Influence of Weaving Parameters on the Mechanical and Filtration Properties of a Fabric

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Abstract

In Alumina industry, the process consists of many different steps of filtration using different types of fabrics. The fabrics must answer to different functionalities such as particle retention, productivity, cake moisture, chemical and temperature resistance. Moreover, all the fabrics have also to be adapted to the type of machines, where they are used, and have to be sometimes elastic or dimensionally stable, resistant to scaling but also against abrasion, be flexible to secure the sealing, and more. All these parameters will influence the filtration performance and the lifetime. But a fabric is built with totally different parameters such as type of yarns, count yarns, weave pattern, and those parameters will define, weight, pore size, air permeability, tensile strength at breaking, T3, T10. So, a legitimate question is how to build the most efficient fabric for the customer with weaving parameters, and how those parameters are relevant.

For that, Sefar has launched a complete study based on fabrics used in the alumina process and create a lot of variants built by changing different weaving parameters, only 1 element at each time, to be able to evaluate the impact of each of them and be able to better adapt the fabric to the functionalities requested. In that study, a standard fabric used in alumina, has been declined in different versions of weave pattern, diameters of yarns in warp direction, count yarn in warp, type of yarns in weft direction such as mono in different diameters up to multi in different dtex. Moreover, to be able to extract correct conclusions, all this changes have been done on the same machine with the same conditions of finishing and even, when it was possible during the same weaving production.

The first results found in lab, shown that some parameters of the fabric have a huge influence on important functionalities such as particle retention or cake moisture but are in contradiction with other important parameters such as tensile strength. This study has shown also that some parameters are not always part of the technical datasheet. But this first conclusions found in lab test is not enough, so in parallel, Sefar and a customer partner have also launched tests to check the relevancies of common parameters in the definition of the fabric as representative of needs.
In the presentation, Sefar will share the results of this study, with answers to some questions but also an opening to new questions.

Keywords: Filter media, Filtration properties, Filtration behavior, Lifetime, Cake moisture, Filtration performances.

1. Introduction

Before to study the impact of the filter media specifications on service life or filtration properties such as cake moisture, or particle retention, it is important to understand the filtration principles and how a filter media is designed. Indeed, those three items of complementary information will illuminate the possibilities given by the filter media in terms of process optimization.

1.1 Filtration Principles

The first important notion is the filtration theory described by Darcy laws and its impact on the filter media development.

$$\frac{Q}{\Omega} = \frac{\Delta P}{\mu \times R} \tag{1}$$

Where:

Q Outflow (also equal to dV/dt)
Ω Surface
µ Viscosity of the slurry to be treated
R Resistance to the flow (incl. Resistance of the cake & resistance of the fabric)
V Volume

Considering $\mathrm{R} = R_{\text{cake}} + R_{\text{cloth}}$
And as $R_{\text{cake}} = a \bullet \frac{dM_{cake}}{\Omega}$
And $dM_{cake} = R_{\text{cake}} \bullet dV$

where:

α specific weight of the cake (/ unit if surface)
W density of the cake
M Mass

We find after some integrations into the previous formula, the following formula:

$$\frac{t}{\mathrm{V}} = \left(\frac{\mu \times \alpha \times W_{cake}}{2 \times \Omega^2 \times \Delta P}\right) \times V + \left(\frac{\mu \times R_{cloth}}{\Omega^2 \times \Delta P}\right) + Constant \tag{2}$$

With this formula, by working at constant pressure, the formula becomes a linear curve type

$$\frac{t}{\mathrm{V}} = a \times V + b \tag{3}$$

In laboratory as t, V, Q, Ω, µ and ΔP are measurable, it is possible to evaluate different filter media and compare their relative own resistance $\mathrm{R}_{\text{cloth}}$, independently of the slurry or the equipment type.

Just as an example, the development of our fabric “High Capacity”.

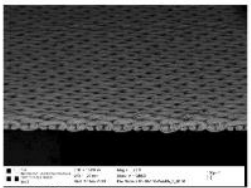

Figure 2: Multifilament, single layer

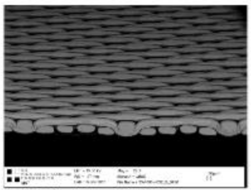

Figure 3: Monofilament, single layer

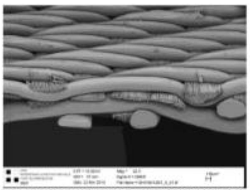

Figure 4: Mono/ Multifilament Double layer fabric

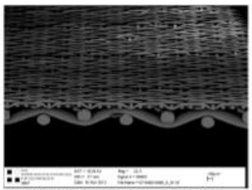

Figure 5: Monofilament, Double layer fabric

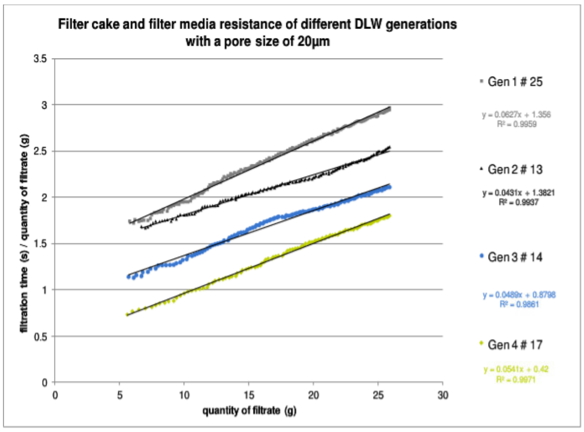

Figure 1. Evaluation of the $\mathrm{R}_{\text{cloth}}$ of different filter media design (on right) and picture of the corresponding filter media (on left).

By using a filter media with a lower R_{cloth}, it has been possible to:

- Increase filtration rate (in that particular case: + 7 %)
- Decrease cake moisture (in that particular case: - 4 %)
- And sometimes also, reduced solid content.

In that case, service life and dimension stability have not been affected.

What is important to understand is that each filter media has its own R_{cloth}, which gives different behavior in filtration, but this value is a result of the design and can be evaluate only in laboratory after the fabrication of the filter media.

The second important notion regarding filtration principles is the difference between filtration and dehydration. This parameter will influence the minimum cake moisture achievable.

Indeed, these steps are often mixed into the "filtration cycle", but in reality, there are two different actions with consequences for the process and for the fabric choice. The target of the Filtration is to separate a mixture of liquid "free"–solid, through a filter medium. The "not free" liquid (shown in Figure 2), which stays inside the cake, is called Interstitial Liquid, and can't be removed during filtration. At the end of the filtration step, the cake is still saturated with the "not free" liquid = Dryness Limit. This limit is the limit where we can't eliminate more liquid without an additional force (inflating, compressive etc.). This additional force is provided by the filter equipment options, like air blowing, compression of membrane, vacuum, … the choice of dehydration option depends on the type of slurry. The cake moisture thus obtained, can't be reduced without adding a heat treatment like shown in Figure 3.

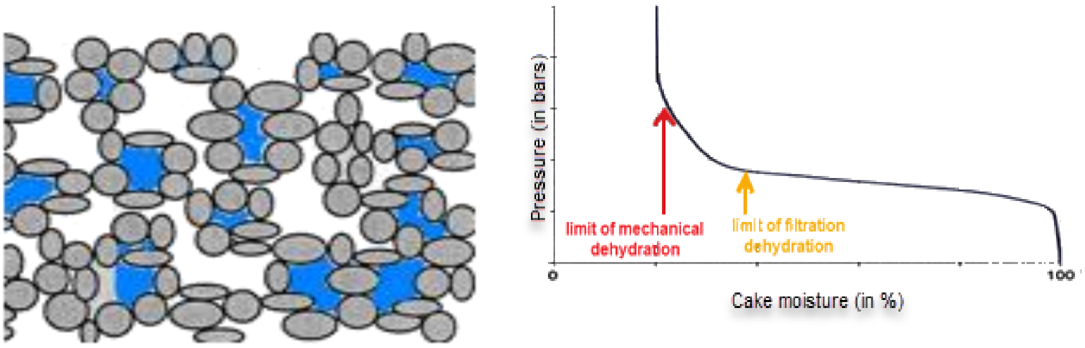

Figure 2. Schema of interstitial Liquid (in blue), Figure 3. Curve of dewatering with dryness limit and limit of mechanical dehydration.

The third and last notion linked to this study is the filtration process and the important fact that the filter media doesn't make the filtration but only prepare the first layer of cake. It is the cake itself which makes the filtration. The filter media is used as the starter, which will build a cake as efficient as possible. The filter media has an influence mainly on cake building (as the example shown in Figure 4), on washing efficiency and on cake release. The other properties such as flow rate, particle retention, or cake moisture are a consequence of the proper starter phase.

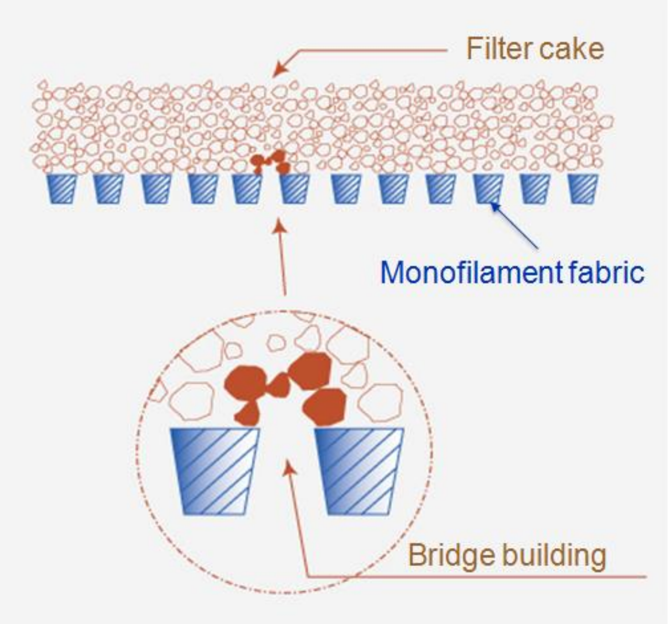

Figure 4. Proper way to build a cake with monofilament filter media

1.2 Filter Media Design

To design a filter media, there are mainly seven criteria to defined. These criteria include yarn choice and weaving and finishing parameters:

- Yarn polymer type such as PP, PET, PA.
- Yarn Type such as monofilament, multifilament, staple fibers
- Yarn diameters in warp and weft
- Yarn count in warp & weft
- Weave pattern
- Calandering set up (including for example: speed, temperature or pressure of each rolls)
- Heat setting set up (including for example: speed, temperature of the conveyer)

As consequences, the following parameters will be defined the specification datasheet, which can include:

- Thickness
- Weight of finished fabric
- Tensile Strength at breaking (T3, T10) in warp and weft direction
- Elongation at breaking in warp and weft direction
- Air Permeability
- Pore Size

Below, in the Figure 5, the comparison between two filter media produced with the same warp (means same yarn type, yarn diameter and yarn count) in warp direction but a different weft, and the differences in terms of specification in Table 1.

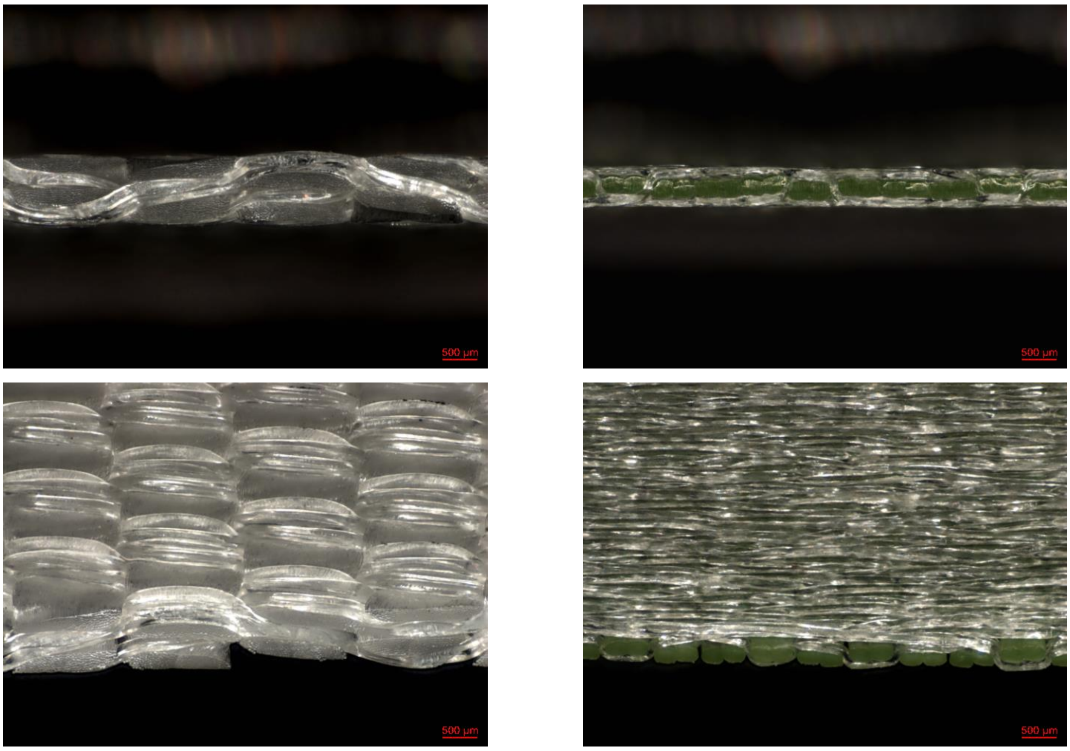

Figure 5. Pictures of 2 filter media (A on left, B on right) same warp but a different weft.

Table 1. Comparison of the specifications between filter media A & B.

Specifications	**Unit**	**Filter media A**	**Filter media B**
Thickness	*µm*	1057	722
Weight	g/m^2	718	500
Tensile Strength at breaking in warp	*N/mm*	152	158
Tensile strength at breaking in weft	*N/mm*	94	56
Elongation at breaking in warp	*%*	32	32
Elongation at breaking in weft	*%*	39	31
Air Permeability (at 200 Pa)	$l/m^2/sec$	15	27
Medium Pore Size (MFP)	*µm*	38	10

By comparing these two filter media, it is already clear that even if weight is different, the breaking force in warp is not influenced, which is totally logical, as it is the same warp construction.

But we can observe also that if air permeability is higher for the filter media B, the medium pore is higher. The question is now, what is the impact of the air permeability and the impact of the pore size on the “real” filtration.

2. Parameters from the Filter Media which Influences Filtration Performances

As an interlocution to this chapter, continuing the comparison between the filter media A and filter media B, on filtration performances based on a laboratory test with a Slurry with particle size at D_{50} =4 0 µm and under pressure 2.4 bars.

Table 2. Comparison of the filtration performances between filter media A & B.

Specifications	**Unit**	**Filter media A**	**Filter media B**
Filtration Time	*Sec*	52	23
Filtrate clarity	*mg/l*	0.26	0.43
Cake moisture	*%*	15.7	12

Note that it was not possible to build a cake with a slurry with particle size at D_{50} = 10 µm with the filter media B even if the MFP was measured at 10 µm, when it was possible to build the cake with the filter media A when MFP is announced at 38 µm. This open questions regarding the correlation between specifications / filter media measurements and filtration behavior. Indeed, if filtration time is higher the filter media with for the lowest air permeability, but the filtrate clarity is better for the filter media with highest pore size.

2.1 Study Concept

After this introduction, it is clear that specifications seem not to be always relevant for fabric choice. Sefar's idea was to launch a study to better understand the important and relevant specifications or information regarding the filter media.

For that, and because it is only possible to measure filtration behavior on produced filter media, a full range of variants has been produced in mono/monofilament fabrics and in mono/multifilament fabrics to be able to evaluate the influence of each design parameters on filtration performance. You can see in table 3, the concept of the different variants:

Table 3. Concept of the variants and possible comparison.

Variants will help to understand the impact of the following design parameters on filtration properties, and consequently on air permeability, pore size, weight or tensile strength.			**Weave pattern**	**Yarn diameter**	**Yarn count**	**Yarn Type**
Warp1	.1	Reference	x	x	x	x
	.2	Same than reference with weft in mono but other yarn Ø and weave pattern WS1	x	x		x
	.3	Same than Warp1.2 but in weave pattern WS2	x			x
	.4	Same than reference with weft in multi type 1		x		x
	.5	Same than Warp1.4 with weft in multi type 2		x		x
	.6	Same than Warp1.4 with weft in multi type 3		x		x
Warp2	.1	Same weft than Warp1.6 with smaller Ø of warp yarn and weave pattern WS1	x	x		x
	.2	Same than Warp2.1 in weave pattern WS2	x			
	.3	Same than Warp2.1 in weave pattern WS3	x			
Warp3	.1	Same weave pattern warp yarn than Warp2 but with more yarns	x		x	x
	.2	Same than Warp3.1 in another weave pattern WS2	x		x	x

	.3	Same than Warp3.1 in another weave pattern WS3	x		x	x
Warp4	.1	Same yarn Ø than Warp3 with mono Ø1 in weft and weave pattern WS1	x	x		
	.2	Same than Warp4.1 in weave pattern WS2	x	x		
	.3	Same than Warp4.1 with mono Ø2 in weft	x	x		
	.4	Same than Warp4.3 in weave pattern WS2	x	x		
Warp5	.1	Same than Warp1.1 with bigger Ø (Ø3) in warp	x			
	.2	Same than Warp5.1 in weave pattern WS2	x	x		
	.3	Same than Warp5.1 but with bigger Ø in weft	x	x		
	.4	Same than Warp5.3 in weave pattern WS2	x	x		
Warp6	.1	Same than Warp1.6 with a bigger Ø in warp	x	x		x
	.2	Same than Warp6.1 in weave pattern WS2	x	x		x
	.3	Same than Warp6.1 in weave pattern WS3	x	x		x

All these filter media have been produced in order to minimize the impact of each parameter, for example, each filter from the same warp have been produced in one shot with the same original warp and all the finishing steps also been in one shot.

Additionally, all filtration tests have been done with one the two selected and calibrated slurry: D_{50} = 10 µm or D_{10} = 40 µm in exactly the same conditions of preparation and pressures done on the equipment shown in Picture1.

Figure 6. Laboratory equipment used to make the first filtration tests.

2.2 Impact of Air Permeability on Particle Retention

It is common to receive request for a lower air permeability filter media in order to improve particle retention.

In the following graphics in Figure 7, it is clear that it doesn't exit any correlation between Air permeability and particle retention

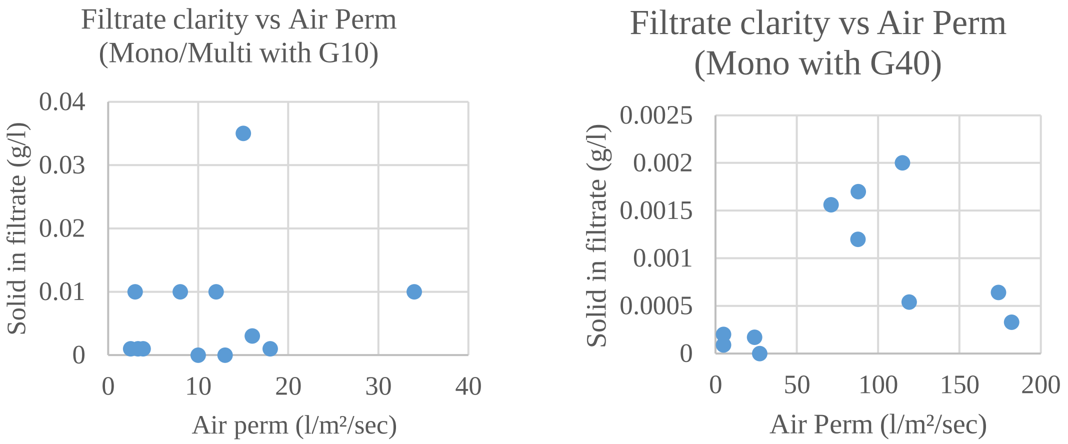

Figure 7. Evaluation of the correlation between air permeability and particle retention.

This is totally logical as air permeability is only the resistance to flow of air (or some other gas) through a porous layer, but not the capacity to stop particles in a liquid. And air permeability is measured at 200 Pa so at 0.002 bars. And particle retention depends of the pressure of filtration as shown in Figure 8.

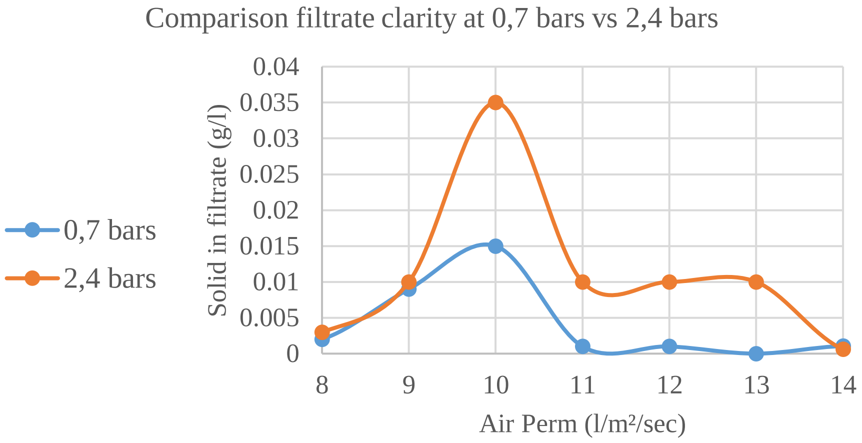

Figure 8. Relation between particle retention and pressure.

2.3 Impact of Medium Particle Size (MFP) on Particle Retention

Same work has been done to check correlation between medium particle size and particle retention.

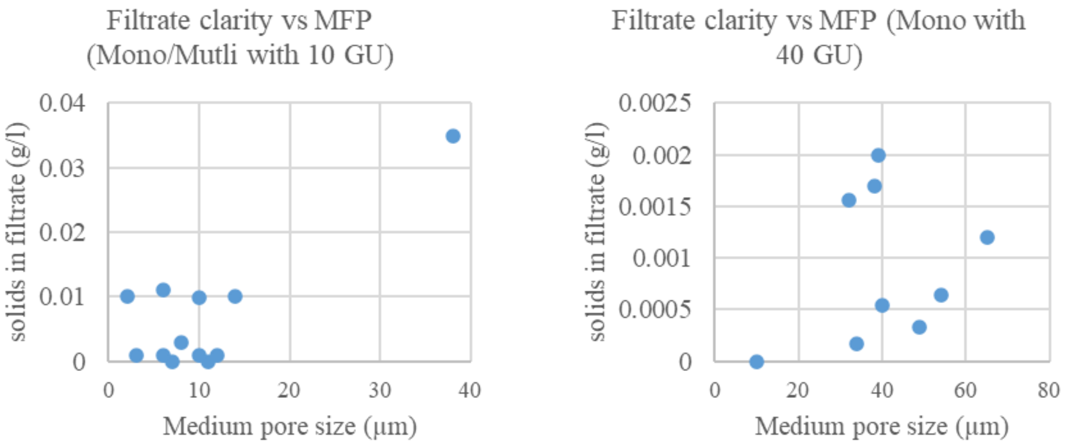

Figure 9. Evaluation of the correlation between particle size and particle retention.

In first approach, the results do not show any correlation. But with a deeper analyze, we can see that for similar filter media (for example same fabric with just a modification of the air permeability through a higher calendaring, or same fabric with a different weave style like on Figure 10), the results show a real correlation, which is still not the case with air permeability also shown in the graph 4.

The first conclusion in that case, is that a correlation exists for filter media which are similar in terms of design.

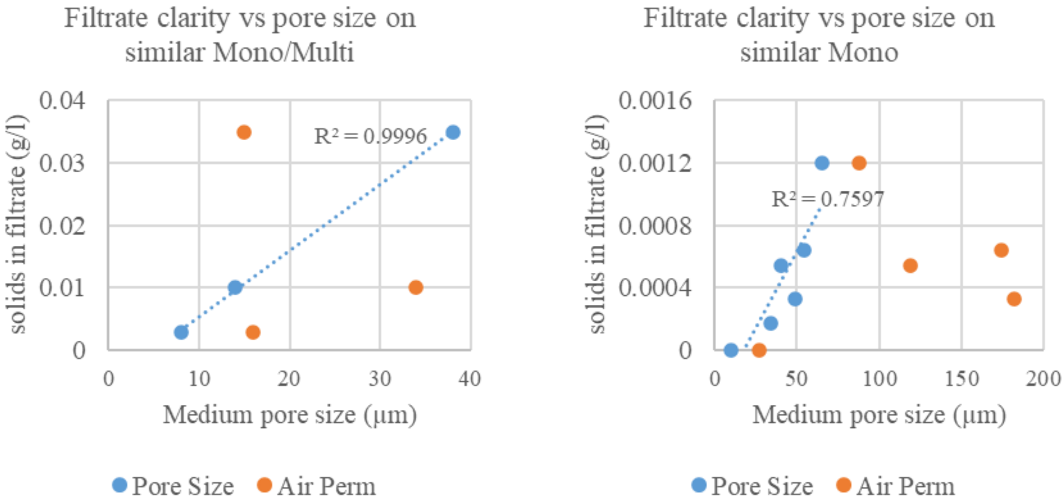

Figure 10. Evaluation of the correlation between particle size and particle retention for similar filter media.

2.4 Filtration Time and Filter Media Air Permeability

As shown in the Figure 11, the study has shown more a tendency than a pure correlation on the link between filtration time and air permeability. The air permeability stays a good indicator but can’t be considered as fully sure for an optimization of the filtration time.

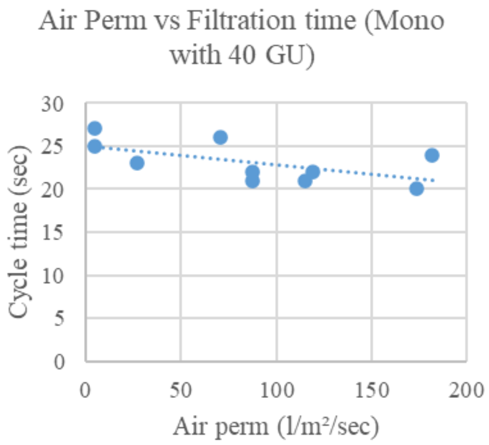

Figure 11. Relation between filtration time and air permeability.

2.5 Cake Moisture and Filter Media Air Permeability

A common belief is that cake moisture is dependent of air permeability. This study has not found any correlation between cake moisture and air permeability but air permeability is impacted by the weave pattern (see Figure 12)

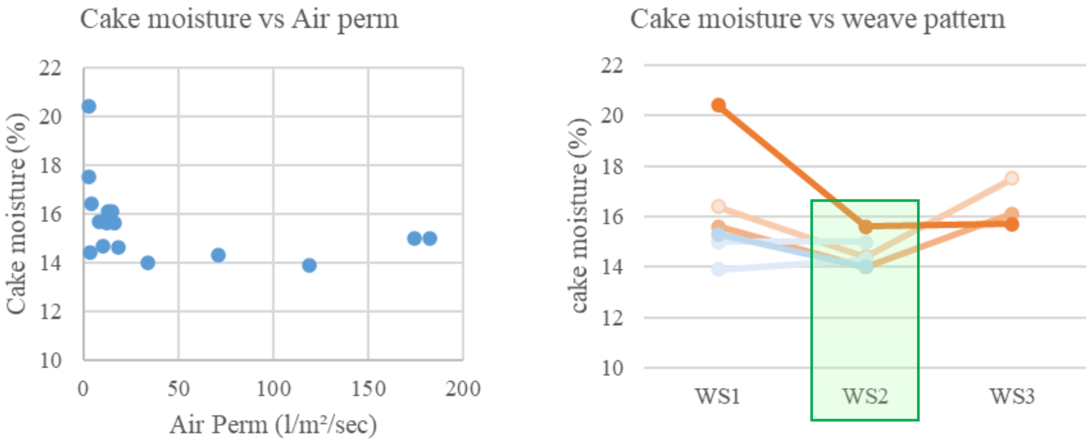

Figure 12. Relation between cake moisture and air permeability (on left) and weave pattern (on right).

2.6 Service life and filter media weight or tensile strength at breaking

A crucial behavior of the filter media is the service life. For this evaluation, a test in real conditions has been made in a bauxite & alumina partner on a filter press for the treatment of tailings. The results described in the Figure 13, shown that, in this case, increasing weight had no effects on service life.

This results have to be used carefully, because service life can depend of many different failure modes. In case of pure mechanical damage, it is highly possible that weight and/or tensile strength at breaking can have a positive effect on service life.

Another study done by Sefar on the clogging, blinding of filter press cloths can be shared during the ICSOBA exhibition.

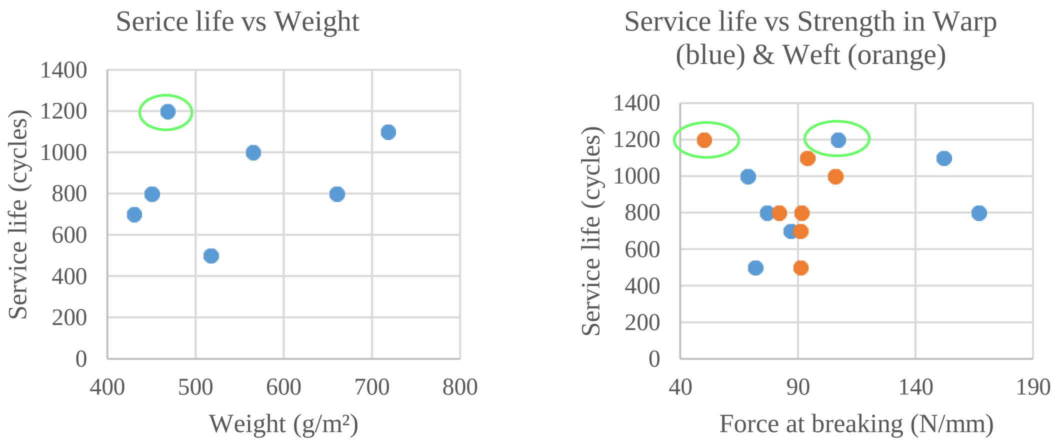

Figure 13. Relation between service life and weight (on left) and tensile strength at breaking (on right).

3. Conclusion

This study has shown three main information which contradict some common belief.

Firstly, there is no interest in using air permeability to choose the proper filter media in terms of particle retention. Air permeability can be considered as a help for possible improvement of filtration time but without full certitude. However, air permeability stays for Sefar a crucial fabrication parameter to ensure a god and reliable product.

Secondly, the medium pore size is a relevant parameter to optimize particle retention, only when we compare similar design of filter media.

Third, to increase service life, it is crucial to first analyze correctly the failure mode. Thinking that a heavier fabric with similar specifications will help would be a mistake.

Sefar is still working on better understanding the relation or no relation between filtration behavior and filter media to be able to develop the best filter media for our customers.