Enhancement of Filter Bag Life in EGA's GTC

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Abstract

Gas treatment centre (GTC) is essential for treating hydrogen fluoride (HF), sulphur dioxide (SO_2) and particulate emissions from aluminium smelting process, using dry scrubbing and wet scrubbing before they are released into the atmosphere. Recently, Emirates Global Aluminium (EGA) has encountered early filter bag failures (in less than one year), which compromised the efficiency, emissions control and cost-effectiveness of the GTC. This paper investigates the causes of early filter bag failure, including factors such as fine alumina, high filtration velocity, dust load and flow patterns in the bag houses. By analysing these factors, EGA developed short-term strategies to mitigate early failures and improve the overall performance and longevity of the filter bags. This paper will share the actions taken to mitigate temporarily the short bag life, which helped to improve the bag life by 6–12 months. Now EGA is aiming to establish long term actions to normalise filter bag life to typical three years.

Keywords: Filter baghouse, Alumina and gas distribution, Abrasion, Filtration area, Filter bag life.

1. Introduction

The filtration bags within a Gas Treatment Centre (GTC) are crucial for the abatement of particulate matter and HF emissions derived from aluminium reduction processes. At Al Taweelah, six GTC units equipped with 116 000 filter bags, with a filtration surface of 283 000 m², have recently encountered premature degradation, reducing their operational lifespan from an anticipated 2.5–3 years to less than one year as shown in Figure 1. This increased maintenance expenditures and operational interruptions, thereby posing significant challenges to operational efficiency, financial stewardship and adherence to environmental regulations.

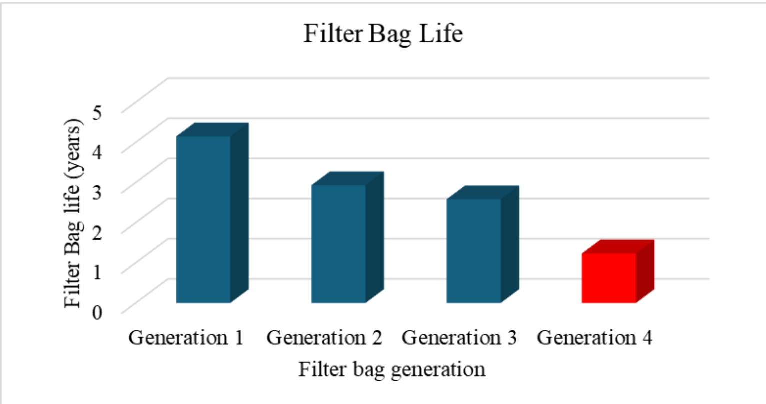

Figure 1. Graphs representing bag lifespan deterioration.

2. Root Cause Analysis (RCA)

An internal EGA team and external experts (from original equipment supplier (OEM) of filter bags and consultants) engaged in a comprehensive multilayered investigation, where various aspects of the filtration system were analysed. The team examined material degradation by analysing the composition and wear patterns of used filter bags, ensuring that any contributing weaknesses were identified. Operating conditions, such as temperature, humidity and pressure, were monitored continuously to establish any correlations with the premature failures. Moreover, the particulate composition was studied meticulously to understand how the nature of the dust and gas interacted with the filter materials.

The collaboration with external experts brought additional insights, leveraging cutting-edge technologies and methodologies. They deployed advanced diagnostic tools to map out the exact points of failure and employed computational fluid dynamics (CFD) simulations to visualise gas flow and particulate distribution within the GTCs. These techniques provided a clear picture of the internal dynamics, enabling the team to pinpoint the root causes of the issues.

The findings from this extensive investigation revealed several key factors responsible for the premature filter bag failures described below.

2.1 High Gas Flow and Velocity

Excessive gas flow velocity can result in abrasion and subsequent deterioration of the filter bag material. To address this issue, EGA embarked on a comprehensive measurement campaign and analysis of gas flow rates from the pots, individual filter compartments, and the stack. The outcome revealed minor imbalances in the gas flow rates from the pots and individual compartments, suggesting the need for recalibration and optimisation to mitigate localised wear and enhance the overall performance of the filtration system.

2.2 Uneven Flow Patterns

Due to localised damage observed in the filter compartment, EGA validated the gas flow patterns in both the design and current condition (Figure 2). To investigate the causes of uneven gas flow, factors such as scale formation, alumina and gas deflector conditions, alumina distribution and gas flow behaviour were reviewed. The finding was that there was a lot of scaling on the gas deflector which could contribute to interrupt the gas flow profile and cause uneven gas distribution, causing localised stress on certain filter bags and reducing their lifespan. Moreover, it was investigated if the OEM designed the compartments have some zones with higher velocity compared to other zones.

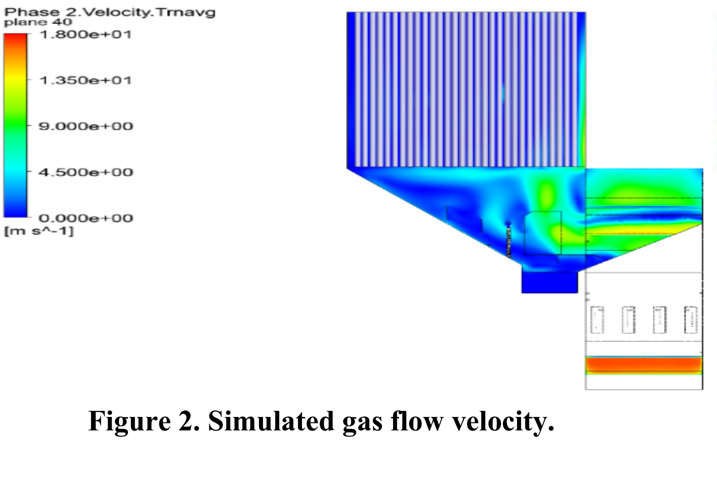

Figure 2. Simulated gas flow velocity.

2.3 Alumina Properties

Alumina plays vital role in scrubbing efficiency and filtration. The following factors have influence on the filter bag life:

- **Abrasiveness:** Alumina particles are highly abrasive, and their constant contact with the filter bags can lead to mechanical degradation.
- **Particle size**: Fine alumina particles can penetrate the filter media, causing clogging and reducing filtration efficiency (Figure 3).
- **Chemical reactivity:** Alumina can react with gases like HF, forming compounds that may adhere to the filter surface and accelerate wear.
- **Attrition index.**

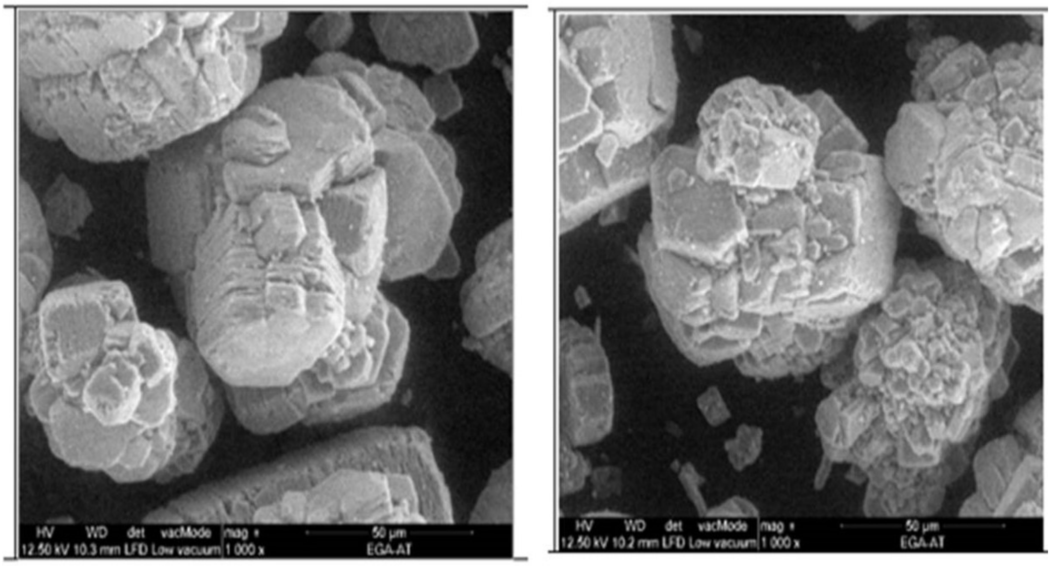

Figure 3. Alumina particle analysis.

2.4 Dust Load and Intake

- **High dust load:** Excessive dust intake reduces cleaning efficiency and increases frequency of cleaning cycles, which can weaken the filter bags over time.
- **Inconsistent dust distribution:** Uneven dust loading can lead to localised clogging and stress, further reducing the durability of the filter bags.

2.5 Capacity and Overloading

- **Overcapacity operation:** Operating the GTC beyond its designed capacity can increase the strain on filter bags, leading to premature failure (Figure 4).
- **Inadequate cleaning systems:** Inefficient cleaning mechanisms may fail to remove accumulated dust effectively, causing blockages and higher pressure drops.

The comprehensive investigation conducted by EGA identified several primary and secondary factors that contributed to the premature degradation and shortened lifespan of the filter bag. The main factor was the presence and characteristics of alumina. In recent years, the recycling of high fine and attrition alumina within the system significantly disrupted the gas profile. This disruption resulted in localised turbulence and elevated gas velocities, which in turn compromised the effectiveness of the filtration. Specifically, the altered flow dynamics led to uneven distribution and reduced efficiency in the pulse-jet cleaning mechanism designed to maintain adequate and uniform coating.

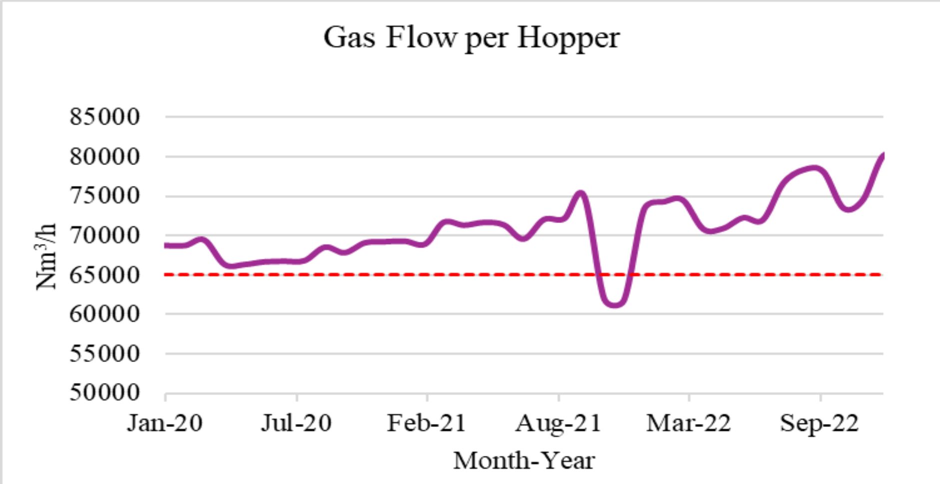

Figure 4. Gas flow per hopper.

Additionally, the accumulation of fine particles on the surface of the filter media aggravated the problem by increasing differential pressure. These conditions accelerated wear and tear of the filter material, thereby diminishing its operational longevity.

Figure 5 provides a detailed visual representation of the Root Cause Analysis (RCA) summary, mapping out the complex interplay between these variables and their impact on the filtration system performance and durability. It highlights the necessity for detailed monitoring of alumina particulate characteristics and flow dynamics to mitigate adverse effects and compromise the lifespan of filtration components in industrial systems.

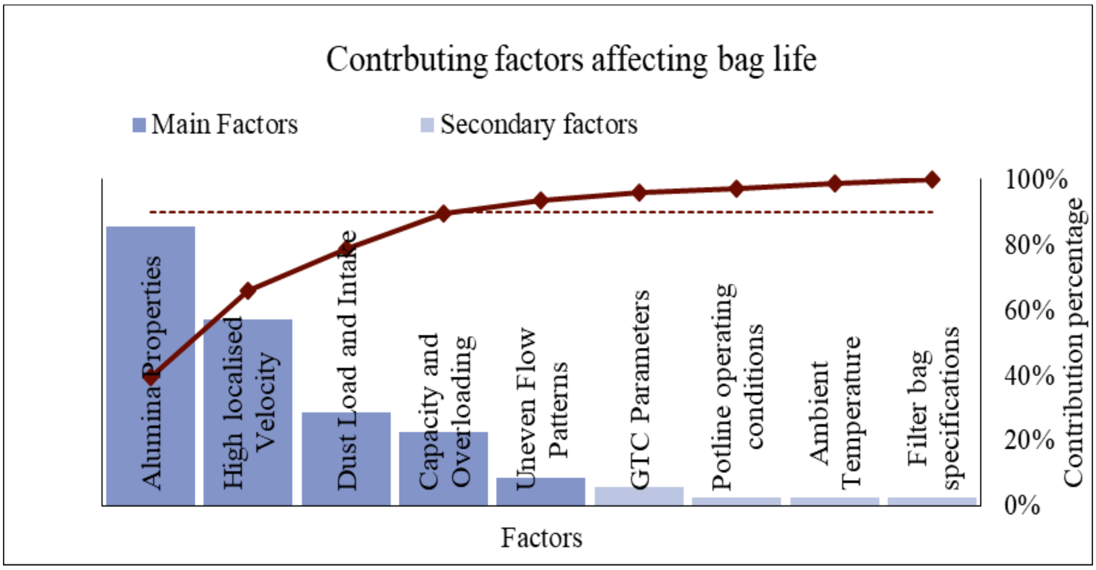

Figure 5. Root cause analysis.

3. Development of Action

EGA formed a dedicated task force comprising cross-disciplinary experts to develop an extensive action plan based on RCA findings. The plan outlines both short-term and long-term objectives with detailed steps for planning, execution, and assessment phases. Short-term actions focus on items that can be implemented quickly with low or no investment, while long-term actions include items that require many validations, longer analyses, and higher investment. This paper will focus on key short-term actions.

The team brainstormed and outlined 42 short-term actions to be assessed and evaluated. However, this paper highlights the most impactful actions that supported EGA in enhancing the lifespan of filter bag and stabilising the situation. Below are further details regarding the key short-term actions.

3.1 Replacement of Damaged Bags in Critical Zone (Mini Refurbishment)

Replacing filter bags in the critical zone of a filter bag house is a maintenance strategy that can offer cost efficiency and reduce downtime compared to full refurbishment. This method addresses the most vulnerable areas of the filtration system while maintaining operational performance. Below are the protocols followed to perform the action effectively

3.1.1 Analysing Filter Bag Failure Pattern in Filter Houses

Conducting a thorough analysis of filter bag failures specifically within the GTC process is crucial for identifying when a replacement is necessary. This process includes:

- **Visual inspection**: Checking for any physical damage, such as tears, holes, abrasive wear or discoloration caused by the high gas velocity or particulates typical in GTC operations. It also involves examining the dust cake build-up to evaluate its thickness, granularity and adhesive qualities, which may be influenced by the nature of contaminants processed or effectiveness of cleaning as shown in Figure 6. Additionally, it is important to inspect the filter media for any signs of chemical degradation, loss of flexibility, or brittleness that could compromise filtration efficiency.

Figure 6. Abrasion damage of filter bag.

- **Sample collection:** Gathering representative samples of failed filter bags, dust cake, and other system components for laboratory testing.
- **Laboratory testing:**
  - Physical property testing: Evaluating tensile strength, air permeability, and filtration parameters (Table 1).

Table 1. Physical property testing: Strength analysis (N/50 mm) and elongation (%).

Sample	Strength warp (N/50 mm)	Elongation warp (%)	Strength weft (%)	Elongation weft (N/50 mm)
Sample 1 - Top	2631	23	2033	22
Sample 1- Middle	2489	24	2100	23
Sample 1 -Bottom	2496	24	2065	23
Sample 2 - Top	1714	21	1171	23
Sample 2- Middle	1626	21	1247	29
Sample 2 -Bottom	1617	21	1249	29

- Chemical analysis: Identifying chemical degradation or incompatibility with filter media materials. (Figure 7)

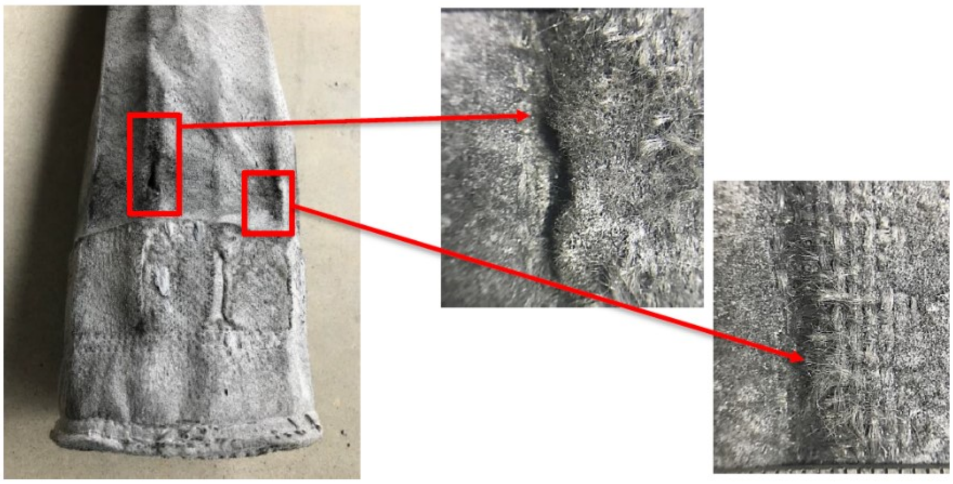

Figure 7. Chemical analysis. Left: Detail of bottom from sample 1 – strong abrasion starting from outside the filter bag, Centre and right: Detail of the failures of the bag.

- Microscopy: Examining wear mechanisms, fibre characteristics, and contamination (Figure 8).

Figure 8. Microscope analysis. Left: Micrograph from the dust side (dust side) as received – sample 1, Right: Micrograph from the cage side (inner side) as received – sample 1.

- Operational data review: Analysing pressure drop, flow rate and cleaning cycles to identify correlations with failures.

3.2 Using Optimised Filtration Media to Address Localised Flow Patterns

Localised flow patterns within filter houses can lead to uneven wear and tear, resulting in premature damage to filter bags and reduced overall system efficiency. Considering that the filtration design in EGA already incorporates uneven velocity distribution, an effective solution involves using filtration media with optimised permeability specifications. This approach combines higher and lower permeability media within the same filter house to manage flow distribution and minimise wear and tear.

3.2.1 Addressing Localised Flow Patterns

Localised flow patterns are often caused by uneven airflow distribution, which creates areas of high velocity and turbulence. These high-stress zones accelerate mechanical wear, ripping, and tearing of filter bags. By strategically varying the permeability of the filter media, these flow imbalances can be mitigated (Table 2):

- Higher permeability media: Installed in areas with low airflow velocity, this media facilitates higher dust capture rates, ensuring optimal utilisation of the entire filtration area.
- Lower permeability media: Deployed in high-velocity zones, this media provides increased resistance to airflow, reducing turbulence and preventing overloading of filter bags.

Using filtration media with varying permeability specifications provides a targeted, cost-effective solution to address localised flow patterns. This proactive approach not only prevents premature wear and tear but also optimises the overall performance and reliability of the filter house.

Table 2. Permeability specifications vs filter compartment zone.

Filter compartment zone	High-stress zones	Low-stress zones
Type and value of permeability $L/(dm^2 \cdot min)$ at 200 Pa	Lower permeability media 70-80	Higher permeability media 130-150

3.3 Optimising Pot Feed System "PFS" Pressure and Vent Dome

Fine alumina particles significantly increase the particulate load on filtration systems, resulting in reduced operational efficiency and performance. The accumulation of these fine particles complicates the cleaning process and escalates maintenance costs due to the need for more frequent replacements of filter bag and other filtration components. Moreover, fine alumina adversely affects HF scrubbing processes by lowering the overall scrubbing efficiency. As a result, there is an increased likelihood of HF saturation within the recycled alumina, leading to higher emissions of HF into the environment. These elevated HF emissions pose significant environmental and regulatory challenges, necessitating advanced control measures to mitigate their impact. Additionally, this issue demands a re-evaluation of filtration system designs and operational protocols to optimise the handling of fine alumina and enhance the efficacy of HF scrubbing processes.

To mitigate the above concern, it is recommended to implement a vent dome and optimisation of pot feed pressures to mitigate dust load and enhance operational efficiency.

3.3.1 Optimum Vent Dome Installation

A vent dome is designed to minimise the emission of fine particulate alumina in the gas treatment centre. By distributing the airflow evenly, it captures and redirects fine alumina particles, significantly reducing their impact on the system (Figure 9).

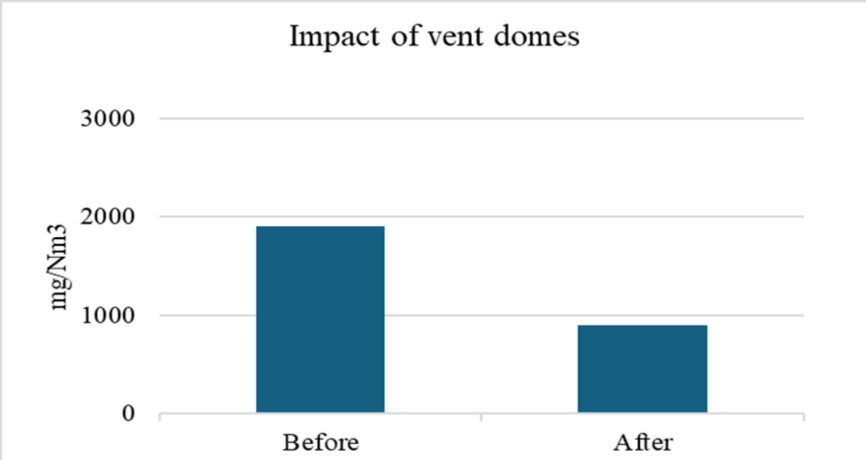

Figure 9. Improvement in dust load after enhancement of vent dome design.

3.3.2 Optimising Pot Feed System (PFS) Pressures

Adjusting PFS pressures can help manage the amount of fine alumina dust produced during the process by:

- Reducing feed pressures decreases the velocity of particles entering the gas treatment centre, which minimises their abrasive impact on filter bags.
- Proper calibration of feed pressures ensures a balance between operational efficiency and dust load reduction (Figure 10).

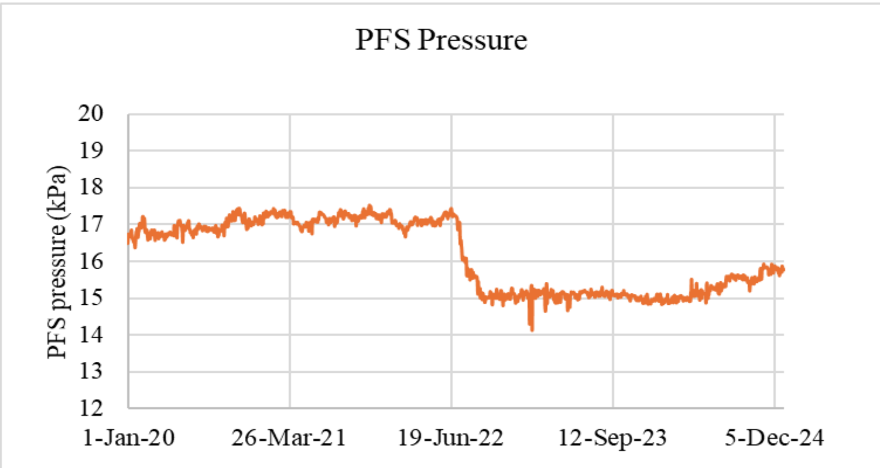

Figure 10. Optimisation of PFS pressure.

3.4 Optimising Alumina Recirculation Rate in GTC

Maintaining an optimal recirculation rate is crucial for capturing HF emissions. Effective recirculation optimises the capture of HF emissions; however, excessive recirculation can result in filter bag overload due to increased dust load, potentially compromising filtration efficiency and leading to operational issues such as pressure drop or filter failure. Additionally, too much dust load affects bag cleaning, making it essential to balance the recirculation rate to ensure efficient emissions capture without overburdening the filtration system.

Enhancing the alumina recirculation rate in a GTC boosts efficiency and minimises filter bag wear. This becomes important with high attrition index alumina, as inadequate recirculation can lead to particle breakdown and shorten the filter's lifespan.

- **Particle breakdown mechanism**: High-velocity impacts during recirculation fragment alumina particles, leading to finer particles that penetrate filter media.
- **Recirculation velocity**: Higher velocities increase collisions, especially with high alumina attrition index.

By optimising recirculation rates (Figure 11) and improving system design, abrasive wear is minimised, enhancing efficiency and lowering maintenance costs.

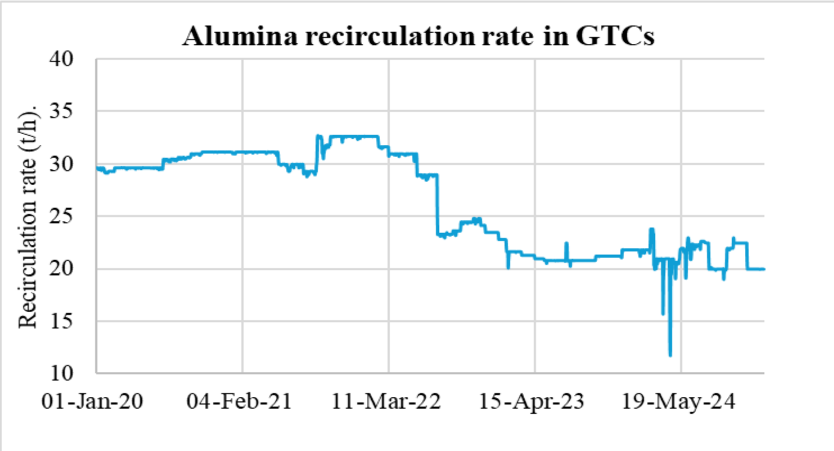

Figure 11. Optimising alumina recirculation rate in GTCs.

4. Outcomes of Short-Term Actions

4.1 Enhanced Filter Bag Lifespan

An improvement in the filter bag lifespan was achieved by optimising alumina recirculation rates, which reduced abrasion and particle attrition (Figure 12).

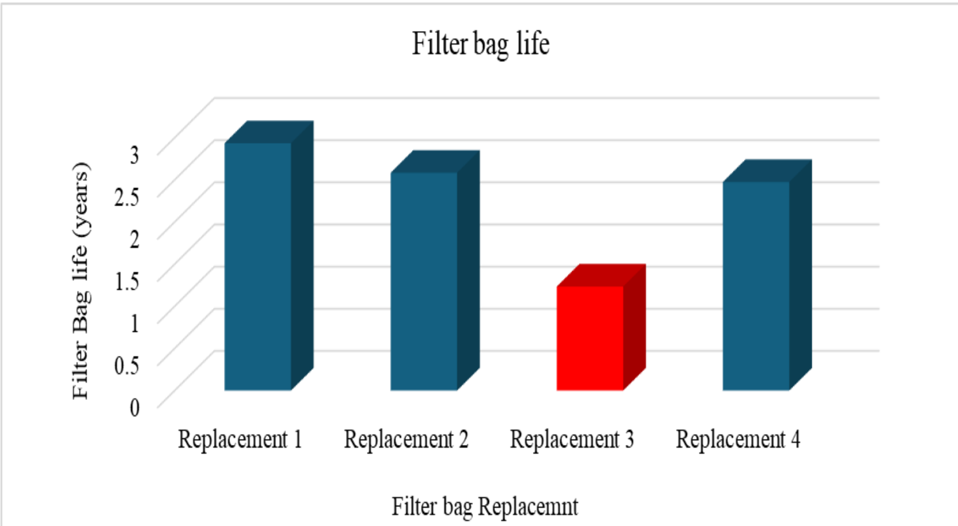

Figure 12. Filter bag lifespan improvement.

Additionally, using different filter bag specifications enhanced gas flow and minimised high abrasion areas, thereby maintaining the structural integrity of the filtration media. This slight improvement led to less frequent replacements. Consequently, this supports prolonged smooth operation and minimises disturbances to the GTC operations.

4.2 Enhanced Environmental Compliance

The extended lifespan of the filter bags and the implementation of short-term actions effectively mitigated both bag damage and emissions as shown in Figure 13. Moreover, enhancements in emission capture technology further contributed to reducing environmental impact and ensuring regulatory compliance.

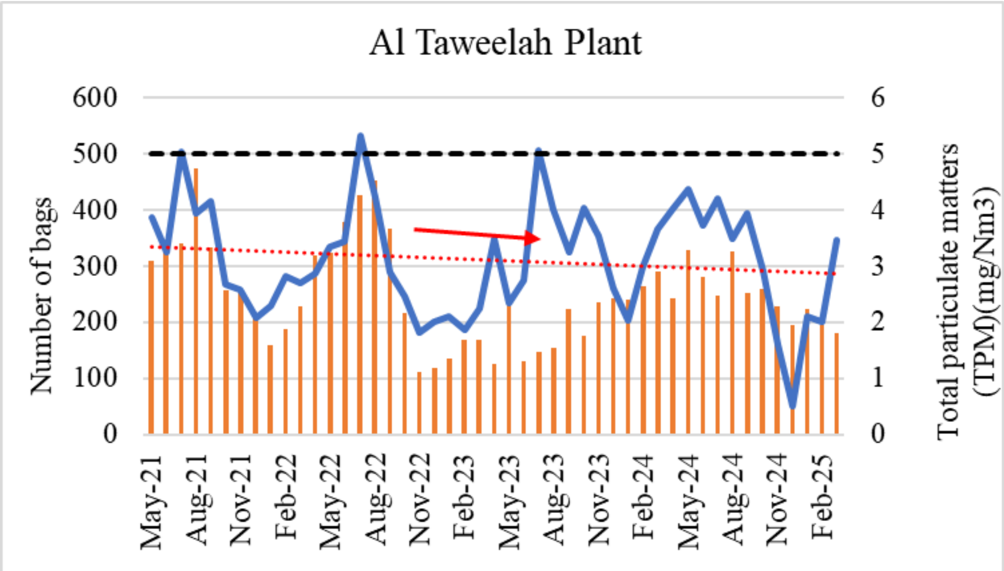

Figure 13. Reduction of total particulate matters (TPM) (mg/Nm^3) emission. Left vertical axis and red graph = Number of damaged bags/month, Right vertical axis, blue curve = TPM, black dotted line = Emission limit, pink dotted line = Average emissions trend.

4.3 Reduced Operational Costs

Enhancing filter bag lifespan saved 1 050 000 USD annually and boosted system reliability. The increased durability reduced replacement frequency and emissions (alumina and fluoride), ensuring compliance with environmental regulations. These improvements led to significant cost savings and a smaller environmental footprint.

4.4 Increased Overall Performance

Short-term actions enhanced the GTC parameters, effectively reducing operational disturbances. By refining control settings and optimising parameters performance, disruptions of potline operation were minimised, ensuring a steady alumina supply and pot gas flow.

5. Conclusions

Solving the issues of short filter bag lifespan and high emissions contributed to EGA core values:

- "Safety and Sustainability": EGA is committed to environmental responsibility, ensuring that products comply with stringent emission standards. By investing in advanced research and development, EGA enhances the durability and efficiency of filter bags, thereby

reducing particulate emissions and lowering overall operational costs through extended service life and improved filtering performance.
- "Teamwork and ownership" were clearly demonstrated through team collaboration and commitment to investigating, brainstorming root causes, generating ideas, identifying improvements, and taking action. The group showed exceptional coordination in tackling challenges collectively, fostering a spirit of mutual support and shared responsibility.
- “Innovation and continuous improvement”. EGA’s commitment to innovation ensures high standards in environmental compliance, workplace safety, and operational excellence. By investing in optimisations, EGA confirms its dedication to a sustainable, resilient, efficient, and environmentally responsible future.

Furthermore, EGA is investing in long-term actions for reinstating the normal filter bag or either enhancing it to achieve more than the original or benchmark filter bag life in this region. This includes the development of advanced filtration technologies and materials that can withstand harsh conditions while maintaining high performance. Additionally, EGA is exploring partnerships and collaborations with research institutions and industry experts to drive further advancements in sustainability practices and environmental protection. These efforts underline EGA's proactive approach to not only meeting but exceeding regulatory requirements and industry standards.