HYDRODYNAMICS OF GAS-LIQUID COUNTERCURRENT FLOW IN RANDOM AND STRUCTURED PACKED COLUMN ON FLOATING PLATFORMS FOR OFFSHORE MARINE APPLICATIONS

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Abstract

The hydrodynamic behavior of 4 types of packings inside an oscillating packed column with gas-liquid countercurrent flow will be investigated in this study. In order to appropriately extrapolate the influence of motions on cross-sectional gas-liquid flow distribution as well as liquid saturation, thorough experiments regarding hydrodynamics will be performed using embedded low-invasive Wire mesh sensors (WMSs) and a hexapod floating motion simulator. The influence of oscillation on the development of gas-liquid stratified flow and temporal fluctuations in liquid saturation will be interpreted. Additional investigation in the subject of liquid residence time and axial dispersion will be evaluated by stimulus-response technique associated with macro-mixing model. Finally yet importantly, fast Fourier transform (FFT) will be applied to analyze the different contributions to oscillating liquid saturation in an attempt to interpret coupling between fluid and hexapod robot motion.

Keywords

Countercurrent flow, FFT, Oscillating, Packed bed, Liquid saturation, Hydrodynamics

Introduction

Multiphase packed bed reactors with countercurrent gas-liquid operation mode are widely applied in the chemical and petrochemical industries, which carry out a large spectrum of catalytic chemical reactions. The performance of reactors is significantly of dependence on the phase interactions inside the beds. Poor fluids distribution or maldistribution entails impaired functioning in the reactor in terms of mass and heat transfer performance.

Challenges arising for packed beds embarked on floating platforms such as floating production, storage and offloading (FPSO), in comparison with classic static oil and gas processing units on land, are the fluids distribution which is highly sensitive and susceptive to ship oscillations stemming from wind and swells. As a result, large deviation of hydrodynamics in oscillating packed beds from land-based one is recognized as a problem with potential incidence on the unit performances. Recent works on the interpretation of the hydrodynamics prevailing in floating packed beds unveiled that deteriorated fluid distribution and liquid axial dispersion resulted from the exposure of the random packed bed to ship translational and rotational oscillations (Assima et al. 2015 and Dashliborun et al. 2015, 2017). Interestingly, the findings. In like manner, the structured packings were also prone to remarkable liquid maldistribution subjected to static tilting and rolling motions.

Aforementioned researches demonstrated that the fluid maldistribution is appreciably inevitable for either random

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or structured packings. Most of the researches, no matter experimental or numerical, concentrated on cocurrent upflow and downflow with various types of packings. However, in most of situations, countercurrent operation is more favorable in the industry owing to its inherent advantages for scrubbing unit operations. More specifically, the experimental studies with respect to the influence of ship motions on the hydrodynamics of countercurrent flows in various packing configurations within embarked processing units are scarce to say the least. Therefore, the present work makes contributions to comprehensive know-how concerning hydrodynamic behaviors of countercurrent flow inside different types of packings, for instance of Raschig rings, open cell foam, monolith and structured packing, onboard floating platforms.

Experiment setup

The schematic design of laboratory-scale setup as shown in Figure 1 consists of segmented transparent Plexiglas column with 57 mm inner diameter and 1200 mm total height. The column is packed up to a height of 1000 mm with different packings in our series experiments. As described in Figure 1, the packed bed is rigidly erected on a NOTUS hexapod platform with six-degree-freedom motions including translations and rotations with various ranges of amplitude and frequency to simulate realistically floating situations. The hexapod motions are precisely programed by generating an effective sinusoidal curve depicted by functions of the type $p = \theta \sin(2\pi f t + \varphi)$, where θ is the amplitude (mm for translation or degree for rotation), f is the motion frequency (Hz), t is the duration of the movements (s) and φ is phase offset (rad). To monitor the evolution of liquid saturation distribution in the packed bed, two lattices low intrusive WMCs will be installed between column segments at position of 200 mm and 800 mm downstream from the very upmost of the column to register the two-phase flow dynamic signatures as well as to detect the tracer pulse.

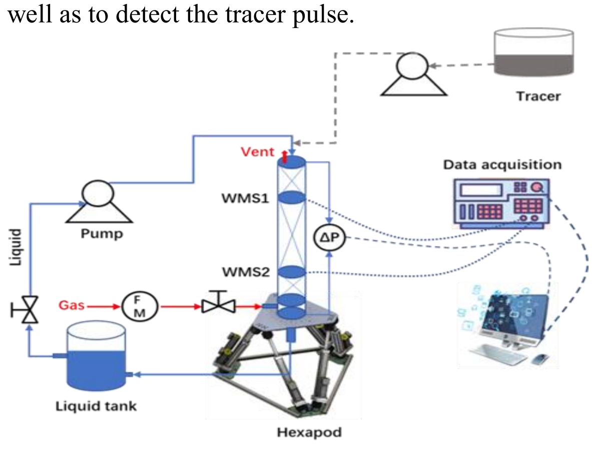

Figure 1. Experimental setup of the stationary-moving packed beds with gas-liquid countercurrent flow embarked on hexapod

Results & discussion

The experiment results reveal that the oscillating motion initiates an appreciable spatial discrepancy in the cross-sectional liquid saturation. The liquid saturation of R1 and R3 exhibits periodic behavior almost corresponding to hexapod rolling. Comparably, in region R2, the liquid saturation is much less stimulated by imposed motion as shown in Figure 2 left. Furthermore, the liquid saturation profile of R1 is examined to identify the effect of column moving frequency. Expectably, the increase of moving frequency would result in a remarkable decrease in the intensity of liquid saturation oscillation as is evident from Figure 2 right. The observation highlights the moving frequency of column has primary contribution to spare enough time for accumulation of the liquid in the lowermost wall region and transverse displacement in the cross section.

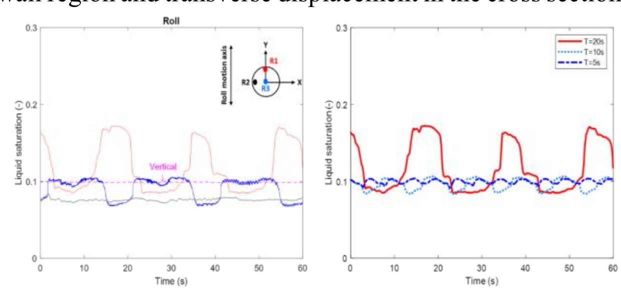

Figure 2. Temporal liquid saturation of Raschig rings a) in different regions subjected to Roll motion with amplitude θ =15deg, oscillating period T=20s b) with different frequency f=0.05, 0.1 & 0.2 Hz at U_g=0.1085 m/s and U_l=0.0026 m/s

Conclusion

The hydrodynamic characteristics of countercurrent gas-liquid flows in a column with various packings inside under rolling oscillations will be compared. The influence of motion amplitude, frequency on hydrodynamic signatures in the subject of liquid saturation and dispersion behavior in different packings will be interpreted based on the wire mesh sensor measurement. Furthermore, fast Fourier transfer will be applied to distinguish the origins of oscillation behaviors.

References

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