Waste to Wealth - Full Utilisation of Red Mud

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Abstract

The main by-product of the Bayer process is the bauxite residue (BR), a red slurry (red mud) consisting of the un-dissolved portion of the bauxite ore. On a dry basis BR are produced at an almost 1:1 mass ratio with alumina, amassing to a total of 100 to 120 million tonnes per year globally. Due to the lack of an economically viable processing method all BR are disposed of in artificial ponds or landfills. The disposal of this residue is a relevant cost for alumina producers and has a relevant environmental impact. A novel process for treating BR has been developed in Greece at the Mytilineos plant during the Enexal project between 2010 and 2014. Through EAF carbothermic smelting the BR are fully converted into two marketable products: pig iron and mineral wool fibers. No solid or liquid by-products are produced. This novel process has been applied for more than a year in an industrial scale pilot plant housing a 1mva ait cleantech EAF and a melt fiberizing line. The experimental campaign in the Mytilineos pilot plant has proven the feasibility of the process to efficiently treat BR and transform them to marketable products. Today, with the increasing metal price, the more stringent environmental policies and the incentives for circular economy, the above-described process, becomes very profitable and sustainable for a complete BR recycling

Keywords: Red mud treatment, Waste to wealth, Maximum recovery of pig iron, Pilot plant, Commercialization

1. Cleantech Solution for Red Mud Treatment

The circular economy offers a major opportunity for the metal industry sector to deliver on climate commitments and other environmental, social and governance objectives, whilst tapping into sources of new and better growth and long-term value creation.

Nearly half of the emissions that cause climate change come from how we make and use products and food. A circular economy gives us the tools to tackle climate change biodiversity loss and erosion of natural capital together.

The adoption of circular practices has the potential to reduce risk and increase resilience through business model diversification, decoupling economic growth from resource use and environmental impact, and better anticipation of stricter regulation and changing customer preferences. These circular practices are strictly related to the application of new processes and technologies capable to convert wastes in products or by-products in a sustainable way, both environmental and economical. In other words, we can not generate circular economy and achieve the goal of "zero waste" without investment on technological innovation.

Mines and metallurgical industries generate large quantities of wastes, in a variety of forms, such as dusts, fines, slag, etc., whose recovery, treatment or disposal is difficult and expensive.

With the Bayer process, the aluminum industry generates "bauxite residues BR, a red slurry (red mud) consisting of the un-dissolved portion of the bauxite ore. On a dry basis BR are produced at an almost 1:1 mass ratio with alumina, amassing to a total of 100 to 120 million tons per year globally. Due the lack of an economically viable processing method all BR are disposed in artificial ponds or landfills. The disposal of this residue is a relevant cost for alumina producers and has a relevant environmental impact" (THE ENEXAL BAUXITE RESIDUE TREATMENT PROCESS: INDUSTRIAL SCALE PILOT PLANT RESULTS - NTUA/AoG).

AIT Europa Engineering aims to offer an innovative and sustainable technological solution to the mineral and metallurgical industry for the transformation of their fine waste in added value products or by-products.

In fact, AIT Europa Engineering is a company specialized in the design and manufacturing of high efficiency technological production systems, for the recovery and treatment of fine waste from mining and metal production.

Metal recovery of fine waste like red mud or steel EAF dust is difficult. The traditional pyrometallurgical technologies are not able to process these materials as it is, without pre-agglomerating it. Plus, their metal recovery rate is too low to generate profits.

The AIT EE "Clean Tech" technology transforms a number of fine metal wastes in high added value raw materials, avoiding any pre-agglomeration process and recovering a higher percentage of valuable metals, generating economical advantages to the mining and metal industries.

The Cleantech technology derives from the intuition and joint effort of two co-inventors:

- Josè Almeida, Mechanical Engineer - over 20-year experience as plant engineer in charge of Electric Arc Furnaces, automated casting plants, industrial control systems, etc., in S.A. and surrounding countries;
- Dr. Kevin Perry, Chemical Engineer, PhD in Pyrometallurgy - over 30 year experience leading research in the areas of metallurgy and thermodynamics. He has worked with prominent South African firms Mintek (1983-1990) and JCI/Anglo Platinum (1990-1997).

2001

Josè Almeida founded AIT (Applied Industrial Technologies Ltd), a company based in Johannesburg (S.A.), specialized in the study, design and manufacture of furnaces for the treatment of wastes and tailings from the mining and metallurgical industry.

2010-14

In this period a 2 MVA and a 5MVA Clean Tech furnaces were produced and installed for the South African customer RST. The two furnaces were used successfully to recover ferrous metals from steel mill EAF Dusts for a few years. Today they are employed to process fine platinum ores.

AIT produced for AMRT a first prototype of Clean Tech furnace that was installed in Greece at ALSA (Aluminum of Greece, today Mytilineos) as part of the ENEXAL research project, promoted by the European Commission. It was a 1MVA CT furnace that was used in numerous tests. Close to 100% of the ferrous metals present in the red mud (a waste derived from the reduction of bauxite into alumina) were recovered.

2019

AIT created AIT Europa Engineering, to which it transferred its know-how and IP. Today the research and development, production and sale of Clean Tech furnaces takes place in the new headquarters in Italy.

2022
AIT Europa Engineering start the design and production of a 5MVA CT furnace that will be used for a period of 4 years in the Hephaestus research project, funded by the European Commission.

1.1 The Cleantech EAF Innovative Configuration

Cleantech furnaces (CTF) operate in AC (alternating current) mode where arcing will be taking place between the tips of the 3 electrodes: the tips now being in slight contact with the slag itself creating a slight slag surface depression. The fact that electrical power is allowed to pass through the slag between the electrode tips means that resistive heating (triangular shape), besides some open-arcing, of the slag is an additional source of heat energy to the system.

This combination of arcing and resistive heating constitutes the basis of the CTF operation, plus the fact that all solid charge is introduced directly into this triangular zone, where there is also a fair amount of localized slag turbulence, makes this inter-electrode region also the primary reaction zone.

To compare this CTF configuration with those of the conventional SAF/EAF, it needs to be noted that:

I. The heating and reaction zones are not separated from each other
II. Slag resistive component is present.

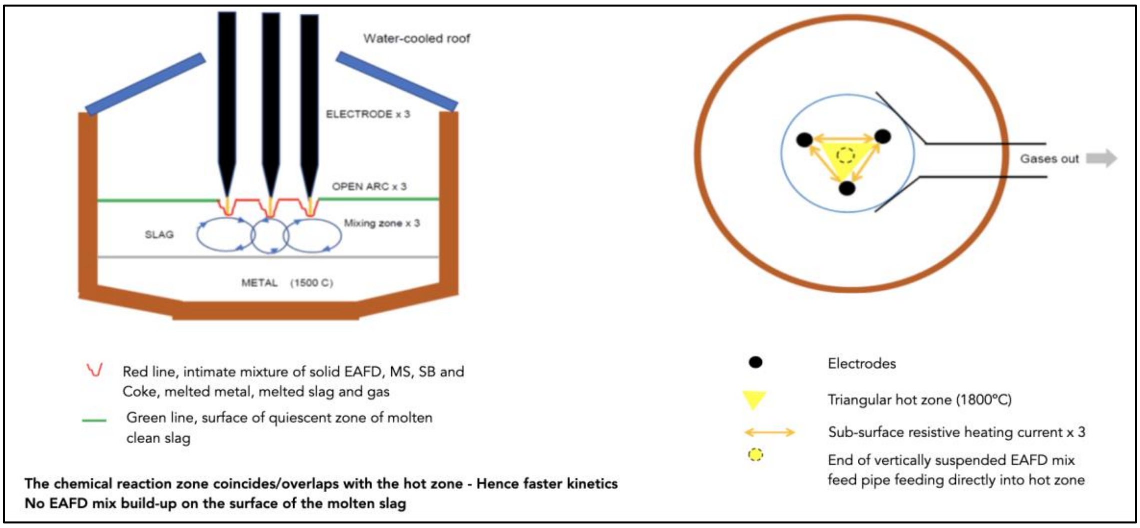

Figure 1. Schematic of the Cleantech EAF innovative configuration.

This configuration allow to operate the furnace in a smelting/reduction mode.

The fine material, previously mixed with reagents, is feed from the top of the furnace, between the three electrodes (hot-top). The electrodes arms movements are automatically controlled, maintaining always electrodes tips at the level of the slag surface. Smelting and reduction of fine materials occur simultaneously in the triangular arc zone, increasing the furnace efficiency and the metal recovery rate.

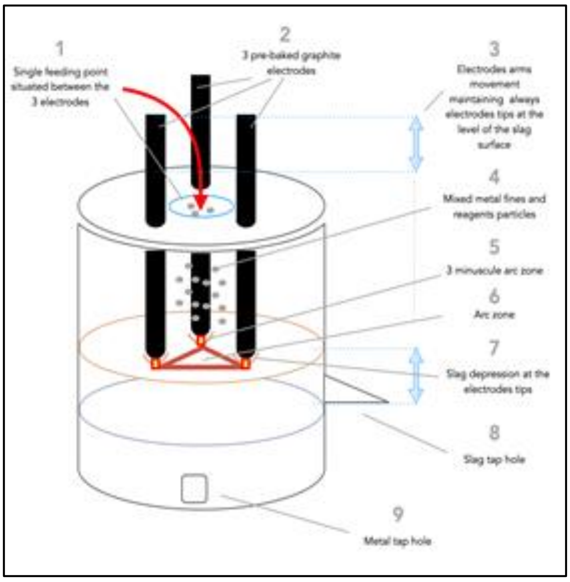

Figure 2. The Cleantech technology applied to red mud treatment

The Cleantech process for treating red mud has been developed in Greece at the Mytilineos plant during the Enexal project between 2010 and 2014. Through Cleantech EAF carbothermic smelting the red mud are fully converted into two marketable products: pig iron and mineral wool fibers achieving the goal of “zero waste”. This novel process has been applied for more than a year in an industrial scale pilot plant housing a 1MVA AIT Cleantech EAF and a melt fiberizing line.

1.2 The Industrial Process Description

- The moist red mud is first dried in a rotary kiln and converted into DRI containing the necessary coal & fluxes required by the CTF to generate the iron metal and slag-derived fiber blanket
- Red mud mixed undergo drying and hardening in the upper zone of the rotary kiln by providing a radiant flame generated by burning the carbon monoxide and organic volatile components in the hot gas evolving in the central zone of the kiln
- From the kiln, the CTF receives a hot pre-blended DRI material to generated liquid cast iron and slag at 1610 °C
- An ORC system is coupled to the hot CTF off gas line generating 800 kWh of electrical energy
- The metal is casted in pig iron ingots
- The slag is directly feed to a fiberization unit to produce mineral wool blankets.

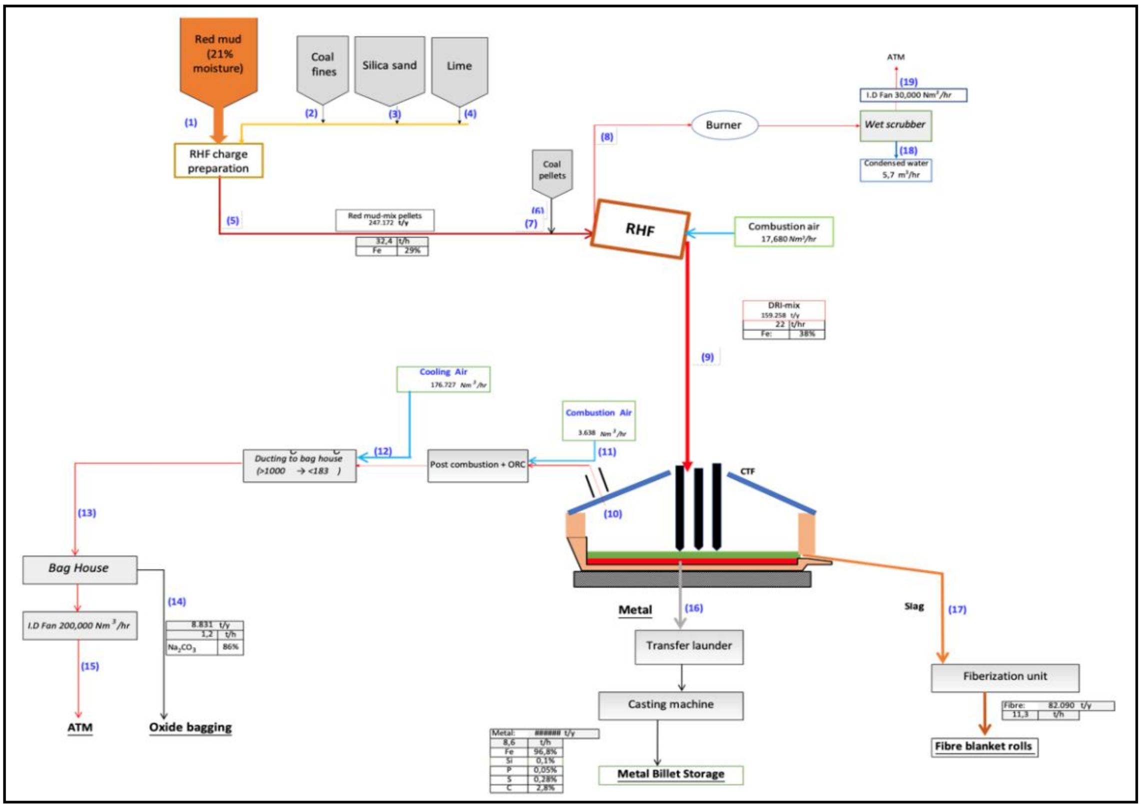

Figure 3. Process flowsheet for treating red mud.

Starting from the following typical red mud characterization:

Table 1. Typical composition of the red mud.

Fe_2O_3	43.02
SiO_2	5.73
CaO	9.9
MgO	0.23
Al_2O_3	21.22
TiO_2	5.23
V2O_5	0.18
Na_2O	2.11
"-CO_2	2.39
"-SO_3	0.39
H_2O – crystalic H_2O	6.09
H_2O – moisture Fixed C	3.32

The Mass & Energy balance of the process can by calculated as follows:

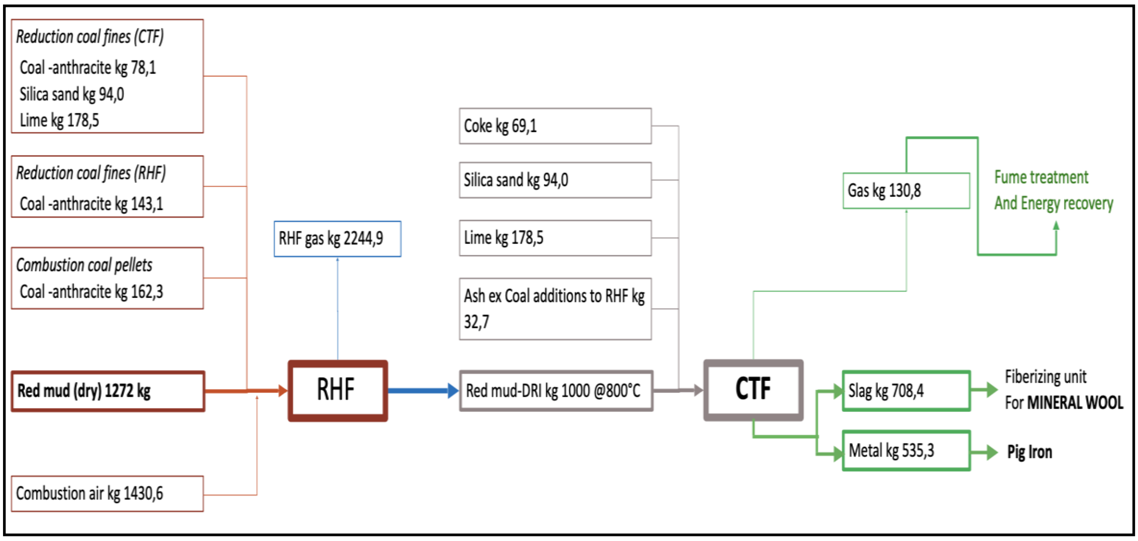

Figure 4. Mass and energy balance for the processing

Giving as result that for each ton of Red mud (dry basis) it is possible to produce approximately 520 kg of mineral wool and 420 kg of pig iron.

For the represented solution the estimated consumption in the CTF is 785,1 kWh/t DRI, while the estimated energy recovery from ORC is 800kWh.

The pig iron can be used as raw material to produce carbon steel or stainless steel.

The chemical composition of the slag obtained from the red mud smelting process allows the production of a fiber with good quality, suitable either for industrial or civil applications. It's possible to produce different kinds of mineral wool product: mattresses, sectional pipe insulation, panels.

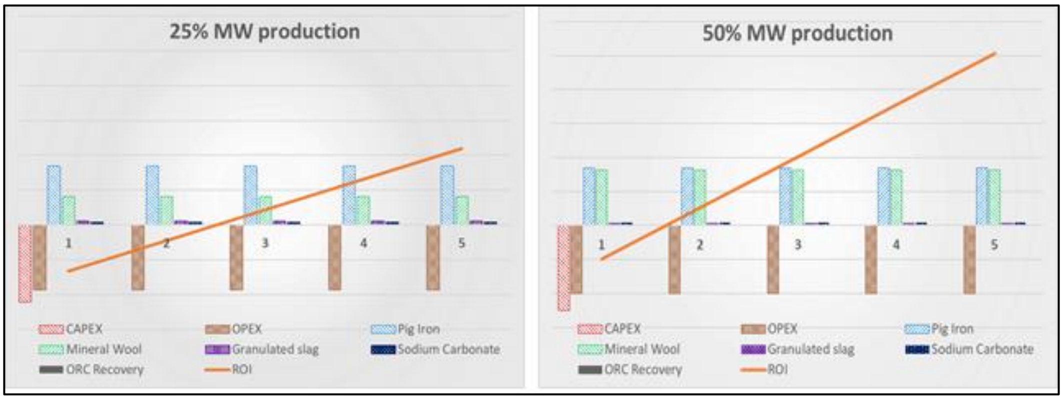

Figure 5. Mineral wool (MW) production

Melted slag, coming from the Clean Tech EAF, is transformed into thin fibers by a spinning centrifuge; fibers are distributed on a felt forming chamber, where are sprayed with a special emulsion (which reduces dust and keeps the fibers soft and flexible) and arranged into the shape of a felt. Felt is then transported to the stitching machine and stitched to the required facing (paper, cardboard, aluminum foil, wire mesh and so on).

Blankets are then cut at the proper length, rolled and packed into a plastic bag and stored in the warehouse, ready for delivery.

Slag temperature must be in a range of 1420 °C – 1480 °C and a viscosity of 10-15 Pois. To maintain the temperature the slag is poured into conditioned ladles.

There is no need to modify the chemistry of the slag.

The global market of thermal insulation materials

The global market size of thermal insulation materials for buildings applications was estimated at about USD 22.73 billion in 2015 and is projected to increase at a CAGR of 4.5 % between 2016 and 2027, reaching USD 38.69 billion by 2027 (Visiongain, 2017).

In 2015 the value demand in the EU was USD 8 471 million and is expected to reach USD 12 768 million by 2027, at a GAGR of 3.48 % (2015-2027) (Visiongain, 2017).

Globally, the most used insulation materials to make different kinds of insulation products are based on mineral wool (glass, stone and slag wool) and plastic foams (EPS, XPS, PUR).

The mineral wool insulation segment accounted for just above half of the overall building insulation global market in 2015

Project economics

A Cleantech plant of 100.000 t/y red mud processing capacity will produce approximately 52.000 t/y of slag to be transformed in mineral wool and 42.000 t/y of pig iron.

We considered two possible scenario: 1) only the 25% of the slag is converted in mineral wool; 2) the 50% of the slag is converted in mineral wool.

With European reference prices estimated from conservative benchmarks, we calculate a ROI of 0.35 for the first scenario and a ROI of 0.5 for the second one.

2. Conclusions

The experimental campaign in the Mytilineos pilot plant has proven the feasibility of the process to efficiently treat red mud and transform them to marketable products. However, with the metal and mineral wool market condition up to 2021, "the economy of the proposed process would have been undermined in industrial scale, thus this novel process could have been considered an economically viable solution for treating the red mud of the primary alumina production only in case of transforming red mud also into a series of other commercial by-products, such as cement additives, geo-polymers, catalysts and others" (THE ENEXAL BAUXITE RESIDUE TREATMENT PROCESS: INDUSTRIAL SCALE PILOT PLANT RESULTS - NTUA/AoG).

Today, with the increasing of metal price, the more stringent environmental policies and the incentives for circular economy, the scenario changed in favor of the above described process, so to be consider now as a valid and economically sustainable solution for the complete red mud recycling.