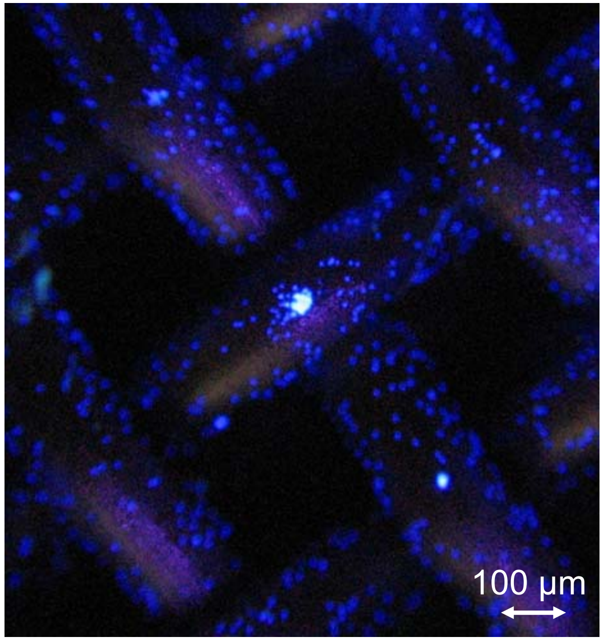

DIMENSIONLESS ANALYZIS OF THE CLEANABILITY OF WOVEN FILTER MEDIA USED IN INVERTING FILTER CENTRIFUGES

2008 AFS Annual Conference
Valley Forge, PA
May 19-22, 2008

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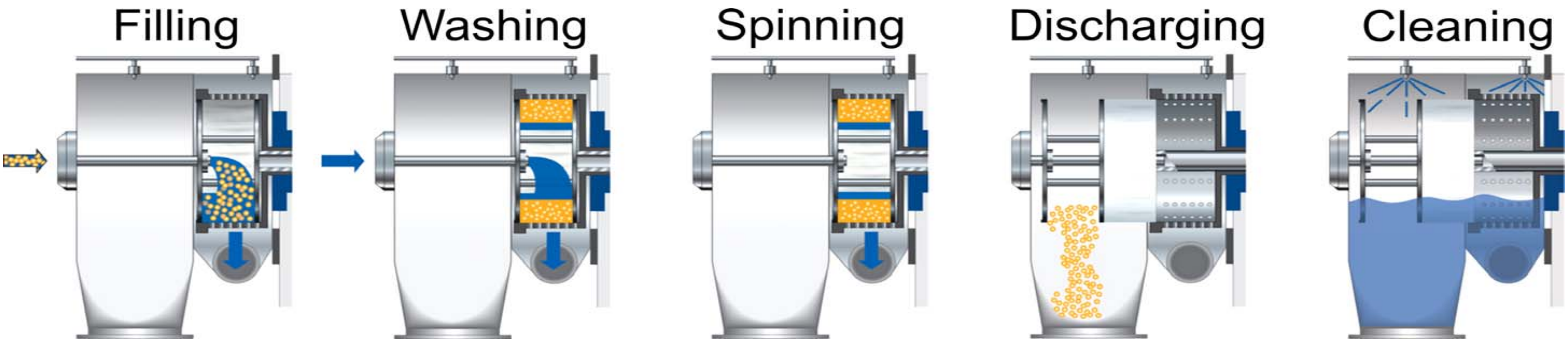
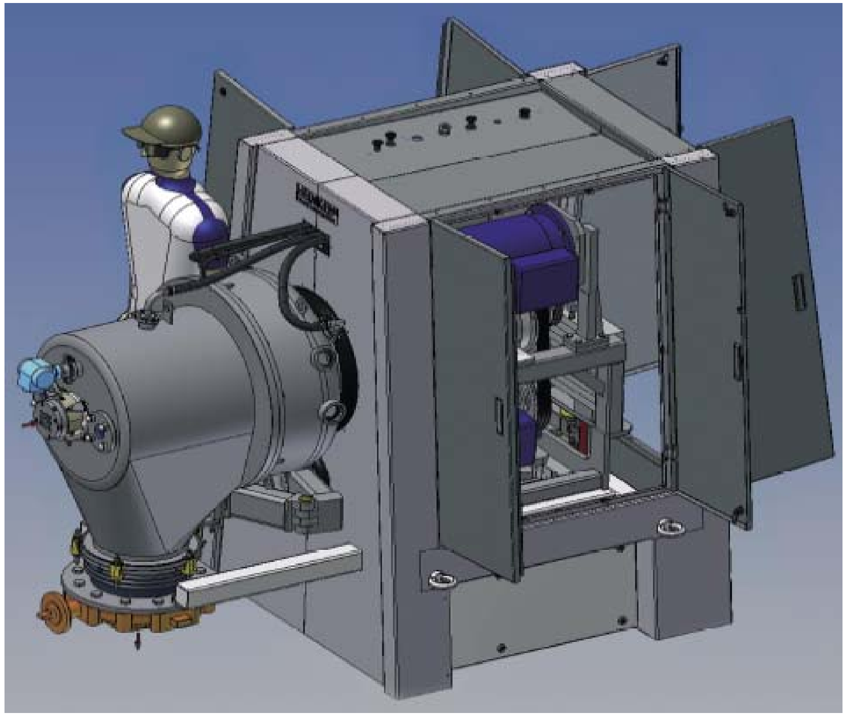
Karlsruhe Institute of Technology

OUTLINE

- Main issue and approach
- Characterization of the filter media (pore size distribution)
- Cleaning of insoluble impurities
  - Determination of the adhesion force (between filter media & particle)
  - Determination of the pressure drop
  - Determination of the friction force
- Cleaning of soluble impurities
  - Determination of the diffusion coefficient D → Schmidt-number
  - Determination of the mass transfer coefficient β → Sherwood-number
  - Validation with the theoretic model for the mass transfer
- Conclusion and Perspectives

THE INVERTING FILTER CENTRIFUGE





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Inverting Filter Centrifuge HF 300

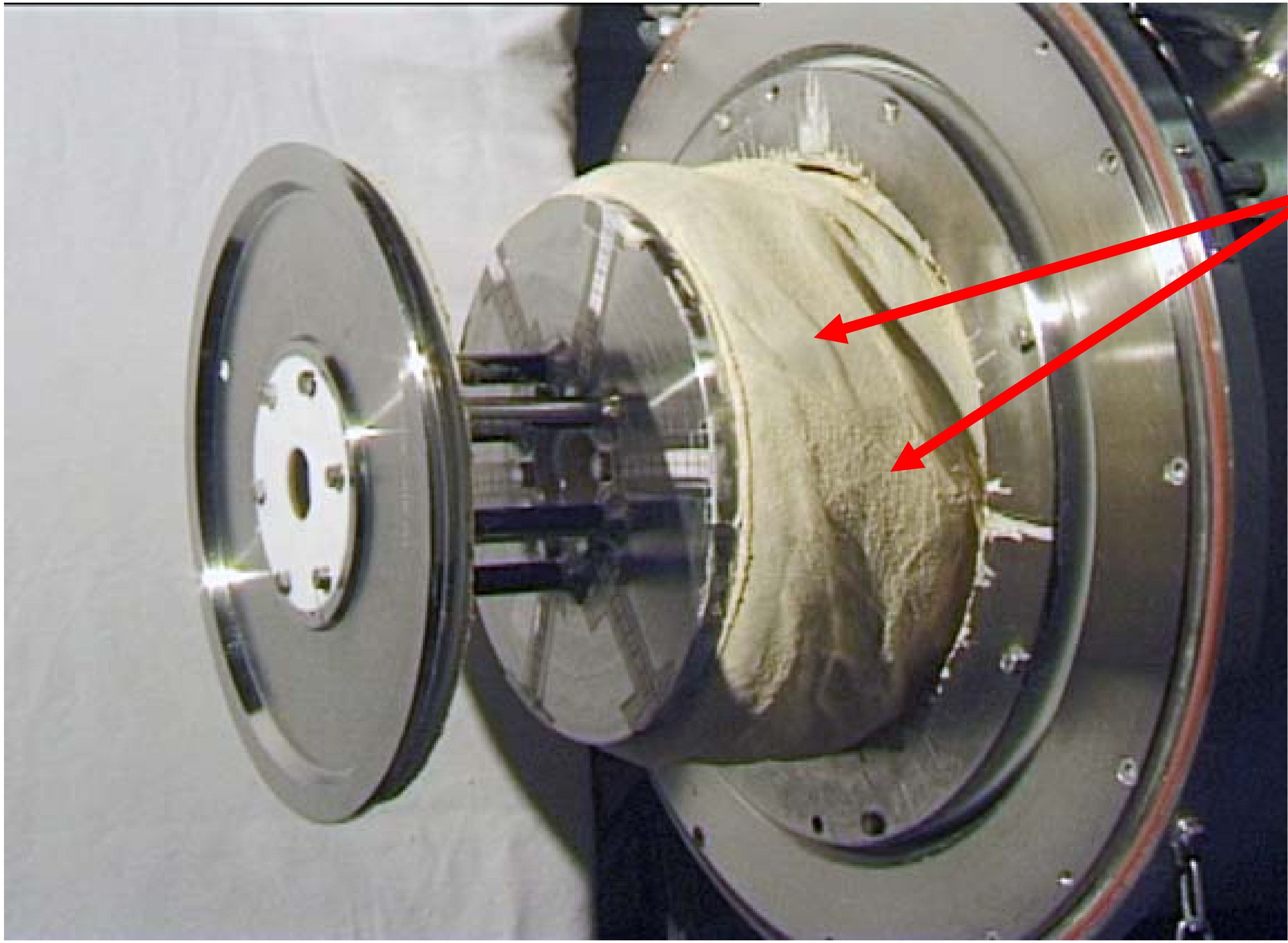
Discharging

Limstone Eskal 150
Cake Height: 65mm
Residual Moisture: 2.1%
Speed: 600rpm

Institut für MVM
Universität Karlsruhe (TH)

HEINKEL®
Heinkel Process
Technology GmbH

DISLODGING

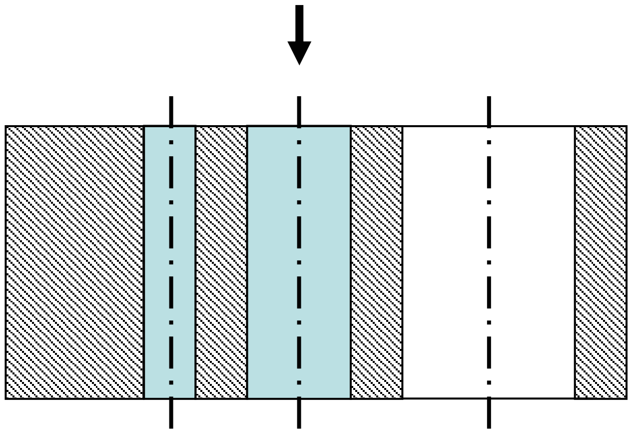


Residues on the filter media

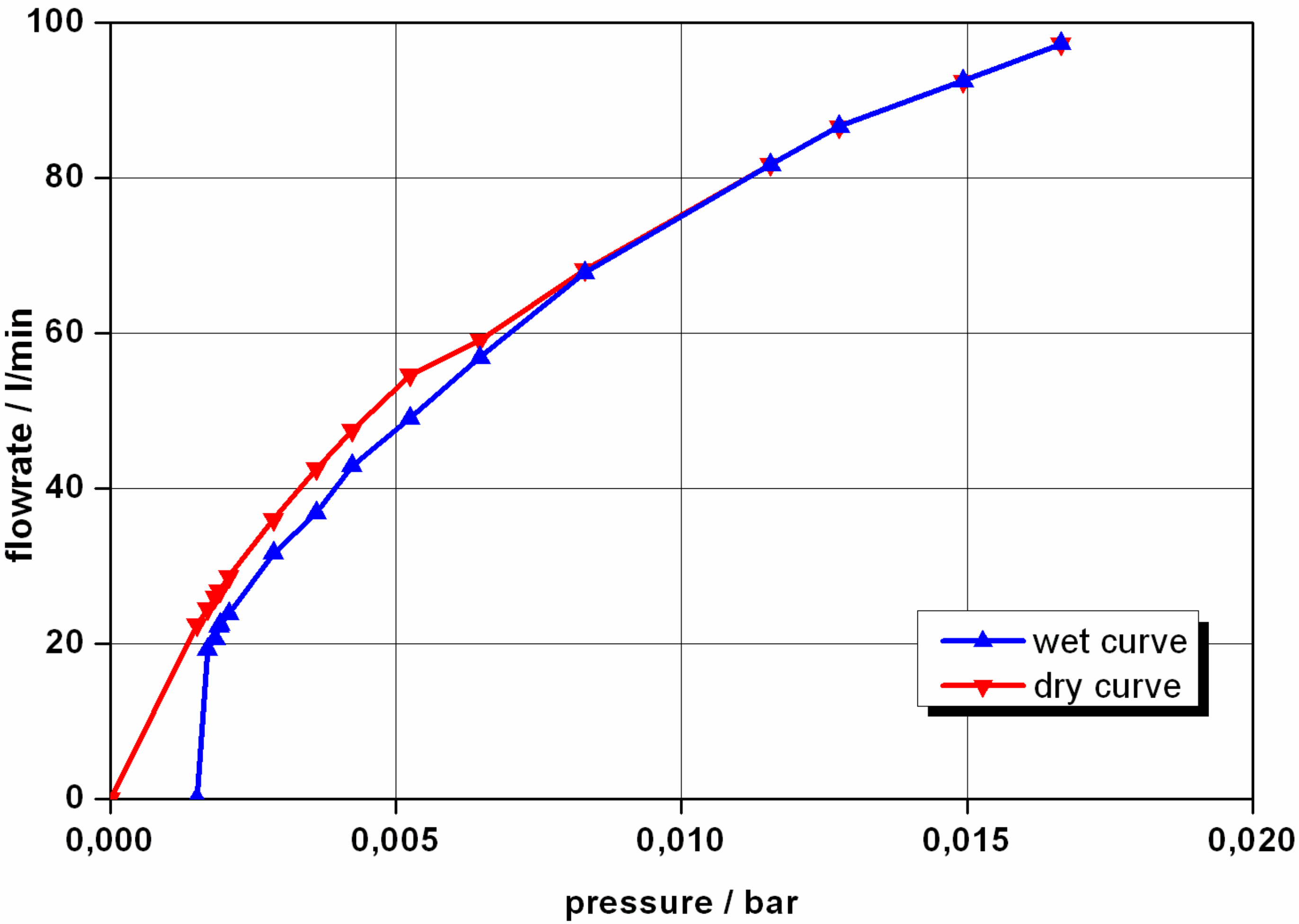
The state after dislodging
is the base for
the CIP-procedure

POROSIMETRY

Bubble Point

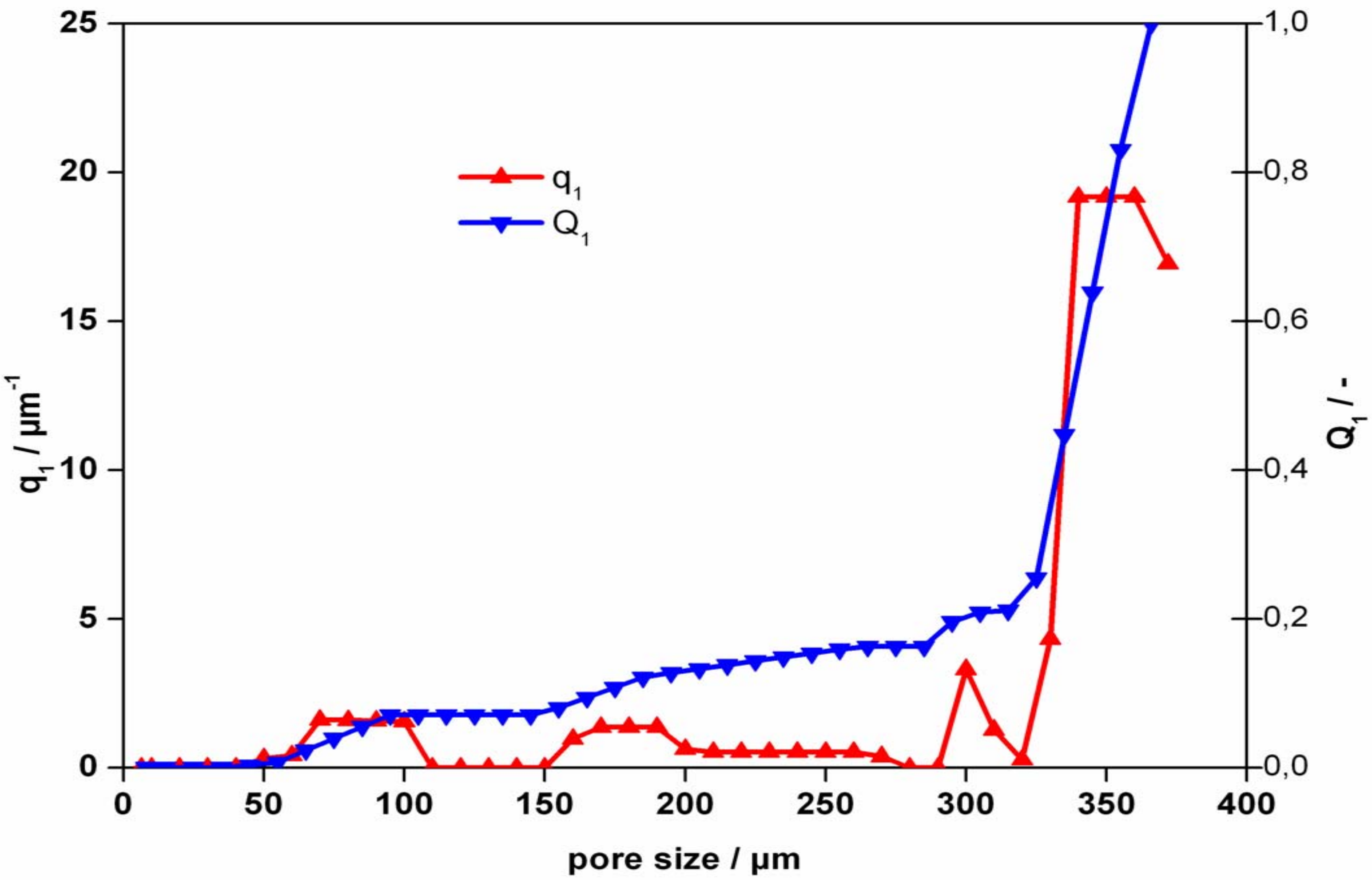


The pressure where the largest pore is free of liquid is called bubble point.

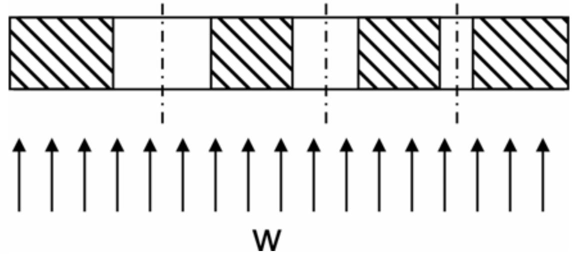


PORE SIZE DISTRIBUTION

Laplace-equation $$p_k = \frac{2\gamma_l \cos\delta}{r}$$

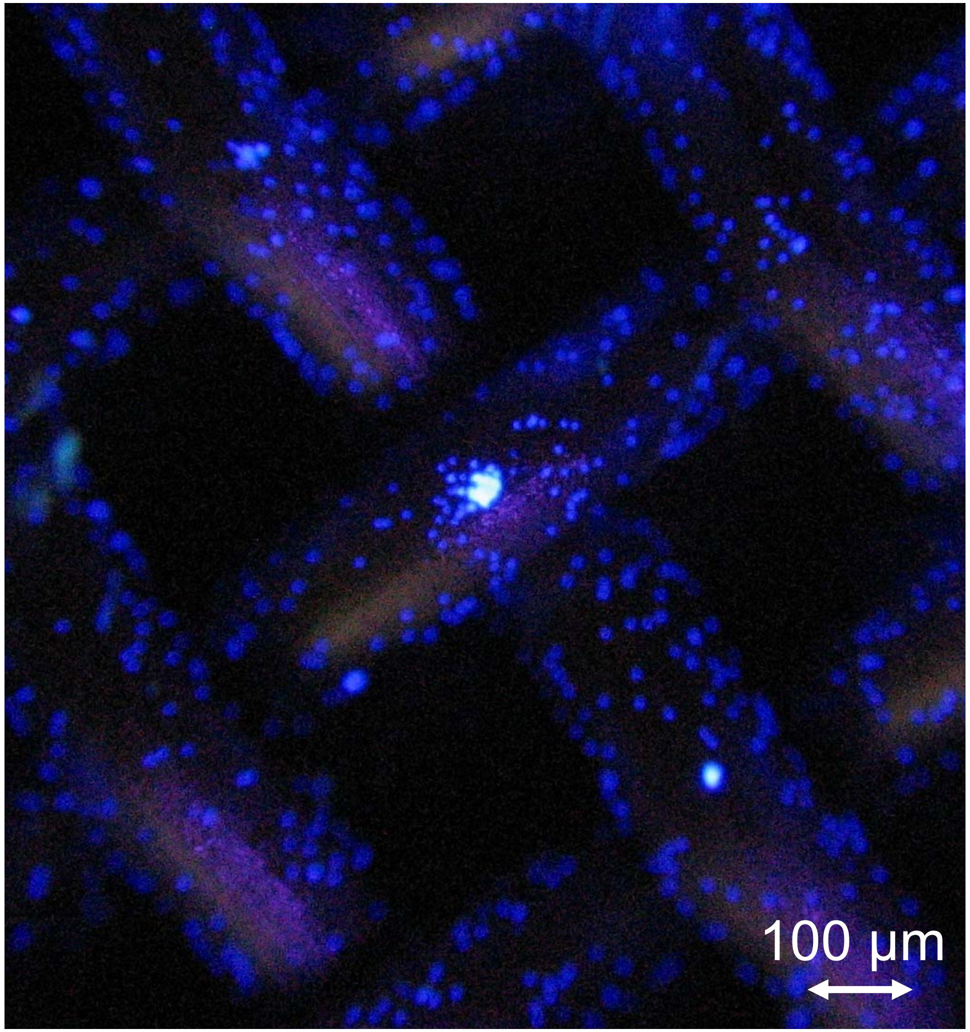


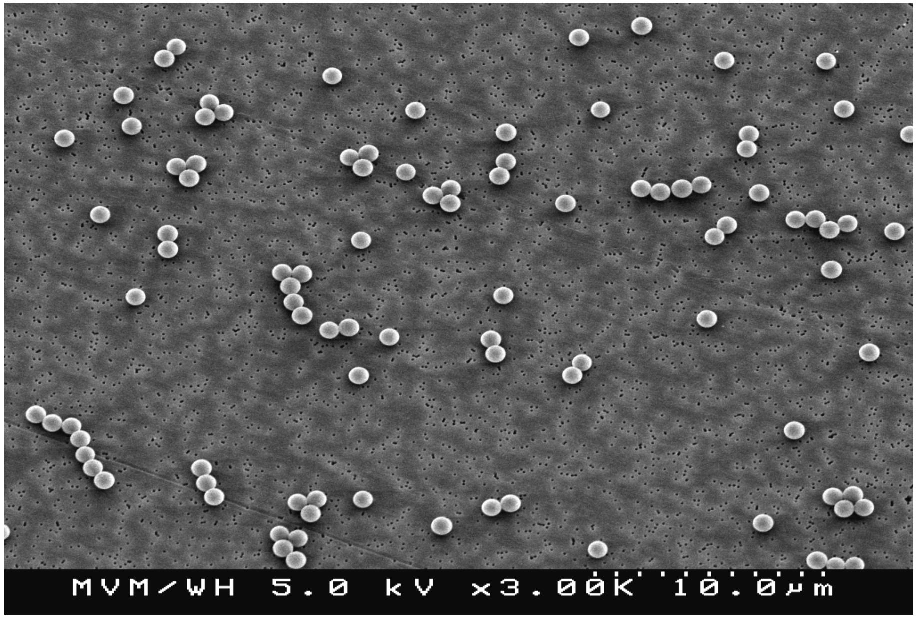
cylindrical capillaries



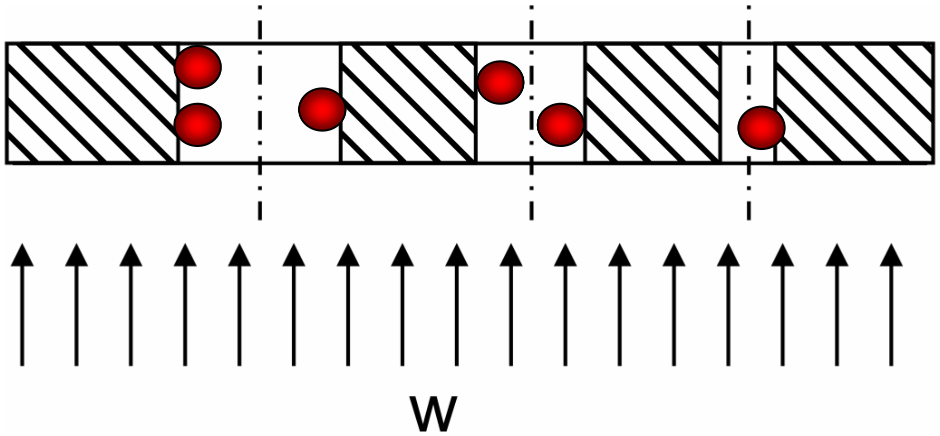
Porometer PMI

MATERIALS AND METHODS





SEM – image of the used latecis particles



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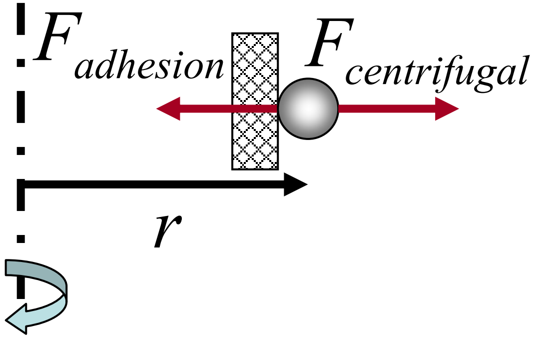
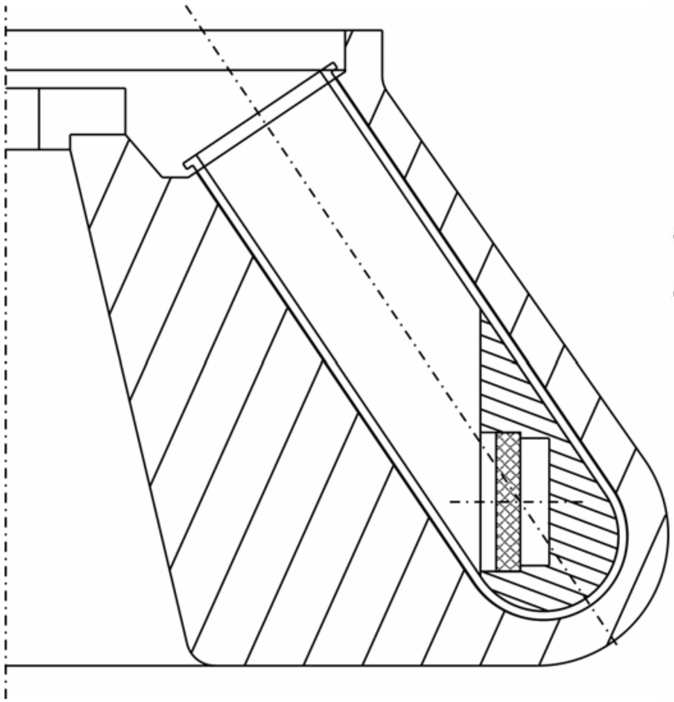
DETERMINATION OF $F_{adhesion}$

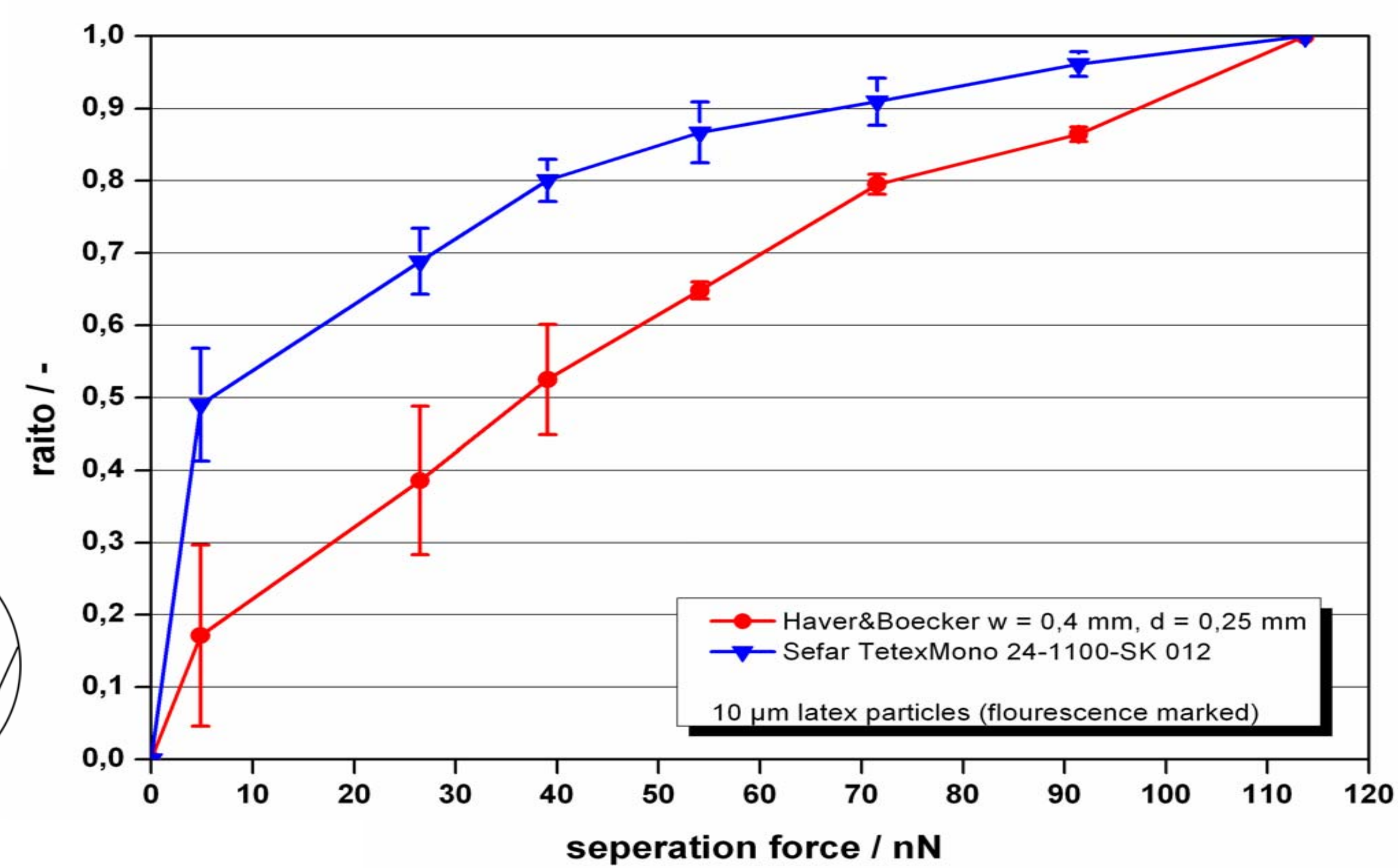


$$F_{centrifugal} = m_{particle} \cdot r \cdot \omega^2$$

centifugal force vs adhesion force

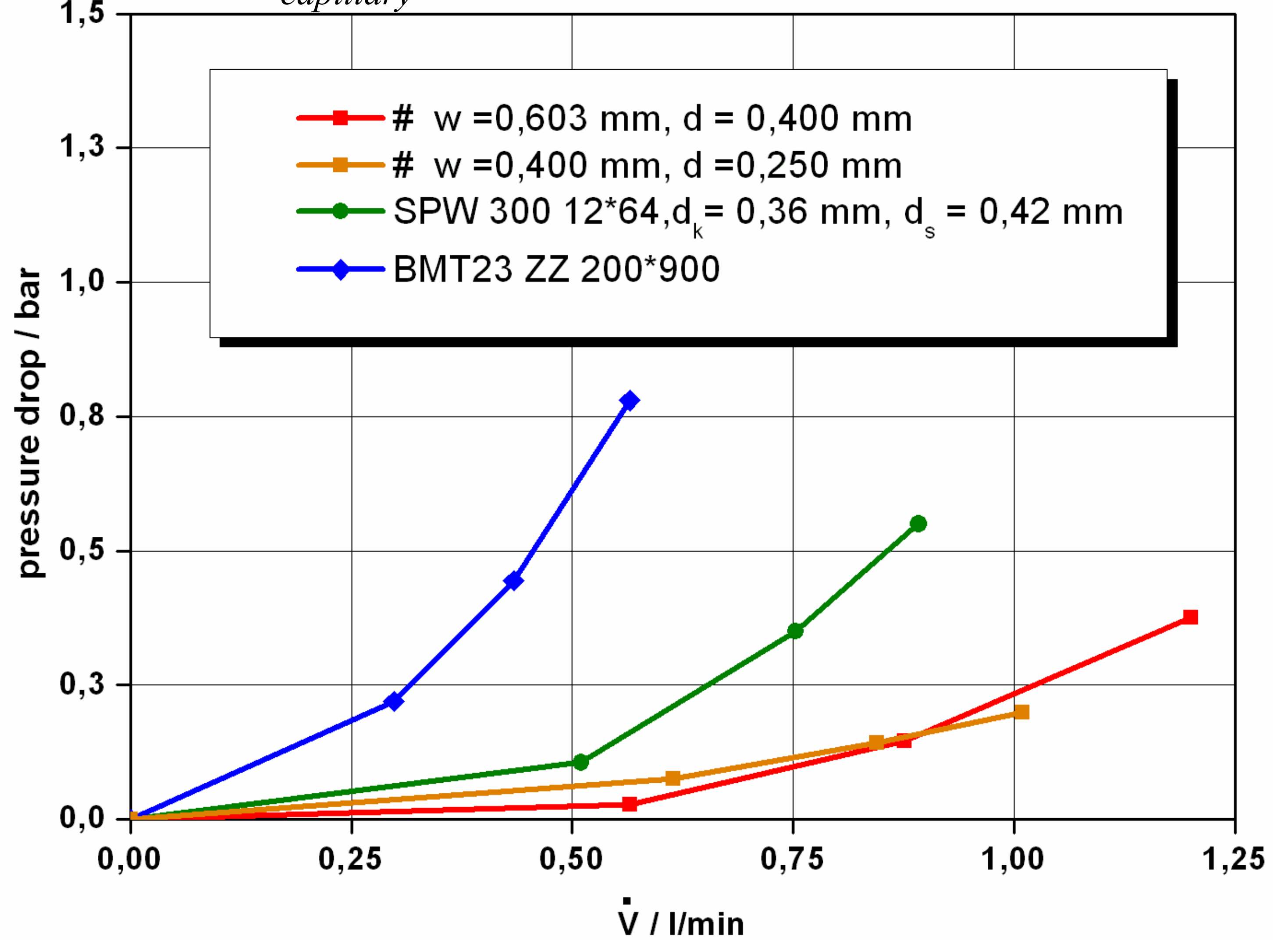
$$F_{adhesion} \leq F_{centrifugal}$$



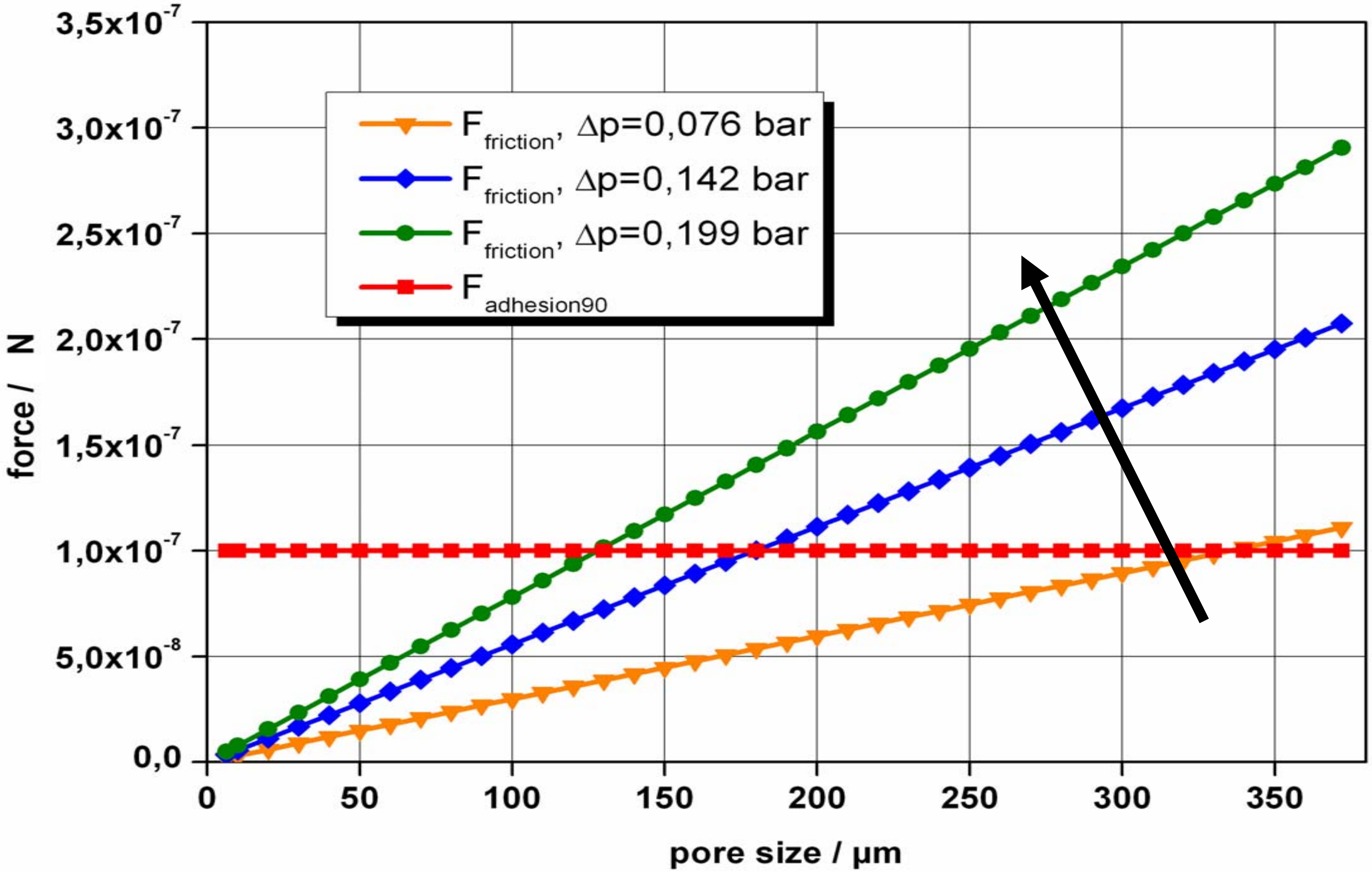


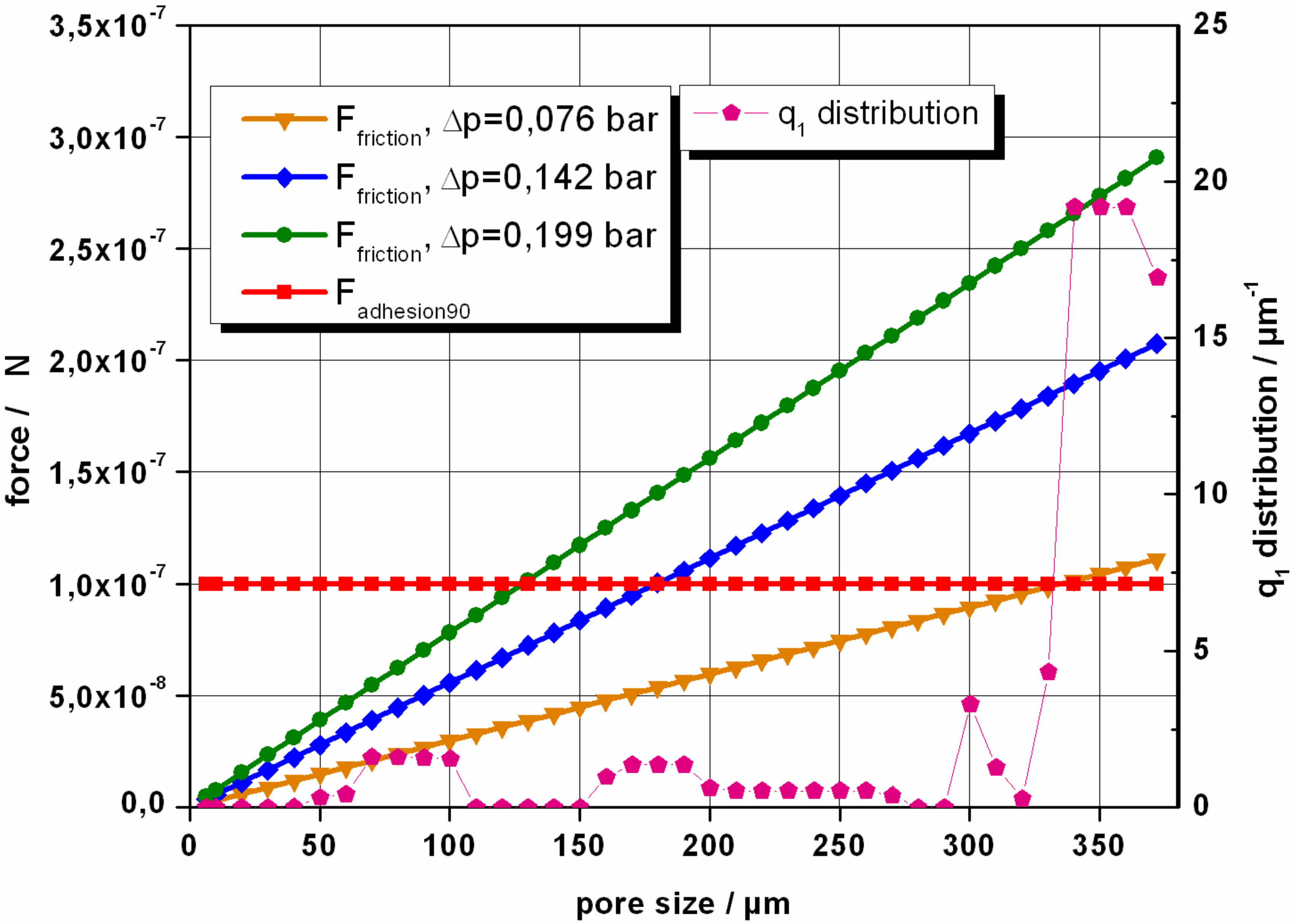
PRESSURE DROP

$$\tau = \frac{\Delta p_v A_{cylinder}}{A_{capillary}} \longrightarrow F_{friction} = \tau \cdot A_{sphere}$$



$F_{friction}$ vs. $F_{adhesion}$





3,5x10^-7
3,0x10^-7
2,5x10^-7
2,0x10^-7
1,5x10^-7
1,0x10^-7
5,0x10^-8
0,0
force / N
0
50
100
150
200
250
300
350
pore size / µm
25
20
15
10
5
0
q1 distribution / µm^-1
F friction, Δp=0,076 bar
F friction, Δp=0,142 bar
F friction, Δp=0,199 bar
F adhesion90
q1 distribution

DIMENSIONLESS ANALYSIS

Reynolds-number

$$Re_{\Psi,1} = \frac{w\,l}{\Psi\,\nu}$$

Schmidt-number

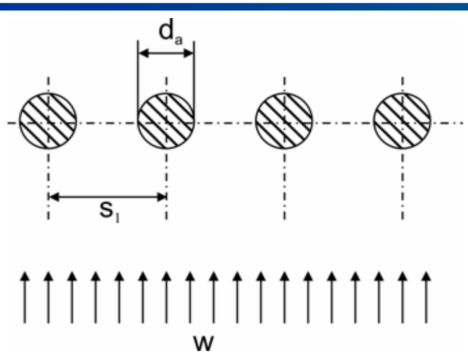
$$Sc = \frac{\nu}{D}$$

Sherwood-number

$$Sh = \frac{\beta\,l}{D} \rightarrow \beta = \frac{D \cdot Sh}{l}$$

Für

$$10 < Re_{\Psi,1} < 10^6 \qquad 0{,}7 < Sc < 10^4$$

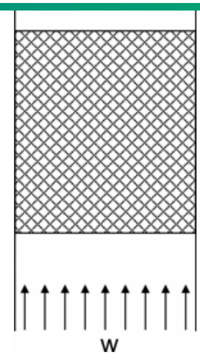


Tubes in a row

$$Sh_{1,lam} = 0{,}664\,\sqrt{Re_{\Psi,1}}\,\sqrt[3]{Sc}$$

$$Sh_{l,turb} = \frac{0{,}037\,Re_{\Psi,1}^{0,8} \cdot Sc}{1 + 2{,}443 \cdot Re_{\Psi,1}^{-0,1}\,(Sc^{2/3} - 1)}$$

$$Sh_{0,row} = 0{,}3 + \sqrt{Sh_{1,lam}^2 + Sh_{1,turb}^2}$$



Packed bed

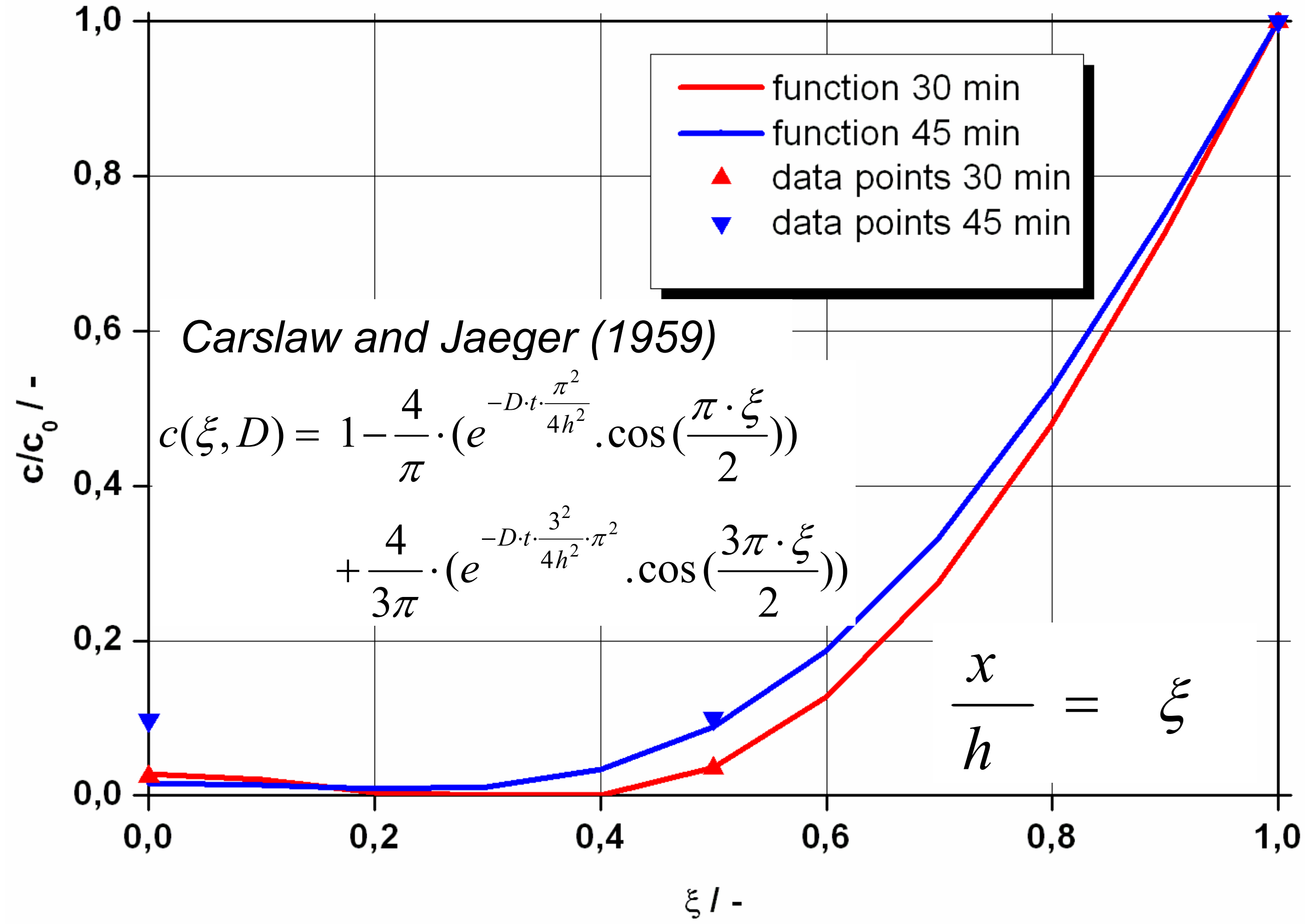
$$Hg = [150\,(1 - \varepsilon) + 1{,}75\,Re] \cdot Re(1 - \varepsilon) / \varepsilon^3$$

$$Lq = 2\,x_f\,Hg\,\frac{2}{3}\,\frac{\varepsilon}{(1 - \varepsilon)^{2/3}}$$

$$Sh / Sc^{1/3} = 0{,}404\,Lq^{1/3}$$

DETERMINATION OF THE DIFFUSION COEFFIZIENT D

$$\frac{\partial}{\partial t}(c(x,t)) = D \cdot \frac{\partial^2}{\partial x^2} c(x,t)$$ second Fickian law



$$c(\xi, D) = 1 - \frac{4}{\pi} \cdot \left(e^{-D \cdot t \cdot \frac{\pi^2}{4h^2}} . \cos\left(\frac{\pi \cdot \xi}{2}\right)\right) + \frac{4}{3\pi} \cdot \left(e^{-D \cdot t \cdot \frac{3^2}{4h^2} \cdot \pi^2} . \cos\left(\frac{3\pi \cdot \xi}{2}\right)\right)$$

$$\frac{x}{h} = \xi$$

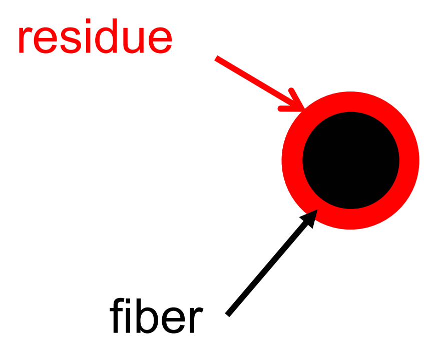
D_{30} =0,19 mm²/s

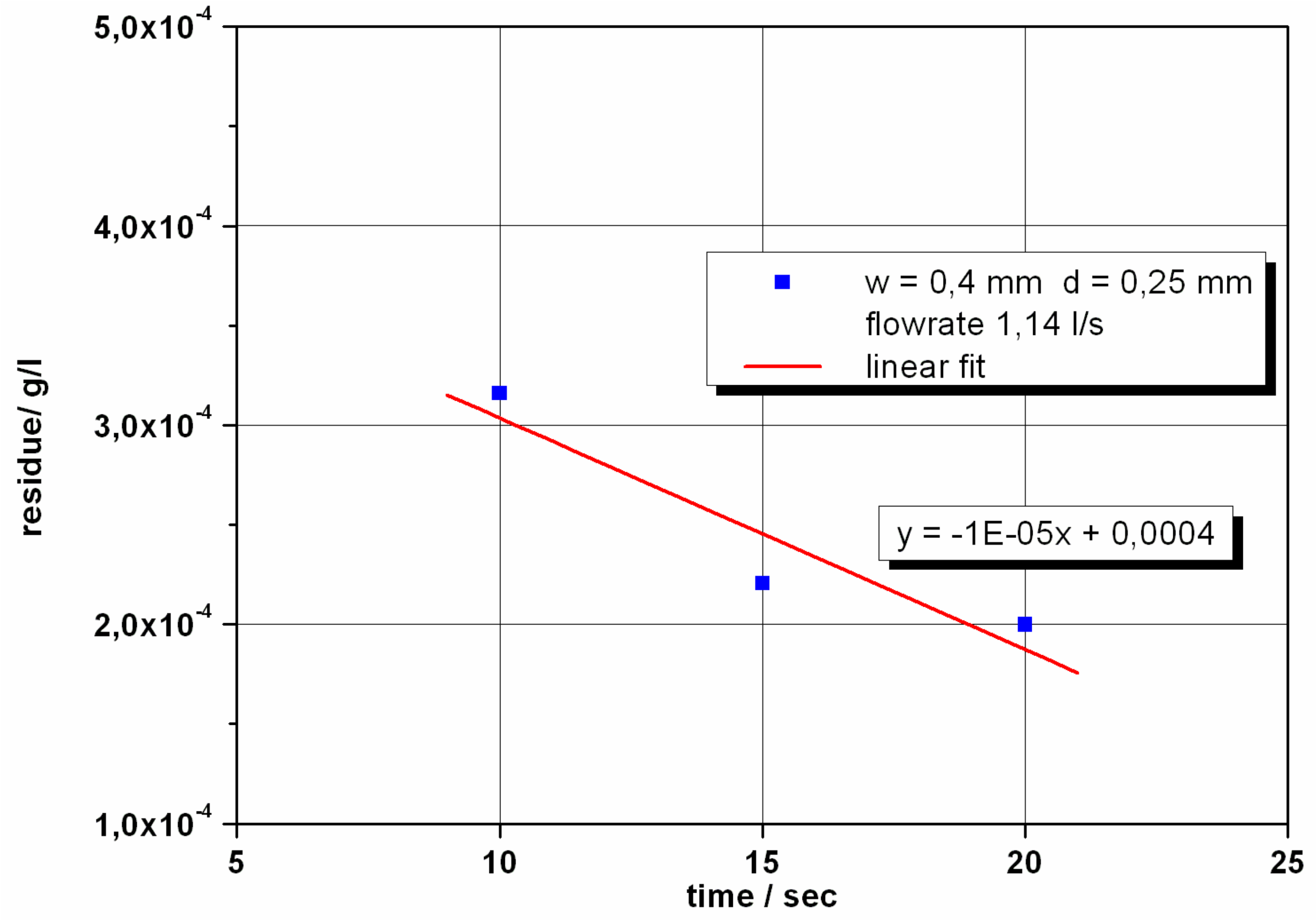
D_{45} =0,17 mm²/s

Schmidt-number $Sc = \frac{\nu}{D} = 5{,}26$

DETERMINATION OF THE MASS TRANSFER COEFFICIENT

Kinetic theory: $$\dot{N}_i = \beta_i \cdot A_s \cdot \Delta c_i$$



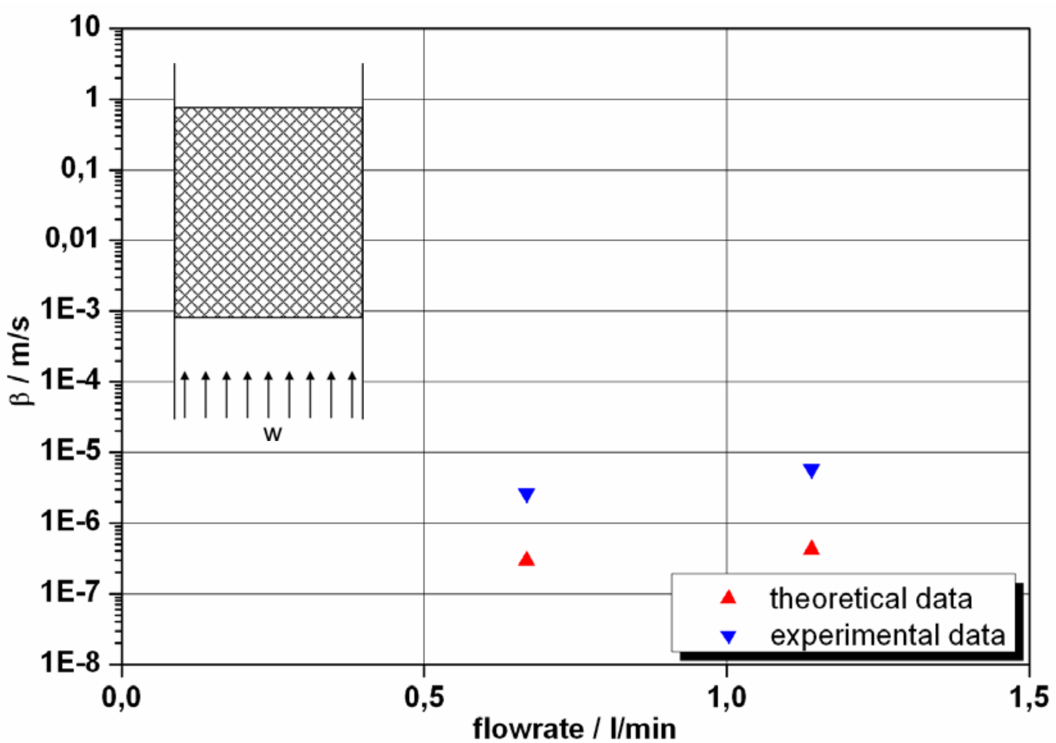


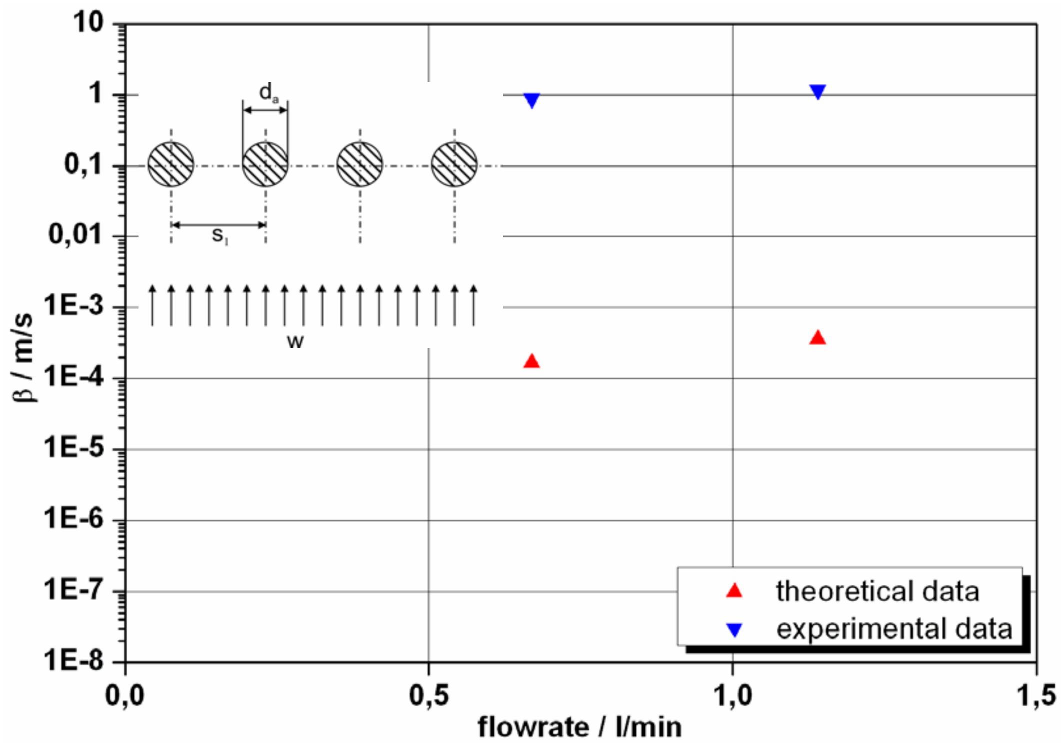
$$\dot{N}_i = \frac{dc_R}{dt}$$

$$A_s = \frac{\sum n_i A_{pi}}{V_T}$$

$$\Delta c_i = c_R$$

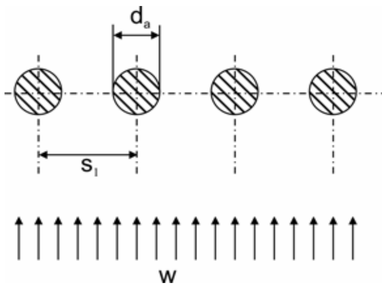
COMPARISON OF THE TWO MODELS



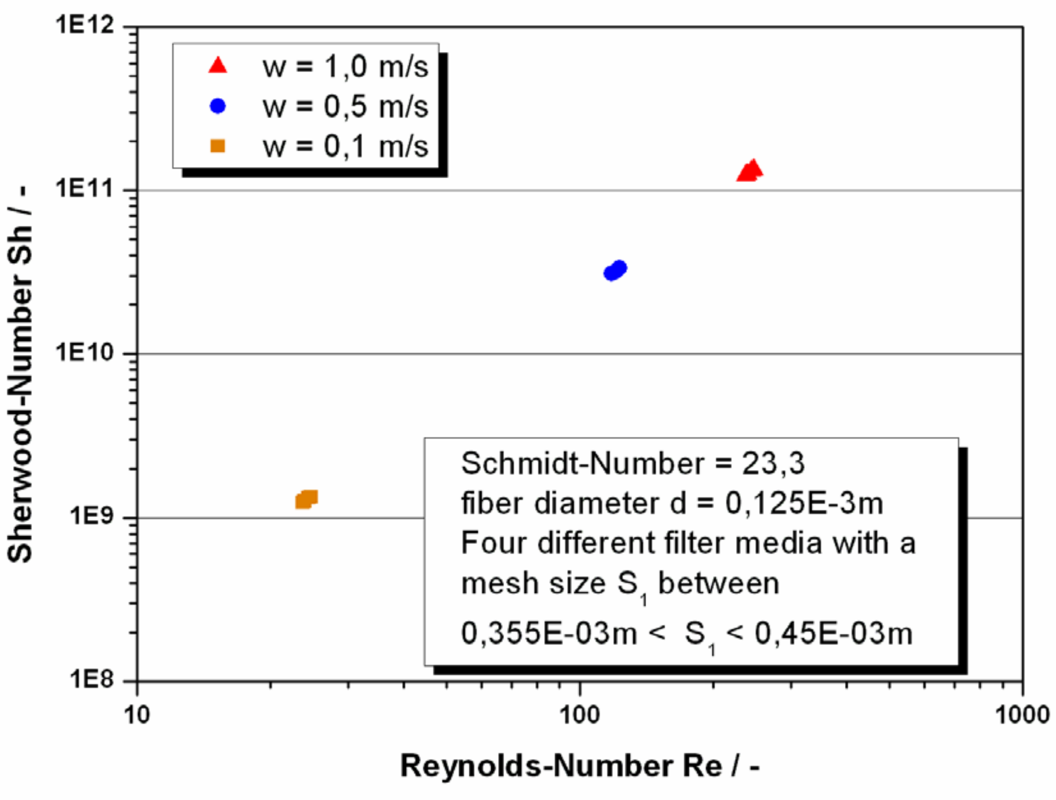


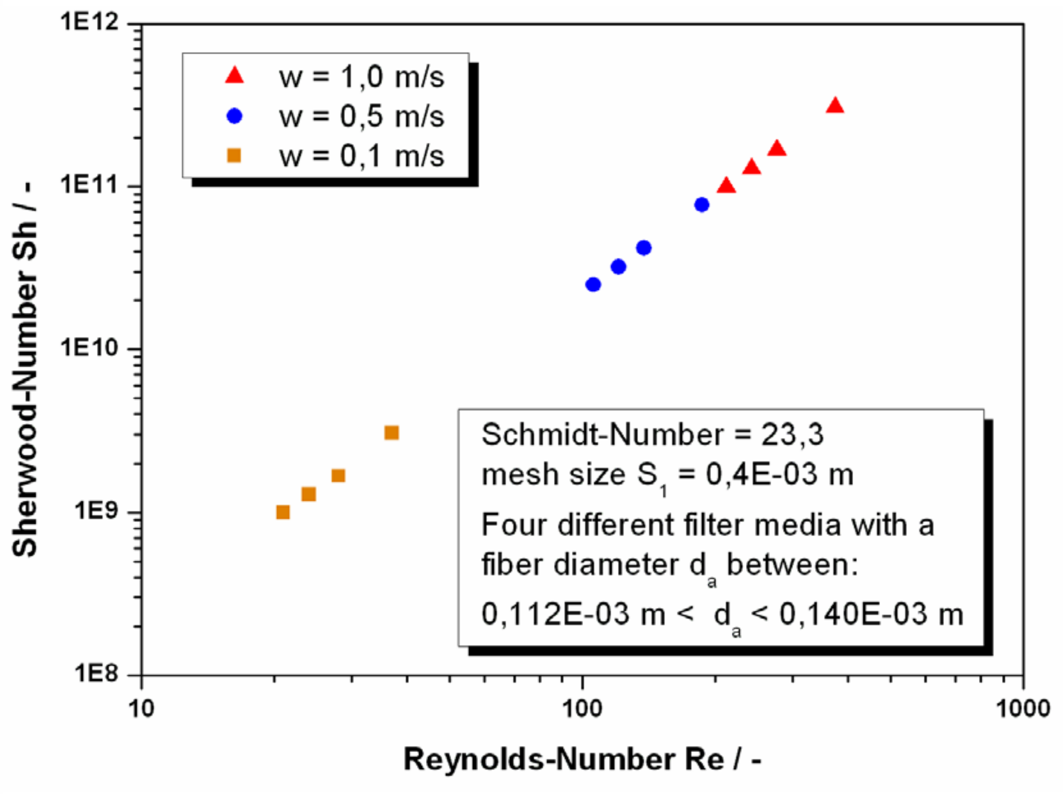
INFLUENCE OF GEOMETRIC PARAMETERS

Constant fiber diameter
Variation of mesh size



Variation of fiber diameter
Constant mesh size





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CONCLUSION AND PERSPECTIVES

- The relevant parameters for the mechanical cleaning of insoluble residues like the pore size distribution, the pressure loss and the adhesion force distribution are determined.
- For the validation of the mechanical cleanability the adhesion force $F_{adhesion90}$ is correlated with the friction force $F_{friction}$. With an overall regard the pores are identified which are not mechanically cleaned.

- The mass transfer coefficient is both determined by the theory and proven by experiments.
- The experimental determined diffusion coefficient leads to the Schmidt-number.
- The experimental results are correlated to the model of a ‚row of tubes' and of a ‚packed bed'.
- The developed dimensionless model leads to a validation due to the cleanability of filter media.

Thank you!

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