------------|------------------|
| 1.  | Before cladding | 2.5             | -715.64               | -721.40          | -709.06          |
| 2.  | After cladding  | 2.5             | -683.50               | -684.36          | -682.67          |

The corrosion potential of the samples, before and after cladding is illustrated in table 3. One may remark the increasing of the potential from -7.9.06mV to -682.67, with means a little modification of the corrosion resistance of the sheet. The results are in accordance with [6,7].

4. Conclusions

In this paper, samples from 3003 aluminum alloy cladded with 4343 aluminum alloy were investigated, revealing the following conclusions:

The thickness of the cladding aluminum alloy 3003/4343, with 0.3 mms thick, ranged from 8.5% ± 1.5%.

Microstructural analysis of the samples prepared from 0.3 mm long, long-life, longitudinal and cross-sectional sheet samples reveals a uniform distribution of the MnAl_6 and α (AlMnSi) phases, most of the MnAl_6 and αAlMnSi phases are spherical, distributed relatively uniformly. The precipitate (Mn) is finely and uniformly distributed throughout the analyzed sample section.

The average grain size increases both at the longitudinal cross section (from 45 μm to 50 μm), or at the transversal cross section (from 38 μm to 39 μm). Alloy 3003 has a structure with elongated grains, wrought in two directions, with diffused boundaries grains.
The brown band size for the 3003 aluminum alloy cladded with 4343 aluminum alloy, according to the Behr specification and electrolytic attack, ranged from 27.37 μm to 49.25 μm, with an average of 17 measurements of 38.43 μm, which represents 12.81% of the total sheet thickness of 0.3mm.

The corrosion potential before cladding is -709.06mV and after cladding is slightly increase to -682.67. This increase may assure a good corrosion resistance of the cladding layer.

5. References
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