Experimental investigation of the effect of gas permeation through vertical membrane on the onset of transition velocity from bubbling to turbulent regime in fluidized bed

EXPERIMENTAL INVESTIGATIOIN OF THE EFFECT OF GAS PERMEATION THROUGH VERTICAL MEMBRANE ON THE ONSET OF TRANSITION VELOCITY FROM BUBBLING TO TURBULENT REGIME IN FLUIDIZED BED

Congress: ECCE10
Topic: Chemical reaction engineering

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Abstract:
Membrane-assisted (MA) fluidized beds have recently emerged as a cutting-edge technology for intensification of a number of industrial chemical processes. MA-fluidized bed reactors combine the benefits of the separation properties of membranes and the advantages of fluidized bed reactors known for their excellent heat and mass transport characteristics; the presence of membranes maximises the volumetric production rate by reducing equilibrium limitations. Hydrogen production from methane reforming is one of the main applications of MA-fluidized beds. Particularly, the Chemical Switching Reforming (CSR) (figure 1) reactor concept has recently been introduced as a promising reactor concept for cost effective pure hydrogen production from steam-methane reforming with integrated CO2 separation. CSR operates under transient behaviour where methane/steam and air are alternatively fed into a single reactor with a bed of oxygen carrier material (which acts both as a catalyst and heat carrier) in order to directly convert methane to high-purity H2. This is achieved through the insertion of hydrogen perm-selective membranes into the reactor, which extract the produced H2 while simultaneously shifting the steam reforming and water-gas shift reactions equilibria towards complete conversion. Relative to conventional chemical looping configurations, CSR offers simpler process design, scale-up and operation, especially under the pressurized conditions required by membrane reactors.

Understanding the effect of vertically inserted membranes on the hydrodynamic behaviour of the fluidized bed reactor is of high importance for the design and optimization of the CSR process. This work presents the experimental results of the effect of gas extraction through vertically inserted membranes on the transition velocity from bubbling to turbulent fluidization regime. A pseudo 2D experimental setup (figure 2) is used where a multi-chamber area with porous plates on the front was constructed and mounted at the bottom of the back plate in order to simulate vertical membranes. Gas can be extracted in specific areas on the back of the set-up through vertically mounted porous plates, thus the influence of the gas extraction, membrane configuration, and particle sizes on the onset of transition gas superficial velocity from bubbling to turbulent fluidization regime is investigated. Absolute and differential pressure fluctuations measured using fast pressure transducers mounted at different heights of the bed are employed to determine the transition velocity. In addition, local solid volume fraction and bubble behaviour determined using the DIA (Digital Image Analysis) technique is employed to highlight the differences in the bed behaviour in the two fluidization regimes.

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