Eighth Australasian Fluid Mechanics
Conference, University of Newcastle,
N.S.W., 28 November/2 December 1983.

SMALL BUBBLE PRODUCTION IN A RADIAL DIFFUSER

P.A. MOHAMED, G.J. JAMESON AND J.A. RAPER

DEPARTMENT OF CHEMICAL ENGINEERING

THE UNIVERSITY OF NEWCASTLE, NSW. 2308 AUSTRALIA

SUMMARY Static pressure profiles and air and water film thicknesses have been measured and used to explain the phenomena occurring in a radial diffuser. The air is found to travel radially in the form of a thin film until that distance when the kinetic energy of the water falls below that required to overcome viscous losses. The air film then ruptures into small bubbles which coalesce before they reach the outside edge of the diffuser.

INTRODUCTION

The generation of bubbles in a liquid is the basis of many mass transfer processes. For example, aeration of sewage and industrial effluents is carried out by bubbling air through the liquid in a holding tank or lagoon, and bubbles are used in flotation cells to concentrate valuable mineral material.

Bubble size has been found to be a significant factor in both aeration(1) and flotation processes(2). Previous investigations show that significant increases in operating efficiency can be achieved if small bubbles (< 1000μm) are used. In the flotation process nearly a fifty-fold increase in flotation rate was observed when the bubble size was reduced from 655μm to 75μm(2).

Conventional venturi spargers have been found to be unsuccessful for the production of the very small bubbles needed to increase the efficiency of these special applications. An alternative method for small bubble production is the radial diffuser in which the gas film is allowed to thin appreciably before breaking up into small bubbles.

EXPERIMENTAL APPARATUS

The radial diffuser studied in the present work consists of a nozzle with throat connected to the atmosphere and a bell shaped entry into a narrow space between two parallel perspex discs which are held horizontally (see Fig.2). The brass nozzle (A) is attached at right angles to the centre of the lower disc (B). There is a small annular space (C) between the nozzle and the throat in the disc. This annular space is connected to the atmosphere. The upper disc is held a small distance from the lower disc by a set of three nuts, bolts, washers and springs (E), located equidistantly around the rim. Three positioning screws (F) moving in threads in the upper disc and resting on the lower disc enable the small space between the discs to be closely controlled. It is this space (G) in which the fluids are allowed to flow radially.

The two discs are each fitted with nine pressure tappings (H) located at equal intervals from centre to outside edge. Each pressure tapping on the upper plate corresponds to a pressure tapping on the lower plate so that differential pressure can be determined. Each set of two pressure tappings is connected through water traps and stop-cocks to a set of two manometers in such a way that the first manometer measures the gauge pressure at the lower plate and the second measures the pressure difference between the two plates.

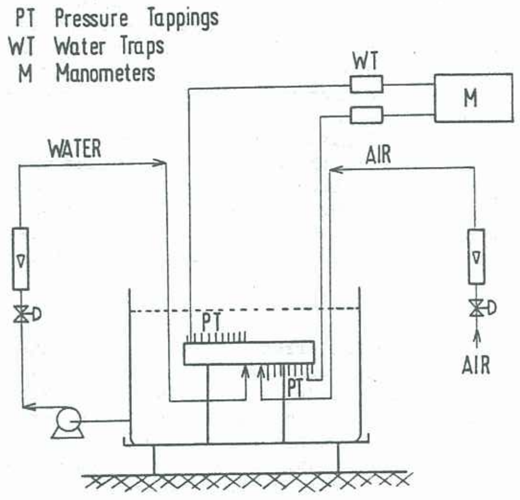

Fig.1 Schematic diagram of the apparatus

This whole unit makes up the radial diffuser. It is held on a stand and immersed in a tank of water. Water in the tank is pumped through a rotameter to the nozzle (see Fig.1). The nozzle has a cylindrical entry section (9.0mm I.D.) with a throat of 6mm I.D. The flowrate of the air entering the annular space is measured by another rotameter. Additional pressure tappings enable the measurement of pressure in the throat and static pressure of the water stream upstream from the nozzle.

When water is pumped through the nozzle the static pressure is reduced, owing to the increased dynamic pressure (or velocity head). When the static pressure falls below that of the atmosphere, atmospheric air enters the annular space and the radial diffuser.

EXPERIMENTAL PROCEDURE

Once steady state is reached, with water and air flowrates stable, it is observed that the water and air flow as *discrete* layers to a particular radial distance from the centre. The air film then breaks into small bubbles and a bubbly mixture flows out of the diffuser. Photographs taken with a short duration flash from a stroboscope indicate that the continuous air film

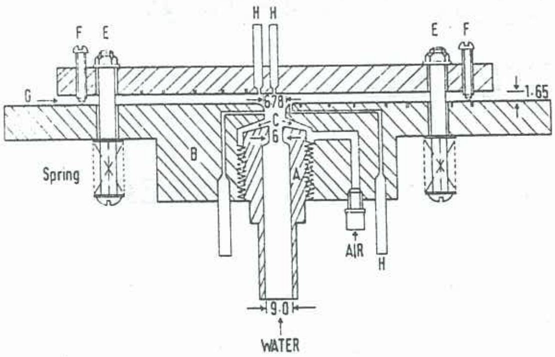

Fig.2 Experimental Radial Diffuser

breaks first into irregularly shaped pockets and then into spherical bubbles. These bubbles coalesce to form larger bubbles while the bubbly mixture is still in the radial diffuser.

In addition to measuring the pressures at each point, the radial position at which film rupture occurs is noted and the air film thickness is measured as a function of distance from the throat. The film thickness was measured by a probe consisting of a needle connected to a micrometer head. The probe was fitted into the pressure tappings on the upper disc with a tight air seal maintained by O-rings. The probe could be lowered until the air-water interface was just disturbed, as evidenced by trailing waves behind the needle point. The micrometer was then read to determine the film thickness, which could be determined in this way to an accuracy of 0.03mm approximately.

RESULTS AND DISCUSSION

The static radial pressure profile as a function of radial distance for a typical set of conditions (Air flowrate = 22.4 cc/s; water flowrate = 271 cc/s) is shown in Fig.3. The air film ruptures very rapidly and as it does so, oscillations are set up which mean that the radial point of rupture varies slightly. This point is marked on the figure.

The static pressure of the water film decreases from a high value at the stagnation point (at the centre of the upper disc) to zero or slight vacuum, where the velocity of the water film is high.

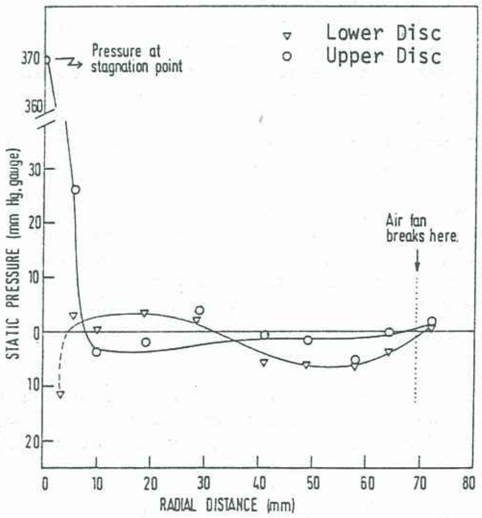

Fig.3 Static Pressure Profiles
Air = 22.4 cc/sec, Water = 271 cc/sec

Air which enters the throat at 5mm Hg vacuum flows at high velocity in the annulus and gains momentum from the high velocity water jet to flow radially along the lower plate. The velocity of the *air* decreases as it flows radially through the increasing cross-sectional area. Some of the kinetic energy is converted to *potential* energy so that the static pressure of the air increases (see Fig.3). Further downstream, viscous dissipation prevents any pressure recovery so the pressure falls below ambient.

The air film thickness is plotted against radial distance in Fig.4. The air film thickness rises to a uniform value and then thins very gradually until break up. It is always a lot thicker than the water film.

As the velocity of the water decreases downstream, the pressure is dissipated as frictional losses, and the static pressure is essentially the same.

Furthermore, since the velocity of the water film is far higher than that of the air, momentum is transferred from the water to the air and surface waves are generated (these can be seen from photographs). The point of film rupture is that radial distance at which the kinetic energy of the water falls below the energy dissipated. At this point there is a sudden increase in the water film thickness so that the entire space between the plates is occupied by a two phase bubbly mixture. The phenomenon will be modelled along the lines of a hydraulic jump (3).

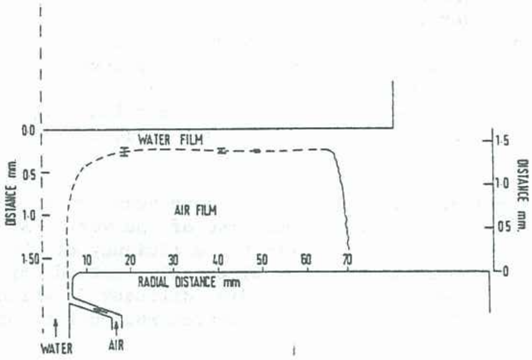

Fig.4 Film Profile
Air = 22.4 cc/sec, Water = 271 cc/sec

CONCLUSIONS

The phenomena occurring in a radial diffuser have been described with reference to the static pressure profiles and the air film thickness.

The air has been found to travel radially in the form of a thin film which thins very gradually and eventually ruptures into small bubbles. These bubbles coalesce before reaching the outside edge of the diffuser.

ACKNOWLEDGEMENT

One of the authors (P.A.M.S.G.Mohamed) is supported by a University of Newcastle Postgraduate Research Scholarship. We are grateful to Mr. J. Richards and Mr. J. Gubbins for their contribution to the design and construction of the apparatus.

REFERENCES

1. Motarjemi, M. and Jameson, G.J., "Mass transfer from very small bubbles - the optimum bubble size for aeration". Chem.Eng.Sci., 1978, 33, 1415.

2. Ahmed, N. and Jameson, G.J., "The effect of bubble size on the rate of flotation of fine particles", Int. J. of Min.Proc. (submitted).

3. Streeter, V.L. and Wylie, E.B., "Fluid Mechanics", McGraw-Hill Ryerson Limited, Toronto, 1982.