Low Bulk Density vs High Bulk Density Aluminium Fluoride: A Comparative Study on Flowability and Practical Applications in Aluminium Smelting

Hanna Sjöberg[1] and Jesper Holmquist[2]
1. CEO
2. Commercial Director
Alufluor, Helsingborg, Sweden
Corresponding author: hanna.sjoberg@alufluor.com

Abstract

Aluminium fluoride (AlF_3) plays an instrumental role in primary aluminium production, acting as a flux and reducing energy consumption significantly. While high bulk density (HBD) AlF_3 is conventionally utilized, the lesser-known low bulk density (LBD) variant, produced using recycled fluorine from the fertilizer industry, represents an eco-friendly alternative. Alufluor is a global LBD producer based in Sweden. Only 13 % of the total global aluminium fluoride volumes are LBD, despite the fact that there are several sources of unutilized fluorosilicic acid in the world. This study aims to debunk misconceptions about LBD AlF_3 flowability, a critical factor for efficient material transportation and feeding to electrolysis pots. A series of flow property tests, carried out by the University of Wollongong in collaboration with Rio Tinto, demonstrated comparable flowability between Alufluor's LBD and typical HBD AlF_3 of high quality, substantiated by experiences from various smelters. Our findings advocate for broader LBD AlF_3 acceptance, presenting it as an efficient, sustainable choice with excellent flowability. The transition from HBD to LBD is seamless, as verified by several smelters, underlining the product's operational versatility and potential for sustainable aluminium production.

Keywords: Aluminium fluoride, Flowability, Sustainability, Circularity, Low bulk density.

1. Introduction

1.1 Aluminium Fluoride in Aluminium Smelting

Aluminium fluoride (AlF_3) plays a crucial role as an additive in the production of aluminium. In the Hall-Héroult process, metal aluminium is extracted from alumina through electrolysis. The liquid bath which is used in the electrolysis is Cryolites which acts as flux, stabilizing the process and lowering the temperature of the melt. AlF_3 is added to the bath to form cryolite when reacting with sodium, present as a trace element in the alumina. With the lowered melt temperature, energy consumption is reduced.

1.2 The Alufluor Process and Product

Alufluor AB is a Swedish AlF_3 producer, owned by Yara and Rio Tinto. At Alufluor, the fluorosilicic acid (FSA) process, also called wet process [1], is used to produce AlF_3. Fluorosilicic acid and aluminium tri-hydroxide (ATH) react according to:

$$H_2SiF_6 + 2\ Al(OH)_3 \rightarrow 2\ AlF_3 + SiO_2 + 4\ H_2O \qquad (1)$$

The FSA raw material is a by-product from other industries, including the fertilizer industry, from where it is often deposited as waste, however in this case recovered and used to create value.

The main application of the formed AlF_3 is aluminum smelting, however the company also provides purer grades of the products used in manufacturing of optical lenses, dental fillings, surface treatment and more. The formed silica is a by-product, which is collected, treated and sold as a product to other applications, as is every by-product or waste coming from the Alufluor operations. Silica is partly recycled back to the fertilizer producers where it is added to the process to capture new fluorine as FSA, hence closing a circular process.

Around 13 % of the global production of AlF_3 is produced with the FSA process [2]. The rest is instead produced in the more common dry process, where fluorspar is used as fluorine source instead of FSA. As fluorspar is a virgin raw material in scarcity, there are obvious benefits with the recycling of fluorine to be used to produce AlF_3 with the FSA process.

1.3 Low-Bulk and High-Bulk Density Aluminum Fluoride

The AlF_3 produced using fluorosilicic acid or fluorspar as a fluorine source results in the same chemical compound, AlF_3. However, the macroscopic properties of the material differ. The FSA based variant, as in the Alufluor case, has a lower bulk density and is referred to as low bulk density (LBD) AlF_3. Conversely, the fluorspar-based variant of higher bulk density is called high bulk density (HBD).

An AlF_3 product is typically ranging between 90-97 % actual aluminium fluoride, also much connected to whether the product is HBD or LBD, where the LBD products are often in the higher concentration range and HBD in the lower. The content of impurities in the product also differs between products, with typically lower impurities present in LBD.

In the table below, typical specifications for HBD products are compared with the specification of the LBD produced by Alufluor.

Table 1. Properties of aluminium fluorides of different bulk density.

	Typical HBD	**Alufluor LBD**
Bulk density	1500 kg/m^3	800 kg/m^3
Active content	90-91 % AlF_3	97.5 % AlF_3
Purity Non AlF_3 P_2O_5 (%) SiO_2 (%) LOI (%)	 9 0.01-0.02 0.05-0.15 0.5	 2.5 0.006 0.08 0.6
Fluorine source	Fluorspar	Fluorosilicic acid
Function in smelter	Excellent	Excellent
Flowability/transportation	Excellent	Excellent
Particle size distribution	<45 µm 8 %	<45 µm 3 %

2. Flowability

2.1 The Importance of Flowability Properties in Aluminium Fluoride

Flowability is a fundamental property for powders, such as aluminium fluoride, which significantly influences their handling and performance in various applications. Essentially, flowability refers to the ease with which a powder flows, without clumping, caking, or jamming during handling. Particle size distribution, shape, inter-particle interactions and other intrinsic properties impact the flowability of a material. High flowability implies that the material flows freely.

Testing various ratios of LBD and HBD have resulted in in protocol for supply shortage scenarios, where an 11 % blend of LBD is used on lines that typically operate with 100 % HBD, without necessitating any changes in operational parameters.

The company also has good experience in running some of their potlines solely with LBD products.

5. Conclusions

The study conducted at the University of Wollongong has demonstrated comparable flowability between Alufluor LBD and traditional HBD. The study encompassed a diverse array of tests aimed at elucidating the flowability properties under varying conditions and applications. In light of these findings, the common perception in the industry that LBD inherently has inferior flowability characteristics has been debunked. The flowability index of Alufluor LBD, a measure of its cohesive strength, was determined to be low, indicating that it possesses high flowability under both instantaneous and three-day storage conditions. Experience from the market indicates that poor flowability is highly connected with particle size distribution, but not to bulk density.

Regardless of smelter size, location, or the technology implemented for material feed, Alufluor LBD has exhibited exceptional performance with no recorded issues. These empirical experiences, coupled with the technical study, support a wider acceptance of LBD in aluminum smelting processes.

LBD AlF_3 presents a more sustainable alternative for aluminium production due to its recycling of fluorine from the fertilizer industry. While conventional AlF_3 production relies on mining of the scarcer fluorspar, the production of LBD AlF_3 utilizes FSA, a by-product from various industries, including the fertilizer industry. By increasing the aluminum industry's utilization of LBD AlF_3 in place of HBD AlF_3, a more circular and sustainable manufacturing process can be achieved.

6. References

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