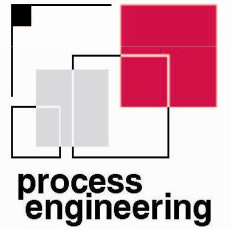


# Validation of Euler-Euler and Euler-Lagrange Approaches in the Simulation of Bubble Columns

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## Introduction

In the pharmaceutical industry bubble column are used extensively for a wide variety of different systems, e.g., catalytic oxidation reactors or shear-sensitive fermentation cultures.

## Objectives

- Computationally study, design and optimize pharmaceutical bubble column reactors.
- Assess the reliability of two different simulation methods for the prediction of the flow in bubble columns.

### Euler-Lagrange LES Model (a)

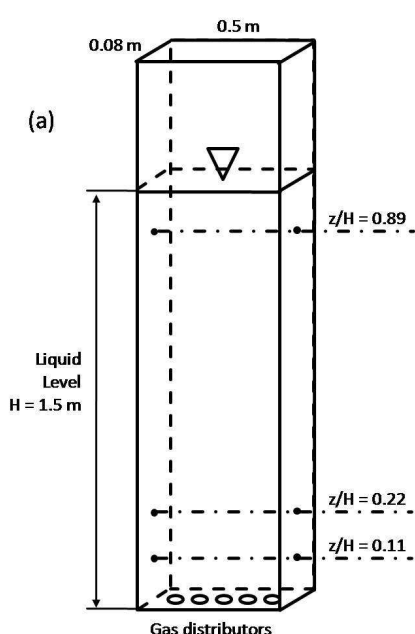
- The filtered Navier-Stokes equations are solved for the continuous phase, i.e., we perform Large Eddy Simulations (LES) on the Eulerian grid.
- Bubbles are treated as discrete particles interacting with the carrying liquid phase (Radl, 2009). The bubble motion is calculated by solving the equations of motion taking into account the gravity, the pressure gradient, the drag, the lift and the added mass force. CFD-package: "OpenFOAM".

### Euler-Euler URANS Model (b)

- Bubbles are transported as a dispersed phase characterized by a bubble-size distribution in each cell of the computational domain. The URANS equations are solved for both phases, considering the exchange of source terms between the liquid and the gas phase (Pfleger and Becker, 2001).
- The turbulence in the liquid phase is resolved by the standard  $k-\epsilon$  model and the advanced  $k-\zeta-f$  model (Hanjalic, 2004). The latter is a three equation turbulence model where the eddy viscosity  $\nu_t$  is related to the velocity scale ratio  $\zeta$ . CFD-package: "AVL FIRE".

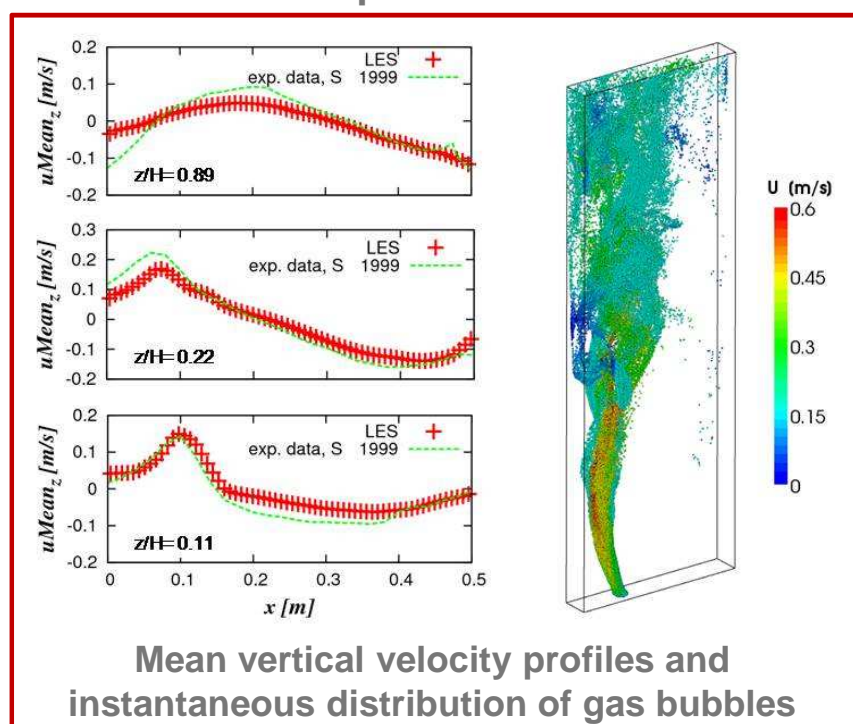
$$\nu_t = C_\mu \zeta \frac{k^2}{\epsilon} \quad \rho \frac{D\zeta}{Dt} = \rho f - \rho \frac{\zeta}{k} P_k + \frac{\partial}{\partial x_j} \left[ \left( \mu + \frac{\mu_t}{\sigma_\zeta} \right) \frac{\partial \zeta}{\partial x_j} \right]$$

## Test case



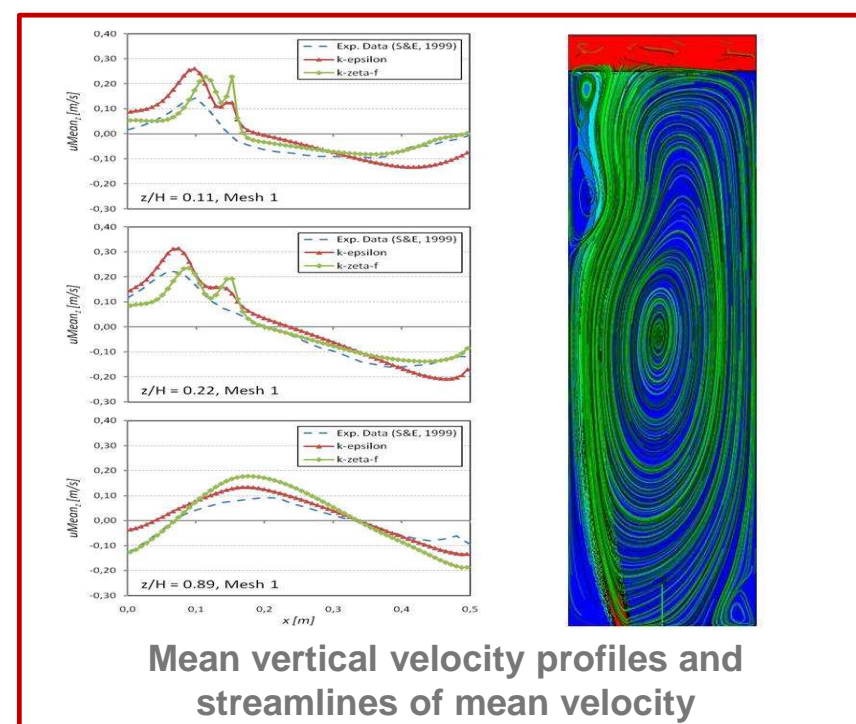
"Becker case"

## OpenFOAM



## Results

## AVL FIRE



## Conclusions

- The Euler-Lagrange LES model produced better results and it may be considered as the most advanced method for the simulation of dispersed multiphase flows.
- Nevertheless, the Euler-Euler calculations with the advanced  $k-\zeta-f$  turbulence model showed promising results on a five-time coarser computational mesh, representing an advantage in terms of computation time and costs for the industrial application.

## References

- Hanjalic, K., Popovac and M., Hadziabdic, 2004, *Int. J. Heat Fluid Flow*, 25, 1047–1051.
- Pfleger D. and Becker S., 2001, *Chem. Eng. Science* 56, 1737-1747.
- Radl S., Suzzi D. and Khinast J.G., 2009, *Chem. Eng. Transactions*, 17, 507-512.