Corrosion Resistance Evaluation and Electrochemical Characterization of an Aluminium Brazing Sheet

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Introduction

Aluminium brazing sheet is a sandwich material made out of two aluminium alloys (AA4xxx/AA3xxx) and is widely used in automotive heat exchangers. Alloy development for down-gauged heat exchangers focuses towards a higher strength in order to maintain the same overall mechanical strength of the heat exchanger, and at the same time keeping the other material properties at least at the same level. One of these properties is the corrosion resistance. The present study is part of a research work devoted to improving the corrosion resistance of a modified aluminium brazing sheet. Using a combined theoretical modelling and experimental characterisation approach, the study reveals the microstructure of the material before and after a brazing process. JmatPro software based on thermodynamic calculations was applied to predict the type and percentage of the existing phases. By combining the theoretical calculations, experimental observations and literature, a detailed particle identification was performed. The study was further continued by combining localized electrochemical cell technique and glow discharge optical spectroscopy (GDOES) for electrochemical depth profiling analysis. Applying electrochemical criteria i.e. breakdown potential, corrosion potential, cathodic and anodic reactivities and tracking their changes as a function of depth, combined with a through depth microstructural analysis, the current study aims to analyze the evolution of electrochemical responses through the brazed material and correlate them to the microstructural features developed due to the brazing process and the resulting corrosion resistance in a modified aluminium brazing sheet.

Experimental

A full microstructural characterization of the material before and after brazing was achieved by optical microscopy (OM), scanning electron microscopy (SEM) and energy dispersive x-ray spectroscopy (EDX). Performing potentiodynamic polarization the electrochemical nature and activity of the overall microstructure were identified. A thorough in-depth electrochemical characterization of the aluminium brazing sheet was obtained by micro-electrochemical cell measurements. Polarization curves in SWAAT solution (1 wt% NaCl solution at pH 2.8 [1]) were obtained at different depths from the surface using controlled sputtering in a glow discharge optical emission spectrometer (GDOES) for sample preparation. The argon pressure was kept at 650 Pa and 40 W power was applied. The calibration of depth versus etching time for the GDOES craters was carried out using a Wyko Vertical Scanning Interferometry (VSI) surface profiler. All the electrochemical experiments were performed with a Dualscope EC localized electrochemical cell with a 1 mm diameter pipette tip. The system involves the use of an electrochemical head consisting of necessary reference and counter electrodes, open to a reservoir cavity to which the plastic tip is attached.
to make the contact with the working electrode similar to glass tip in the case of high resolution micro-electrochemical systems.

Results

Optical images of the material under investigation both before and after brazing are shown in Figure 1. The image of the material before brazing shows the clad layer with a brighter contrast. Elongated coarse particles with a dark grey contrast in the clad layer are Si particles. EDX analysis revealed also the presence of some small additional precipitates containing Al, Fe, Cu, and Si. In the core material a wider variety of particles exists with different sizes and chemical compositions [2].

The result of particle identification and distribution analysis for the material before and after brazing is summarized in Figure 2. The type and distribution of the particles for the non-brazed and brazed material is demonstrated in this figure.

The breakdown potential and OCP profiles through the structure of the material are summarized and presented in Figure 3. Scattering of the results are presented through error bars in this figure. The breakdown potential was measured at $10^{-2}$ mA.cm$^{-2}$ current density. The OCP values represent the potential of the surfaces at the start of polarization measurements after 10 minutes of stabilizing.

Figure 1. Optical images of the brazing sheet structure before (a) and after brazing (b).

Figure 2. Particle identification on Fe spectrom for non-brazed and brazed material [2].
Conclusion

Besides silicon (which is the most dominant particle), $\beta$-AlFeSi and $\alpha$-Al(Fe–Mn)Si are the other existing primary particles in the non-brazed clad material. $\alpha$-Al(Fe–Mn)Si and Al$_2$Cu were found to be the primary dominant particles that exist in the core structure. Regarding the size, two types of particles are distinguished. One is the particles which are larger than 1–2 µm and their sizes can reach up to 20 µm. These are mainly $\alpha$-Al(Fe–Mn)Si particles. The second group contains particles with sizes below 1 µm. These are mainly Al$_2$Cu and a-Al(Fe–Mn)Si particles. The a-Al(Fe–Mn)Si particles are mainly accumulated at the surface, in the diffusion zone and the core material.

Accumulation of copper on the surface of the re-solidified clad material, the reduction of the copper content of the particles and the increase of silicon concentration in the diffusion zone were found to be the major changes that occurred during the brazing process.

The anodic and cathodic reactivity of the top surface areas were significantly higher than that of the bulk, thus indicating these areas to be more susceptible to localized attack. The results highlight the importance of the top 10 microns depth in controlling the corrosion performance of the aluminium brazing sheet.

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References