Graz University of Technology

process & particle engineering

Flippr

Towards Simulation-based Engineering of Fibre Fractionation Equipment

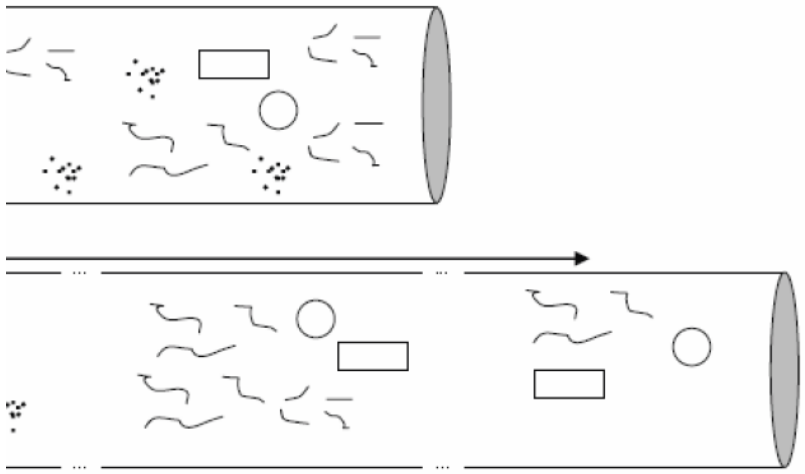
Separation Effects and Orientation Statistics of Fibres in Coiled-Pipe Suspension Flow

Jakob D. Redlinger-Pohn, and Stefan Radl
Institute of Process- and Particle Engineering, Graz University of Technology

Motivation – The Tube Flow Fractionator

Fibre suspension flow in coiled tubes is common process in any paper mill. From experimental studies with a coiled tube it is known that

- ✓ **fibres segregate** according to their length [1,2].
- ✓ However, the segregation mechanism **is not understood**.
- ✓ Currently: **black-box model [1]**
- ✓ Current hypothesis: **"turbulent fluctuations"** cause separation.



Sketched separation mechanismn [1]

[1] O. Laitinen, BioResources 6 (2011) 672-685
[2] L. Jagiello, TU Graz, 2013

Agenda

(1) Motivation

(2) Code and Modeling Approach

(3) CFD – Simulation

(4) CFDEM® - Simulation

(5) Experiment

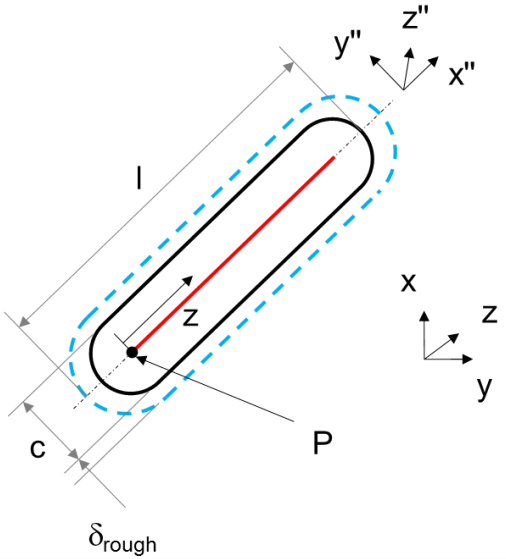
(6) Conclusion

IPPT FLIPPR team

Code and Modeling Approach

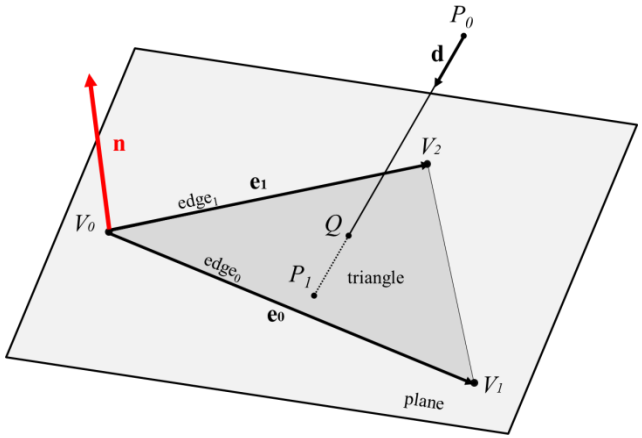
Two phase fibre-fluid simulation with **LIGGGHTS® and CFDEM®** (DCS Computing, Linz, Austria)

- **Implicit fibre-fluid** drag and torque interaction
- **One-way coupling** of fibres to the fluid (Stokes drag and buoyancy force)
- **Fibre-Wall** interactions (wall-normal interaction, Hook stiffness)
- Surface **roughness effects**



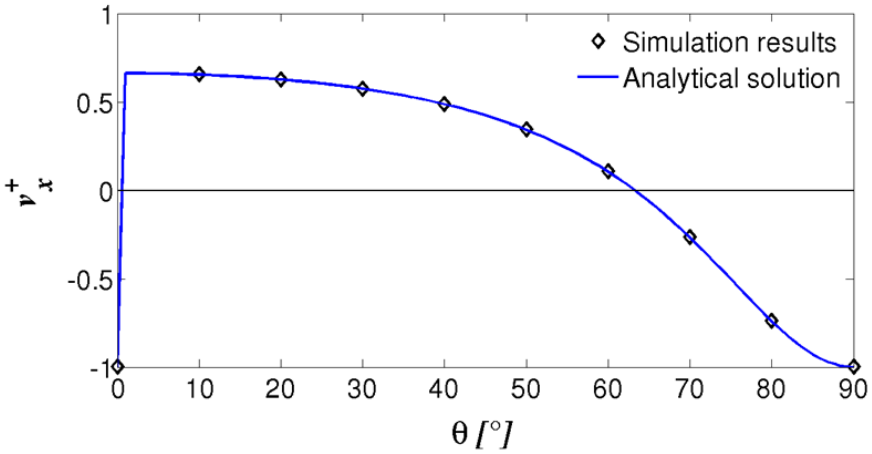
Code and Modeling Approach

Fibre-wall contact detection realized by **line-segment interaction [3]**



Line intersecting with a triangle

Fibre-wall impact for different impact angles **validated** against **analytical solution** [4]



Rotational and translational rebound velocity

[3] P.J. Schneider, D.H. Eberly, Elsevier, 2003

[4] M.Kodam, et.al., Chem.Eng.Sci., 2010

CFD – Simulation of Toroidal Flow

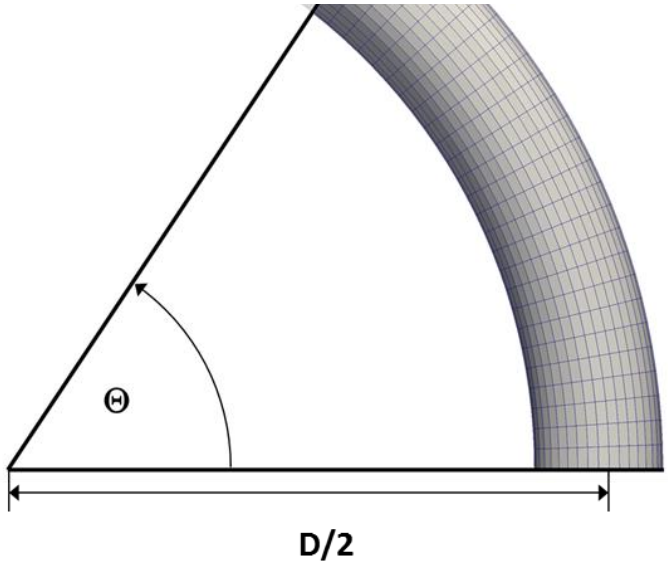
Simulation of toroidal flow was guided by recent published literature [5-7]:

- **DNS** of fluid flow
- Cross sectional mesh: **blocked and radially clustered** using Cubit
- Toroidal tube **extruded** from cross sectional mesh yielding a half torus at curvatures κ of 0.043 and 0.1

Final **mesh size** of ca.

6 Mcells for κ 0.1

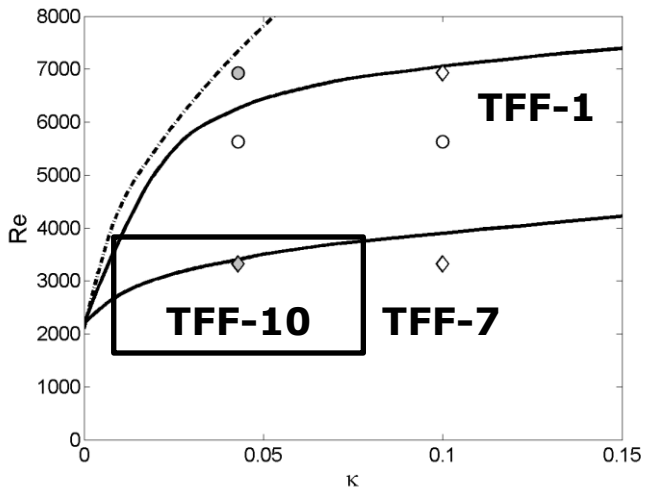
15 Mcells for κ 0.043



[5] Piazza and Ciofalo, Int. J. Therm. Sc. 49 (2010) 653-663
[6] Piazza and Ciofalo, J. Fluid. Mech. 687 (2011) 72-117
[7] Hüttl and Friedrich, Computers & Fluids 30 (2001) 591-605

CFD – Simulation of Toroidal Flow

Set-up of cases according to
(i) experimental case, and
(ii) Literature [6]



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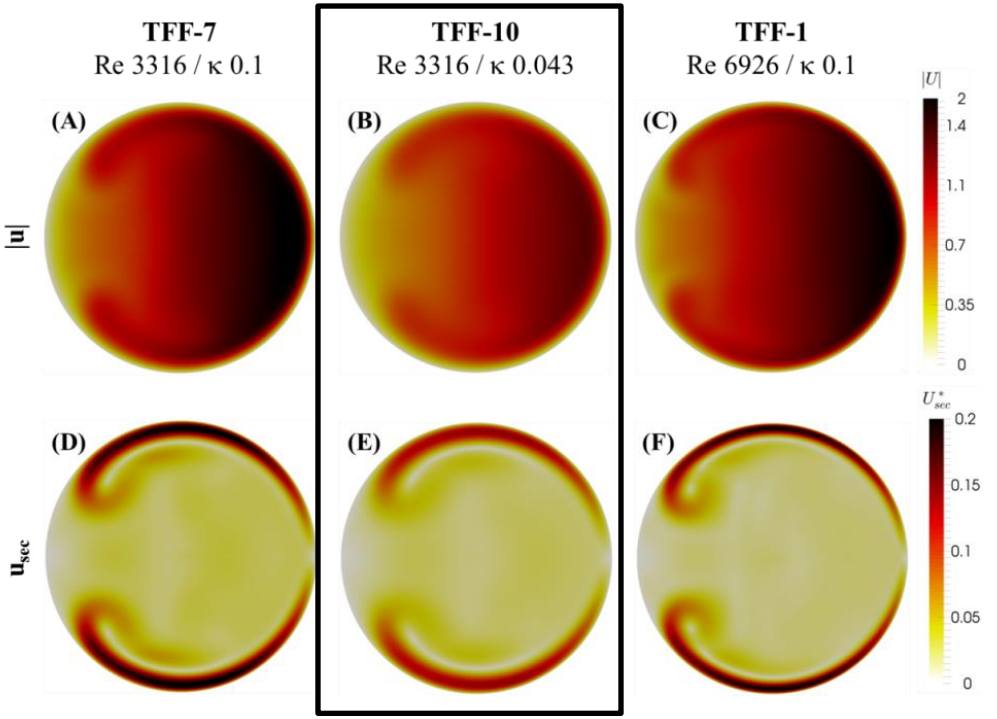
Simulation for **20 LETOT's** after reaching a (quasi) steady state

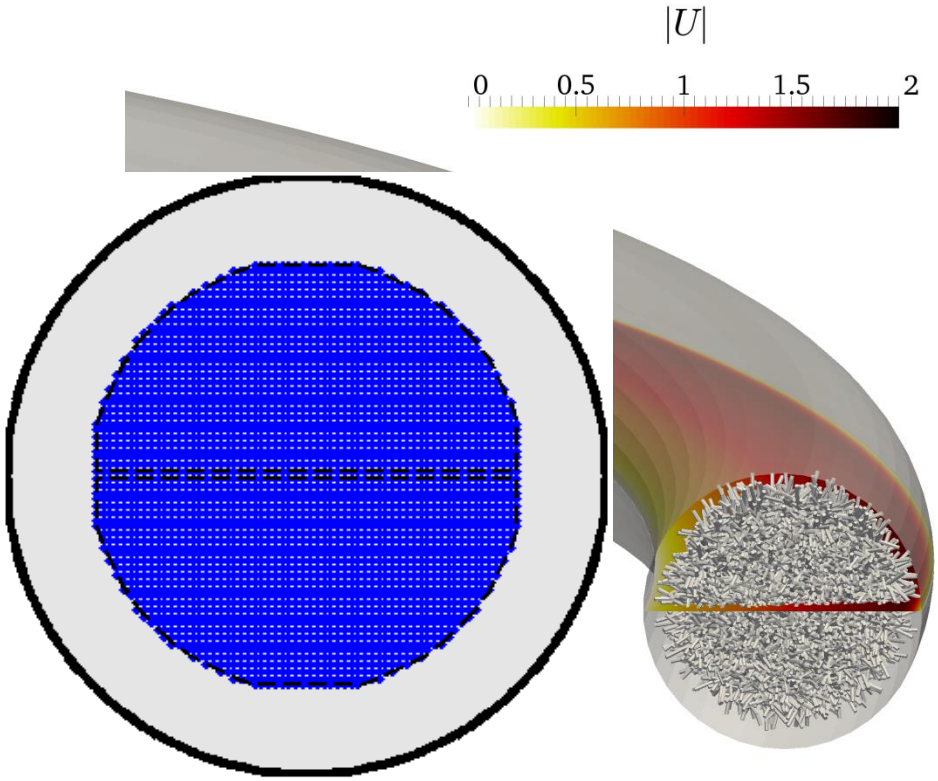


[6] Piazza and Ciofalo, J. Fluid. Mech. 687 (2011) 72-117

CFDEM – Fibre/Fluid Simulation

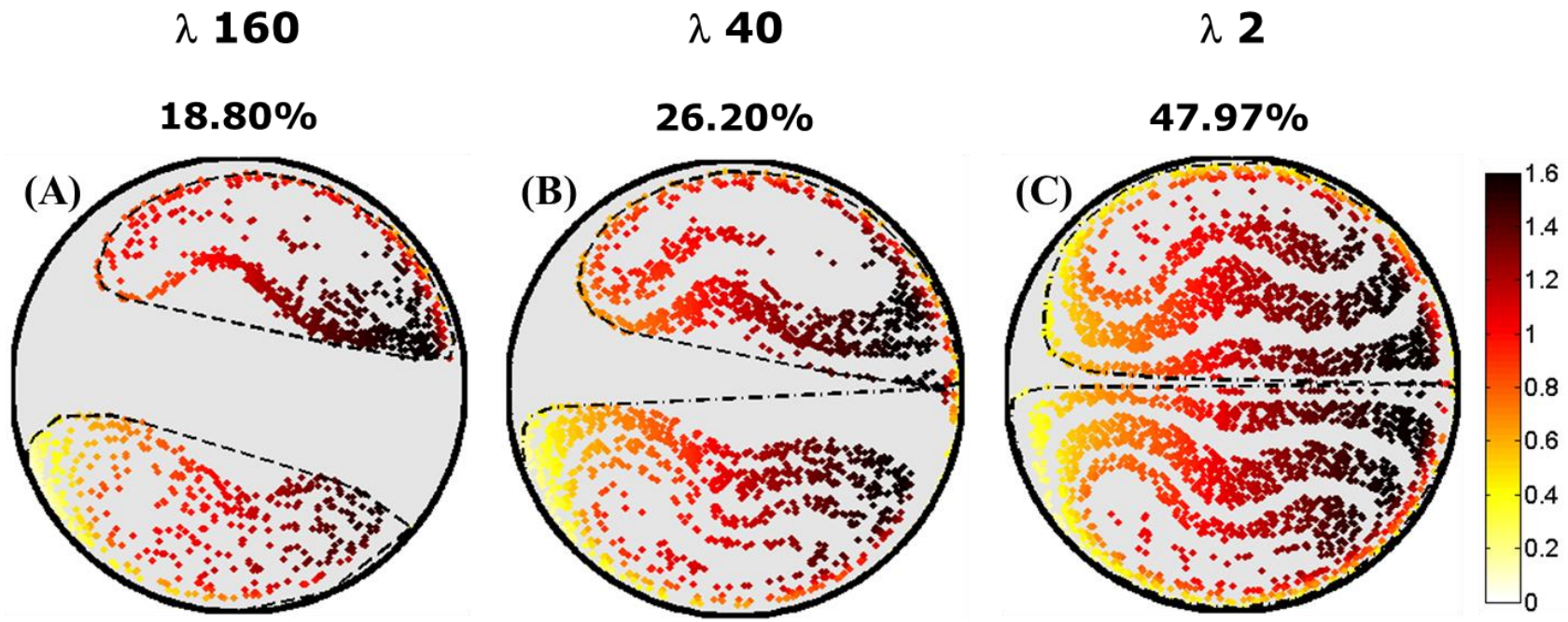
(1) Insert Fibres of aspect ratio
λ **160, 40, and 2**

(2) Hit CFDEM® Project **Engage**



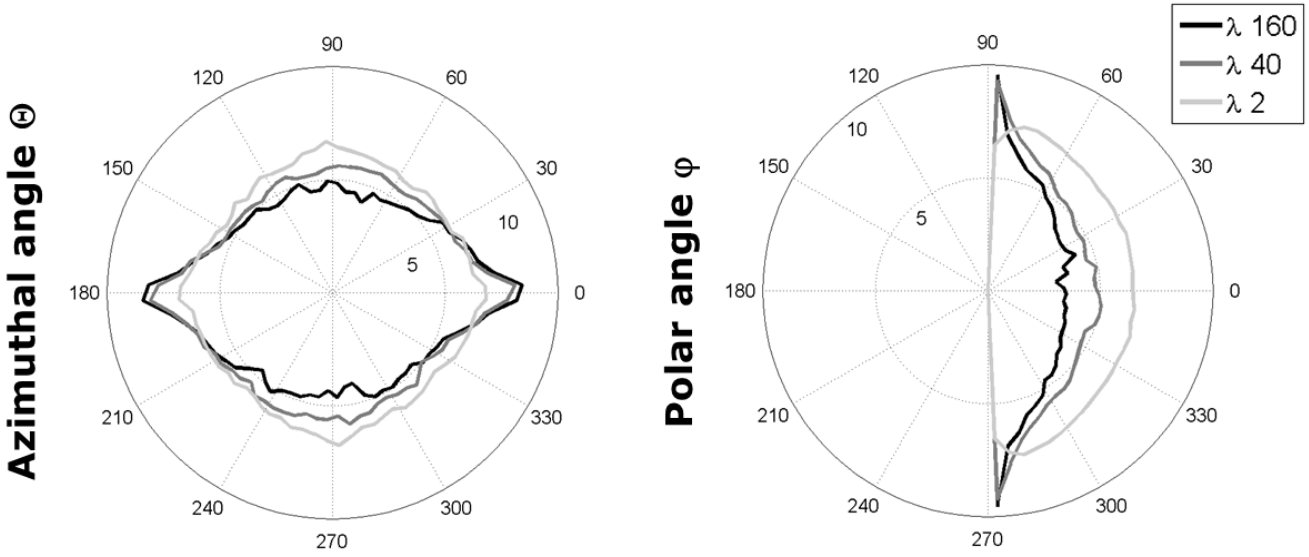
CFDEM – Fibre/Fluid Simulation

Fibre **cross-sectional position** at t = 178.6

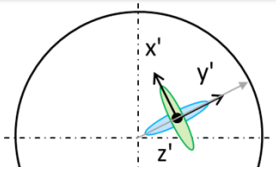


CFDEM – Fibre/Fluid Simulation

Fibre orientation at t = 178.6



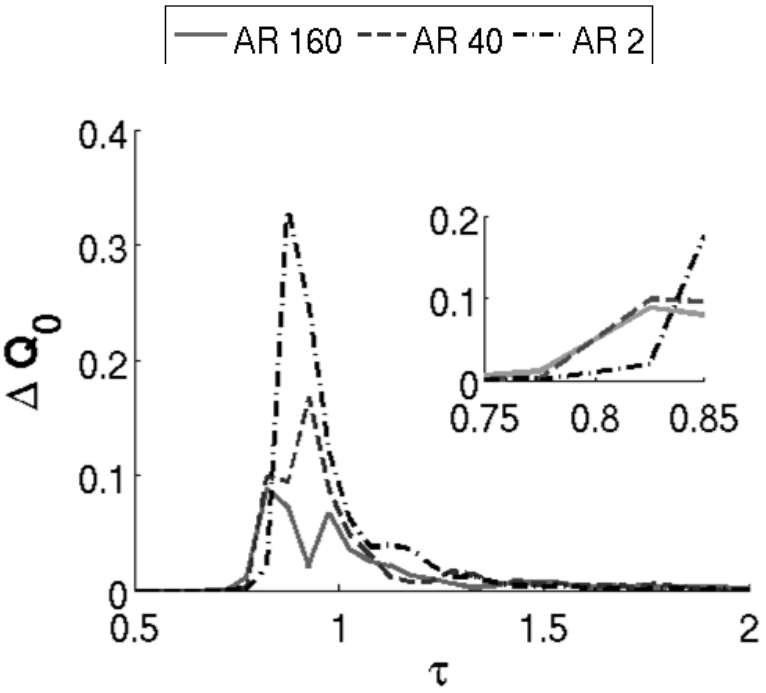
Number of fibres presented as logarithmic values



	Azimuthal angle Θ	Polar angle φ
y wall normal	90 270	0 180
x wall tangential	0 180	0 180
z stream wise	0 180	90 270

CFDEM – Fibre/Fluid Simulation

Residence time distribution of fibres with different size

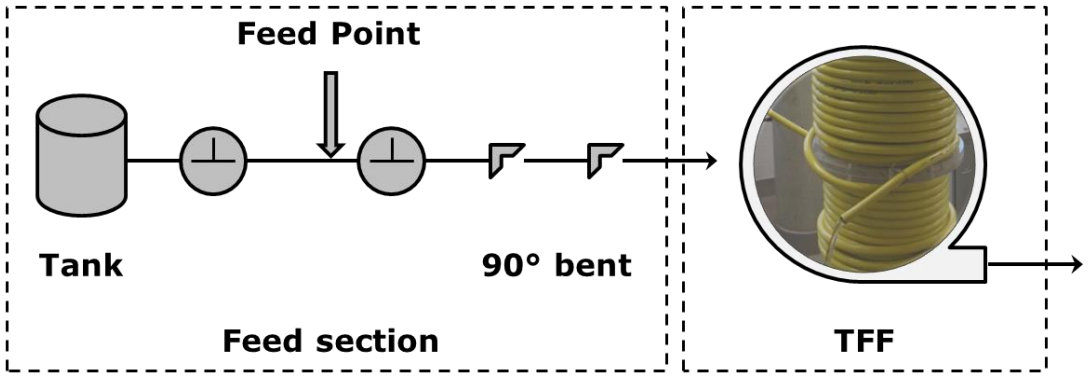


Long fibres exits the TFF first

Long fibres are split into two fractions

Experiment – TFF Mass Balance

Experimental Set-Up according to **Tube Flow Fractionator** described by Laitinen [1] implemented at the Institute of Paper-, Pulp- and Fibre Technology [2]



TFF **key element**

- Fractionation pipe
  L 100 m
  d_i 0.016 m

Materials

- Monosized synthetic cellulose fibres

[1] O. Laitinen, BioResources 6 (2011) 672-685
[2] L. Jagiello, TU Graz, 2013

Experiment – TFF Mass Balance

Mass balance experiments at different concentrations:

- **Fibre network regime** (0.1%) **76%**
- **Individual fibre regime** (0.03%) **73%**

Collection of fibres until $\tau = 1$ and gravimetric determination of the collected mass

TFF **key element**

- Fractionation pipe
  L 100 m
  d_i 0.016 m

Materials

- Monosized synthetic cellulose fibres

Conclusion

- ✓ CFDEM® simulation of dilute fibre suspension
- ✓ Different fibre sizes realized
- ✓ Fibre position, fibre orientation, and fibre movement analyzed
- ✓ **Ratio of sedimentation velocity to secondary motion is key for the fractionation effect**
- ✓ Experiments performed with synthetic cellulose fibres
- ✓ **Results for dilute fibre systems are in agreement with the simulation results**
- ✓ Fibre network might affect the fractionation process

PROJECT MEMBERS

Industrial partners:

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heinzel pulp
ZELLSTOFF PÖLS AG

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Scientific Partners:

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