Improvement in Sodium Reduction Process During TAC

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Abstract

The Treatment of Aluminium in Crucible (TAC) process, integrated to sodium reduction skimming stations in Emirates Global Aluminium (EGA) Al Taweelah smelter, consists essentially in the addition of aluminium fluoride (AlF_3) to the molten metal during the first seconds of agitation and resulting in removal of alkali metal components through the formation of stable fluoride compound. This entire operation is to reduce aluminium oxidation and avoiding factors that could impact the performance of the final aluminium products. Despite its effectiveness, this process incurs substantial costs, due to the consumption of AlF_3 and TAC rotors. The continuous recirculation of AlF_3 particles in the molten metal induces erosion and abrasion on the TAC rotor, that necessitates frequent replacement and escalating maintenance and spare costs. In 2021, 861 t of high bulk density AlF_3 costing 4.9 MUSD were consumed. The use of high density AlF_3 with sharp and abrasive crystal faced particles for metal treatment leads to micro-cutting and more severe erosion and abrasion resulting in higher consumption of rotors. Comparing to low bulk density AlF_3 with rounded shape particles, micro-ploughing and built-up wedges were mainly observed. This leads to lower erosion and abrasion of the rotor surface. This paper proposes the optimization of TAC operation to achieve the required metal quality and process efficiency, while reducing the cost associated with AlF_3 and TAC rotors consumption. Consequently, it is proposed substituting high bulk density AlF_3 with low bulk density AlF_3 for molten metal treatment. This change aimed to reduce erosion and abrasion on the TAC rotor, thereby prolonging its lifespan and reducing operational costs. Indeed, the implementation of low bulk density AlF_3 yielded to promising results by achieving a remarkable 39 % reduction in AlF3 consumption, as compared to the initial target of 20 %, with operating life greater than 600 cycles per rotor. This represents a substantial reduction of 54 % in rotor consumption. These improvements not only enhanced process efficiency but also generated significant and validated savings of approximately 0.6 MUSD.

Keywords: Sodium reduction of molten aluminium, Low bulk density aluminium fluoride, Skimming station, Treatment of aluminium in crucible, Cost reduction.

1. Introduction

Treatment of Aluminium in Crucible (TAC) is a critical process used in EGA's Al Taweelah smelter. This process, integrated with sodium reduction skimming stations, involves the addition of aluminium fluoride (AlF_3) to molten aluminium. The primary objective is to remove alkali metal components, which can otherwise adversely affect the aluminium properties and performance. However, the traditional use of high bulk density AlF_3 leads to significant wear and tear on TAC rotors, incurring high costs for replacement and maintenance.

2. Background of the Process

The TAC process involves adding AlF_3 to molten aluminium during the initial seconds of agitation. This addition helps in forming stable fluoride compounds, which effectively remove alkali metals from the aluminium. This step is crucial in reducing oxidation of aluminium and maintaining the quality of the final product. Despite its effectiveness, the process is costly due to the consumption of AlF_3 and the wear on TAC rotors. In 2021, the smelter consumed 861 t of high bulk density AlF_3, costing approximately 4.9 MUSD. Figures 1 and 2 show the equipment at a sodium reduction skimming station.

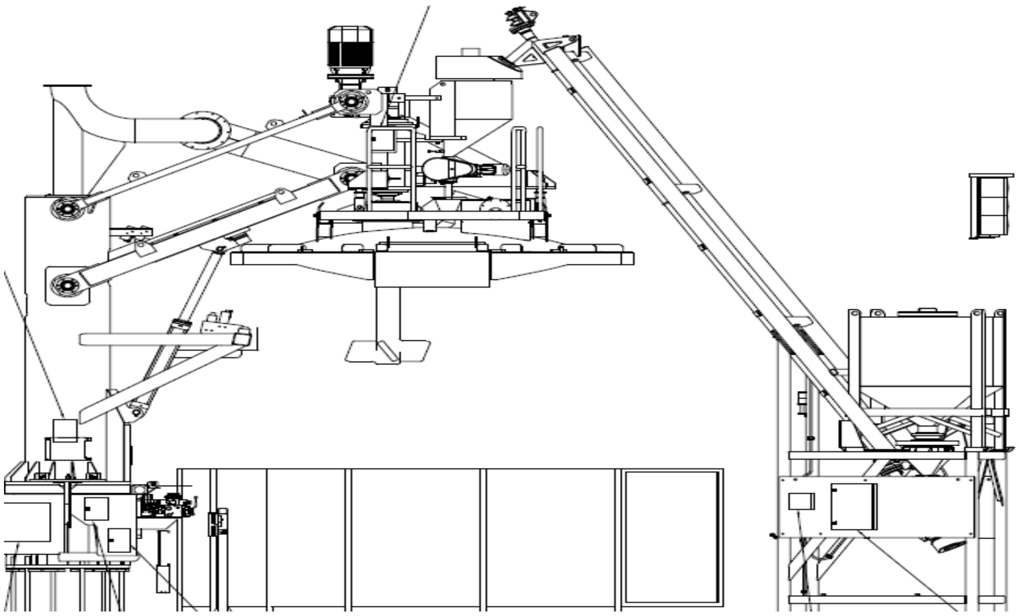


Figure 1. Sodium Reduction Skimming Station: Rotor and ALF$_3$ handling equipment [1].

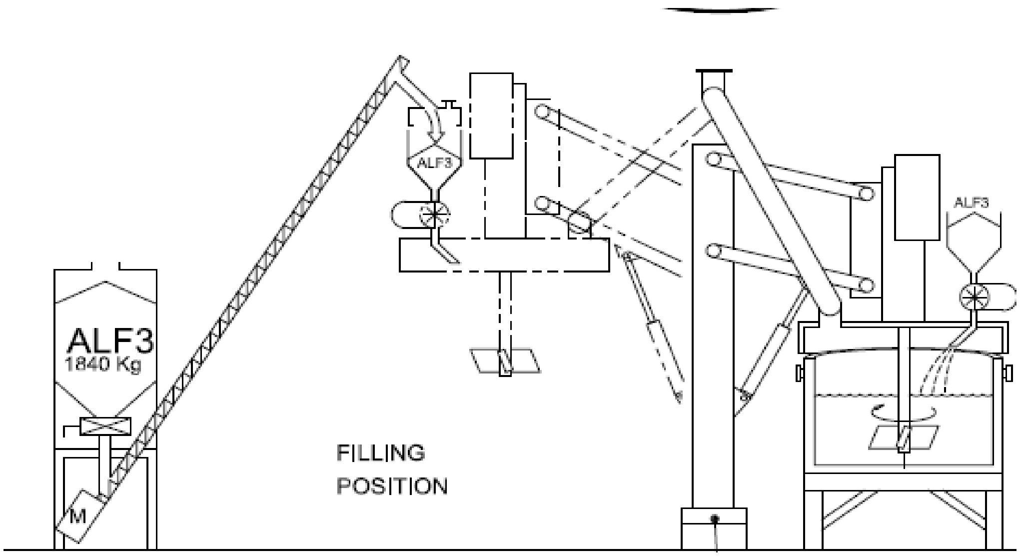


Figure 2. Metal treatment with AlF$_3$ and rotor and allied equipment [1].

3. Use of High Bulk Density (HBD) AlF_3 for Metal Treatment

Traditionally, HBD AlF_3 has been used for the TAC process due to its effectiveness in removing alkali metals from molten aluminium. However, the sharp and abrasive particles of HBD AlF_3 (refer to figure 4) lead to micro-cutting, causing severe erosion and abrasion on the TAC rotors. This results in frequent rotor replacements and high maintenance costs, impacting the overall cost-efficiency of the smelter operations.

Figure 3 explains the process of AlF_3 feeding into molten aluminium and its impact on rotor impeller blades, AlF_3 powder is being added in controlled quantity into the crucible in enclosed environment where rotor attaches with lid.

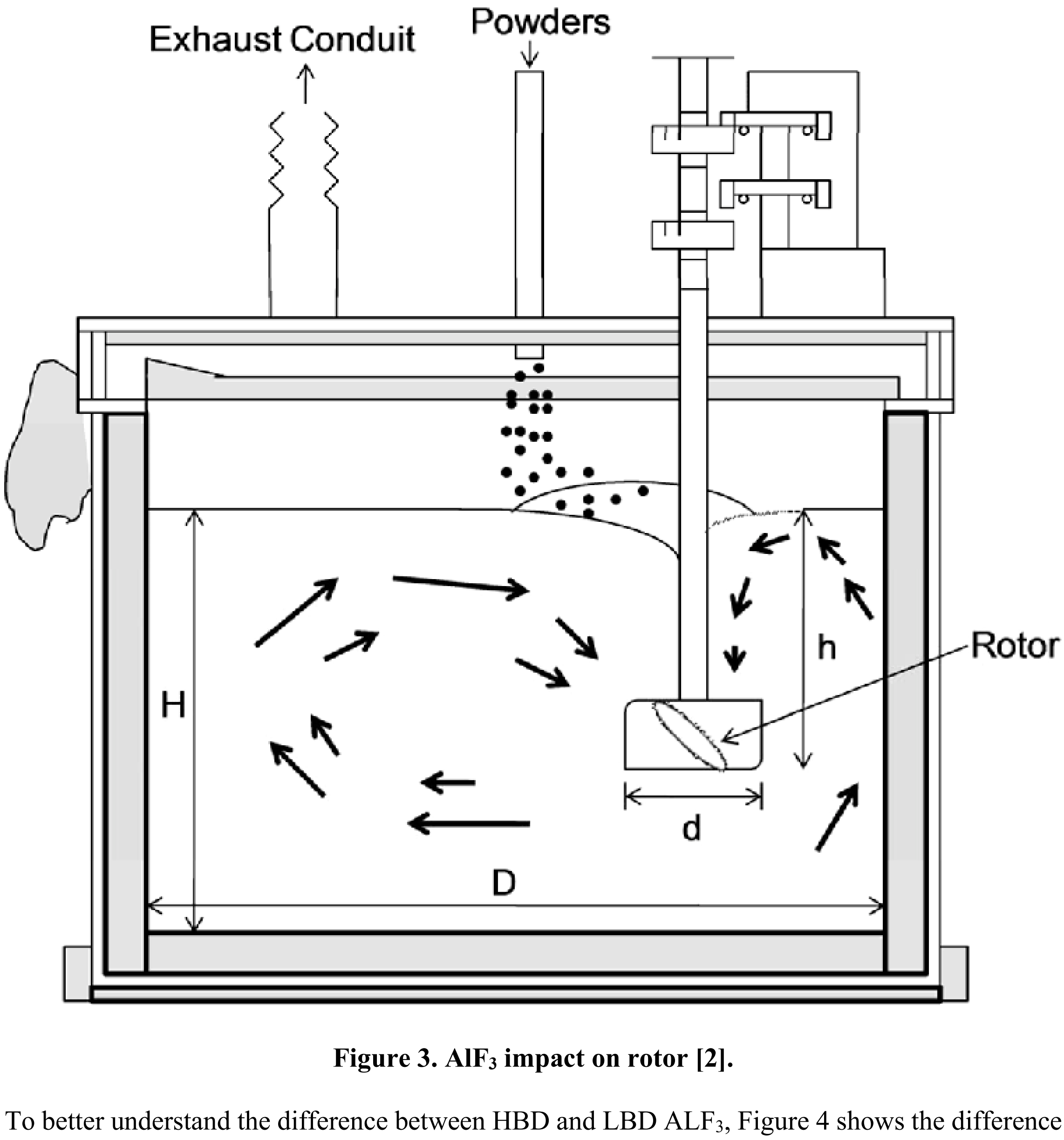


Figure 3. AlF_3 impact on rotor [2].

To better understand the difference between HBD and LBD ALF_3, Figure 4 shows the difference between LBD and HBD AlF_3 particles using SEM.

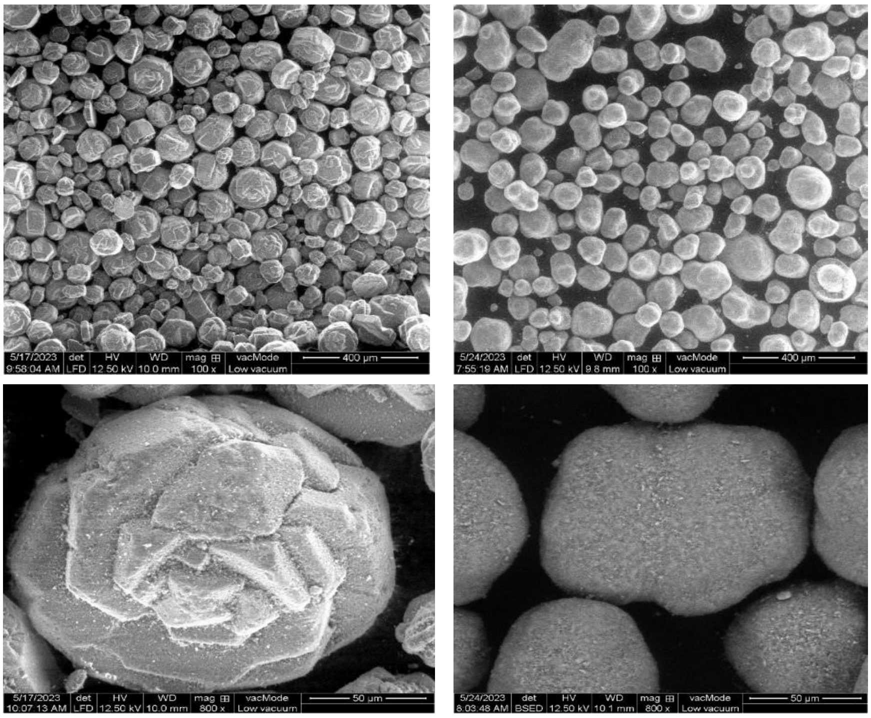


Figure 4. AlF_3 HBD (right) and LBD (Left) under scanning electron microscope.

4. Challenges and Cost Implication

In 2021, the use of HBD AlF_3 led to the consumption of 861 t, costing 4.9 MUSD. The continuous wear on the TAC rotors required frequent replacements, further increasing maintenance costs. This high-cost structure prompted the investigation into alternative solutions to optimise the process.

Figure 5 presents the mechanisms of erosion and abrasion and impact of AlF_3 on rotor surface particularly rotor blades.

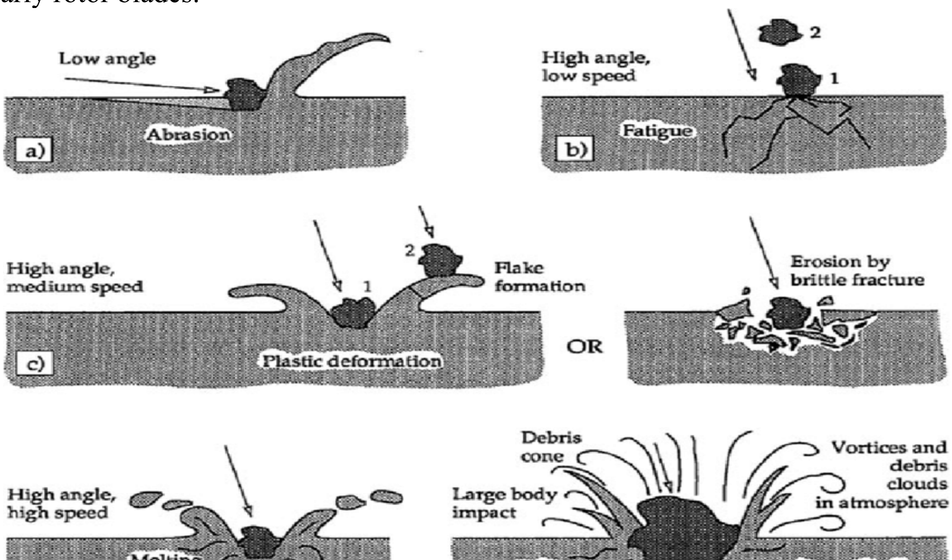


Figure 5: Erosion and abrasion mechanism [3].

Despite the higher cost of AlF_3 HBD, Figure 6 shows how the HBD particles impact the rotor surface and impeller blades.

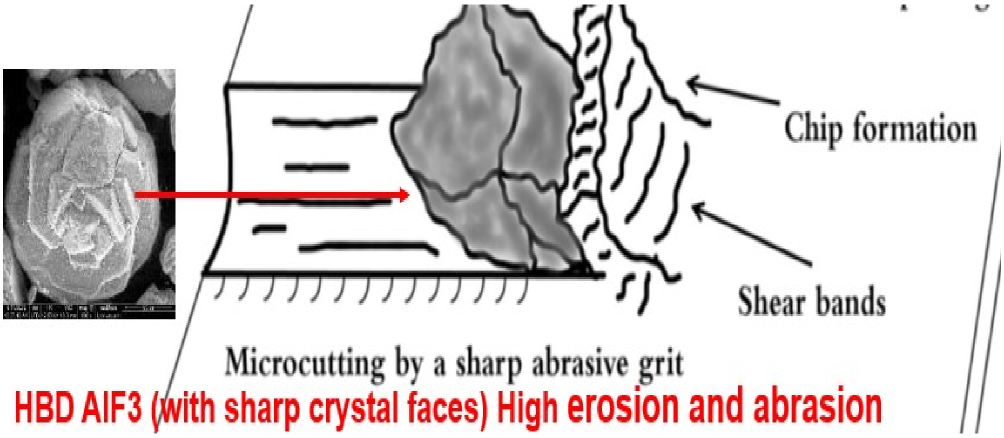


Figure 6. High erosion and high abrasion due to HBD AlF_3 particles [4].

Real time picture of rotor where erosion and abrasion are visible is shown in Figure 7.

Figure 7. Condition of replaced rotor with eroded impeller blades.

5. Use of Low Bulk Density (LBD) AlF_3 and Impact on Operation and Rotor

To address the high costs and rotor wear, a proposal was made to substitute high bulk density (HBD) AlF_3 with low bulk density (LBD) AlF_3. LBD AlF_3 has rounded particles, which are less abrasive compared to the sharp, crystalline particles of HBD AlF_3 (Figure 8). This change aimed to reduce the micro-cutting and severe erosion that occur during the process. Initial results from this substitution were promising, with a significant reduction in AlF_3 consumption and less wear on the TAC rotors.

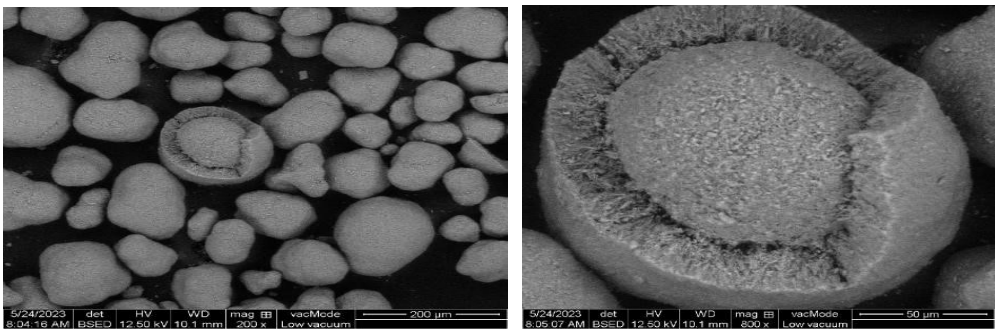


Figure 8. Low bulk density AlF_3 particles under scanning electron microscope.

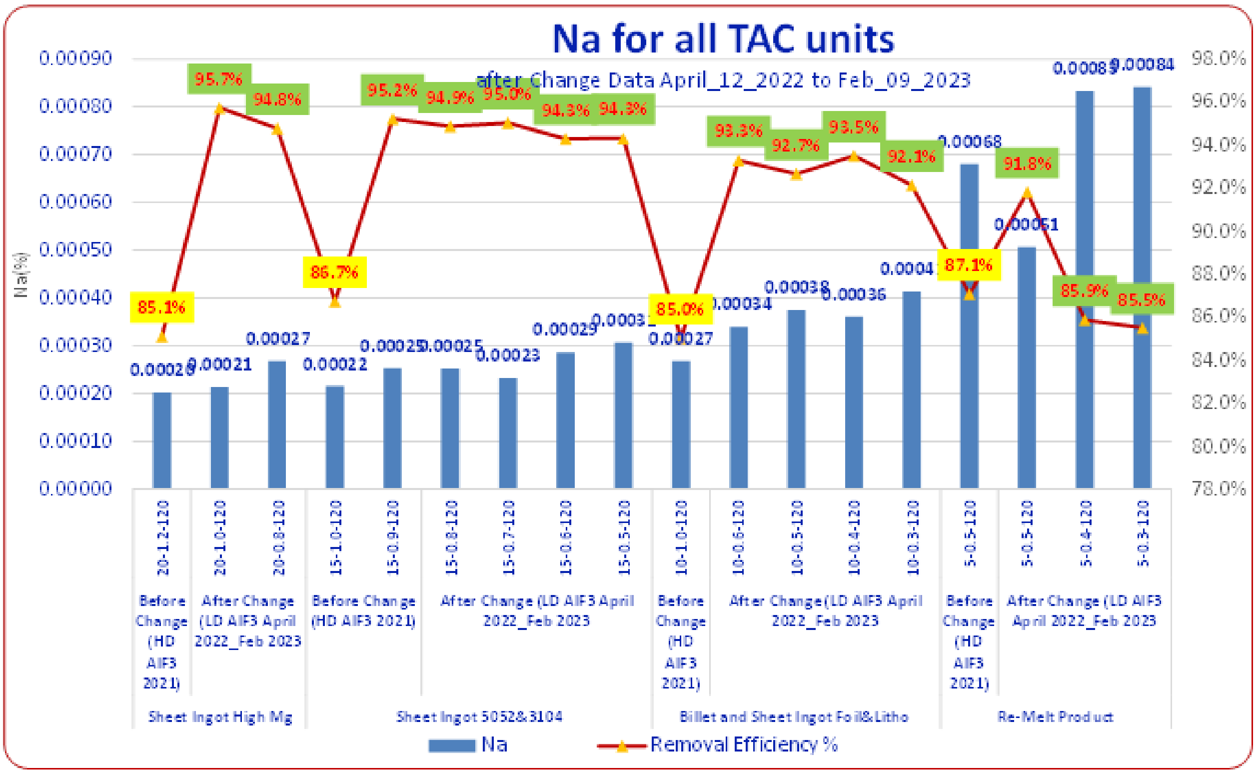
Main parameters of AlF_3 comparing high bulk density with low bulk density material are given in Table 1.

Table 1. Comparison of LBD and HBD AlF_3.

Sample No.	Key Parameters	Unit	LBD	HBD
1	Purity as AlF_3	%	95 min	90 min
2	Free Al_2O_3	%	5.00 max	9.00 max
3	P_2O_5	%	0.04 max	0.03 max
4	SiO_2	%	0.15 max	0.28 max
5	Fe_2O_3	%	0.05 max	0.05 max
6	SO_4	%	0.50 max	0.50 max
7	Na_2O	%	0.30 max	0.67 max
8	CaO	%	0.098 max	0.67 max
9	LOI at 550 °C for 1.2 h	%	1.45 max	0.068 max
10	Bulk density	kg/m³	750 max	1 350 max
11	Angle of repose	Degrees	35	35
12	Flowability	s	160	60
13	+ 20 Mesh	%	NIL	NIL
14	- 325 Mesh	%	15 max	25 max

6. Operational Changes Impact on Operation and Improvements in Process and Rotor Operating Life and Benefits

The implementation of LBD AlF_3 resulted in a 39 % reduction in AlF_3 consumption, far exceeding the initial target of 20 %. This reduction not only lowered material costs and improved process efficiency but also lowered the frequency of rotor replacements. The rounded particles of LBD AlF_3 led to less severe erosion and abrasion on the TAC rotors (Figure 9). The operating life of the rotors increased to over 600 cycles per rotor. The rotor replacement rate decreased by 54 % from 126 replacements in 2021 to 58 replacements in 2022 (Figure 10). These improvements translated into operational efficiency and substantial cost savings of approximately 600 kUSD.



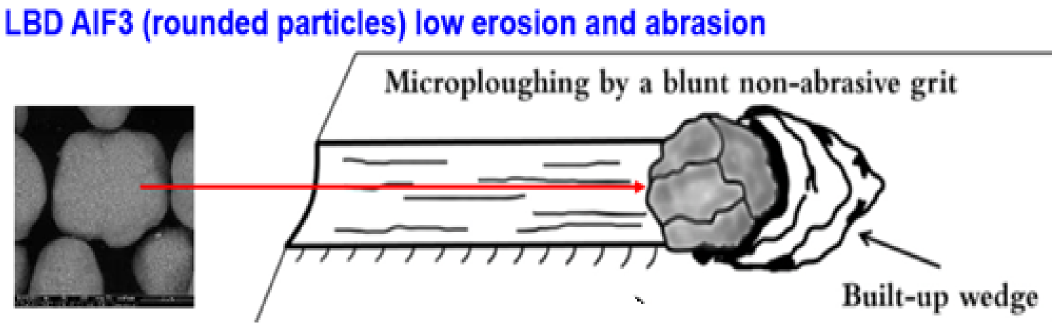


Figure 9. Low erosion and low abrasion due to LBD AlF_3 particles [3].

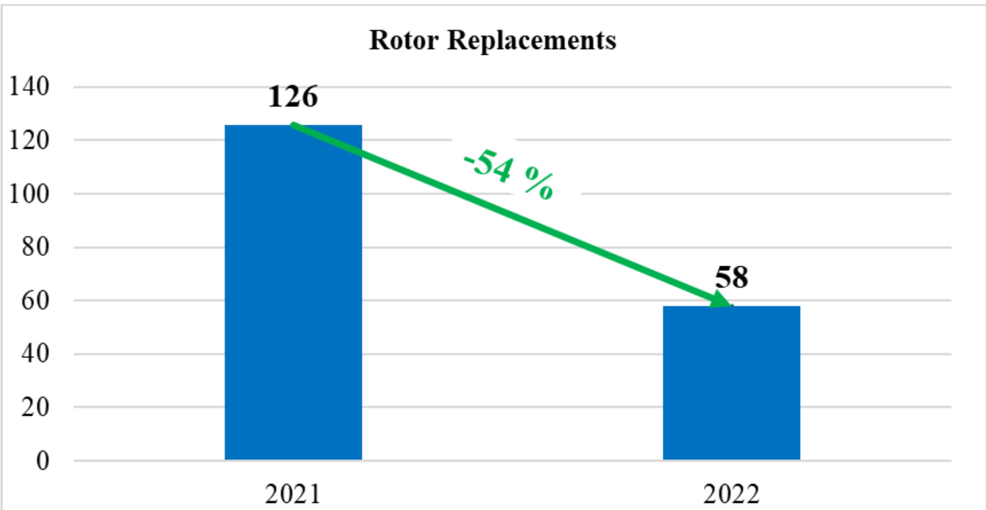


Figure 10. Improvement in rotor life by using the LBD AlF_3.

7. Learning from the Project

The successful substitution of HBD AlF_3 with LBD AlF_3 highlights the importance of optimising material properties to enhance process efficiency and reduce costs. Key learnings from this project include:

1. The importance of particle shape and density in reducing wear and tear on machinery.
2. The significant cost savings achievable through material optimization.
3. The need for continuous monitoring and adjustment of operational parameters to maximize efficiency and lifespan of equipment.
4. This project demonstrates that with careful analysis and strategic changes, substantial improvements in process efficiency and cost savings can be achieved in industrial operations.

8. Conclusions

The optimization of the TAC process through the substitution of high bulk density AlF_3 with low bulk density AlF_3 has proven to be a successful strategy in reducing operational costs and improving process efficiency. The reduction in AlF_3 consumption and the extended lifespan of TAC rotors have resulted in significant cost savings and enhanced the overall performance of the smelter. This case study underscores the value of continuous process improvement and material optimization in achieving operational excellence in the aluminium industry.

9. References

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