

Optimization of a flocculation-sedimentation treatment plant with lamellas (FLUENT)



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Zweckverband
Landeswasser-
versorgung

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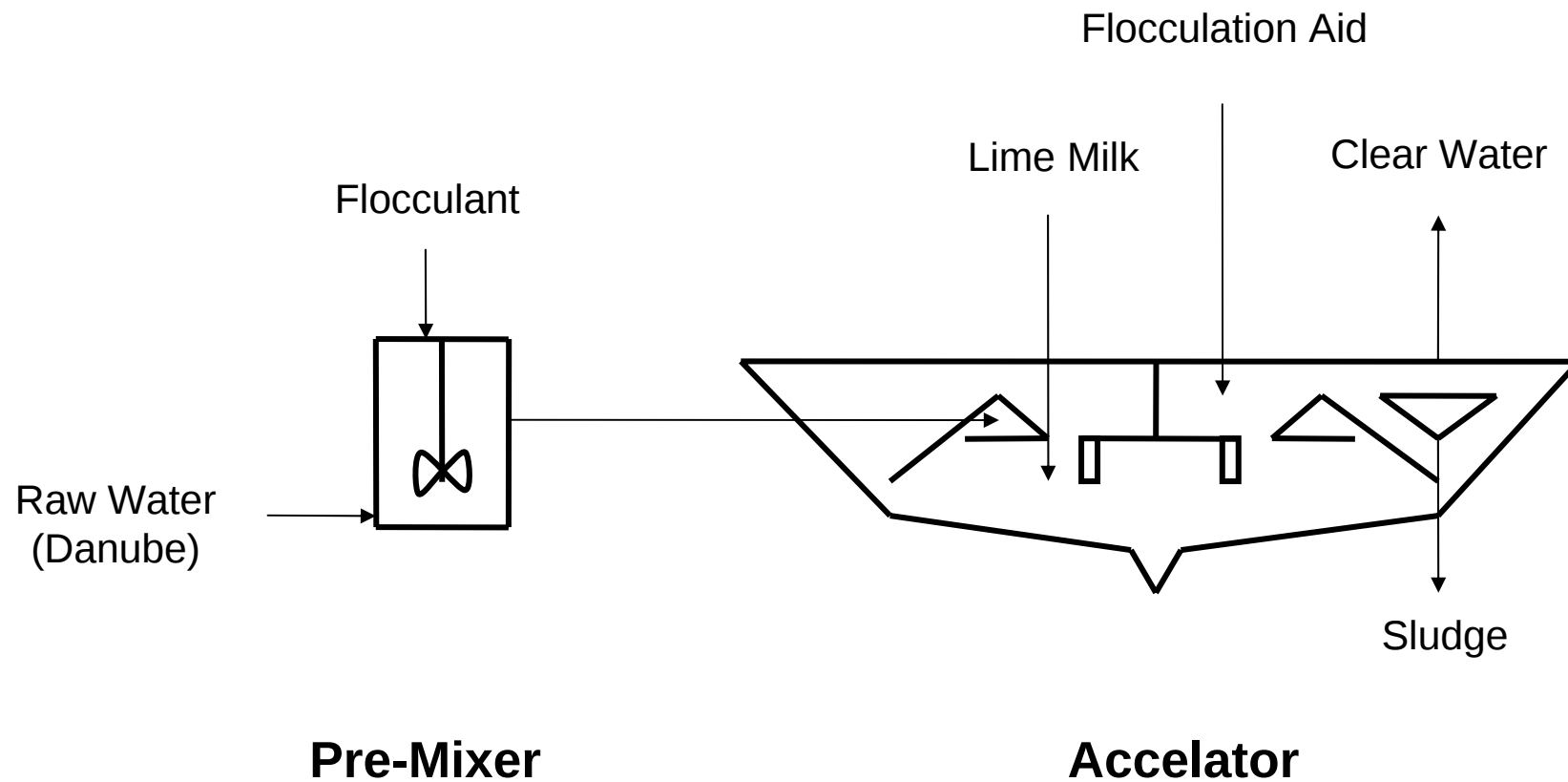


Background Information

- The Zweckverband Landeswasserversorgung provides drinking water for the north-east of Baden-Württemberg and parts of Stuttgart
- Water delivery 90 Mio m³/a
- Within the water treatment plant of Langenau raw water from the river Danube is purified



Flow diagram of the flocculation-sedimentation



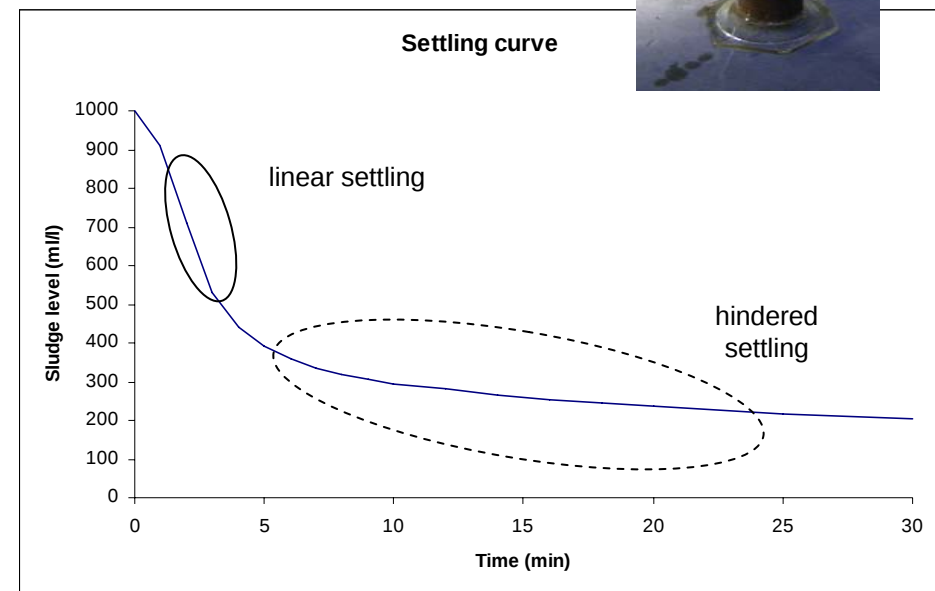
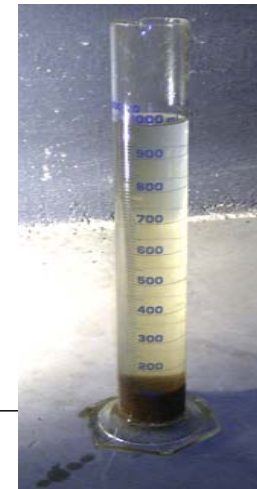
Overview

- Capacity 400 to 800 l/s
- Diameter Accelerator: 36 m
- Height Accelerator: 9,5 m

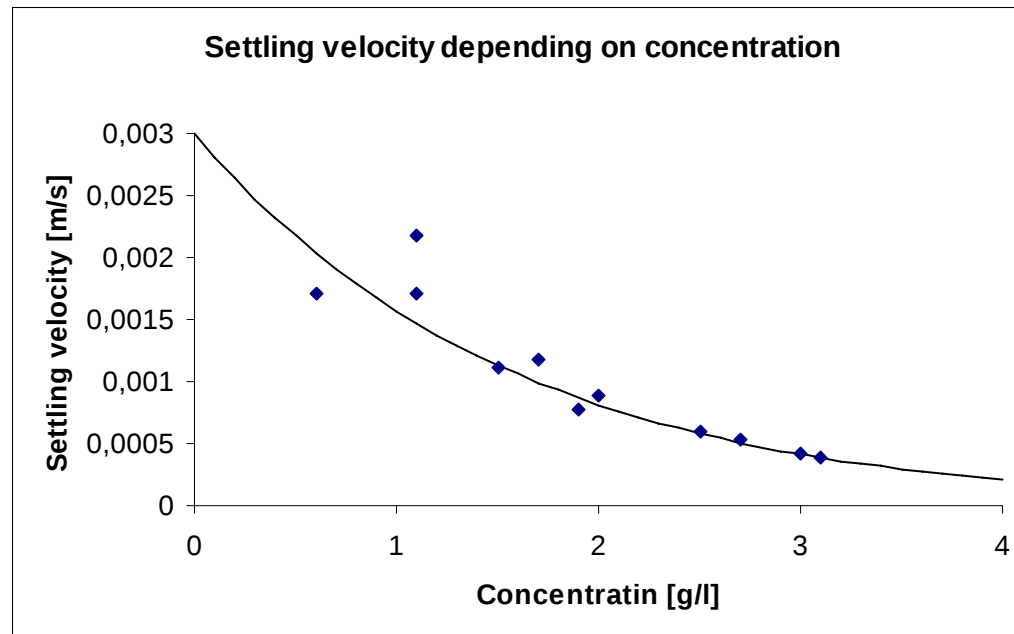


Measuring the settling velocity

- During the settling test the sludge level is measured over the time
- Within the first minutes linear settling takes place
- Thereafter hindered settling takes place
- Within the phase of linear settling the concentration and settling velocity is constant → settling velocity for a certain concentration
- Relatively easy to measure (standard test DIN 38 414)
- Height of the sludge level after 30 Minutes is called sludge volume (important parameter in waste water treatment plants)

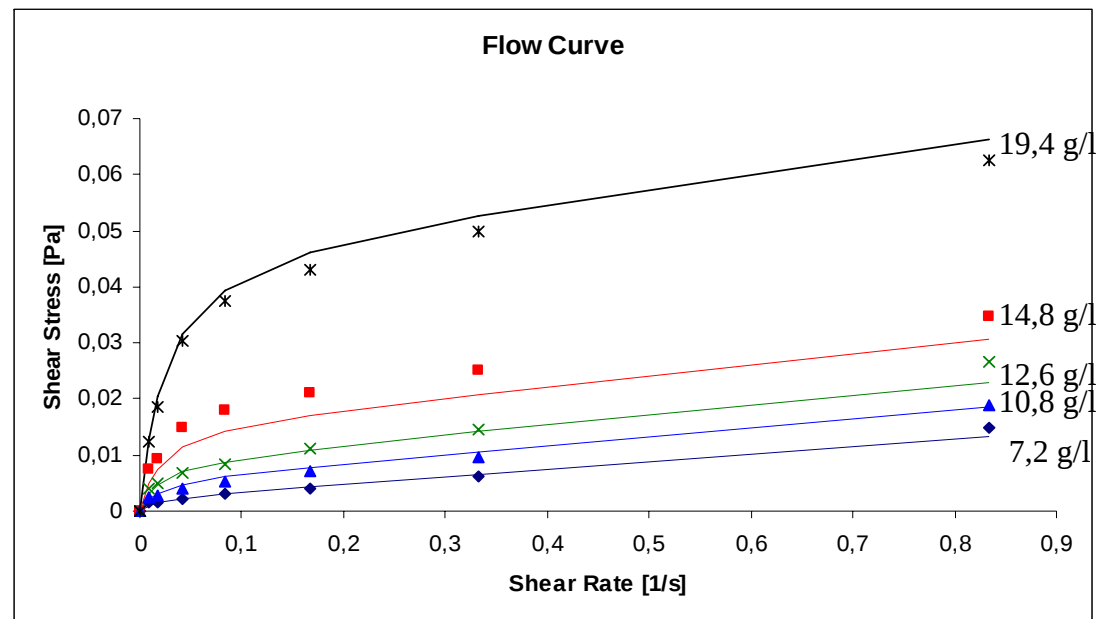


Settling velocity depending on concentration



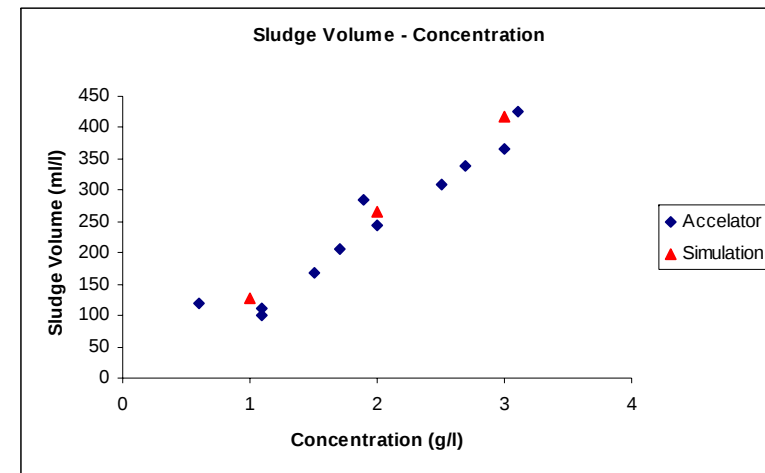
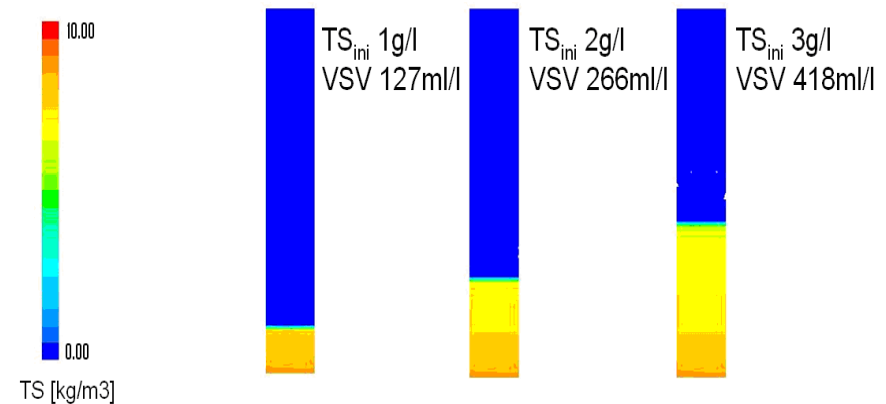
Rheology

- Non Newton fluid
- Shear thinning
- Viscosity depending on concentration



Validation of sludge modell

- The settling test was simulated with FLUENT
- The results were compared with the measurements
- Simulation and measurements fit quite well according to sludge volume



The sludge model

- Sludge is modeled with a „user defined scalar“ (uds) and contains of following components:

Convection

Settling velocity depends on concentration

Diffusion

Turbulent diffusion depends on density gradients („full buoyancy effect“)

Viscosity

Viscosity depends on concentration and shear rate

Density

Density depends on concentration

The sludge model

- Components which will be developed in further research projects:

Convection

Settling velocity, regarding low concentrations

Viscosity

Viscosity of low concentrated sludge,
Yield stress,
Time dependent viscosity

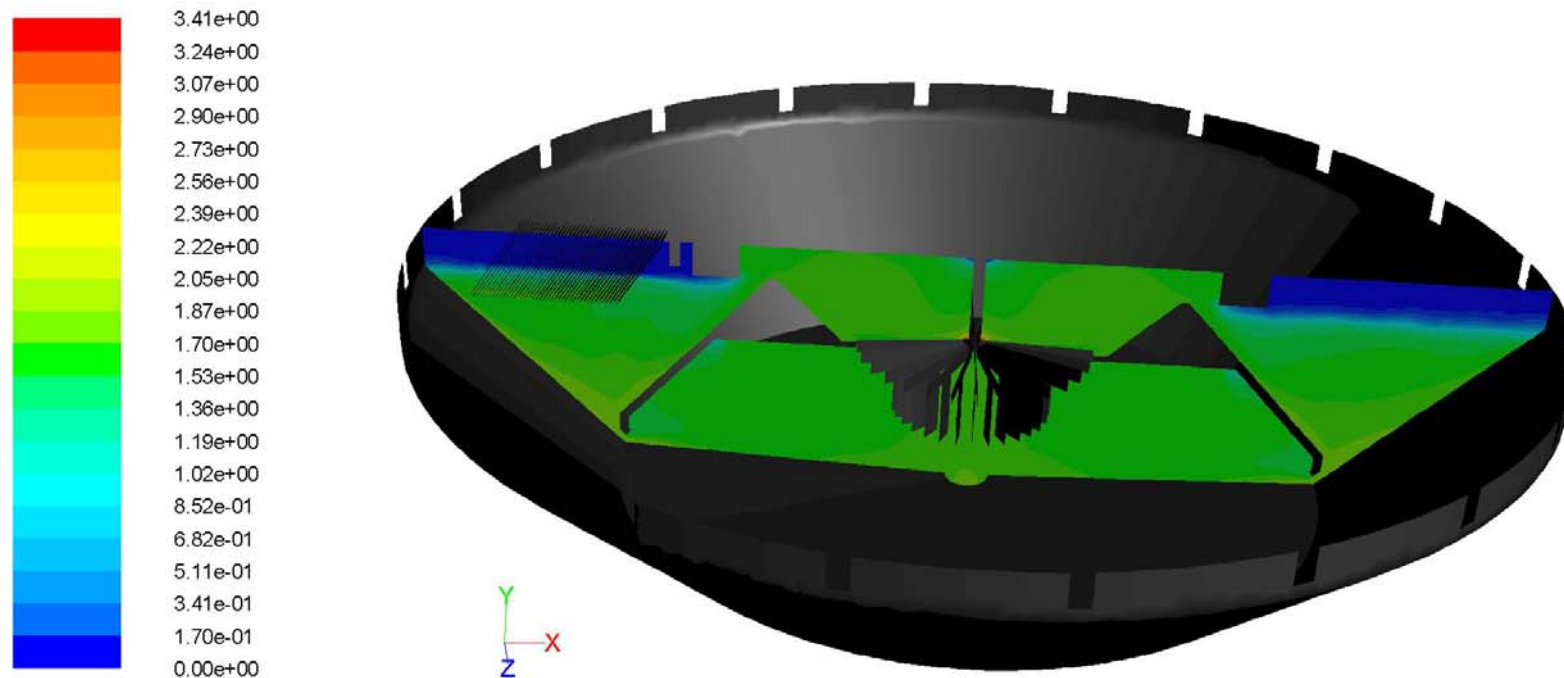
Parameter Identification

Mathematical Optimization of model parameters

Multiphase or Singlephase?

- Even though the sludge model is a singlephase approach it interacts intensively with the flow regime
 - Advantage: no particle size of flocs required to determine the settling velocity
 - Modelling of sludge with multiphase approaches also possible, but require complex models to describe the variation and distribution of particle sizes
 - Singlephase approach requires less computational efforts
 - To model the sedimentation process a relatively long flow time is required. Example for this case: 12 cores, 8 Mio cells, 3.600 seconds flow time, ~30.000 iterations à 20 seconds/iter → 1 week per calculation
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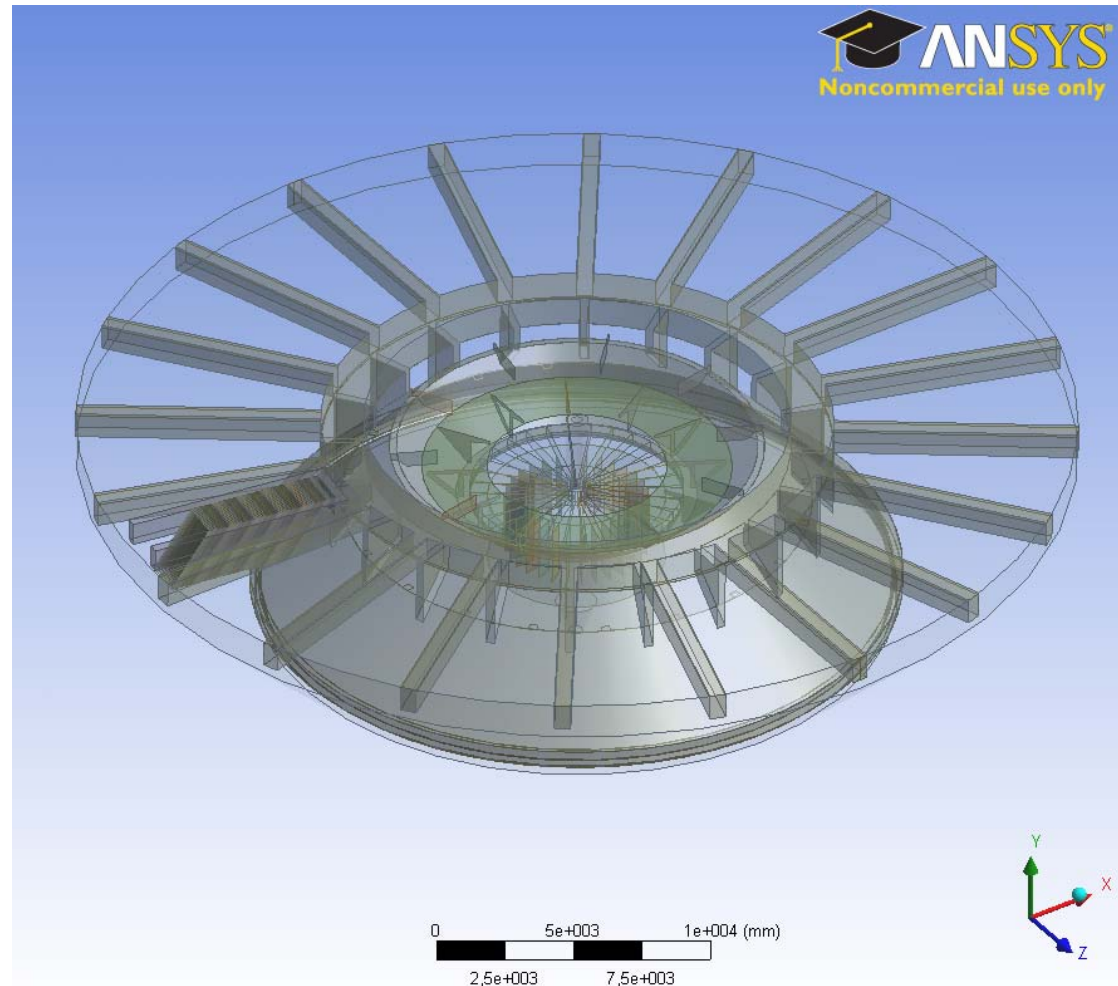
4 Variations of lamella clarifier: different slope and distance between lamellas (5 or 10cm)



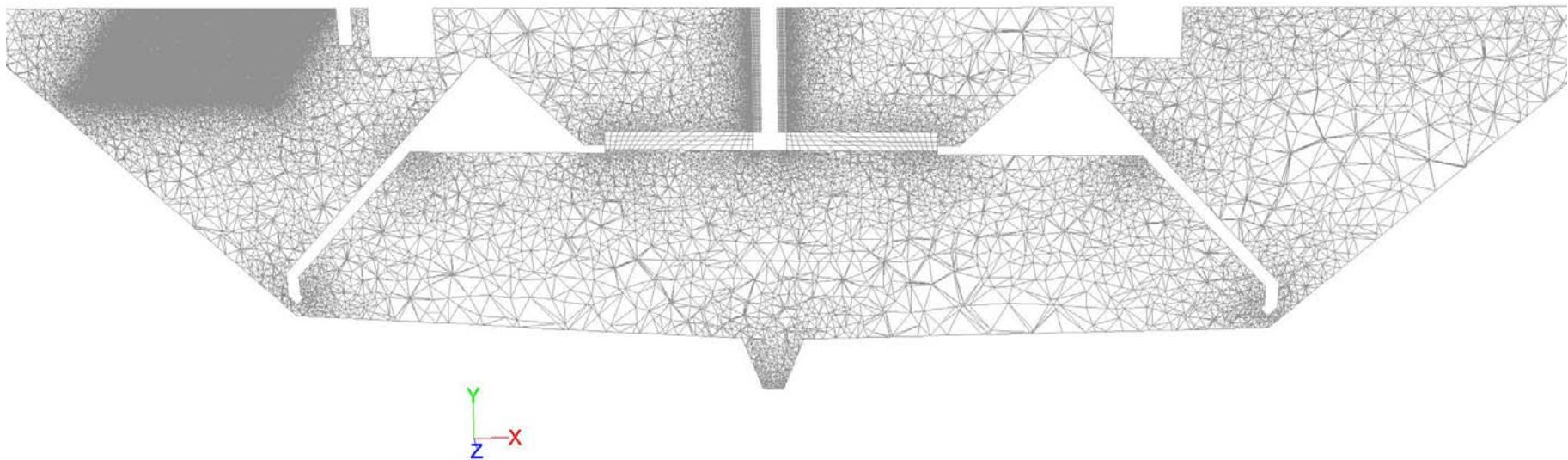
Contours of Scalar-0 (Time=3.6005e+03)

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ANSYS FLUENT 12.1 (3d, pbns, ske, transient)

Geometry



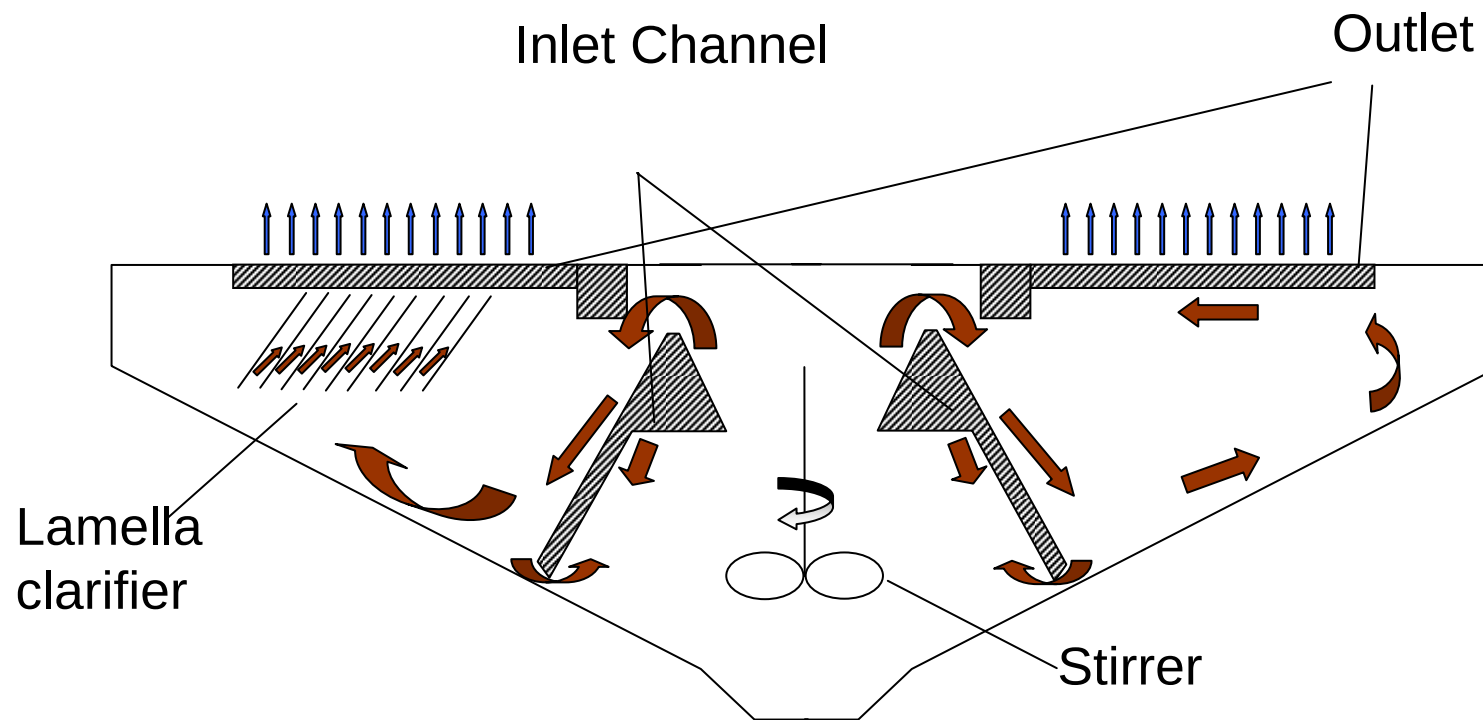
Grid: between 6 and 13 Mio cells



Mesh (Time=3.6005e+03)

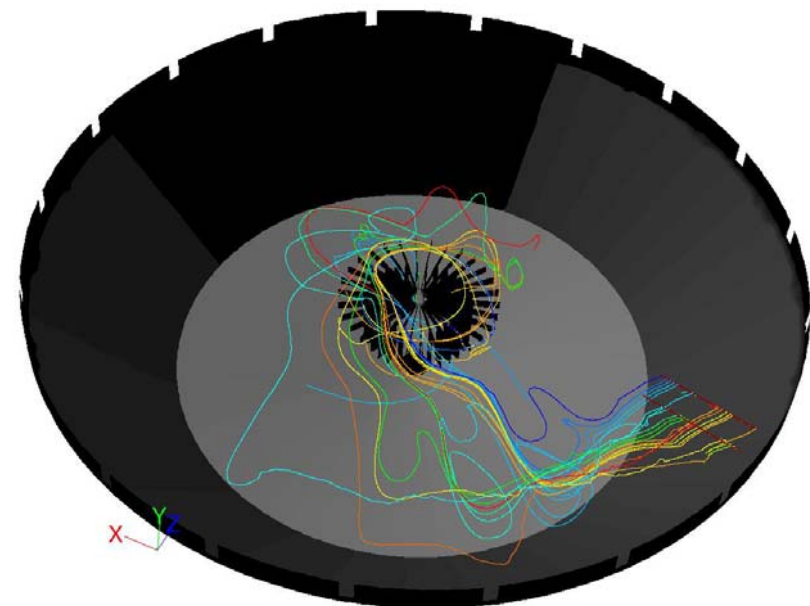
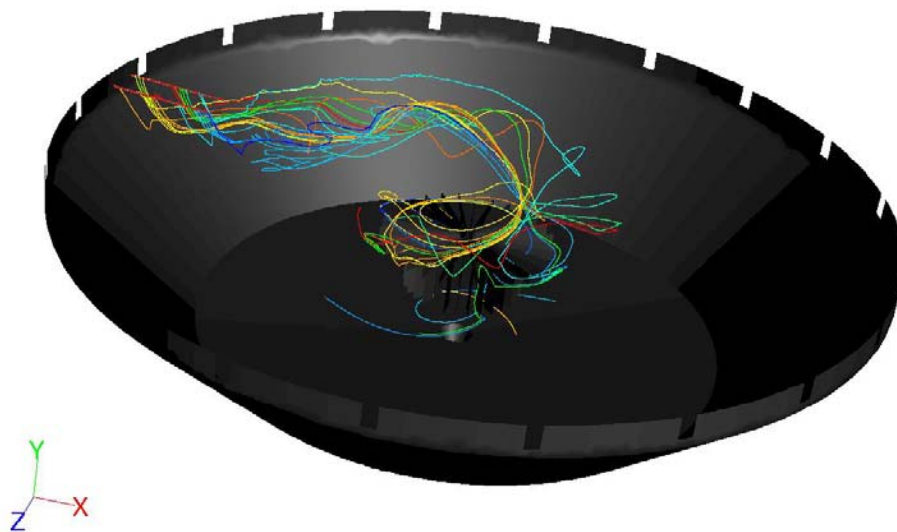
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Scheme

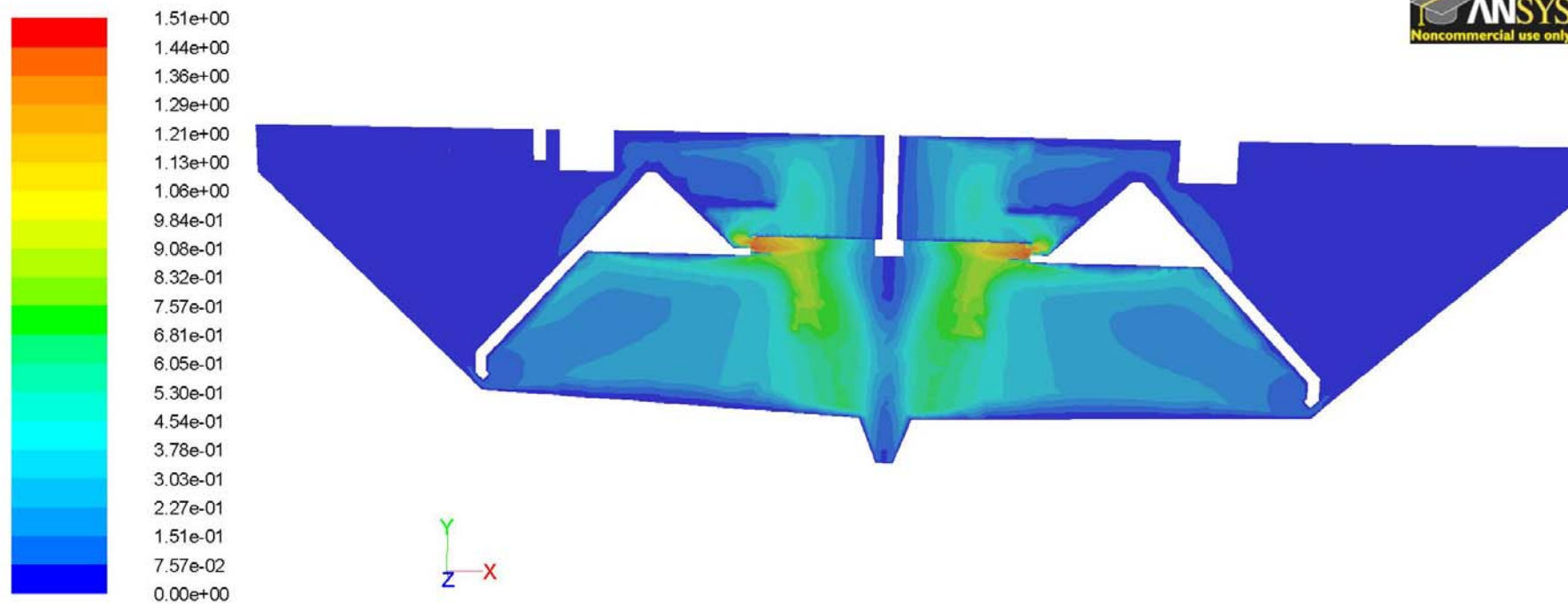


(C) by Dr.-Ing. Alexander Sonnenburg

Pathlines



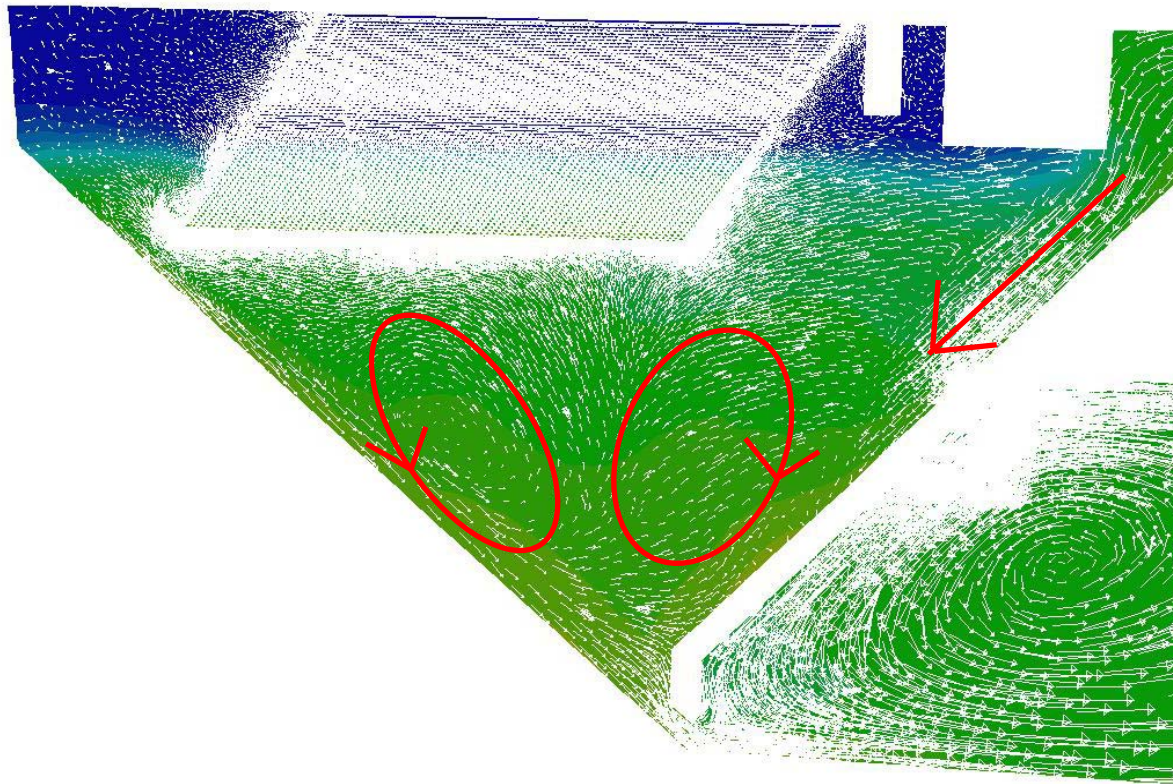
Velocity



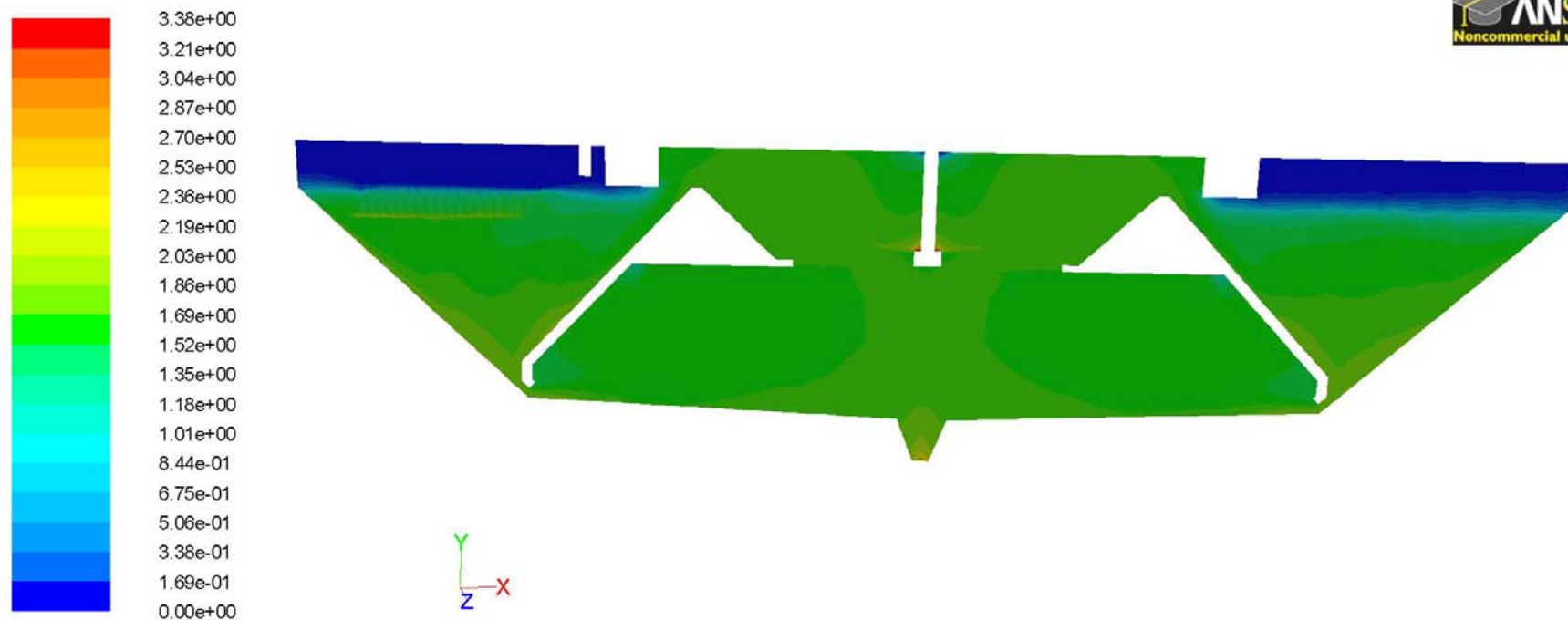
Contours of Velocity Magnitude (m/s) (Time=3.6005e+03)

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Flow regime



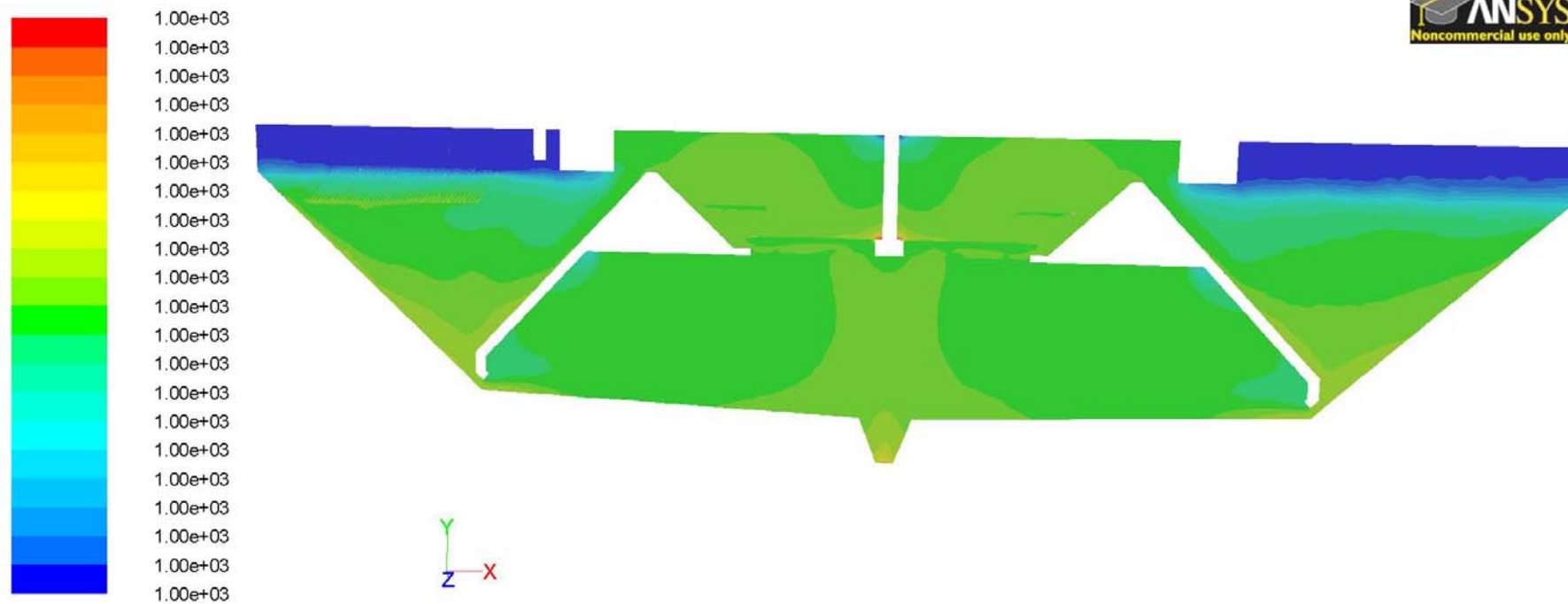
Sludge concentration



Contours of Scalar-0 (Time=3.6007e+03)

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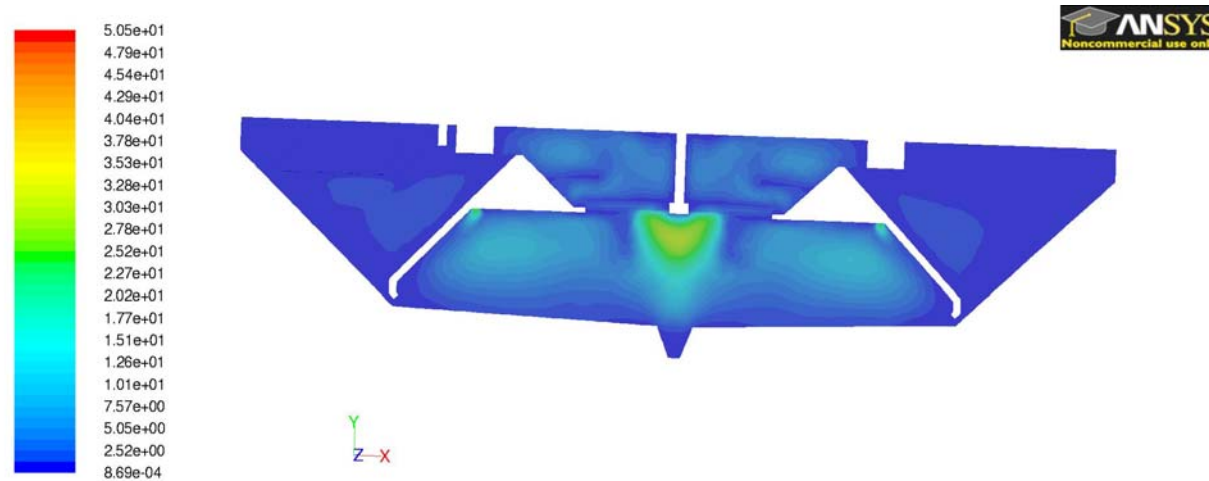
Density



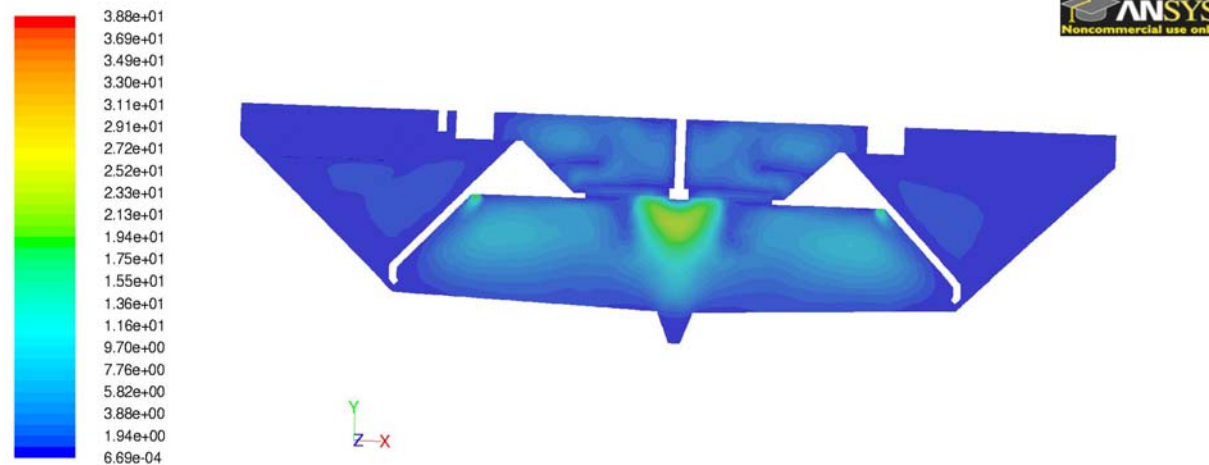
Contours of Density (kg/m³) (Time=3.6005e+03)

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Coupling turbulent viscosity - diffusion coefficient (Schmidt Number 1.3)

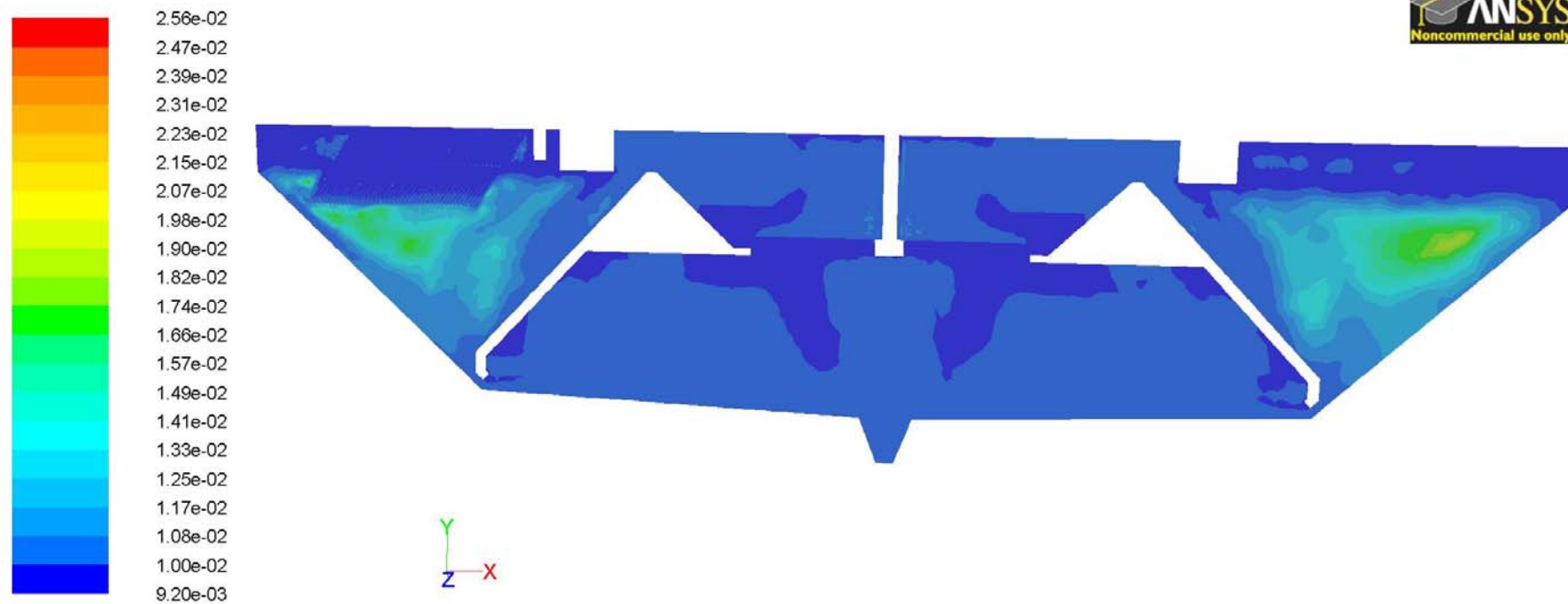


Contours of Turbulent Viscosity (kg/m-s) (Time=3.6005e+03)



Contours of Diffusion Coef. of Scalar-0 (Time=3.6005e+03)

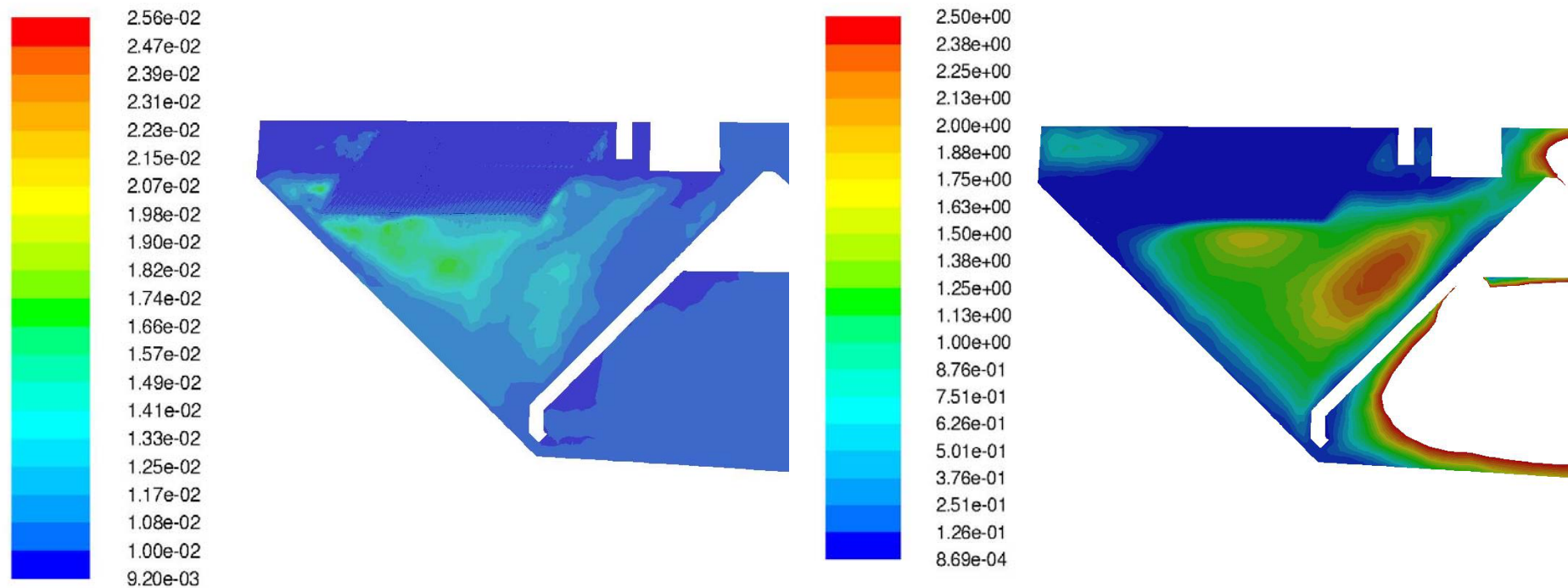
Molecular viscosity



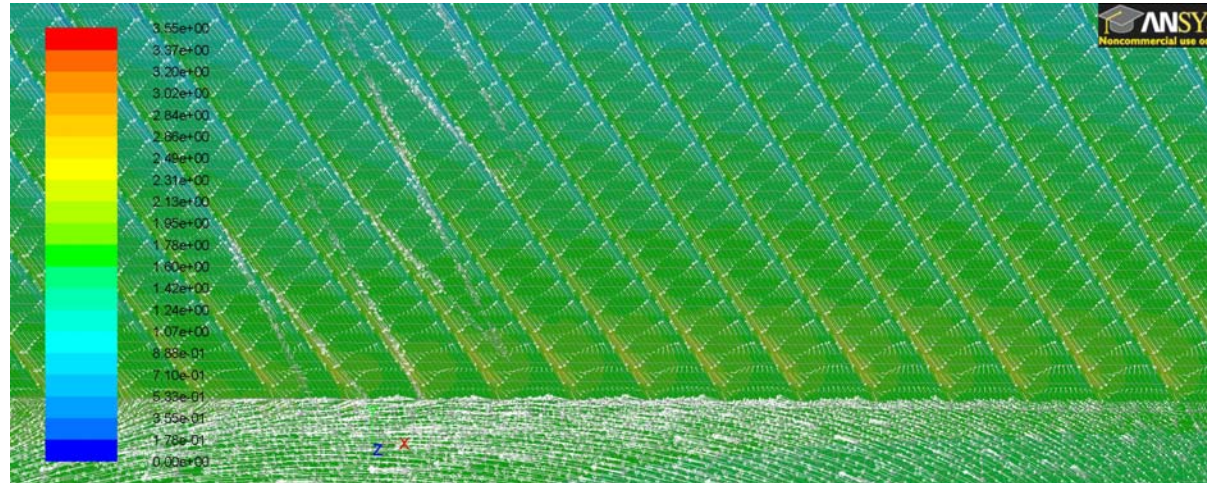
Contours of Molecular Viscosity (kg/m-s) (Time=3.6005e+03)

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Molecular viscosity vs. turbulent viscosity in the sedimentation zone



Grid effects



13 cell rows between
lamellas: backflow of
highly concentrated sludge



7 cell rows between
lamellas: no backflow of
highly concentrated sludge

Results

- Results can be seen only in comparison between the simulations. For validation on the real plant the lamella clarifier has to be built and measurements have to be taken to compare simulation with reality.
 - Sludge concentration at the outlet of lamella clarifier are 2 (10cm distance) to 5 (5cm distance) orders of magnitude lower than without
 - The slope has no significant effect on the flow regime or the outlet concentration
 - The grid quality is very important for the results
 - Further research is necessary to improve the sludge model and to verify it with the real plant
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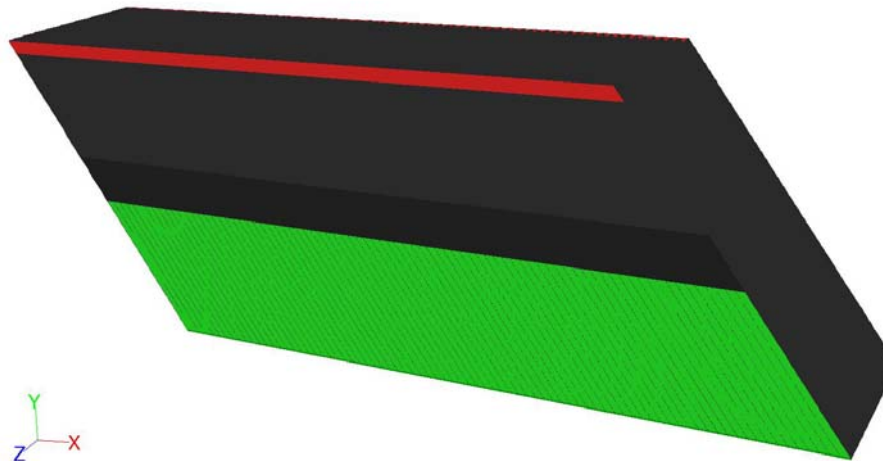
Thank you for your attention



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Mesh (Time=3.6005e+03)

ANSYS FLUENT 12.1 (3d, pbns, ske, transient)
Apr 29, 2011