Fibre Orientation and Related Headbox Optimization Systems

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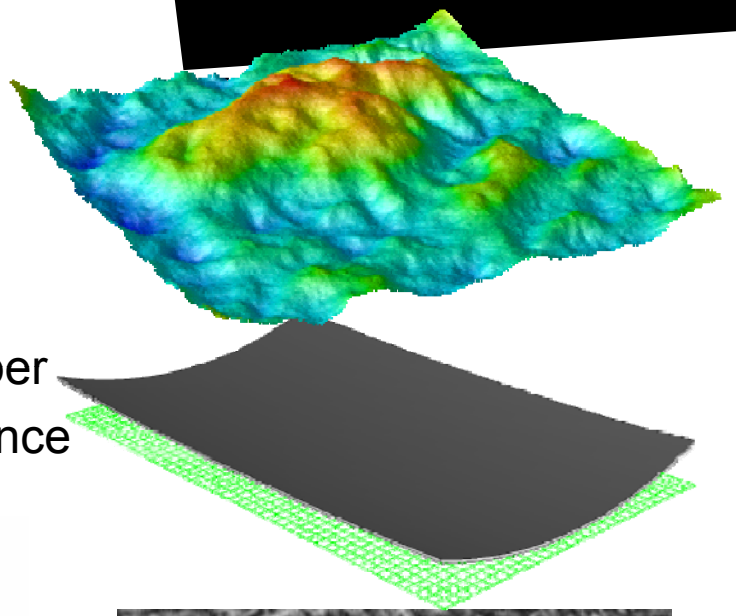
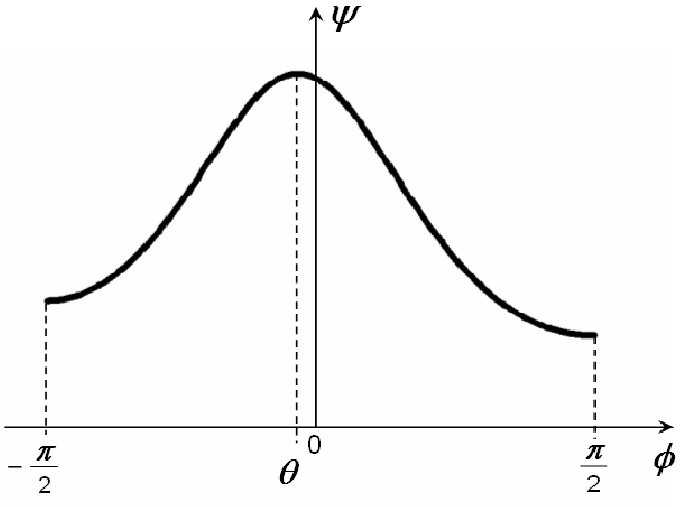
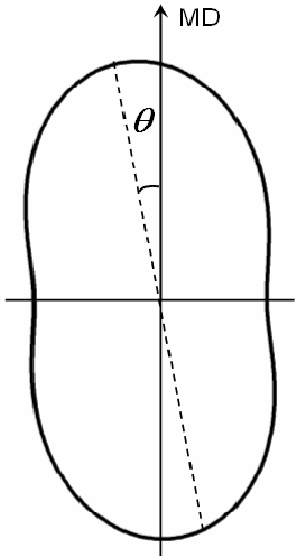
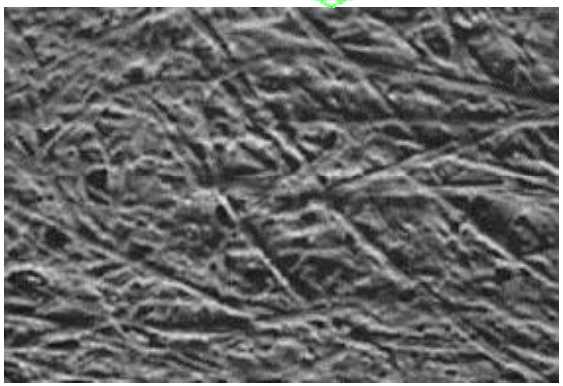
Fibre Orientation

- Basic fibrous structure of the paper sheet is formed at the wet end of a paper machine - headbox and forming section
- Fibre orientation (angle and anisotropy) determines the dimensional stability of the paper
- Velocity gradients align fibres whereas turbulence makes orientation more random



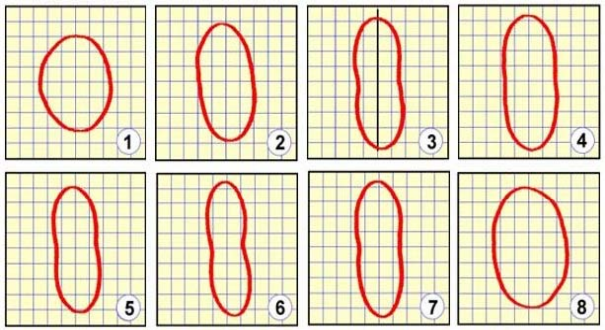


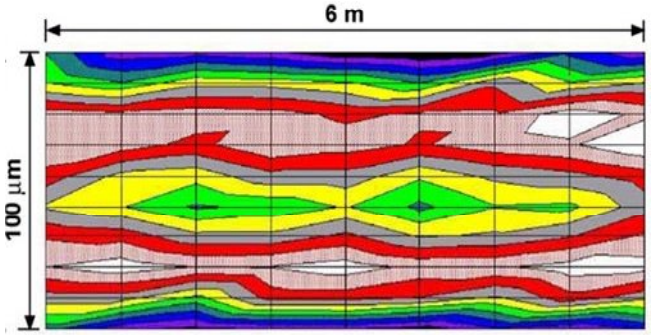


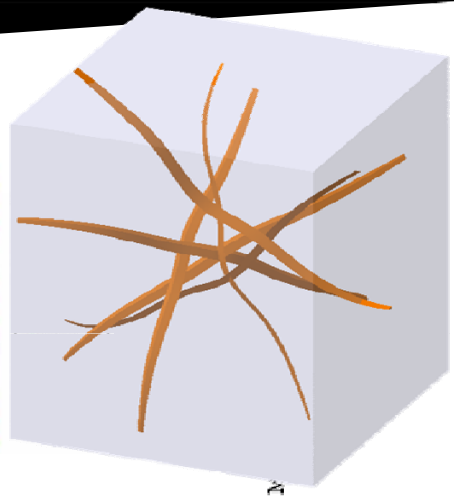


Fibre Orientation, its Anisotropy and CD Angle Profile

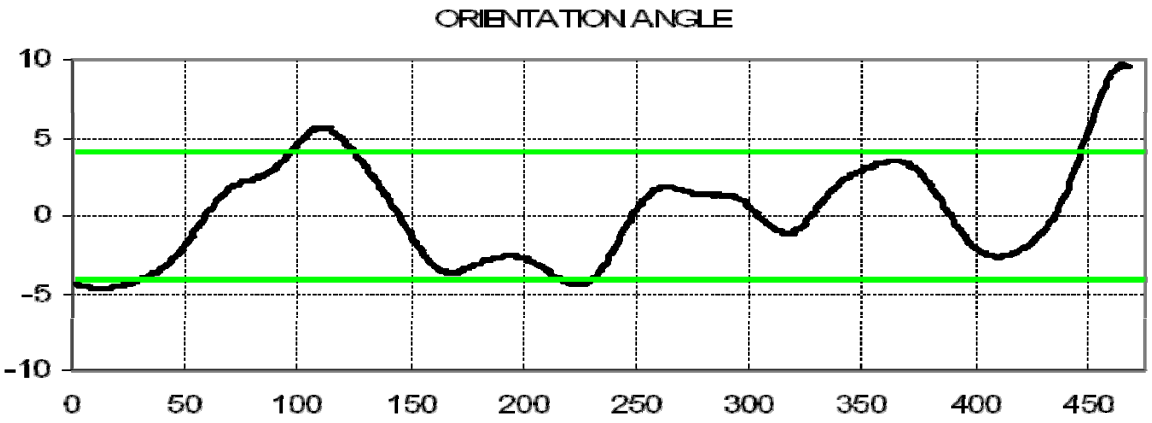
- Fibre orientation distribution in each location

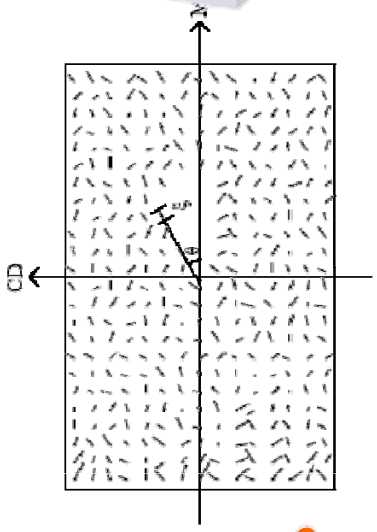




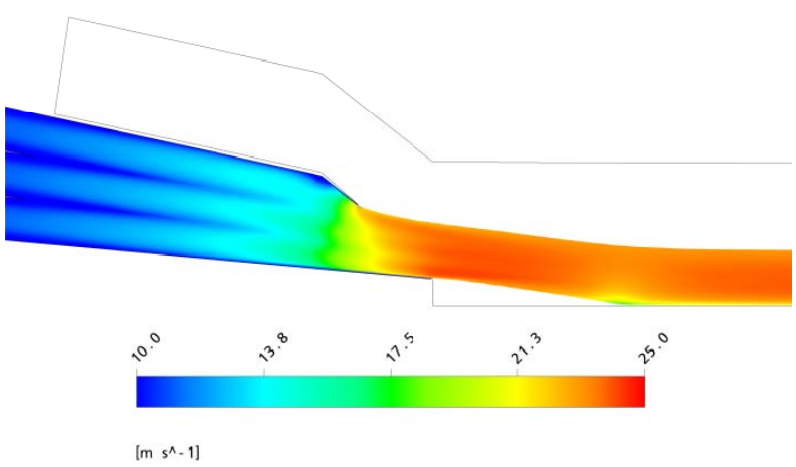


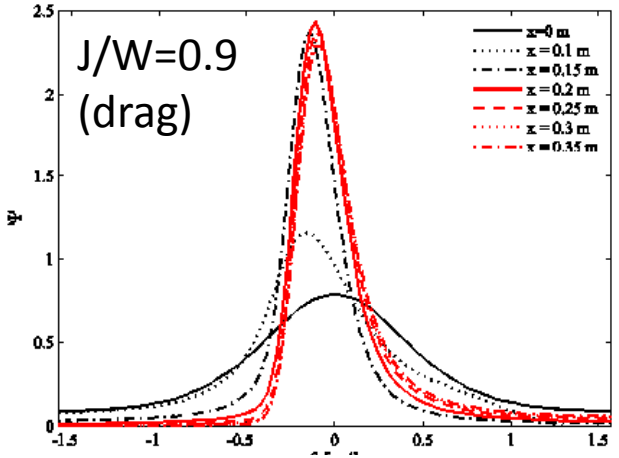
- The average fibre orientation angle profile in cross direction (CD) of a paper machine

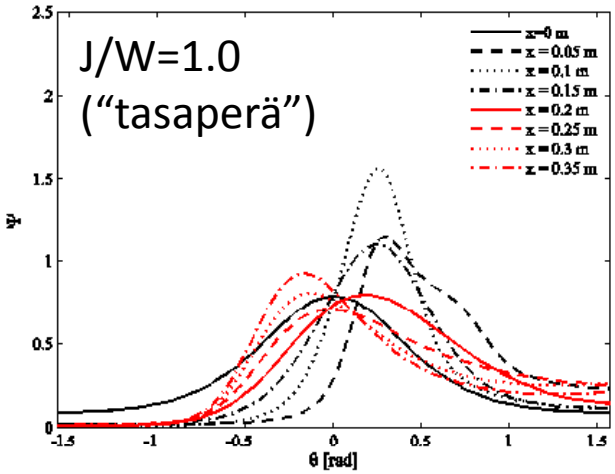


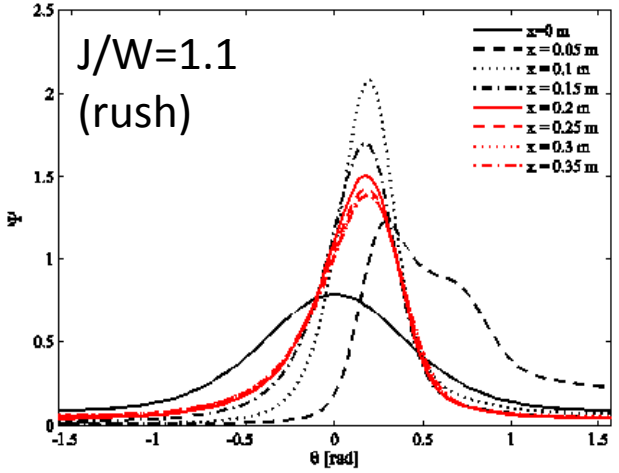


Modelling of Fibre Orientation Probability Distribution (FOPD)





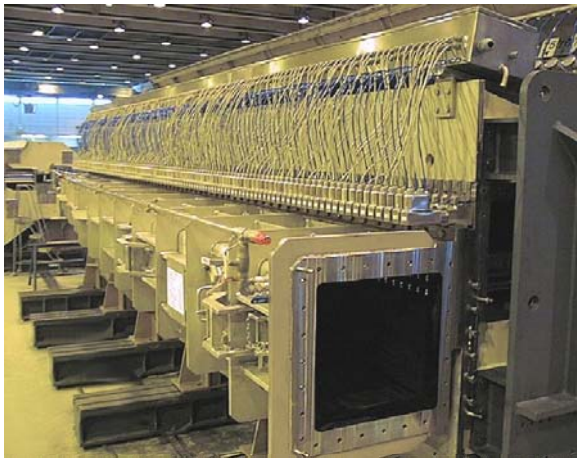


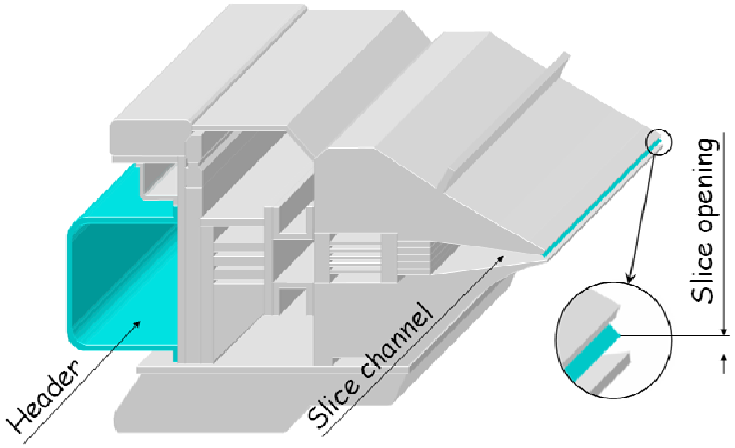


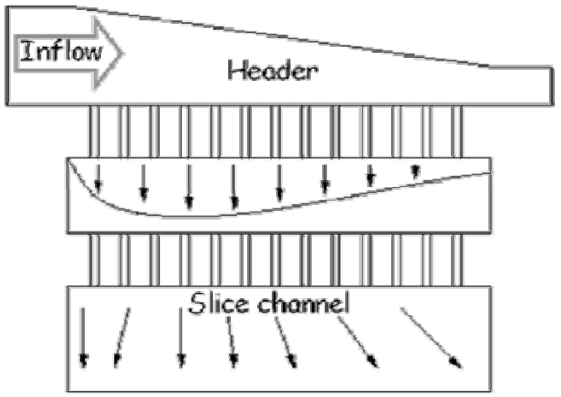
J=Jet speed
W=wire speed

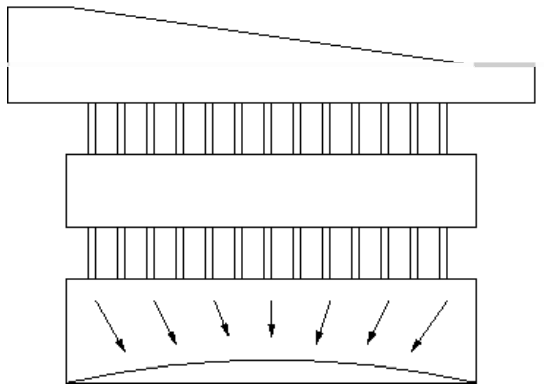
Niskanen, Hämäläinen (2011), NPPRJ (in press)

CFD-based Optimization for Fibre Orientation Angle Profiles



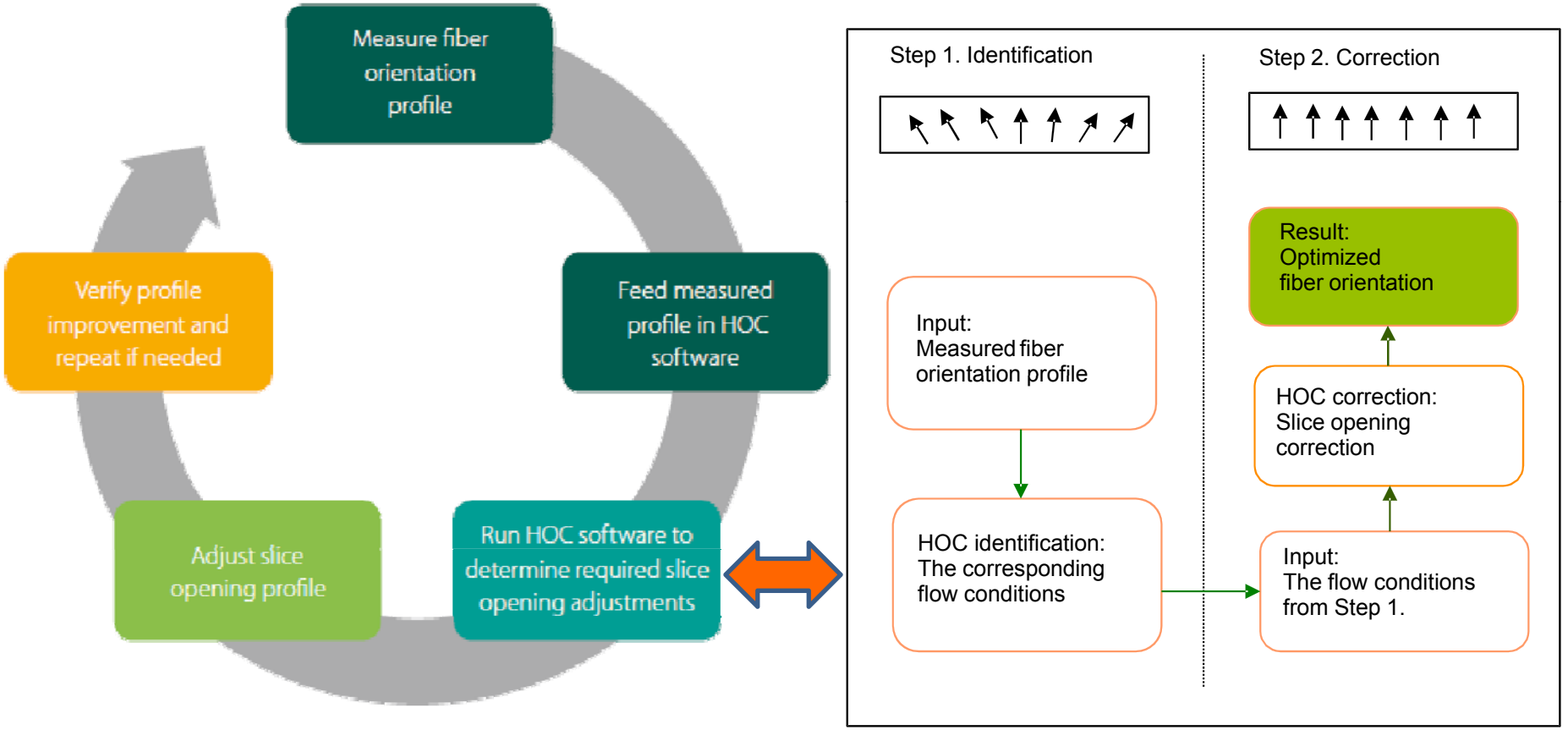






- Optimal shape design of the tapered header to get even flow distribution
- Optimal control of the slice opening to avoid CD velocities in the jet
- Based on depth-averaged NS equations
- Software tools developed to industry

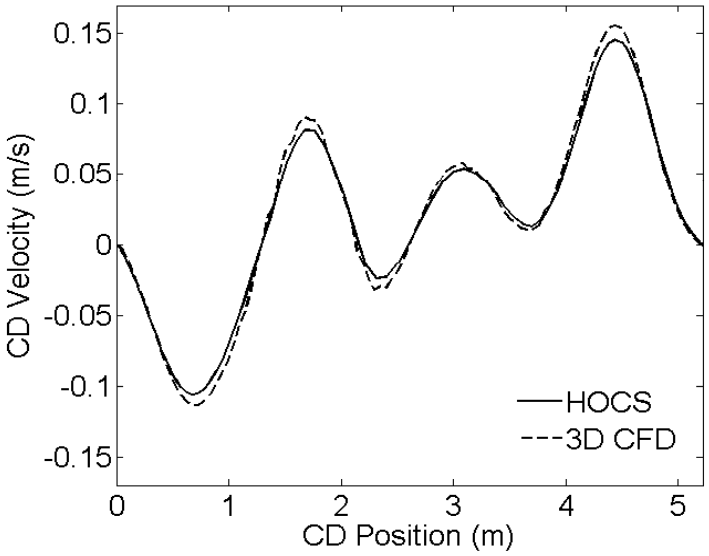
HOC Software



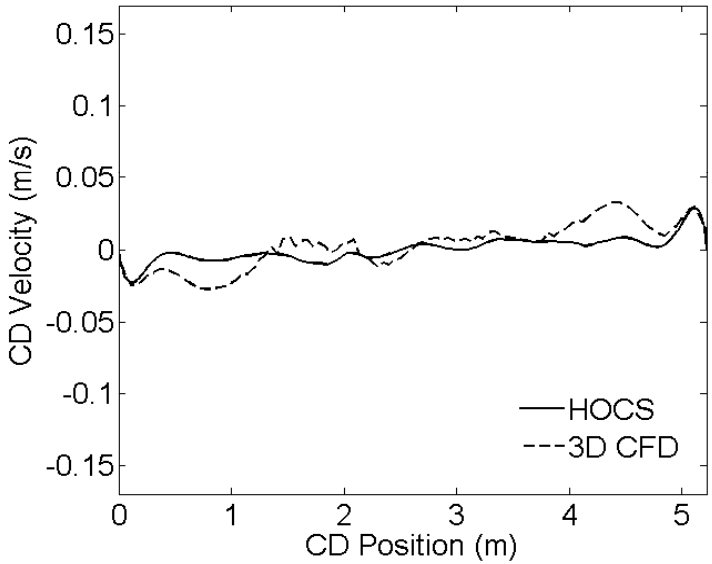
Tammenoja (2009), Results Pulp&Paper (Metso publication)

HOC Software
Extremely Fast CFD Model

Step 1: identification



Step 2: correction



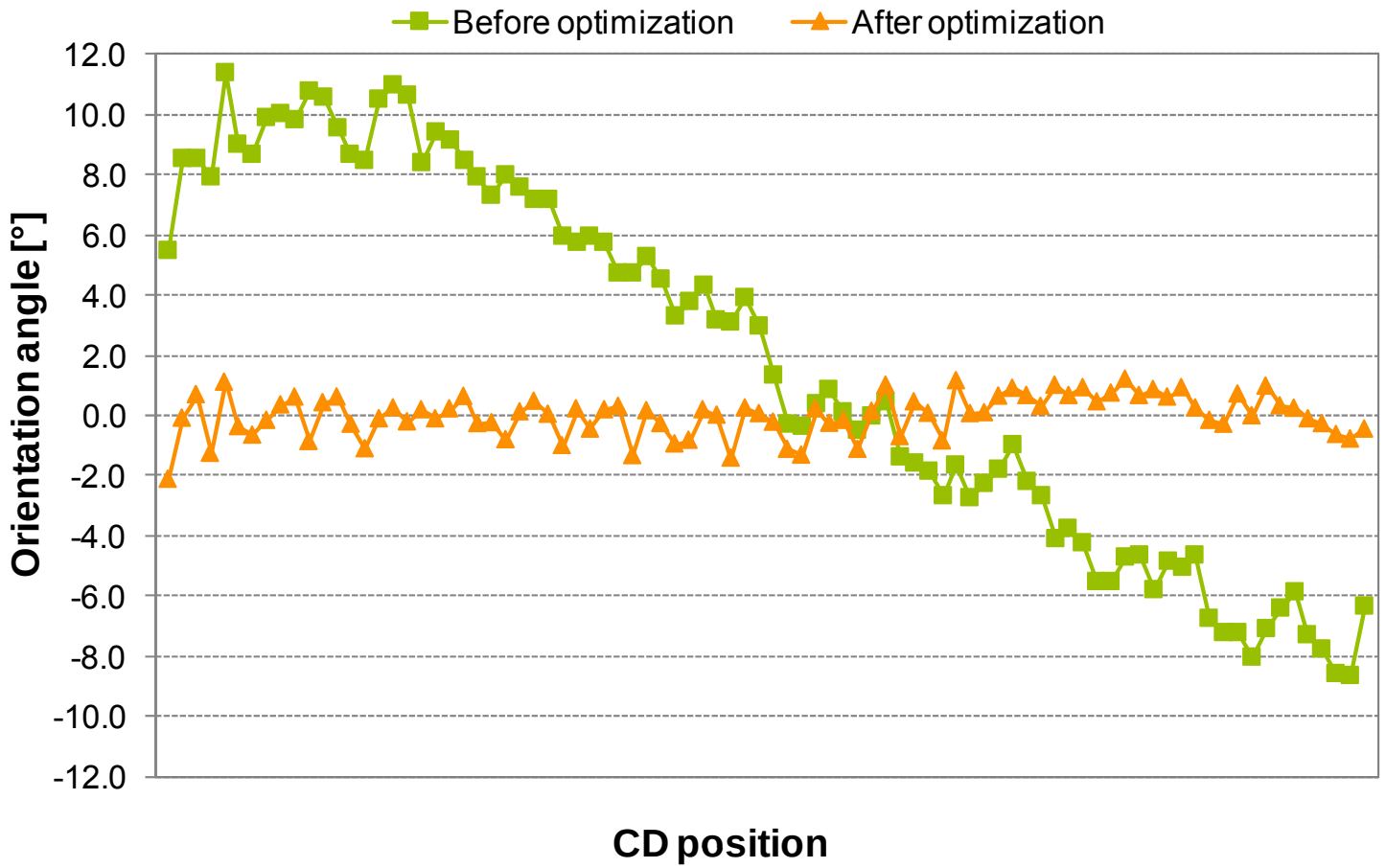
CFD model inside HOC software:

- 2D, laminar, depth-averaged
- 5 000 elements (stabilized FEM)
- **CPU time is 5 seconds**

3D CFD (ANSYS-CFX):

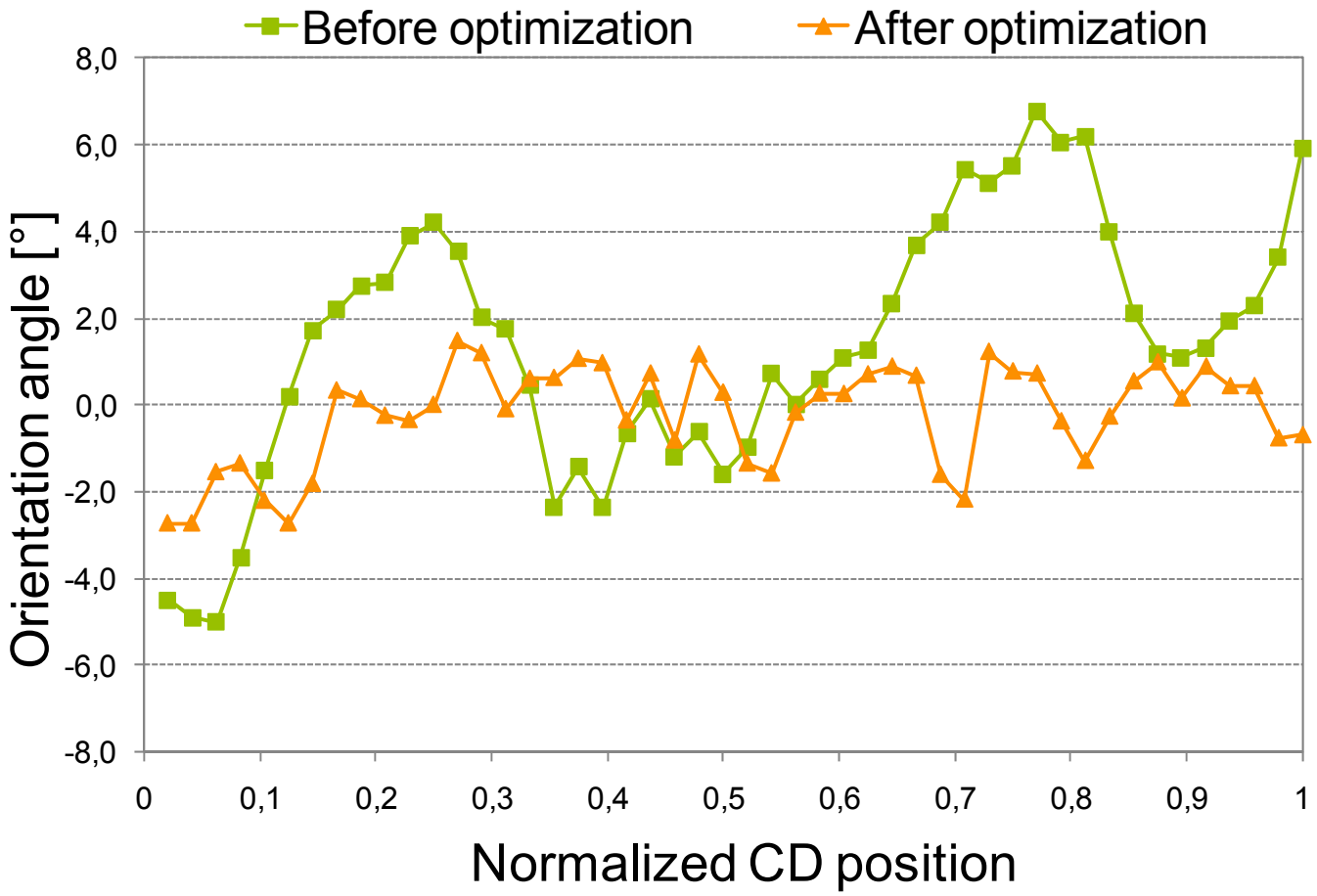
- 3D, turbulent, free jet
- 2-3 million cells
- **CPU time is 1 hour**

HOC Software
Mill Example A



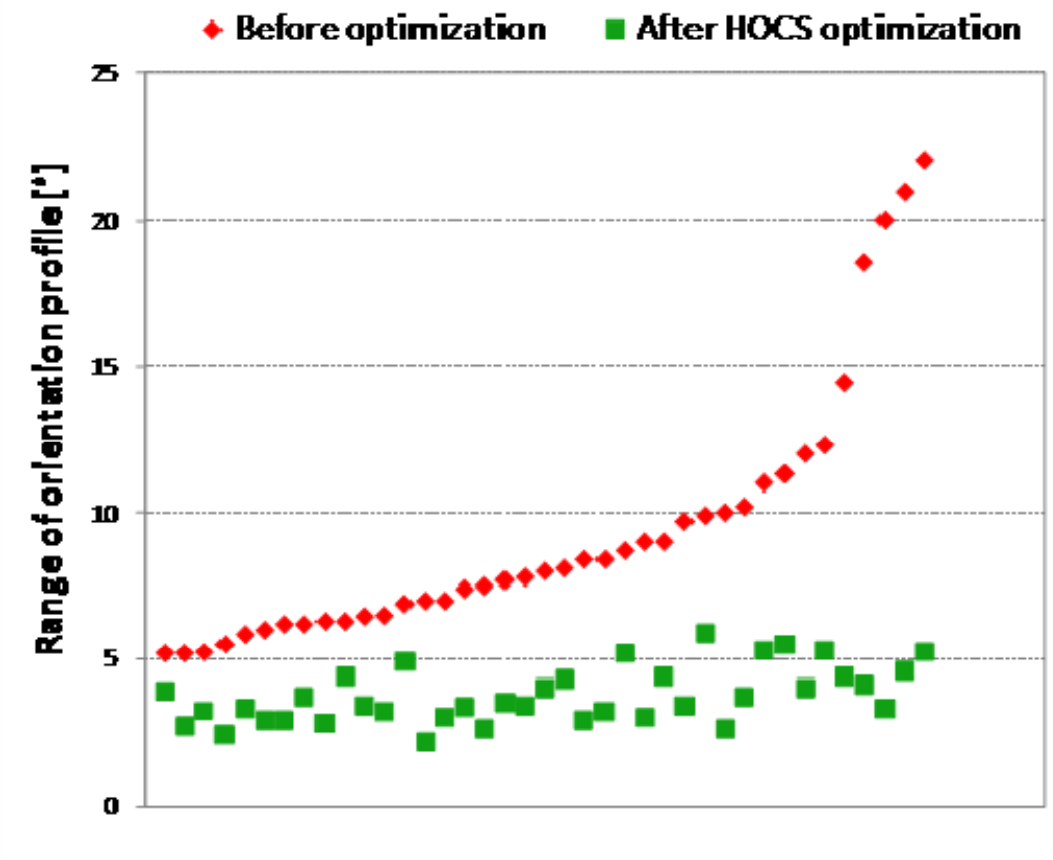
- ***Max-Min orientation range = 20 degrees before optimization***

HOC Software
Mill example B



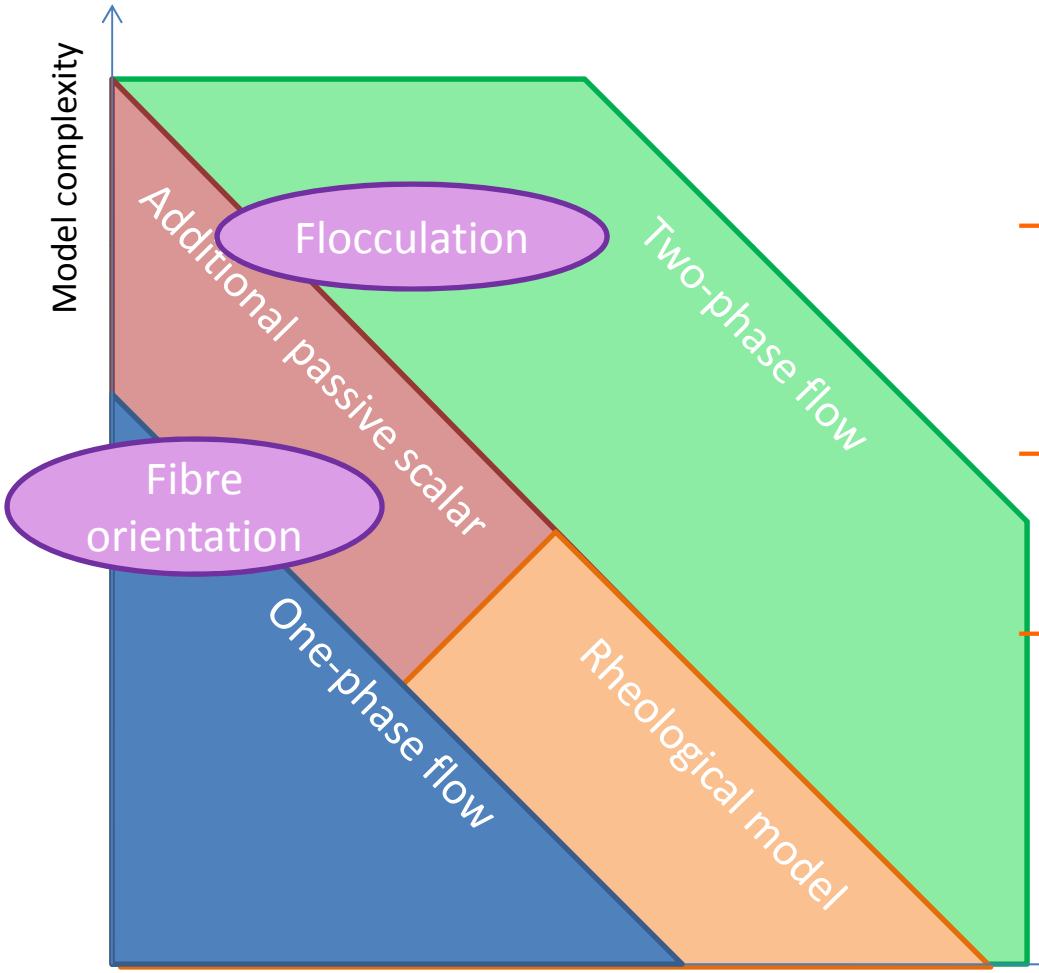
More than 50 paper machine headboxes optimized so far

Open your mind. LUT.
Lappeenranta University of Technology



Avikainen, Hämäläinen, Tarvainen (2010), NPPRJ, 25(4)

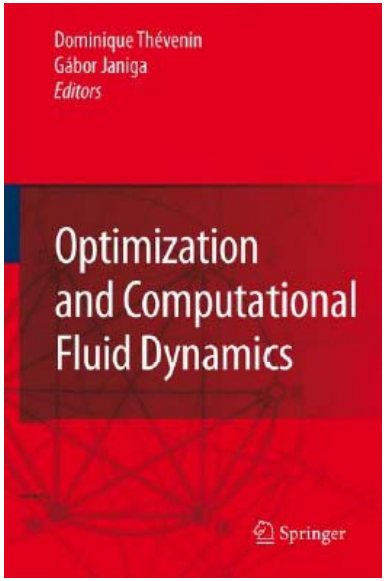
Conclusion: *Different Modelling Approaches for Different Purposes*



- One-phase model (pure water)
  - Meter-scale phenomena in headbox
  - Routine CFD analyses
- Rheological model (effective medium)
  - Head losses in pipes, stock preparation processes, MC,..
  - No large concentration variations
- Passive scalar (one-way coupling)
  - Dilute suspensions
  - Fibre orientation probability distr.
- Two-phase flow (two-way coupling)
  - Carrying phase (water) and dispersed phase (fibres or flocs) handled separately
  - Concentration variations, slip velocity between the phases,...

References and Acknowledgements

- Fibre Orientation Probability Distribution (FOPD) modelling
  - Doctoral theses by T. Hämäläinen (2008) and H. Niskanen (2011)
  - Niskanen et al., IJMF (2011)
  - Hämäläinen et al., J.Eng.Math. (2011)
  - Niskanen, Hämäläinen, NPPRJ (in press)
  - Other authors from KTH, UBC, etc.
- CFD-based Optimization
  - Hämäläinen et al. in “Optimization and Computational Fluid Dynamics”, Thevenin, Janiga (2008)
  - Avikainen et al., NPPRJ (2010)



- Acknowledgements
  - CFD-based optimization software tools have been developed since 1995 at University of Jyväskylä, VTT, Metso (Valmet) and Numerola
  - Thanks to Paper Physics Group at University of Eastern Finland, Kuopio for the results of FOPD modelling in 2004-2011