Axial Dispersion Coefficient Measurement in Two-Phase Flow

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By using a tracer technique to measure liquid-phase velocity profiles in vertical cocurrent air-water flow (*1*) it was found possible to calculate liquid-phase axial dispersion coefficients through suitable analysis of the resulting pulse response. Because of limitations of the equipment and the measurement technique, a complete treatment was not possible. Despite this fact, we feel that the results are of interest.

The experimental system is a closed loop consisting of two 10 ft. vertical sections of 3 in. pipe, a crossover joining the two pipes at the top, and a pump at the bottom to circulate air-water mixtures around the loop. Since it is a closed loop, the equipment provides bubbly flow simultaneously in cogravity and counter gravity flow. Electrical conductivity probes placed at known radial and axial positions in the vertical section of the loop made possible the monitoring of electrical conductivity at two points within the loop. This made possible the use of an arbitrary pulse for determining axial dispersion coefficients as described by Levenspiel and Bischoff (*2*). The conductivity-time curves were converted into concentration-time curves through a calibration of the equipment with known salt solution.

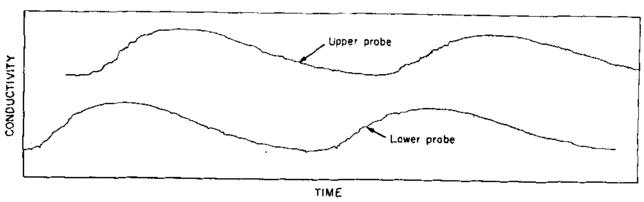
In order to perform experiments in two-phase flow at known values of void-fraction, the system was filled to the desired level with water, allowed to run for five minutes, and pulsed at the top of the downflow leg with 200 ml. sodium chloride solution. Typical outputs of the recorder are shown in Figures 1 and 2. Figure 1 is a record made in one-phase flow while Figure 2 is a record made with an overall void-fraction of 30%. The broadness of even the early deflections is due to the action of the pump. The Figures do not show all of the deflections recorded for one pulsing of the apparatus; the upper section of the figure shows the deflection just after the pulse has been introduced and the lower section shows the deflections just before the pulse has become completely mixed with the water originally in the system. Actually, there were about 20 sets of deflections for each pulse introduced.

It was noted that the deflections become flatter and wider as time proceeds. This is to be expected since the pulse is becoming more mixed with the water with each circulation around the loop. As the pulse becomes wider and wider, it is finally spread throughout the experimental loop. In many runs the overlapping of pulses could be noticed on the second and third pulse. For this reason, only the first three pulses, which were the sharpest were analysed.

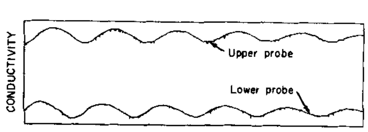
In comparing the one-phase with the two-phase record, it is observed that the one-phase record shows a much smoother conductivity vs. time curve. The dips in the two-phase record are due to the presence of air bubbles in the system.

Axial dispersion coefficients were calculated for each point across the tube radius at which conductivity-time curves were recorded using the formula $\Delta\sigma^2 = 2/N_{Pe}$.

Because the tail of the concentration-time curve is the most important part of the curve, some treatment was necessary before the dispersion coefficient could be calculated. It is also the least accurate due to overlap of the successive deflections recorded. A popular method for treating the tail was suggested by Levenspiel and Sater (*3*). In this method, the tail of the concentration-time curve is assumed to behave as an exponential decay. This assumption is based on the fact that the response of an open system to a perfect pulse input has a tail corresponding to an exponential decay. This method proved unsatisfactory since it yielded negative dispersion coefficients in some cases, which is probably due to the fact that our system was a closed system and the method was postulated for open systems. The method used by us was to plot the natural logarithm of the time from the time a deflection

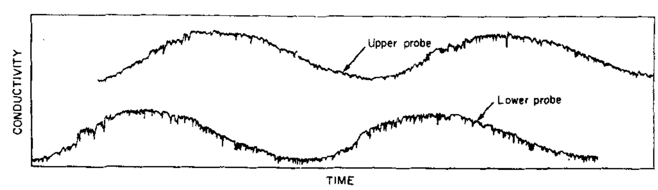


Deflections recorded just after introduction of pulse. Chart speed = 25 mm/sec.

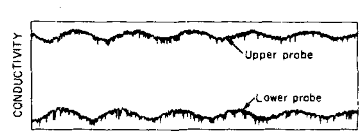


Deflections recorded just before pulse completely mixed with water in system Chart speed = 5 mm /sec

Fig. 1. Recording of single-phase flow experiment in upflow.



Deflections recorded just after introduction of pulse Chart speed = 25 mm./sec. Void-fraction 30%.



Deflections recorded just before pulse completely mixed with water in system Chart speed = 5 mm./sec. Void-fraction 30%.

Fig. 2. Recording of two-phase flow experiment in upflow.

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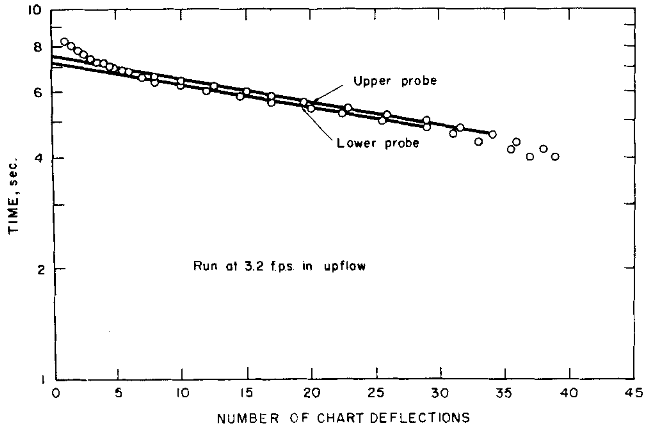

Fig. 3. Treatment of electrical conductivity curves.

was noted on the first probe vs. the chart deflection. When this plot is made, the tail of the curve falls on a straight line, with the exception of the very end of the curve. The straight line is drawn with the last points falling off the line and extrapolated to zero deflection. This treatment approximated the tail of the curve very well even though we can not justify it theoretically (see Figure 3). Typical dispersion coefficients calculated using this tail of curve approximation are shown in Table 1. Complete data tables may be found in reference *1*.

We believe that the measurement technique could be of value in studying two-phase systems.

TABLE 1. LIQUID PHASE AXIAL DISPERSION COEFFICIENTS IN UPFLOW

Void fraction	Avg. liquid velocity ft./sec.	axial dispersion coef. sq.ft./sec.
10%	6.2	2.0
20%	6.2	2.0
30%	6.2	2.7
10%	3.2	0.23
20%	3.2	0.18
30%	3.2	0.30

ACKNOWLEDGMENT

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NOTATION

σ^2 = second moment about the mean
N_{Pe} = Peclet Number

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Some Remarks on the Stability of Parallel of Non-Newtonian Fluids

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STABILITY OF PLANE POISEUILLE FLOW

The part played by viscoelasticity in contributing towards drag reduction and related phenomena in the turbulent flow of viscoelastic liquids has been investigated experimentally by many authors. The concensus of opinion is that viscoelasticity is a dominant factor, while the variation of apparent viscosity with rate of shear assumes a secondary role. Accordingly, a stability analysis was carried out by Chan Man Fong and Walters (*1*) for plane Poiseuille flow to determine what effect elasticity had on the stability criterion. They found that, according to infinitesimal disturbance theory, elasticity destabilizes the flow. This appears to be in agreement with some experimental results (*2* to *4*), but not with others (*5*, *6*). In fact, extreme values of the critical Reynolds number have been found to range from 1 to 6,000.

One possible reason for the apparent discrepancy between the various experimental studies may be that the non-Newtonian viscosity of the elastic liquids has a larger effect than was supposed in the case of the more concentrated polymer solutions.

In order to clarify this point, a stability analysis was carried out (*7*) for a third-order fluid which exhibits a variation in viscosity with rate of shear in simple shear. The analysis of Chan Man Fong and Walters (*1*), was carried out for what was essentially a second-order fluid in the sense of Coleman and Noll (*8*), and the extension of this work to the third-order fluid would appear to be the next step towards resolving the present dichotomy (*9*). Some justification for using the order constitutive equations in what is called an *unsteady* flow problem can be obtained a posteriori from a detailed comparison of