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MEASUREMENT METHOD FOR DETERMINING THE RESIDUAL FLUX DEPOSITS IN A HEAT EXCHANGER FROM A CONTROLLED ATMOSPHERE BRAZING LINE

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ABSTRACT. The brazing technology of aluminum alloys having the highest efficiency, used at manufacturing heat exchangers, is the controlled atmosphere brazing with the NOCOLOK flux. The major inconvenience of the process is the residual flux retained on the internal surfaces of the heat exchanger, which in certain quantities may react with the cooling agents leading to gels that may compromise the functionality of the heat exchangers. The present paper presents a method of measuring the residual flux quantity based on the repeated experimentation and measurements taken on the horizontal, and vertical brazing manufacturing lines.

Keywords: *brazing technology, heat exchanger, residual flux, Nocolok, experimental, method.*

INTRODUCTION

The new applications for the internal combustion engines with their high performances require being equipped with heat exchangers that function at high thermal and structural load. The most efficient way to conform the heat exchangers to these new specifications is brazing then using the controlled atmosphere process using Nocolok fluxes.

Using the controlled atmosphere brazing process present at RAAL company [1] the following steps have to be followed: firstly the surfaces of the constructing parts have to be plated with the filler material and free of

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impurities in order to achieve the wettability condition; the parts have to be assembled such that the contact between them has to be fixed and discontinuous making capillary spaces at the junctions, the flux has to be present at least on one of the plated surfaces, as showed in Figure 1[2][3], and lastly but not the least the brazing atmosphere has to be composed from an inert gas such as N_2 with O_2 content lower than 100 ppm.[4]

After the preparing step of removing any traces of humidity the assembled structure is heated in ovens with inert atmosphere following a preset profile of temperature: at 565 °C the melted flux deoxidize the surfaces and protect them against the reoxidation, starting with 577 °C the filler material will melt and under the capillarity effect will flow in the spaces between joints, after keeping the structure at the brazing temperature for 2-3 minutes the fast cooling phase begins with the solidification of the filler material and followed by the solidification of the flux melt resulting in residual flux.

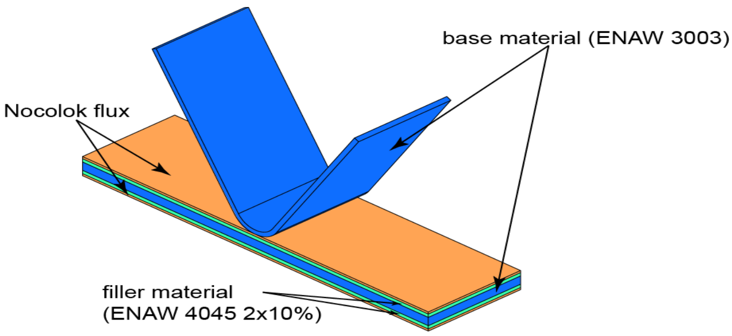

Figure 1. Brazing components

The residual flux can react with the warm cooling agent present in the heat exchanger during exploitation, leading to creation of gels which may compromise the heat exchanger operation. This residual flux imposes the introduction of a new step in heat exchanger manufacturing process, namely the internal cleaning of the heat exchanger. Measuring the residual flux with the filter paper is a long process that increases the manufacturing time and the price of the heat exchanger, and is not very accurate because a part of the residual flux is dissolved in the cleaning fluid.

In this paper we will present an alternative method of determining the residual flux by measuring the conductivity of the cleaning fluid – dematerialized water -and through the K^+ concentration we can determine the amount of residual flux present in the fluid this method presents the advantage that it can be made during the washing process and reduce the time for this process.

RESULTS AND DISCUSSION

Multiple probes where sampled from the same heat exchanger as seen in Figure 2 having different K^+ concentration, measured according to [5][6] for which the conductivity was measured according to [7] with an uncertainty of 2.8% @ 95% confidence level in range of 100÷1200 [µS/cm].

Knowing that the stoichiometric coefficient of the residual's flux, $KaIF_4$, K_3AIF_6, components, has value of 3.42 we can determine the residual flux quantity dissolved in the solution in [mg/l]. The Figure 3plots the experimental data obtained.

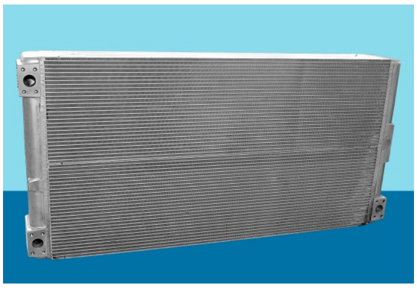

Figure 2. Heat exchanger used in the study

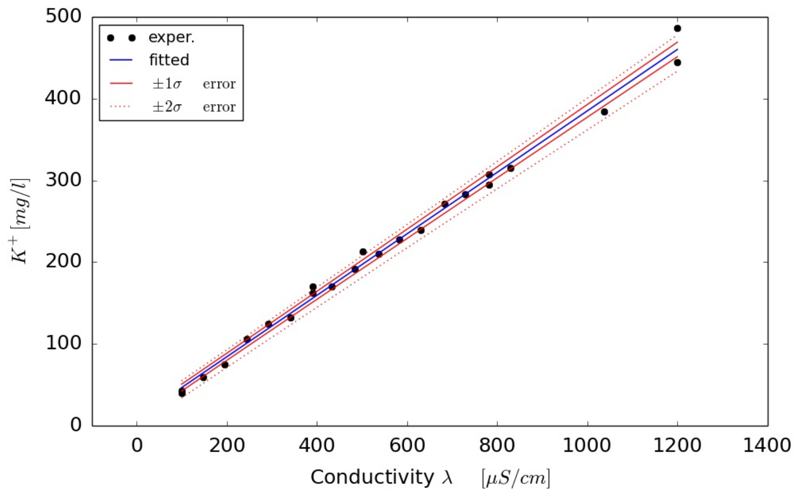

Figure 3. K^+ dependence of conductivity

The experimental data where fitted using a linear function:

$$K^+(\lambda) = a \cdot \lambda + b \tag{1}$$

resulting in the coefficients a and b having the values and the uncertainties[8] presented in Table1:

Table 1. Coefficient values

coeficient	value	1·σ	2·σ
a	0.376	0.007	0.014
b	9.4	4.1	8.2

With the final function being:

$$K^{+}(\lambda) = (0.276 \pm 0.014) \cdot \lambda + (9.4 \pm 8.2) \; @ \; 2 \cdot \sigma \quad (2)$$

The fit has a reduced χ^2 of 0.0033 which tells us that the linear model chosen is a good approximation of the K^+ dependence on conductivity. The fit with the uncertainty at 1·σ and 2·σ is also presented in Figure 3.

Because of the large domain for which the fit was created care should be taken in using it below a conductivity of 200 [μS/cm] where the relative uncertainly of the function rise exponentially, as seen in the Figure 4.

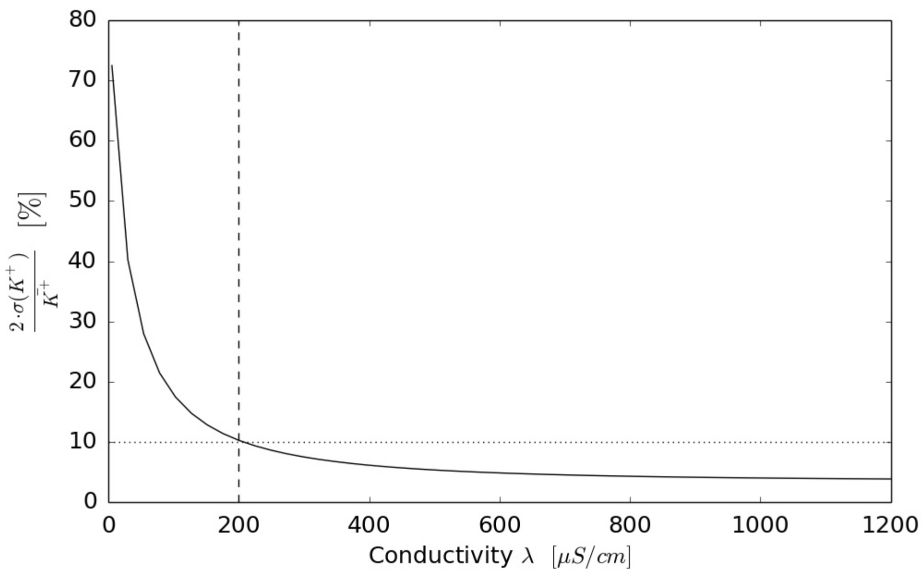

Figure 4. Relative error of the fitted function

The 10 [%] uncertainty at 200 [μS/cm] is reasonable for the residual flux weight estimation, and as can be seen from the Figure 4 the uncertainty drops till a 3.85 [%] at 1200 [μS/cm].

CONCLUSIONS

In real life applications, the residual flux present in heat exchanges after the brazing process, give a conductivity in the rage of 250 to 1500 [μS/cm], and knowing that the uncertainty of the K^+ concentration is below 10% in the required range we can conclude that the procedure using the conductivity as a basis for measure the residual flux quantity present in the heat exchangers is a good one.

A second advantage of this method is that it can be easily implemented on the assembly line of the heat exchangers without the need to invest in expensive equipment

With this method implemented the next step will be implementing the complete removal of the residual flux without affecting the support material.

EXPERIMENTAL SECTION

The heat exchanger's constructive parts are mechanically assembled and prior to loading it in the brazing oven the flux is applied by means of immersion in an immersion bath having the composition of 15.5% Nocolok flux, 0.2% Antarox, and 84.3% demineralized water achieving the 5 g/m^2 flux loading.

After the brazing process has finished the heat exchanger's internal volume was washed with demineralized water at 95°C and a constant recirculation speed using a quantity of 240 l of water. The conductivity of the washing solution is monitored and measurements where took at a constant time interval of 5 minutes until the temperature became constant as in Figure 5.

After a period of approximately 80 min the conductivity of the water begins to have a constant value, which signifies that all the residual flux is contained in the washing fluid.

We proceed further at doing the leaching test that consists in filling a heat exchanger sample with distilled water and inserting it in the thermostatic chamber which is kept at 95 °C for 24 hours.

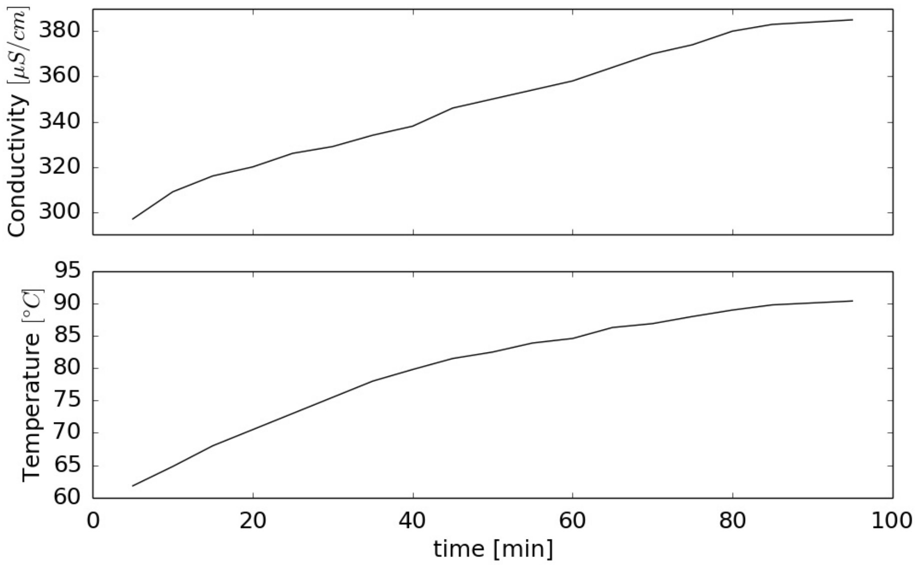

Figure 5. Temperature versus time

After this period the sample is drained of the water content which on which the conductivity and the concentration of the Potassium cations are measured. The initial and final data for this test are showed in the table below:

Table 2. Leaching test data

Quantity	Value	Unit
demineralized water vlume	20	[liter]
time	24	[hours]
mean temperature/test	90	[°C]
conductivity at start	5	[μS/cm]
conductivity at end	460	[μS/cm]

This process is repeated for all the measured heat exchangers and for which the data is showed in this study.

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