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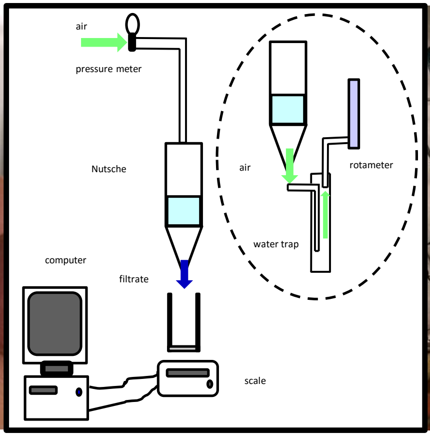
INSTITUT FÜR MECHANISCHE VERFAHRENSTECHNIK UND AUFBEREITUNGSTECHNIK

Permeability ratio – output variable to quantify crack on filter cake



147th WISE

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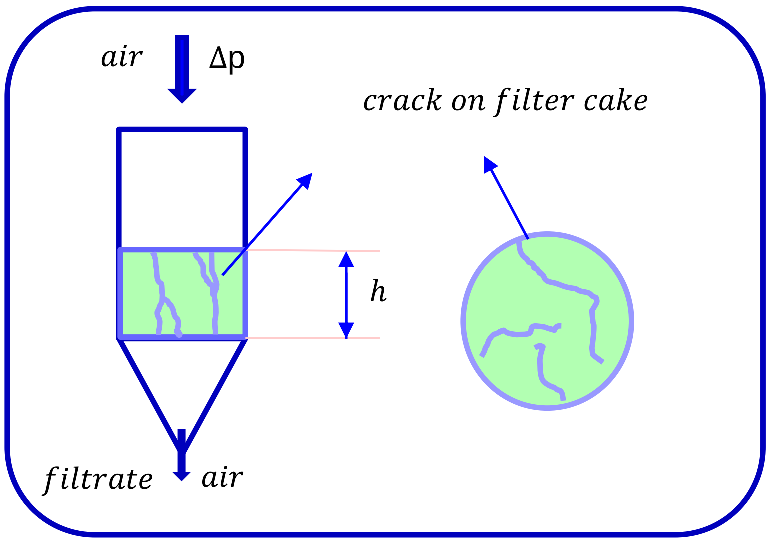
Permeability ratio – relevant variable to quantify cracking on filter cake

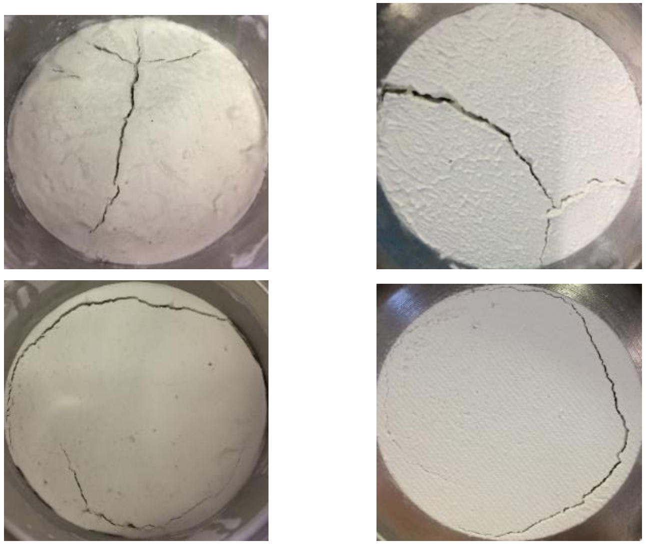
1. Motivation
2. Experiment equipment and materials
3. Test and result
4. Discussion and next steps...

1. Motivation

The crack is formed during filtration and washing process and is the undesired phenomenon. This phenomenon lead to:

- Higher gas/water washing consumption,
- Air flows through the cracks, not through porous medium ⇒ higher compressed air consumption
- Higher residual moisture content





1. Motivation

The best method to **remedy cracking on filter cake** is of course*, avoid the crack formation* or *prevent the filter cake from crack totally* as well as *understanding mechanism of the formation of cracking*:

- Quantitative crack formation
- Survey input parameters which effect on shrinkage crack formation, explain result
- Using advantage methods to reduce the impact of input parameters on crack formation

1. Motivation: Permeability ratio

Once a cake has cracked, a channel is formed and gas permeability increases significantly as the gas flows preferentially through the cracks rather than the pores in the filter cake because:

- Cracks size are bigger than pore size
- Cracks develop directly from top to bottom of filter cake. Therefore, water and gas, which flow by this way, is usually less tortuous than through pores?

Crack formation and the amount of cracking are indicated by permeability ratio

$$\textbf{Permeability ratio } \boldsymbol{\beta} = \frac{\boldsymbol{k_G}}{\boldsymbol{k_L}}$$

Where k_G: permeability for gas

k_L: permeability for liquid

1. Motivation: Porous media during filtration with

Incompressible flow

Water

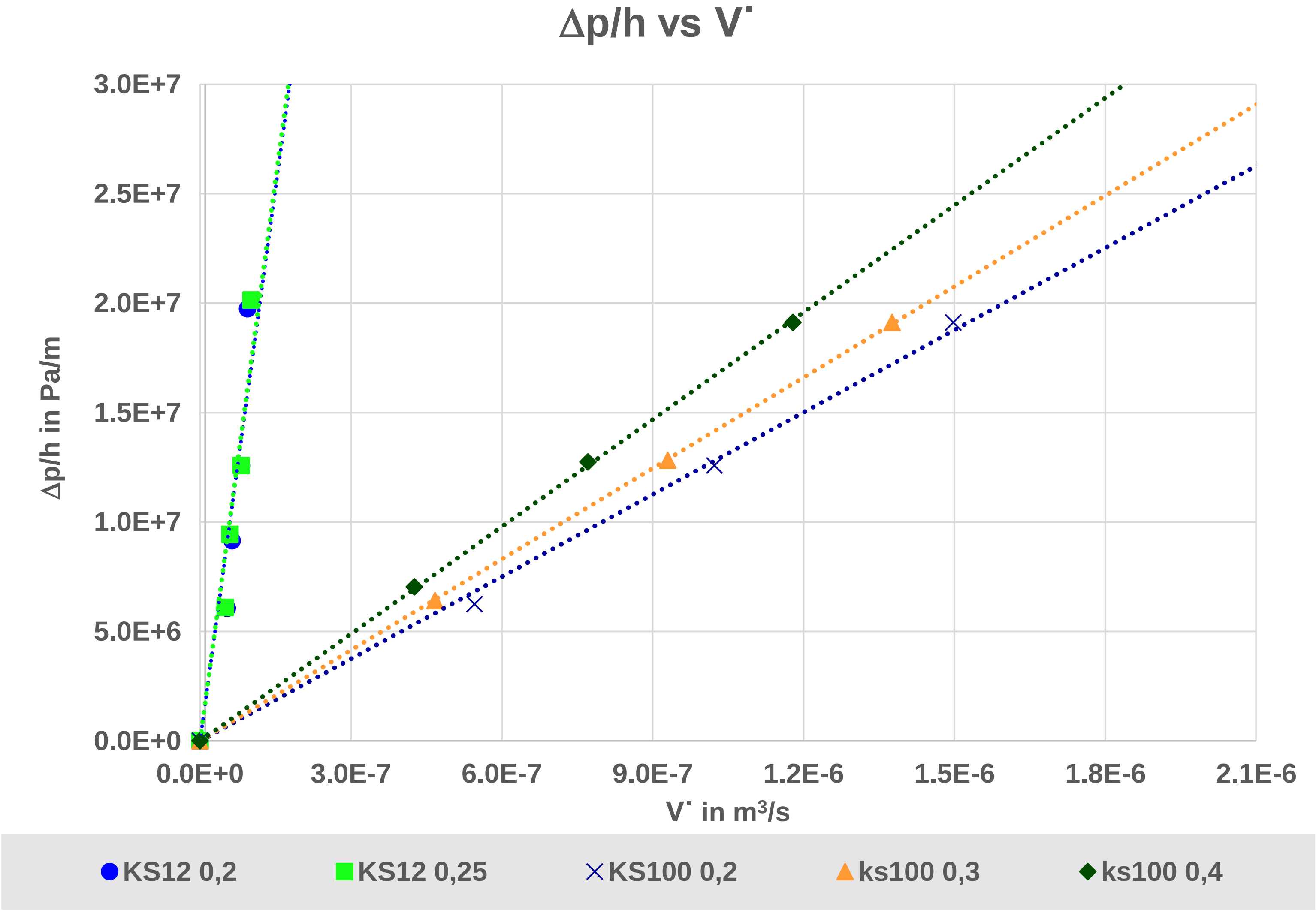
- **Laminar regime**
- $\frac{\Delta p}{h} = \frac{\mu}{A.k}.\dot{V}$
- Turbulent regime
- $\frac{\Delta p}{h} = \frac{\mu}{k}.v + \frac{\rho}{k_1}v^2$

Compressible flow

Gas

- **Laminar regime**
- $\frac{p_1^2 - p_2^2}{h} = \frac{2.\mu.p_2.\dot{V}}{A.k}$
- Turbulent regime
- $\frac{\Delta p}{h} = \frac{\mu}{k}.v_m + \frac{\rho}{k_1}v_m^2$

1. Motivation: For incompressible flow (water)



1. Motivation: Liquid permeability K_L

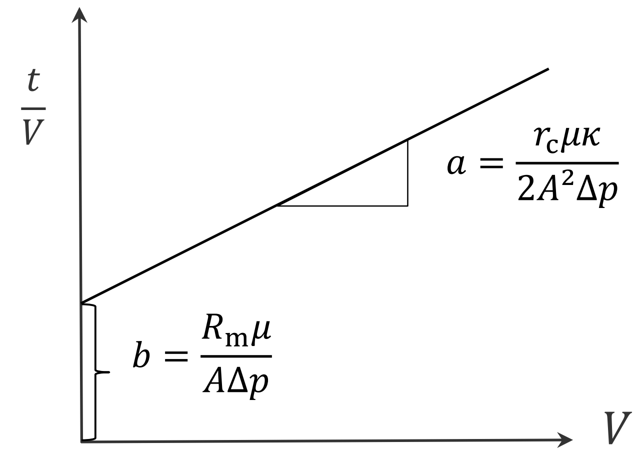
According Darcy for incompressible and laminar regime:

$$\Delta P = \frac{\mu.h.dV}{A.k.dt} \quad \Rightarrow \quad \frac{dV}{dt} = \frac{\Delta P.A.k}{\mu.h} \quad \Rightarrow \quad \frac{dt}{dV} = \frac{\mu.h}{\Delta P.A.k} = \frac{\mu}{\Delta P.A}.(R_c + R_m) \ (1)$$

Rc is resistance of filter cake, $= r_c.\frac{\kappa}{A}.V$

(1) can rewrite: $\frac{dt}{dV} = \frac{\mu.\kappa.r_c}{\Delta P.A^2}.V + \frac{\mu}{\Delta P.A}.R_m$

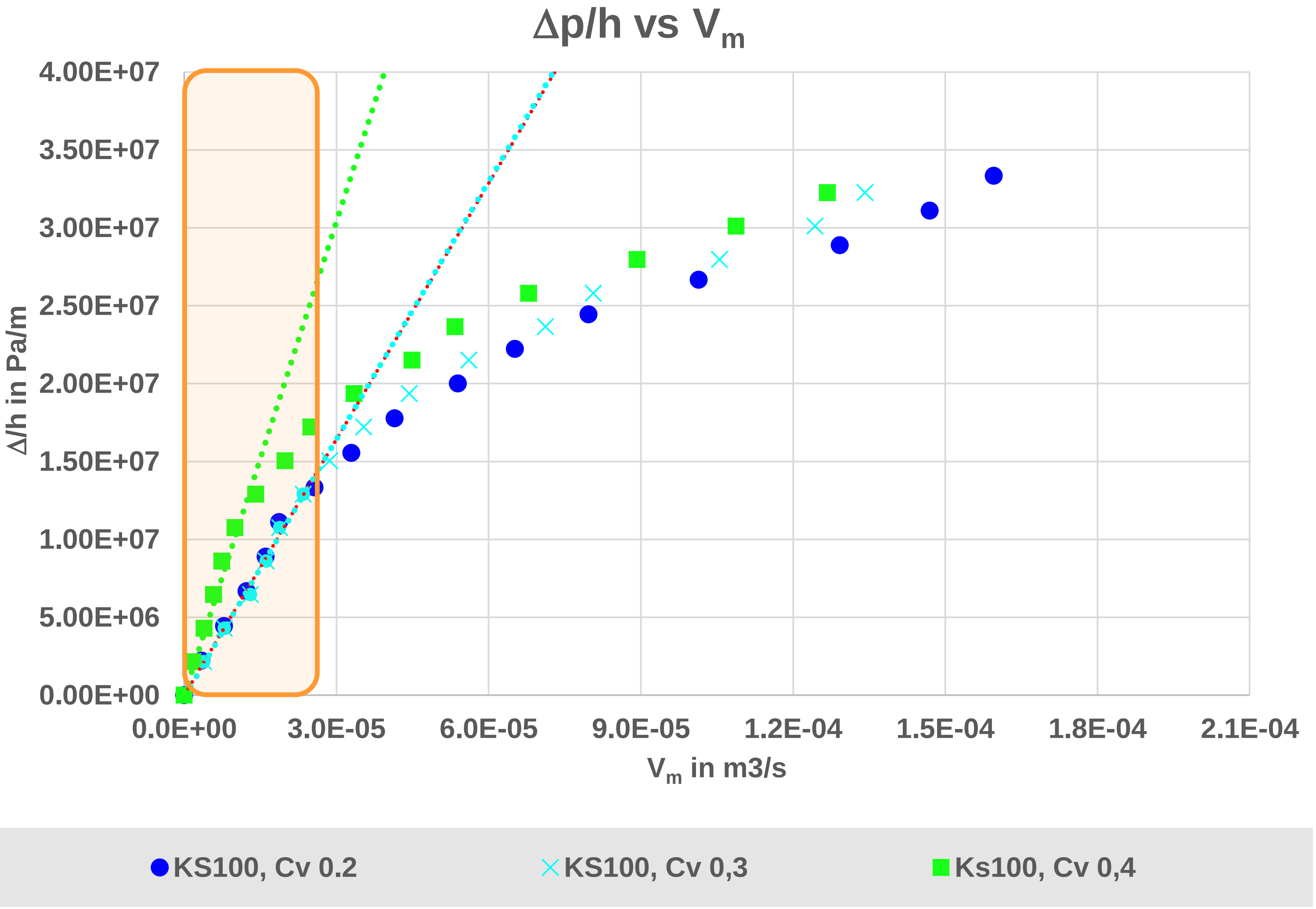
$$\Rightarrow \frac{t}{V} = \frac{\mu.\kappa.r_c}{2\Delta P.A^2}.V + \frac{\mu}{\Delta P.A}.R_m$$



$$\kappa = \frac{c_v}{1 - \varepsilon - c_v}$$

$$\boldsymbol{k_L = \frac{1}{r_c}}$$

1. Motivation: For compressible flow (air)



1. Motivation: Gas permeability

- Deliquoring without crack, gas permebility is calculated:

$$k_G = \frac{k_{G\,m}}{k_{Grl}}$$

Where: k_{Gm} is gas permeability measurement

$$k_{G\,m} = \frac{2(p*\dot{V})_t*\eta_G*h}{A*(p_1^2-p_2^2)}$$ (1) *(Darcy for compressible and laminar regime)*

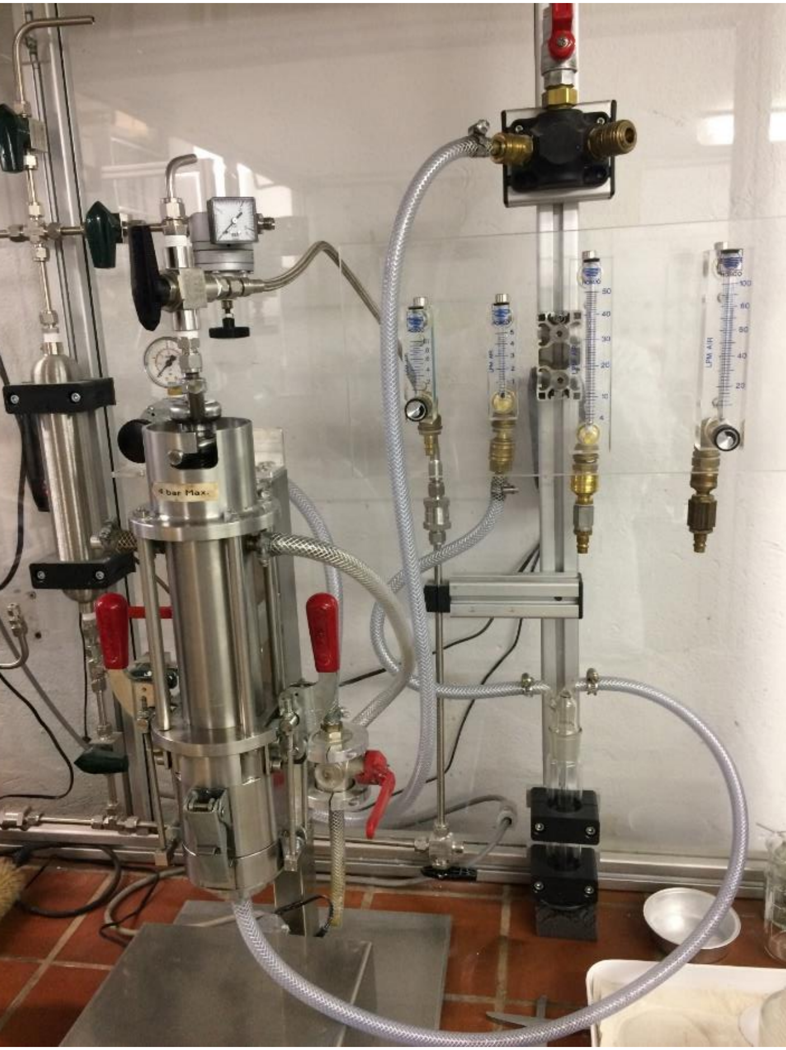
k_{Grl} is relative gas permeability

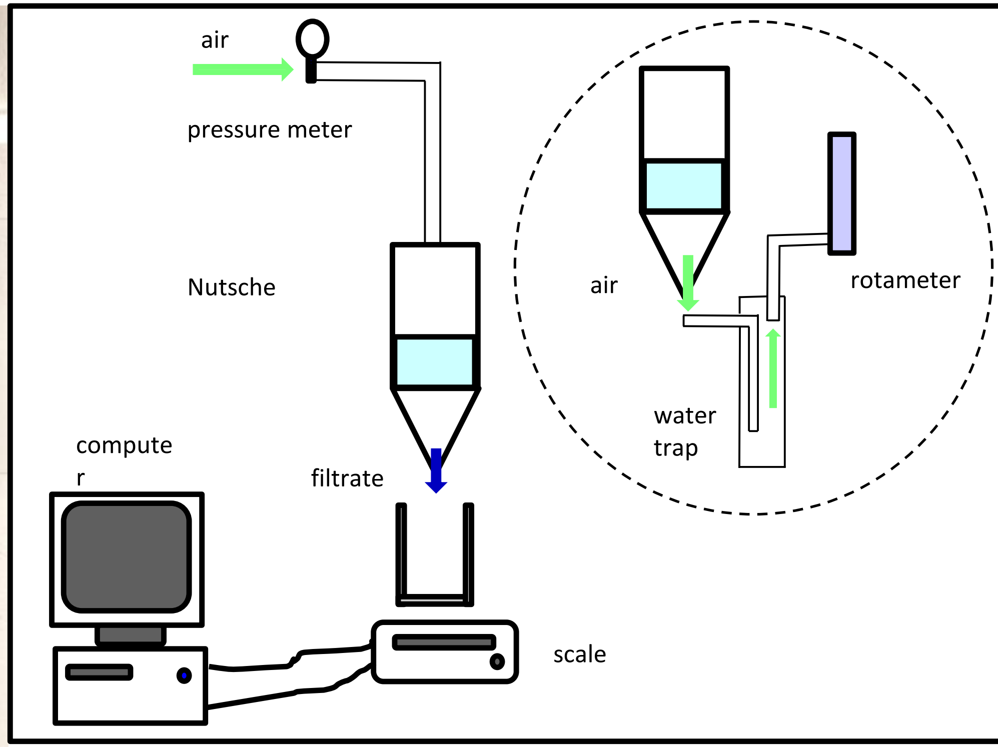
$$k_{Grl} = (1-S_R)^2*(1-S_R^{(2+\lambda)/\lambda})$$ *(Accordingh R.J Wakeman)*

Where $S_R = \frac{S-S_\infty}{1-S_\infty}$ and $\lambda = 5$ for practical purposes

- For system with crack, the term which called "absolute gas permeability" (***$k_{G\,m}$***) is used (1)
  - Problem: crack occur – system in turbulent regime ???

2. Experiment equipment and materials





Filtration rig : Area of 0.001964 m^2 (*is built according to VDI 2762/2)*

Air volume flowrate meter : 4 kind of Rotameter 0,1-10; 0.4-5; 4-50; 10-100 in NL/min at 1 atm and 0 degree Celcius

2. Experiment equipment and materials

Filter cloth: *05-1010-SK 006 with air permeability of 18 $m^3/m^2/h$ at 20 mm WS*

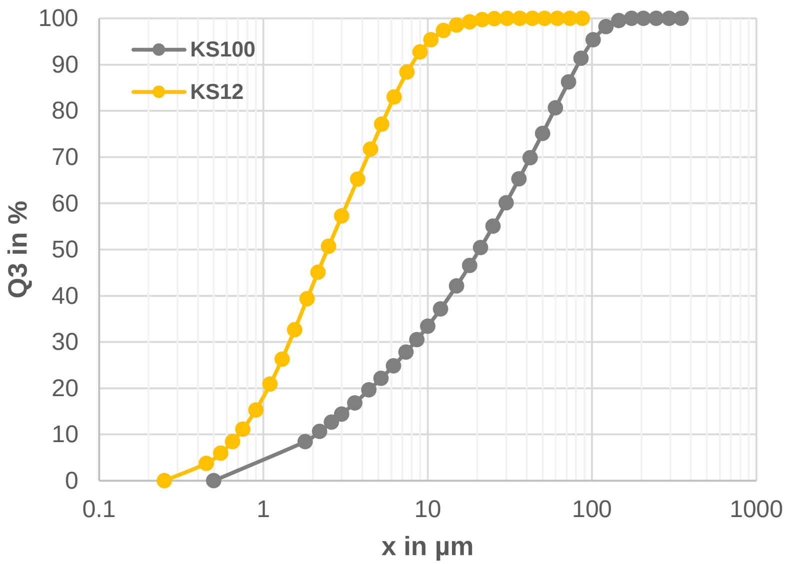
Air pressure difference: *change from 1 to 3 bar*

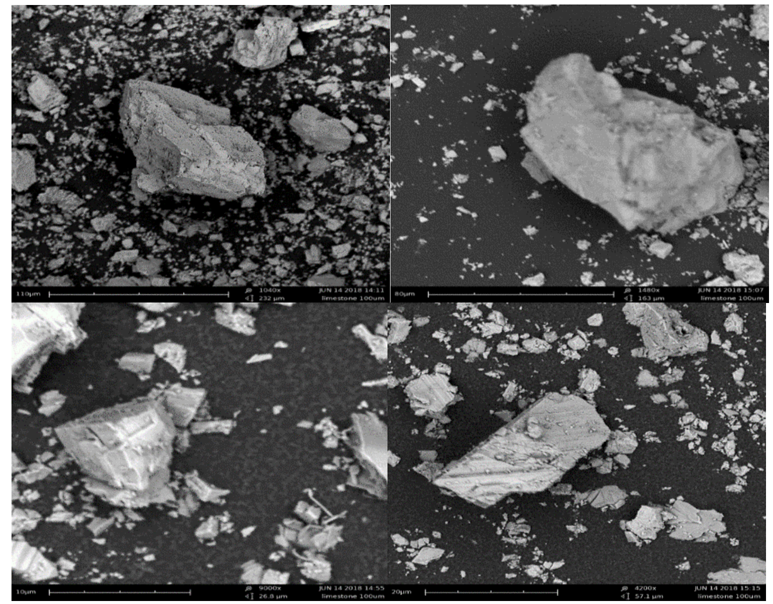
Volume fraction: *change from 0,05 – 0,4*

Mass of solid: *change from 30 gram – 90 gram of limestone (density 2.71 g/cm^3)*

Distilled water is used: *will be changed depend on volume fraction and mass of solid*

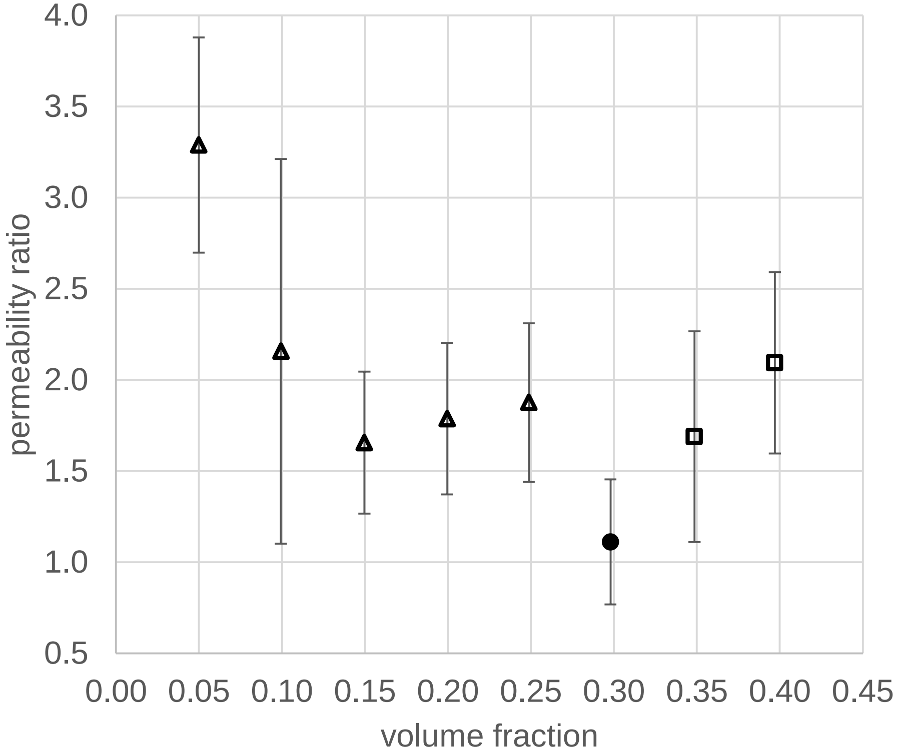
2. Experiment equipment and materials

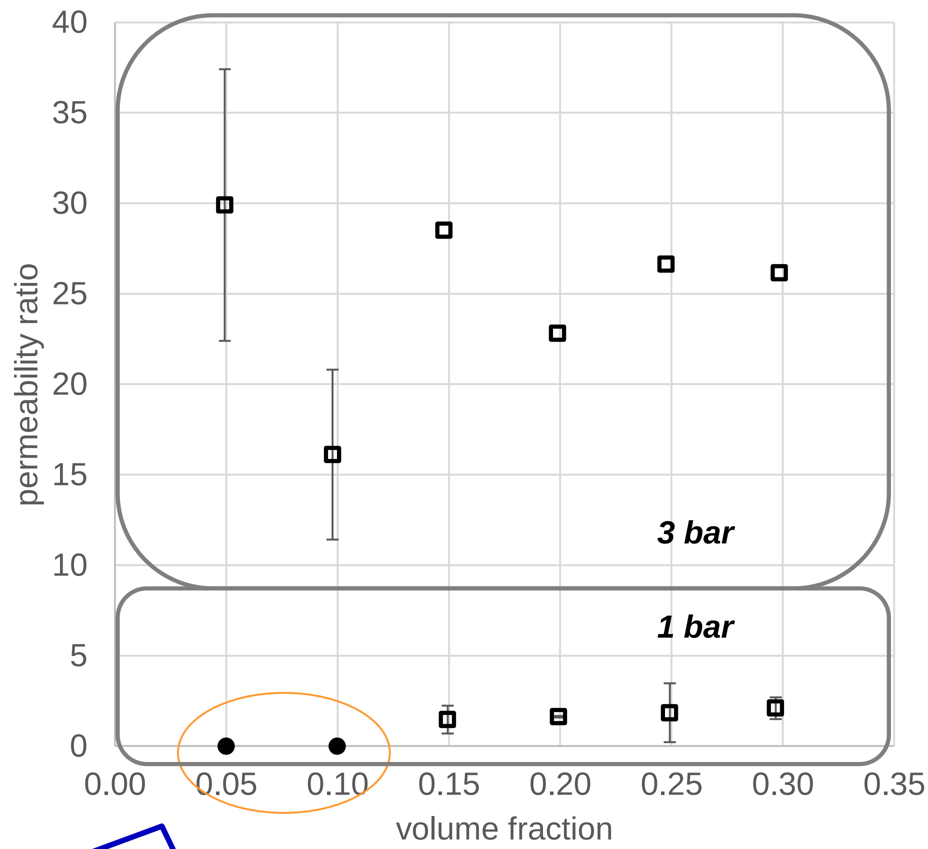




Materials	x_{50} in µm	Span $(x_{90}-x_{10})/x_{50}$	Broadness x_{90}/x_{10}	x_{10} in µm	Cumulative passing 10 µm in %
KS12	2.46	2.98	11.34	0.71	94.51
KS100	20.68	3.88	39.61	2.08	33.39

3.Result: Influence of volume fraction for KS100 (left diagram and KS12 (right diagram)





●: deliquoring
Δ: shrinking
□: cracking

There is no air flows through filter cake

3. Result: Influence of volume fraction

KS100_cv_0.2_h_~15mm_1 bar

KS100_cv_0.3_h_~15mm_1 bar

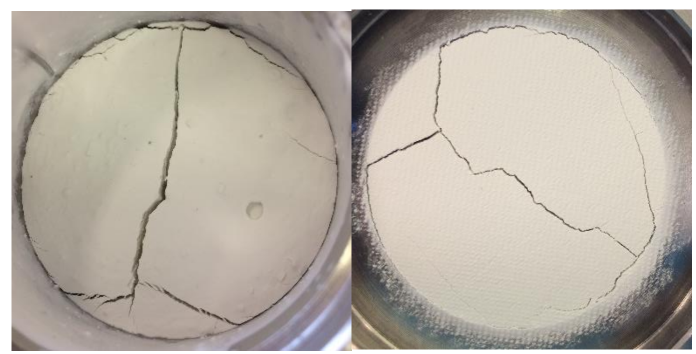
KS100_cv_0.4_h_~15mm_1 bar

3.Result: Influence of volume fraction

KS12 _cv_0.2_h_~15mm_1 bar

KS12 _cv_0.3_h_~15mm_1 bar

KS12 _cv_0.2_h_~15mm_3 bar



KS12 _cv_0.3_h_~15mm_3 bar

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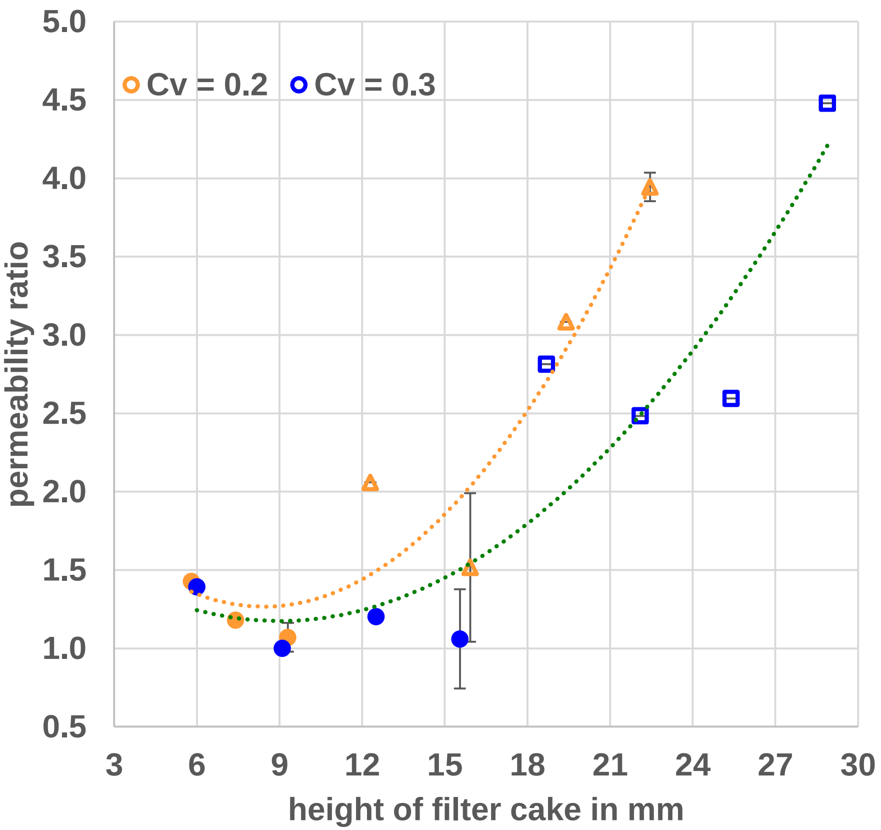
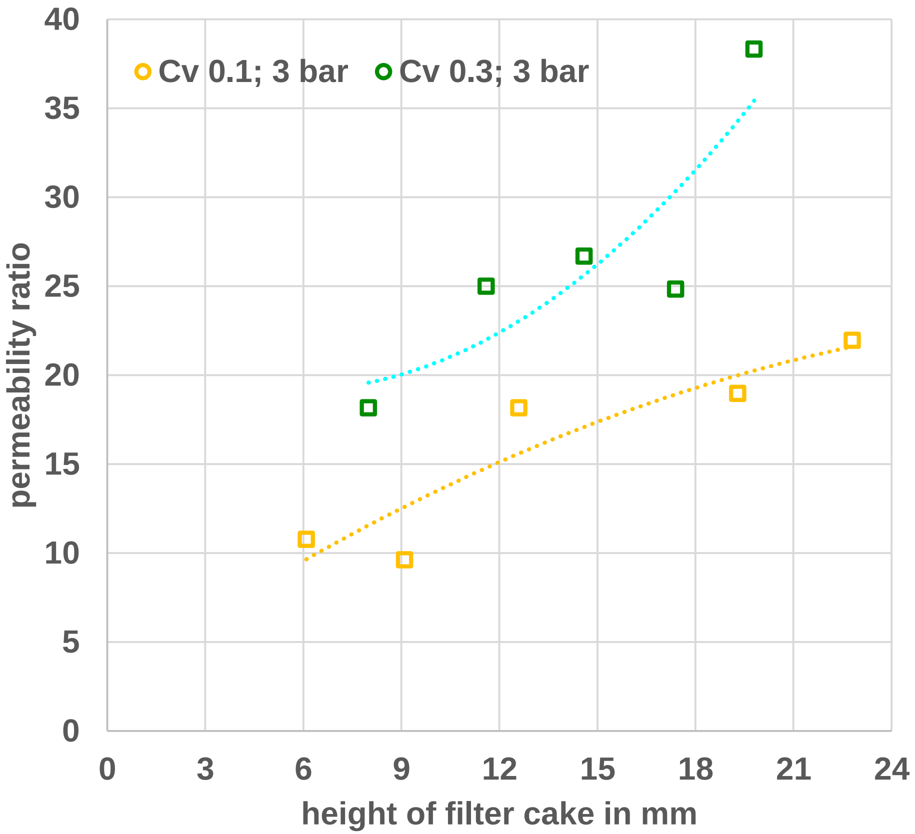
3.Result: Influence of height of filter cake for KS100 (left), and KS12 (right)





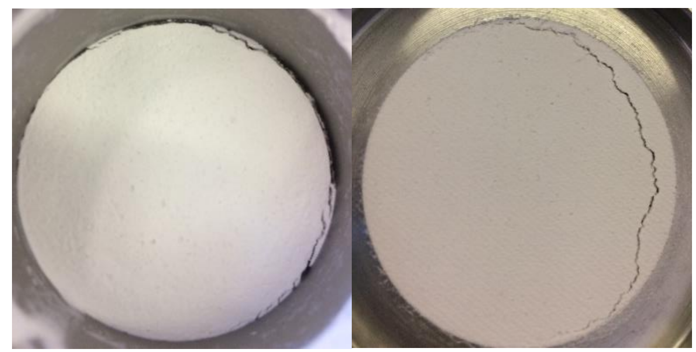
•: deliquoring   Δ: shrinking   □: cracking

3. Result: Influence of height of filter cake

KS100_1 bar_h_9.2mm_cv_0.2

KS100_ 1bar_h_22.6mm_cv_0.2

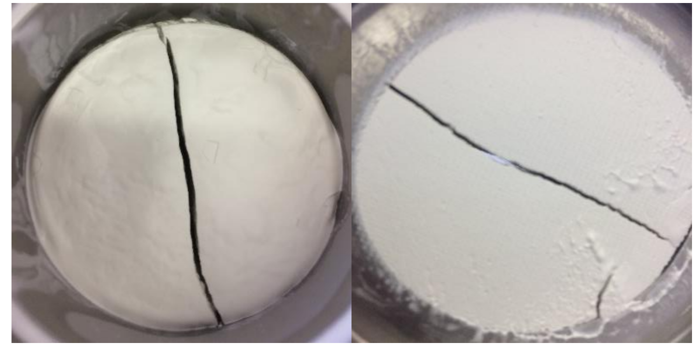
KS100_1 bar_h_9.1mm_cv_0.3



KS100_1bar_h_22.1mm_cv_0.3

3.Result: Influence of height of filter cake

KS 12_ 3bar_h_9.1mm_cv_0.1

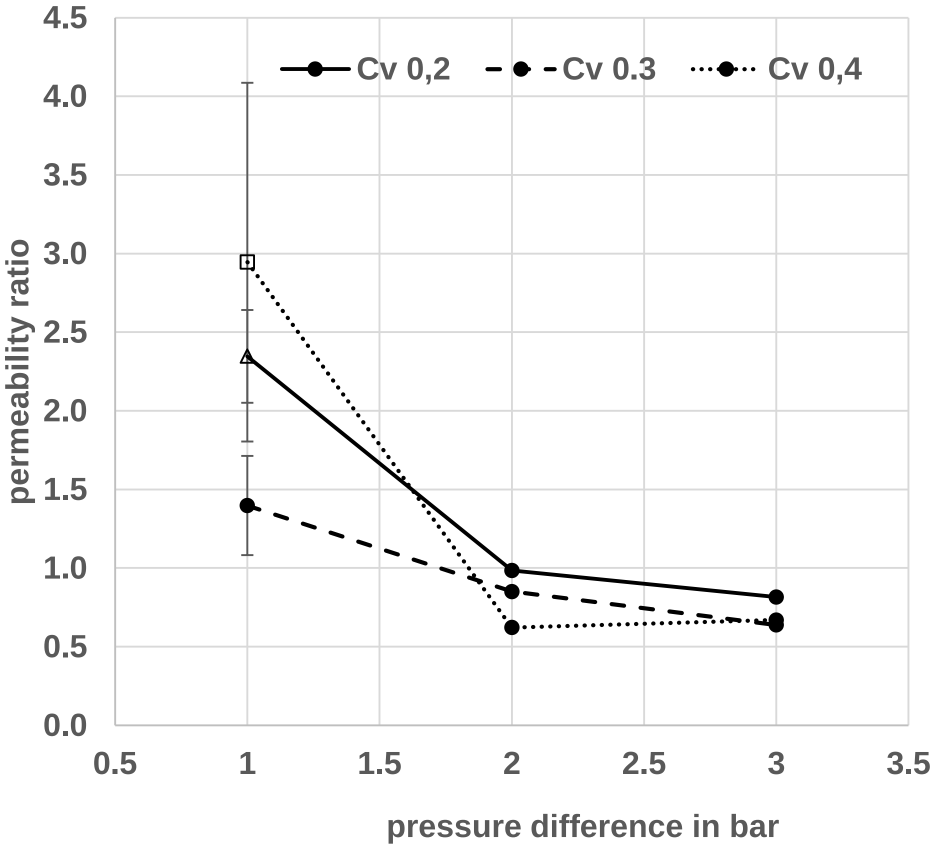


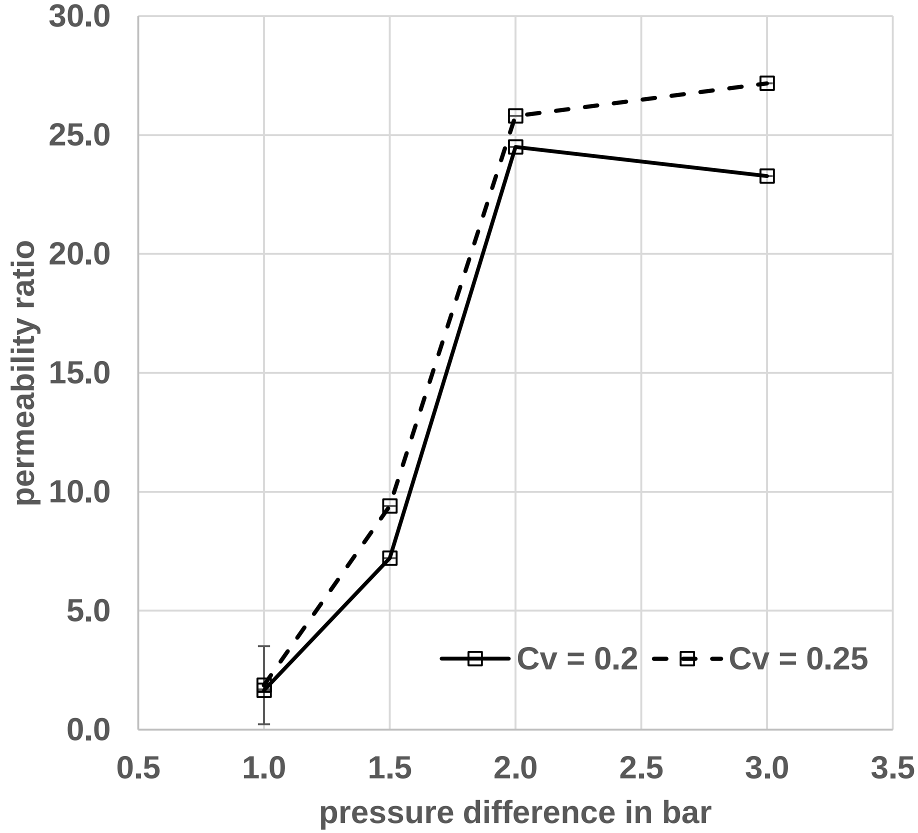
KS 12_ 3bar_h_19.3mm_cv_0.1

KS 12_ 3bar_h_8mm_cv_0.3

KS 12_ 3bar_h_19.8mm_cv_0.3

3. Result: Influence of pressure difference for KS100 (left), and KS12 (right)





•: deliquoring Δ: shrinking □: cracking

3.Result: Influence of pressure difference

KS100_Cv_0.2_h_~16mm_1bar

KS100_Cv_0.3_h_~16mm_1bar

KS100_Cv_0.4_h_~16mm_1bar

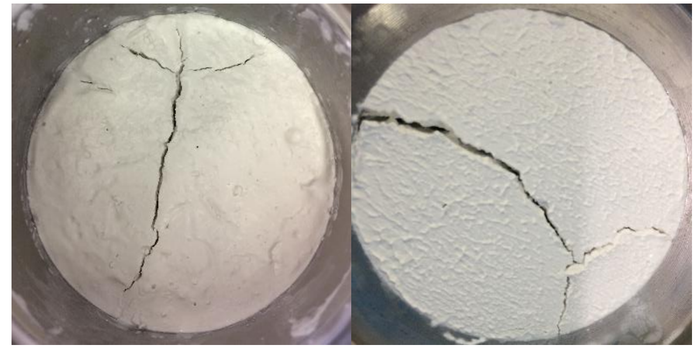
KS100_Cv_0.2_h_~16mm_3bar

KS100_Cv_0.3_h_~16mm_3bar

KS100_Cv_0.4_h_~16mm_3bar

3.Result: Influence of pressure difference

KS12_ Cv_0.2_h_~16mm_1bar



KS12_ Cv_0.25_h_~16mm_1bar

KS12_ Cv_0.2_h_~16mm_3bar

KS12_ Cv_0.25_h_~16mm_3bar

4. Discussion and next step...

- Permeability ratio is a appropriate parameter to decribe and estimate degree of the crack on filter cake

  - Liquid permeability is measured through tests, $k_G = \frac{1}{r_c}$
  - Gas permeability is measured through Darcy equation for compressible flow, is modified with relative gas permeability when deiquoring without crack. When crack occur, should I using absolute value??

- According tests, it can be realised that cracking and shrinkage can be formed by sedimentation, wall effect and interraction forces between particles

  - Crack occur by wall efect or shrinkage due to sedimentation can be reduced by higher applied pressure difference
  - Crack occur by particles interaction force should be treated by another way.

4. Discussion and next step...

- Crack is form because of interaction forces between particles in filter cake. If liquid is drained simultaneously both in large and small pore, particles is not effected by capillary force. The result is less crack occur. $\Rightarrow$ steam pressure filtration
- Crack is observed only on top and at bottom. Crack is need to observe internal of filter cake $\Rightarrow$ tomography measurement
- Publication...
- Coal sampling and test...

Thank you for your attention!

Danke für Ihre Aufmerksamkeit!