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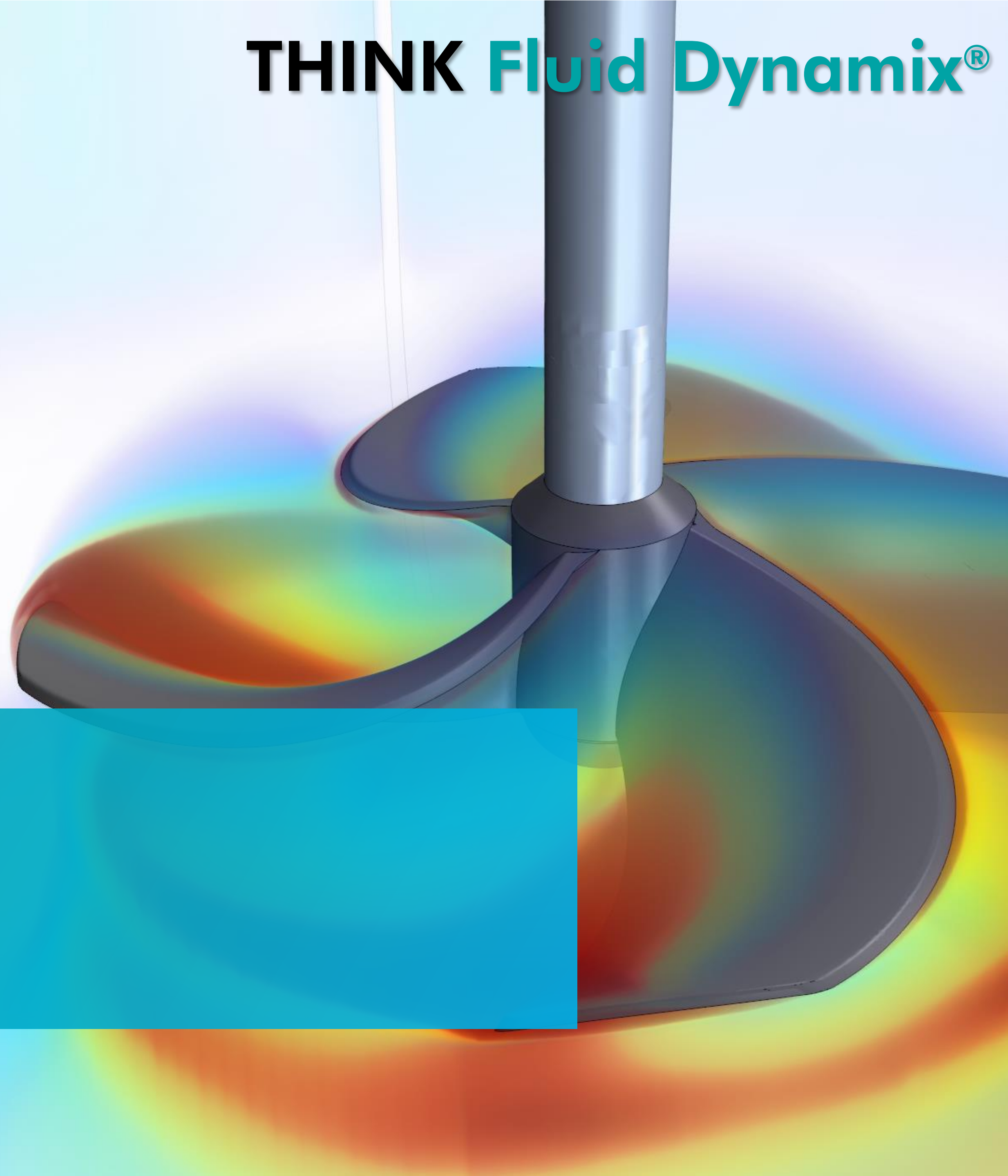

THINK FLUID DYNAMIX

Mixing, Homogenization & Blend Time

THINK Fluid Dynamix®

CFD ENGINEERING & CONSULTING

Provided by:
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THINK Fluid Dynamix is the CFD based engineering and consulting business unit of **INVENT** Umwelt- und Verfahrenstechnik AG.

Definitions & Concepts

- What is mixing?

- Basic mixing tasks

In industrial process engineering mixing is a unit operation that involves manipulation of a heterogeneous physical system to make it more homogeneous. By homogenization is understood the minimization of the concentration gradient of different compounds or temperature gradients in the entire system. This unit operation plays a critical role in many chemical processes: from food in grocery stores, healthcare and pharmaceutical products, to polymers, minerals, paint and coating, biofuels, and many others.

A distinction is made in process engineering between the following basic mixing tasks:

1. Homogenization:	Reduction of concentration or temperature gradients within a defined system
2. Suspension:	Whirling up and suspending solid particles
3. Dispersion:	liquid/liquid: emulsions, polymerization, etc.
4. Dispersion	liquid/gas : aeration, mass transfer
5. Heat transfer :	Intensifying of the heat transmission (cooling, heating)

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Definitions & Concepts

- Mixing mechanisms

- Turbulence

Mixing Mechanisms

- Dispersion or diffusion is the act of spreading out
- Molecular diffusion is diffusion caused by relative molecular motion and is characterized by the molecular diffusivity
- Turbulent diffusion is dispersion in turbulent flows caused by the motion of large groups of molecules called eddies, this motion is measured as the turbulent velocity fluctuations
- Convection (or bulk diffusion) is dispersion caused by bulk motion

Turbulence

Turbulent phenomena play a central role for much of liquid mixing technology by reducing the scale and the intensity of segregation for any system and by enhancing reaction times and mass or heat transfer. Turbulent motion is the natural state of most fluids and yet, it remains one of the biggest unsolved problems of the classical physics. Turbulent flows can merely be described as the flow regime characterized by chaotic fluctuation of the velocity and pressure field.

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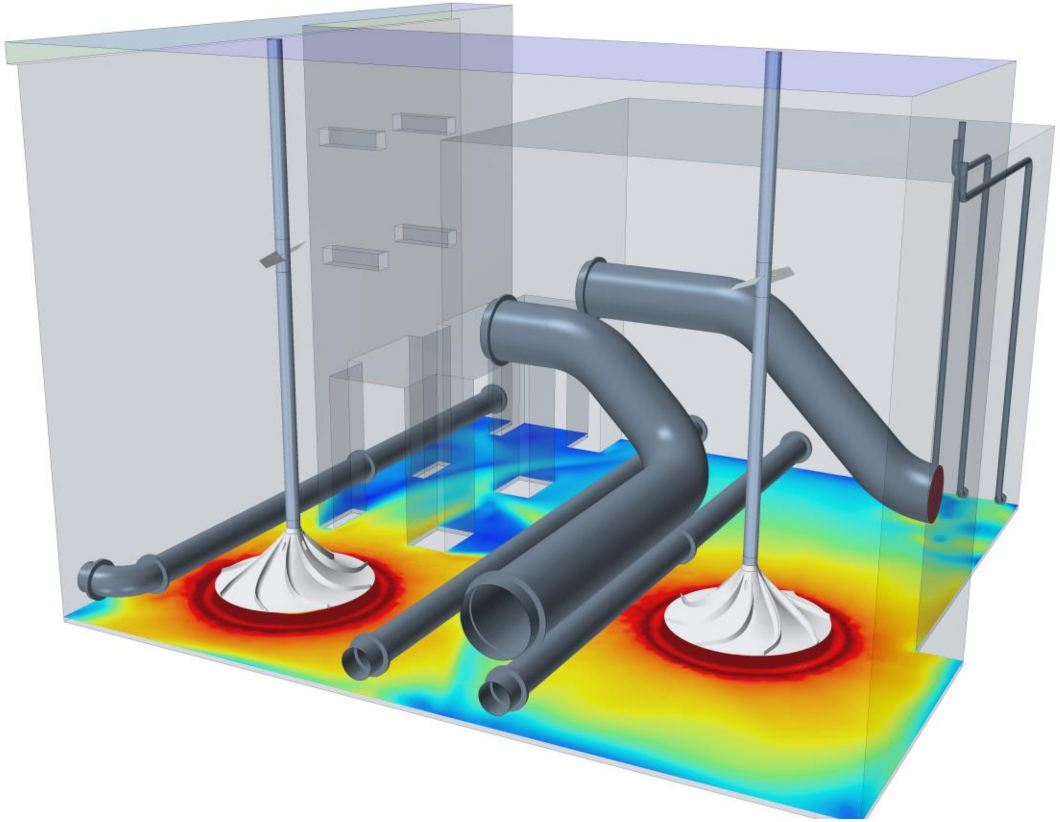
CFD Simulation and Mixing

- Numerical modeling of mixing applications



Agitation is a stirred tank is one of the most common operations, yet presents one of the greatest challenges in the area of Computational Fluid Dynamics. Stirred tanks typically contains one or more impellers mounted on shafts, and optionally can contain baffles and other internals, such as spargers, coils and draft tubes. The more accurate is the geometrical modeling of the physical domain, the more reliable are the results of the simulation.

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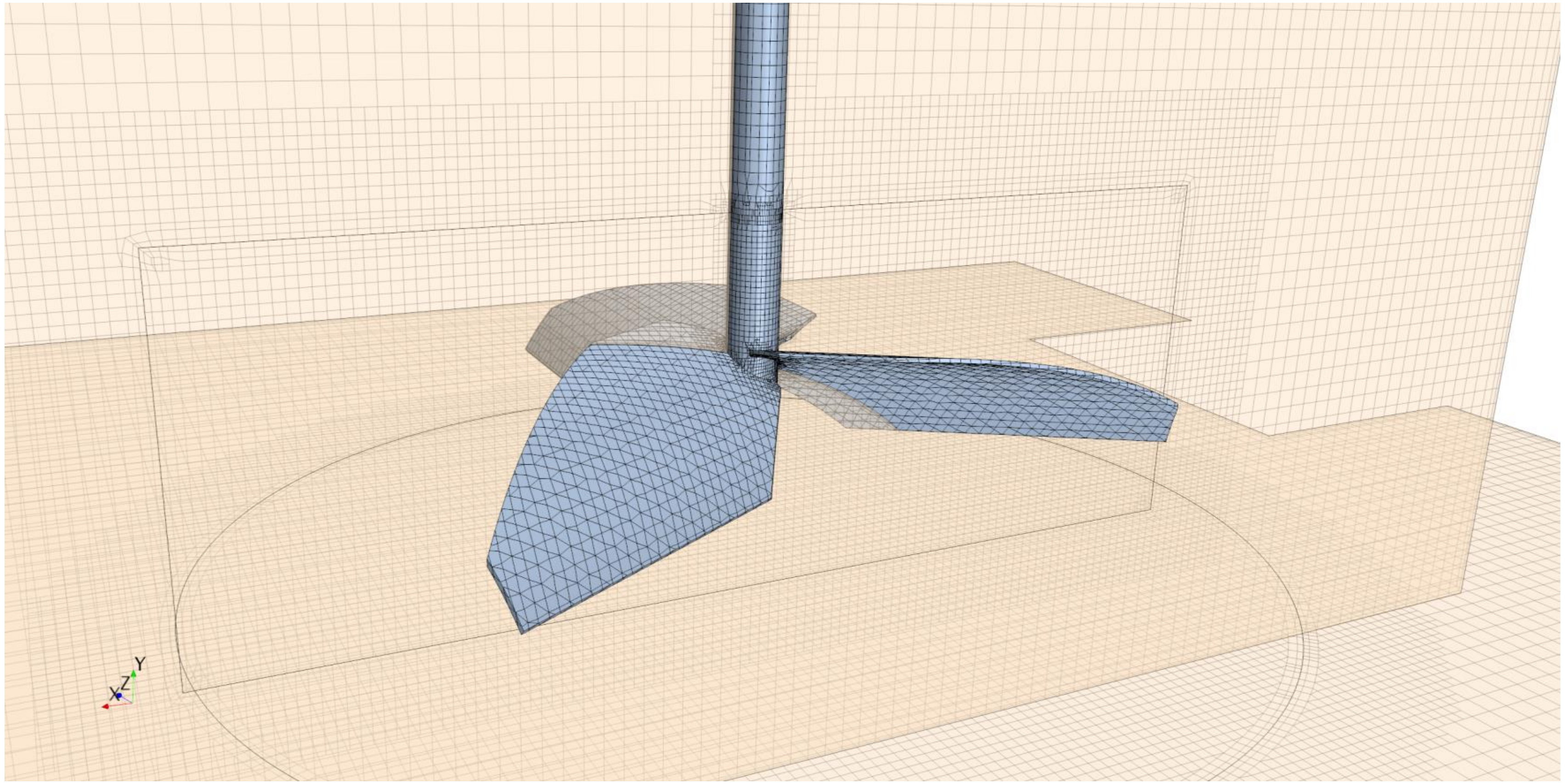
CFD Simulation and Mixing

- Numerical modeling of mixing applications



Modeling a stirred tank using CFD requires consideration of many aspects of the process. The computational grid must fit the contours of the vessel, the mixer elements and all internals, even if the components are geometrically complex. The motion of the mixer must be treated as a special way. In case more than one phase is involved in the mixing operation, also the physical characteristics of each phase and their interactors must be defined.

CFD Simulation and Mixing

- Performance

- Cost effectiveness

CFD animation in YouTube

In order to reduce the investments and operating costs, Computational Fluid Dynamics (CFD) has become an establish tool to analyze and optimize stirred tank reactors. There is no longer need to take the conventional route of experimental trial and error, which is expensive and very time consuming. Nowadays it is possible to reliably simulate dozens (or hundreds) of design in very short time.

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CFD Simulation and Mixing

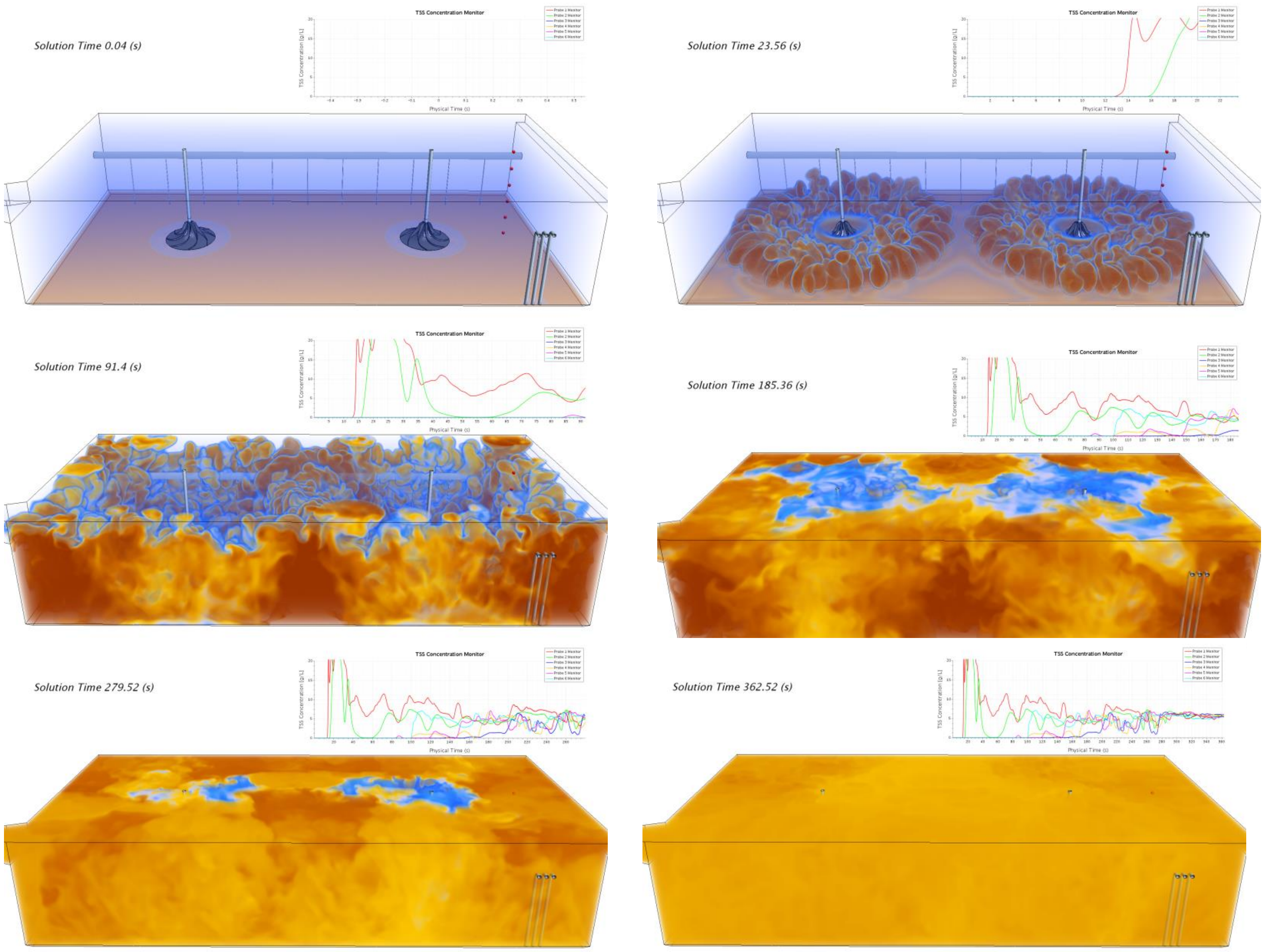
- Applications

- Steady-State analysis of stirred tank reactors
- Identification of mixing quality (scale and intensity of segregation
- Identification of dead zones or short-circuiting
- Unsteady analysis (real time simulation) for any kind of stirred tank reactor
- Unsteady analysis of blend time.
- Suspension of solid particles
- Suspension of activated sludges and modeling of settling characteristics
- Retention Time Distribution (RTD) analysis for a series of N complete mixed reactors

CFD Simulation and Mixing

- With unsteady-CFD it is possible to analyze a system over a period of time to understand overall mixing patterns.

CFD animation in YouTube



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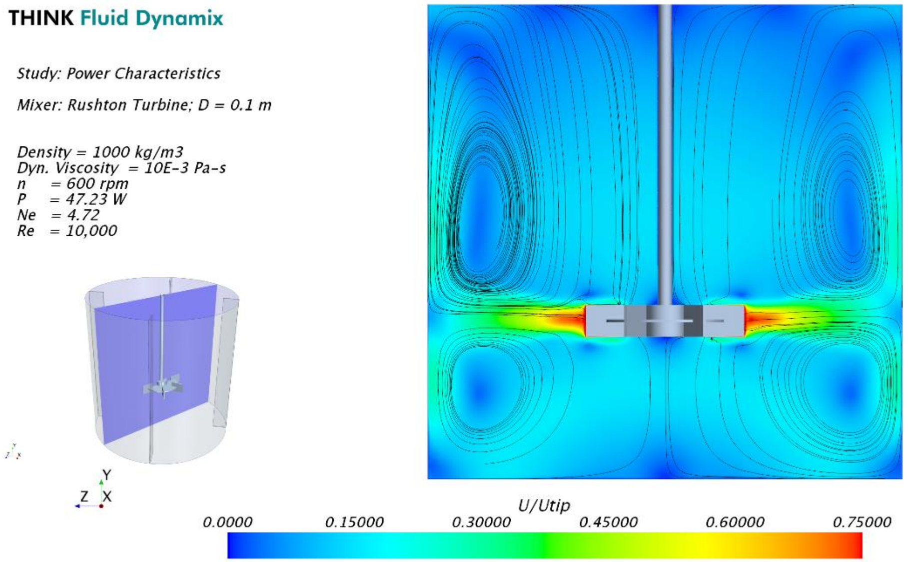
CFD Simulation and Mixing

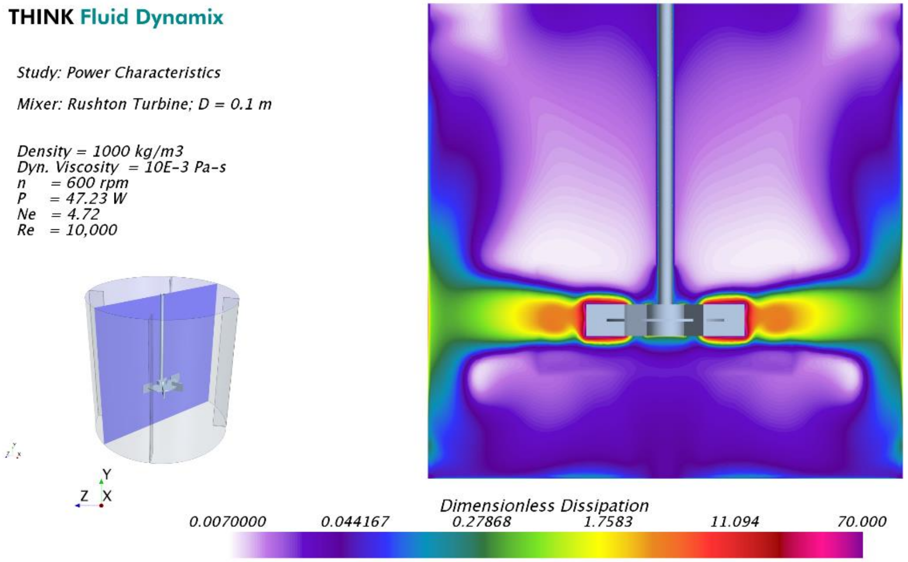
- Examining flow field

CFD animation in YouTube

There are many ways to examine the flow field results, some of which are described below:

- Scalar velocity field
- Turbulent dissipation field
- Velocity vector field
- Streamlines
- Contours
- Isosurfaces
- Particle tracks
- Volume renderings
- Animations
- Etc.





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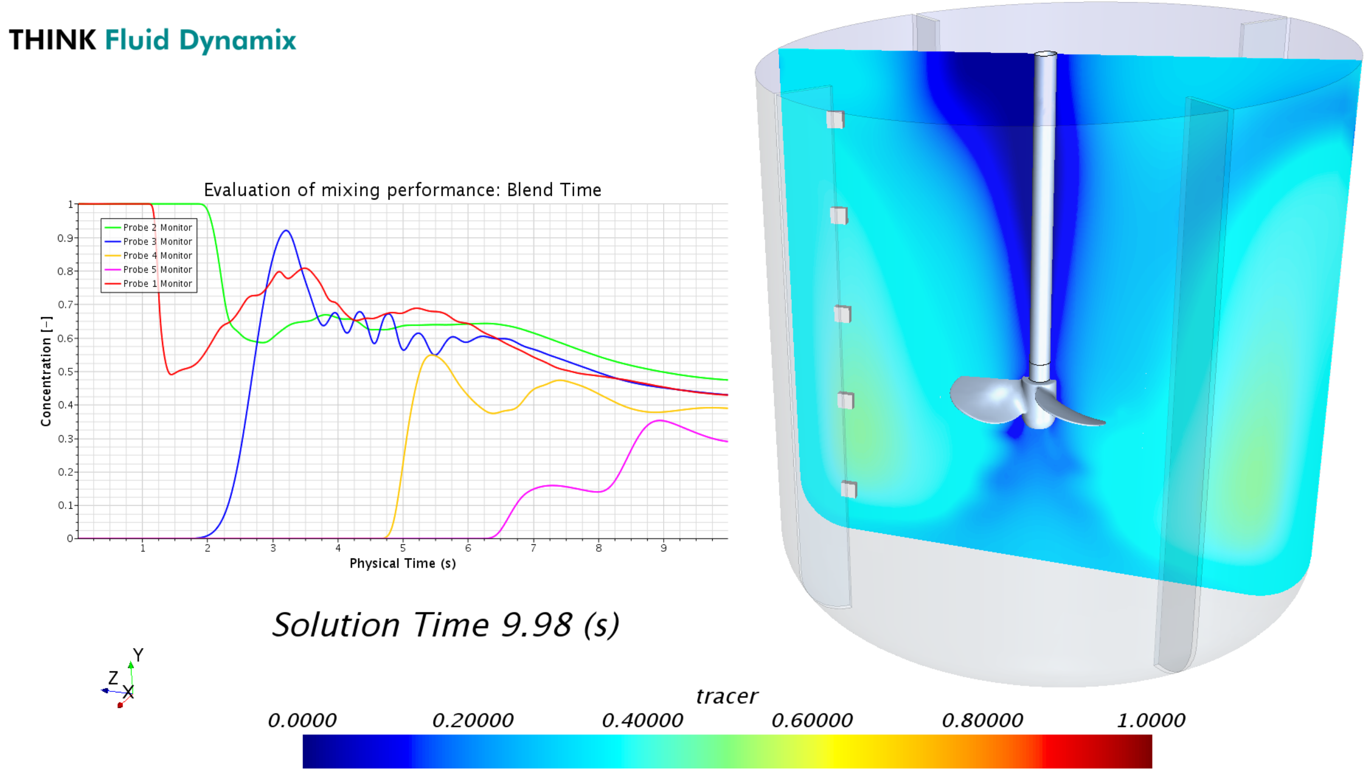
CFD Simulation and Mixing

- Analysis of blend time

CFD animation in YouTube



Blend time is the time required to achieve a predefined level of homogeneity of a tracer in a mixing vessel. This is one of the most important parameter to evaluate the mixing efficiency of mixing devices.

Performing unsteady CFD calculations the operation in a stirred tank can be completely characterized in terms of velocity flow field, averaged flow patterns, distribution of tracer after some period of time is passed, power requirement for the motor, time required to achieve adequate blending, etc.

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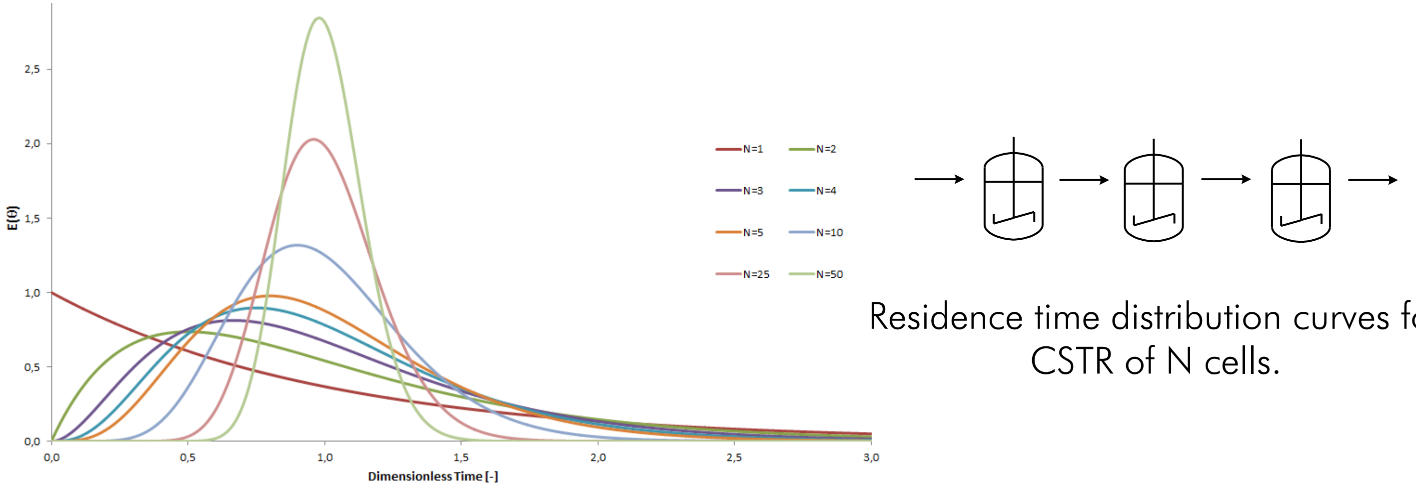
CFD Simulation and Mixing

- Residence Time Distribution (RTD)

A concept of central importance in flow processes is the residence time distribution (RTD), first developed by Danckwerts (1953). It says that in a mixed tank with cascades of mixers in row, each mixer should build its own mixing zone and the mixers should work independent from each other.

To determine the retention time of the wastewater in the basin a tracer test has to be made. During this test a tracer is added to the medium and the time necessary for the tracer to pass through the basin is measured.

RTD analysis are excellent to diagnose pathological behavior in complete stirred tank reactors but it fails at identifying the cause of the problems. Through CFD it is not only possible to perform numerically a conventional RTD analysis but also to study the flow and the dispersion of the tracer over a period of time in order to identify the specific causes of the issues.

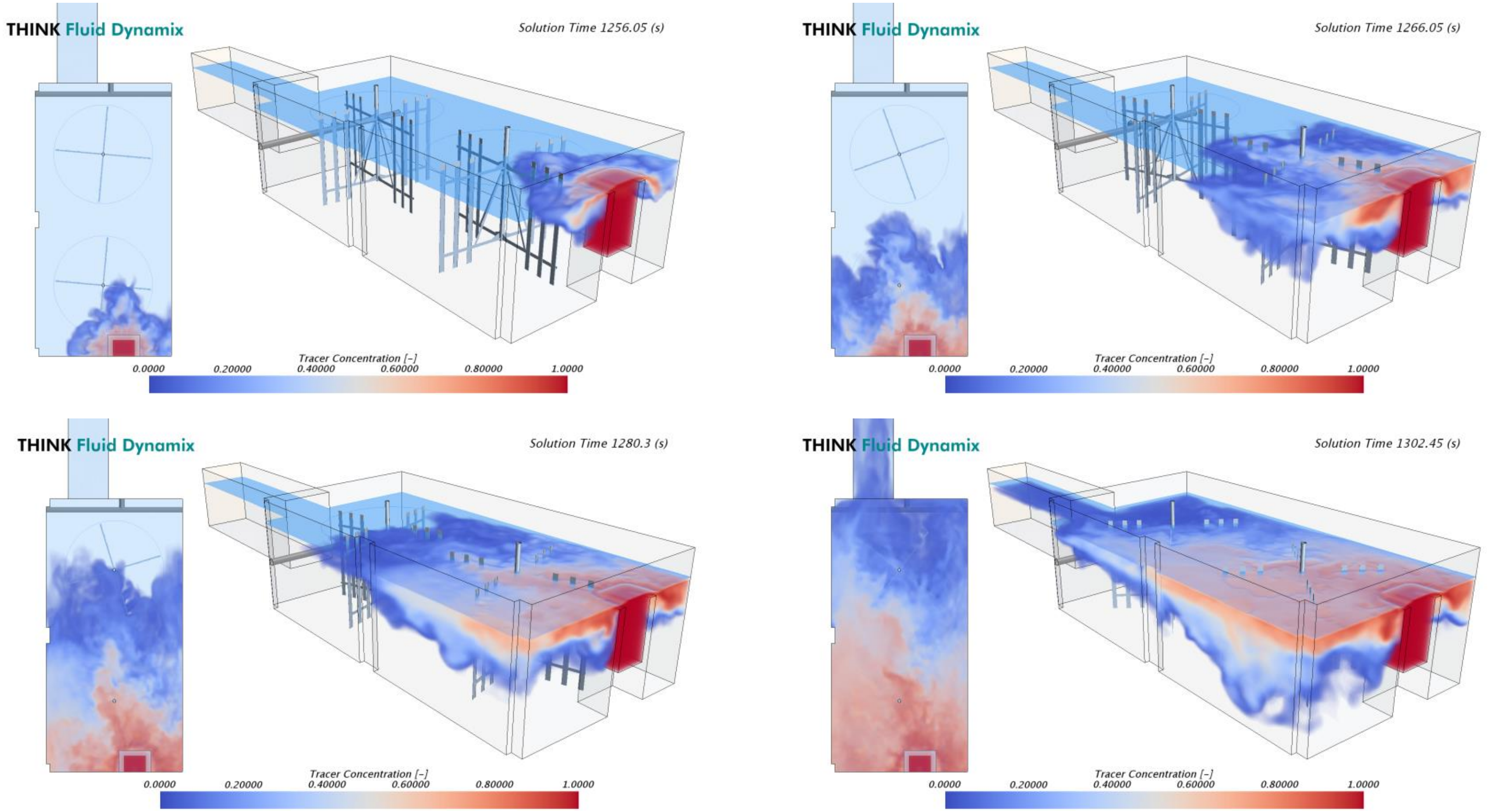


Residence time distribution curves for CSTR of N cells.

CFD Simulation and Mixing

- CFD as a tool to identify pathological behavior in complete stirred tank reactors

CFD animation in YouTube



The residence time distribution is a 1-dimensional analysis of the mixing behavior of a complete stirred tank reactor. Once issues in the mixing operation of a reactor are identified, a complete spatial and temporal analysis of the tracer dispersion within the reactor is required in order to specifically determine the causes of the problems and to find concrete solutions.

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Modeling Mixing Tanks

A new way of studying process operation

A new way of design and optimization

Numerical simulations are the perfect environment for identification of problems, parameter studies and optimization work

- Identification of mixing quality (scale and intensity of segregation) and determination of blend time
- Identification of dead zones or short-circuiting
- Unsteady analysis (real time simulation) for any kind of stirred tank reactor
- Suspension of solid particles
- Suspension of activated sludges and modeling of settling characteristics
- Retention Time Distribution (RTD) analysis for a series of N complete mixed reactors
- Etc.

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Technical Competence

Company Video in YouTube

THINK Fluid Dynamix offers support and assistance with the design, optimization, and modernization of hydraulic structures in water and wastewater treatment plants.

More than 25 years of experience innovating and developing revolutionary solutions allow us to provide unique and in-depth analysis and solutions. We have a comprehensive functional and industrial expertise, and are passionate about taking on challenges that matter to our clients and to the environment.

The design of optimized process applications and hydraulic structures for the water and wastewater treatment industry requires a high level of multidisciplinary scientific and engineering skills. An optimal solution should show energy efficiency while maintaining a robust and reliable system approach

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Sources:

Metcalf & Eddy (2014), Wastewater Engineering, 5th ed.
Paul, Atiemo-Obeng, Kresta (2005), Handbook of Industrial Mixing, 1st ed.