

# Analysis and modelling of liquid phase turbulence kinetic energy equation in bubbly flows via direct numerical simulation

Project *Multi-Phase* : Sponsored by the *BMBF* and coordinated by *Evonik Industries* (Dr. M. Becker)

Multi-scale modeling which allows numerical investigation and optimization of industrial scale multiphase reactors

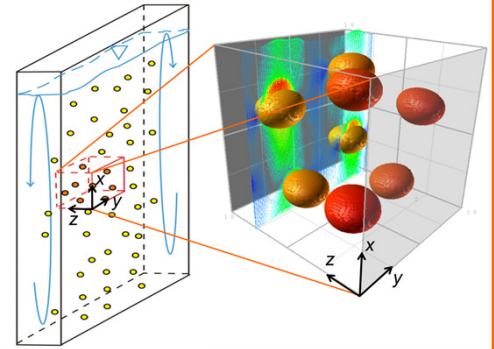
Contribution of KIT in BMBF project: Development of improved turbulence models for bubbly flows by using DNS

- Volume-of-fluid method (TURBIT-VOF)
- Part of a flat bubble column
- Two lateral side walls (z)
- Periodic boundary conditions (x,y)
- Grid independent results (20 cells /  $d_B$ )
- Non-equidistant grid in wall direction (z)
- Morton Number =  $3.1 \times 10^{-7}$

## DNS of bubble swarms

Case	A1	A2	A3*	A4*
Bubbles	5	5	6	5
$\varepsilon$ [%]	2.1	2.1	2.5	2.1
$d_B$ [mm]	1.6	2.0	2.0	3.0
$E\ddot{o}_B$	0.747	1.167	1.167	2.625
$Re_B$	35	55	60	115

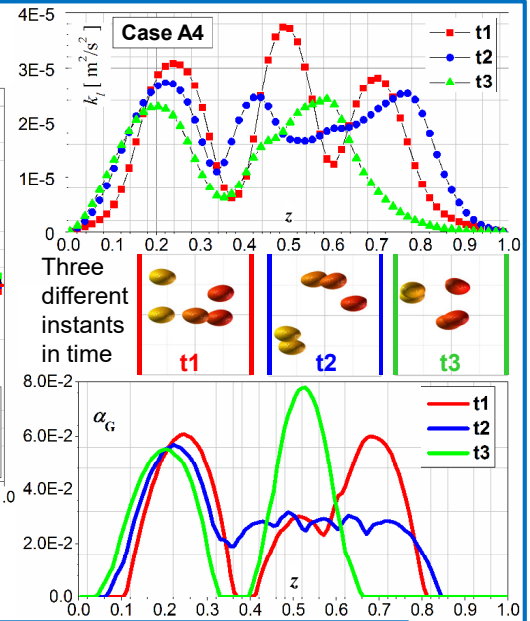
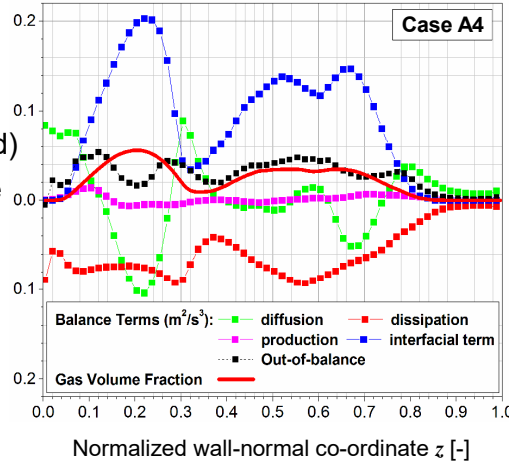
\* Only the results for Case A3 and Case A4 are discussed here



## Evaluation of $k_L$ - equation by using DNS data

### Profile of $k_L$ and budget of $k_L$ transport equation

- Profiles of turb. kinetic energy  $k_L$  and gas void fraction change considerably during simulation
- Budget of  $k_L$  (plane+time averaged)
  - Interfacial term is the main source
  - Production by shear is negligible
  - No local equilibrium between total production and dissipation
  - Diffusion redistributes the surplus of production of  $k_L$  from regions of high to low void fractions
- Closure terms are not in balance



## "Exact" $k_L$ - equation from DNS data

## A-priori testing

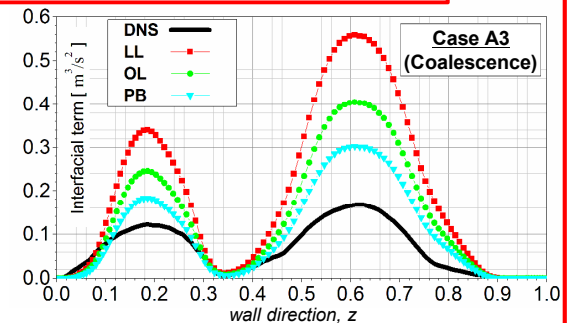
## Closure assumptions from literature

- Models overestimate the DNS data
- For better comparison: Drag coefficient of Tomiyama et al. (1998) will be used
- Other closure terms shall be tested (especially diffusion term)

Models for interfacial term*	$C_D$
LL	$W_D$ $2/3(E\ddot{o}_B)^{0.5}$
OL	$0.75W_D$ $2/3(E\ddot{o}_B)^{0.5}$
PB	$(1-\alpha_G)1.44W_D$ 0.44

\* LL: Lopez de Bertodano et.al. Int J Multi.Flow, 1994.

OL: Olmos et.al. CES, 2003. PB: Pflieger & Becker. CES, 2001.



Improved models validated by using DNS data

## A-posteriori testing

Euler-Euler simulations with OpenFOAM

Implementation of improved models in Open FOAM

Validation by experimental data for various scale bubble columns