ALUMINUM DROSS PROCESSING IN A ROTARY PLASMA FURNACE

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ABSTRACT

This publication presents the main experimental and theoretical results concerning the recovery of aluminum from dross without use of any fluxing salts.

Dross processing experiments have been conducted in a rotary plasma furnace operating in the transferred and non-transferred mode, using different plasma gases. The investigation involved the treatment of more than 100 kg of dross using plasma torches with less than 100 kW power.

The experimental work showed that this process is far more economical and kind to the environment than the conventional route using a salt flux.

An equilibrium thermodynamic calculation at elevated temperature makes possible the prediction of by-products at various temperatures.

INTRODUCTION

Dross is a by-product of smelting, melting and casting of aluminum. Normally it equals 1-3% of cast-house production. This dross is rich in aluminum (typically 50%) and contains aluminum oxides, aluminum nitrides and other metallic impurities depending on the source of the dross. This aluminum is usually recovered. The classical commercial process used for recovery involves crushing, sizing and melting the metal from the dross in an oil or gas-fired rotary furnace under a salt flux. This salt flux consists essentially of a mixture of sodium and potassium chloride.

After melting, aluminum and slag are tapped from the furnace. With this process large amounts of salt slag is produced. The salt slag mixture consists mainly of oxides, nitrides, chlorides and also still contains some aluminum metal. Approximately 5% aluminum usually remains in the salt slag.

Because it contains some soluble residues that can contaminate both ground water and atmosphere, this salt slag is generally dispatched to specially selected landfill sites.

The economy of the classical process is very doubtful because the tax of disposal of slag is rapidly increasing. On the other hand, the processes for recycling the salt slag which are available today are very capital intensive and not flexible enough to meet requirements of today's secondary aluminum industry.

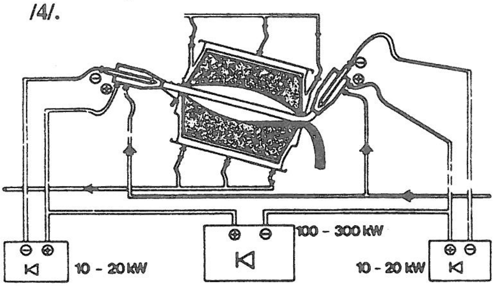
What is needed therefore is an efficient process which avoids production of salt slag. The increasing overall processing cost for dross recycling makes the use of plasma technology very interesting as a non oxidising heating and melting source instead of use of fossil fuel burners (see references /1/ and /2/).

This was the background to the decision by Alusuisse-Lonza and EDF to collaborate to try to develop a plasma process avoiding use of a salt flux.

EXPERIMENTAL SET-UP

For the experimental work a rotary furnace equipped with two plasma torches was used. Figures 1 and 2 show the principle of the furnace.

The furnace can be used in the transferred (figure 1) or non-transferred (figure 2) mode. This furnace was developed a few years ago to process different refractory materials and toxic wastes in powdered form. A detailed description of the furnace is given in references /3/ and /4/.



TRANSFERRED PLASMA ROTARY FURNACE

Figure 1

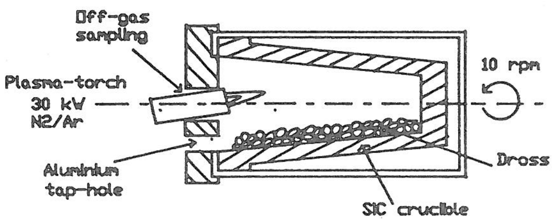


Figure 2: NON-TRANSFERED PLASMA ROTARY FURNACE

In the case of the transferred mode (figure 1) two plasma torches are mounted on opposite sides of the furnace in the axis of rotation. An arc is created between the two plasma torches using one torch as anode and the other as cathode. The advantage of working in this mode is that it uses less plasma gas and has a better energy efficiency compared to the non transferred mode. In the transferred mode the crucible itself is made by solidifying molten Al_2O_3 powder while rotating the chamber at high speed.

In the non-transferred mode (figure 2) the furnace is closed at one end. A silicon carbide crucible is used as lining. The plasma torch is pointed at the roof of the furnace, so the plasma flame is not directly heating the dross. It is heated from bellow by indirect heating because of rotation of the furnace /1/. In addition, the rotation agitates the dross and facilitates product separation and uniform dross heating .

The furnace works with a low over-pressure which creates a controlled atmosphere during processing and prevents oxidation of the treated material.

EXPERIMENTAL RESULTS

a) transferred mode:

After loading with dross the furnace was flushed with Nitrogen and heated while rotating at between 10 to 200 rpm. The dissipated plasma power was between 30 to 100 kW. As plasma gas we used a mixture of Argon and Nitrogen gas at 100 l/min.

The arc between the two plasma torches was not stable. Parasitic arcs were produced between one torch and the dross, leading to hot spots which eventually evaporated part of the treated product. The dross was over-heated in every test.

This resulted in a very low metal recovery of less than 20%. This investigation was therefore not evaluated further.

b) non-transferred mode:

A total of about 100 kg of aluminum dross was processed during the course of this evaluation.

The dross originated from SFRM, a secondary smelter in France formerly part of the Alusuisse-Lonza group. The metal content was on average approximately 75%.

Batches between 4 and 11 kg were processed in each run.

The best plasma gas mixture experienced with this experimental set-up was: 15 Nl/min of Argon and 20 Nl/min of Nitrogen with a plasma torch power of 30 to 35 kW and a furnace rotation speed of 10 rpm.

The flow sheet of a typical dross treatment is showed in figure 3.

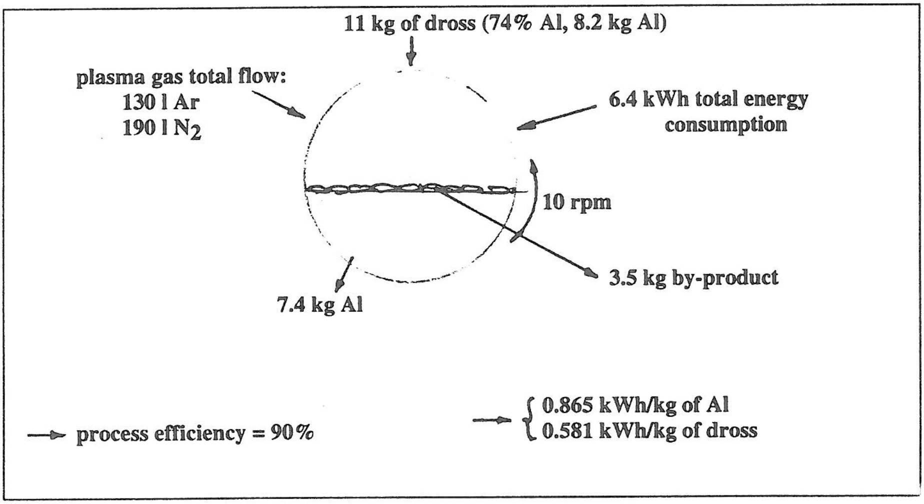


figure 3: flow sheet of a typical dross treatment.

Careful mass and energy consumption is necessary to measure the process efficiency and the related economics. In the above mentioned run we recovered 7.41 kg aluminum and 3.5 kg of by-product. This means that the process efficiency was 90%.

The total energy consumption was 581 kWh/t per tonne of dross. Therefore an energy of 865 kWh is used to produce 1 tonne of aluminum.

A metallographic investigation of the recovered aluminum showed no inclusions (see photo 1 and 2).

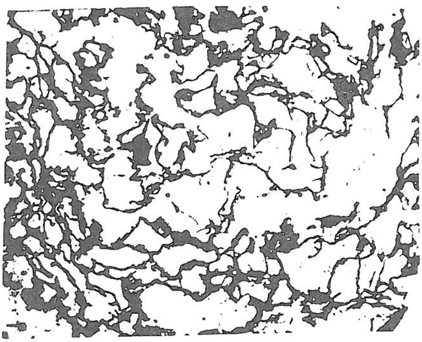


Photo 1: dross (200:1)

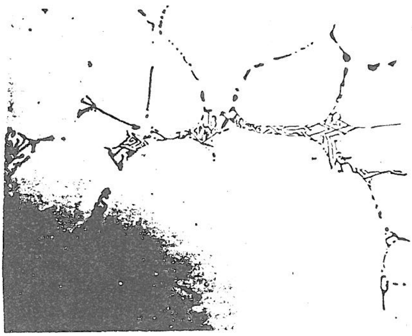


Photo 2: recovered aluminum (200:1)

<u>Off-gas measurements and chemical composition of the by-products</u>

The aim of measuring exhaust gas and particulate matter during the melting of the dross was to see if the process met European standards or if major investments in gas cleaning would be necessary. For this reason we used a specialised consulting company /5/ to perform these measurements.
The sampling was done at the exit of the furnace near the plasma torch (see figure 2). The results of this investigation are summarised in the following table:

	Total C (organic matter)	NO/NO_2	CO	particulate matter	other gases	by-product
Dross	(1)	(2)	(1)	(3)	(4)	(5)

1: no special care needed

2: NO/NO_2 production has to be reduced by installation of a cooling system to cool the exhaust gas before contact with the outside atmosphere.

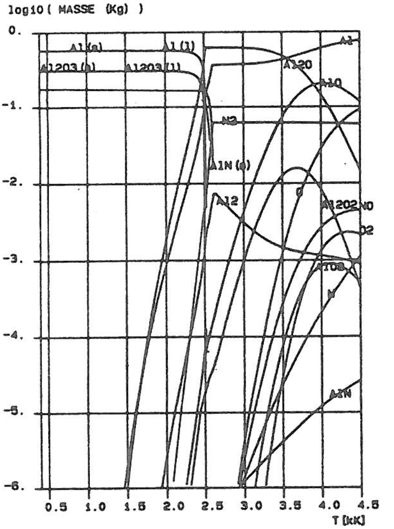
3: a filter system is needed to collect particulate matter
(dust < 370 mg/m3)

4: other gases HCl < 10 mg/m3,
HF = 2 mg/m3,
SO_2= 5 mg/m3.

5: the by-product left in the furnace is a greyish powder floating on top of the liquid aluminum consisting mainly of Al_2O_3 (90%), Al (8%) and small amounts of AlN.

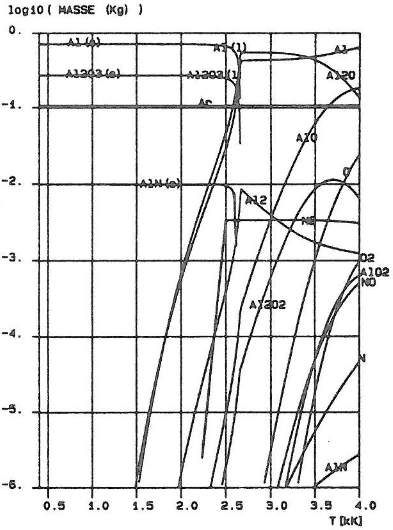
THERMODYNAMIC EVALUATION:

The action of the plasma with a mixture of Al_2O_3/AlN/Al in an air, Nitrogen and Argon plasma with a thermodynamic equilibrium has been evaluated /6/.
This allows the determination of the molar fraction distribution of the various gaseous chemical components and the mass ratio of the condensed solids at specific temperatures and pressures for a typical industrial plasma Ar ,N_2 and air dross treatment case(figures 4,5).



1kg: 72%Al (s) /27%Al2O3 (s) /1%AlN (s) /60Nl d'air

Figure 4



1kg: 72%Al (s) /27%Al2O3 (s) /1%AlN (s) /60Nl d'Ar.

Figure 5

We can note that aluminum recovery in N2 or air plasma mode is similar; in this case, the choice of gas has only a limited effect on the efficiency of the aluminum recovery process /7/; the nitrogen and oxygen react with aluminum to form AlN or Al_2O_3. Consequently economical considerations are the prime reason for the choice between these two plasma gas types.
However, the Argon plasma allows an Al recovery >13% than with other gases. In this case, an economical comparison taking into account this theoretical results and including the cost of Ar = 6 FF/m3 and Al = 7 FF/kg, gives a real advantage to the argon plasma choice.

ECONOMICS OF THE PROCESS

The investment (excluding building and utilities) for a production unit with a processing capacity of 15 000 tonnes of dross per year is 22 millions FF. Based on our experimental results the size of the torch should be 1 to 1.2 MW. The cost of treating one tonne of dross is of order of 661 FF with Nitrogen plasma (see figure 6). In all these calculations no depreciation was included.

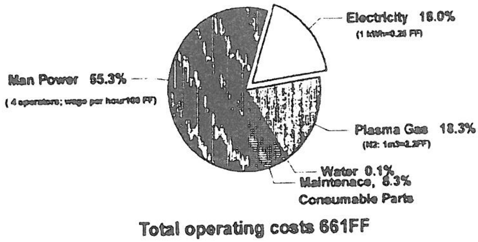


figure 6: Split of the various costs to process one tonne of dross

CONCLUSIONS

The findings can be summarised as follow:

1- the recycling of dross in a rotary plasma furnace working in transferred mode is technically difficult to control;

2- the recycling of aluminum dross with no fluxes in a rotary furnace working with a plasma torch in non transferred mode is technically and economically possible;

3- The process has a very high flexibility and is able to work during periods when electricity is cheap.

In order to determine the economic viability of the process , it is necessary, before the industrial stage, to proceed to feasibility tests on a semi industrial scale taking advantage of the know-how acquired to date and making allowance for improvement of the energy consumption values
EDF is ready to help industrial partners with the conception of a pilot plant.

REFERENCES

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