

Investigations on Hydrodynamic in a Stirred Tank for Educational Purposes

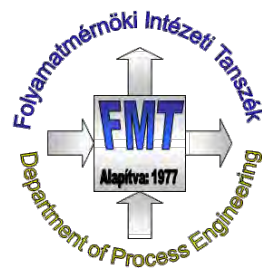
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COMSOL User Conference Stuttgart 26-28, October 2011





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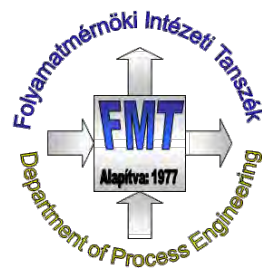


- ▶ Introduction
- ▶ Governing equations
- ▶ Modelling and method
- ▶ Results
- ▶ Education
- ▶ Conclusions





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

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

▶ Two-variable k-ε model

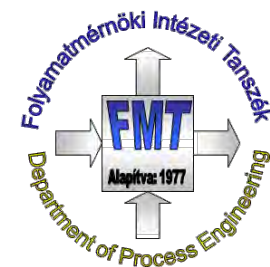
$$\rho \frac{\partial u}{\partial t} + \rho(u \cdot \nabla)u = \nabla \cdot \left[-pI + (\mu + \mu_T)(\nabla u + (\nabla u)^T) - \frac{2}{3}(\mu + \mu_T)(\nabla u)I - \frac{2}{3} \rho k I \right] + F$$

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

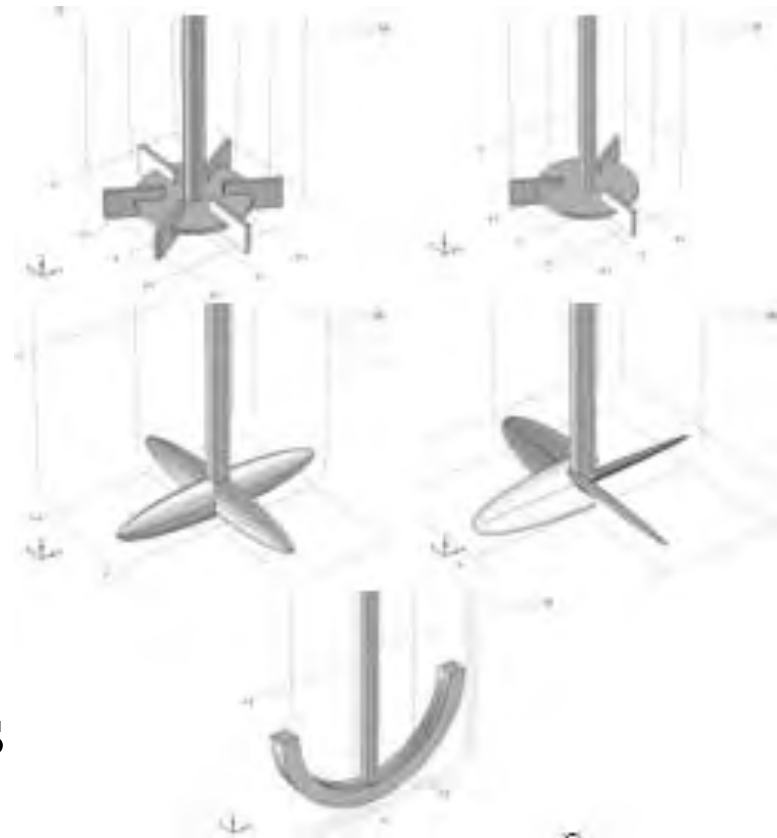
$$\rho \frac{\partial \varepsilon}{\partial t} + \rho(u \cdot \nabla)\varepsilon = \nabla \cdot \left[\left(\mu + \frac{\mu_T}{\sigma_e} \right) \nabla \varepsilon \right] + C_{\varepsilon 1} \frac{\varepsilon}{k} P_k - C_{\varepsilon 2} \rho \frac{\varepsilon^2}{k}$$



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

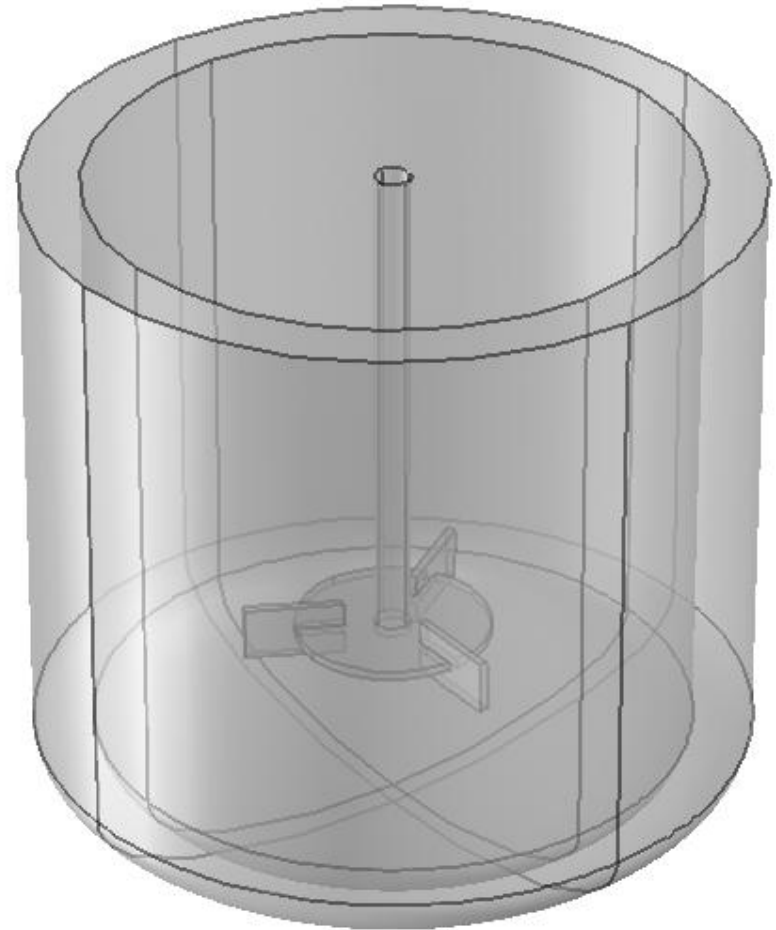




Modelling example

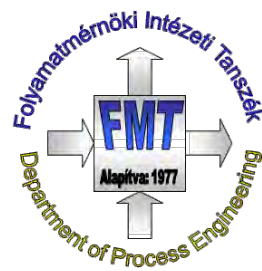


- ▶ Three bladed turbine impeller
- ▶ Ellipsoid bottom tank
- ▶ Counterclockwise revolution
- ▶ Liquid mixing

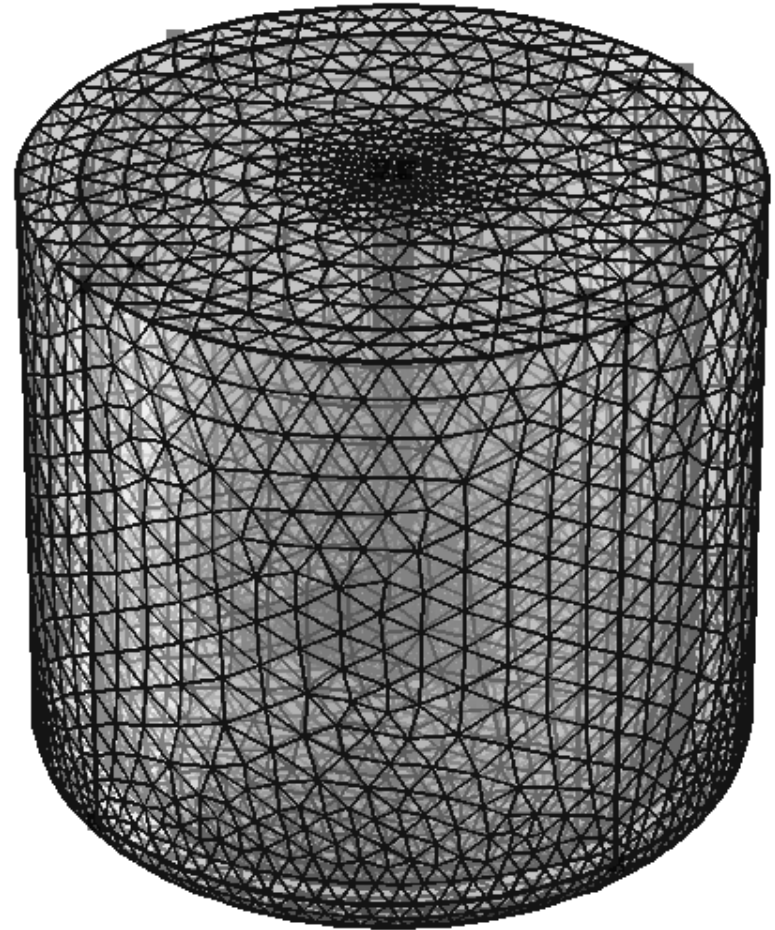




Modelling example

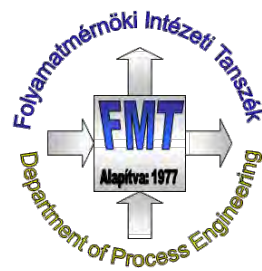


- ▶ Rotating machinery
 - Laminar
 - Turbulent
- ▶ Moving mesh model in 3D
- ▶ ~100k tetrahedral mesh element
- ▶ ~750k degrees of freedom
- ▶ Transient analysis, direct or iterative solvers





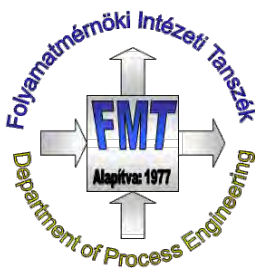
Modelling example



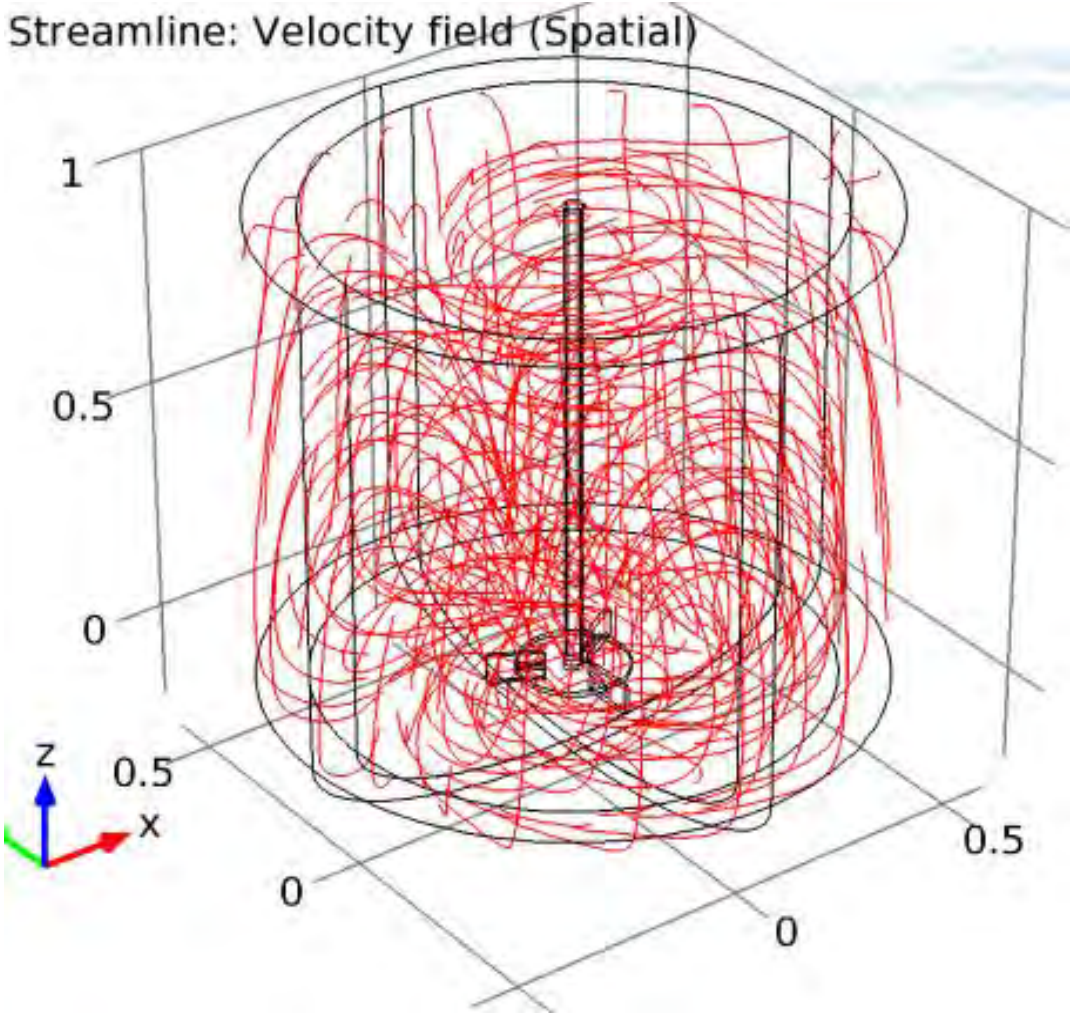
- ▶ Direct solvers at high speeds, iterative solvers at lower speed
- ▶ COMSOL version 4.1 was used
- ▶ Intel Xeon W3530 computer was used for computation 16 GB RAM
- ▶ Solutions last from 6 hours-to 100 hours



Results



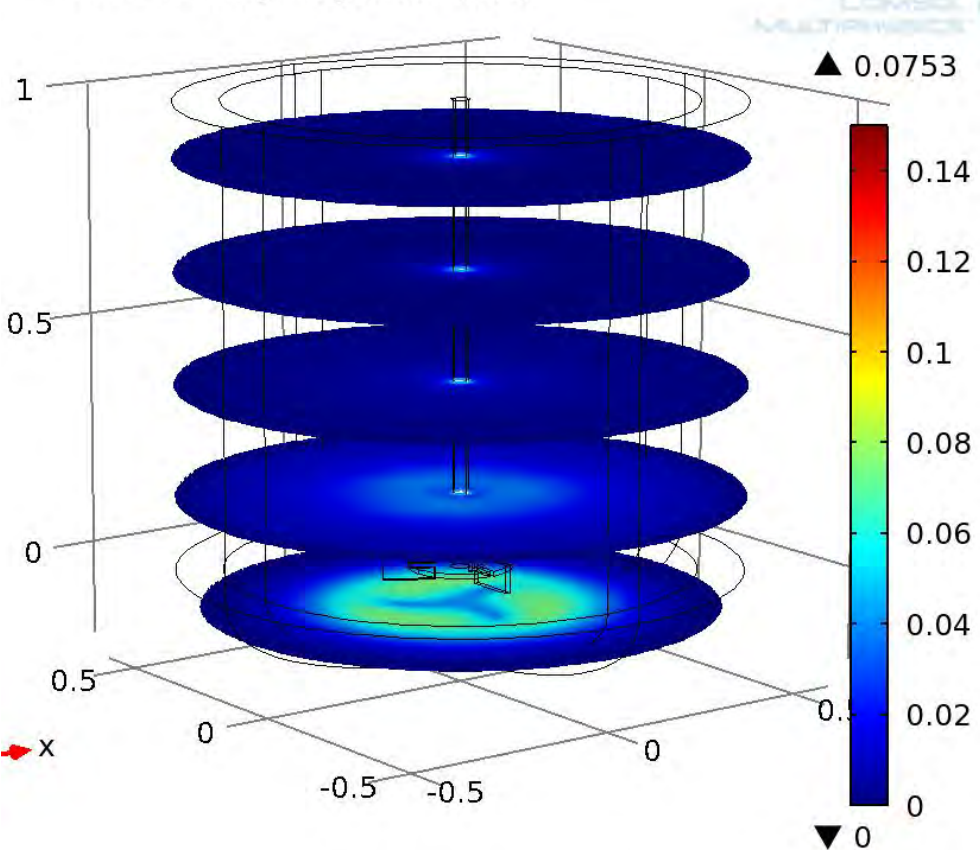
- ▶ Streamline results
- ▶ xy slice results
- ▶ 3D avi animations



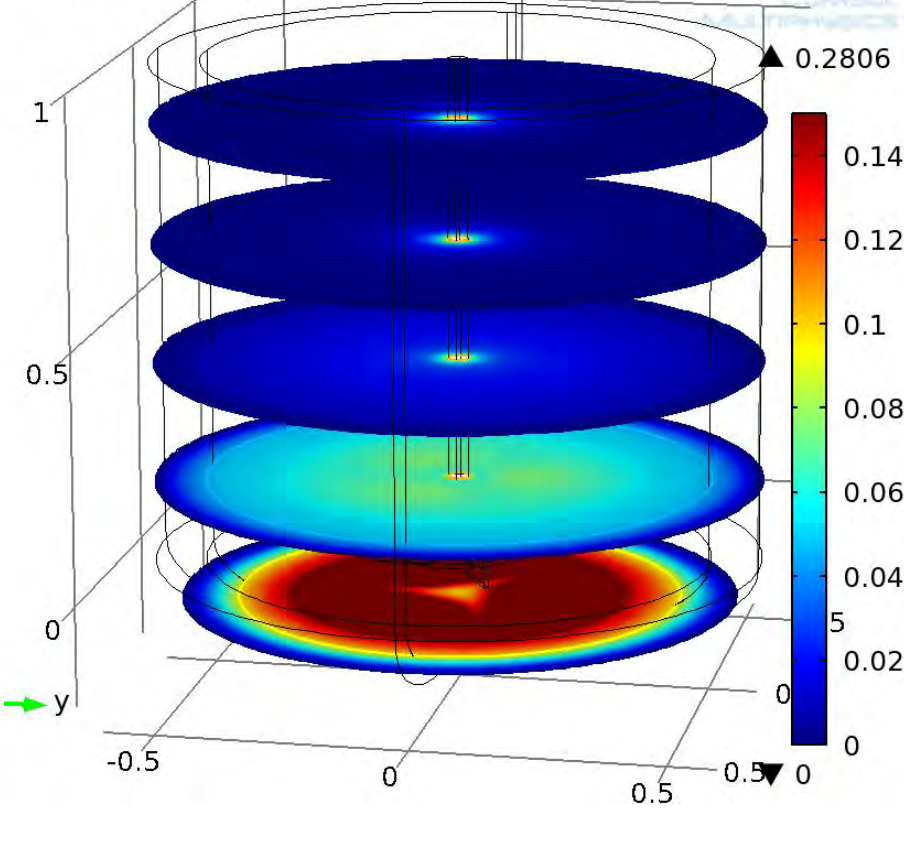


Results

Slice: Velocity magnitude (m/s)

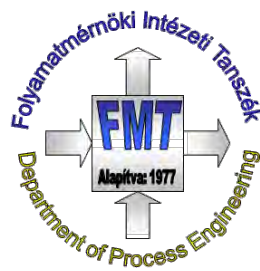


Slice: Velocity magnitude (m/s)





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



Fluid Dynamic examination of stirred systems using COMSOL Multiphysics

magyarul

- About Mixing
- Computational Fluid Dynamic models
- Description of the application
- Access to the applications

About Mixing

Introduction

The stirred vessel is one of the most widely used devices in the industry. There are several way to sort chemical reactors, for example by operation (batch, half-continuous, continuous), or by the used impeller type (turbine, jet, blade etc.). The mixing system of the vessel is always an important angle

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



Query form



pr.mk.uni-pannon.hu/diss

Fluid Dynamic examination

MAGYARUL

Vessel type

- Flat bottom
- Round bottom
- Ellipsoid bottom

Impeller type

- Six-bladed turbine
- Three-bladed turbine
- Blade
- Anchor

Revolution speed

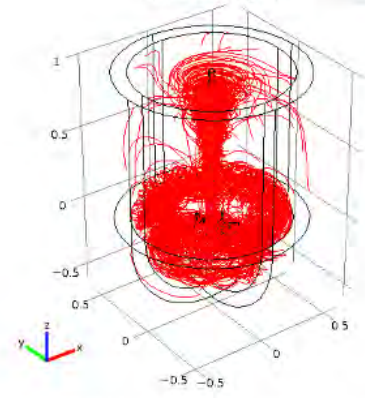
- 20
- 50
- 100

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



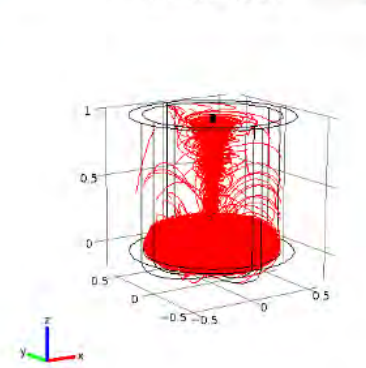
Round bottom tank with six-bladed turbine impeller 50 1/min

Streamline: Velocity field



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

Streamline: Velocity field

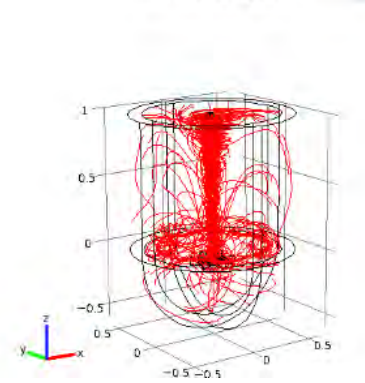


Flat bottom tank with six-bladed turbine impeller 100 1/min



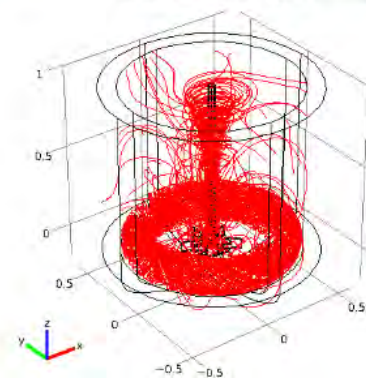
Round bottom tank with six-bladed turbine impeller 100 1/min

Streamline: Velocity field



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

Time=10 Streamline: Velocity field



<http://pr.mk.uni-pannon.hu/disszeminacio/keverok/index.php>

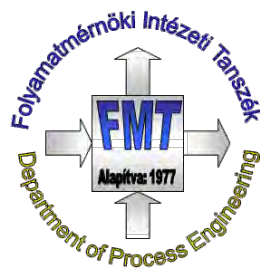


YouTube channel



The screenshot shows a YouTube channel page for 'Macromixing csatornája'. The main video player displays a 3D simulation of a mixing process with a color scale from 0.0 to 0.3. The video title is 'sik_penge_45_20.avi'. The channel description includes the text: 'Feltöltte: Macromixing | 2011.04.13. | 17 megtekintés' and '45°-os pengékeverő szimulációja 30 l/min-es fordulatszámú.' The channel has 18 uploads, including 'sik_penge_45_20.avi', 'propeller_20.avi', and 'sik 8 20 b'. The channel profile shows it was created on 2011.02.22 and has 28 subscribers.

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



Conclusion

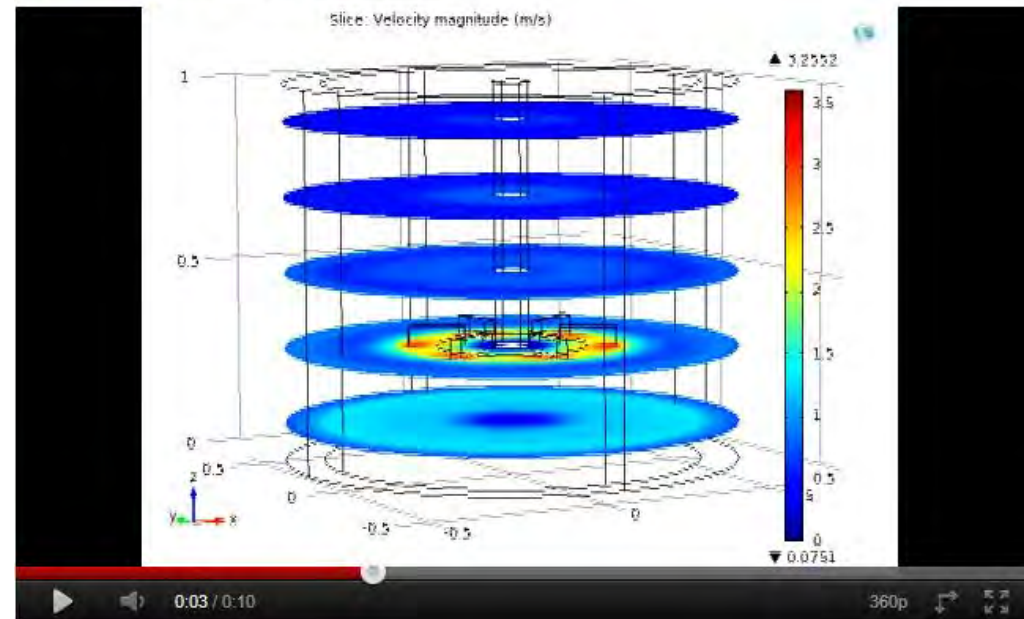
- ▶ Several geometries
- ▶ Different impellers
- ▶ Educational website
- ▶ Open access results
- ▶ YouTube videos

turbulent100

Macromixing

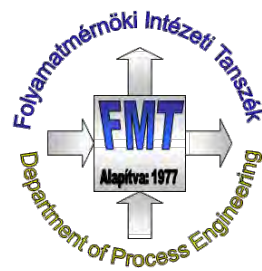
45 videó

Feliratkozás

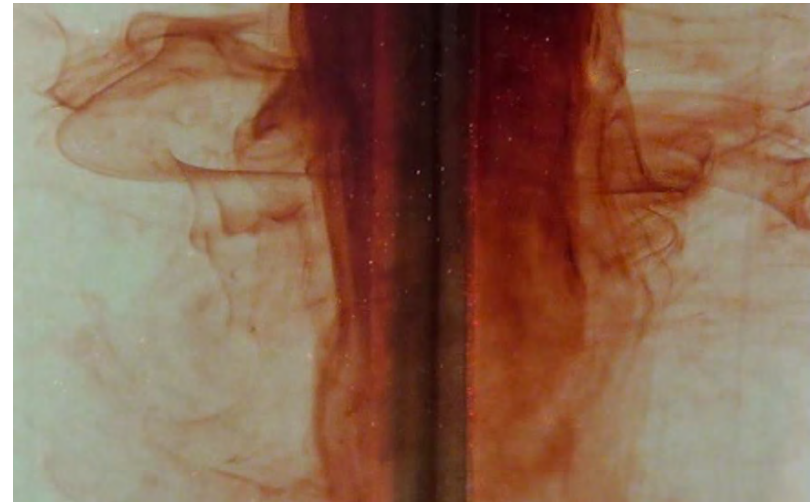




Future plans

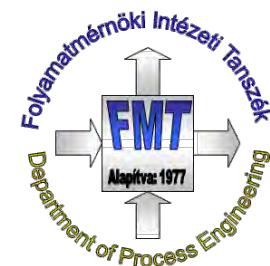


- ▶ Higher revolution speeds
- ▶ Static part attached to the stirred system
- ▶ Multi – impeller systems
- ▶ Continuous systems
- ▶ Model validation





Acknowledgement



This work has been supported in part by the TAMOP-4.2.2/B-10/1-2010-0025 project.

Thank you for your attention!