# CHARACTERIZATION OF TECHNICAL TEXTILES FOR SOLID FLUID FILTRATION

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***Abstract**: In solid fluid separation, textiles represent a key element of the set-up where it represents the barrier between disperse solid particles and the clean fluid. Among other characteristic textile data, the specific flow at standard test conditions is relevant information of filter performance. But new filter media with comparable characteristic data may exhibit quite different filter performance in terms of filtration rate and filtrate clarity. Even when the filter performance is similar with new filter media, filter performance can deteriorate quite differently over time. For a better description of the interaction between filter media and suspension the determination of the so-called permeability distribution (PD) is proposed. This characteristic function can be derived from filtration tests as well as during actual operation and it is based upon a characteristic transient pressure drop profile or volume flow profile that evolves during filtration.*

***Keywords:** filtration, flow resistance characterization, permeability*

## 1. Introduction

Porous media, most prominently textiles, have a wide range of application. Particularly in technical separation, i.e., filtration they represent a key element of the set-up. In solid fluid separation filter media represent the barrier where disperse solid particles are accumulated either inside the filter media through depth filtration or by cake filtration on top of the filter media. [1][2][3]

As a standard, information about the filter media is provided such as mechanical, thermal, and chemical stability, geometric data at various scales, i.e., filter fibre characterization in terms of cross sectional area and fibre roughness, weaving or knotting technique, filter mat thickness, filter media pore size and shape distribution, respectively, and finishing procedure, e.g. calendaring [4]. In addition, information is sometimes provided such as the chemical composition, surface properties of the filter media and standardized flow resistance measurements, generally expressed as a specific flow of water or air at a standard pressure difference [5].

This information is all necessary and helpful in correctly guiding filter selection for a certain separation task. But in essence it proves insufficient to correctly predict the actual performance of a filter media for a specific separation task [6]. Thus, tests are paramount where a representative filter media sample is used in the laboratory or pilot plant and the filter performance is established with the original dust or slurry sample. New filter media with comparable characteristic data may exhibit quite different filter performance in terms of filtration rate and filtrate clarity without apparent reason. Even when the filter performance is similar with new filter media, filter performance can deteriorate quite differently over time resulting in significantly different life times.

To better account for the interaction between filter media and slurry/solid laden gas the determination of the so called permeability distribution (PD) is proposed [7]. This PD goes well beyond a mere specific flow resistance value, since it accounts for the permeability of the actual filter media including its permanent contamination and aging situation. This characteristic function can be derived from filtration tests as well as during actual operation and it is based upon a characteristic transient pressure drop profile that is the result of an unequivocal permeability distribution of the filter media. Thus, the transient development of these permeability distributions allows a more substantiated extrapolation of filter performance including guidance for the optimal life span of a filter media until replacement. The consequences of different filter cleaning measures on subsequent filter performance can be evaluated and, to some extent predicted.

## 2. Experimental

The PD method is applied to experimental results that stem from two different filter test set-ups: One resembles a laboratory bag filter for dust removal from gas streams and that is operated at constant gas flow [7]. The other is a filter test unit for collecting solid particles from a liquid suspension and that is operated at constant pressure difference. The flow sheets of both set-ups are displayed in Fig. 1.

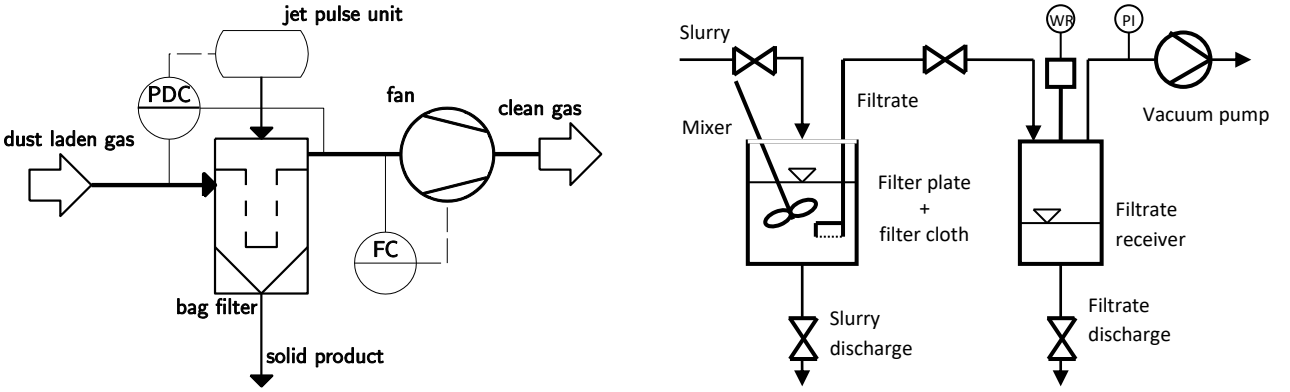



**Figure 1:** Flow sheets of experimental set-ups: continuous particle filter from gas flow at constant gas flow and variable pressure difference (left), discontinuous particle filter from liquid slurry at variable filtrate flow and constant pressure difference (right)

### 2.1 Particle filtration from gas streams at constant volume flow

Experimental pressure drop data was gathered from a laboratory-scale bag filter plant [7]. This plant consisted of a two-screw feeder that supplied a constant mass flow of dust to a dispersion nozzle. The dispersed dust was mixed with the gas stream, which was sucked through the filter plant by an induced draft fan. The gas volume flow after the filter was recorded and controlled to a certain set value via the frequency-controlled fan. The dust-laden gas entered the filter housing near the bottom. In the filter housing three filter bags were mounted on wire cages. The bags were pervaded by the dust-laden gas from the outside to the inside. Dust particles were retained at the outer surface of the filter bags. The clean gas flowed upwards inside the filter bags and was collected in the clean gas header. Due to the dust that accumulated on the filter bags, a filter cake formed and the overall permeability of the filter decreased. As the fan kept the volumetric flow rate of the gas constant, the pressure drop through the filter increased. The filter was regenerated either after a certain pressure drop over the filter was reached or after a certain time interval for filtration has elapsed. Filter regeneration was carried out by a reverse air jet pulse. Each filter bag could be regenerated separately. In Figure 1 basic flowchart of the filter plant is given.

The plant operated at ambient temperature and atmospheric pressure. Commercial grade non-precipitated $CaCO_3$ with a mass mean diameter of 5 µm and a bulk density of 1200 kg/m$^3$ was used as sample dust. The filter medium in the experiment was a polyphenylensulfide (PPS) and polyimide (PI) needle felt on a polyimide (PI) supporting scrim which was heat treated on the dust side. Only the online measurements of pressure drop across the filter and gas volumetric flow rate are used in this work. The measurement locations are shown in the flowchart in Fig. 1 indicated by PDC for pressure difference and FC for flow. The dust concentration is calculated according to:

$$c_{solid} = \frac{\dot{m}_{solid}}{\dot{V}} \qquad (1)$$

The specific cake resistance value $\alpha_m$ is determined from the slope of the linear asymptote of the pressure drop cure as laid out in [8].

The controlled gas volume flow changed slightly due to the response time of the control loop which can be seen in Fig. 2.

**Table 1:** Design and operating data of laboratory scale bag filter plant

| $A_{tot}$ (m$^2$) | $\dot{m}_{solid}$ (kg/s) | $\eta_{gas}$ (Pa·s) | $\alpha_m$ (m/kg) | $\dot{V}$ (m$^3$/h) |
|---|---|---|---|---|
| 2.04 | 8.4e-4 | 1.8e-5 | 6.67e9 | 240 |

### 2.2 Particle filtration from liquid slurry at constant differential pressure

Commercial grade Calcium hydroxide was dispersed in water to obtain a slurry that was put in an open mixing vessel where a filter plate covered with a commercial grade filter woven filter cloth was submerged. While all ball vales were closed, a vacuum pump was started to evacuate the system to a set differential pressure. Once this differential pressure was reached the ball valve connecting the filter plate with the filtrate receiver was opened and the filtration started, i.e., the filtrate started flowing and filling the filtrate receiver

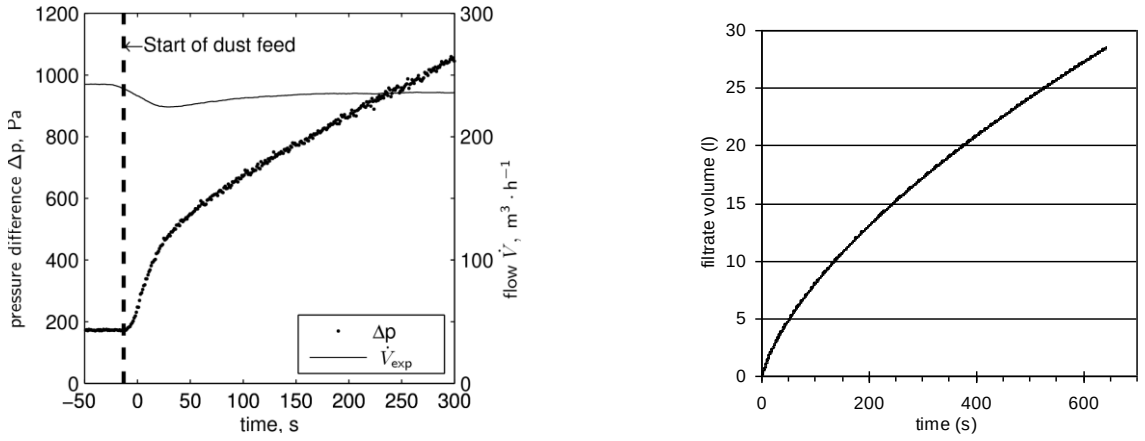
and the filter cake was formed and continuously growing. The weight increase was continuously recorded. After a preset time the experiment was terminated by closing the ball valve in the line after the filter plate. At the same time the filter plate was lifted out of the slurry tank and the filter cake thickness was measured. The cake was scraped off the filter plate and heated in a heating oven to determine the characteristic data of the filter cake, i.e., solid content and cake porosity.

**Table 2:** Design and operating data of laboratory scale liquid filter test unit

| $A_{tot}$ ($m^2$) | $\Delta p$ (bar) | $\eta_{liquid}$ (Pa·s) | $\alpha_m$ (m/kg) | $\rho_{liquid}$ ($kg/m^3$) | $c_{solid}$ ($kg/m^3$) | $\rho_{solid}$ ($kg/m^3$) |
|---|---|---|---|---|---|---|
| 0.01 | 0.4 | 1.14e-3 | 2.16e8 | 1000 | 166.7 | 2240 |

## 3. Experimental results

In Figure 2 typical results are displayed of an experiment: For air/solid filtration at basically constant volume flow a transient pressure difference curve is displayed on the left side and for water/solid filtration at constant pressure difference the cumulative volume of filtrate is displayed in the right side. Both curves exhibit a concave shape, which is at the first glimpse remarkable for constant flow filtration but quite typical for constant pressure filtration. Deriving characteristic data of filter and cake resistance, respectively, poses some difficulties in both cases: In the constant volume flow case, the initial fast rise in pressure drop can be attributed to a distributed filter cloth permeability [8]. In the constant pressure case, the classical correlation of t/V over V does not give a linear correlation or a convex shape due to e.g. cake compression effects [9], but a concave shaped curve particularly at the beginning of filtration. This can be due to particles that at least partly block the filter media right after start of the filter test [10] which is often also termed filter blinding [11] and which results in a possibly quite inhomogeneous filter permeability for the subsequent filtration.




a. b.

**Figure 2:** Experimental results of filter tests: a. continuous particle filtration from gas flow at constant gas flow and variable pressure difference, and b. discontinuous particle filtration from liquid slurry at variable filtrate flow and constant pressure difference.

## 4. Model

The filter model assumes Darcy flow through the filter media and thus the relation of flow velocity and pressure drop is linear:

$$v = k_o \frac{\Delta p}{\eta} \qquad (2)$$

This equation is extended towards filter cake formation and further manipulated by separating the variables of filtration area and time which gives:

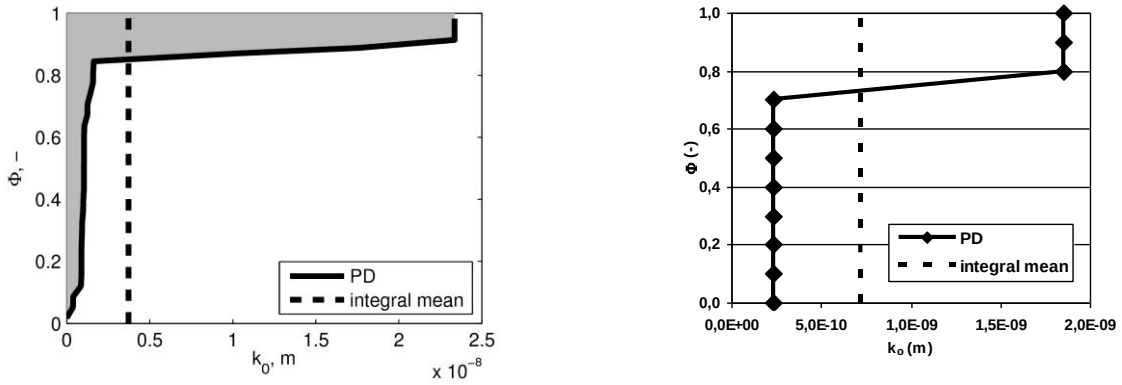
$$\frac{\eta \cdot \dot{V}(t)}{\Delta p(t)} = \int_{A=0}^{A_{total}} \left[ k_o^{-2}(A) + s(t) \right]^{-1/2} \mathrm{d}A \qquad (3)$$

where s(t) denotes the filter state as derived in detail in [8]

$$s(t) = k^{-2}(t, A) - k_o^{-2}(A) \qquad (4)$$

with k as the combined permeability of filter cake and filter medium.

Figure 3 shows the results of the permeability distributions (left air/solid and right water/solid test) of the filter media as the best fit of the experimental data. It shows that in both cases a rather large filter area fraction of around 80% exhibits a rather low permeability whereas the rest is quite open.




a. b.

**Figure 3:** a. Permeability distribution (PD) and mean value based on experiment from continuous particle filtration from gas flow at constant gas flow and variable pressure difference, and b. discontinuous particle filtration from liquid slurry at variable filtrate flow and constant pressure difference.

## 5. Conclusions

A constant and mean filter cloth resistance value does not necessarily describe the flow resistance of a filter cloth adequately. A new method is proposed to allow for a distributed filter cloth resistance, which is termed permeability distribution. This method is applied to particle removal from a gas stream at constant volume flow as well as particle removal from a liquid suspension at constant pressure difference and both filter media show a quite pronounced permeability distribution. Such a distribution might be one of the reasons why seemingly similar filter media – exhibiting the same mean permeability value – still show quite different filtration performance both in filtrate clarity as well as filtration rate.

### Notation

| | | | |
|---|---|---|---|
| $A_{tot}$ | total area of filter ($m^2$) | $\dot{V}$ | Volume flow ($m^3/h$) |
| $c_{solid}$ | solid concentration ($kg/m^3$) | v | velocity (m/s) |
| $k_0$ | permeability at start of filtration (m) | $\alpha_m$ | specific cake resistance based on mass (m/kg) |
| $\dot{m}_{solid}$ | solid mass flow (kg/s) | □ | cumulative area distribution function (-) |
| $\Delta p$ | pressure drop across filter (bar) | $\eta$ | dynamic viscosity (Pa·s) (Index: liquid / gas) |
| s | filter state ($1/m^2$) | $\rho$ | density ($kg/m^3$) (Index: solid / liquid) |

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