RECOVERY OF ALUMINUM FOIL IN THE INDUCTION FURNACE

Antão Rodrigo Valentim (UTFPR)
valentim.ro@gmail.com
ivanir Luiz de Oliveira (UTFPR)
ivanir@utfpr.edu.br
João Luiz Kovaleski (UTFPR)
kovaleski@utfpr.edu.br

The present study investigates the efficiency of aluminum foil recycling process where each foil has a thickness of 0,03mm, using induction furnace, in the production of alloy SAE 329. The aluminum foil did not suffer any treatment or grindding, and they were grouped and packed in the crucible of the furnace manually. In the total, 79 processes were developed, obtaining a recovery yield of 93%. Comparisons with income from other types of scrap in different types of furnaces were made. Despite the small thickness of aluminum foil, which has directly influenced on reducing the yield of the process, the recovery in the induction furnace was efficient.

Palavras-chaves: recovery, recycling, aluminum foil, induction furnace, casting

1. Introduction

Recycling aluminum is advantageous in a socioeconomic and environmental point of view, beyond his excellent recyclability, because it can be recycled infinite times without leaving his character. The economy in electric power in aluminum recycling is in the order of 95% if it be compared to the conventional process, electrolysis, used in the primary aluminum production. To recycle aluminum is dispended 0.7kWh/kg of energy, meanwhile in the primary process is dispended 14kWh/kg. (SZENTE et al., 1997).

In the year of 2008, Brazil was, in the eightieth consecutive year, world leader in recycling aluminum cans, with an index of 91.5% in the commercialized cans, with means 165.8 thousand tons in the year. (ABAL, 2009a)

Despite aluminum can have achieved high levels of recycling, materials like aluminum foils, very used in the Packaging sector, showed low levels of efficiency in recovery. These foils are of difficult recycling because his low thickness turns lower the metallurgic efficiency. As pronounced by ABAL (2009b), in the year of 2007, the aluminum produced to packaging sector was 30% of the total aluminum produced in Brazil.

In the aluminum recycling method that fuses scrap to turn it into ingot, a dangerous waste is produced, the dross, also called, depending of the levels of aluminum present, white or black salt cake. The production of dross is connected to the amount of protection salts used during the fusion process.

The furnaces normally used in the aluminum recycling are the rotary type, who have burners who uses fossil fuels and air as heating source and a saline flux to prevent great loses in aluminum by oxidation and to improve the coarsening and precipitation of melted metal because turns easy to remove the layer of oxide in the surface of the aluminum (BENDER; CRUZ, 2005).

Normally are used 30 a 40%, in weight, in saline flux in relation of total load of the furnace, a eutectics mixture of NaCl e KCl. In the scrap fusion process the flux is melted in the first place, the after the furnace is loaded with the scrap to be melted. To better the protection of the melted bath is added to the saline flux, cryolite.

Researches, who seek solutions to improve in the aluminum scrap fusion process and consequent reduction of the rate of generation of residues, are being realized.

Tenório et al. (2002) e Tenório & Espinosa (2001) studied the influences of the addiction of another salts (NaF, KF, CaF_2) in the eutectic mixture of NaCl e KCl, to understand and improve the action of the saline flux in the aluminum recovery and to reduce the viscosity of the protective layer that is formed. Xiao & Reuter (2002) evaluate the addiction of cryolite (Na_3AlF_6) in the composition of the flux NaCl e KCl, noting an improvement in the efficiency. It’s clear to a relation between the increase of size of scrap and the increase in the efficiency.

Khoei et al. (2003) analyzed the thermal behavior of the rotaries furnace, using the creation of a 2D and a 3D models, generated by the software ELFEN, of the Rockfield Software Limited, to evaluate several positions to the flame into the furnace and different speeds of rotation. So it’s possible to improve the efficiency of the rotaries furnace with the change and simulating of these parameters.

Samuel (2002) e Fogagnolo et al. (2003) studied alternative ways to recycle aluminum scrap in splinter sizes that consists in compression of the aluminum in high pressures at cold or hot, but without melting the metal.

Mashhadi et al. (2008) noticed an improvement in efficiency of the recycling aluminum in splinter sizes; alloy AA336, when the compressions at cold temperatures along with protection flux (KCl, NaCl e KF). As the pressure of the compression increases, the efficiency increases too. The better result was achieved using to beginning of the fusion, with a pressure of compression of 900 MPa.

Furnaces with better efficiency, higher than the conventional rotatory, uses oxygen as oxidizing and lighter fossil fuels. Among the several developed furnaces, may mention the Tilting Rotary Furnace" (TRF). This furnace has only one point to input and output, works in positive pressure, which lower the need of protective fluxes of the bath. His tilting movement jointly with rotaries system allows more thermal efficiency, reducing the production cycles (NOKITA METAL, 2008).

Studies realized by *Linde*, a company that acts in industrial gas production sector, introduce new conceptions to rotaries furnace, the Universal Rotary Tiltable Furnace (URTF). The principal innovation is the utilization of more than one oxygen injection to improve the combustion, uses also an depurated burning control system, combining an oxi-fuel burner with resources to flame control to burn out eventual organic compounds and volatiles contained in the load (oils, varnishes and inks paints), by injecting oxygen into the furnace. This process allows the use of molten salts, though in low amounts (BENDER; CRUZ, 2005).

In Brazil, the *Instituto de Pesquisa Tecnológicas* (IPT) developed a new concept in plasma furnace. Designed with the main objective to recycle aluminum aggregated with plastic, which exists in long-life packaging. Unlike the conventional rotatory furnaces, the transference of heat, predominantly, happens from the wall of the furnace and to this to the load, during the heating faze and the fusion of aluminum scrap, working with the load at an average temperature over the temperature of the walls. Another character of this furnaces is that it can be used to recover the dross of the aluminum (BENDER; CRUZ, 2005).

A furnace underutilized and understudied, that is applied in the aluminum recycling, is the electric induction furnace, that features such as differential, if compared to another furnaces used in aluminum scrap recycling, the capacity to better homogenization of the produced alloys, caused by the turbulence induced in the bath by the electromagnetic field, coming from the induction (LUZGIN et al., 2004).

Veran & Kurzan (2007) studied the influence of the variation in the amount of commercial flux, based in sodium and potassium chlorides, and of the melting temperature in the efficiency of the process and metallurgic quality of the bar produced in the fusion of aluminum cans scraps. The better result achieved was of 90,8%, obtained in the fusion, in an electric induction furnace, in a temperature of 850°C using of 20% of flux.

This study aims to show the results of efficiency obtained in the recycling of aluminum foils with 0,03mm thickness, to acquire SAE 305 alloy bars, produced in an electric induction furnace.

The first chart shows the chemical composition of the aluminum foil and the second chart shows band of the alloy SAE 305 chemical composition, according to ABNT-NBR 13180 standard.

Elements	Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Al
percentage	0,35%	0,697%	0,016%	0,568%	0,035%	0,010%	0,003%	0,030%	0,017%	98,259%

Table 1 – Chemical composition of the aluminum foil 0,03mm.

Elementos	Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Sn	Outro	Al
minimo	11,00%	-	-	-	-	-	-	-	-	-	-	-
maximum	13,00%	1,00%	0,60%	0,35%	0,10%	-	0,50%	0,35%	0,00%	0,15%	0,25%	83,70%

Source: ABNT-NBR 18130.

Table 2 – Range of chemical composition SAE 305 alloy.

2. Materials and methodology

To execute this study was used an electric induction furnace , with a power of 100 kW, working in a frequency de 3.000Hz and a graphite can with maximum capacity of about 55 kg of melted aluminum.

To calculate the load in each fusion, to obtain the SAE 305 alloy, was used a spreadsheet elaborate in the software Microsoft Excel. The Chart 3 brings the amount of material used in six rounds of 79 realized, as the efficiency of each one.

Material	**01**	**02**	**03**	**04**	**05**	**06**
Aluminum foil (kg)	46,08	45,68	45,80	45,36	45,26	45,06
Silicon (kg)	6,40	6,40	6,40	6,40	6,40	6,40
Total Load(kg)	52,48	52,08	52,20	51,76	51,66	51,46
Weight of the part (kg)	45,34	48,64	50,40	49,50	44,64	47,86
Efficiency	**86,39%**	**93,39%**	**96,55%**	**95,63%**	**86,41%**	**93,00%**

Table 3 – Chart of loads in a few rounds.

The aluminum foils, in flap forms, were united and folded to obtain bales, to ease the load and accommodate into de furnace can, picture 1. The metallic silicon used in the making of the alloy was a purity of 99.48% and granulometry equal to 1/10 mm.

Picture 1 – Loading the furnace.

The loading of the furnace was made manually. The metallic silicon was added to the bath when the melted aluminum represents about 50% of the can capacity. The working temperature ranged from 750°C to 780°C. After the casting of the material began the slagging of the melted aluminum. The slagging was produced with commercial flux, which was added in amounts of 0.5% in weight, in relation to the total load, followed to a bath agitation, with a help of a scummer, properly painted, during 3 minutes. In the end of this process, the dross was removed.

In each fusion was separated a sample, picture 2, which went through a process of machining to perform an chemical analysis by optical spectrometry.

Picture 2 – Sample to chemical analysis.

Being the material into the range of the chemical composition specified by the standards, the melted aluminum was drained into forms made of cast iron. The bars produced weight about 8k. The medium time of each round was about 1 hour to 1 hour and 10 minutes, since the furnace load to draining of the alloy into the forms.

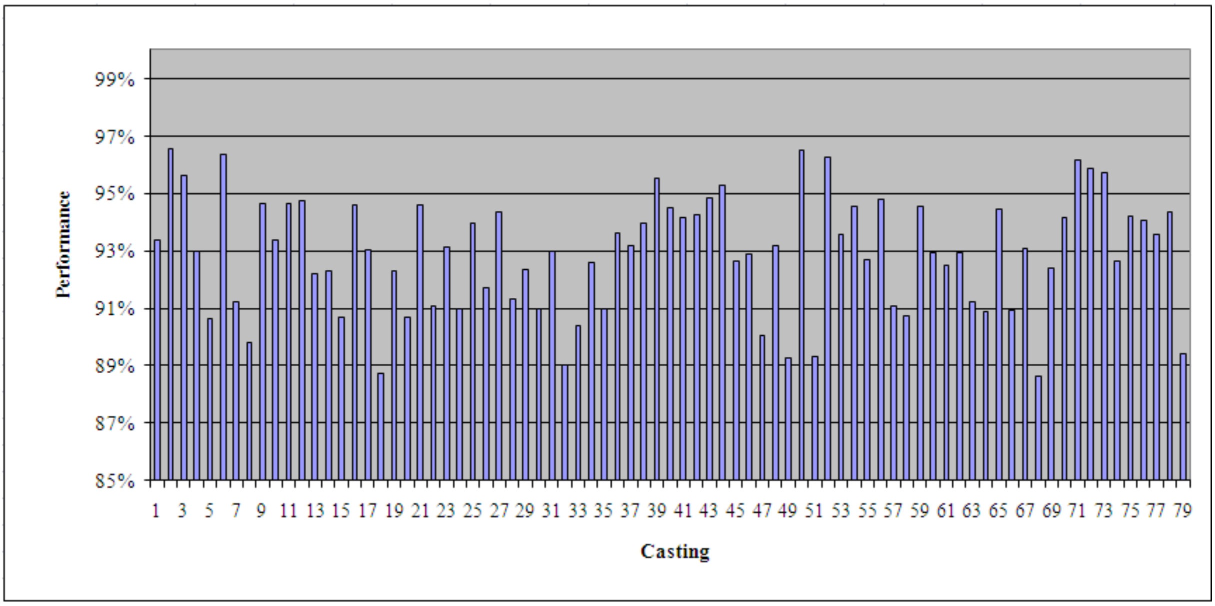
Was done 79 casting. The efficiency of this process was calculated by the relation between weight of the aluminum ingot and the weight of the load into furnace.

3. Results e discussion

The average efficiency achieved in this study was 92.9%, being the higher equal to 96.5% and the lower equal to 88.6%. The picture 3 shows the efficiency obtained in each casting. Can notice an efficiency fluctuation of 7.9%, difference between the highest and the lowest rate, caused by the variations in the quality of the aluminum foil. Some of them came with an oxide film, which influenced in the efficiency of the rounds that used this stuff.

According Kurzan (2006), the company Noviles achieves efficiency in the casting of aluminum cans in order of 81%, in conventional rotary furnaces, due to the pre-processing of the scrap.

Tilting furnaces like *TRF®* shows efficiency of 85% (NOKITA METAL, 2008).

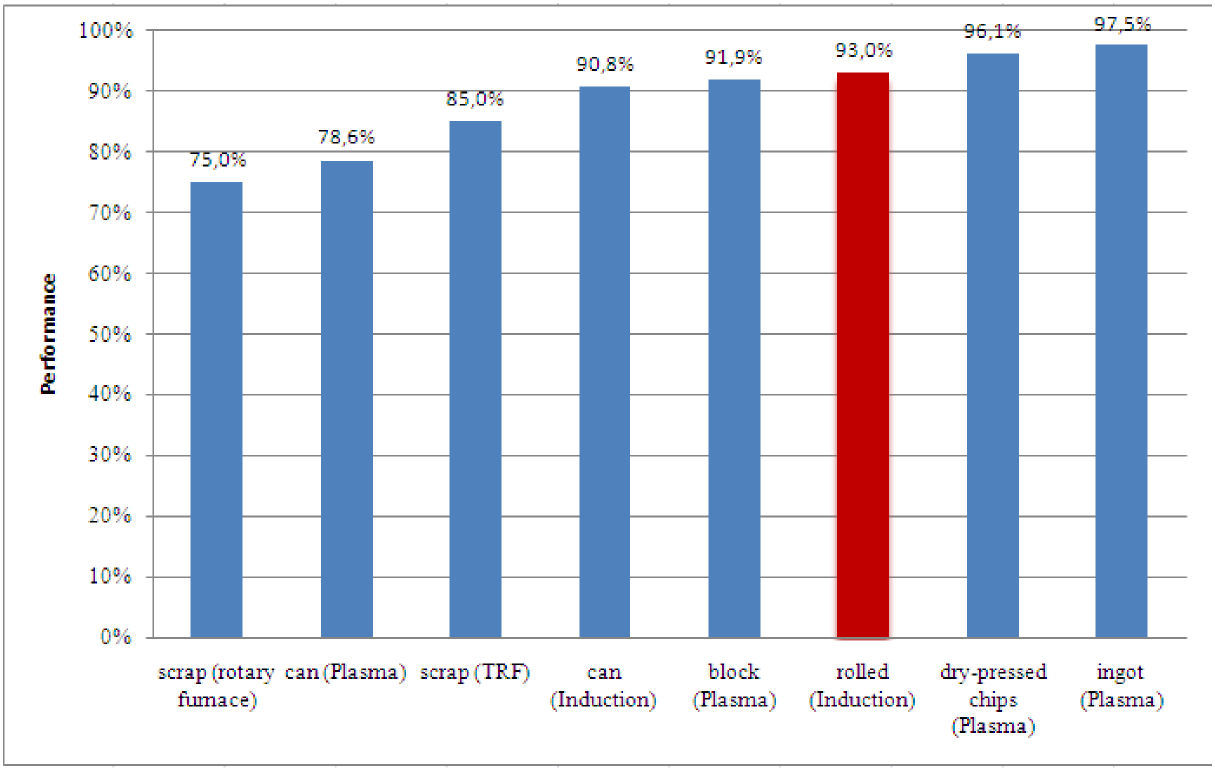


Picture 3 – Efficiency obtained in the casting.

Results obtained by Bender et al. (2005) in fusions using plasma furnaces, using cans, blocks, pressed and dry chips, and ingot, obtained respectively efficiencies of 78,6%, 91,9%, 96,1% and 97,5%. Comparing these results with the results obtained in the casting of rolled in an electric induction furnace only was achieved similar results with denser scraps, which consequently generate more efficient casting.

In the casting of the dry chips, the high efficiency was obtained because the splinter was compressed and free of contaminants, like lubricating oils coming from machining (SAMUEL, 2002; FOGAGNOLO et al., 2003).

Kurzan (2006) studied the use of electric induction furnace, in the casting of aluminum cans, achieving an efficiency equal to 90.8%, efficiency higher than the obtained with another technologies, like the rotary plasma furnace to similar materials. The picture 4 shows a comparative between the efficiency obtained in the casting of aluminum scrap in several kinds of furnaces.



Picture 4 – Efficiency obtained in different kinds of fusion furnaces with different kinds of aluminum scraps.

4. Conclusion

Was collected efficiencies of 79 casting realized in the manufacturing of the SAE 305 alloy, using aluminum foils with thickness of 0,03mm, obtaining an efficiency rating of 92,9%. Despite electric induction furnaces aren't often used in aluminum recycling, the results obtained in this study shows that researches of the use of this kind of furnace in the aluminum recycling must be interesting.

5. Acknowledgements

To the *Universidade Tecnológica Federal do Paraná* (UTFPR) and the *Fundação Araucária*, by support in the conduct of the study.

Reference

ABAL – Associação Brasileira do Alumínio. Banco de notícia; 2009a. http://www.abal.org.br/noticias/lista _noticia.asp?id=618. Acesso: 19 de outubro de 2009.

ABAL – Associação Brasileira do Alumínio. Relatório de sustentabilidade a indústria do alumínio; 2009b. http://www.abal.org.br/downloads/Abal%20RA%202007.pdf. Acesso: 19 de outubro de 2009.

ASSOCIACAO BRASILEIRA DE NORMAS TECNICAS. *Ligas de alumínio em lingotes para fundição.* NBR 13180 – Rio de Janeiro: ABNT, 1994.

BENDER, O. W.; CRUZ, A. C. da. *Reciclagem do alumínio pelo uso de forno plasma: forno piloto IPT*. II Congresso Internacional do Alumínio, São Paulo, SP, Brasil. Anais, 2005.

FOGAGNOLO, J.B.; RUIZ-NAVAS, E. M.; SIMÓN, M.A.; MARTINES, M.A. *Recycling of aluminium alloy and aluminium matrix composite chips by pressing and hot extrusion*. Journal of Materials Processing Technology (2003), p. 792-795.

LUZGIN, V. I.; PETROV, A Y.; TIMOFEEV, A. I. *Equipment and technology for recycling nonferrous metals.* Metallurgist, v. 48, n. 9, october 2004, p. 536-538.

KHOEI A.R.; MASTERS, I.; GETHIN, D. T. *Numerical modelling of the rotary furnace in aluminium recycling processes.* Journal of Materials Processing Technology (2003), p. 567-572.

KURZAWA, U. *Estudo da reciclagem de latas de alumínio por fusão em forno elétrico a indução.* 2006. Mestrado em Ciência e Engenharia de Materiais – Universidade Estadual de Santa Catarina.

MASHHADI, A. H.; MOLOODI, A.; GOLESTANIPOUR, M.; KARIMI, E. Z. V. *Recycling of aluminium alloy turning scrap via cold pressing and melting with salt flux*. Journal of Materials Processing Technology (2008), p. 1-5.

NOKITA METAL. *Latest developments in recycling aluminium dross and scrap using tilting rotary furnaces***.** Disponível: <http://www.noktametal.com/rtf-nm-en.htm >. Acesso: 15 de Julho de 2008.

SZENTE, R. N.; SCHROETER, R.A; GARCIA, M. G. AND BENDER O.W. *Recovering aluminium via plasma processing***.** JOM Journal of the Minerals, Metals and Materials, v. 47, n. 11, p.52-55, nov. 1997.

VERRAN, G.O.; KURZAWA, U. *An experimental study of aluminum can recycling using fusion in induction furnace*. Resources, Conservation and Recycling (2008) 731–736

VERRAN, G.O.; KURZAWA, U.; PESCADOR, W.A. *Reciclagem de latas de alumínio visando melhor rendimento e qualidade metalúrgica no alumínio obtido.* Revista Materiais, v. 10, n. 1, p. 72-79, Joinville, SC, março 2005.

TENÓRIO, J.A.S.; ESPINOSA, D.C.R. *Effect of salt/oxide interaction on the process of aluminum recycling*. Journal of Light Metal 2 (2002), p. 89–93.

TENÓRIO, J.A.S.; CARBONI, M. C.; ESPINOSA, D.C.R. *Recycling of aluminum:effect of fluoride additions on the salt viscosity and on the alumina dissolution*. Journal Light Metal 1 (2001), p. 195-198.

SAMUEL, M. *A new technique for recycling aluminium scrap*. Journal of Materials Processing Technology, p. 117-124, december 2003.

XIÃO, Y; REUTER, M.A. *Recycling of distributed aluminium turning scrap*. Minerals Engineering, p. 963-970, july 2002.