

NOTE

ENHANCING PERFORMANCE OF A TRICKLE BED REACTOR AT LOW LIQUID FLOWRATES

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Abstract: When a differential Trickle Bed reactor is operated at low liquid flowrates wetting is incomplete. The rate enhancement found under partial wetting is considered by a 1-D model that takes into account the effect of gas and liquid flowrates, liquid volatility and gas solubility and kinetic parameters. Theoretical and experimental results are in agreement.

Keywords: Trickle Bed Reactor, Gas-phase Reaction

I. INTRODUCTION

The performance of a Trickle Bed Reactor (TBR) at low liquid mass velocities, below 3 to 5 kg/m²s, is rather difficult to interpret because the trickling liquid does not actively wet the entire surface of the catalyst. The reaction rate over externally incompletely wetted packing can be greater or smaller than the rate observed over completely wetted packing. When the reaction is liquid-limited and the liquid reactant is non-volatile, reaction rate decreases as the liquid flow rate is reduced. However, when the key reactant is in the gas phase, reaction rate increases as wetting decreases. Two different situations could be found: In one case, rate enhancement is not very relevant and in the other, rate and temperature increase significantly. We focus our attention in the last issue, and the key question to be answered is whether operation of a TBR under incomplete wetting can significantly improve reactor performance.

It is well documented that incomplete wetting of a catalytic pellet enables the limiting volatile reactants to be more rapidly supplied, so the mass transfer resistances diminish and this translates into a moderate enhancement in the overall rate as the liquid flowrate diminishes. Goto and Mabuchi (1984) reported examples of this behavior for the oxidation of aqueous ethanol and Haure *et al* (1992) observed this effect in their studies on SO₂ oxidation at low liquid flowrates.

On the other hand, if the liquid reactants are

volatile and significant heat effects are present, then a gas-solid catalyzed reaction between the vaporized liquid and the gas can occur in the dry catalyst. In this situation, a very significant increase in reaction rate and temperature is observed as the wetting efficiency decreases (Al-Dahhan and Dudukovic, 1995).

The occurrence of phase transition during an exothermic multiphase reaction has been extensively documented. Watson and Harold (1993) reported several studies from the literature in which hot spots were detected. Less understood are the mechanisms by which the phase transition occurs. Watson and Harold (1993, 1994) studied the Pd-catalyzed hydrogenation of cyclohexene and α -methylstyrene (AMS). They used a single catalytic pellet reactor to confirm that, under certain conditions, the heat evolved by the reaction can drive the vaporization of the liquid phase. The overall reaction rates were not measured.

Castellari *et al* (1997) studied the hydrogenation of AMS in a laboratory TBR. A temperature rise of 15°C was observed at the lowest liquid flowrate studied and global rates were up to six times the rate at complete wetting. An isothermal one-dimensional model was developed to describe the reaction in the wetted areas or liquid-solid catalysis, and the gas-phase reaction between volatilized AMS and H₂ in the non-wetted areas of a bed consisting of commercial Pd/Al₂O₃ catalytic pellets.

In the present study we theoretically analyze the impact of several variables such as liquid volatility or concentration, gas solubility, mass transfer and kinetics-diffusion on the reactor performance at incomplete wetting. Global reaction rates can be predicted by a simple model. If the rate increase is substantial then a more rigorous model –nonisothermal and heterogeneous– is needed, but this is out of the scope of the present work.

II. MODEL FORMULATION

We based our study in the model developed by Castellari *et al.* (1997) for the hydrogenation of AMS. It can be used to describe the first order

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