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FINE BUBBLE GENERATION IN A COLUMN REACTOR BY PLACEMENT OF A DIAPHRAGM ACROSS A LOW FREQUENCY SOUND FIELD

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Low frequency sound (50 – 500 Hz) is known for improving mass transfer in a gas-liquid medium. For fast reactions in bubble columns low frequency sound waves can be used for the enhancement of mass transfer. Any reduction in generation of fine bubbles will result in increasing the yield for mass transfer area controlled reactions. In the present investigation, through placement of a diaphragm across a sound field, bubble sizes were further reduced by about 8.3%. These phenomena are demonstrated in the present paper.

Keywords: Bubble generation, diaphragm, column reactor, sound field

Introduction

Fast reactions in bubble columns are mass transfer controlled. Therefore, an acceleration of mass transfer is of great importance for an increased bubble column reactor performance. Gas dispersion typically supplies the gas needed for a chemical reaction in a liquid, or the oxygen demanded by organisms in bioengineering. In all such processes, a component is required to be transferred from the gas bubbles to the surrounding liquid. For fast chemical reactions, the overall processes are limited by the efficiency of transfer of gas from the bubbles to the liquid phase.

The present paper reports the development of a novel diaphragm which reduces the bubble diameter mainly owing to a wetting effect, and as a consequence the mass transfer rate per unit volume is increased. Additionally, low-frequency sound applied to a bubble column enhances fast reactions by avoiding coalescence and breakage of large bubbles and an accelerated flow arround the bubble. The energy input into the bubble column by a low frequency vibrator is an order of magnitude less than that for a stirred gas-liquid vessel. The vibration frequency has to be tuned to obtain a maximum area per unit volume. This effect was demonstrated by Harboum and Hourghton [1], Baird [2], Jameson and Davidson, [3], Jameson [4], Bartsch [5], and Krishna et al. [6].

Experimental

The preliminary measurements and characterization of bubbles generated are performed using a configuration, shown schematically in *Fig.1*, by means of video technique. The vibration device is mounted at the bottom of the column as displayed. The column is filled with demineralised/degassed water. The volumetric gas flow of 5% of the total volume of a column nearly 400 cc/min was maintained constant throughout the experiment and the quantity of air is measured. With a view to demonstrate resonance-induced bubble production, experiments have been carried out in a 40 mm diameter glass column having a double walled cell with a height of 1.2 m. Sound vibration in the frequency range from 10 Hz to 5 kHz, in the power range of 5 – 30 W was produced by a vibrator which can deliver 500 W.

At various positions along the column, the bubble size distribution is recorded using a video camera: Sony SSC M 370 CE (it was a CCD Black and White camera) along with camera adapter: L / S - W 130 P. Further details of the system used are: Cannon TV Zoom lens PH 6X8-II, 8 – 48 mm, 1:1.0 (No. 112 054),

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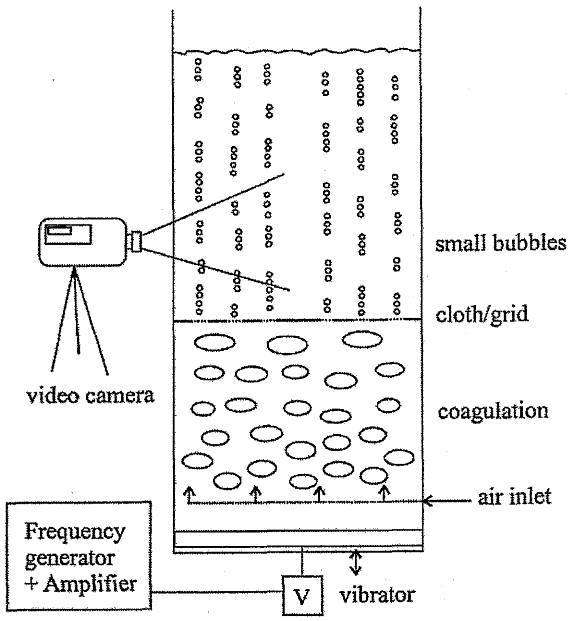

Fig.1 Experimental test set up

Made in Japan, in association with a video recorder JVC HR–S6900 EG. The data were evaluated by a computer programm called Image Grabber 24 by Neotech.

Development of a novel diaphragm

A metal plate as a gas sparger has been designed with radial slots, as shown in *Fig.2*, arranged in three concentric rings of slots. Each slot is of 1.5 mm width and 2.5 mm length. Eddying and high pressure is avoided by the flow distribution through the slots of the plate. The radial slot plate has shown some improvement in generating fine bubbles reducing an average bubble size by 4% compared to conventional needle system, which is not a remarkable achievement. Therefore, a new diaphragm was developed, see *Fig.3*. It consists of two elements, a thin copper plate and a filter cloth fastened on it. A copper plate of 35 mm diameter was taken and six concentric circles having 6,10,15,20,25, and 30 mm diameters were marked. Leaving the central circle, a number of holes were pierced in the space available between alternate rings using a 0.45 mm diameter fine needle. About 40 holes per sq. cm. are approximately made in the available annular space. Then in a composite style the diaphragm was made by fastening together the copper plate with a filter cloth which was attached to the copper plate by glue put on the outer edge as well as in the inner annular space available between concentric rings having holes. At the centre of this system a hollow metal tube of 6 mm diameter is firmly fixed for holding the system as well as to facilitate the gas to flow through. A set of four cable binders are used for holding the system firmly and to maintain concentricity and for keeping it coaxially with the glass column.

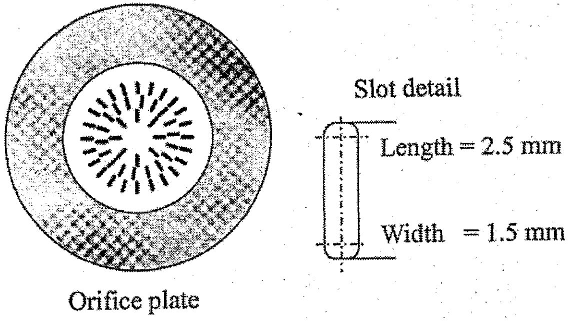

Fig.2 Radial slot plate for improved bubble generation

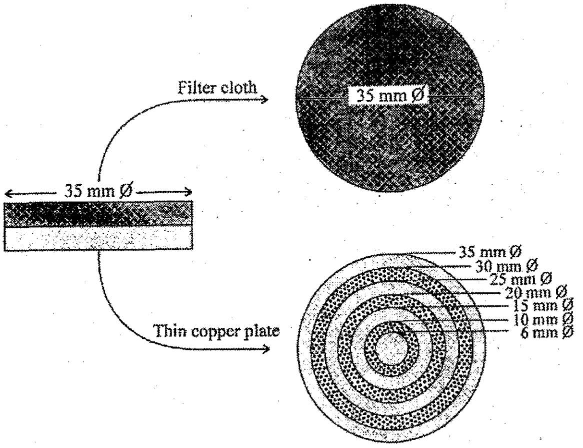

Fig.3 A composite novel diaphragm developed

Results and discussion

Initially gas is injected through a conventional needle sparger at a rate of 400 cc/min. Bubbles are formed successively emerging out from the needle tips. As soon as the sound is applied (using 50 Hz frequency, 25 W power) the bubbles are recorded by a videa camera, and the bubble size distribution is determined at a distance of 50 cm above the sound source.

Then using a thin copper plate along with a filter cloth, as shown in *Fig.3*, it has been observed that the bubble size radii were considerably reduced. In order to get a bubble size reduction, the frequency of the vibrator and the distance of the diaphragm from the column bottom have to be fine-tuned. The diaphragm should be placed at a position where the liquid convection owing to the vibrator is strong.

Gas of about nearly 5% by volume was injected from bottom through needles at a rate of 400 cc/min. In all these experiments the diaphragm is placed in such a way that always the metal foil was facing the sound source at the bottom, whereas the filter cloth was located upwards. The positive effect of introducing the newly developed diaphragm in improving bubbles to finer sizes can be clearly seen in *Fig.4*. The effect of the newly developed diaphragm is that bubbles are smaller with uniform distribution.

A comparative study of bubbles produced before (without) and after (with) the introduction of new composite diaphragm clearly reveals that introduction or replacement of new composite diaphragm across a low frequency sound field produces finer bubbles, and, therefore, leads to a further increased surface area responsible for enhanced mass transfer.

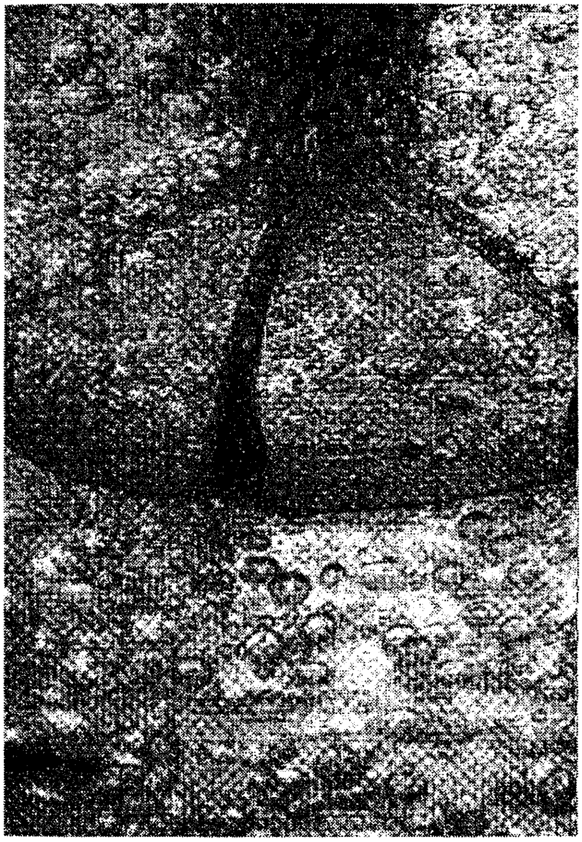

Fig.4 Bubble distribution with new diaphragm when placed across a sound field

By measuring the bubble diameters for at least 100 bubbles on either side of the central vertical axis, the average Sauter mean diameter values of bubbles were computed. The average bubble diameters thus obtained without and with the use of the new diaphragm are 1503 and 1378 μm respectively. This study demonstrates that about 8 – 9% smaller bubbles can be obtained by inserting the new diaphragm into the sound field. In the present study, chances of bubble coalescence is low since the bubbles released through the neighbouring zones maintain definite time lag intervals caused by sound vibrations. The interfacial area per unit volume for the above set of conditions was evaluated. The results revealed that there has been a 1.4 times increase in interfacial area by the introduction of the new diaphragm across the existing sound field. Hence the results are encouraging. One should keep in mind that the vibrator increases the surface area already by 50%.

An important finding in this investigation is that the bubble size depends mostly on the material of which the filter cloth is made rather than the port or mesh sizes of the metal or filter cloth.

Conclusions

1. The newly developed diaphragm when placed across the sound field can produce at least 8 – 9% smaller bubbles compared to the bubble size obtained by the vibrator alone. The vibrator together with the diaphragm gives an increase in the transfer surface by a factor of 2.1. This leads for fast reactions to considerably higher yields per unit time and volume owing to an improved mass transfer.
2. If the diaphragm is closely placed to the sound source, further improved effects are expected.

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REFERENCES

1. HARBOUM K. L. and HOURGHTON G.: Chem. Eng. Sci., *1960*, 13, 90 – 92
2. BAIRD M. N. I.: Chem. Eng. Sci., *1963*, 18, 685 – 687
3. JAMESON G. J. and DAVIDSON J. F.: Chem. Eng. Sci., *1966*, 21, 29 – 34
4. JAMESON G. J.: Chem. Eng. Sci., *1966*, 21, 35 – 48
5. BARTSCH A.: Z. Naturforsch, *1995*, 50A, 228 – 234.
6. KRISHNA R., ELLENBERGER J., URSEANU M. I. and KEIL F. J.: Naturwissenschaften *2000*, 87, 455 – 459
7. VALENTIN F. H. H. and PREEN B. V.: Chem. Ing.Tech. *1962*, 34, 194 – 199