Homogenization Time and Axial Dispersion in Bubble Column

Mark Terentyak[1, 2*], Sandra Orvalho[1], Pavel Zeman[1,2], Mária Zedníková[1, 2]

1 Czech Acad Sci, Inst Chem Proc Fundamentals, Res Grp Multiphase Reactors, Prague, Czech Republic;

2 University of Chemistry and Technology, Prague, Czech Republic

**Corresponding author: terentyak@icpf.cas.cz*

Highlights

- Heterogeneous flow regime in bubble column
- Homogenization time and axial dispersion obtained
- Relation between gas holdup and gas and liquid hydrodynamic conditions

1. Introduction

Bioreactors, like bubble columns, are important tool of biotechnology which gives us many useful and essential products for our daily life, for example food and pharmaceutics. Cell culture used in these processes often require steady supply of oxygen, thus controlled aeration and homogenization is necessary [1]. However, aeration requires very precise setup, otherwise cells can die of oxygen starvation or whole process will not be economical. In order to control the oxygen mass transfer, the interlink between the liquid hydrodynamics and mass transfer coefficient needs to be characterized. Present contribution aims to study the liquid hydrodynamics in bubble column operated under heterogeneous flow regime (namely homogenization time and axial dispersion coefficient). Obtained results will be applied to model the mass transfer in bubble column operated under non-ideal flow conditions.

2. Methods

Experiments were carried out in bubble column with diameter 0.19 m. Distilled water was used as liquid phase and air as gas phase. Tested aspect ratios (ratio of liquid free height and column diameter AR) ranged from 3.0. to 6.0 (free liquid height 0.57 to 1.14 m). Perforated plate was used as gas distributor generating heterogenous flow regime [2]. Tested superficial gas velocities (u_s) were in range 0.02 – 0.20 m/s. Gas holdup (ε_G), volumetric fraction of gas in gas-liquid dispersion, was obtained from measurement of level increase during aeration. Homogenization time t_{95}, time necessary to reach 95 % of homogeneity in liquid, was measured via colorimetric method. Process was visualized via bromothymole-blue and solutions of HCl and NaOH were used as tracers. Whole process was recorded on camera and t_{95} was calculated via image analysis. Axial dispersion coefficient D_a was determined by tracing experiment with multiple conductivity probes, each placed at different height. Solution of KCl was used as a tracing agent. Time profile of tracer concentration was fitted by a model with D_a as fitted parameter [3].

3. Results and discussion

Obtained results provide significant influence of aspect ratio and gas flow rate on all measured quantities, gas holdup, homogenization time and axial dispersion coefficient. Based on data analysis, correlation between dimensionless mixing time t_{95}' and ε_G was developed (see equation for ε_G in Fig. 1). The shape of correlation follows from the drift flux model developed for heterogeneous flow regime in bubble column [2]. The model assumes the upward bubble advection in the central part of the column and the gas hold up is given mainly by these bubbles. Present correlation is modified to consider the dimensionless mixing time t_{95}' which is related to the liquid mixing time t_{95}, superficial gas velocity u_s and overall dispersion height H ($t_{95}' = t_{95} \cdot u_s/H$).

Data for axial dispersion D_a were also correlated with gas holdup using the equation shape following the drift flux model of bubbles [2] (see equation for ε_G in Fig. 2). The dimensionless parameter used in the correlation is the modified Peclet number relating the gas convection and liquid axial dispersion

($Pe = H \cdot u_s / D_a$). Both correlations include the empirical constants, which were obtained by fitting the experimental data.

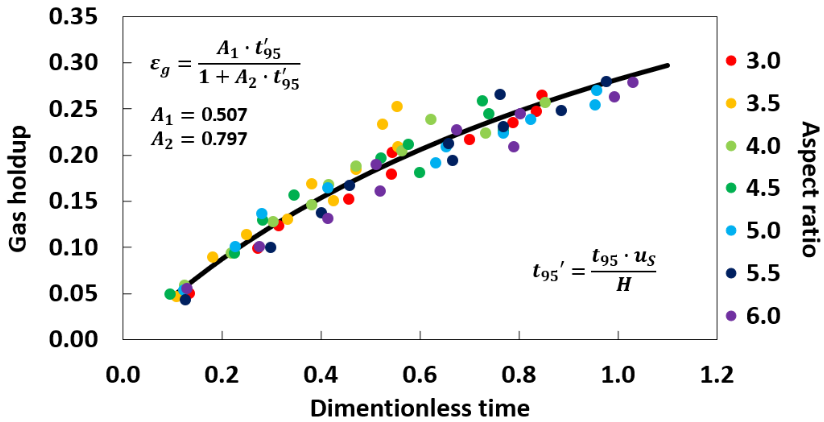

Figure 1. Correlation between gas holdup and dimensionless homogenization time

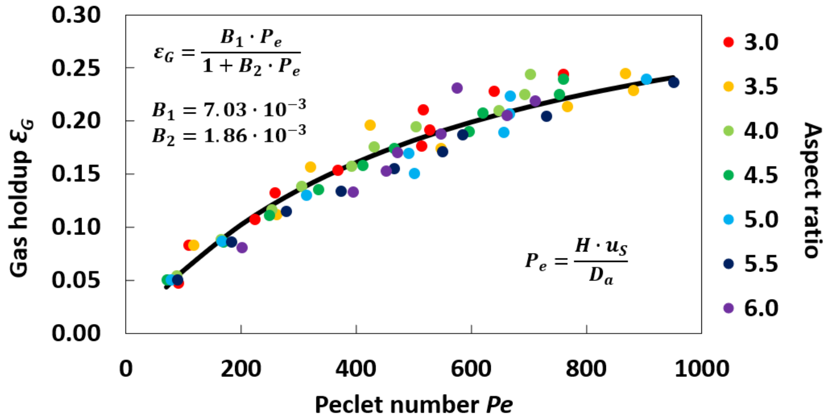

Figure 2. Correlation between gas holdup and Peclet number

4. Conclusions

Homogenization time and axial dispersion coefficient were experimentally obtained in bubble column operated under heterogeneous flow regime. These quantities were used to develop new correlations characterizing the relation between the gas holdup and both gas and liquid hydrodynamic conditions in bubble column. Results will be used to model the mass transfer in bubble column assuming the real liquid mixing.

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Keywords

Bubble column; homogenization time; axial dispersion coefficient; gas holdup