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MEASUREMENT OF LOCAL GAS-PHASE PROPERTIES USING AN OPTICAL PROBE IN A THREE-PHASE SYSTEMS – PRELIMINAR RESULTS

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EXTENDED ABSTRACT

Introduction

Three-phase systems are present in several industrial fields. Over the past decades many research groups have been studied solids influence in the behaviour of gas-liquid mixture.

In the gas-phase solids influence is characterized by: (1) changing bubbles behaviour (shape, rise and formation); (2) altered radial and axial profiles; (3) influence mixing and dispersion; (4) modified gas hold-up and flow regimes profile (Banisi 1995; Warsito et al. 1997; Fan et al. 1999; Gandhi et al. 1999; Mena et al. 2005). Is also important to take in account solid-phase characteristics as: size, concentration and chemical properties (wettability and hydrophobicity). Generally gas hold-up decreases for moderate solid concentrations/sizes, non-wettable and hydrophobic particles. The opposite effect occurs for fine particles in small amount or large particles in high amount and also in wettable and hydrophilic particles (Zon et al. 2002; Mena et al. 2005)

There are several techniques to study local flow structures. Among these techniques invasive techniques as phase detection probes are used (Boyer et al. 2002). Phase detection probes are cheaper and easier to apply in industrial process. They can be applied on for two-phase (Jhawar and Prakash 2007) or on three-phase flows (Mena et al. 2008). Optical probes have been frequently, developed and successfully applied, because they are simply to operate. They allow to measure not only gas-phase concentrations (hold-up) but also bubble velocities, size distributions, mean interfacial area, mean Sauter diameter and are also able to identify flow regimes. However some of this properties are only possible to measure if some assumptions are taking in account (Cartellier 1992).

The typical signal obtained by a bubble that is pierce can be seen in *figure 1*. It also shows the most important points to be detected when a bubble is pierced the fibber.

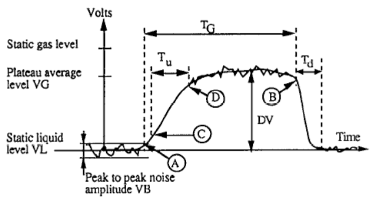

Figure1. Bubble Detection. Legend: A – Beginning of Bubble; B – End of Bubble; C – Begin Rising; D – End of Rising (from Cartellier 1992).

Gas residence time (T_G) and rising time (T_u) are used to determined local gas hold-up, bubble velocity and chord size according the following equations:

Gas hold-up: $e_g = \sum T_G / t_{acq}$ (1)

Bubble Velocity: $v_B = A \cdot T_u^{\,B}$ (2)

Bubble Chord: $ch_B = v_B \cdot T_G$ (3)

When optical probes are applied to three-phase systems the solids contamination may occur and it depends mainly from the solids properties. Solid-tip interaction may induce inadequate signals due to contamination of the optical fiber (Mena et al. 2008). Or the contamination can be caused by cluster formation around the tip. The particle agglomeration avoids bubble-tip interaction and no signal is obtained. This type of contamination was found when Spent Grains were used as solid-phase

Method for solving SG contamination

An injection system was implemented that acts periodically near the probe tip. The liquid-phase is injected periodically (by an electro-valve) and the turbulence that it promotes cleans the tip. Some drawbacks were identified when injection near the probe is applied and then the period of time where injection is done must be removed from the optical probe raw signal and after the signal is evaluated. The amount of signal to cut becomes one of the critical parameters for gas hold-up determination, because if more or less signal is cutted changes the t_{acq} will occur and gas hold-up values may be over or underestimated. Different cutting percentages of injection time were tested and the obtained values were then compared with the gas hold-up values obtained by mehod presents in literature (Cartellier 1992). The tests were made under the same conditions with and without injection. The error percentage between our method (new) and the proposed method (old) was calculated using the general equation:

$$\%ERROR=abs(e_{old}-e_{new})/\ e_{old}*100 \quad (4)$$

The cutting zones include not only the time when the injection was performed but also fractions of time before ("Add1" from 0% to 50%) and after ("Add2" from 0% to 100%) the injection. This means that, per each injection period (2.5 s), the minimum time removed were 0.5 s corresponding only to the injection and the maximum time 1.25 s corresponding to a cutting of 50% before and 100% after the injection (included).

Results and Discussion

The obtained results indicated that the new method generally over estimates the gas-phase properties for 250 mL/min while to 400 mL/min is the opposite. Considering only the comparation of gas hold-up results, the error between the two methods is in average below 10%. The best "cutting" percentagem of signal determined are displayed in *table 1*.

Table 1. Cuting frequencies which correspond to error between methods below 10%

Q_{GAS} / (mL/min)	Add1	Add2
250	< 37.5%	< 37.5%
400	From 25% to 50%	From 50% to 100%

Bubble Velocity and Chord Size are not so affected by the percentage of signal that is removed but the average error is higher (between 8% and 20%). There main reason for this is the aquicision rate used (10 MHz) which was lower when compared with the one used in two-phase flow (50 MHz). This lead to inacurraed T_u values and consequently to bigger errors. It is important to have in account that only the gas hold-up is dependent on the overall aquicition time (see eq. 1). So the most important parameter to define the amount of signal to cut is the gas hold-up.

Using this method it was possible to study the local gas-phase properties of an Air-Water-Spent Grains systems in an Air-lift reactor.

Conclusion

Generally it was possible to develop a method that allows the use of the optical probe in three-phase systems. This will allow a good understanding of the biotechnological systems where three-phase systems are present.

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