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EFFECT OF AMPLITUDE ON MASS TRANSPORT, VOID FRACTION AND BUBBLE SIZE IN A VERTICALLY VIBRATING LIQUID-GAS BUBBLE COLUMN REACTOR

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ABSTRACT

Two-phase and three-phase Bubble Column Reactors are used in many chemical, petroleum, and bio-systems processing applications such as the hydrogenation of coal slurry to produce synthetic fuels during the Fischer-Tropsch process. Vertical vibration of a Bubble Column Reactor has previously been shown to increase mass transfer, increase void fraction, decrease bubble size and establish interesting flow phenomena through kinetic buoyancy or "Bjerknes force". However, the effect of kinetic buoyancy on the flow field, mass transfer, and flow properties such as void fraction is not fully understood. While previous research has focused on the effect of vibration frequency ($10 < f < 120$ Hz) at low amplitudes, ($A < 2.5$ mm) very little attention has been given to the effect of larger amplitudes. Therefore, a new experimental set up was designed, built, verified by comparison to previous research, and used to collect mass transfer, void fraction, and bubble size data at high amplitude (2.5 mm $< A < 9.5$ mm) over a frequency range of 7.5-22.5 Hz. Comparison of the results with previous research shows similar local maxima occurring for void fraction and mass transfer, but that an optimum amplitude may exist for mass transfer which is independent of frequency. Statistical analysis and comparison of the results with data from the literature suggests a stronger relationship may exist between kinetic buoyancy and mass transfer than previously theorized.

INTRODUCTION

There are many applications for Bubble Column Reactors (BCRs) including aeration of organic organisms in bio-reactors, hydrogenation of coal-slurries to produce synthetic fuels used in the Fischer-Tropsch process, and gasification of solvent for chemical reactions.

It was discovered in the early 1960's that vibration could help improve efficiency in BCR processes by increasing the mass transfer rate [1-4]. Some additional research expanded the theory [5-7], but it was not until the early 2000's that the science was reinvigorated [8-16]. Recent research has gone so far as to develop theoretical, physics based models to try and predict mass transfer and void fraction in BCR systems undergoing vibration [14-15]. These models were tested in a limited manner, but have yet to be fully understood or validated against a large body of experimental data.

Therefore, a fundamental understanding of the multiphase flow properties such as void fraction and bubble size distribution as well as the related mass transfer properties are crucial to understanding and thereby improving the operation of BCRs. It is with this concept in mind that the current research is carried out.

A common method to measure the volumetric mass transfer coefficient, $k_L a$, in a BCR is to solve the transient mass balance for the whole column (batch) leading to Eq. (1) [7-16],

$$\frac{dC}{dt} = k_L a\left(C^* - C\right) \tag{1}$$

where C is the instantaneous concentration of dissolved gas in the liquid, C^* is the saturation concentration and t represents time. Provided the BCR is assumed to be well-mixed (i.e. concentration is uniform throughout the batch), measurement of the instantaneous oxygen concentration of the liquid at any point in the column is representative of the batch. BCRs are generally assumed to be well-mixed due to the level of turbulence within the liquid column.

The void fraction is defined as the ratio of volume occupied by the gas phase to the total volume in a multiphase system. The BCR is considered a batch system and as such the void fraction can be measured by,

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