

Aluminum Can Recovery by Thermal Plasma

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Abstract

The work described here was conducted aiming the recovery of the aluminum contained in beverage cans using plasma technology. The proposed technology has a number of advantages over the traditional process, particularly in terms of aluminum recovery, energy consumption and environmental impact. The experiments were conducted in a 60 kg plasma furnace; graphite electrodes were used for the generation of the plasma. The results of the experimental work are presented and compared with reported results obtained using traditional technology.

1. Introduction

Aluminum is an excellent material for using in the packaging of food since it is essentially non interactive with most of liquid and solid types of food, 100 % recyclable, light, has good mechanical properties and it is relatively inexpensive. In particular, aluminum cans have received increased attention as beverage containers. These cans are used for packaging of beer, soft drinks and juices in increasing amounts; more than 98 % of the beverage cans used all over the world are made of aluminum nowadays (1,2).

The aluminum cans can be recycled almost infinitely without significant losses in the quality of the material. The push towards the recycling of the aluminum is due to: a) considerable smaller energy consumption for remelting than producing aluminum - 0.7 kWh against 14 kWh; b) lower environmental impact (for each kg of new aluminum produced, 4 kg of residues are generated); c) reduction on the waste generation (domestic waste that would normally need to be discarded).

It is a common practice to remelt aluminum cans in rotary furnaces; gas or oil burners produce the necessary heat for the melting of the cans (the furnaces operate at approximately 750 °C). Salt (NaCl or KCl) is added in the furnace to avoid the

oxidation of the aluminum and at the same time to promote the agglomeration of the aluminum drops into the melt. The salt forms an insulating layer above the aluminum melt; in average 25 kg of salt per 100 kg of cans is used per heat. The salt is removed from the furnace prior to the tapping of the furnace and it is recycled for the next heat. After few heats (in average three) the salt is removed from the furnace and discarded.

The present technology has the following drawbacks: a) discard of the salt is potentially harmful to the environment (the salt has to be discarded in special places (industrial landfilled), due to its potential toxicity); b) use of the salt is potentially harmful to the workers of the furnaces (off gases are extremely rich in salt and harmful to humans when inhaled); c) the salt attacks the equipment (refractory walls and metal parts have to be replaced frequently); d) inefficiency of the process in terms of energy (part of the heat is used to melt the salt; the salt also forms a thermally insulating layer, preventing part of the heat from the burners to reach the aluminum cans); e) lower recovery efficiency of the aluminum (part of aluminum is oxidized even with the use of the salt); f) higher process costs, due to the purchase and discard of the salt and maintenance of the equipment (corrosion due to the salt).

What follows is a summary of the experimental work conducted by the Plasma Group of IPT for the development of an alternative technology for the remelting of aluminum cans. The technology is based on a plasma furnace operating at similar temperatures as the traditional furnaces (that use oil/gas burners) but using a controlled atmosphere inside the furnace.

2. General Description of the Plasma Process

The process for the remelting of aluminum cans developed is based on a plasma technology. The furnace used was similar to a normal rotary one but instead of oil/gas burners it was installed a plasma system that provides the energy of the process.

A continuous feeding system was developed, allowing an almost continuous operation of the furnace (except for tapping). The atmosphere inside the furnace was controlled; air was not allowed inside the furnace, avoiding the need for using protective salts.

In the developed process, the cans are fed as received; the volatile material of the cans (part of the paint of the cans is volatile) is exhausted and burned in a flare. The plasma rotary furnace is tapped from time to time, this is the only time that the feeding and rotation of the furnace is interrupted.

3. Equipment - Experimental Procedures

3.1 Equipment

a) Rotary furnace

The plasma rotary furnace had a capacity of 60 kg of molten aluminum; the approximated dimensions of the furnace are: external diameter = 1 meter; length = 1.5 m. The rotation speed of the furnace could be controlled and it was maintained during the experiments between 2 and 20 rpm. The refractory used inside the furnace was made of 50 % alumina and it is easily found commercially.

b) Plasma system

Two graphite electrodes were used to generate the plasma. The electrodes had a central hole of 7 mm diameter for the injection of the plasma gas. Argon was used as the plasma gas; the gas flow rate was monitored and maintained at approximately 10 l/min during the operation of the furnace.

c) Feeding system

The cans were fed into the furnace as received. Only macroscopic impurities such as large pieces of glass or metals were removed prior to feeding. The feeding system was homemade and consisted of a rotating screw; a system of mechanical seal and gate valves prevented the entrance of air into the furnace. Approximately 5 kg/minute of cans could be fed using this system.

d) Flare

The off gases consisted mainly of the volatile material coming from the paint of the cans. The gases were burned in a flare, consisting of an exhaust pipe and a burner. A mechanical seal (disk) was installed in the exhaust pipe for controlling the pressure inside the furnace.

e) Control of the plasma

A power supply with a maximum output of 100 kW was used for providing the D.C. current for the plasma generator. The arc current and voltage were continuously monitored and the values stored in a microcomputer. The distance between the electrodes could be changed between 0 and 35 cm; the initiation of the plasma was done by electrode contact.

f) Control of the process

Temperatures of the furnace (inside and at the outside surface of the furnace) were continuously measured using thermocouples; the temperatures were registered in a microcomputer and in a recorder. The pressure inside the furnace was also continuously measured and recorded.

3.2 Experimental Procedures

a) Heating of the furnace

The furnace was heated initially for around two hours in order to increase the temperature from ambient to approximately 750 °C inside the furnace. The plasma gas

during the heating cycle was argon, at a flow rate of 6-10 l/min. The arc current was in average 400 A, and the voltage 75 V.

b) Feeding

Once the furnace had reached the process temperature (750 °C inside), the aluminum cans were fed continuously into the furnace until reaching 60 kg of material inside the furnace. The arc current during the process was reduced to between 250 and 300 A, and the voltage fluctuated between 75 and 90 V for a 20 cm arc (distance between the electrodes). The argon flow rate was kept at 10 l/min during the entire melting process.

c) Tapping

After 60 kg of aluminum cans was fed into the furnace, the temperature inside the furnace was still kept at 750 °C (controlling the current going into the plasma system) and the furnace rotating at 2 rpm for approximately 15 minutes. The rotation of the furnace was stopped and aluminum was tapped, resulting in ingots of approximately 10 kg each. The feeding operation started again, continuing the process. The average feeding-tapping cycle resulted in 60 kg/h of aluminum produced.

4. Experimental Results

A summary of the most important results obtained during this work is presented in Table I. The arc current, voltage, specific energy and electrode erosion refer to the feeding and tapping cycles (heating cycle excluded); the values are averages for the whole cycle. The results presented in Table I are average values obtained during 3 separate experiments. The total aluminum fed and recovered are the results of these 3 separate experiments.

Table I

Cans Fed kg	Al. Recov. kg	Perc. Recov. %	Arc Current A	Arc Voltage V	Specific Energy kWh/kg	Electro. erosion µg/C	Powder Generat. kg
525	456	91.4	270	110	0.70	2.3	39

Samples of the aluminum obtained in different heats were analyzed by emission spectroscopy; a typical analysis showed the following composition: Copper - 0.18 % ; Chrome - 0.02% ; Iron - 0.38 % ; Magnesium - 0.92% ; Silicon - 0.17 % ; Zinc - 0.03 % . The balance is aluminum.

A comparison between the plasma and the traditional processes for the recovery of aluminum from cans is presented in Table II..

Table II

	Aluminum Recovered %	Energy Consumption kWh/ton	Refractory Costs US\$/ton	Landfilled Costs US\$/ton
Traditional	75	2100	12	100 - 150
Plasma	90	700	3	10

5. Discussion

It can be seen from Table I that the aluminum recovery of the process via plasma is very high (more than 90% of the aluminum contained in the cans). The calculation of recovery of aluminum took into consideration that approximately 5 % of the weight of a can is due to the paint (this value was given by the manufacturer of the cans and verified in a test in our laboratory), which is essentially made of organic materials. Therefore, from the 525 kg of cans fed, only $525 \times 0.95 = 498.8$ kg is aluminum. Since 456 kg of aluminum were recovered, the aluminum recovery is approximately 91.4 %.

The remaining aluminum contained in the cans was found in a powder form mixed with carbon. This residue was formed during the experiments and found out to be due to the fixed carbon of the paint that did not volatilize. Since there is no oxygen inside the furnace and the temperature of the system is relatively low (750 °C), the non volatile carbon compounds remained with the aluminum melt. This carbon prevented that some of the aluminum (approximately 5 %) was incorporated into the melt. Once the residue was removed from the furnace, it was found to be made of approximately 30 % carbon and 70 % aluminum. This residue has an ideal composition to be used as an exothermic or reducing powder in metallurgy, and therefore it does not justify any effort for further recovering the aluminum present in it. A total mass balance of the process shows:

Aluminum in - 498.8 kg (considering 5 % paint); Aluminum recovered - 456 kg;
Powder recovered - 39 kg; Aluminum contained in the powder - 27 kg (approx.). Total aluminum recovered = $(456+27) = 483$ kg

This gives a recovery rate of almost 97 % of the aluminum of the cans. The difference in the recovery rate (compared to the theoretical one) is probably due to some losses during the process (tapping particularly) and to imprecision in the amount of paint per can. Also some humidity and dirty of the cans could affect the above values, explaining the differences between the theoretical and the experimental recovery values.

The analysis of the aluminum obtained showed that there is no contamination of the aluminum melt by any source (refractory material). The energy consumption during the experiment is much lower than in traditional furnaces; this is due to the lack of salt in the system (no energy is lost to melt the salt) and to a better use of the energy (lower volume of hot off gases leaving the furnace). If the prices of crude oil and electricity are considered, the costs of both processes are equivalent in terms of energy.

The erosion rate of the graphite electrodes is quite low (2.3 $\mu\text{g}/\text{C}$); this is probably due to the lack of oxygen in the system. The reduction in the consumption of the refractory material is a reflection of the cleaner process (no salt added) when compared with the traditional technology (Table II).

Since there is no residue in the plasma process (excluding the carbon-aluminum powder formed, which can be used in metallurgical applications as explained before), the costs of land filled are significant lower than in the traditional process. This is a strong point in favor of the plasma technology.

The overall comparison between the two technologies points to a smaller cost for the plasma process (in the order of 35 % less than for the traditional process). This is not considering the increasing demand for cleaner processes, what should result in tougher laws for the discard of toxic residues such as the ones of the gas/oil burner technology.

The technology is reaching a commercialization stage now; the envisioned users are small scale remelters (100-500 ton/month) that represent more than half of the aluminum can/swarf (similar composition as cans) remelters in Brazil and other countries.

6. Conclusion

A plasma system has been developed for the recovery of aluminum from beverage cans. The results obtained with a pilot scale rotary furnace of 60 kg indicate that the aluminum recovery was significant higher than the traditional technology, approaching the theoretical value. No salt or other compounds were added to the plasma process, reducing considerably the operating and maintenance costs of the process when compared to the traditional technology with oil/gas burners. And most important, avoiding the use of salt resulted in a much cleaner process, without the generation of residues that need to be land filled, as it is the case of the traditional process.

References

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