CFD Modelling of the Flow Inside an LC Refiner

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A joint meeting

COST Action FP1005

Fibre suspension flow modelling - a key for innovation & competitiveness in the pulp & paper industry

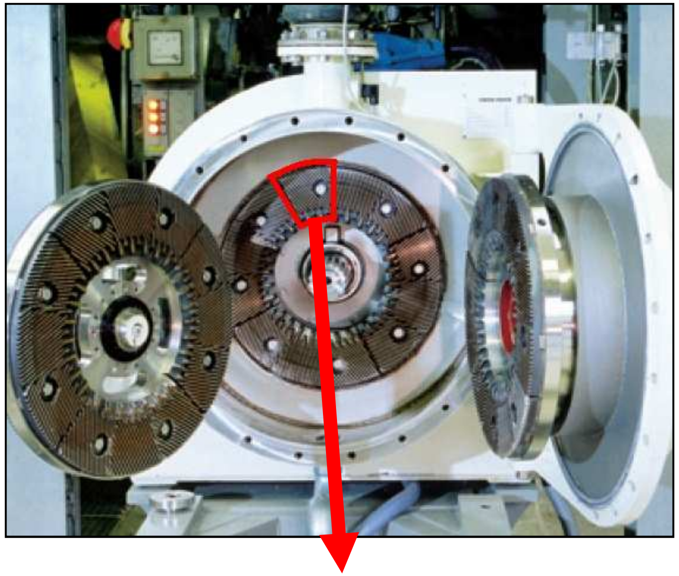
ERCOFTAC SIG 43

Fibre suspension flows

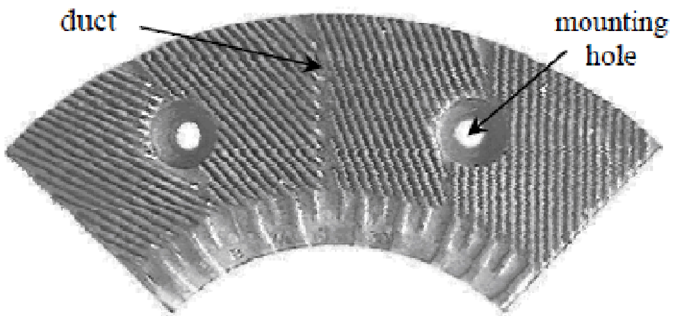
Outline

- Introduction / Motivation
- Numerical model
  - Simplified / full geometry
  - Boundary conditions
  - Governing equations
- Results
  - Simplified geometry - Diverging grooves
  - Full geometry - General flow pattern
- Summary / Perspectives

plate disc refiner



typical refiner filling



Geometry – assumptions

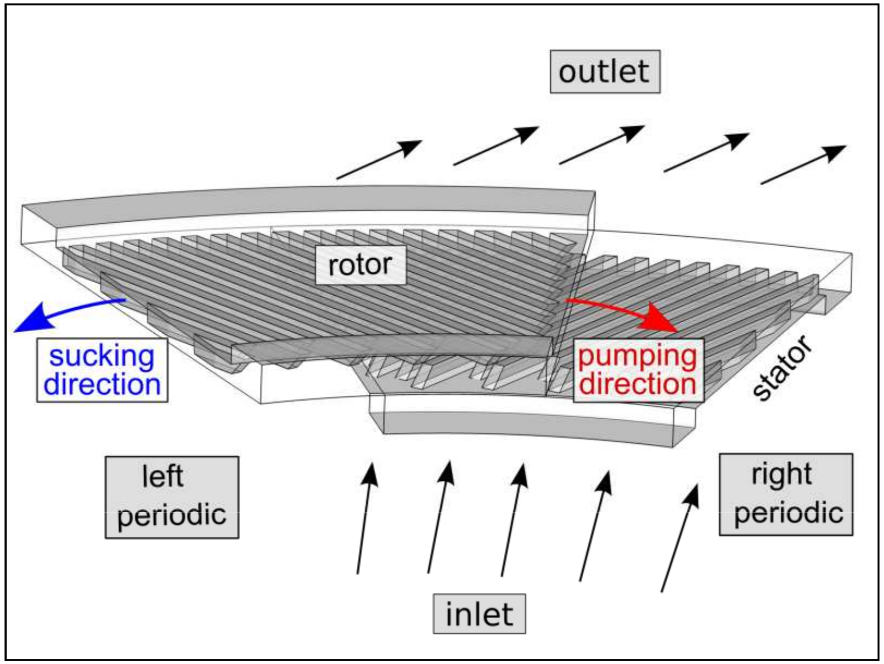
simplified

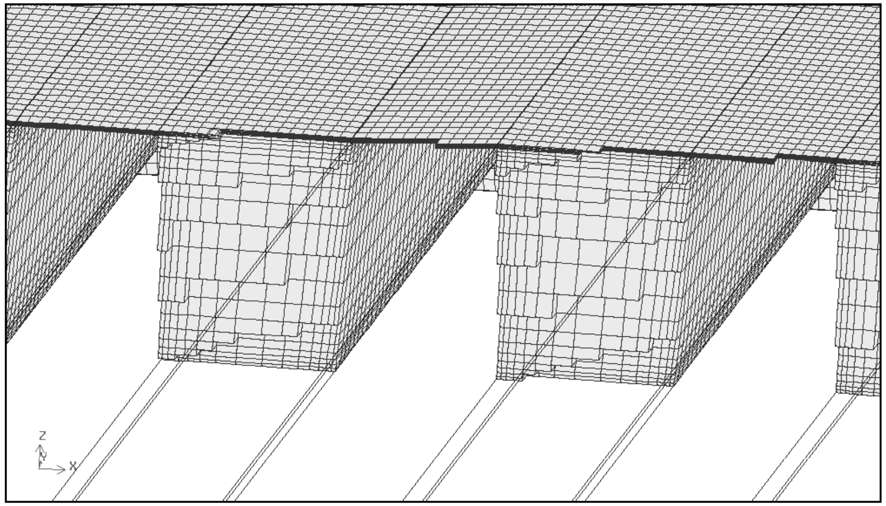
- neglected housing ⇒ axisymmetric outlet (instead of point outlet)
- neglected axial part of inlet, radial inlet applied
- periodicity of discs geometry - single-segment (30 degrees of angular extent - 1/12)

full

- 12 segments
- housing
- single-pipe outlet

Boundary conditions





- simplified filling
- inlet - VELOCITY INLET
- outlet - PRESSURE OUTLET
- PERIODIC B.C.
- INTERFACE for sliding meshes

- geometry and mesh - GAMBIT
- mesh: 6 / 24 mln cells
- FLUENT 6.3 / 13

Governing equations

- pulp suspension treated as a **single-phase continuum** (N-S, continuity)
- flow character assumed to be **laminar** (confirmed by simulation results)
- pulp modelled as either **Newtonian** or **non-Newtonian** fluid

$$\frac{\partial \boldsymbol{U}}{\partial t} + \boldsymbol{U} \cdot \nabla \boldsymbol{U} = -\frac{\nabla p}{\rho} + \frac{\mu}{\rho} \nabla^2 \boldsymbol{U}$$

$$\nabla \boldsymbol{U} = 0$$

$$\mu = f(\boldsymbol{\gamma}) \quad \text{or} \quad \mu = \text{const}$$

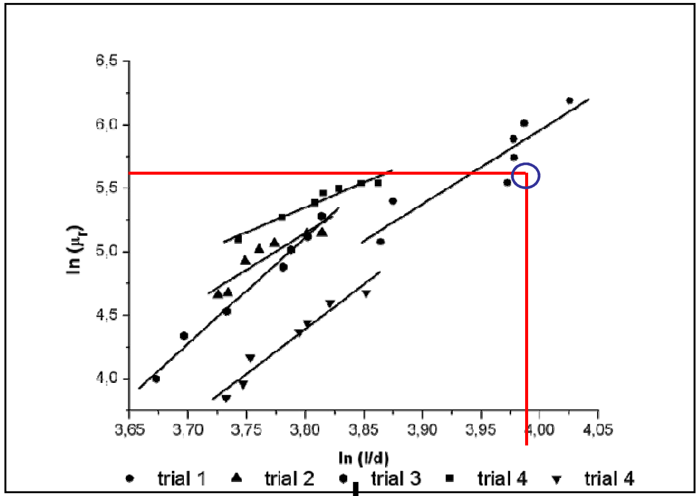
where $\boldsymbol{\gamma}$ - rate of deformation tensor

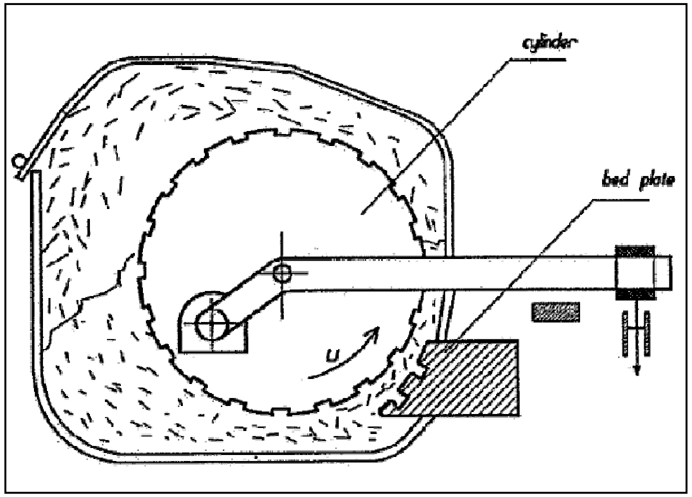
- fibre-fibre and fibre-wall interactions are neglected - main goal was to analyze the **LC refining hydraulics**

Pulp material properties

Newtonian fluid - constant apparent viscosity

softwood pulp, C_m = 4%, fibre lenght = 1400 μm, diameter = 26 μm



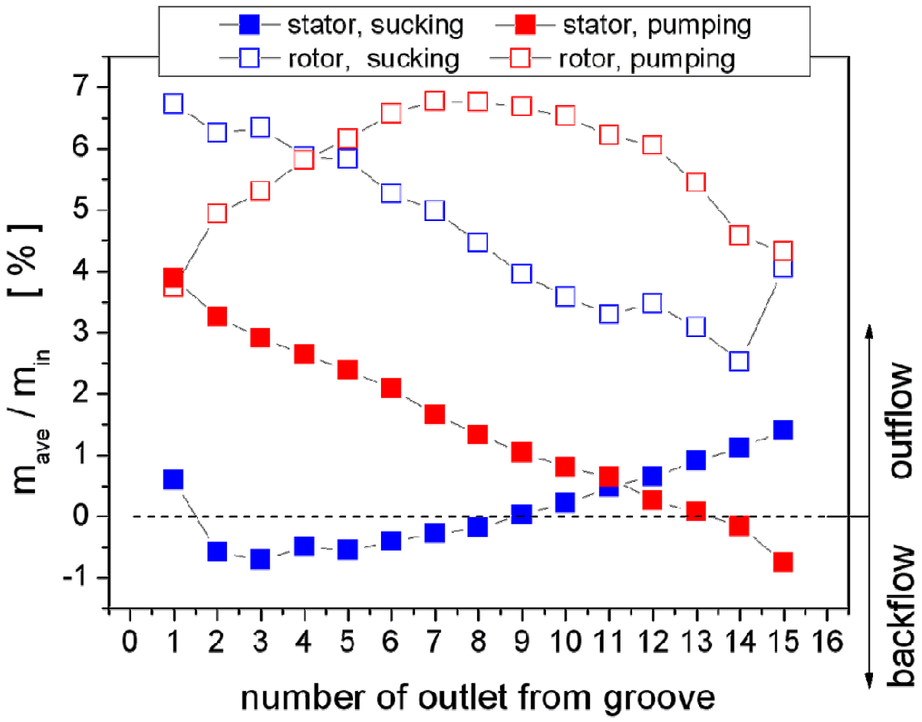


ln(l/d) = 3,986 ⟶ $\ln(\mu_r) = 5{,}91$ ⟶ $\mu_r = 370$

$$\mu_{pulp} = \mu_r \cdot \mu_{water} = 370 \cdot 0{,}001003 = \boxed{0{,}371 \text{ Pa}\cdot\text{s}}$$

source:Radoslavova, Silvy, Roux, 1996,,TAPPI Papermakers Conf., Philadelphia

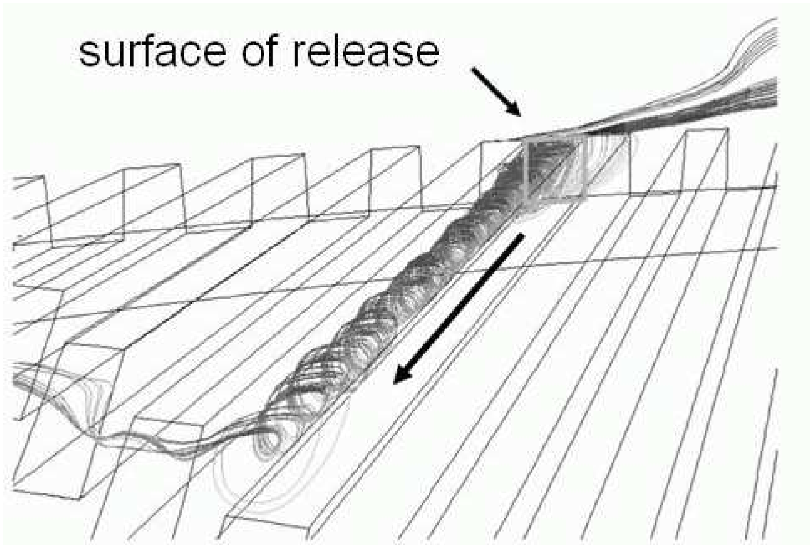
General flow pattern



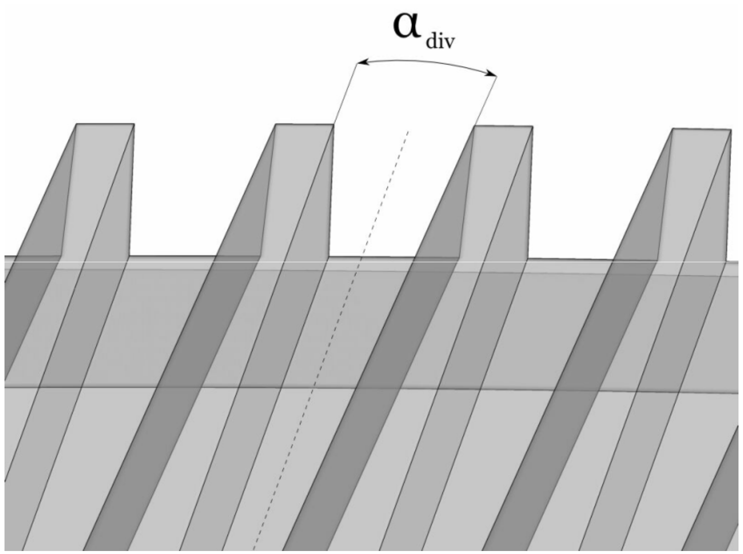
reverse flows in stator disc

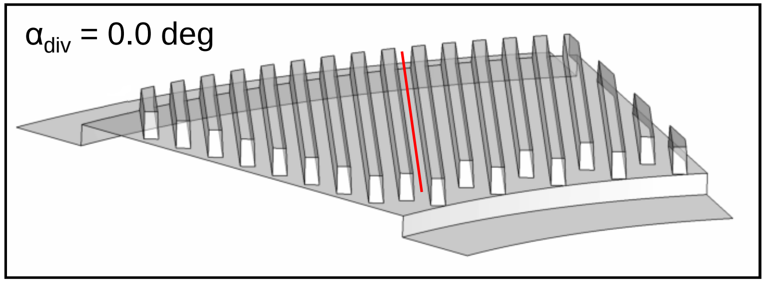
⇓

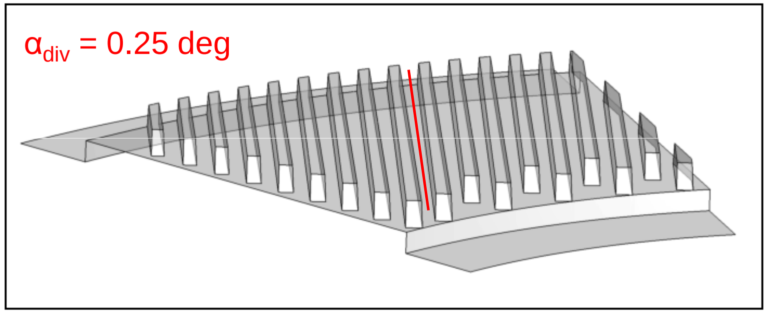
enhanced internal circulation

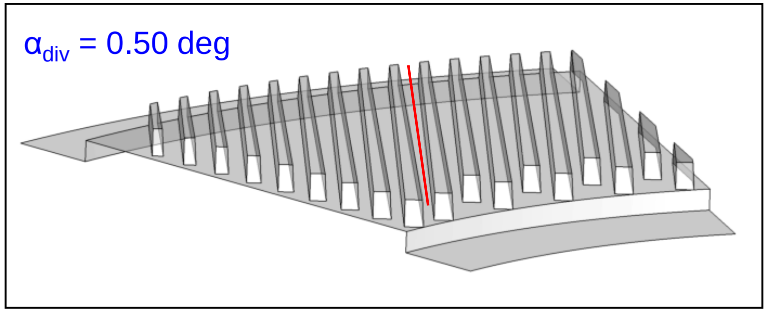


Diverging grooves

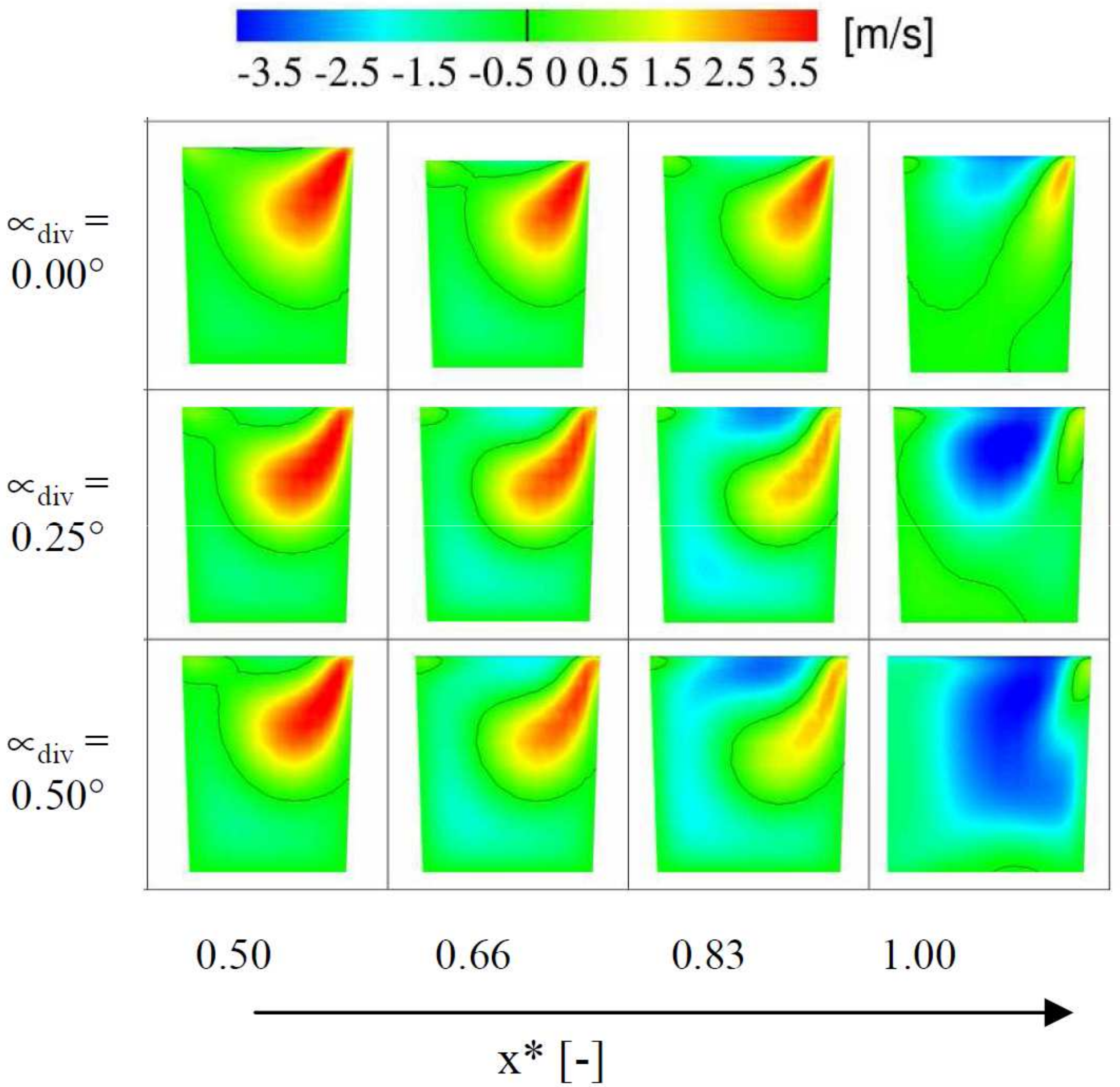






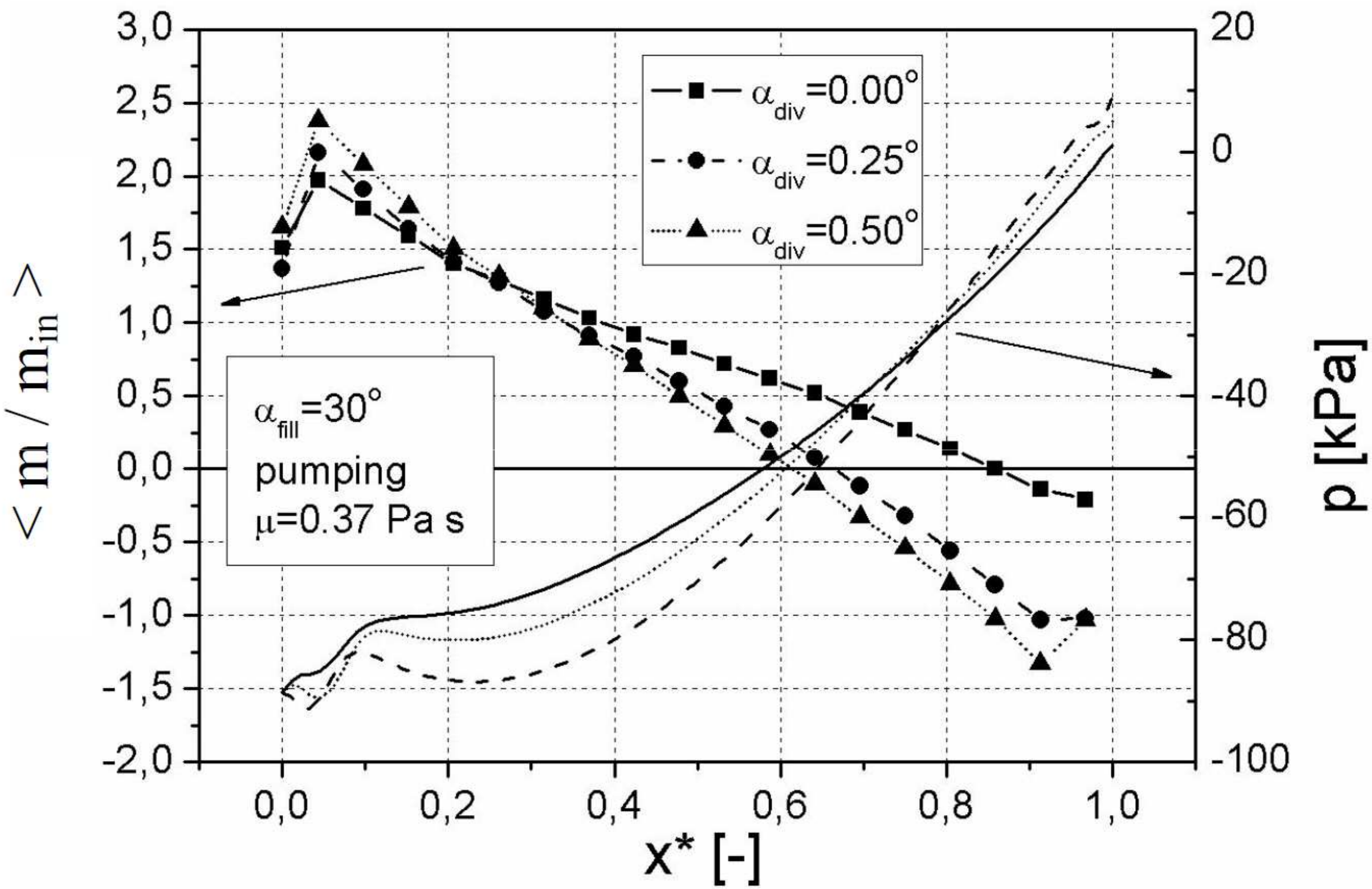


Diverging grooves

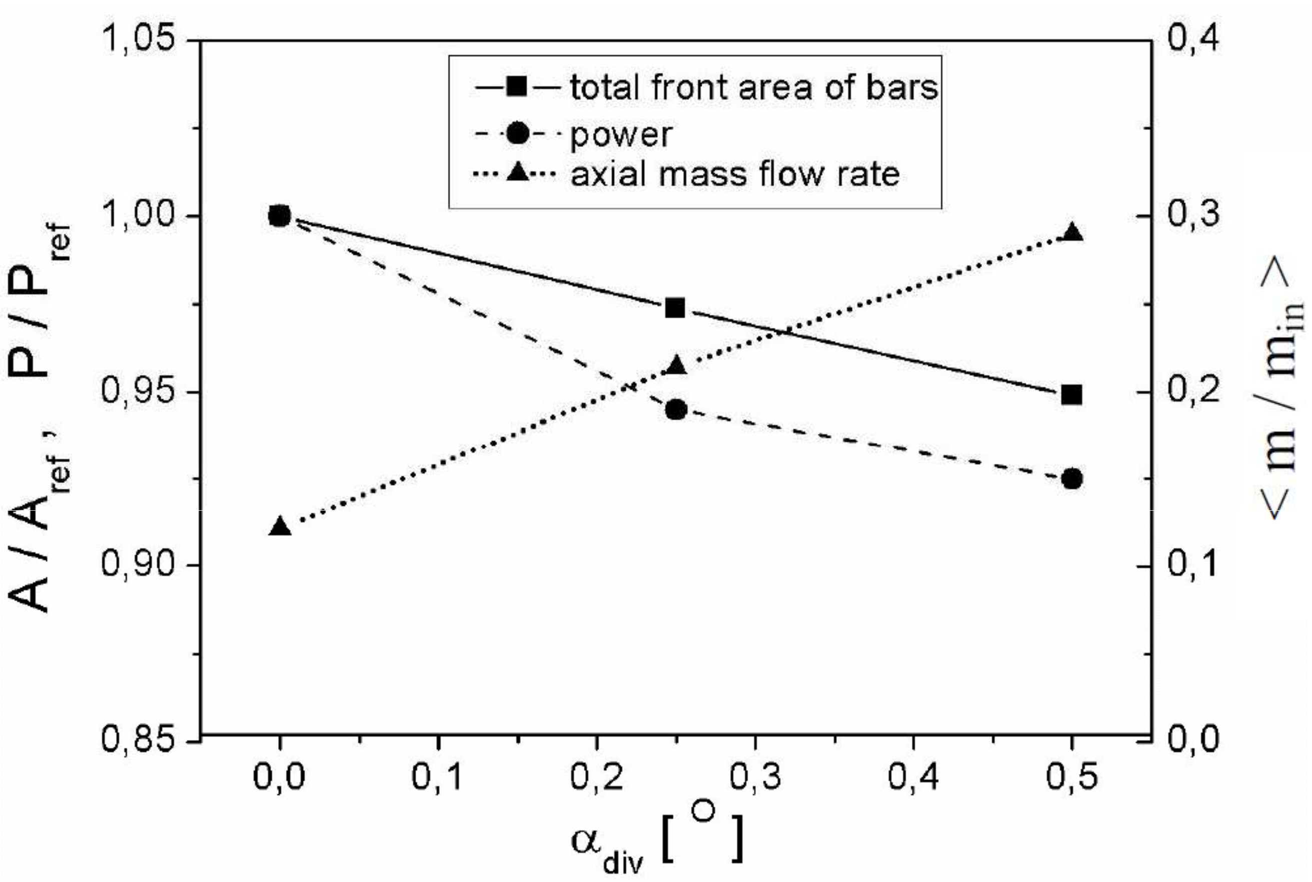


intensification of reverse flow

Diverging grooves



Diverging grooves

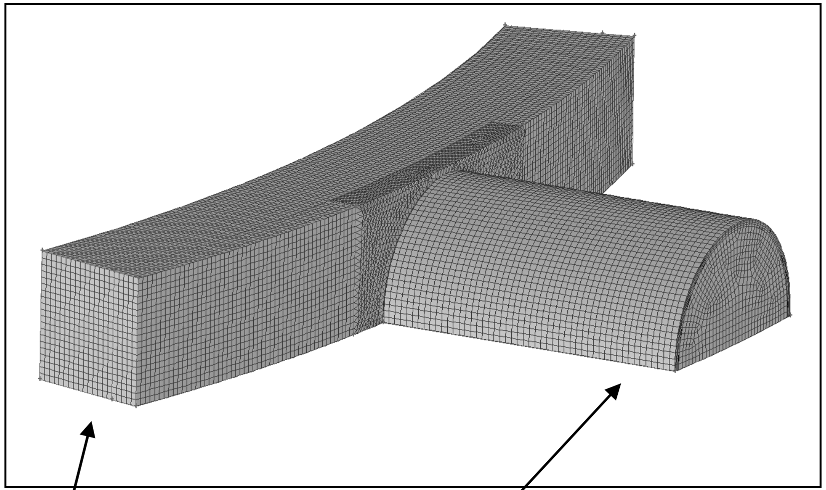


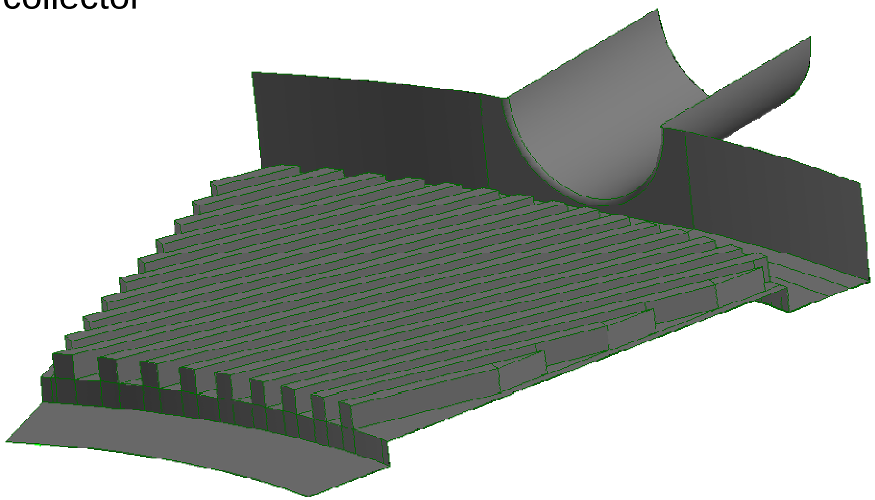
- **mass flux exiting stator grows**
- **power consumption decreases**

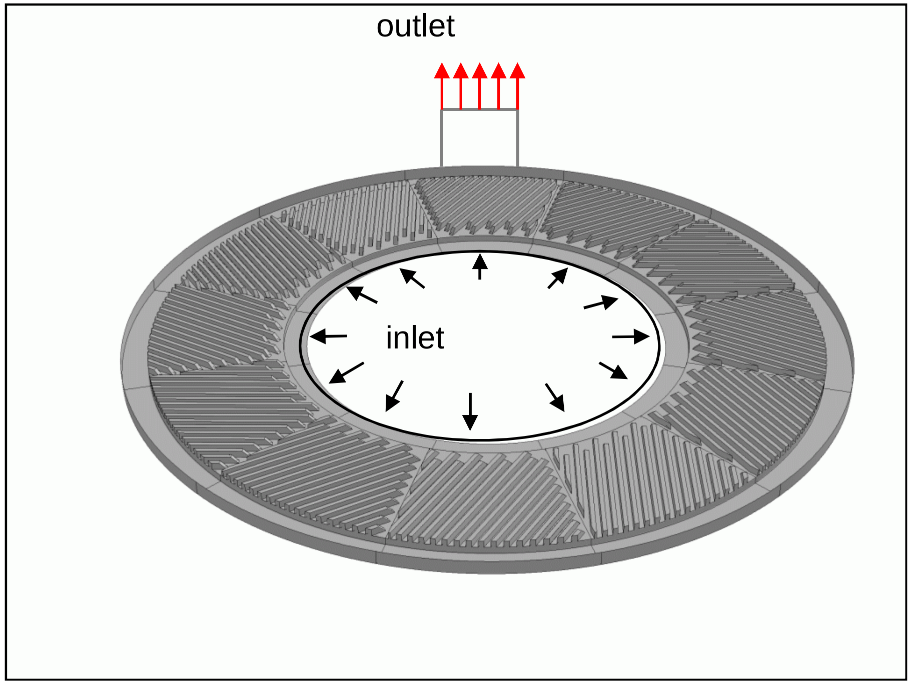
Full refiner simulation

Full refiner geometry model

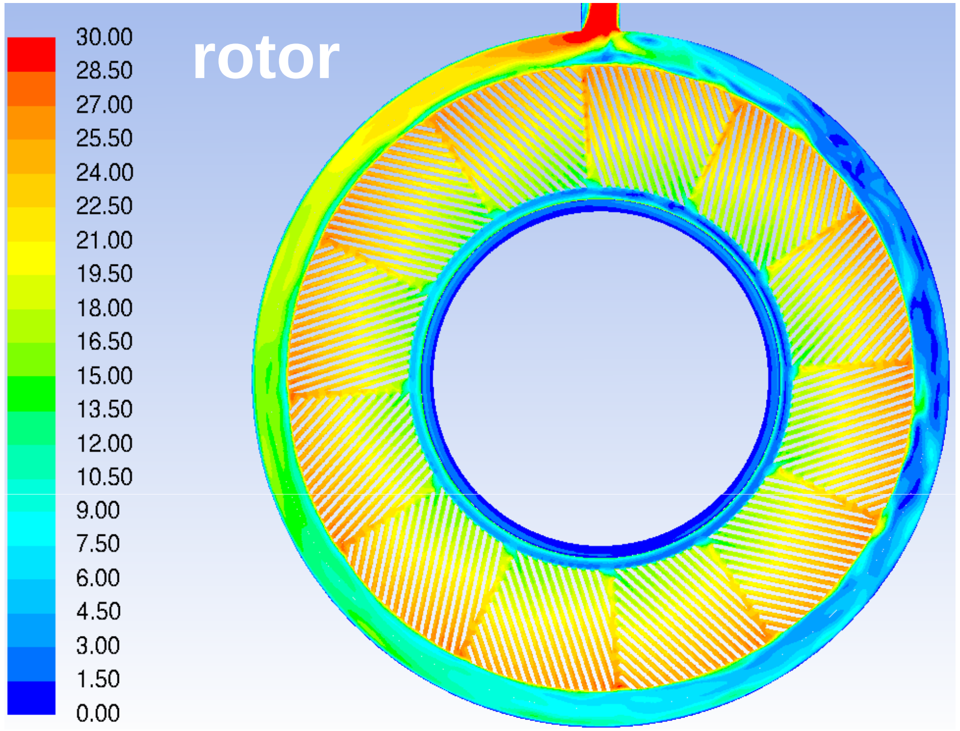
- housing included
- pipe outlet
- 12 segments

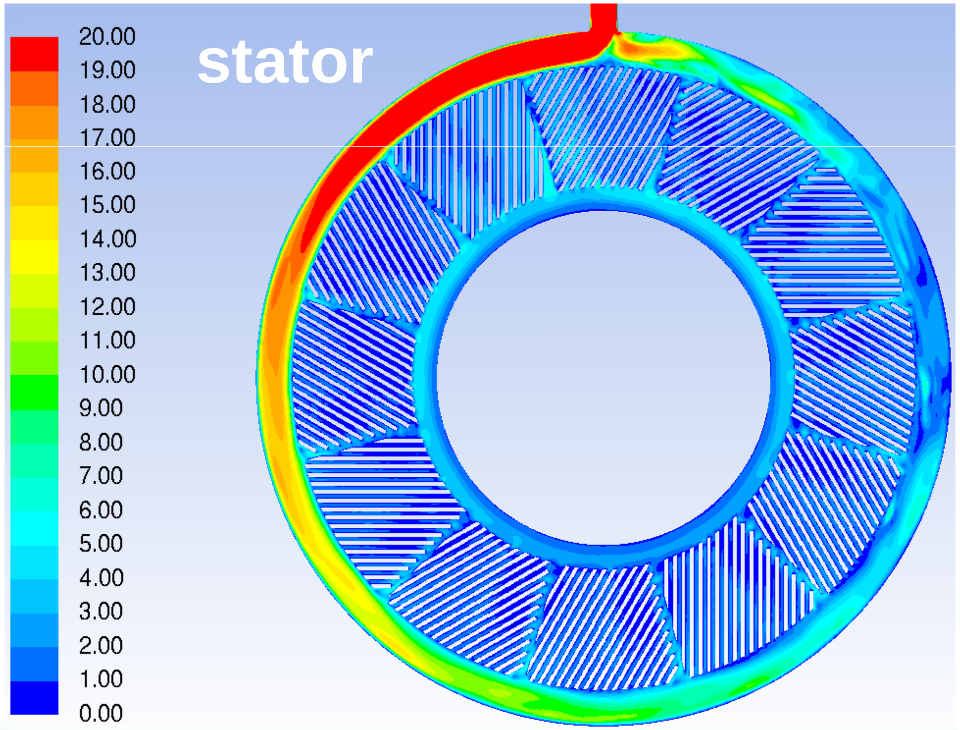




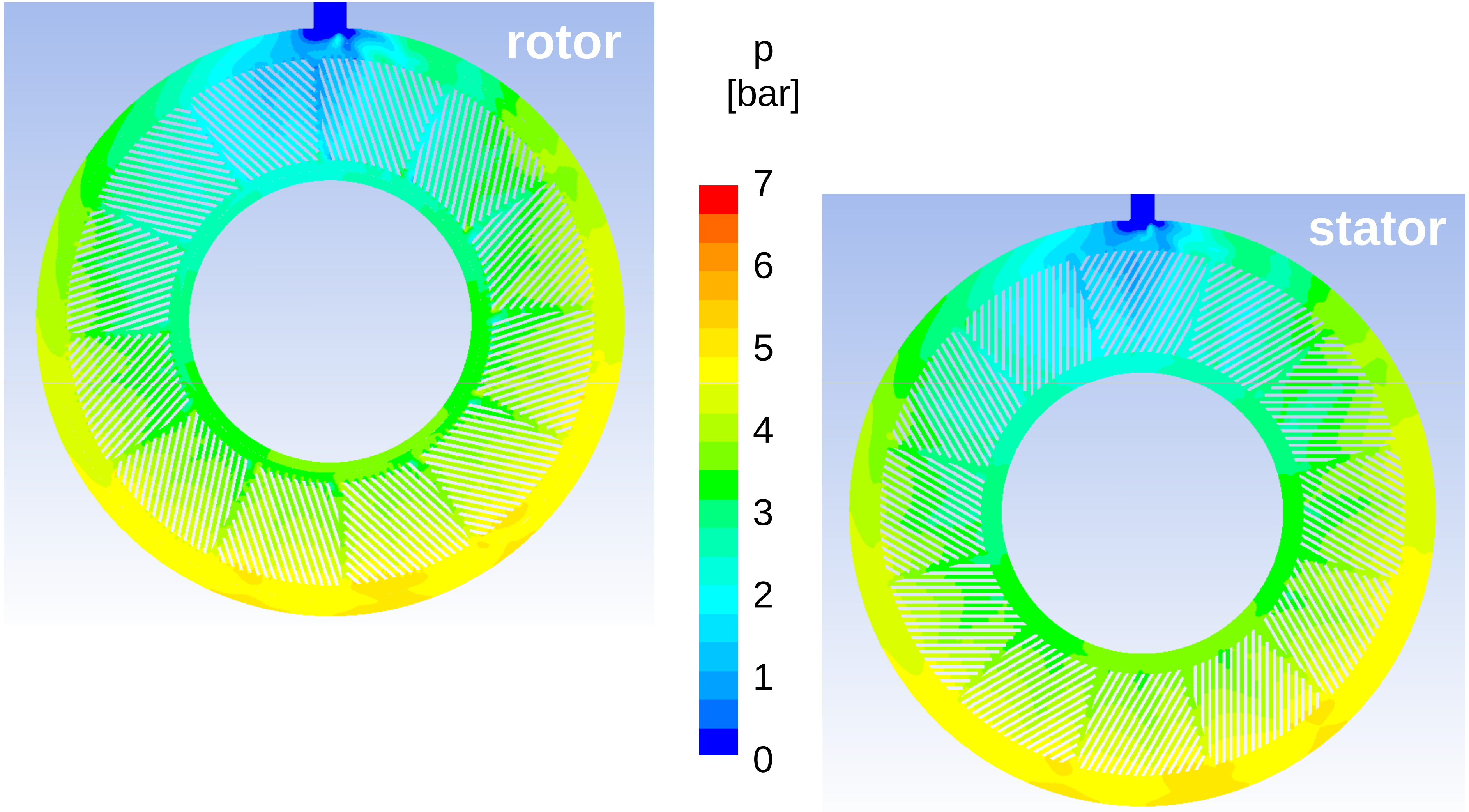


Velocity magnitude





Pressure distribution



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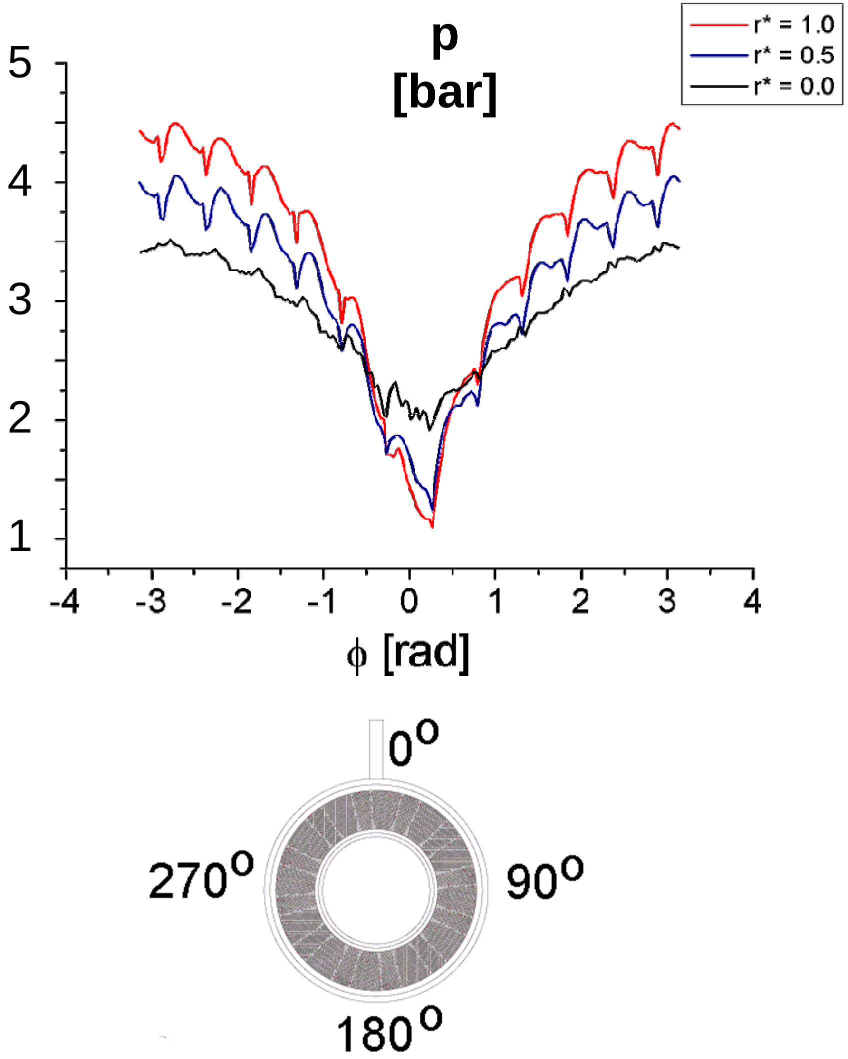

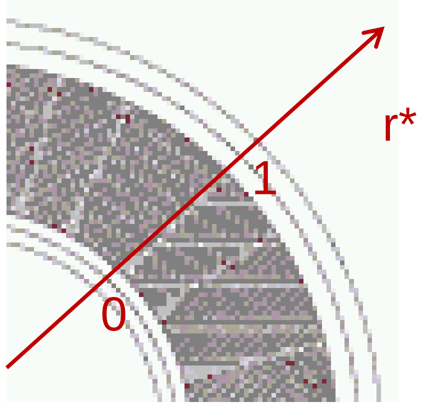

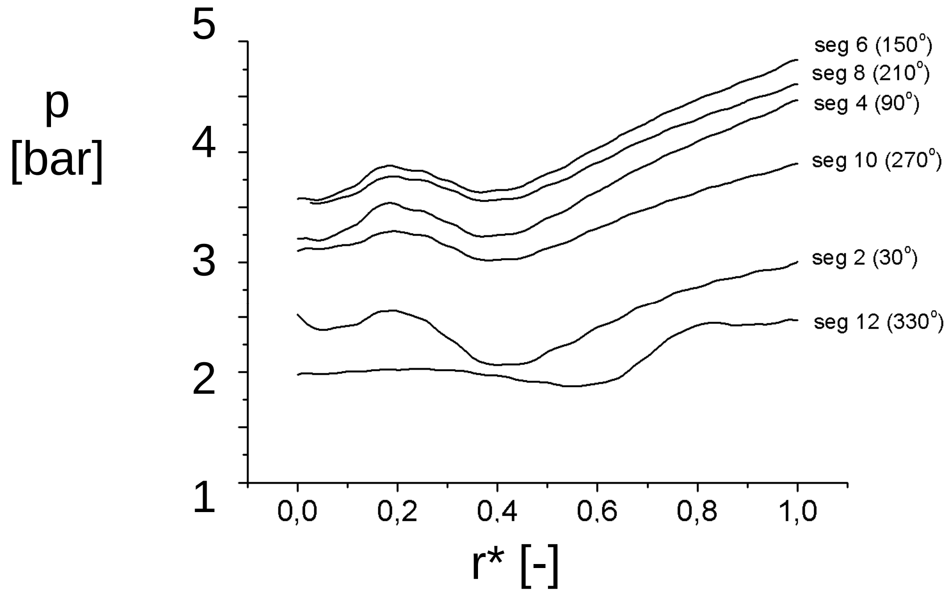

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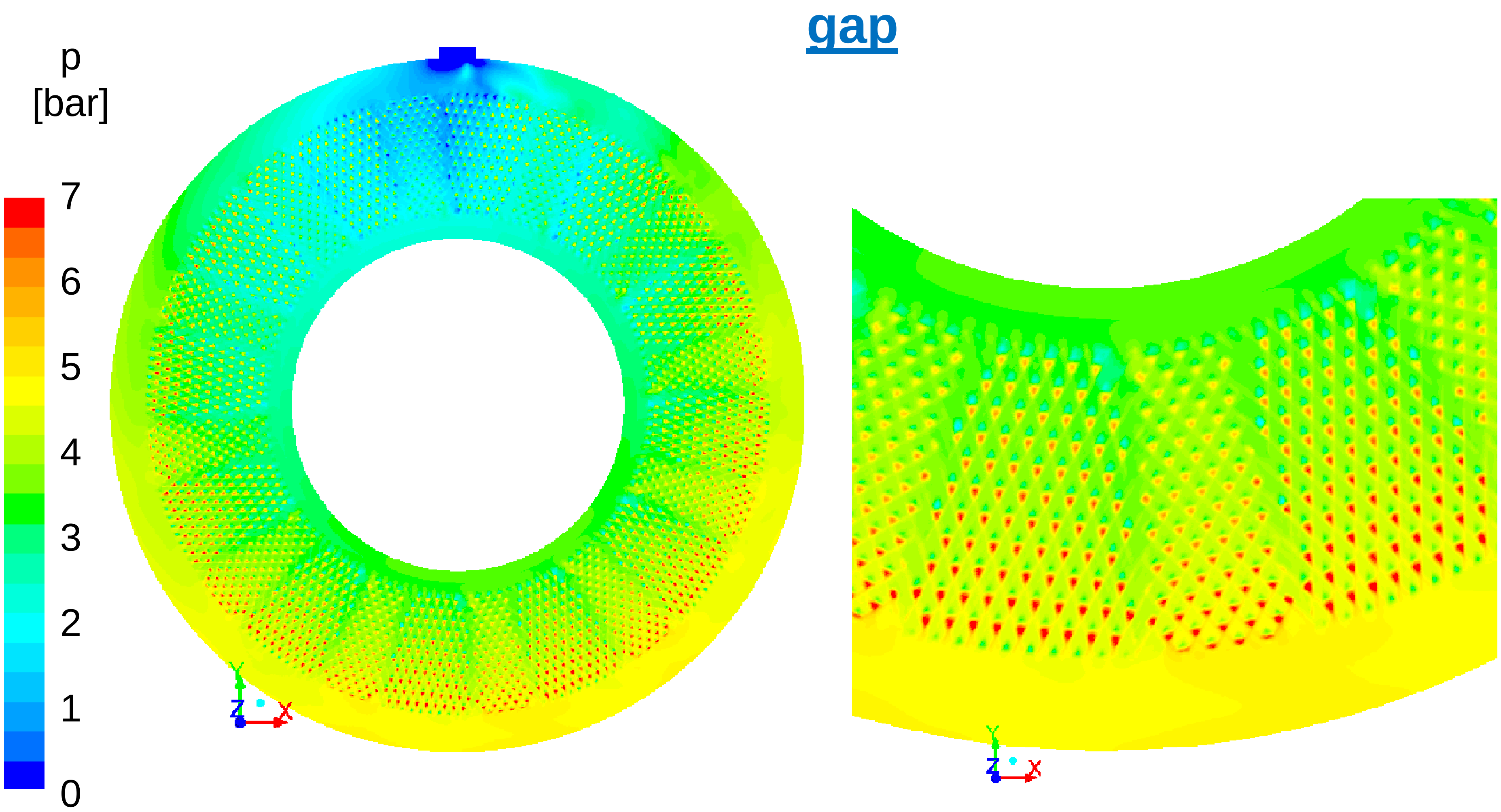
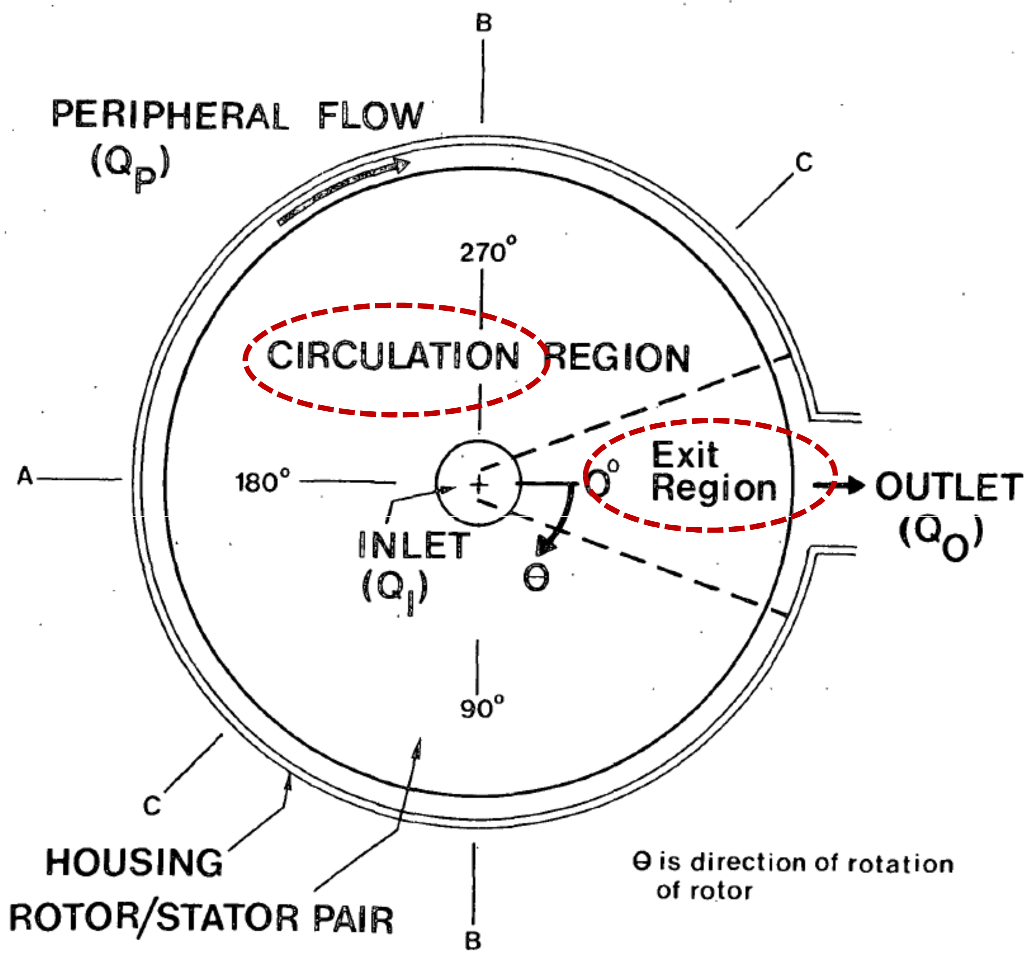
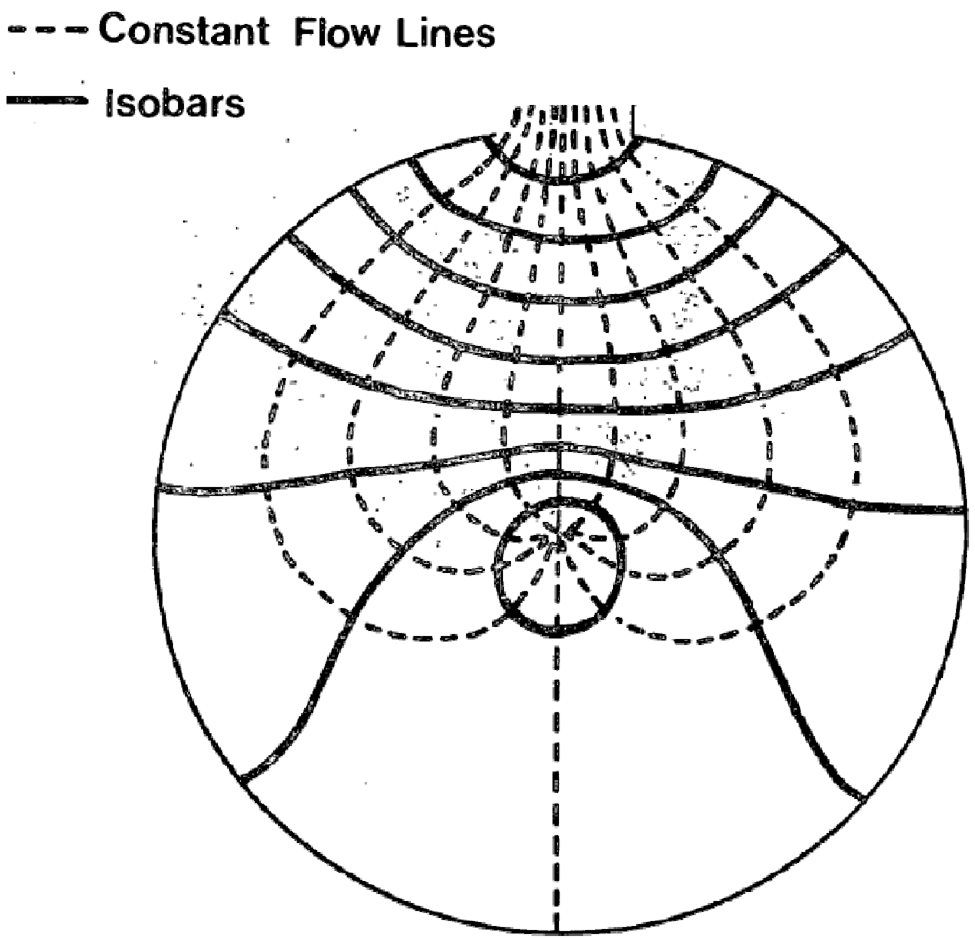


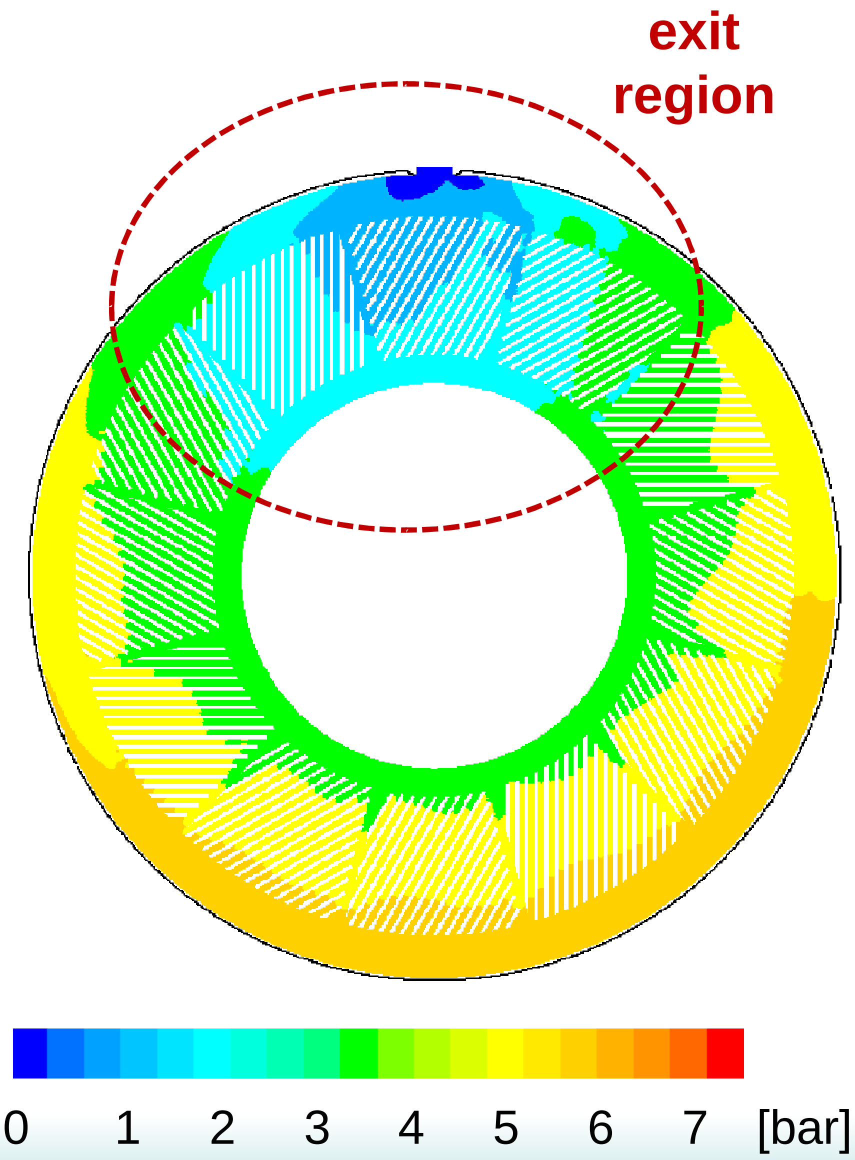
LC refiner flow model - Fox et al.



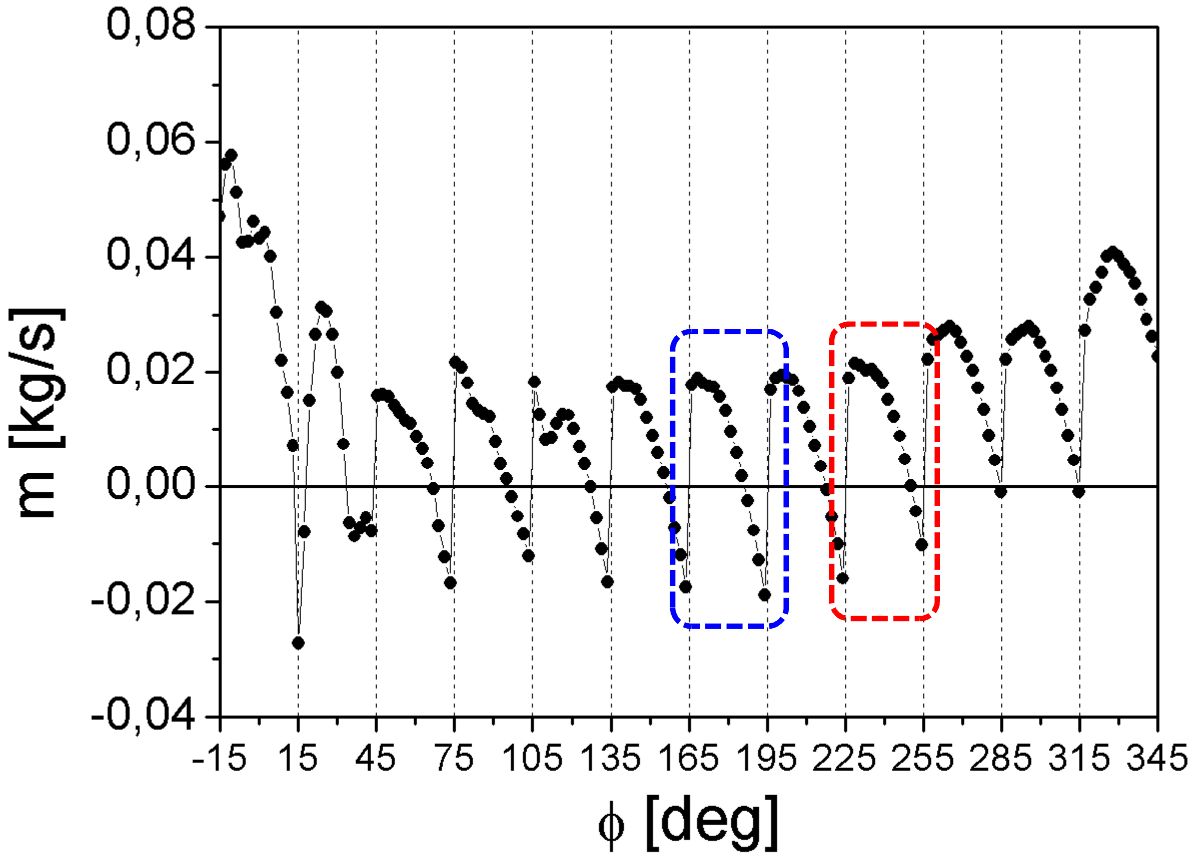
Fox, T.S., Brodkey, R.S. Nissan, A.H., 1979, TAPPI J., 62 (3)

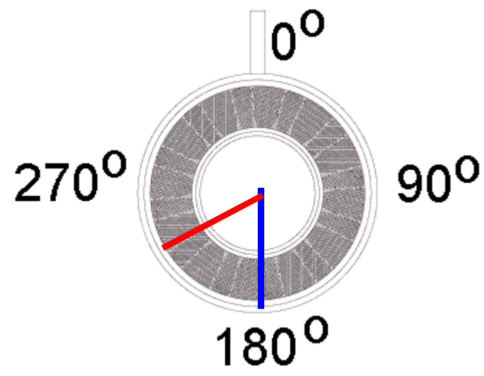
Pressure distribution - CFD vs Fox et al.





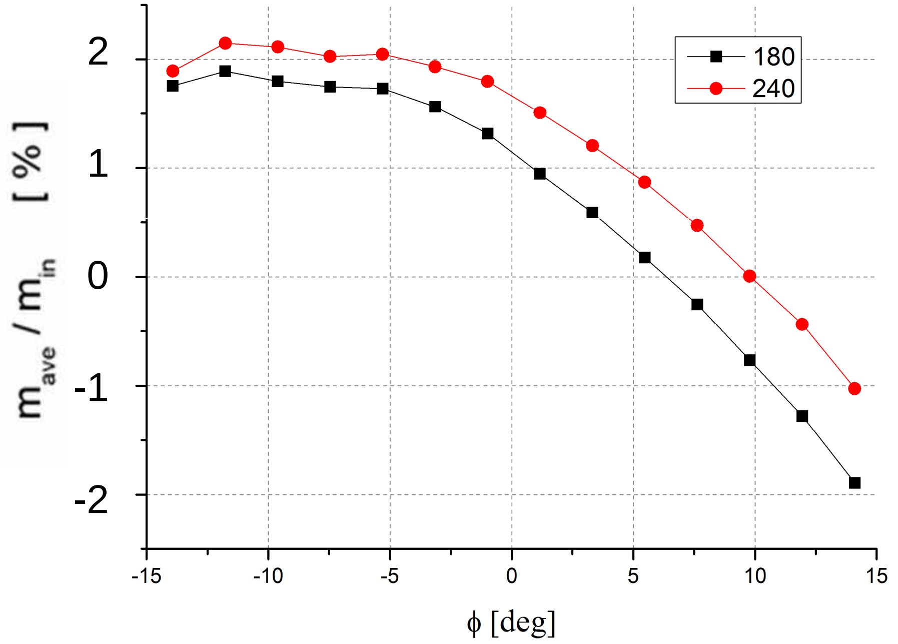
Mass flux at filling outlet



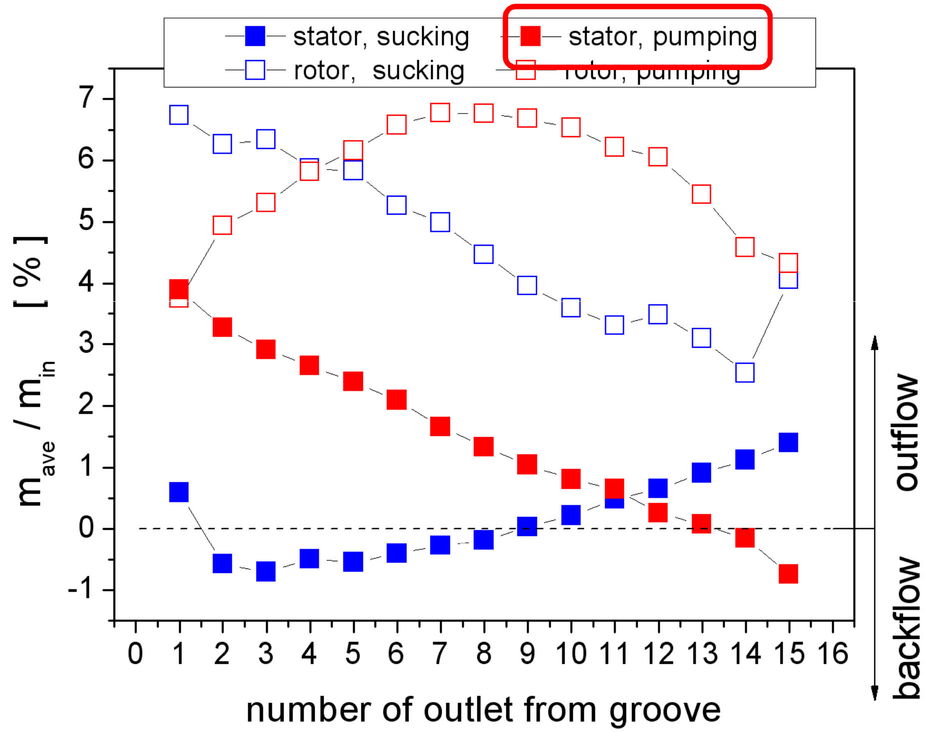


Mass flux at filling outlet

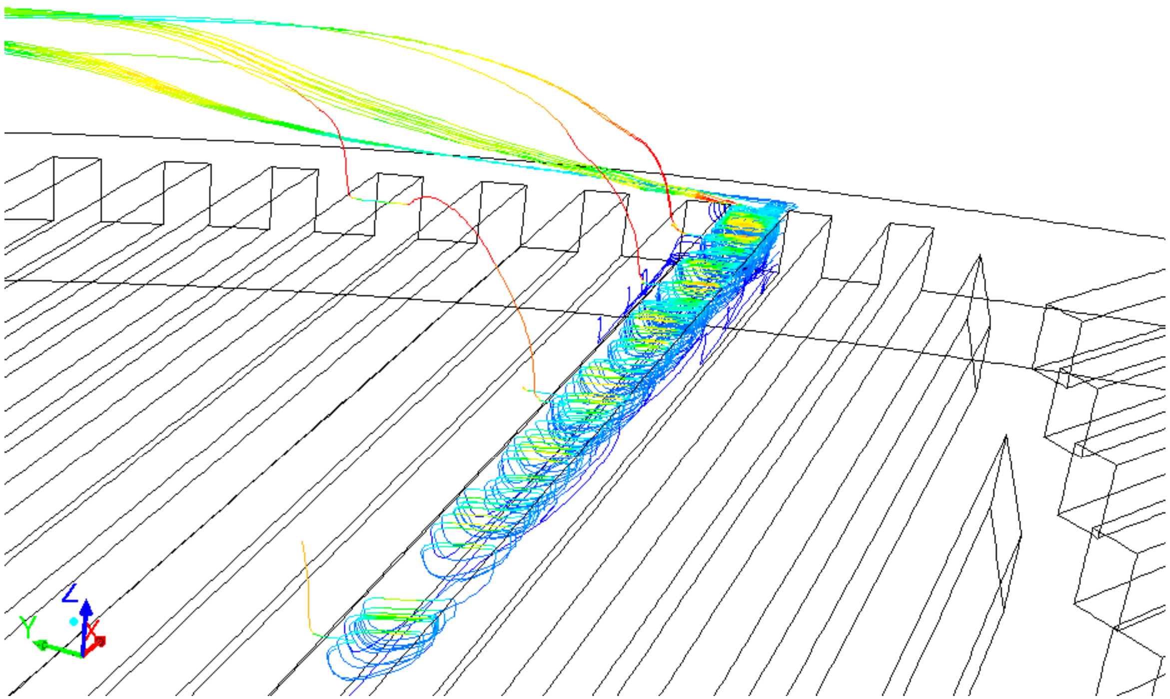
full refiner



single-segment refiner



Flow reversals in stator



full refiner

Summary / Perspectives

Simplified geometry model

- qualitative agreement with experimental observation - adequate numerical model
- divergent grooves:
  - modified pressure distribution and enhanced flow reversals
  - no energy penalty - improved flow quality

Full geometry model

- circulation / exit regions - analogy to Fox et al.
- existence of the backflows in the stator
- mass flow rate distributions stongly non-uniform and rotor position dependent

General

- no fibres included...
- CFD can really help - useful tool in process optimisation
- time consuming simulations
- ongoing simulations / data processing for varying conditions

Thank You for Your Attention