Sustainable recycling of Aluminium salt slags by ALSA

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0. Abstract

The trend in the aluminium recycling market is towards total recycling.
In the future it will be a matter of re-circulating the previously landfilled Al salt slag and ball mill dust to the production chain and of re-processing it into saleable products.

In the field of Aluminium salt slag reclamation there are various competitors available. Out of them, despite of a lot of plants operating technically similar processing procedures only a very few have reached stable cost covering and waste free operation.

ALSA for example has demonstrated the feasibility of there waste-free treatment processes for all sorts of Al salt cakes, slags and ball mill dusts with its plants in Hanover and Lünen in Germany for more than 18 years.
Under the roof of Global Environmental Technologies GmbH (GET), ALSA now offers an economically advantageous and ecologically sustainable alternative to landfilling on the basis of a new generation of state-of-the-art plant and equipment.

1. Introduction

Aluminium is a recycling-friendly material.
As a result, in the developed industrial countries, stable closed loop cycles have been developed to ensure repeated use of the metal.
Primary metal from the primary smelters is cast into various products and after the actual use has been finished, the metal is returned as scrap to the secondary smelters where it is remelted and returned to the market place.

Dross is produced at various stages in the melting process in the aluminium primary and secondary smelters and foundries. This consists primarily of aluminium metal (40 to 80 %) and oxides of aluminium and its alloy metals.

The aluminium metal included in the dross can be partially recovered by re-melting or by milling and screening.
This again generates two waste products:

- ball mill dust as a result of the mechanical process
- aluminium salt slag or cake as a result of the re-melting.

Aluminium salt slags respectively cakes thus occur when melting both scrap aluminium, and dross for recovering and recycling aluminium metal in the product cycle.
A distinction is made between primary and secondary dross, depending on the origin of the scrap and dross.

Smelting is done by batches for example in rotary furnaces of various designs, with the addition of varying quantities of melting salt which covers the surface of the molten aluminium metal. This salt layer has the dual purpose of protecting the metal

from burning, and also, the separation of the impurities contained, and the reaction products generated (nitrides, oxides, carbides, sulphides, etc.) from the molten metal.

The melting salts used are mixtures of KCl and NaCl (55 to 95 % NaCl). Various fluxing agents, such as fluorspar or cryolite, are also added to the melting salt mixtures to lower its melting point.

At the end of the smelting process the metal and slag are cast separately.

The aluminium salt slags and cakes consist predominantly of between 20% and 65% melting salt, various oxides (25% to 75%) and 4% to 10% aluminium metal, depending on the smelting process employed.

Ball mill dust, on the other hand, contains substantially less melting salt, finer metal and a higher proportion of oxides (up to 95%).

Recent developments have tended to lean towards using increasingly smaller quantities of melting salt. However, it can be assumed that a certain amount of melting salt will continue to be necessary in the future for secondary smelting.

The effect of the reduction of the specific amount of salt slag (i.e. per mt of re-molten aluminium metal) is counteracted by the overall increase in aluminium metal production. This means that in the long term, the production of aluminium salt slags and salt cakes can be regarded as approximately constant.

Unlike the specific melting salt content in aluminium salt slags, the oxide content will grow. Its utilization should therefore be regarded as a significant strategic problem. The “oxides” is a mixture predominantly of aluminium oxide (corundum), aluminium hydroxide, Mg-spinel, silica and aluminium nitride.
The composition fluctuates considerably depending on the composition of the metal alloys being melted, and the smelting process employed.

Depending on the alloying metals added to the aluminium and the fluxing agents used, Al, Mg, Si, Ca and oxygen and at least another 25 chemical elements in a wide variety of chemical compounds are found in the insoluble “oxides”. These include numerous heavy metals, fluorine, sulphur, alkalis, phosphorus, nitrogen, etc.

Table 1 shows the range of chemical variations in the oxides of the Aluminium salt slags respectively cakes.

Table 1:

compound	% by mass, dry substance
Al_2O_3	60 … 85
MgO	1 … 8
SiO_2	1 … 10
CaO	1 … 5
Na_2O	1 … 7
N	0.5… 10
F	0.5… 11
Cu	0.1… 0.5

One factor which makes the treatment, and also land filling of aluminium salt slags and cakes and ball mill dusts more difficult is the reactivity of some constituents of the "oxides". Compounds such as AlN, Al_4C_3, AlP, Al_2S_3, etc., but also fine aluminium metal are unstable under normal ambient conditions in contact with moisture and are decomposed exothermically, producing poisonous (ammonia, phosphine, hydrogen sulphide), and explosive gases (hydrogen and methane).

20 years ago aluminium salt slag and salt cake as well as ball mill dust represented the end of the economically useful aluminium metal cycle.
They were (and are) dumped in landfill sites as waste, although they contain substantial amounts of valuable substances. Salt slag was only processed in a few rare instances; the only recovery practiced was generally the relatively simple recovery of coarse metal particles by dry crushing and screening (i.e. nugget picking).

ALSA (a subsidiary of GET GmbH) was the first company to implement processes in their plants for recovering all the valuable components, starting in the middle of the 1980s in Germany.

Driven by a wide variety of remelting procedures resulting in various salt slags and cakes, the complicated chemical and mineralogical compositions of the substances previously mentioned, and the dangerous reactions already described, the principle followed when developing the first generation of ALSA plants was that of maximum safety. That meant that every step in the process and every chemical reaction was carried out in its own plant part or machine. The residence time in the plant was accordingly relatively long (up to 20 hours), and a total of 14 process steps had to be carried out.

This principle ensured primarily stable operation and constant product quality, even with heavy fluctuations in raw material properties. However, it required relatively high investment and operating costs.

Since then, ALSA has shown in their plants in Germany that in principle, all kinds of aluminium salt slag, salt cake and ball mill dust can be processed. They have also shown that all the products (Al-granulate, melting salt and oxides) can be produced in stable quality, and can also be reintroduced into the market place.

The metal granulates and melting salts have in the meantime become sought-after raw materials for secondary smelters. The oxides are sold under the name "SEROX", as a raw material for the production of cement, high alumina cement and rock wool, among others. The process operates without waste, i.e. without land filling.

Based on some 15 years experience in the operation of Al salt slag processing plants, the GET subsidiary ALSA GmbH (ALSA) developed a new treatment concept in the late 1990s.

The aims were:
- a simplified process in technical terms
- a plant type that is cost competitive to land filling everywhere in the world.

The principle was implemented for the first time at the RAQ plant in Becancour / Canada. This plant, with an annual capacity of 50,000 mt, processes the salt slag produced by RAQ when re-melting dross. Some 10 Canadian Al primary smelters send their dross and dust to RAQ, with ALCOA as the biggest client.

GET is about to prepare the construction of another plant in Norway with a capacity of 70.000 metric tons of salt slag per year.

2. The new process

The new process was developed and tested step by step, based on many years of experience.

In keeping with the already mentioned principle of KIS (keep it simple), the process comprises only the following 8 (instead of 14 previous) steps:

- Pre-crushing of coarse material
- Wet milling and digestion
- Wet screening
- Filtration of screen undersize fines / brine clarifying
- Crystallisation of the salts
- Drying of the products
- Combustion of the process gases
- Off-gas scrubbing

Equipped with these features, the new plant generation offers every possibility to flexibly adapt the engineering and costs to local site conditions around the world, even for small dross remelting plants.

The following objectives were achieved, while still maintaining the necessary high safety standards:

- **Simplification by process integration**
- **Short residence time**
- **No waste**
- **Closed water loops**
- **High-quality products**
- **Prevention of metal losses**
- **High operational availability**
- **Utilization of process gases to generate process energy**
- **Observance of environmental standards and labour safety codes applicable at the facility site**
- **Compact design**
- **Possibility of modular plant design**

All in all, a continuous development has made the process much more economical to operate.
Thus, we are offering our customers a real alternative to landfilling - from the viewpoint of operating costs as well as of investment costs.

3. Technical details

"The devil is in the detail", as a saying goes. This applies particularly to the new generation of plant and equipment from ALSA and GET.
At first glance, there is a temptation to conclude: "What do you need the know-how from ALSA for? It's within everyone's capability! "

We would, in this connection, like to draw attention in the following to selected problems which need to be resolved for the operation of Al salt slag processing plants maintaining at the same time a high operational availability:

- Development of combustible and explosive gases
- Development of toxic gases
- Simultaneous milling of ductile, tough and brittle substances
- Handling and conveying of problematic materials, suspensions, gases
- harsh demands on construction materials (changing pH-ranges, ammonia, and chlorides)
- Fine Al-granulates of high quality
- Marketing of all the products

Especially the comprehensive marketing of all the products ensures the economical and ecological sustainability of the plant's operation. The marketing of the granulates and of the melting salts does not present any problems. It is a somewhat different matter for the oxides. They are, in principle, a high-grade Al2O3 raw material. Yet, outside ALSA, hardly any experience exists in practice regarding its use for portland cement or mineral wool production, for example. Initially, the customer needs intensive advice in connection with the very complex composition of this product in order to adapt the method of use to its particular properties. Besides the applications already mentioned, it has a potential for other high-grade uses which ALSA has developed. They include, for instance, use for aluminous cement, insulation of electrolytic cell bottoms, lightweight cellular materials, and fluxes respectively desulphurising agents for high-grade steels.

ALSA possesses the know-how necessary to resolve all the aforementioned problems. To a large extent it is knowledge that cannot be found in textbooks and can only be gained through many years of practical operation.

4. Conclusions

The trend in the aluminium recycling market is towards total recycling.

In the future it will be a matter of re-circulating the previously landfilled Al salt slag and ball mill dust to the production chain and of re-processing it into saleable products.

In the field of Aluminium salt slag reclamation there are various competitors working only on a few types of processing techniques.

Table 2: comparison of competing techniques in the field of Al salt slag treatment

features of technique	company	all kinds of slags and dusts processable?	cost competive to land filling?	waste-free?
crushing/milling/screening, pressurized digesting, recovery of Aluminium metal, recovery of KCl	K+S, Germany	no	in Germany	no
crushing/milling/screening, digestion, filtration, Recovery of Al-metal, partly oxide recovery and calcination	-Aluscan, Norway -AlumiTech,USA	no	Europe: yes USA: no	no
crushing/milling/screening, digestion, filtration, Aluminium metal and salt recovery , off-gas washing and burning,	-RE-Metall, Spain and UK -RVA, France -Alcoa, Italy	no	Europe: yes	partly
crushing, dry and wet milling/screening, digesting, oxide filtration and drying, recovery of fine and coarse metal, various salt grades, off-gas washing, closed water circuit	ALSA GmbH, Germany	yes	in Germany	yes
dry pre-crushing, wet milling and screening, fine and coarse metal, oxide filtration and drying, salt recovery, off-gas burning, closed water circuit	GET GmbH, Canada, Norway, ...	yes	generally yes	yes
White dross only No scrap No organics (oil,etc.)	Plasma Septor Al.Q.	no	no	Yes, but very limited

Despite of a lot of plants operating technically similar processing procedures only very few have reached stable cost covering and waste free operation.
That shows:

- that there are not only merely technical textbook problems that have to be solved but
- that a great deal of special know how and practical operating skills are necessary to operate a salt slag treatment plant safely and efficiently.

Of the operators shown above, only ALSA/GET offers a comprehensive solution of total recycling for all sorts of salt cakes and slags.

ALSA has demonstrated the feasibility of there process with its plants in Hanover and Lünen for more than 18 years. The have recently opened a new plant in Canada/Becancour and have a proposed plant in Norway (Karmoy).

ALSA started expanding by building and operating new plants only after having solved the main problems of Aluminium salt slag treatment and provided the evidence of practical feasibility and worldwide price competitiveness to land filling.

Under the roof of Global Environmental Technologies GmbH (GET), ALSA now offers an economically advantageous and ecologically sustainable alternative to landfilling on the basis of a new generation of state-of-the-art plant and equipment that enables the waste-free processing of Al salt slag and cake and ball mill dust.

ALSA knows that the future only belongs to the waste free and self-sustaining Aluminium salt slag reclamation techniques that are cost competitive to the land filling fees around the world.

ALSA now offers a concept based on many years of experience, which provides the following advantages ;

- processability of all types of Al salt slag, salt cake and mill dust
- freedom from waste and independence from waste disposal and landfilling prices
- independence from amendments in environmental legislation
- flexible response to changes in the aluminium market
- exclusion from environmental liability for waste materials and pollution legacies
- independence from melting salt prices
- minimized metal losses.