A FOURIER TECHNIQUE FOR THE DETERMINATION OF BUBBLE CHARACTERISTICS IN FLUIDISED BEDS

by

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Abstract

Several attempts are reported on measurements related to bubbles and their movements in fluidised beds. The methods used are surface photographic methods, application of probing light sensors, capacitance sensors into the bed, x-ray, gamma-ray, and cine photographic methods, all involving various data processing techniques. This paper describes a method developed at the Department of Chemical Engineering of University of Peradeniya of Sri Lanka for measurements of bubble sizes and velocities by means of pressure measurements within the bed and thereafter analyses of pressure signals in order to obtain the bubble sizes and bubble flow behaviors.

1.0 Introduction

In a gas-fluidised bed, it is generally considered that the bed consists of an "emulsion" phase and a "bubble" phase (1). The emulsion phase is assumed to consist of a mixture of solids and gas under incipient fluidising conditions. Air in excess of the incipient fluidising requirements leave the distributor of the fluidised bed as bubbles leading to the bubble phase.

The overall mass transfer coefficient vital for sizing various pieces of process plant is linked to the dynamics of the fluidised bed, which in turn depend on the bubble size distribution and velocities within the vessel.

Photographic methods of bubble observation on surface of the bed do not give the behavior inside the bed(2). Even though x-ray methods give detail behavior of the bubbles the instruments are expensive and application requires skills (1, 2, 3).

Fluctuations in pressure within a fluidised bed could result due to the passage of bubbles through a fluidised bed. A non - interfering pressure probe can detect the pressure changes. Fourier techniques can be conveniently employed to analyze pressure variations with time in a fluidised bed. A method is described in the following sections whereby the pressure data are analyzed in order to detect the bubble movements, bubble velocity and bubble frequency within an experimental fludised bed.

2.0 Experimental setup

The experimental setup used for the study is shown in fig. 1 The unit, shown in Figure 1A, mainly consists of the following

FIGURE 1A EXPERIMENTAL UNIT

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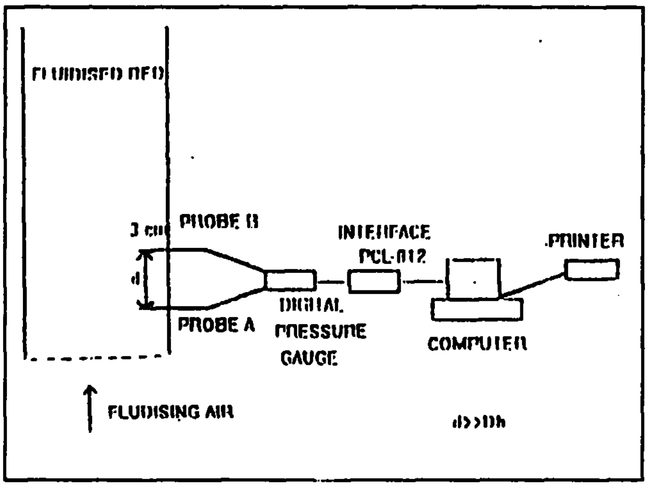


Figure 1: Schematic Diagram of the Measurement System

1. A fluidisation vessel,
2. A Digital pressure gauge and pressure probes
3. Data acquisition system.

These units are described below.

Fluidisation vessel: Studies were conducted in a 10cm internal diameter transparent fiber glass vessel, 2.5m high. The fluidising air was introduced at the bottom of the column through a metal sieve distributor. A manually operated flow controller (flap) was used at the outlet of the fluidisation vessel to control the gas velocity in the bed. Sieved rice husk of 1.3mm average particle size is used as the fluidising solid. The bed was operated at 1.29 m/s.

Digital pressure gauge and probe : This unit is set up to use a digital-quartz pressure transducer (model: DG-430K-20070A of TOKYO AIRCRAFT) as a pressure sensor while digitally indicating the sensor output signal in the form of line arised pressure value. Also an analogue output voltage of 0 to 10 volts was available.

The operation of the pressure sensor is based on a principle that a resonance frequency of a crystal oscillator varies depending on a load (stress) acting on that oscillator. Namely the piezo-electric effect applied is used here. A single crystal quartz is used as the oscillator. Resonance frequency of the pressure sensor varies within a range of approximately 40 - 36kHz. Reported accuracy of measurement was approximately 0.01% of full scale. An insertion length of 3cm was used in this experiment.

Analogue output:

Output voltage of 0-10 volts, and accuracy 1% of full scale and out put impedance 10 ohm or less were available.

Data acquisition: The analogue output data is acquired using the PCL-812 high performance, high speed, multi-function data acquisition card and data acquisition software. Using this software data acquisition can be done with various sampling rate ($1x10^{-8}$ to 50 Hz) and running time.

3.0 Measurements

Variation of output voltage from the pressure gauge was monitored with time when fluidisation occurred inside the transparent vessel. The data acquired were stored in a computer for Fourier analysis thereafter.

4.0 Concept of analysis

Consider a bubble moving across probe A as shown in fig. 2A and fig.2B. Each time a bubble reaches the probe (fig.2A) and leaves (fig.2B) a significant pressure change at the probe A can be expected during traverse of a bubble through the probe. As a result, a reptition of varation of the pressure is to be expected in pressure monitoring each time a bubble reaches and leaves the probe. The travel time for a bubble to move across the probe could therefore be obtained with measurments and isolating significant perturbations of pressure due to a bubble moving across a probe thereby enabling detection of the time (Ω) between a bubble entering and leaving the probe.

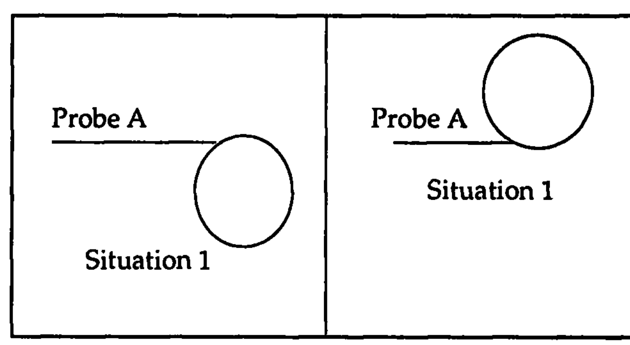


Figure 2A : Bubble Entering Probe A **Figure 2B : Bubble Leaving Probe A**

Pressure variation with time could further be Fourier analyzed in harmonics. If a correct period is selected it could be expected that a dominant harmonic and less significant harmonics could be traced depending on the frequency of emission of the bubbles. The method of analysis is described below.

The data obtained is Fourier analyzed with varying period of time and the ratio of the most significant amplitude to the next significant is evaluated. The producer of calculations are repeated for different periods of harmonic until a maximum ratio is obtained. The period so obtained is an indication of repetition of bubble movements across the probe and represents bubbles frequency.

Bubble velocity within the bed is estimated as follows: If two probes are located one a reasonable distance x away (Fig.3) from the other, the time to traverse an identified bubble from one probe to the other could be evaluated by preesure mearsurments and the average velocity V of bubble could be expressed as V=x/t,

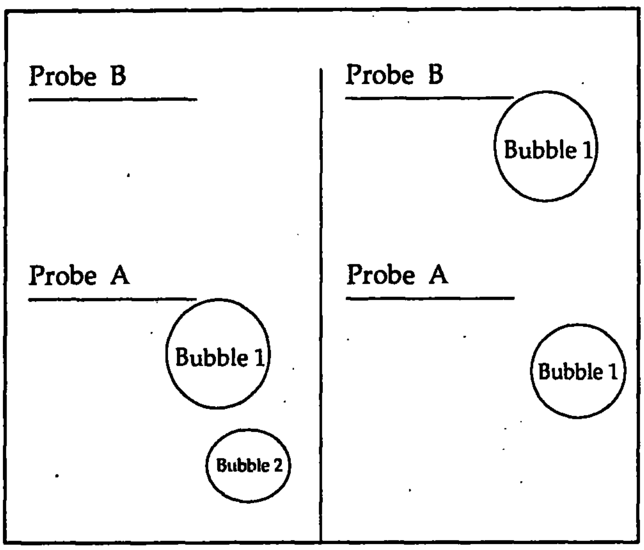


Figure 3 A: Bubble Entering Probe A

Figure 3B : Bubble Entering Probe B

Where, t is the peak shift corresponding to a bubble obtained from the graph of pressure against time. Here the distance x should be large compared with the diameter of bubble to be evaluated.

The diameter of a bubble could therefore be evaluated as Ω/V Where V is evaluated as mentioned earlier.

From the Fourier analysis of the pressure variation data bubble frequency could also be calculated.

5.0 Results

One set out of several sets of data taken at a trial is shown in fig.4. The data were Fourier analyzed up to first 5 harmonics for varying periods of the harmonic. Fig.5, Fig.6, Fig.7, Fig.8, show Fourier analysis plots of signals obtained at 5 Hz sampling rate; 3,6,12,14 s periods The ratio of maximum of the most significant to the next significant harmonic was analyzed and the maximum of the ratio was found to be at a period of 12.23 s. The average bubble frequency can therefore be taken as $1/12.23\ s^{-1}$ (i.e. $0.08\ s^{-1}$)

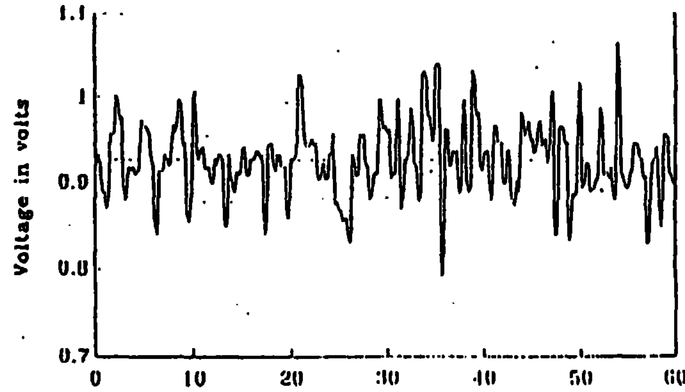
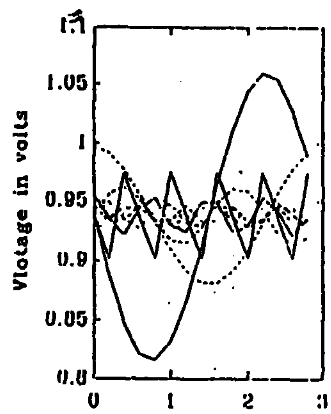
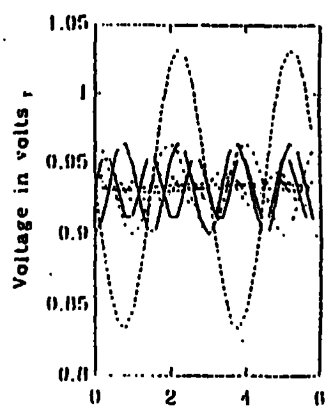


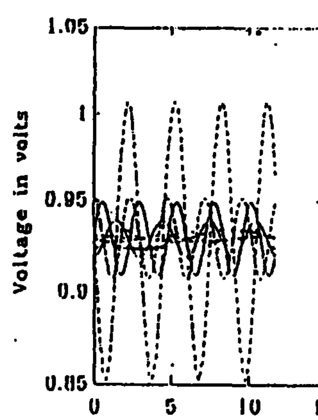
Figure 4 :
Pressure (Output Voltage) Variation with time



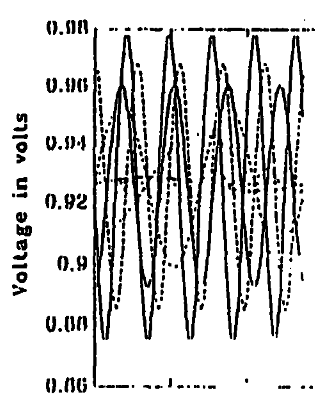
Time in seconds
Figure 5 :
Harmonic Period 3 s



Time in seconds
Figure 6:
Harmonic Period 6s



Time in seconds
Figure 7 :
Harmonic Period 12 s



Time in seconds
Figure 8 :
Harmonic Period 14 s

The average time of deviation of pressure measured by probe from mean pressure is found to be 0.91 s. This could be represented by the time a bubble entering and leaving a probe. The velocity of a bubble within a fluidised bed has been represented (5) by Davidson's formula as $V=0.71\ (g*D)^{0.5}$ where; g is the acceleration due to gravity D is the bubble diameter. Hence the bubble diameter could be evaluated as 4.09 cm. It should be noted that the size of bubble 4.09 cm obtained using Davidsons formula is comparable to the vessel diameter. Davidson formula (5) is generally applicable for estimation of velocity of bubbles without wall effects, and without bubble coalescence. Any error of the bubble size resulting due to wall effects may be regarded to be small. Trials with two probes were not conducted due to time constraints. However it is anticipated that the bubble diameter obtained in this paper will be verified by experiments with two probes in the future. Also it is anticipated that a fast Fourier Transform, Technique will be adopted in future mechanical analysis for further accuracy.

6.0 Conclusions

Pressure measurement and Fourier analysis is seen to be a useful tool to study the bubble behavior inside the fluidised beds. The method developed can be used to measure bubble behavior within the fluidised beds even under adverse process conditions such as combustion, gasification or reaction.

7.0 References

1. Kunii, D.& Levenspiel, o.,' Fluidisation Engineering,' 2nd ed., Butterworths Heinmann, London, 1991.

2. Rowe, P.N., & Partridge, B.A., Trans. Instn chem. Engrs, ' An X-ray study of bubbles in fluidised beds', 43, T157, (1965)

3. Lanneau, K.P. Trans. I. chem. E, Gas-solid contacting in fluidised beds, 38, 125, (1960).

4. Addis, E.J., Bagshaw., W., and Napier., B.A., An experimental study of bubble flow in a fluidised bed combustion using a novel optical probe., Paper presented at conf. on fluidised bed combustion. London, December (1991).

5. Allahawala, S.A., Singh, B and Potter, O.E., Chem.Eng.commun., Vol II, 255-280, Gordon and Breads Sc. Publishers, (1981)