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BRIEF COMMUNICATION

THE EFFECT OF THE SIDE ARM DIAMETER ON THE TWO-PHASE FLOW SPLIT AT A "T" JUNCTION

B. J. AZZOPARDI
Engineering Sciences Division, AERE Harwell, Didcot, Oxon, England

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1. INTRODUCTION

Branches, such as T junctions, occur in many types of process plants and water cooled nuclear reactors. It is often important to know the split of two phase flow at such junctions. However no general method exists for calculating the quality in the side arm or the main outlet tube (for a given quality in the inlet tube). The simple assumption that the qualities in the outlet tube and side arm are equal and therefore equal to the quality of the inlet tube can be very far from the truth. Moreover the deviations can favour either phase entering the side arm. Some examples are shown in figure 1.

Recently, Azzopardi & Whalley (1982) have put forward a model which permits prediction of the flow split for annular flow. They suggest that the liquid taken off through the side arm comes from the film on the main tube wall. This occurs because the liquid in the film has a momentum flux similar to the gas and both are relatively easily diverted. In contrast the entrained drops, which have a much higher momentum, are not easily diverted. Azzopardi & Whalley also suggest that the part of the gas and liquid film, which are taken off, both come from the same segment of the main tube. The model can be applied to both vertical and horizontal annular flows; in the latter case the circumferential

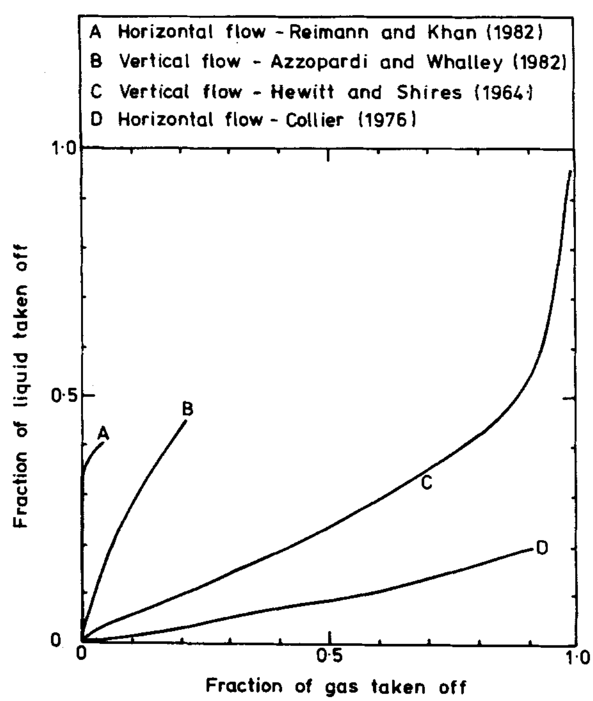

Figure 1. Examples of two phase flow split at a "T" junction.

distribution of film flow rate must be known, as the amount of liquid taken off is determined by integrating the film flow rate over the appropriate segment.

For other flow patterns the momentum profiles for the phases will differ from those for annular flow. Therefore the above model would not expect to apply. In these cases the alternative approaches suggested by Azzopardi & Baker (1981) for bubbly flow and Saba & Lahey (1982) for high flux churn flow should be considered.

In the experiments of Azzopardi & Whalley a small but systematic difference could be seen between data from different side arm diameters. The present work has extended the study to diameter ratios of 0.8 and 1.0 (thus giving a range from 0.2 to 1.0). The data is then used to provide a correcting term to the model of Azzopardi & Whalley. Some trends in the results of other workers are also explained by means of this correction.

2. EXPERIMENTAL ARRANGEMENT

The experiments were performed in a vertical tube, the length between the point where the air and water were mixed and the "T" junction was 4.3 m. The pressure at the "T" junction was maintained at 1.5 bar. The air and water were mixed by a porous wall device: the air flowed up the tube and water passed through the sinter to form a film on the walls of the tube.

The "T" junctions used were machined out of blocks of acrylic resin, as in the previous experiments reported by Azzopardi & Whalley (1982). The actual junction area was not rounded in any way, and so the "T"s used were as square edged as possible. The air and water entering the side tube were separated in a cyclone, the air flow measured by a gas meter and water flow were measured by weighing timed efflux. For each flow condition in the main tube, the total flow rate in the side tube was gradually increased until the air velocity in the side tube was of the same order as the air velocity in the main tube.

3. RESULTS AND DISCUSSION

The results of the flow splits obtained in the present work have been analysed together with those previously reported by Azzopardi & Whalley (1982). The data for one inlet flow rate are shown in figure 2, where an obvious but not always clean cut trend of diameter ratio can be seen. Like the appropriate part of the previous data, the latest results, which are all for annular flow, can be well described using the concept that only liquid flowing as a film on the wall is diverted into the side arm. Moreover, the angular portion of the liquid film that is diverted and the gas that is taken off are taken to both come from the same segment of the main tube. However an examination of the full set of data, with its wide range of diameter ratios, shows that there is a systematic variation with diameter ratio. The larger the diameter ratio the greater the take off. This result should not be surprising as one of the main effects of the side arm diameter is to control the axial distance over which take off is possible. Therefore for small diameter side arm parts of the liquid film which might have been dragged across to the side arm by the gas being taken off only arrive at the appropriate part of the tube wall after they have passed the side arm opening and are not taken off. Visual inspection of the data indicates that the effect of diameter ratio (d_s/d_t) is approximated by:

$$\frac{\theta}{\theta'} = 1.2\left(\frac{d_s}{d_t}\right)^{0.4} \qquad [1]$$

θ is the angle over which the film is taken off ($2\pi G_{\mathrm{LTO}}/G_{\mathrm{LF}}$), where G_{LTO} is the flow rate of liquid taken off through the side arm and G_{LF} is the flow rate of liquid travelling as

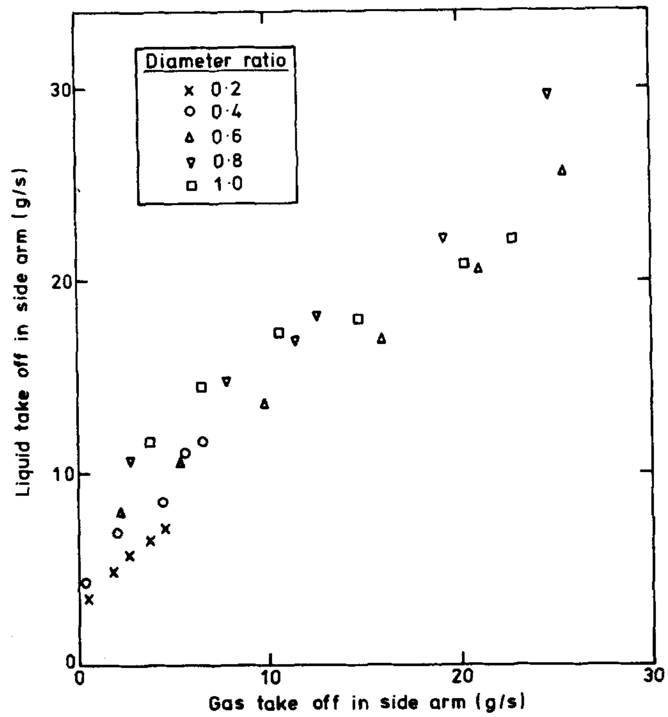

Figure 2. Effect of diameter ratio on take off at a side arm ($G_G = 55.6\ \mathrm{kg/m^2s}$, $G_L = 79.4\ \mathrm{kg/m^2s}$).

a film on the walls of the main channel. θ' is the value of the angle determined from the concept that the liquid taken off and the gas taken off both come from the same segment of the tube. The relationship between these two quantities is given by the equation suggested by Azzopardi & Whalley:

$$\frac{G_{GTO}}{G_G} = \frac{1}{2\pi}(\theta' - \sin\theta') \qquad [2]$$

where G_{GTO} is the flow rate of gas taken off through the side arm and G_G is the flow rate of gas in the main tube. These two equations have been used to predict the amount of liquid taken off for each gas take off condition and the results are plotted against the experimentally obtained liquid take off values in figure 3. Most of the data can be predicted to within $\pm 30\%$, and it is only data from very high inlet qualities that deviates significantly. These data tended to deviate even within one side arm diameter group.

Zetzmann (1982) has recently reported data which shows at least qualitatively a similar trend of flow split with diameter ratio. Results for identical conditions show that for a diameter ratio of 0.5 less liquid is taken off than for the corresponding case with a diameter ratio of 1.0. His data have not yet been analysed in the above manner so that the agreement cannot be quantified any further. In addition, he has obtained data for which the conditions are the same but the junctions differ only in the angle between the main tube and the side arm. Obviously under these conditions axial length increases as the angle between the tubes decreases from the 90° value. In one example, Zetzmann data for liquid taken off at 90° and at 45° are in the ratio 0.85. Substitution of the actual axial length of the side arm junction for side arm diameter in [1] give a value for this ratio of 0.87. This provides some support to the suggestion that it is the axial length of the side arm that affects the amount of liquid taken off.

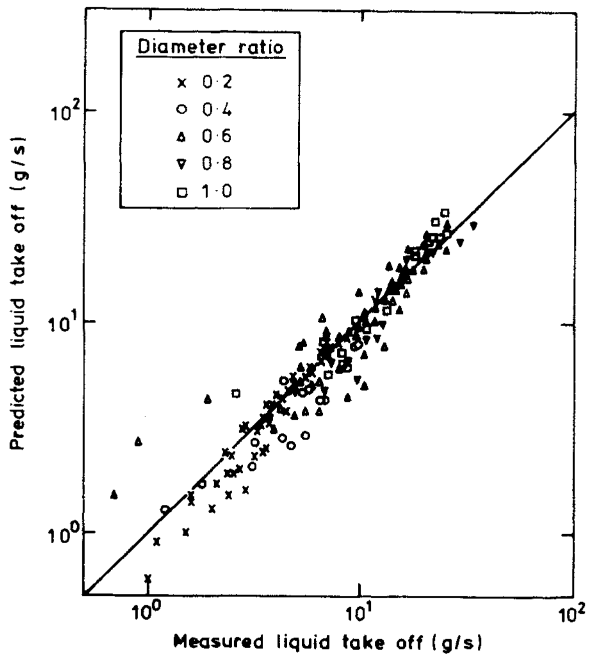

Figure 3. Prediction of liquid take off.

4. CONCLUSIONS

(i) Measurements have been made of the split of annular two phase flow at T junctions of diameter ratios of 0.8 and 1.0. The results have been related to earlier work with diameter ratios of 0.2, 0.4 and 0.6.

(ii) An effect diameter ratio is present. A correction term is provided to the equation of Azzopardi & Whalley (1982). In this equation the liquid taken off is the liquid travelling in that portion of the film occupying the same segment as gas taken off.

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