**Euler-Euler Simulation of Bubbly Flow in Stirred Tanks**

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**Highlights**

* A previously established baseline model for bubbly flow is applied to stirred tanks.
* One extension found necessary is the use of a Reynolds stress turbulence model.
* A second one is a correction factor to describe turbulence effects on drag.
* Good agreement is found for a comprehensive dataset from different literature sources.

**1. Introduction**

Aerated stirred tanks are frequently used equipment in industries ranging from chemical engineering and biotechnology to minerals processing. In principle, CFD simulation of such equipment on industrial scales is feasible within the Euler-Euler framework of interpenetrating continua. Practical application, however, requires suitable closure models to account for phenomena on the scale of individual bubbles, which are not resolved in this approach. Validation of such models is the purpose of the present contribution.

**2. Methods**

Starting point for the investigation is a baseline closure model that has previously been used in a large number of CFD studies on bubbly pipe flows and flow in bubble columns [1]. The model comprises drag, lift, wall, virtual mass and turbulent dispersion forces. Previous work from other researchers has shown that due to the high levels of turbulence in stirred tanks, a modification of the drag force is required [2], which is included in the present simulations. For the liquid turbulence an isotropic k-ω SST model has been adopted in the baseline model, however, it turned out that only rather poor agreement with experimental could be achieved for stirred tanks. To overcome this, two common variants of anisotropic Reynolds stress models are applied due to Launder, Reece, and Rodi (LRR, [3]) and Speziale, Sarkar, and Gatski (SSG, [4]). Correspondingly, anisotropic source terms modeling the bubble-induced turbulence are used [5].

**3. Results and discussion**

To validate the model, a database is accumulated from different literature sources, which comprises measurements of gas fractions and average velocities data relating to fluctuating velocities such as turbulent kinetic energy or Reynolds stress. In addition, information on the bubble size is needed, which appears in virtually all sub-models. For the present purpose the average value suffices since only monodisperse simulations will be performed. Extensive study of numerical parameters has been undertaken such as grid-size, time-step and location of the boundary between rotating and fixed domains. Comparison between simulation and experiment for singlephase flows shows that mean velocities are captured well by the Reynolds stress models but turbulent fluctuations tend to be somewhat underpredicted. For the multiphase flows, the peak in radial mean velocities is underpredicted by the turbulence k-ω SST model (Figure 1a), which neglects the anisotropic effects, and the axial component of mean gas velocity is too small if the turbulent modification of the drag force is omitted (Figure 1b). If both effects are taken into account, similar agreement is obtained between simulation and experiment as for the singlephase flows. A detailed account of the results has been given in [6].



gas axial velocity

at $2r/D\_{t}=0.85$

liquid radial velocity

at $2r/D\_{t}=0.85$

**Figure 1.** Comparison between simulations using different models (red: k-ω SST model without drag correction, green: k-ω SST model with drag correction, blue: SSG model with drag correction) and experiments (symbols) from [7].

**4. Conclusions**

With the modification factor for the drag force due to [2] and a Reynolds stress model with anisotropic source terms modeling the bubble-induced turbulence [6] reasonable agreement with the experimental data can be achieved. A slight preference for the SSG over the LRR turbulence model is identified. Concerning further model development, improvement of the BIT modeling appears most promising to improve the model predictions. The development of better models should be accompanied by the acquisition of improved experimental data for model validation. In particular the availability of mean liquid and gas velocities, turbulent fluctuations and gas fractions for the same configuration would be very beneficial to interpret the simulation results.

**References**

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