

HYDRODYNAMICS OF GAS BUBBLING THROUGH ORGANIC LIQUIDS

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Summary The bubble diameter values were calculated from theoretical model. The model has been based on the original approach by Prince and Blanch. It assumes an equilibrium between the coalescence and redispersion processes, and uses a simplified method of solution of the population balance equations. The experiments were carried out with different organic liquids in two bubble columns. A numerical experiment enabling simple calculation of the influence of the properties of liquids on the bubble size is presented.

Bubbling of a gas through a layer of liquid is frequently used for contacting the two phases. It is widely applied in chemical, pharmaceutical and food industries, as well as in biotechnology and environmental protection.

Most of the experimental work described in the literature was carried out with air–water system, at ambient temperature and pressure. For this reason extrapolation of the existing correlations to non-aqueous liquids and/or elevated temperature or pressure is always risky. Only recently a general theoretical approach has been attempted by several workers([1], [2]).

The present work has the following aims:

- to develop a general theoretically based description of the process;
- to verify the proposed model for a wide range of temperature and pressure, using different gas-liquid systems and equipment of different scale;
- to use the verified model for a numerical experiment, enabling simple calculation of the hydrodynamic parameters of gas bubbling through liquids in various conditions.

To achieve the above aims a research program has been carried out, comprising the development of a theoretical model and its experimental verification. The model has been based on the original approach by Prince and Blanch [1]. It assumes an equilibrium between the coalescence and redispersion processes, and uses a simplified method of solution of the population balance equations. The experiments were carried out with different organic liquids in two bubble columns:

- a glass laboratory column 9 cm diameter and 200 cm high with different gas distributors (porous gas distributor and spargers with holes) operated at atmospheric pressure and low temperature, with seven liquids: acetaldehyde, acetone, cyclohexane, isopropanol, methanol, n-heptane and toluene.
- a stainless steel pilot plant column 30.4 cm diameter and 400 cm high (gas distributor – spargers with holes) operated at elevated pressure (up to 1.1 MPa) and temperature (up to 160°C), with cyclohexane as a liquid.

The measurements have been carried out at different heights from the sparger and for a range of gas velocities, in the homogenous flow regime. The bubble diameters were measured by photographic method, with at least 500 bubbles measured for each experimental point. It has been established that in the dynamic equilibrium region the bubble size distribution was independent of both the axial and the radial position in the column.

Very good agreement of the calculated and experimental data has been found. The agreement is better than that between the experimental values of the average bubble size and those obtained from the existing correlations (see Figs. 1 and 2).

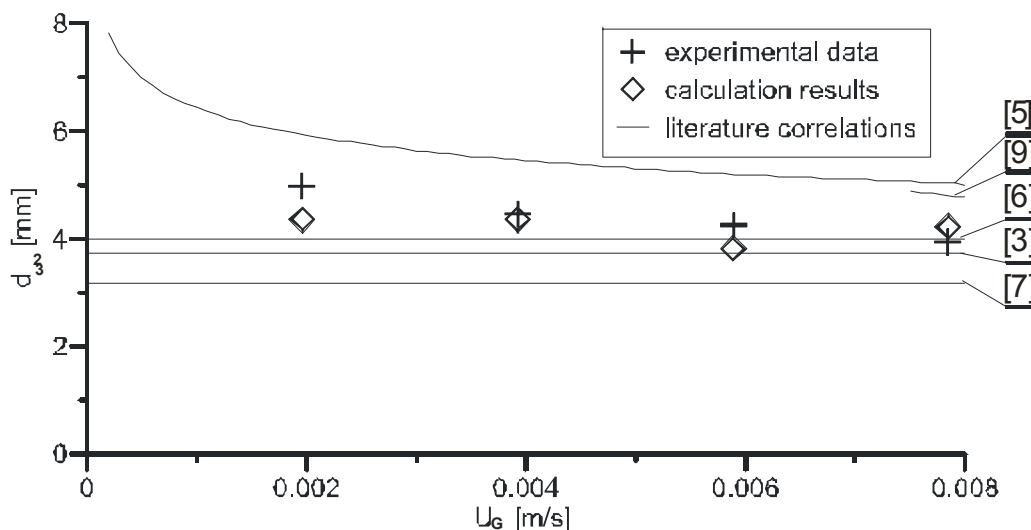


Fig.1 Dependence of the Sauter bubble diameter on the saturated gas superficial velocity for the air – toluene system (laboratory column).

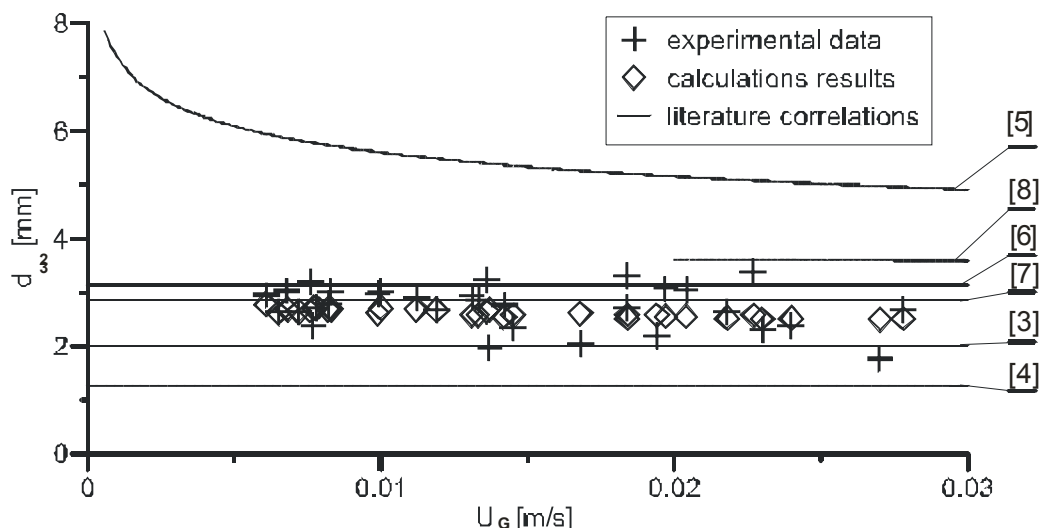


Fig.2 Dependence of the Sauter bubble diameter on the saturated gas superficial velocity for the nitrogen-cyclohexane system (pilot plant column, $t=160^{\circ}\text{C}$; $P=1.0\text{ MPa}$).

A numerical experiment has been carried out find a theoretically sound correlation relating mean bubble diameter in the main section of the bubble column with the liquid physicochemical properties (density, viscosity, surface tension), and the superficial gas velocity. A correlation has been proposed in an approximate, dimensionless form:

$$Fr = A \cdot \left[\frac{u_G^4 \cdot \rho}{g \cdot \sigma} \right]^{\frac{1}{2}}$$

where: A – constant,
Fr – Froude number,
g – gravity acceleration,
 u_G – superficial gas velocity,
 ρ – density,
 σ – surface tension.

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