Reduction of Specific AlF_3 Consumption in Hindalco Hirakud Smelter

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Abstract

Hirakud Smelter (HKD), a unit of Hindalco Industries Limited is a part of Aditya Birla Group (ABG). Hirakud Aluminium is an integrated aluminium smelting complex which uses GAMI Technology and is one of the oldest smelters in India, established in 1959. The potlines, converted from Søderberg to prebake in 2009, have inherent challenges in terms of technology and retrofitting the old pots to prebakes.

Aluminium production is a continuous process. Addition of aluminium fluoride is today a well-established practice in the operation of industrial aluminium electrolysis cells. The main purpose with this additive is the lowering of the melting point and its beneficial effect with respect to reducing the solubility of metallic aluminium in the electrolyte. The composition of the electrolyte changes continuously during electrolysis. In addition to alumina, which is consumed in the process, the concentration of excess AlF_3 also varies due to several reasons, the main one being reaction with soda (Na_2O) and moisture that enters the electrolyte:

$$3\ Na_2O + 4\ AlF_3 = 2\ Na_3AlF_6 + Al_2O_3 \tag{1}$$

$$2\ Na_3AlF_3 + 3\ H_2O = 6HF + Al_2O_3 + 6NaF \tag{2}$$

AlF_3 being very costly raw material, the smelters are trying to reduce specific AlF_3 consumptions to reduce the emissions and the cost of the metal. Hindalco Hirakud smelter being oldest smelters, many initiatives taken in last one year to reduce the specific AlF_3 consumptions. This paper describes the action taken by the smelter team to reduce the AlF3 consumptions.

Keywords: Aluminium reduction cell, AlF_3, Fume Treatment Plant (FTP).

1. Introduction

The aluminium smelting process at Hirakud Smelter involves the use of AlF_3 as a crucial additive to reduce liquidus temperature for the reduction of alumina to aluminium. Aluminium fluoride for commercial use in Aluminium smelters is typically manufactured by two processes. The “dry” process uses fluorspar as the source of fluoride. The “wet” process uses fluorosilicic acid as the fluoride source. Aluminium fluoride is used as a bath additive, to maintain a desired excess fluoride target in the bath [1-3]. The main purpose of this additive is the lowering of the liquidus temperature and its beneficial effect for reducing the solubility of metallic aluminium in the electrolyte. The composition of the electrolyte changes continuously during electrolysis. In addition to alumina, which is consumed in the process, the concentration of excess AlF_3 will also vary due to several reasons, the main reason being the reaction with soda and moisture that enter the bath with alumina, according to the Equations (1) and (2).

Evaporation of $NaAlF_4$ is another factor that affects the AlF_3 balance of the cells. The water in alumina reacts with the fluoride in the bath to form HF according to the Equation (3):

$$3H_2O + 2AlF_3 \rightarrow 6HF + Al_2O_3 \quad (3)$$

To compensate these losses and to maintain desired excess AlF_3 in pot bath, charging of aluminium fluoride is essential in pots. However, the high consumption of AlF_3 not only translates to increased operational costs but also has environmental implications. Being the oldest smelter and having technological constraints in Hirakud, this paper aims to explore and propose strategies for reducing the specific AlF_3 consumption in the smelting process at Hirakud Smelter while maintaining operational efficiency and productivity. To compete in the global market in terms of sustainability and higher productivity with quality, each smelter must work strongly on the probable factors which might have appeared as major setbacks in the future. Most modern smelters are adopting innovative approaches to have minimum losses in the potline and have a stable operation. Similarly, Hirakud Smelter also had to find ways to minimize losses, to improve efficiencies of fume treatment plants as well as potlines, to optimize process parameters and thereby reduction in aluminium fluoride consumption in the potline.

2. Brief Description of FTP

The function of FTP in a potline, is to extract fumes from the pots, extract and recycle HF, and release clean air into the atmosphere. Major components of the fumes are:

a. Fluoride (gaseous and particulate)
b. Particulate matter (alumina)
c. CO, CO_2 and SO_2.

As a part of the FTP design, before releasing into atmosphere, the fumes are scrubbed with alumina.

FTP consists of the following main subsystems:

a. Ducting network – To collect fumes for individual pot and taking them to the FTP baghouse.
b. Baghouse – To collect particulate matter across filter media. At this part, alumina interacts with fumes to get maximum adsorption and HF is trapped. Cleaning of filter media is done at regular frequency.
c. Induced draught (ID) fan system – to create negative suction in the entire system.

At Hirakud, there are five pot lines. Lines 1-4 are operated at 85 kA, and Line 5 at 235 kA. In 85 kA, there are three FTP's – FTP 1, 2 and 3 and in 235 kA potline – FTP 4. All the FTPs are catering the requirement of 12 potrooms.

3. Challenges Faced in FTP

FTP-1 system collects fume Line-1 and PR-8 pots. Ideal location of FTP should be between two adjacent pot rooms of a line, but in case of FTP-1 it is located after Room 4 of Line-1 as the Line-1 pots are converted from Søderberg to prebake. Total ducting length of FTP-1 is approximately 1 km with many bends. So, we were not able to collect all the fumes from pots due to large pressure drop across the double layered ducting system with numerous bends and damaged ducts in the ducting system; this was impacting FTP performance and less enrichment of FTP secondary alumina. Enrichment of alumina has direct impacts on AlF_3 consumption which is a major raw material of aluminium production.

Besides these, the following challenges were persisting in FTP system:

- The lateral ducts connected to FTP-1 are 70 % jammed from inside (Figure 1) since they are from Søderberg time. This was creating restrictions in proper fume suction from individual pots to FTP.
- As the duct-lines were more than 20 years old, at many places the lateral and branch ducts were corroded, damaged and beyond repair. This was leading to external air/water ingression affecting potroom process.
- Unbalanced fume flow in east and west sides of the FTP-1 & 2 inlet ducts.
- Disruption in pulsing valves (hang valves) and deformation in valve body due to aging.
- Issue in pulsing valve solenoid arrangement system.
- Design issue.

Figure 1. Jammed fume ducts.

4. Challenges Faced in Potroom

Apart from operational challenges, inadequate fume suctions from pots were causing high fugitive emissions inside the potroom. This was leading to less enrichment of secondary alumina, resulting in high bath temperature and disturbance in thermal balance of the potline. Due to this, a surge in aluminium fluoride consumption was observed (Figure 2) and productivity and efficiency of the potline was hampered. Poor hooding efficiency was another contributing factor for less enrichment and high aluminium fluoride consumption in Poline-1.

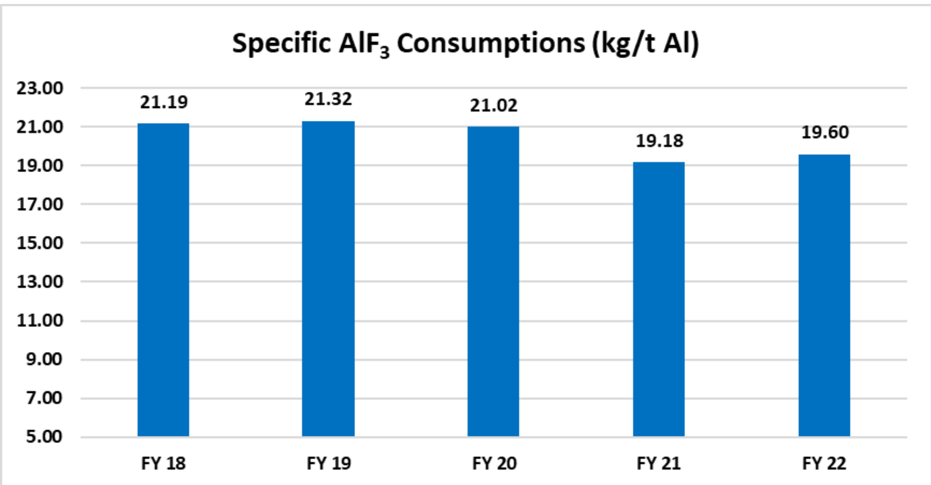

Figure 2. AlF_3 consumption over the years.

5. Methodology Used for Duct Line Replacement

There was a perception that the deposition of material in the duct system was because of conversion from Søderberg to prebake pots. Also, due to complex layout of the plant, there were multiple bends in the ducting system. This may also be contributing to low suction pressure in the potline.

The following steps were taken for the replacement of entire duct system, connected to FTP-1 in online mode:

- Brainstorming was performed jointly by Potroom and FTP team.
- A Computational Fluid Dynamics (CFD) study was carried out covering entire ducting network and developed design for best suited ducting network with respect to space constraint (Figure 3).

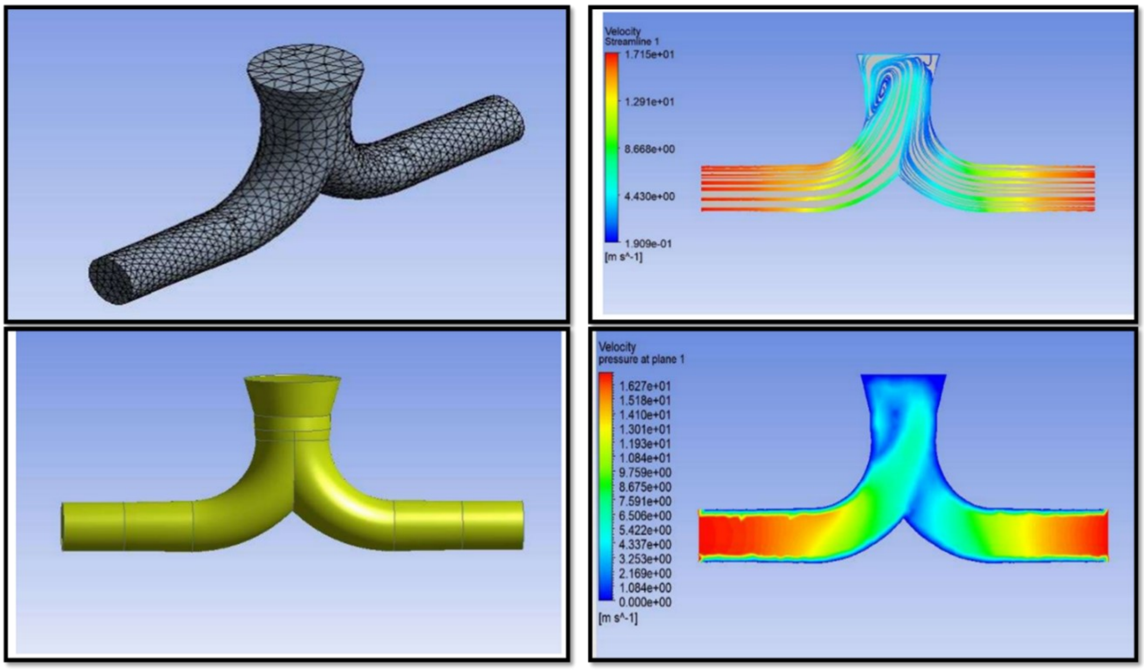

Figure 3. An example of CFD simulation result for the ducting network of FTP 1&2.

- Single layered impulse duct design was also incorporated to match the latest suction system of FTP technology supplier.
- Development of Safe Operating Procedure (SOP) and Hazard Identification and Risk Assessment (HIRA) for efficient and safe execution of the online duct replacement of 170 connected pots.
- Dismantling of existing duct lines one-by-one and erection of new duct line in a time-bound manner. At the same time, temporary connection of ducts was made so that no external air ingression/fume suction loss was possible and the potroom process was the least affected.
- Due to space constraints, we were unable to use any Hydra, Mobile Elevated Work Platform (MEWP) for erection and dismantling job. The entire project job has been carried out manually with the help of chain block only. As it was a retrofitting job, at many places we had to do minor modifications and take decisions in suit-to-site manner. For the connection of Y-pieces, 4-5 h shut-downs were taken and the target job was accomplished on time without any major implication in potroom processes.

- As fume suction line and alumina air slide vent pipes are connected to each other, we had to dismantle the vent pipes from old ducts and reconnect it with the newly installed duct in short time was a very tough task. The same job was completed in much less time for ensuring smooth alumina feeding to potroom during the project.
- Training, skill development and motivating workers to work in a hazardous hot environment taking all the necessary precautions was a very tough task.

6. Actions Taken in FTP and Potrooms

Apart from duct replacement, several actions were taken in FTP and the potroom to improve gas suction rate from pots and to improve alumina enrichment.

6.1 Potroom

- Regular hooding audits started in the whole potroom which helped a lot to improve the hooding efficiency by better work practice, and defective hood maintenance and replacement (Figure 4). Figure 5 shows poor hooding of some pots before the audits started, and good hooding after the audits.

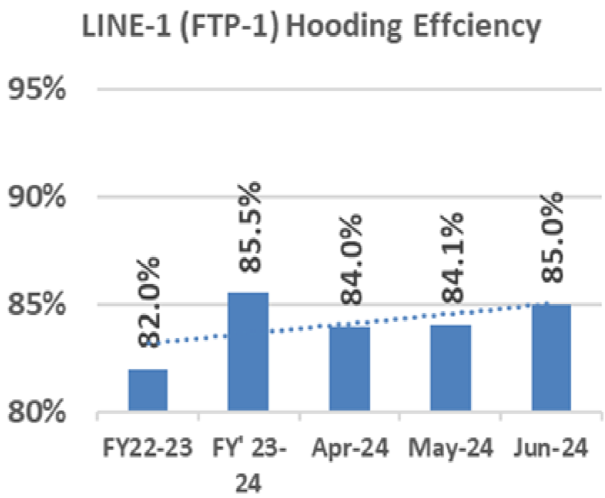

Figure 4. Line-1 hooding efficiency.

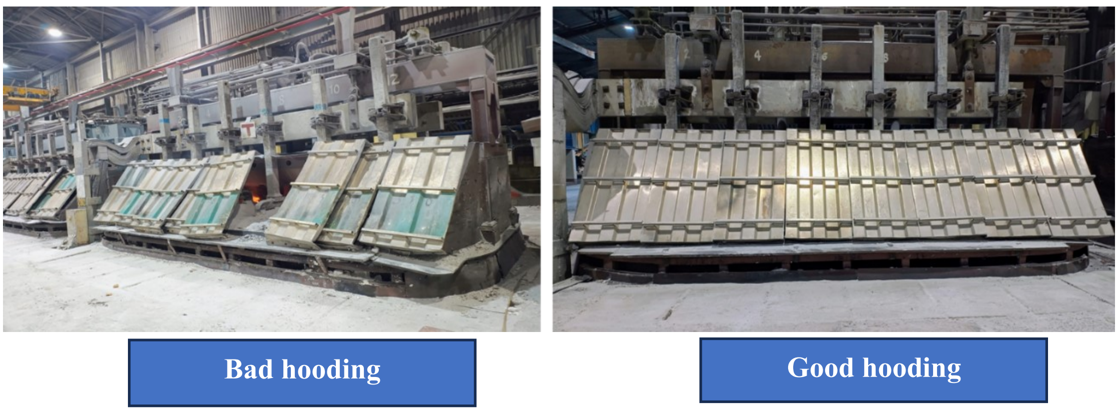

Figure 5. Poor hooding before the audits started (left), and good hooding after the audits started (right).

- Audits for leakages in the duct line inside the potroom and their immediate rectification started.
- Optimization of thermal balance in pots to keep bath temperature in desired range.
- Stringent control over AlF_3 feeding in pots.
- Maintaining total fluoride in aluminium fluoride which is going to be charged in pots higher than 64 %.
- Stringent control over process parameters.
- Reduction in standard deviation of bath temperature and excess AlF_3 and decrease of bath temperature (Figure 6) led to less fluoride emissions.

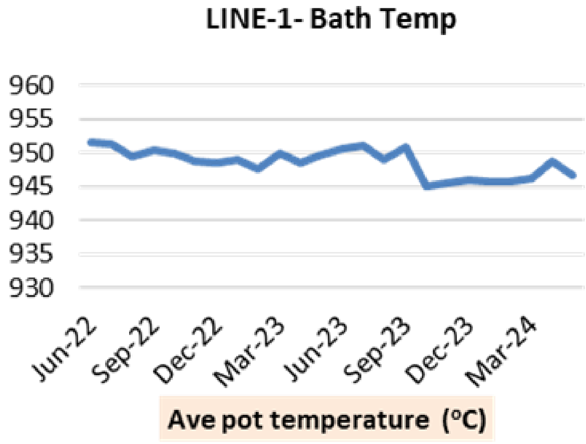

Figure 6. Line-1 bath temperature.

6.2 FTP

- Duct thermography and periodical cleaning once every 6 months.
- Checking of individual pot flow and suction damper position (pot balancing).
- Monitoring/correcting pulsing valve faults on shift basis.
- Maintaining differential pressure and keeping it within the range of 1.62-1.77 kPa.
- Leakage arrest of all fresh air ingression points to FTP-1 system.
- Filter bag replacement and schedule of 3 years instead of 5 years.
- Commissioning of portable HF analyser and measurement on regular basis.

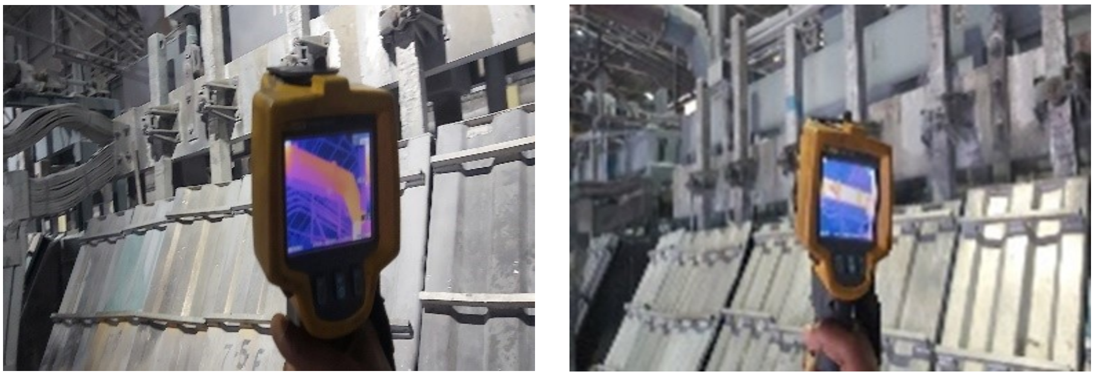

Figure 7. Taking thermograms of a duct section.

All these initiatives helped a lot in overall improvement of FTP-1 efficiency and thereby improvement of enrichment value.

7. Results

Due to replacement of lateral ducts, pot balancing, improvement of hooding efficiency and proper thermal balancing of pots Hirakud potlines and FTP have given both, tangible and intangible benefits. Earlier, due to choking of ducts and external air ingression, the HF concentration at FTP baghouse inlet was 30 mg/Nm^3. But, after replacement of the duct and performing pot balancing across the potrooms, we found the HF concentrating at the bag-house inlet to be 60 mg/Nm^3. The increase in suction and HF concentration was a major contributor in the reduction of AlF_3 consumption in potrooms. As HF concentration was increased, it led to increase in alumina enrichment at FTP. Also, disturbances in process parameters have been improved resulting in better pot stability. Enrichment increased from 1.10 to 1.45. Since March 2023, we are getting a consistent value in the range 1.4 to 1.5 in FTP 1 (Figure 8).

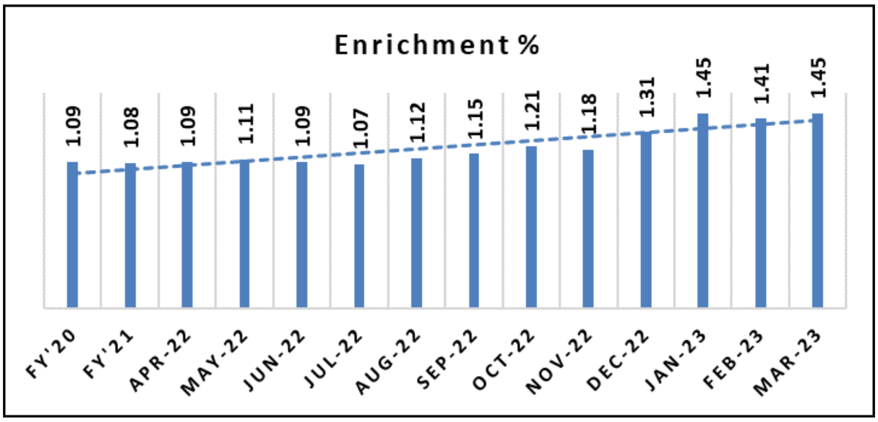

Figure 8. Alumina enrichment.

8. Conclusions

AlF_3 consumption reduced in Pot Line 1 since March 2023 from 20.71 to 17.74 kg/t Al (Figure 5), which is having huge impact on cost. Earlier, we used to pay hundreds of thousands USD as demurrage to local farmers because of crop damage due to high HF emission. Now, with improved conditions, demurrage amount is zero in the financial year 2024. This has also created a sustainable environment both inside and outside plant premises.

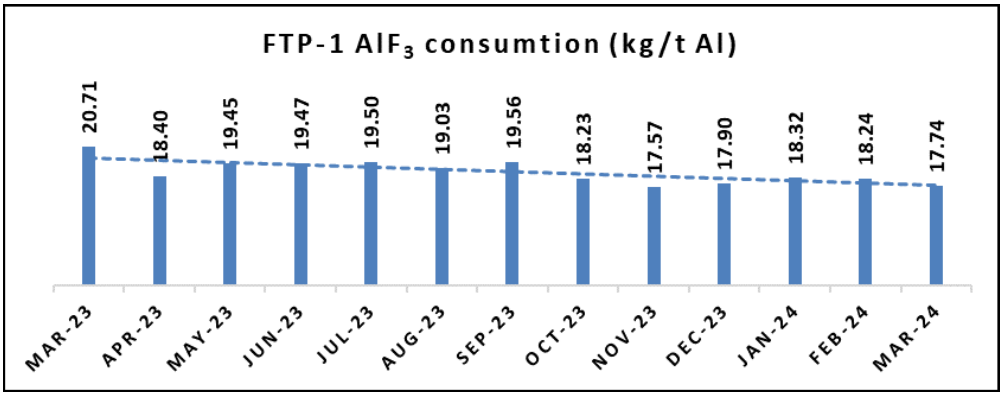

Figure 9. FTP-1 AlF_3 consumption.

9. Acknowledgement

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10. References

1. Peter M. Entner, Control of AlF_3 concentration, *Light Metals* 1992, 369-374.
2. Peter M. Entner, Further development of the AlF_3- model, *Light Metals* 1993, 265-268.
3. K. R. Kloetstra, S. Benninghoff, M. A. Stam and B. W. Toebes, Optimisation of Aluminium Fluoride Control at Aluminium Delfzijl, *Proceedings of the 7th Australasian Aluminium Smelting Workshop*, 11-16 November 2001, 506-514.