MECHANICAL, ELECTRICAL AND STRUCTURAL CHARACTERIZATION OF EC ALUMINUM MODIFIED WITH DIFFERENT FE CONTENTS

Washington Luis Reis Santos, wluis12@gmail.com
Ulysses Rodrigues dos Prazeres, ulysses.rodrigues@globo.com
José Maria do Vale Quaresma, quaresma.fem@unicamp.br
Rodrigo Kenichi Sato Soares, rodrigo-kss@hotmail.com
Emmanuelle Sá Freitas, mmanufreitas@gmail.com
GPEMAT/FEM/ITEC/Federal University of Para

Alexandre Luis Amarante Mesquita, alexmesq@ufpa.br
GVA/FEM/ITEC/ Federal University of Para

Abstract. *This work has the objective of investigate the iron element effects about the Al-EC (Aluminum Eletroconductor) mechanical, electrical and structural characterization modified with 0,05% Cu. This material is intended to electrical energy transmission and distribution. For determination of these characterists, a test specimen through the solidification "U" mold was produced and then submitted to rolling and drawing processes. After that, the specimens were divided in two lots for heat treatment, which analyzes the heat resistance properties of material to realize the electrical and tensile conductivity test respectively. The obtained fractures from tensile test were analyzed with electronic scanning microscopy with purpose of verifying the influence of different Fe concentrations in fracture appearance. The test results permitted a more detailed evaluation about the iron element effect in obtained conductors profile and its influence about the fractures topography.*

Keywords*: Heat Treatment, Mechanical Properties, Electrical Properties.*

INTRODUCTION

Actually the selection criteria of cables types for utilizing on transmission and distribution of wires is a science which has been studied for many industries and researchers. A correct choice of the conductor cable, based in its operational performance and particularly in its transmission capacity, turns increasingly in a factor of competitiveness and quality. With prevision of a considerable increase on demand of electrical energy in the next years, and with the present reduction of investments on expansion and constructions of new wires, it is necessary to explore better the existent wires. [Nascimento 1999].

With new tendencies on electrical sector, all business, since basic generation and transmission until sub-transmission and distribution, has necessity to provide an increase on earnings and in transmission, where the costs of new wires are very high. It is essential to develop techniques which allow increasing the transport capacity in low cost, contemplating the recapacitation of the existent installations.

In this context, the group of research and engineering of materials (GPEMAT) developed a study which has as base the development of new electrical conductors to repotentialize transmission wires manufactured from materials which permit regimes of operation in continuous form superior than the Al 1350.

The present study objectives to develop an analysis on effect of iron element on some mechanical, electrical and physical characteristics for Al-EC (electro conductor aluminum or Al-1350) material destined to transmission and distribution of electrical energy. This research will enable a vision of how this element interferes on properties of the studied materials, looking for optimizing the results for the chemical compositions studied.

MATERIALS AND METHODS

The alloys were obtained by directly casting from Al-EC (electro conductor aluminum or Al-1350) and were poured in an ingot mold in "U" shape for being possible to remove cylindrical test specimens as observed on figure below.

Figure 1 – Split mold in "U" shape

Plastic deformation was realized by the aid of a rolling mill enabling the obtainment of wires in 4 mm diameter followed by drawing, with reductions of Ø=3.6mm, 3.18mm e 2.89mm, as shown on following figures.

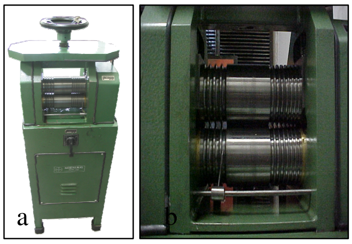

Figure 2 – Electrical rolling mill utilized.

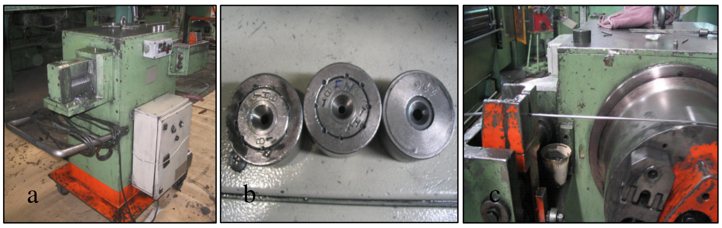

Figure 3 – Scheme showing the obtainment of the utilized profile: (a) Motorized pointer with puller of wires for nonferrous metals; (b) diamond wire gages utilized and (c) drawing moment.

For checking electrical properties was used as reference NBR-6814, where is described the measurement method of electric resistivity of a conductor in continuous current, for wires and electrical cables. For realizing the test was utilized a MEGABRÁS kelvin bridge model MPK-2000, illustrated on Figure 4.

Figure 4 – Photos of a set of components of kelvin bridge utilized for measuring the electric resistivity.

The obtained profiles on wires shape in 2.90 mm diameter were submitted to tensile test according to NBR-6810 norm. In this characterization step the obtained profiles, already on wires shape with desired diameter were submitted to tensile tests, realized in KRATOS traction machine model IKCL1-USB, illustrated on Figure 5, coupled into a micro computer with data acquisition system.

Figure 5 – (a) KRATOS test machine, model IKCL1-USB and (b) data acquisition system.

Test thermal nature is realized according to specification realized by COPEL (Companhia Paranaense de Energia), which describes that electrical conductors characterized as heat-resistant do not have to show a higher loss than 10% of its tensile strength when submitted to 230°C temperature for an hour.

The heat treatment demanded were executed in ovens of stove type with NEVONE brand, model NV-1.3, as illustrated on Figure 6.

Figure 6 – NEVONE stove, model NV-1.3.

RESULTS AND DISCUSSIONS

The following graphs shown were treated, superior and inferior limits, according to geometric average of medium deviation and are referred to the pouring realized (Al EC-0.05% Cu) modified with [0.14; 0.22; 0.32]% Fe.

Since the generated data in this study, we can evidence that with an increase on iron content in the alloy was obtained an increase on mechanical resistance as observed on figure g, and in the left side we can visualize an increase on surface of the fracture for 0.14 and 0.32 % Fe content.

For lower quantities of solute in alloy was possible to observe smaller micro cavities and deeper when compared with 0.32% iron content. This fact can be related to few places of nucleation and much spaced which tends to generate micro cavities as fracture handbook suggests.

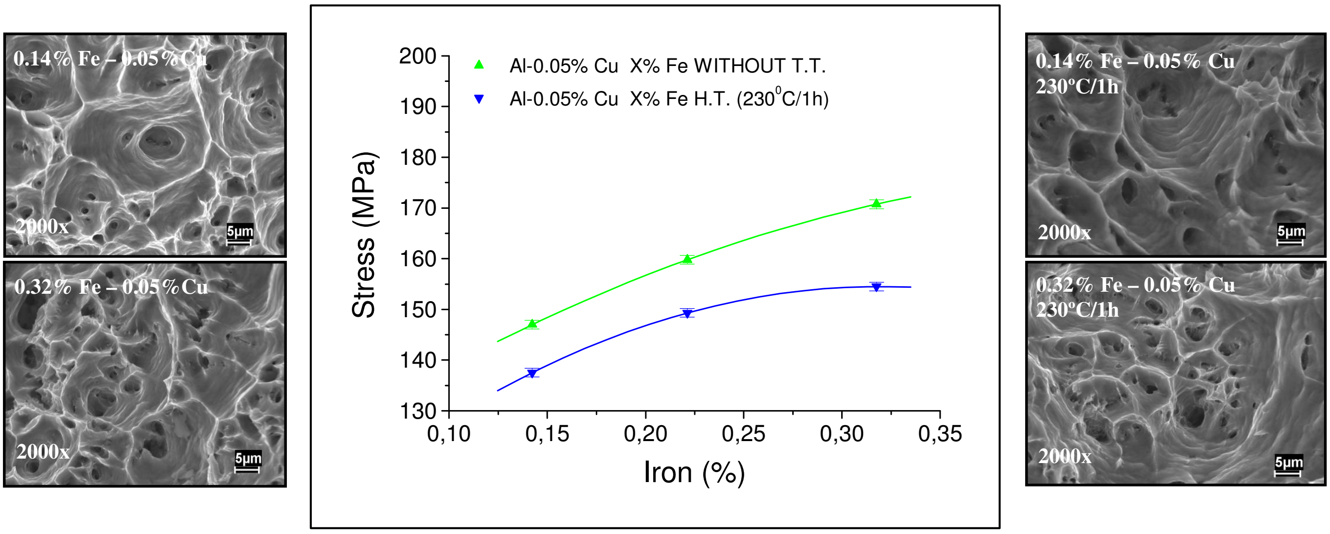

Figure 7 – Correlation between aspect of the fracture and tensile strength for heat-resistant aluminum alloys, modified with iron, after and before heat treatment.

When is compared the temperature effect, for heat-resistant test of the material, we noticed that the iron has strong influence in relation to this loss response on tensile strength, evidencing that higher iron content supports lower loss as can be seen on graphic of the Figure 7.

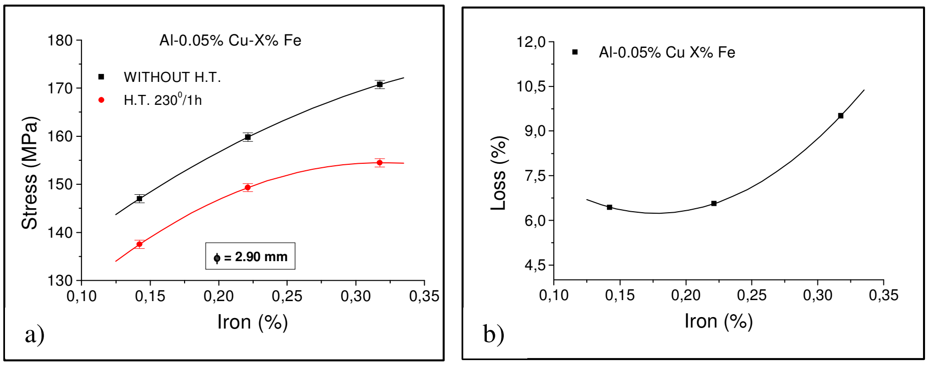

Figure 8 – Comparative of heat treatment effect on tensile strength for aluminum alloys, modified with iron contents and heat treated to 230°C/1h: (a) alloy modified with iron and (b) percentage loss for the submitted alloys to heat-resistant test.

For electrical conductivity test that was measured in IACS, was observed that higher the iron content lower will be conductivity in the alloy, however we have to associate this result to mechanical resistance of the material and conductivity in IACS of the used alloys on distribution and transmission of energy. The more adequate content to these parameters tends to be 0.32% Fe content, in despite of its density is being slightly changed due iron content, but its resistance turns favorable for applying of conductors cables.

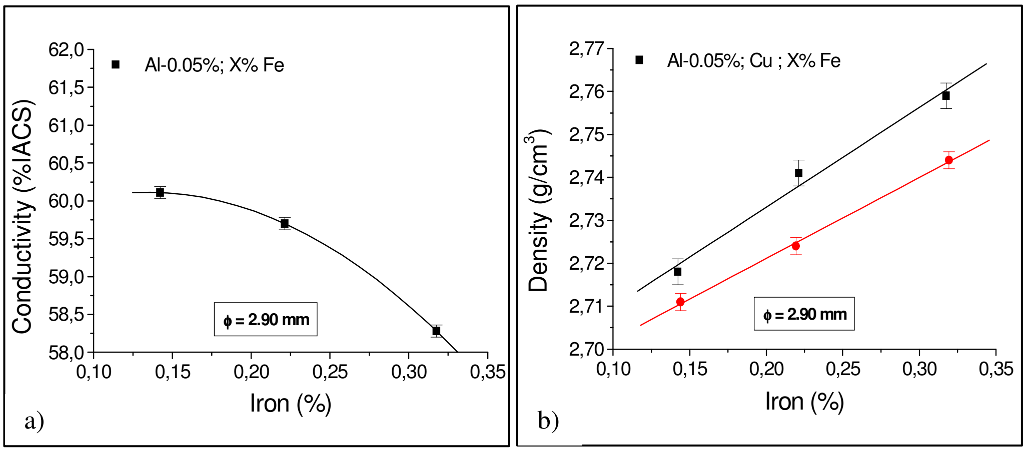

Figure 9 – Comparative between iron effect on electrical conductivity and density of the Aluminum alloys modified with iron content, after and before heat treatment: (a) electrical conductivity and (b) density for aluminum with iron.

Fractures of the aluminum alloy modified with iron

For better observation of the fractures surfaces will be presented figures referred to the alloys after and before heat treatment.

Through the observations by a set of presented images, of the alloys after and before the test of 230°C/1h, that despite having an increase on iron content the micro cavities in first evaluation, almost remains unaltered. It is noted that iron tends to order and homogenize the micro cavities and this performance is more efficient after the test of 230°C/1h, when the phenomenon of micro cavities coalescence is lower when compared to the alloys with lower iron contents.

The variation of medium diameter of the micro cavities with heat treatment is softened with an increase on iron in alloy, as can be observed on the following figures.

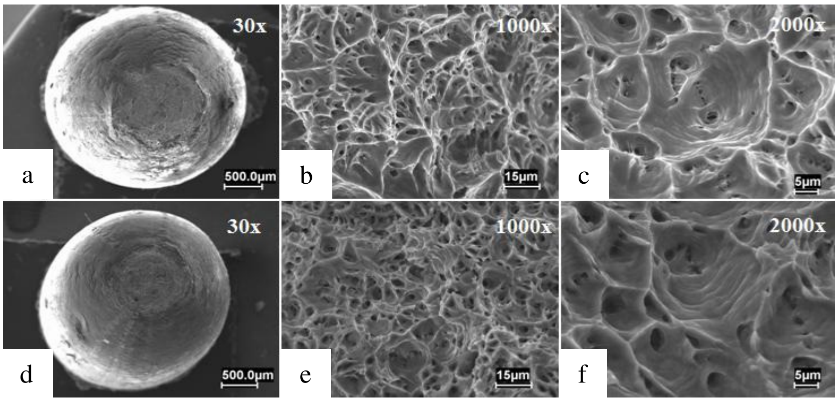

Figure 10 – Aspect of the fracture for heat-resistant aluminum alloys modified with 0.05% Cu e 0.14% iron after and before treatment: (a), (b) and (c) before heat treatment of 230°C/1h and (d), (e) and (f) after treatment.

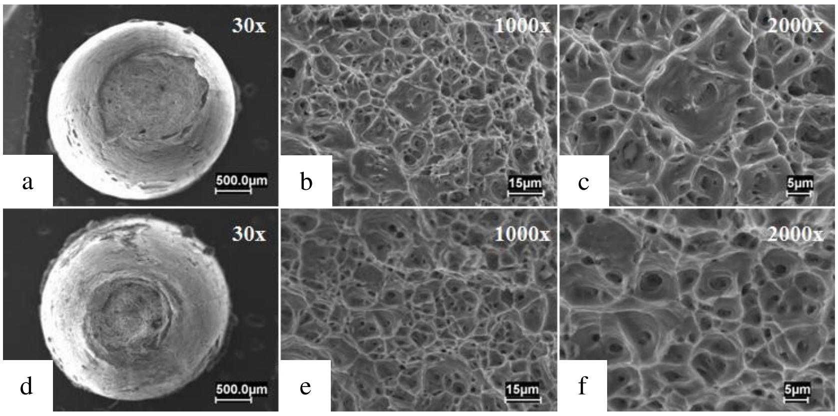

Figure 11 – Aspect of the fracture for heat-resistant aluminum alloys modified with 0.05% Cu e 0.22% iron after and before treatment: (a), (b) e (c) before heat treatment of 230°C/1h and (d), (e) and (f) after treatment.

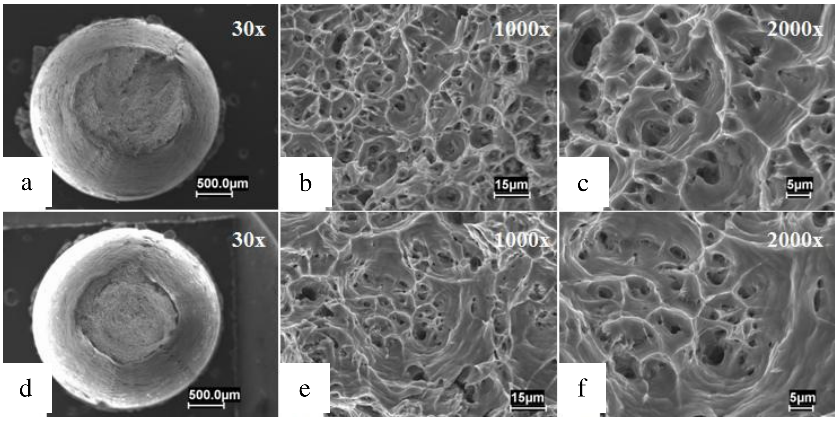

Figure 12 – Aspect of the fracture for heat-resistant aluminum alloys modified with 0.05% Cu e 0.32% iron after and before treatment (a), (b) and (c) before heat treatment of 230°C/1h and (d), (e) (f) after treatment.

CONCLUSIONS

The variation of medium diameter of the micro cavities with heat treatment is softened with an increase on iron in alloy, as can be observed on the figures relative to the fractures. The insertion of iron on electro conductor aluminum modified with 0.05% Cu, in studied interval, provides an increment on Tensile Test almost of 25 MPa, deformation capacity remains almost constant and electrical conductivity falls softly.

The aluminum alloys modified with different iron contents, present a greater increase than Tensile Test. Electrical conductivity was softly increased with addition of larger iron element content, as well as density of the alloy.

The changes related to fracture aspect, that means micro cavities, for the alloys after and before heat-resistant test, remain more evident for alloys with lower copper content, because was possible to observe with more clearness the micro cavities coalescence, generated by increase and permanence of 250 ºC temperature during 1h. The iron in higher quantities demonstrated a heat-resistant characteristic, as can be seen on graph referred to loss on resistance in function of iron content, this characteristic also can be observed in 2000 times amplifications of the fracture topographies for contents above 0.14% where is possible to visualize a decrease on variation of the micro cavities.

ACKNOWLEDGEMENTS

Post-graduation Program in Mechanical Engineering UFPa.

REFERENCES

ASM Metals HandBook Volume 12 1987 - FRACTOGRAPHY
COPEL - Paranaense Company of Energy.
Nascimento Carlos A. M. 1999 “EXPERIMENTAL METHODOLOGY FOR THE USE OF HEAT- RESISTANT CABLES (TAL) IN LINES AND DISTRIBUTION NETWORKS”
NBR-6810 - ABNT
NBR-6814 - ABNT
Prazeres, Ulisses Rodrigues 2007 “EVALUATION OF IRON EFFECT ON FORMATION OF MACROSTRUCTURE AND MECHANICAL AND ELECTRICAL PROPERTIES OF ELECTRO CONDUCTOR ALUMINUM.”

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