SPL and Red Mud: Value Creation from Hazardous Wastes

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Abstract

Spent pot lining (SPL) and red mud are well-known waste products from the aluminum industry and have been the cause of significant spending for all aluminum producers. The SPL generation rate is approximately 1 to 1.5 million tonnes per annum, representing a significant environmental burden to the aluminum industry. Previous reports indicated that more than half of the total amount of SPL generated is stored in lined or unlined sites or buildings, waiting for further treatment. Similarly, for every tonne of alumina refined, approximately 1 - 1.5 tonnes of red mud is generated. While disposal and storage options exist, there is a clear and present need for better ways in managing wastes from the primary aluminum industry. At the University of Toronto, the Process Metallurgy Research Labs in collaboration with Dastur Innovation Labs are working extensively to understand the chemistry of SPL and red mud and extract value out of these wastes. Some of the potential values of SPL are: (a) as a flux in the non-ferrous industry (b) as an alternate to coal in ironmaking blast furnaces and (c) as a carbon injection source in the electric arc furnace (EAF). The value of red mud can be realized as a flux for the more efficient desulphurization and dephosphorization of steel, which saves the steel industry significant costs by reducing process times. Experimental and simulation techniques along with economic assessments have been performed to test these ideas, and the results and feasibility are discussed in detail.

Keywords: SPL, red mud, waste to value, experiments, simulation.

1. Introduction

Spent pot lining (SPL) is a by-product of the aluminum industry, obtained from the used Hall-Héroult electrolytic cells. A typical Hall-Héroult cell is schematically shown in Figure 1 below [1]. Due to a very high melting point of alumina (2045 °C), it is dissolved in cryolite (Na_3AlF_6) to lower its melting point to 970 °C. Molten alumina is then reduced electrochemically with carbon electrodes via the following reaction:

$$C(s) + 2O^{2-}(l) \rightarrow CO_2(g) + 4e^- \text{........ oxidation at anode}$$

$$Al^{3+}(l) + 3e^- \rightarrow Al(l) \text{ .... reduction at cathode}$$

$$2Al_2O_3(l) + 3C(s) \rightarrow 4Al(l) + 3CO_2(g) \qquad (1)$$

During the electrolysis process, other products are also formed due to diffusion of fluorides into carbon cathode blocks, leakage of air into the bath, or absorption of the electrolyte into the refractory lining. These reactions, along with the consumption of the carbon electrodes, lowers the overall cell efficiency, necessitating cell replacement after 5 to 8 years [1]. While the outer steel shell can be reused, the remaining cell material comprising of solidified electrolyte, refractory lining and electrodes, known as spent pot lining (SPL), is usually discarded. The material above the collector bar (depicted in Figure 1) comprises mostly of carbonaceous components and is referred to as 1st cut SPL, whereas the material below comprises mainly of refractory silicates and is referred to as 2nd cut.

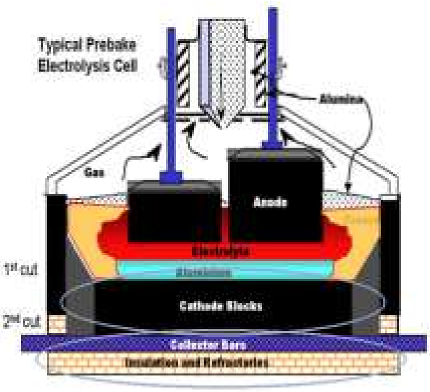

Figure 1. Schematic of a typical Hall-Héroult Cell [1].

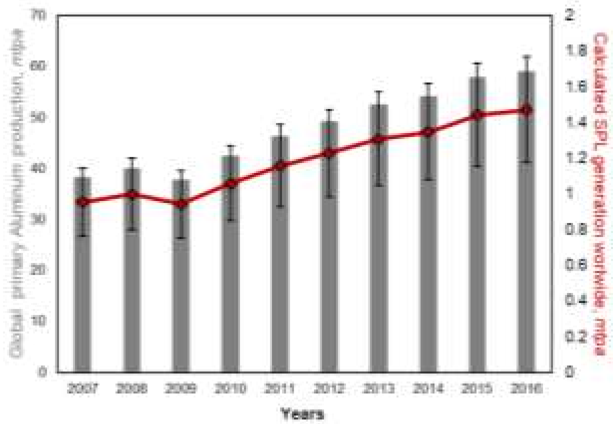

Figure 2. Global production of primary aluminum (based on [20]) and SPL (calculated).

SPL is classified as a hazardous waste material in 1988 by the U.S. Environmental Protection Agency (USEPA) [2, 3] and as a special waste in Canada [4] due to the presence of leachable cyanides and fluorides. The compositions of SPL vary widely [2, 4-6, 7-19], on account of variation in the cell lining components, dismantling procedures, and time under operation.

The production of global primary alumina increased from 40 to 60 Mtpa during the time period of 2007 - 2016 [20]. Considering approximately 25 kg of SPL generation per ton of primary aluminum produced [8], the global SPL generation rate can be approximated to have risen from 1 to 1.5 Mtpa during the same time period. This presents a significant environmental burden to the aluminum industry. The variation of primary aluminum production and approximated SPL generation rates is depicted in Fig. 2. The current SPL disposal options are as follows:

a) Secured landfills which require costly remediation [10],
b) Use as a feedstock for other industries (e.g. steelmaking [18, 21], mineral wool industry),
c) Fluidized bed combustion [17]
d) Pyrohydrolysis and pyrosulfolysis [2]
e) Fuel in aluminum cast house burners [22]

capacity. Further innovation in utilizing SPL and red mud as value-added byproducts rather than hazardous waste streams to be mitigated will allow for the aluminum industry to obtain forward momentum and become a more sustainable industry. Future work includes the development of AlF_3 crystals from SPL for medical drug applications and also ways to remove fluorides from SPL to avoid the detrimental of sooty NaF during combustion applications.

7. References

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