Numerical study of the generation and dispersion of a bubble jet in microgravity

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Recently, a first series of drop tower experiments was conducted, which proved the excellent performance of a new method of generation of monodisperse microbubble suspensions in microgravity.

Results are relevant for a large variety of systems which may exploit the enhanced efficiency of biphase flows in space technology.

The experimental system allows also to address a number of basic questions concerning the collective dynamics of bubbles.

Drop number 1: \( Q_1 = 0.69 \text{ ml/s}, \ Q_g = 0.27 \text{ ml/s} \)

\[ \mu g, t = 0.24 \text{ s} \quad \mu g, t = 0.76 \text{ s} \]
Theoretical approach

We represent the turbulences using the standard $k-\varepsilon$ model.

The dispersion of bubbles are represented with a scalar magnitude $P$ (the probability density of bubbles) which is diffused within the jet by means of a diffusivity factor of the same magnitude than that of $k$.

**Standard $k-\varepsilon$ model**

\[
\frac{\partial (\rho k)}{\partial t} + \nabla \cdot (\rho k \mathbf{U}) = \nabla \cdot \left[ \left( \mu + \frac{\mu_t}{\sigma_k} \right) \nabla k \right] + 2\mu_t E_{ij} \cdot E_{ij} - \rho \varepsilon \\
\frac{\partial (\rho \varepsilon)}{\partial t} + \nabla \cdot (\rho \varepsilon \mathbf{U}) = \nabla \cdot \left[ \left( \mu + \frac{\mu_t}{\sigma_\varepsilon} \right) \nabla \varepsilon \right] + C_1 \varepsilon \frac{\varepsilon}{k^2} 2\mu_t E_{ij} \cdot E_{ij} - C_2 \rho \frac{\varepsilon^2}{k^2} \\
\mu_t = \rho C_\mu \frac{k^2}{\varepsilon} \\
C_\mu = 0.09; \sigma_k = 1.00; \sigma_\varepsilon = 1.30; C_1 = 1.44; C_2 = 1.92
\]

**Probability density $P$ of bubbles**

\[
\frac{\partial P}{\partial t} + \nabla \cdot (UP) = \nabla \cdot \left[ \frac{k^2}{\varepsilon} \nabla P \right]
\]
Results and Conclusions

Good qualitative agreement with experimental results

Numerical results show that nonhomogeneous diffusivity is necessary to have realistic patterns of bubble dispersion.

We also find that the local diffusivity of bubbles is of the order of that of the kinetic energy of turbulences, which scales as $k^2/\varepsilon$, and that diffusion and advection are quantitatively comparable.

We conclude that the proposed stochastic model for bubble dispersion based on the $k$-$\varepsilon$ model of turbulence with local diffusivity is a proper description of experiments.