Honda, Gregory S. Ph.D., Purdue University, August 2015. The Hydrodynamics of Trickle Bed Reactors. Major Professor: Arvind Varma.

The hydrodynamics of trickle bed reactors have a significant impact on reactor design, operation, and performance. The effect of bed and operating variables on the hydrodynamics must therefore be accurately characterized. However, literature studies are limited to a narrow range of variables. This work evaluates the effect of operating outside that scenario on the reactor hydrodynamics. Specifically, this is addressed by investigation of i) the effect of catalyst particle size distribution on trickle flow hydrodynamics, ii) the effect of reactor diameter for beds of activated carbon, iii) the effect of pre-wetting procedure on flow regime transition, and iv) the effect of particle size, particle shape, bed void fraction, and gas-liquid surface tension on the trickle-bubbly transition.

Studies reported in the literature are typically restricted to systems of beds packed with catalyst supports of a uniform size. The first part of this work addresses the impact of supports with particle size distributions on reactor hydrodynamics. An experimental database of pressure drop and liquid holdup was developed and, by careful definition of the particle diameter, literature models were adapted to account for the particle size distribution. The resulting models give improved predictions for packing media with a particle size distribution while maintaining applicability to uniform systems.

In the next study, the effect of scale on the hydrodynamics of a trickle bed reactor was investigated for beds packed with granular activated carbon. A new pre-wetting procedure was developed in order to achieve reproducible results. Pressure drop data demonstrated that an effect of vessel diameter did not occur, which confirmed the literature criterion for negligible wall-effects.

Following the trickle-flow studies, the effect of pre-wetting was evaluated for the trickle-bubbly and trickle-pulsing transition. The transitions from trickle to bubbly flow and trickle to pulsing flow were investigated in the range of gas superficial velocities v_G = 4-220 mm/s using air and water, with additional consideration of the effect of pre-wetting procedure. Flow regime transition was detected by standard deviation of pressure drop and visual observation, with further confirmation using a high speed camera. Results show a significant effect of pre-wetting procedure on the liquid superficial velocity at a fixed gas superficial velocity required for transition from trickle to bubbly and trickle to pulsing flow. At low gas superficial velocities, where the transition from trickle to bubbly flow occurs, a significant departure from literature model predictions is observed. Below v_G = 20 mm/s, rather than the expected increase in liquid superficial velocity required for transition with decreasing gas superficial velocity, the transition is observed to be essentially independent of the gas flow.

In previous literature, the hydrodynamics of trickle bed reactors operating near the trickle-bubbly flow regime transition have not been fully characterized in the literature. In the final portion of this work, an air-water system is used to investigate the effects of particle size, particle shape, void fraction, and surface tension on the trickle-bubbly flow regime transition in trickle bed reactors. The flow regime transition is detected based on standard deviation of pressure drop with confirmation by visual observation. For all cases, the liquid superficial velocity required for the trickle-bubbly transition was found to be relatively independent of the gas superficial velocity. Literature models, defined for the trickle-pulse transition, are unable to predict this trend when

extrapolated to low gas superficial velocities. To address this, a correlation is proposed which accurately represents the trends observed in this work.