Investigations on Hydrodynamic in a Stirred Tank for Educational Purposes

Attila Egedy, Tamás Varga, Tibor Chován
University of Pannonia, Department of Process Engineering
Veszprém, Hungary

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Introduction

- Investigate on mixing in a batch stirred tank
- Macromixing phenomenon
- Fluid dynamics education
- Fluid dynamics research
- Design, and optimization support

Governing equations

- Navier-Stokes model

$$\rho\frac{\partial u}{\partial t}+\rho(u\cdot\nabla)u=\nabla\cdot\left[-pI+\mu\left(\nabla u+(\nabla u)^T\right)-\frac{2}{3}\mu(\nabla u)I\right]+F$$

- Two-variable k-ε model

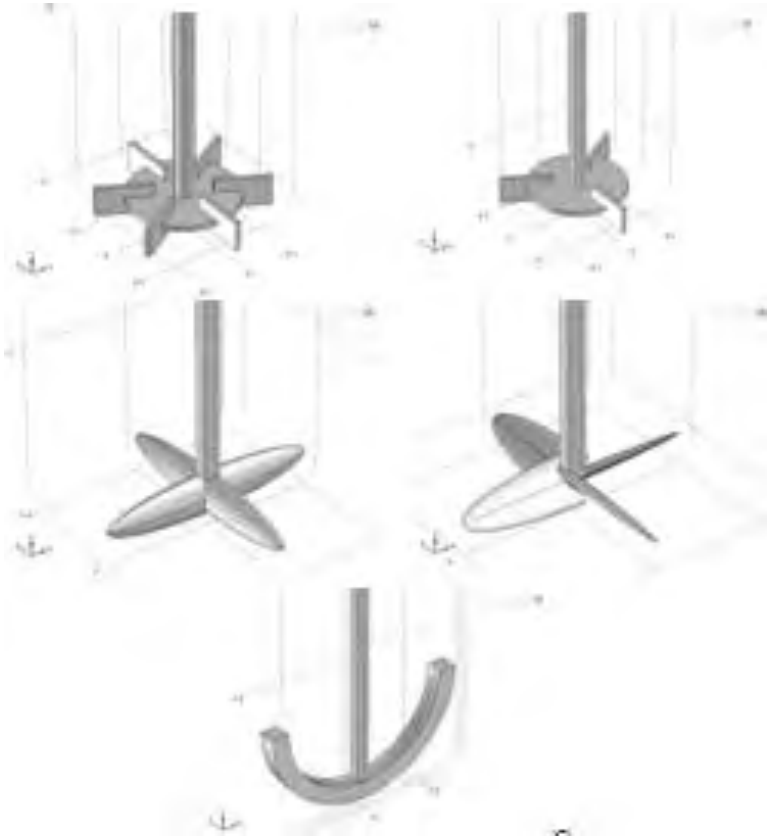
$$\rho\frac{\partial u}{\partial t}+\rho(u\cdot\nabla)u=\nabla\cdot\left[-pI+(\mu+\mu_T)\left(\nabla u+(\nabla u)^T\right)-\frac{2}{3}(\mu+\mu_T)(\nabla u)I-\frac{2}{3}\rho kI\right]+F$$

$$\rho\frac{\partial k}{\partial t}+\rho(u\cdot\nabla)k=\nabla\cdot\left[\left(\mu+\frac{\mu_T}{\sigma_k}\right)\nabla k\right]+P_k-\rho\varepsilon$$

$$\rho\frac{\partial \varepsilon}{\partial t}+\rho(u\cdot\nabla)\varepsilon=\nabla\cdot\left[\left(\mu+\frac{\mu_T}{\sigma_e}\right)\nabla\varepsilon\right]+C_{\varepsilon 1}\frac{\varepsilon}{k}P_k-C_{\varepsilon 2}\rho\frac{\varepsilon^2}{k}$$

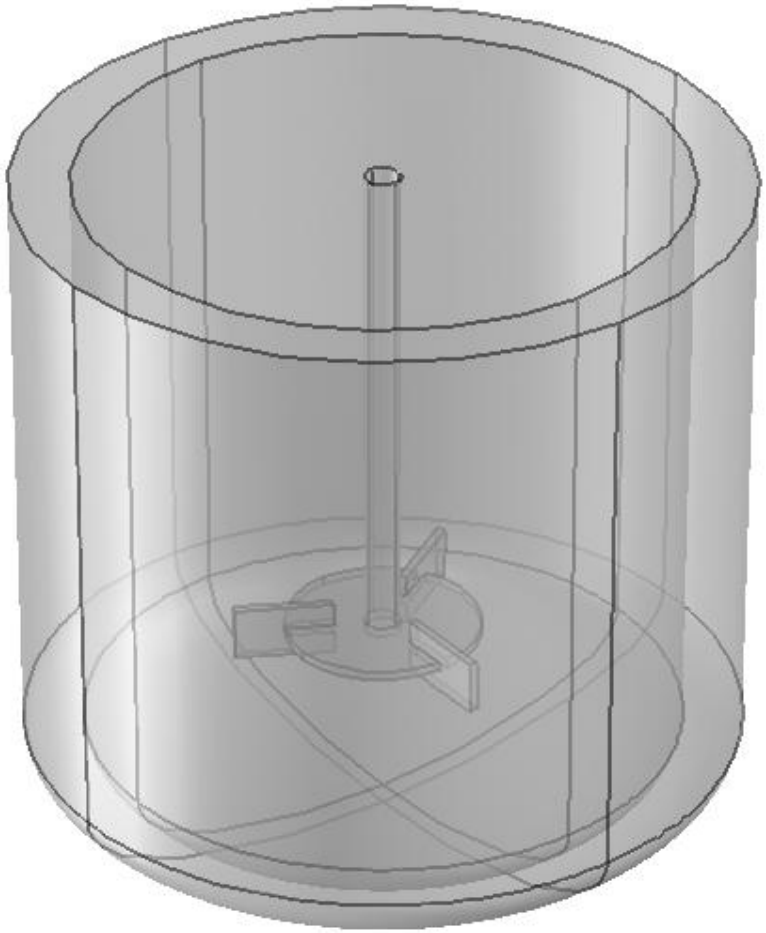
Modelling and method

- Three different tank geometries
  - Flat bottom
  - Round bottom
  - Ellipsoid bottom
- Six different impeller geometries
  - Three and six bladed turbine
  - Blade and 45° blade impeller
  - Propeller and Anchor impeller
- Three different revolution speeds
  - 20, 50 and 100 1/min



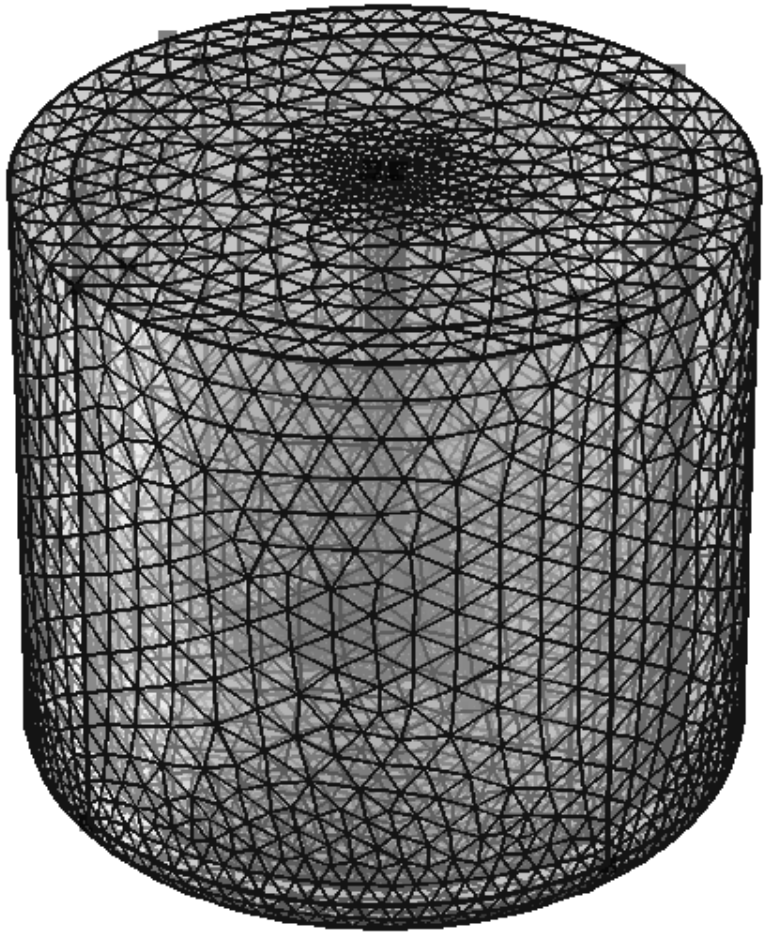
Modelling example

- Three bladed turbine impeller
- Ellipsoid bottom tank
- Counterclockwise revolution
- Liquid mixing



Modelling example

- Rotating machinery
  - Laminar
  - Turbulent
- Moving mesh model in 3D
- ~100k tetrahedral mesh element
- ~750k degrees of freedom
- Transient analysis, direct or iterative solvers

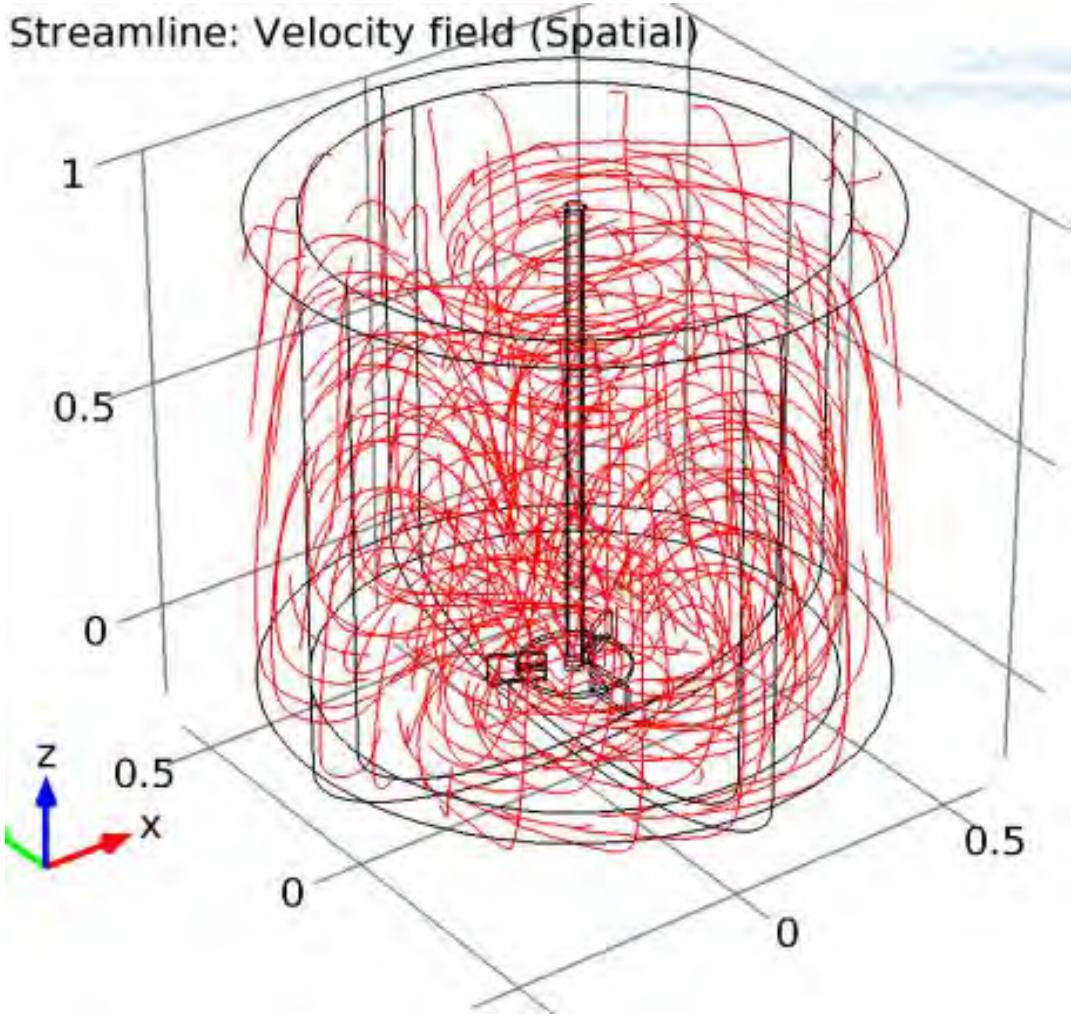


Modelling example

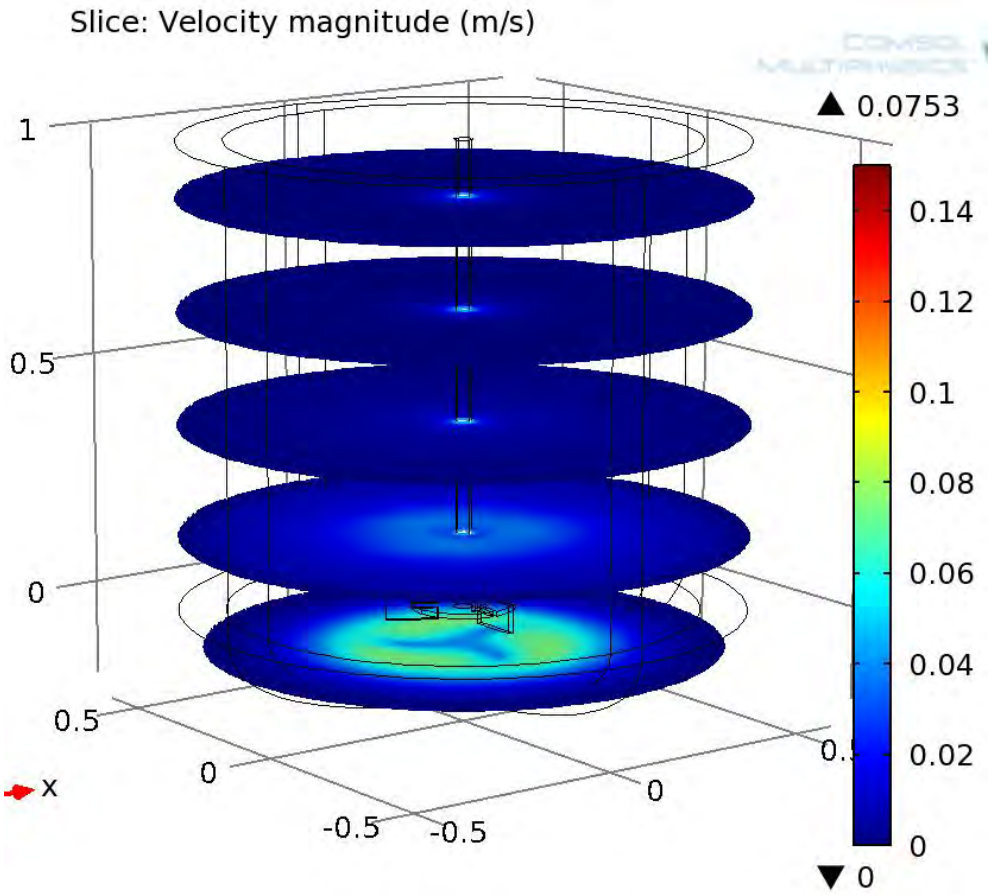
- Direct solvers at high speeds, iterative solvers at lower speed
- COMSOL version 4.1 was used
- Intel Xeon W3530 computer was used for computation 16 GB RAM
- Solutions last from 6 hours-to 100 hours

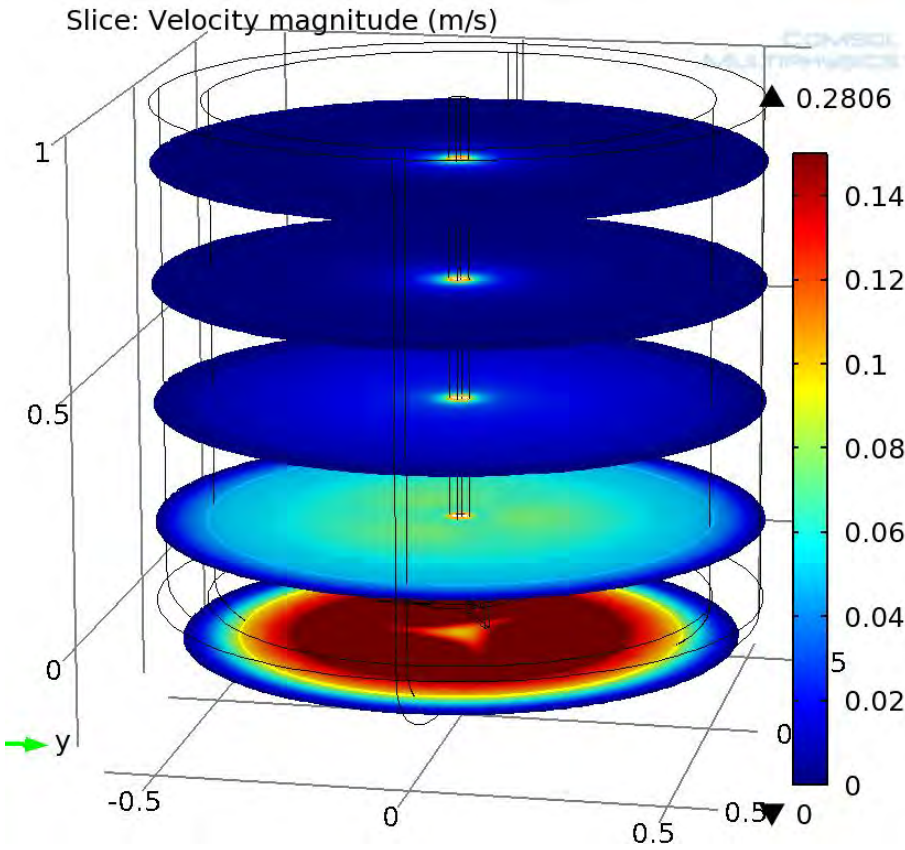
Results

- Streamline results
- xy slice results
- 3D avi animations



Results


Slice: Velocity magnitude (m/s)
▲ 0.0753
0.14
0.12
0.1
0.08
0.06
0.04
0.02
▼ 0
1
0.5
0
0.5
0
-0.5
-0.5
0
x


Slice: Velocity magnitude (m/s)
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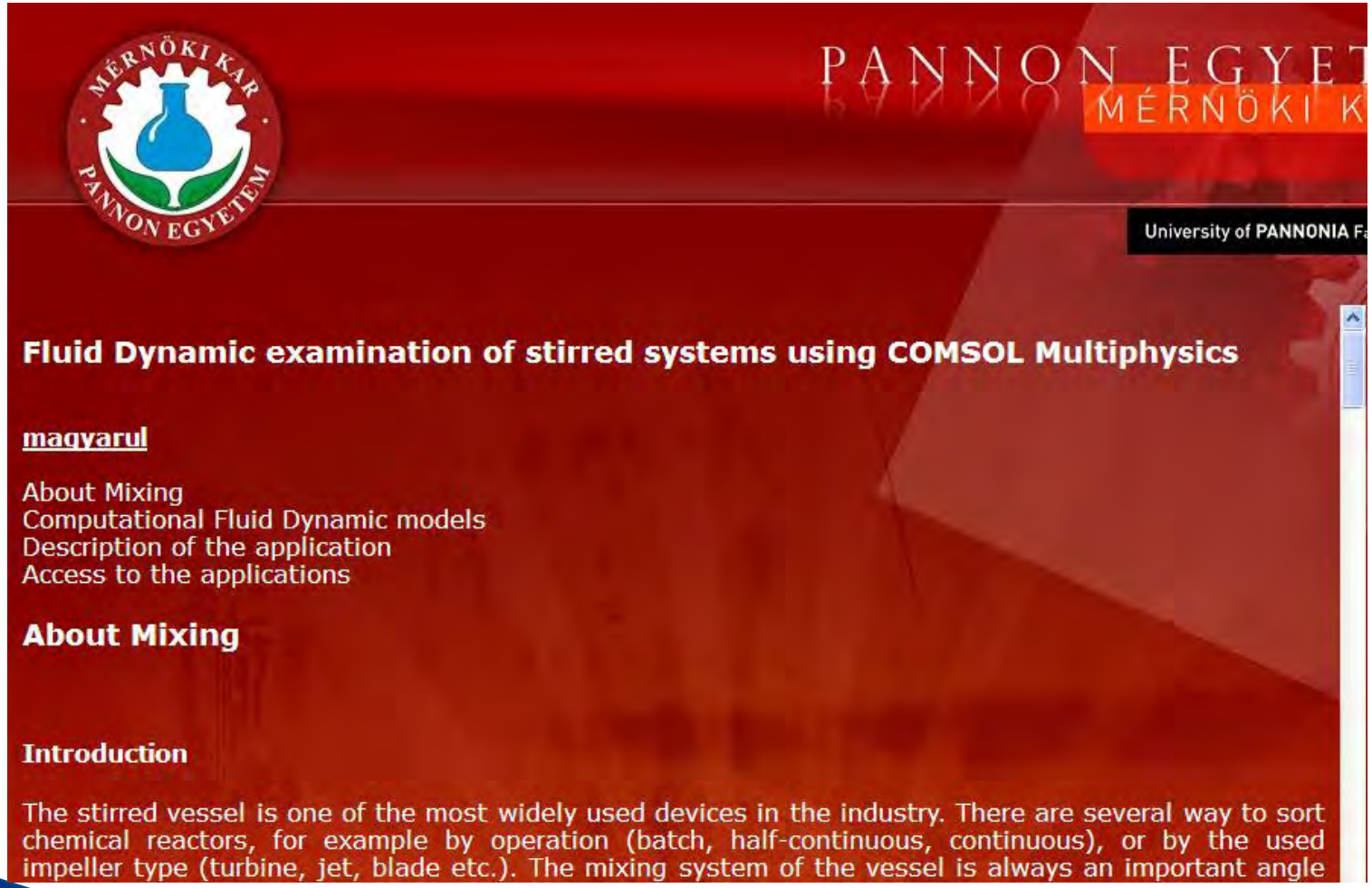
0.14
0.12
0.1
0.08
0.06
0.04
0.02
▼ 0
1
0.5
0
y
-0.5
0
0.5
0
0.5

Education

- Open-access website to examine the results
- Introduction to Computational Fluid Dynamics, and COMSOL Multiphysics
- Results on streamline plot
- Animations of mixing via youtube channel Macromixing

Education website



http://pr.mk.uni-pannon.hu/disszeminacio/keveres.html

Query form

pr.mk.uni-pannon.hu/diss

Fluid Dynamic examinatio

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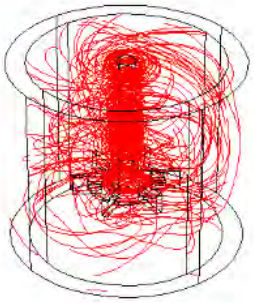
Vessel type
- ☐ Flat bottom
- ☐ Round bottom
- ☐ Ellipsoid bottom

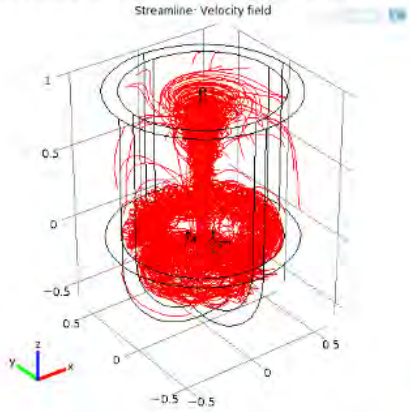
Impeller type
- ○ Six-bladed turbine
- ○ Three-bladed turbine
- ○ Blade
- ○ Anchor

Revolution speed
- ☐ 20
- ☐ 50
- ☐ 100

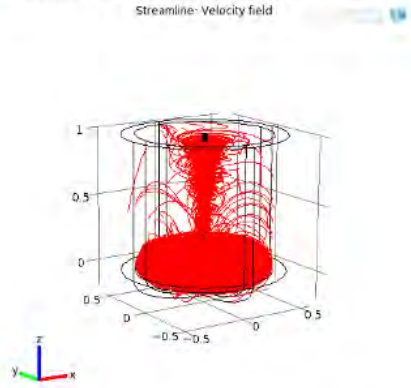
Flat bottom tank with six-bladed turbine impeller 50 1/min



Round bottom tank with six-bladed turbine impeller 50 1/min

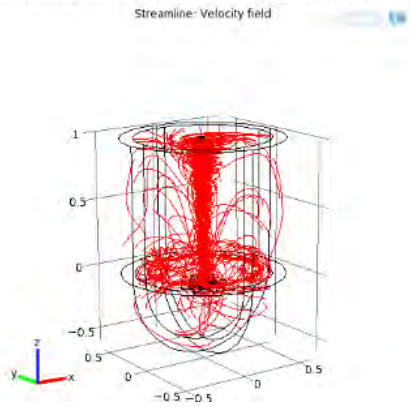


Ellipsoid bottom tank with six-bladed turbine impeller 50 1/min

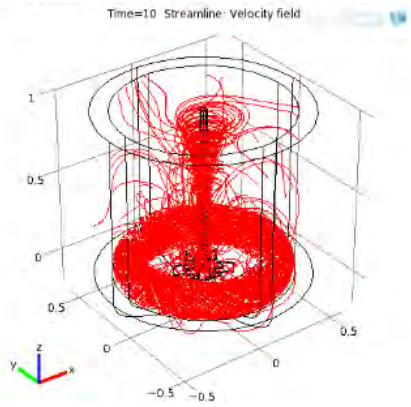


Flat bottom tank with six-bladed turbine impeller 100 1/min

Round bottom tank with six-bladed turbine impeller 100 1/min



Ellipsoid bottom tank with six-bladed turbine impeller 100 1/min



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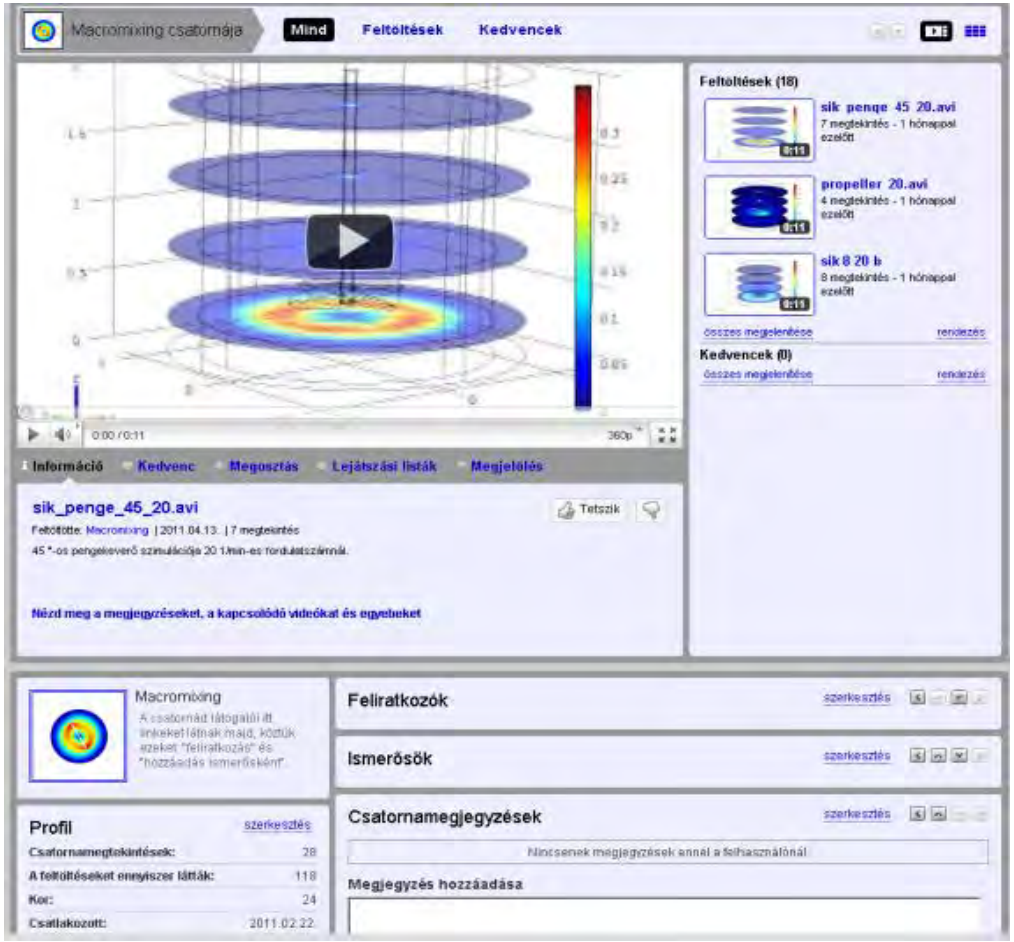
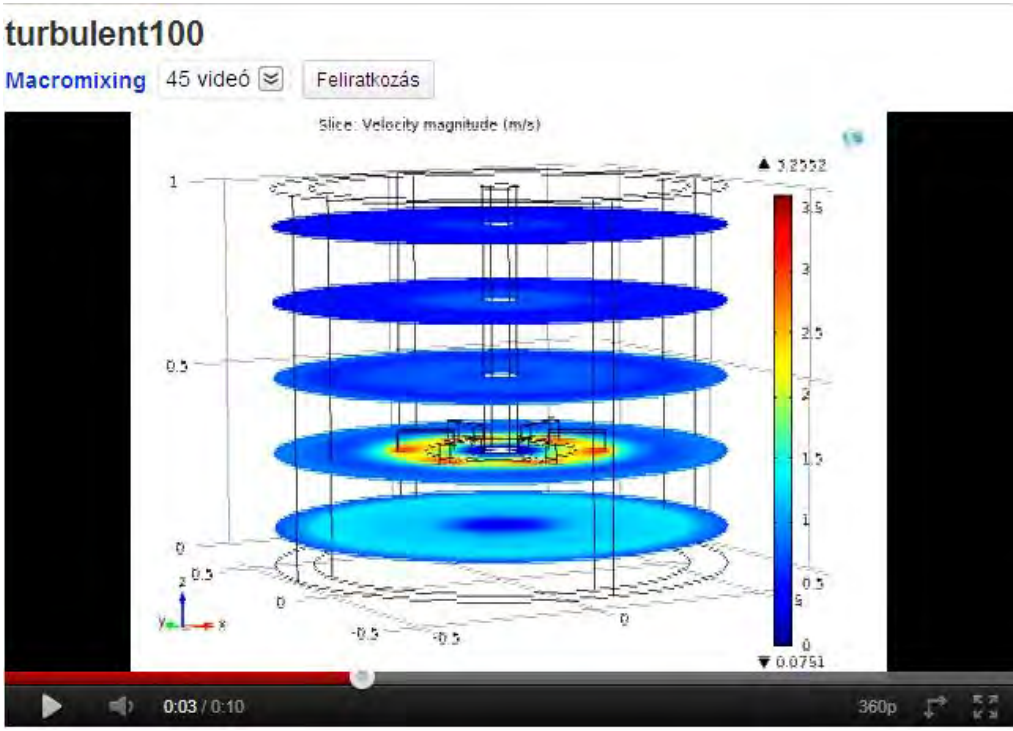
YouTube channel



http://www.youtube.com/user/Macromixing

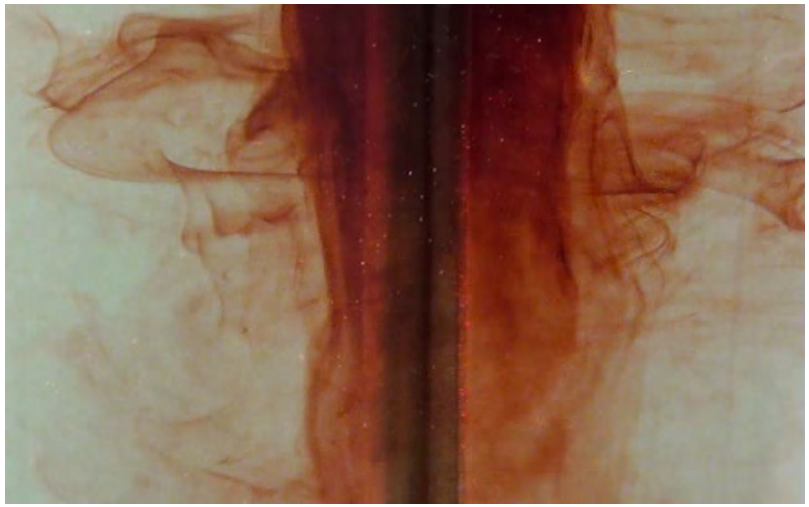
Conclusion

- Several geometries
- Different impellers
- Educational website
- Open access results
- YouTube videos



Future plans

- Higher revolution speeds
- Static part attached to the stirred system
- Multi – impeller systems
- Continuous systems
- Model validation



Acknowledgement

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Thank you for your attention!