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SHORTER COMMUNICATIONS

ON THE EVALUATION OF "LIQUID FLUCTUATING VELOCITY" DURING BUBBLING OF GAS THROUGH A LIQUID

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NOMENCLATURE

- H, plexiglass cylinder height [cm];
- l, electrode length [mm];
- $\overline{W}_c$, mean liquid fluctuating velocity [cm/s];
- α, void fraction;
- ϕ, plexiglass cylinder diameter [cm];
- ϕ_e electrode diameter [mm].

INTRODUCTION

IN THIS paper are reported some particular results of experiments carried out to evaluate the "liquid fluctuating velocity" in two phase systems (air–liquid), at zero flow-rate of the liquid phase. It is known that the "liquid fluctuating velocity" is a kinematic quantity characterizing the agitation induced in a liquid by an ordered flow of gas bubbles. Data obtained are compared with those reported by Malkus–Zuber and Konsetov in their theoretical studies of the phenomenon.

Tests were performed providing a rather uniform distribution of the gas phase in the liquid; measurements of the most significant variables affecting the flow regime—such as air flow rate, bubble size and rise velocity—have been made in different test conditions.

The experimental apparatus is schematically represented in Fig. 1. Air is bubbled into the liquid contained in a vertical Plexiglass cylinder (ϕ = 9·5 cm, H = 200 cm) through a rubber sparger base; flow issues from three nozzles placed symmetrically about the cylinder axis at the vertices of an equilateral triangle. The gas flow-rate of each orifice can be measured and kept constant during the tests. Mean "void fraction" values, at different flow regimes in the column, are evaluated by the level displacement method.

The liquid phase velocity fluctuations, induced in the system by the stirring action of the gas bubbles, are detected by a probe introduced into the liquid through the container wall. Owing to the small velocity fluctuations occurring in the system, a high sensitive detector was required; an electrolytic flowmeter has been found suitable. This probe consists essentially of two parallel platinum electrodes (ϕ_e = 0·5 mm; electr. spac. = 0·5 mm; l = 7 mm) through which a d.c. current of 1 μA was kept constant by a constant current supply. For a more detailed description of this detector, and of its performance principles, see notes [1], [2], The probe signal was detected with a digital high impedance voltmeter connected to a data logger set. Amplitudes of the "liquid fluctuating velocity" can be determined by comparison of the probe signals, obtained from the tests, with those obtained during the calibration of the measurement apparatus in a suitable channel. The velocity measurements were performed traversing, with the measuring

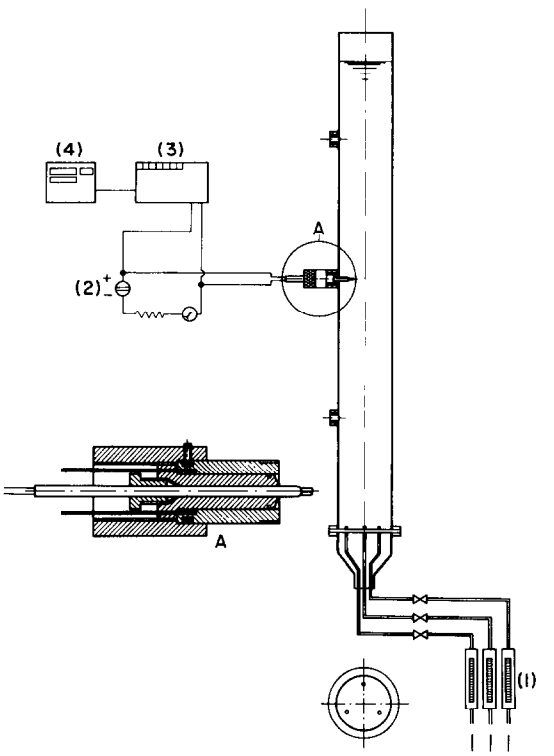

FIG. 1. Experimental apparatus. A: Movable probe; (1) Air flow-meters; (2) Constant current supply; (3) Digital voltmeter; (4) Data logger.

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probe, some cross-sections of the tube, far downstream from the nozzle region, where an isotropic turbulent regime has been previously found in the liquid phase.

The experiment results show that the liquid velocity fluctuations occur, in the steady state, around a velocity value which is highly influenced by the number of bubbles present in the unit volume. The magnitude of this velocity, $\overline{W}_c$, has been calculated as root-mean-square value of the data recorded on a printer at the sampling rate of 1 reading per s, in a time interval of about 5–10 min for each test. This characteristic velocity $\overline{W}_c$ can be assumed as the representative quantity for the liquid agitation, at the different flow regimes.

Data obtained are shown in Fig. 2, where the mean values $\overline{W}_c$ of the liquid velocity amplitude are plotted as a function of the "void fraction" values α. The experimental data show that the mean liquid agitation increases with increasing void fraction, and moreover, that its characteristic velocity amplitude is relatively small, even at the highest occurring values of α.

The bubbles rise velocities obtained by cinematographic method in the same field of "void fraction" values, ranged from 25 to 31 cm/s.

It seemed of some interest to compare our experimental results with the values obtained from the Malkus–Zuber analysis. Zuber [3], in his evaluation of the dynamic effect produced on a boiling liquid by steam bubbles, extends to a two-phase system the method of analysis previously presented by Malkus [4] in his studies on the convective motions in monophase systems. Malkus–Zuber relation is reported by a full-line on Fig. 2, as a function of α.

In the same Fig. 2 is as well represented a new relation proposed in a recent note [5] by Konsetov for the evaluation of the liquid fluctuating velocity in terms of the "void fraction".

From the results and comparisons presented, we may conclude that the values predicted by the analysis are in qualitative agreement with our experimental data; the agreement with the Malkus–Zuber's relation seems to be the most significant, and this fact can be in some way justified by a comparative examination of the assumptions on which are based their calculations.

Finally it seems to the Authors that the above mentioned qualitative agreement gives a full significance to the assumption of the $\overline{W}_c$ velocity, as a criterion for the evaluation of the agitation produced in a liquid by a gas bubble flow.

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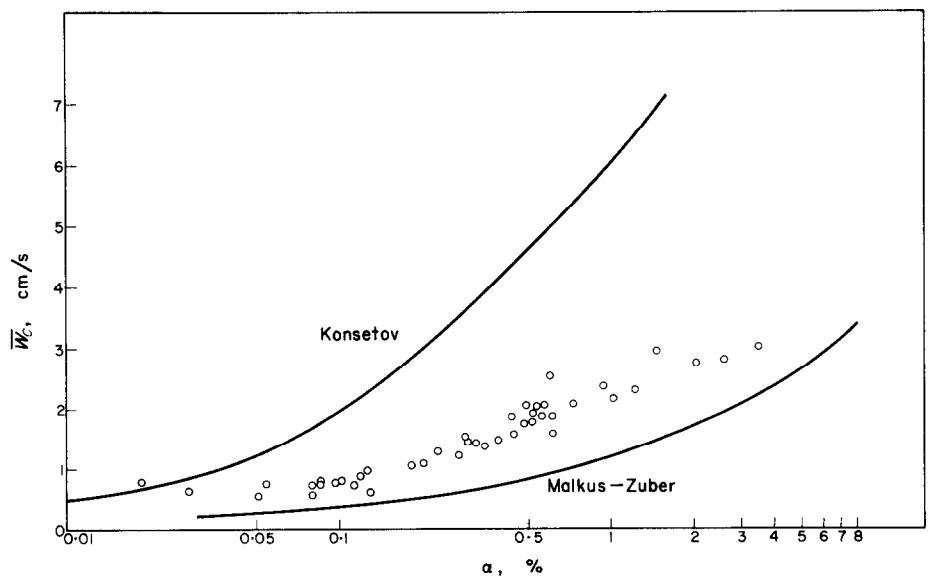

FIG. 2. Comparison of experimental data of mean fluctuating velocity, with predicted values of Malkus–Zuber and Konsetov.