A New Fabric Material with Anti-scaling Properties for Security Filtration in Bayer Process

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Abstract

The security filtration in the Bayer process presents one of the most challenging environments for filtration fabrics. Almost all materials exposed to the hot, corrosive solution—supersaturated with alumina hydrate—become coated within hours by a hard precipitate known as hydrate scale. Its formation not only poses a significant challenge for tanks and piping maintenance and cleaning, but it is particularly problematic for filter media, as it rapidly clogs the pores. Even with regular caustic cleaning, filter bags become obstructed primarily due to scaling and require frequent replacement. Over the years, various filter media have been tested to resist scaling, but with limited success. However, a newly developed material from Sefar has demonstrated outstanding resistance to scaling. One of the key challenges in evaluating new fabrics in a plant environment is data analysis. To accurately assess the performance of the new fabric, a statistical approach is required to isolate the effects of cloth scaling from other influencing factors. This paper presents the production improvement of 7 % achieved with the new fabric and details the data treatment method used in the plant evaluation.

Keywords: Bayer, Alumina, Scale, Filtration, Fabric.

1. Introduction

Scaling is a major challenge in alumina production because of the buildup of mineral deposits, primarily from tricalcium aluminate, sodium aluminate and other impurities, on equipment surfaces [1]. This buildup reduces heat transfer efficiency, clogs pipelines, and increases energy consumption. Frequent shutdowns are needed for cleaning and maintenance, leading to costly downtime and reduced productivity. Scaling also hampers flow at security filtration, gradually clogging fabrics resulting in short lifetime. Prevention of scaling is not an easy task, even PTFE parts, one of the best-known non-sticking materials, are scaled over time. It is a challenge to find a new non-scaling material and also to evaluate its effect in a plant operation in which conditions can vary within minutes.

A new fabric called X-Treme made of a material that was never tested before in Bayer liquor, according to our knowledge, was developed to delay scaling. The fabric is made of a polyolefin base polymer with a special treatment. In order to evaluate its performance in regards of scaling it was compared to our best material resistant to scaling. The incumbent fabric of reference, called X-Scale, is a polypropylene base fabric with a fluorocarbon coating. The production of the X-Scale will be stopped soon following the PFAS ban. The two fabrics have exactly the same weaving style, same number of threads in both direction and the same yarns diameters. Figure 1 shows a scanning electron micrograph of the X-Scale and X-Treme fabric surfaces.

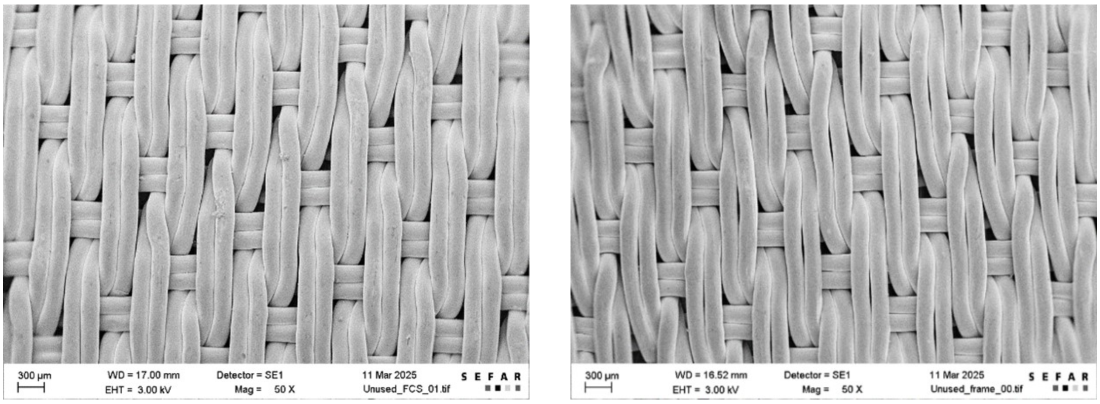

Figure 1. Scanning electron micrograph of the X-Scale (left) and X-Treme (right).

The scaling resistance is evaluated indirectly by measuring the filtration rate variation of fabrics over time. The general equation of filtration rate by surface area is given by:

$$\frac{dV}{Adt} = \frac{\Delta p}{\mu(R_E + R_C)} \tag{1}$$

where:

dV Volume variation, m3/h
A Surface area, m2
dt Time variation, h
Δp Pressure variation, kPa
µ Viscosity
R_E Equipment (Support, frame, fabric) (resistance,
R_C Cake resistance,

The challenge is to measure a variation in the resistance of the fabric within a complex and time-varying industrial process. Equation 1 needs to be detailed further in order to better reflect reality. Thus, Equation (1) becomes:

$$\frac{dV}{Adt} = \frac{\Delta p}{\mu\left[\, R_{c(t)} + \Delta R_{c(t+1)} + R_{e(t)} + \Delta R_{e(t+1)} + R_{F(t)} + \Delta R_{F(t+1)}\right]} \tag{2}$$

where:

R_F Fabric resistance,
$\Delta R_{c(t+1)}$ Cake resistance variation over time
$\Delta R_{e(t+1)}$ Equipment (Support, frame) resistance variation over time
$\Delta R_{F(t+1)}$ Fabric resistance variation over time

The goal of our tests is to demonstrate that the X-Treme fabric is less prone to scaling. To achieve this, we need to measure the change in resistance $\Delta R_{F(t+1)}$ for both fabrics.

To accurately assess the intrinsic resistance of the fabric, the methodology assumes that all auxiliary resistances remain uniform across every filtration cycle within the test duration. Empirical chemical and temperature data confirm that slurry viscosity remained essentially constant throughout. Furthermore, by enforcing a fixed filtration time, the cake layer consistently attains the same thickness each cycle, allowing the cake resistance to be treated as invariant. These assumptions—constant viscosity and cake resistance—significantly streamline the analytical modelling of filtration performance. The variation in equipment resistance is primarily attributed to frame aging and caustic cleaning cycles – two known factors that allow for its estimation. Given that pressure, flow rate, and filtration surface area are measured, changes in fabric resistance can therefore be estimated.

The methodology involves comparing the variation in filtration rate between the two fabrics during normal plant operation, using a full-scale filter representing approximately 300 m^2 of fabric. A schematic of the plant configuration used for the test is shown in Figure 2. The test with the X-Treme fabric was conducted on Filter 2, while Filter 1 served as the reference. Figure 3 presents a typical Kelly used during the test.

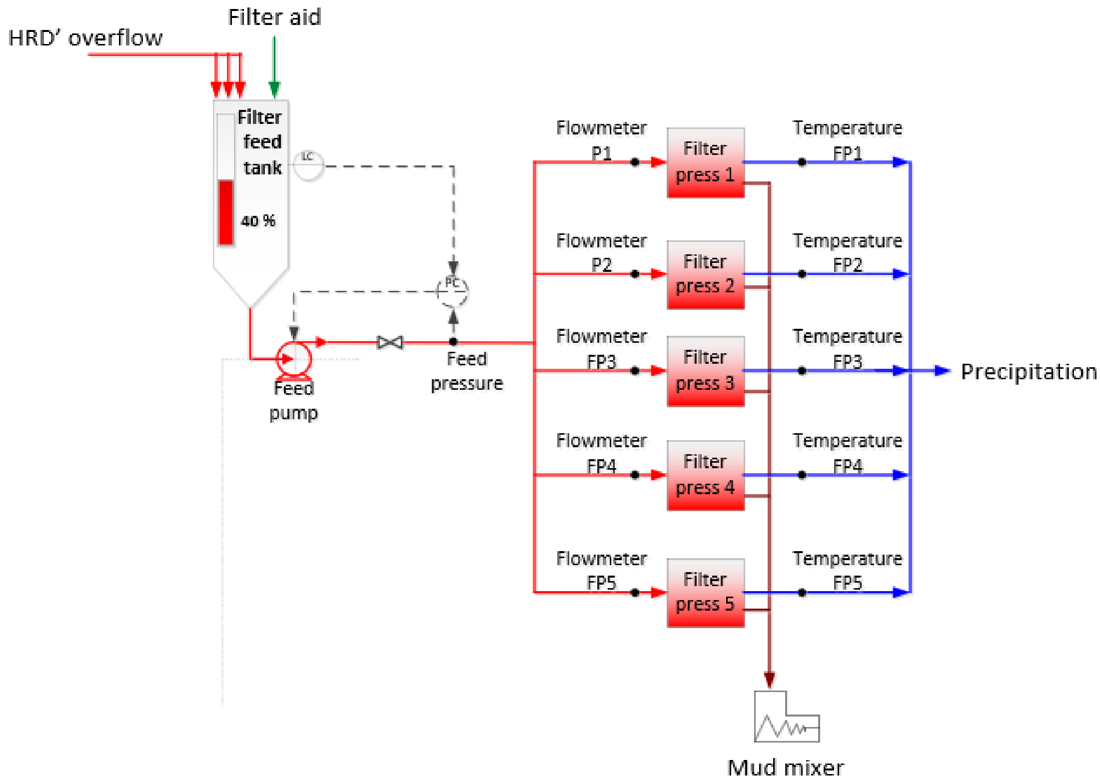

Figure 2. Schematic of the filtration process.

Figure 3. Typical Kelly filter used for the test.

2. Results and Discussion

Figure 4 shows a typical 10-hour filtration cycle. The initial flow peak reflects the filling phase, while the sharp drop corresponds to pressure losses. To isolate the resistance of the fabrics from that of the cake, the analysis focuses on the early stage of each cycle – between 20 and 40 minutes – when the filter is fully filled but the cake is still thin. This interval offers stable conditions where the contribution of the cake to total resistance is minimal. Around 60 cycles, recorded over a two-month period, were analysed. In Figure 5, each point represents the average filtration rate over this 20-minute window, revealing the gradual decline in media permeability due to fouling or scaling over time

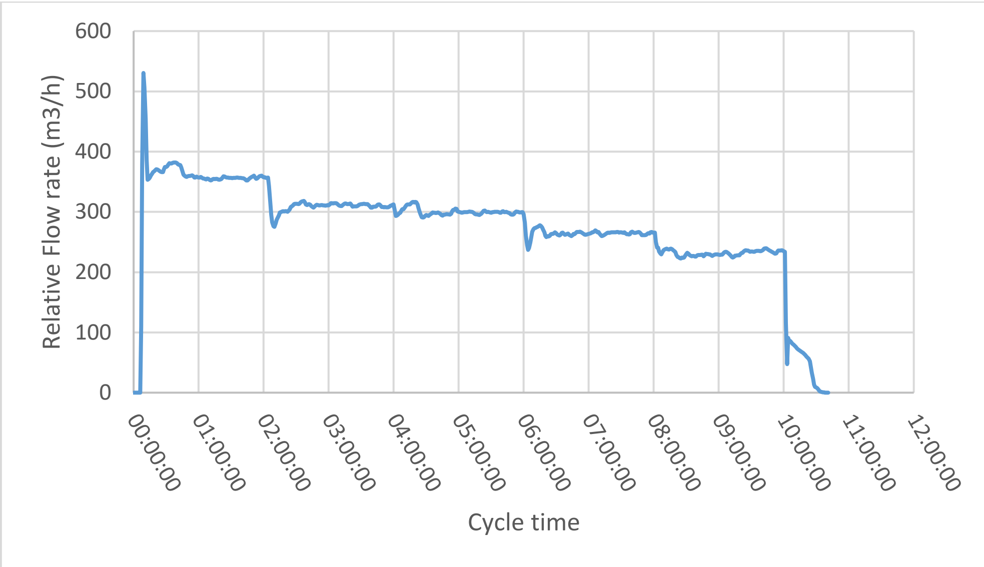

Figure 4. Typical 10-hour filtration cycle.

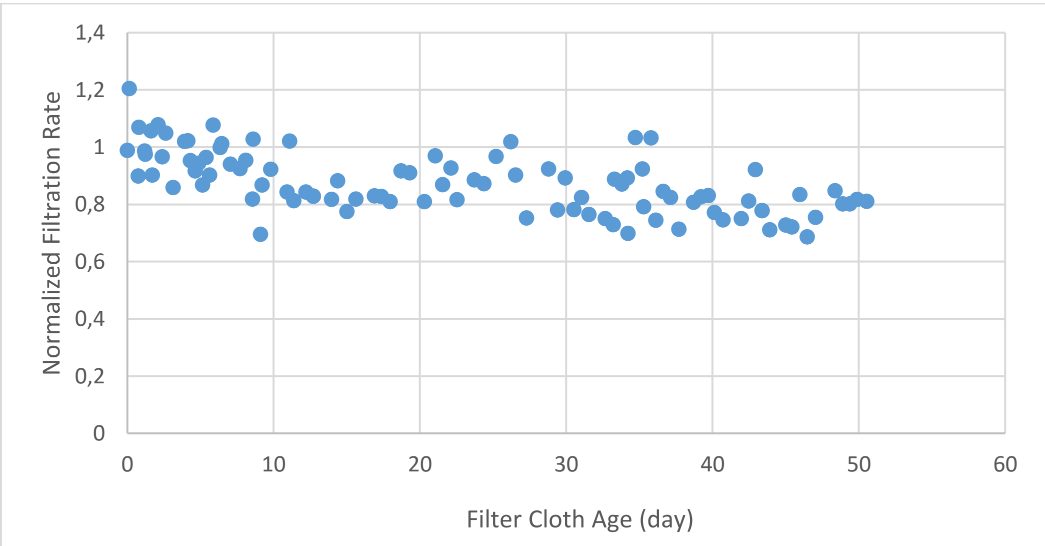

Figure 5. Typical filtration rate decreases over fabric lifetime.

A statistical approach was used to determine the strength of the correlation between the filtration rate and the frame age, the time since the last caustic cleaning and the fabric age. Considering the variability of the plant operation conditions, the statistical approach was at first to compare the

X-Treme performance with the X-Scale performance on the same filter at two different periods in the cycle. Then the two were compared on two different filters but on a slightly shifted period. The expectations are that there will be no correlation between X-Treme age and filtration rate. Table 1 presents the statistical correlation of the parameters with the filtration rate for each trial.

Table 1. Correlation factor between filtration rate and different parameters.

	Trial 1	Trial 2	Trial 3
Press	2	2	1
Fabrics	X - Scale	X - Treme	X -Scale
Operation Time since Caustic cleaning	0.225	0.22	0.30
Fabric age	0.00	0.332	0.007
Pressure	0.00	0.00	0.00
Temperature	0.240	0.30	0.23

The correlation factor p which represents the probability of correlation was obtained from a statistical analysis software, a *p* value of 0.05 is commonly used as a correlation threshold then a value below 0.05 is considered as correlated. From the table the results indicate that there is a low probability of correlation between X-Treme age and filtration rate while the *p* value shows that there is one with X-Scale. The impact of the Fabric Age is mainly associate with scaling of fabrics. This tend to prove that X-Treme does not seem to be affected by scaling over time. The results also showed that there is no correlation between operation time since the last caustic cleaning and liquor temperature which is not real. The effect of caustic cleaning and liquor viscosity is well known. This just confirms that caustic cleaning schedule and liquor temperature were kept relatively constant during the trials and then no impact from those were detected.

Following the positive initial results, the plant schedule was adjusted to allow for a second synchronized comparative test. The purpose of this second test was to ensure that cake resistance and liquor viscosity remained identical for both fabrics. Therefore, according to Equation 2 and using the synchronized approach, any observed difference in the evolution of the filtration rate can be attributed solely to fabric aging. As plant pressure varies during operation, it is necessary to normalize the filtration rate to a reference pressure. The adjusted equation is provided below:

$$\left(\frac{dV}{Adt}\right)corr = \frac{dV}{Adt} \times \left(\frac{P\ ref}{P}\right)^{0.5} \tag{3}$$

where:

$(\frac{dV}{Adt})corr$	Corrected value of filtration rate, $m^3/h.m^2$
$\frac{dV}{Adt}$	Filtration rate at a pressure P, $m^3/h.m^2$
ref	Reference pressure, kPa.

The above equation was taken from a Rio Tinto internal report [2]. This equation is used as a reference to compare the performance of fabrics. Despite its limitations, it provides a reasonable approximation of what occurs in real operating conditions.

Similarly to Figure 5, Figure 6 presents the normalized mean filtration rate data as a function of time, but for the synchronized trial. Each point represents the average filtration rate for one filtration cycle. As previously described, 20 filtration rate values are recorded per cycle and corrected using Equation 3. The data shows that linear regression analysis reveals a decreasing trend in filtration performance for the X-Scale fabric, while the filtration rate for the X-Treme fabric remains stable over time

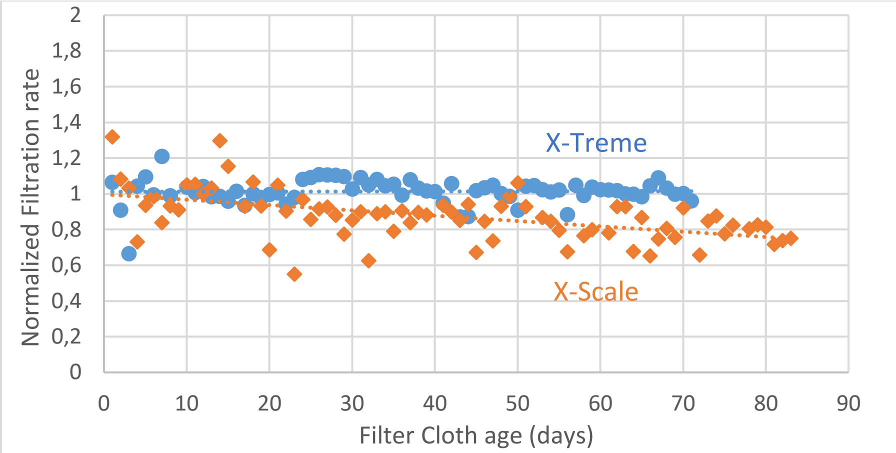

Figure 6. Normalized filtration rate over days.

The difference in slope between the two trials reaches -0.003 m/h per day. Based on the previous assumption, this decline can be attributed to the non-scaling properties of the X-Treme fabric.

Furthermore, air permeability measurements conducted on fabric samples at the end of the test revealed a 90 % decrease for the X-Scale fabric, while the permeability of the X-Treme fabric remained unchanged.

The non-scaling characteristics of the X-Treme system were also confirmed through visual inspection. Figure 7 shows the filter bag surfaces of both systems at the end of the trial. The X-Scale bags exhibit clear discoloration due to iron oxide deposits (reddish staining), whereas the X-Treme bags maintained their original white appearance. This difference in scaling behaviour between the fabrics was further validated by scanning electron microscopy (SEM) analysis, as shown in Figure 8. The EDX analyses show that the scale contains Al, Ti , Si, Ca, Na, Fe (Figure 9). The crystalline phase of the scale was not determined, but its composition seems to indicate that of sodalite [3].

Figure 7. Photo of the X-Scale (left) and X-Treme (right) bags surface at the end of the test.

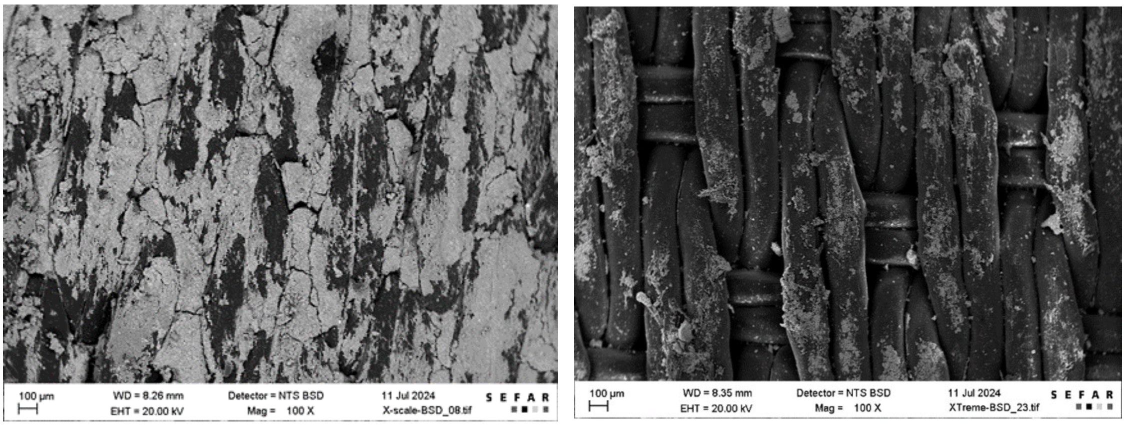

Figure 8. SEM of X-Scale (left) and X-Treme (right) at the end of the test.

The impact of scaling on flow rate is cumulative, with flow gradually decreasing over time. It is important to note that during the test, both fabrics were cleaned with hot caustic every three cycles. Despite this regular cleaning, the X-Scale fabric still exhibited a slight decrease in flow. Based on calculations using a slope of -0,003 $m^3/h.m^2$ per day, in the absence of scaling, up to 7 % more volume of liquor could be filtered after 60 days. This supports the idea X-Treme prevents solid sticking to fibres.

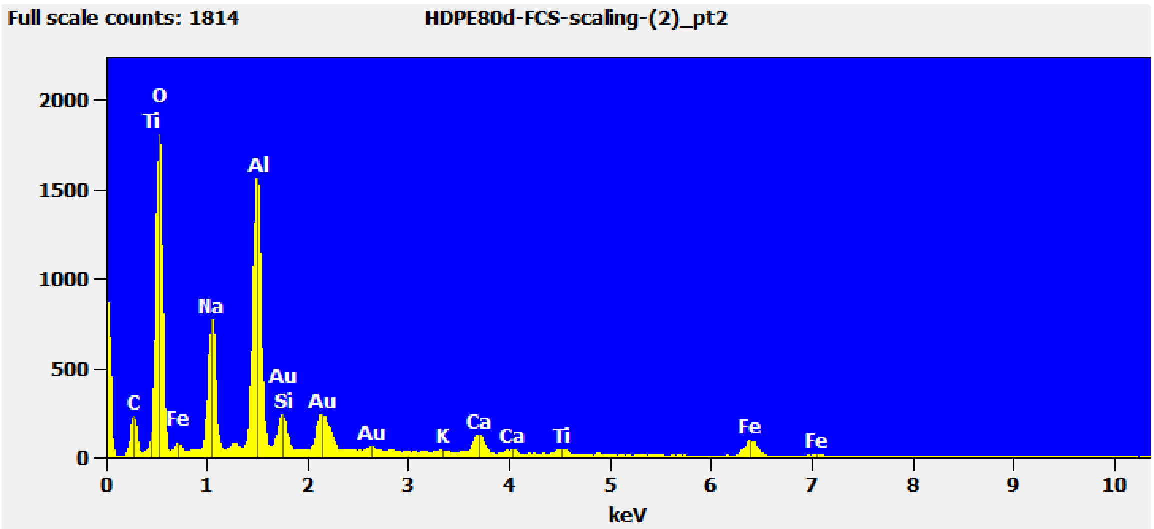

Figure 9. EDX analysis of scale on X-Treme.

3. Conclusions

The new X-Treme fabric was compared to the X-Scale fabric during security filtration in the Bayer process. Results showed that, after approximately 60 days, the flow in filters using the X-Scale fabric had decreased to about 80 % of the initial values. In contrast, filters with the X-Treme fabric maintained consistent flow throughout the same period. These findings align with air permeability measurements: the X-Treme fabric retained its permeability, while the X-Scale fabric experienced a 90 % reduction. Visual inspection also confirmed the absence of scale buildup on the X-Treme fabric surface. Additionally, production using the new fabric increased by 7 %, and maintenance personnel reported the easy removal of cake by hosing. The next step is to run the fabric until failure to determine its maximum service.

4. Reference

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