Application of Computational Fluid Dynamics
in the development and optimization of stock preparation equipment

ANDRITZ
Pulp & Paper

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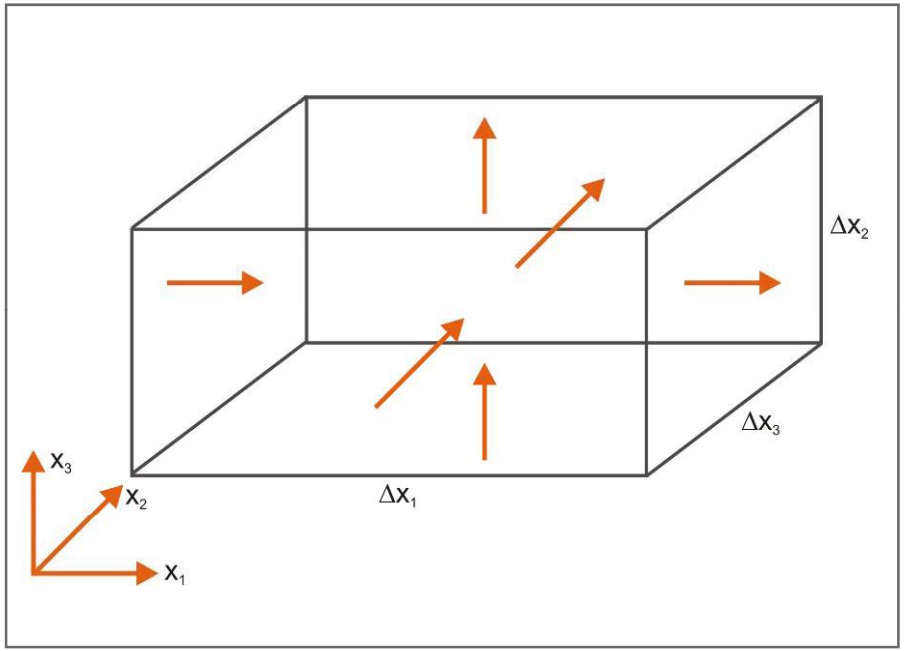
RETHINK PAPER:
Lean and Green

Content

- Theoretical background
- Simulation of pulper
- Simulation of disperser
- General guide lines

Theoretical Background

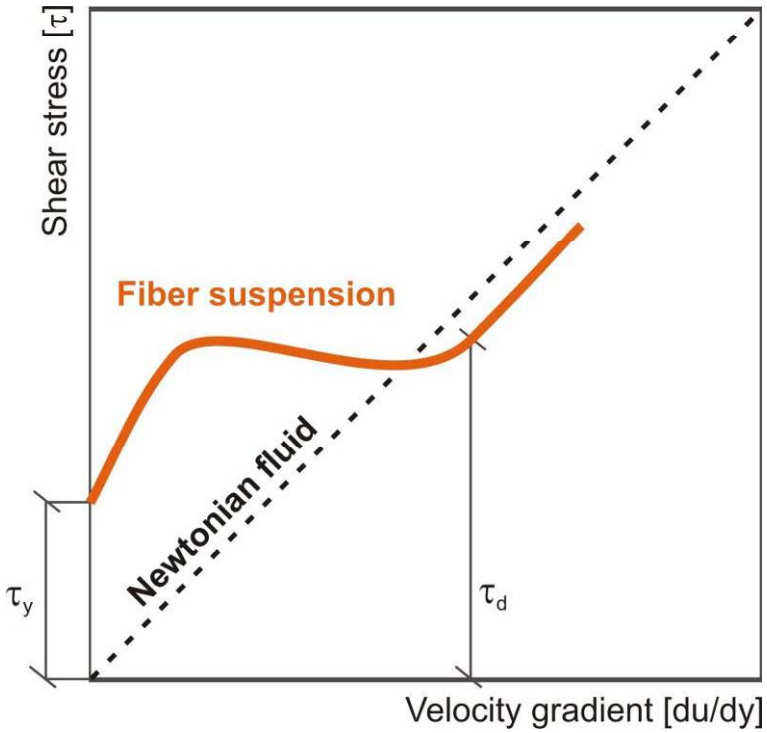
- Conservation of mass and momentum in a rectangular volume
- Computational domain is filled with several hundred thousands of such cells



Non Newtonian Behavior of Pulp Suspension

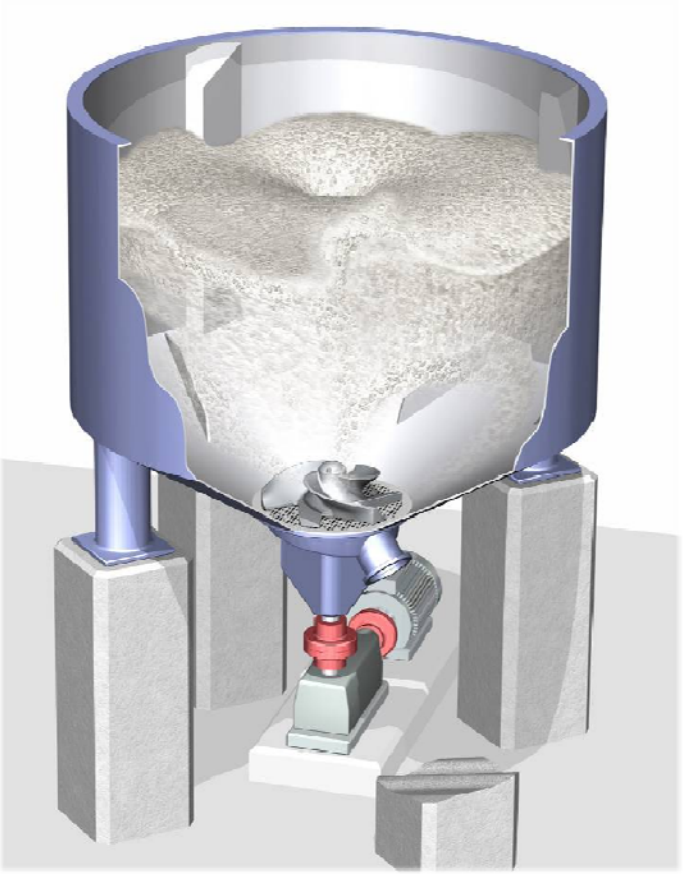
- Newtonian fluid:
  a liner relationship between the shear stress and the velocity gradient

- Pulp suspension:
  - high viscosity at low velocity gradients
  - significant drop at higher shear rates
  - consistency and fiber length have big influence



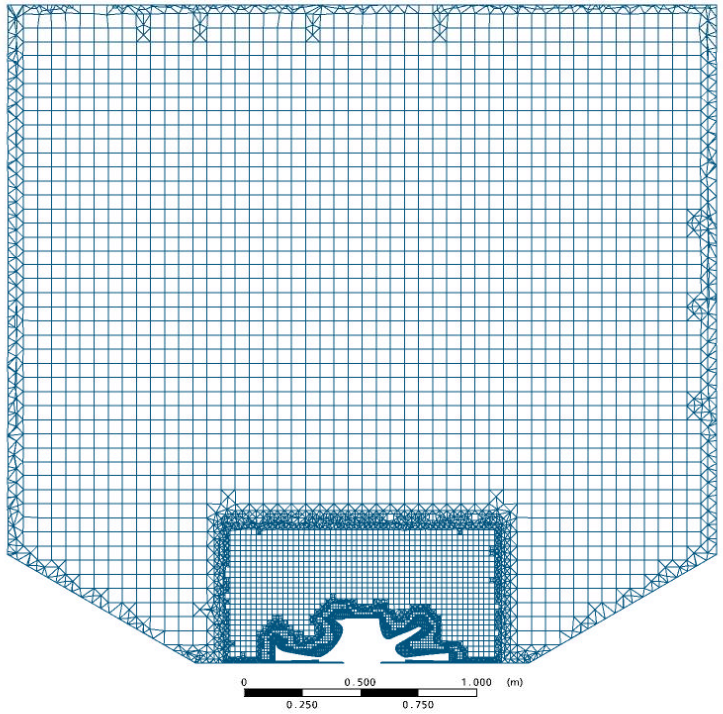
Vertical Pulper

- Free surface
- Flow is influenced by
  - Type of pulp
  - Consistency
  - Type of rotor
  - Rotor speed
  - Design of vat
  - etc.
- Measurements inside pulper are difficult, especially next to rotor



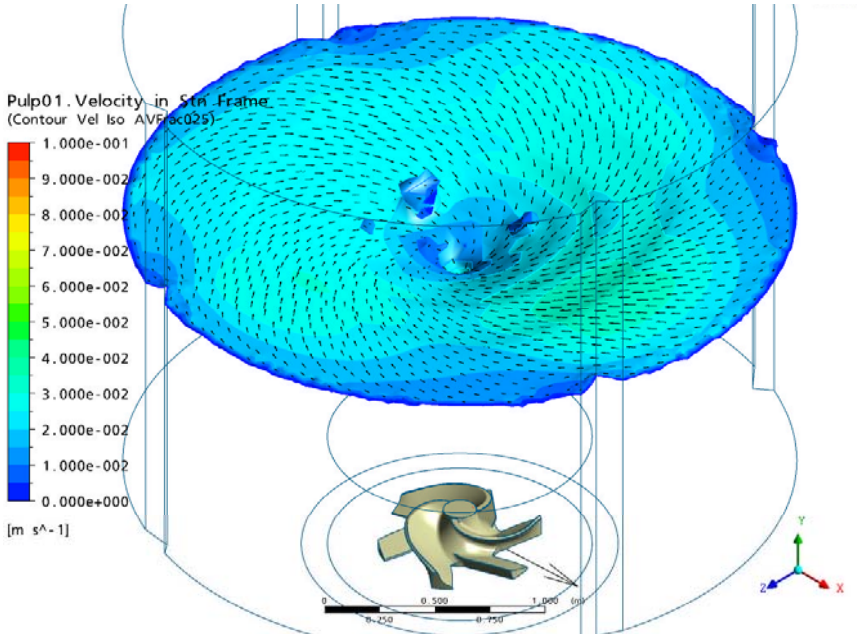
Simulation of Pulper

- 3-D grid
- k-ε Model
- Volume of fluid model (VOF)
- Constant consistency
- Steady state solution



Simulation of Pulper

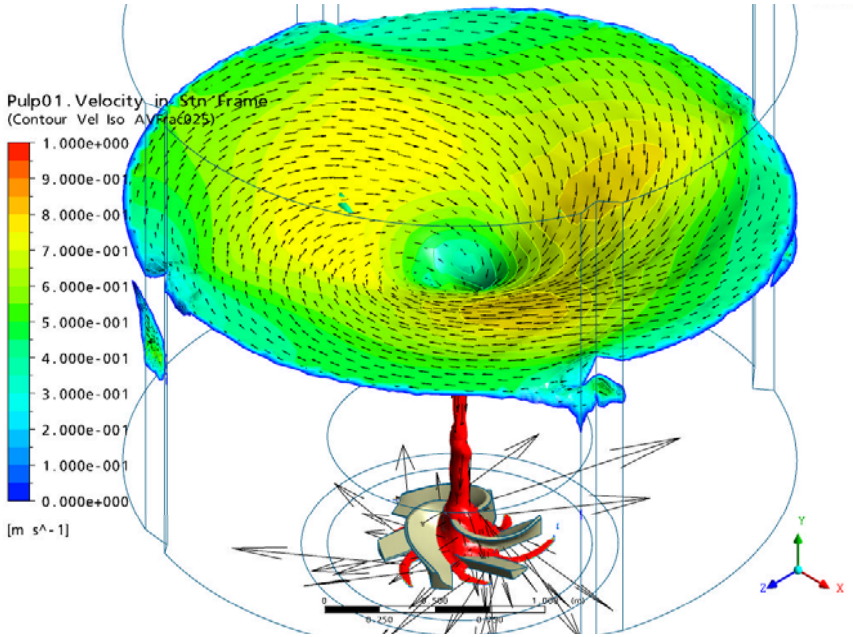
- Surface of pulp suspension is defined by cells with equal air to fluid ratio (25%)
- Velocity and shape of this surface are compared to pilot plant results to verify CFD simulation
- Figure beside is at standard rotor speed



Rotor Velocity
Influence on Surface Shape and Speed

Increasing speed of rotor:

- Change in shape of surface
- Increased speed of surface
- Air is pulled towards the rotor→ decreased efficiency

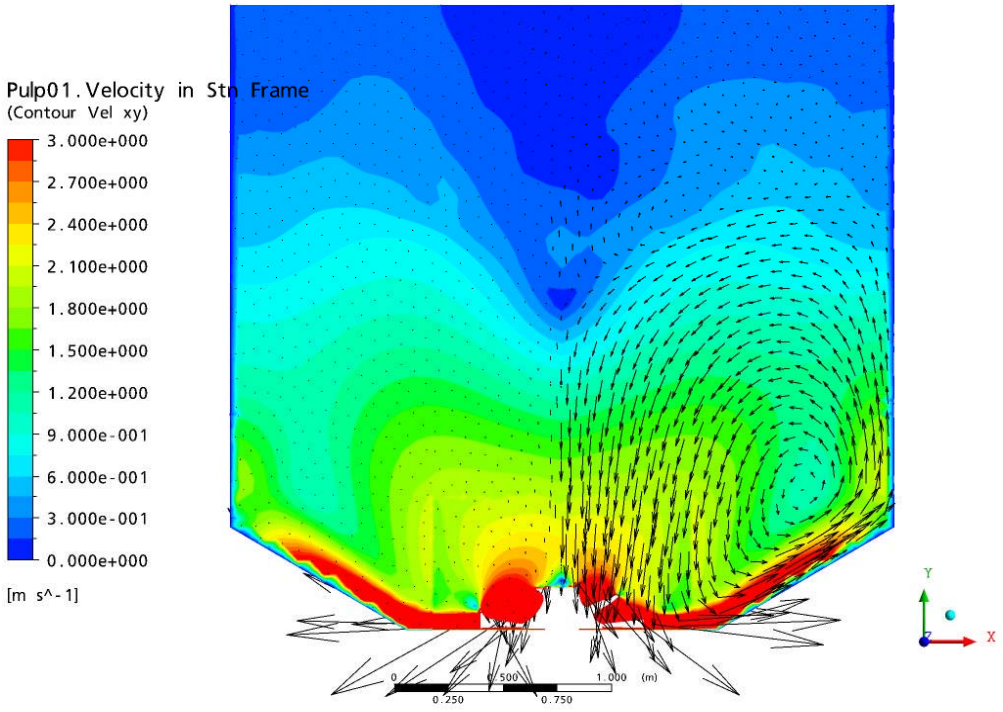


Velocity
in a Vertical Plane Through the Rotor

Planes at different locations give insight into pulper flow:

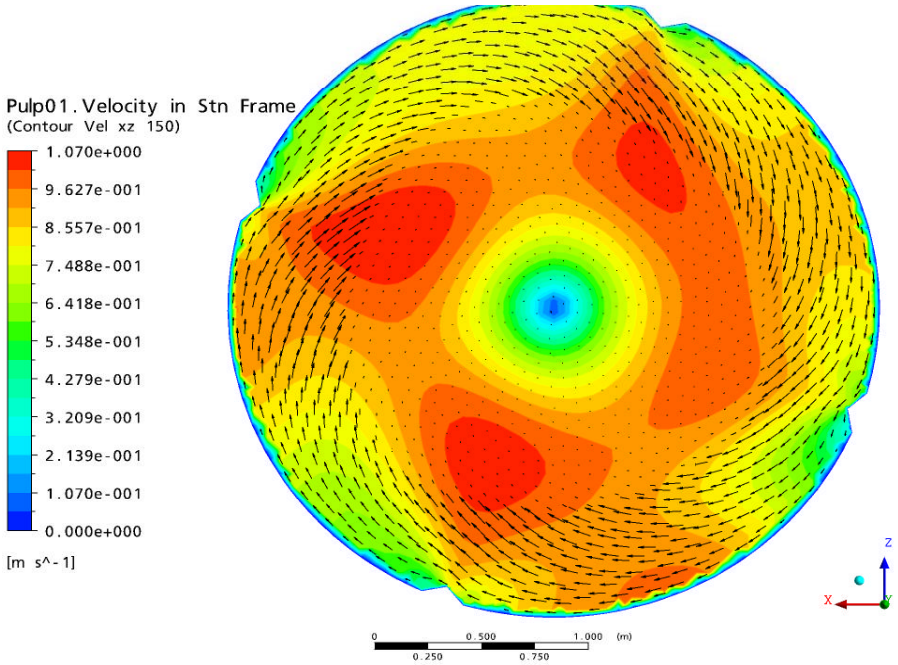
- Velocity distribution next to rotor
- Location of swirl center

Note: Air and pulp phases cannot be distinguished in this picture

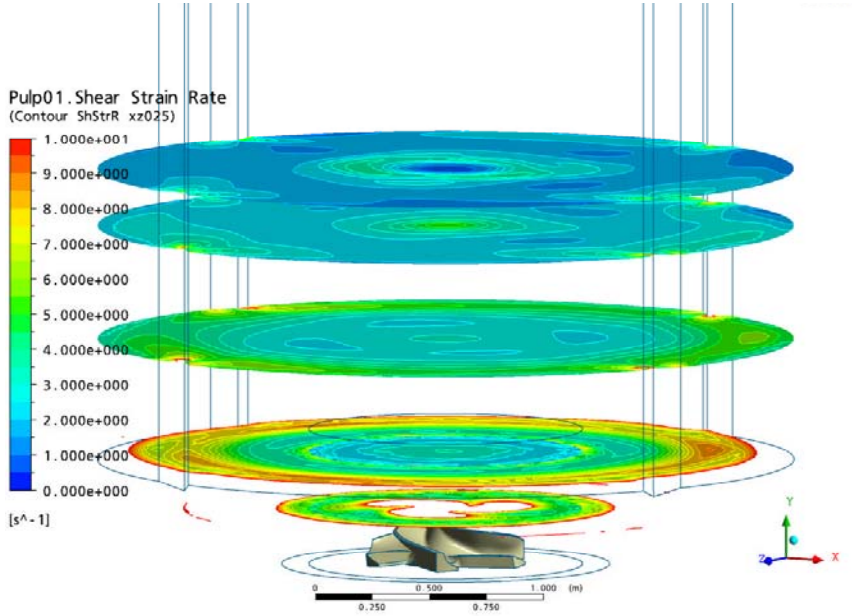


Velocity
in a Horizontal Plane 1.5 m Above the Rotor

- Hot spots in plane above rotor are influenced by vat design
- No dead zones behind triangle guiding vanes



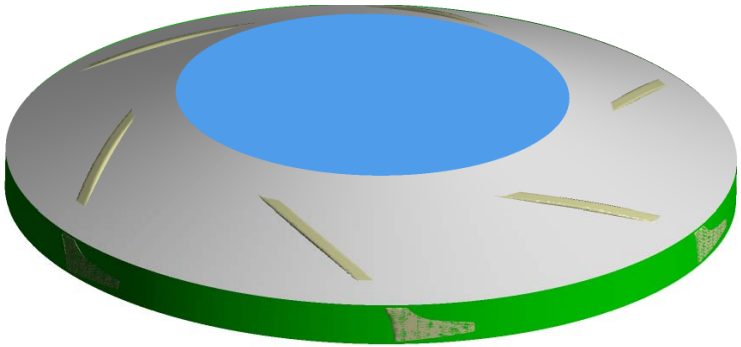
Shear Strain Inside the Pulper Vat



Pulping is most efficiently done by shear force, therefore volume with sufficient shear force can be maximized by rotor and vat design.

Control Surfaces Around the Rotor

Blue zone: inflow area
Gray zone: intensive mixing
Green zone: outflow area

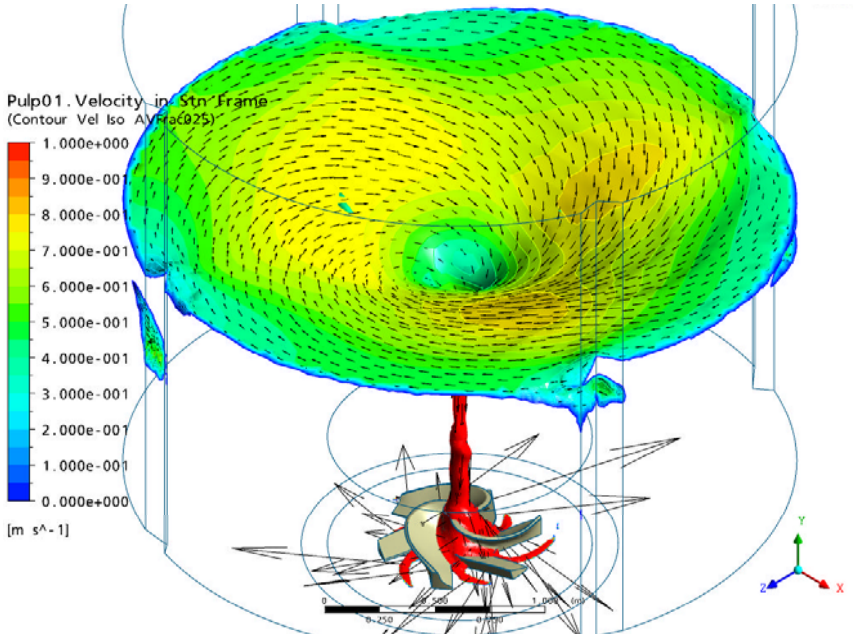


Pumping curves and efficiency calculation

Very helpful for rotor comparison and fine tuning

Influence of Pulp Consistency on Surface Shape and Speed

- In pulper simulation, consistency has significant influence on result
- Picture with high rotor speed and standard consistency

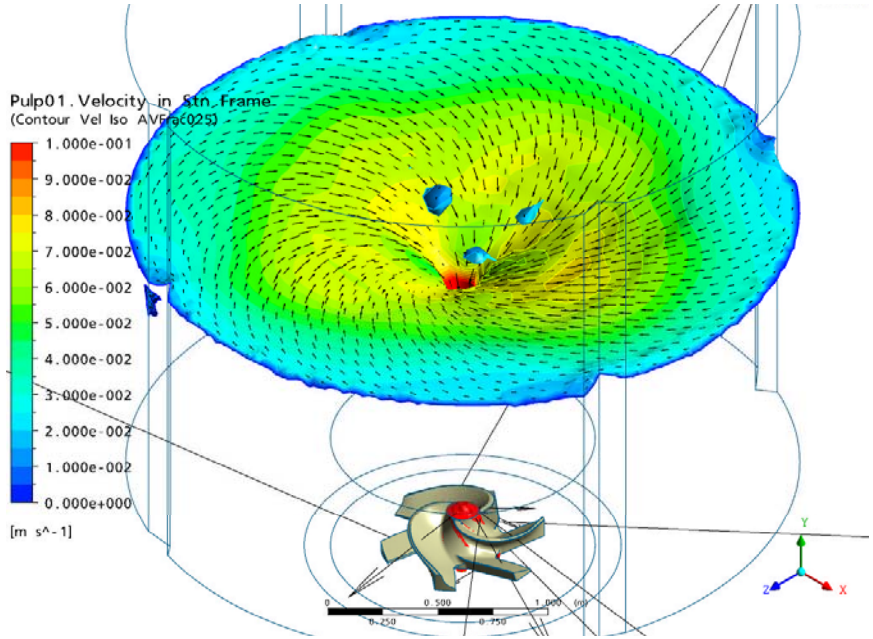


Influence of Pulp Consistency on Surface Shape and Speed

- Addition of virtual pulp bales increase consistency:
  - Surface velocity decrease
  - Surface shapes flattens
  - Significant less air around rotor

→ Pulping efficiency increases

Maximum consistency has to be found



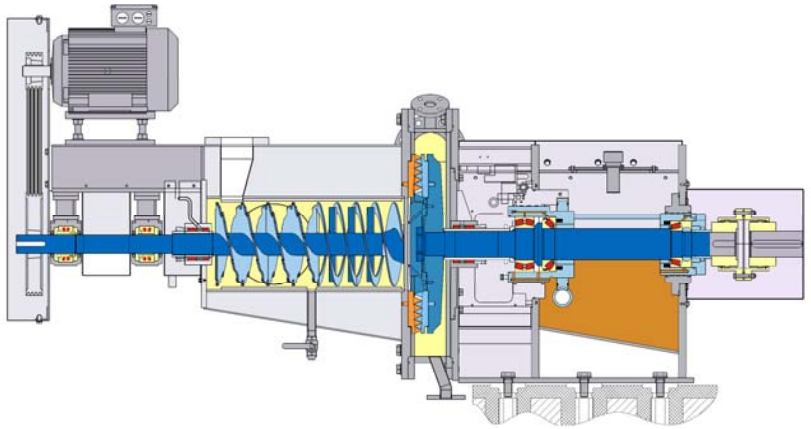
Summary of Pulper Simulation

- Model set up and compared to pilot plant results
- Design of rotor and vat can be optimized by velocity and shear strain
- Control surfaces allow definition of additional parameters like pumping curves
- Pulp consistency has significant influence on efficiency and can be optimized

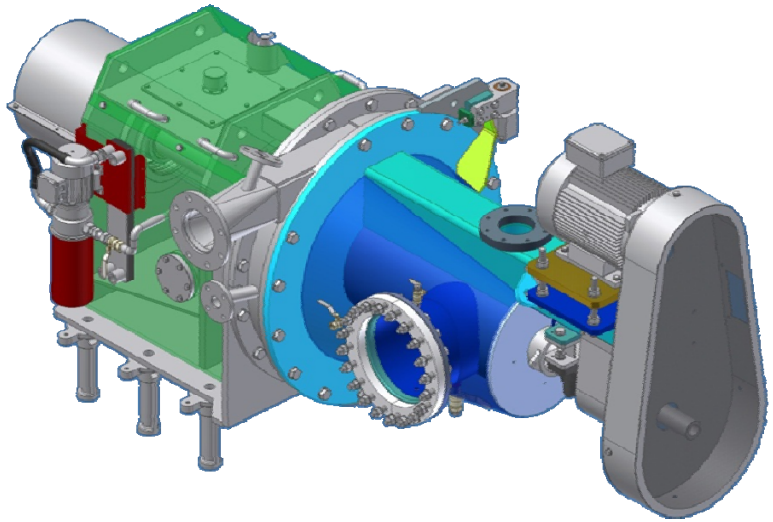
Disperser with LC discharge

Used in recycling application for disintegration of dirt and stickies

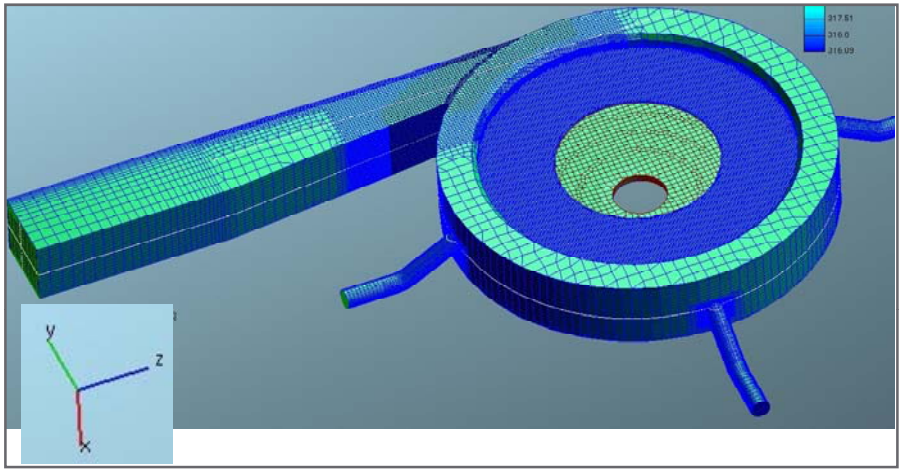
In some applications water is added after dispersing zone for dilution



- Water addition without influence on dispersing result
- Maximize consistency
- Stable operation



Disperser with LC discharge

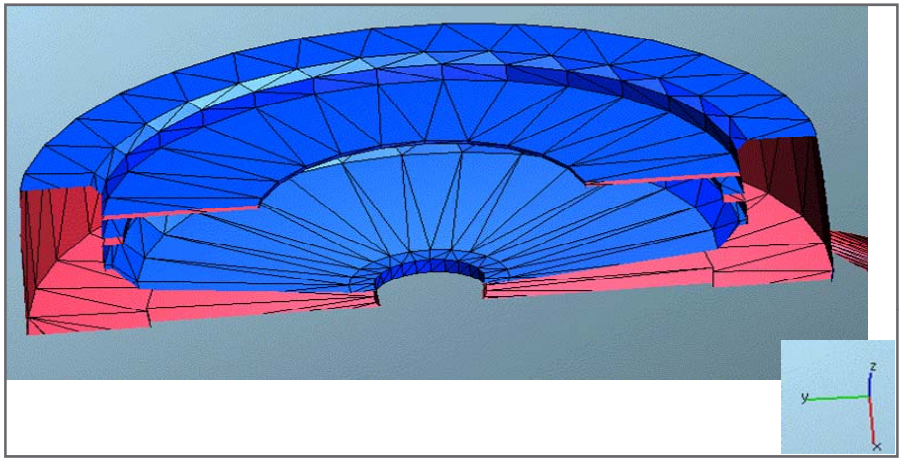


Challenges for simulation

- High speed in rotor
- Tooth design of rotor
- Consistency from 30% to 0% (dilution water)
- Heating with steam

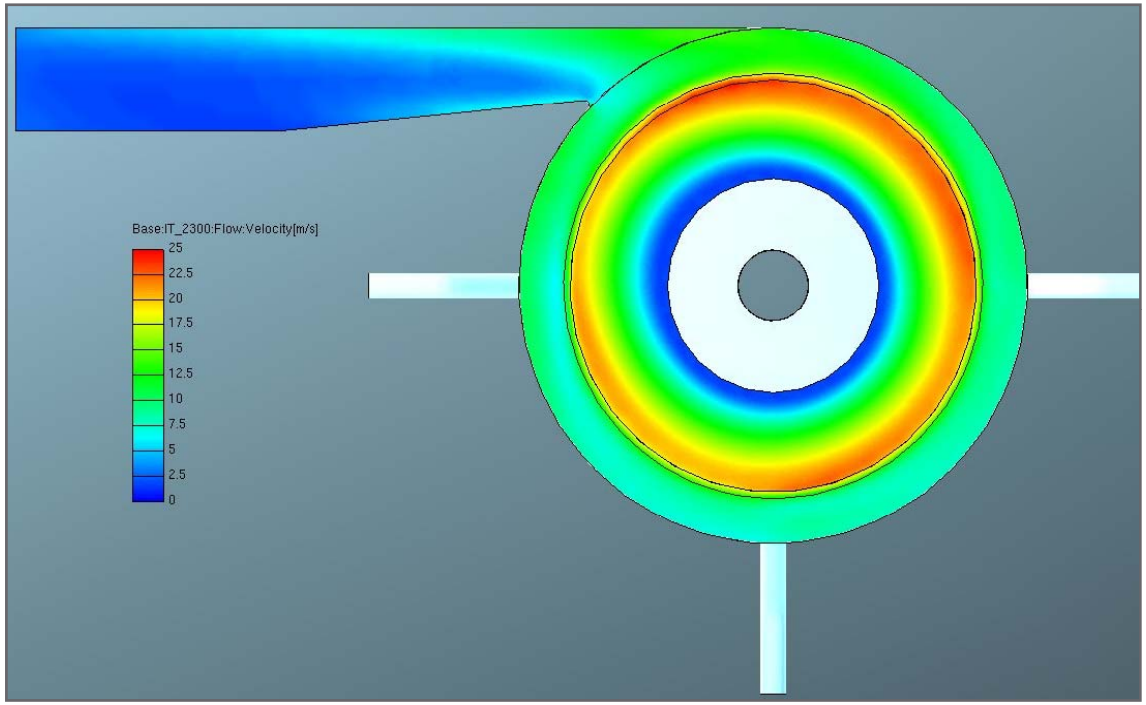
Grid of the Disperser Housing

- Just outlet zone was simulated
- Gap approximated by flat discs



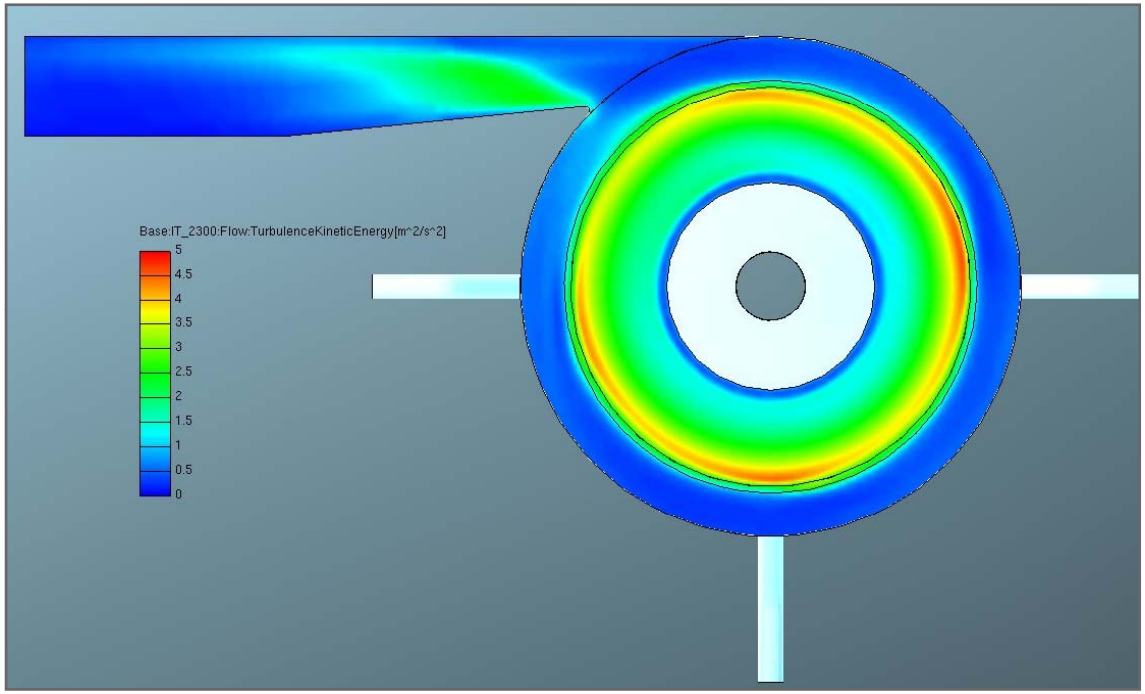
- k-ε Model
- Case 1: single phase with scalar marking of the pulp
- Case 2: Euler-Euler two phase model with variant consistency
- Steady state solution

Velocity
in the Plane of the Disperser Gap



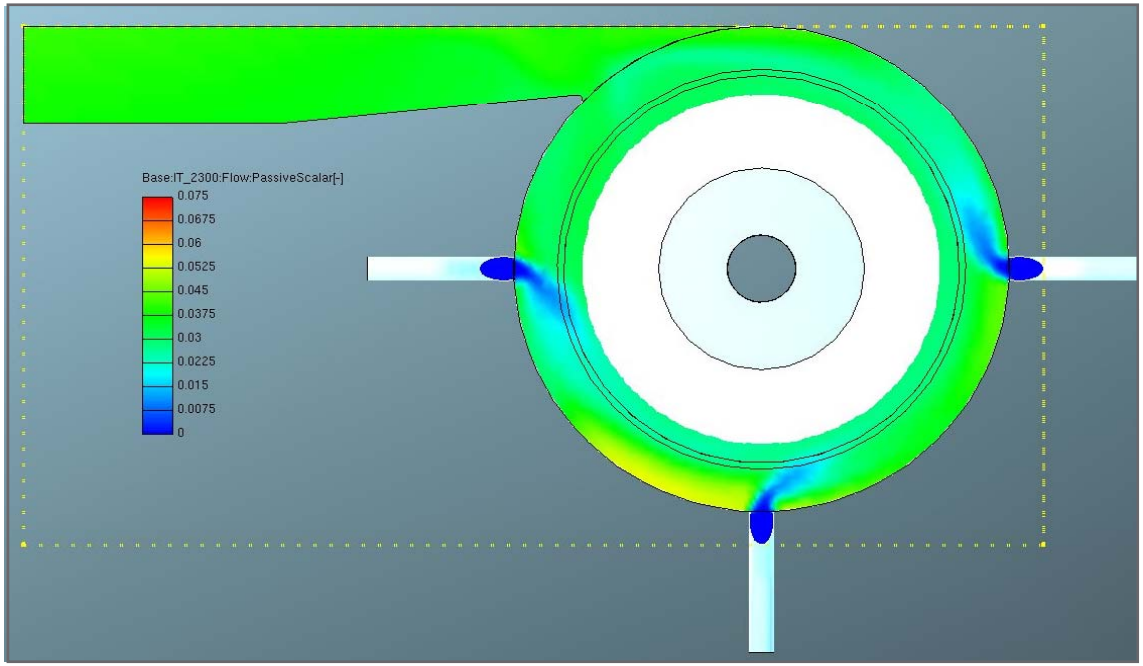
- High speed in dispersing gap
- About half speed in housing
- No influence of water addition

TKE
in the Plane of the Disperser Gap



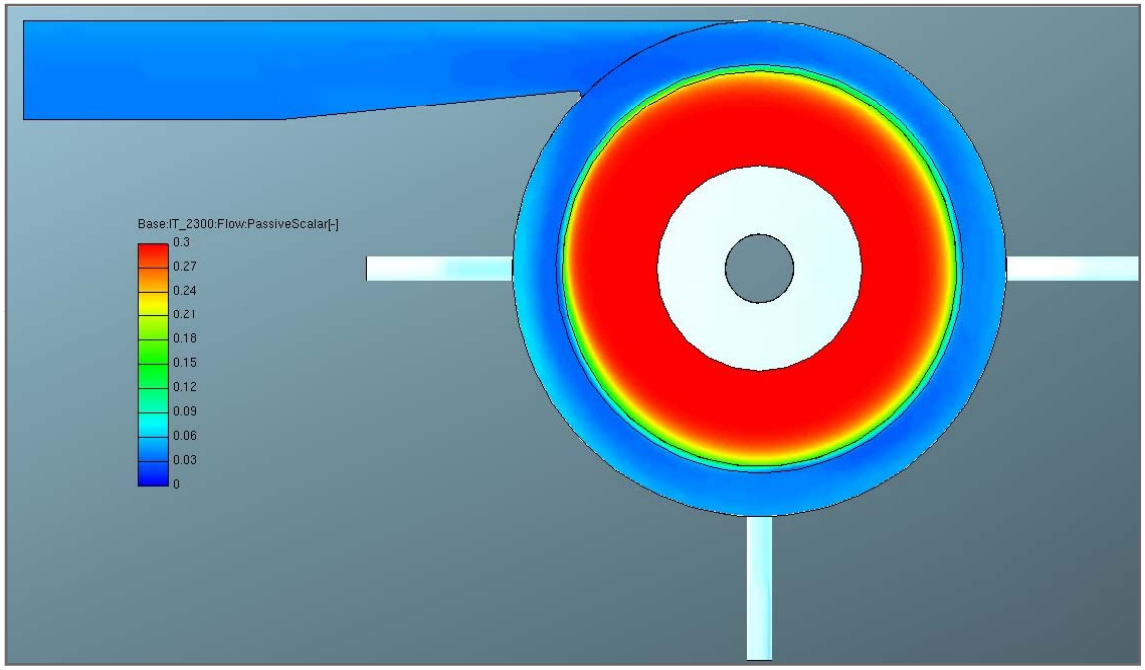
- High turbulent kinetic energy close to disperser gap
- Second mixing zone at beginning of outlet pipe

Mass Fraction of Pulp in the Plane of the Water Inlets



- Dilution water is accelerated in rotation direction
- Mixing of dilution water and pulp needs about 90°

Mass Fraction of Pulp in the Plane of the Disperser Gap

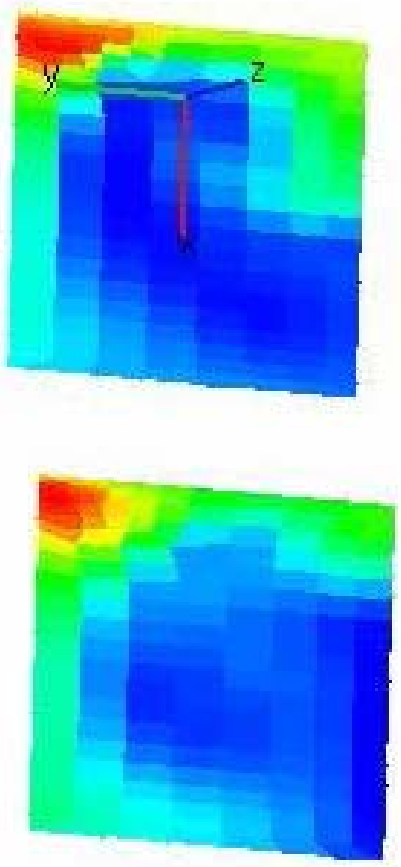


- No influence of water addition on mass fraction in disperser gap
- Very fast homogenization in ring area

Comparison of Consistency Variations in the Outlet Pipe

- Case 1 (upper figure):
  single phase with scalar marking of the pulp

- Case 2 (lower figure):
  Euler-Euler two phase model with variant consistency



Minor differences between the pretty simple upper and the numerical complex lower

→ Just starting and final geometry had to be calculated with the much more complex model

Summary of Disperser Simulation

- Not total disperser but just region of interest simulated
- Geometrical model simplified to keep computational effort reasonable
- During optimization of design simple consistency and 2-phase model could be used
- Consistency of pulp has no influence as shear forces are extremely high

Guidelines – Basic Questions

- What additional information should be obtained by CFD?
- Is it needed to simulate the whole machine or just certain area of interest?
- How much simplification is possible without disturbing the results?
- Do we have models to simulate the process fully?
- How to compare the calculated results to experimental data to validate the approach?

Building Leadership Excellence

Thank you for your attention.

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