Recovery of Flux Salts from Black Aluminium Dross

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Abstract

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Aluminium smelter and re-melting operations generate a huge amount of industrial waste i.e. aluminium dross. This aluminium dross contains salts like NaCl and KCl which are hazardous for the environment.

Dross is classified based on aluminium content: high-grade (60–80 % aluminium, medium-grade (25–50 %), and low-grade/residual (< 25 %) based on recoverable metallic aluminium. India generates a huge amount of dross annually, mainly from primary production, recycling, and downstream processes. There are many research papers that report the hydrometallurgical methods that use aluminium dross to make aluminium alum and other products for industrial applications, these methods are also patented. Some of the recent applications of aluminium dross state its employment in manufacturing, refractory products, composite materials, concrete materials, and production of hydrogen, methane, and ammonia gases.

In recent years, extensive research has been done at JNARDDC on the recovery of flux salts at bench-scale and converting the residue into refractory to achieve the zero-waste concept. The paper reports the work expanded to salt-containing secondary dross (Black), recovering salts, and maximizing alumina content. More than 97 % of salts have been recovered during the process using leaching and precipitation. This approach transforms low-grade dross into a valuable alumina (> 98 %) source, converting refractory products. This will help the industry to curtail the expenses towards purchasing salt for metal recovery and save money.

This process will enhance the environmental sustainability of dross management by minimizing waste, enabling salt re-use, and alumina value addition. Also, a safe and cleaner technological process is the demand of time, and in this regard, the utilization of waste dross for the recovery of salt is an alternative to recycle/reuse which will not only reduce the slag generation but also solve environmental issues.

Keywords: Black aluminium dross, Sodium-Potassium Chloride salts, Dross slag, Refractory products.

1. Introduction

To produce secondary aluminium, the melting of aluminium scrap along with white dross is carried out within a rotary furnace, which contains an oxyfuel/air fuel burner [1–3]. The salt fluxes are added in the process to cover the surface of the molten aluminium bath. This will help in the agglomeration and separation of aluminium in molten form, within the solid oxide part, protecting the metallic aluminium from oxidation [4, 5]. The non-metallic components content will be entirely absorbed by this liquid flux, which generates a black color residue known as black dross (BD). Black aluminium dross (BAD) is a complex and contaminated byproduct formed during the secondary aluminium and aluminium dross recycling, mainly due to the use of chloride-based fluxes such as sodium chloride (NaCl), potassium chloride (KCl), and potassium aluminium fluoride (PAF). These fluxes, typically used in rotary furnaces in a 3:1 or 2:1 NaCl to KCl ratio, along with small amounts of fluoride salts like $KAlF_4$ or NaF, aid in metal recovery, prevent oxidation, and separate impurities. However, this process also leads to the generation of black dross, a residue containing salts, carbides, nitrides, and residual aluminium. This black dross is collected from the upper layer of the molten metal. Generally, 200–600 kg BD are generated in one tonne of aluminium metal, depending on the scrap mixture used [6, 7]. In 2013, it was reported that 1.1 million tonnes of BD were generated worldwide [7]. The black dross contains some amount of metal aluminium (Al), a high content of NaCl, KCl, Al_2O_3, and other impurities like Al_4C_3 and AlN. Because of these contents and properties like leaching and impurities (Al_4C_3 and AlN), BD is declared as a toxic and hazardous industrial waste. BD gives emission of NH_3, CH_4, PH_3, H_2, H_2S, etc., some poisonous, explosive and harmful gases if they come in contact with humidity [6, 8–11].

Iron, present in most aluminium scrap, forms intermetallic compounds like $FeAl_3$, while magnesium, especially from 5XXX series alloys, forms stable compounds such as MgO, Mg_3N_2, and $MgAl_2O_4$. These Fe- and Mg-based compounds increase the non-metallic content of black dross, reduce aluminium recovery efficiency, and make the recycling process more challenging compared to white dross from primary production. Hence, the further treatment and disposal of this BD is very necessary for the betterment of environmental impacts. The proper disposal in the landfill will also solve the purpose of groundwater pollution. This will be decided by the economic and justifiable regulations of the particular country.

In general, the dross treatment processing can be of two types: hot and cold processing techniques. for white dross processing, generally hot processing route is adopted. The industrial approach for processing of black dross is the cold processing technique, which is either a wet or dry process. In this process, the BD is trapped directly and dried naturally by spreading it on the open floor before any further treatment [3]. After drying naturally, it is crushed and sieved to separate out the aluminium metal content from the salt cake [3, 12]. The wet process involves water leaching. The insoluble oxides will be filtered out and can be taken for recycling and extraction, and the salts will be contained in the filtration water, which is then evaporated and crystallised to extract the salts [3, 8, 10]. The present studies focus on the recovery of salt from waste aluminium dross and the application of the remaining dross in suitable refractories.

2. Methodology

2.1 Sample Collection

About 100 kg of aluminium dross sample was collected manually (Figure 1) from Shanark Industries, Butibori, a wholesaler of aluminium products and aluminium alloy sheet in Nagpur. The whole sample was packed in a plastic bag. The utmost care was taken while transporting the sample to JNARDDC. The sample was found to be heterogeneous as it contains metals and oxides of aluminium.

2.2 Sample Preparation

The aluminium dross sample was prepared by crushing and grinding using a ball mill machine for around 30 minutes. After homogenizing the whole lot, the quantity was reduced to around 1 kg using the quartering and coning method to make a representative sample of the same lot.

The whole sample was treated as a lot. The dross sample was pulverized and classified into two main parts, lumpy and powder dross. Big-size metals shown in Figure 2 were separated by hand picking and kept separately. The rest of the sample was screened using a standard sieve of mesh no 5 (i.e. 4 mm). The powder-fine dross sample shown in Figure 2 was screened from medium-

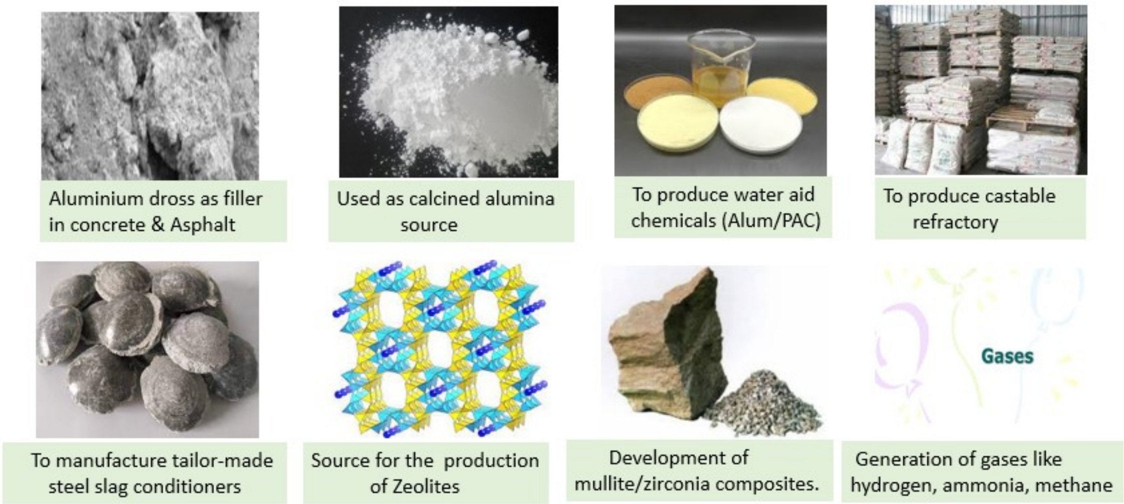

Figure 7. Commercial applications of residual dross.

4. Conclusions

- This process enhances the environmental sustainability of dross management by minimizing waste and enabling salt reuse.
- A safe and cleaner technological process is the demand of time and in this regard, the utilization of waste dross for recovery of salt from it is an alternative to recycle/reuse which will not only reduce the waste generation but also solve environmental issues.
- Process know-how for NaCl and KCl salt extraction and residual dross for suitable refractory applications.
- The dross residue after recovering the fluxes is rich in Al_2O_3 and can have potential refractory applications like filler in concrete & asphalt, as a calcined alumina source, water aid chemicals (Alum/PAC), castable refractory, steel slag conditioners, production of zeolites, mullite/zirconia composites, gasses generation like hydrogen, ammonia, methane, and others.

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