

DRYOUT PHENOMENON IN THE PERIODIC OPERATION OF A TRICKLE BED REACTOR

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Abstract— Periodic operation was investigated for the hydrogenation of alpha-methylstyrene to cumene over 0.5% Pd on alumina spheres. The effect of several variables such as gas flow rate, gas and liquid composition, and liquid feed temperature on unsteady-state liquid flow modulation in a Trickle Bed Reactor is studied. These parameters affect the depletion time of the volatile reactant as well as the temperature profiles of the dry cycle. A criterion is presented that allows for an estimation of the maximum temperature during the dry cycle based on mass and energy balances.

Keywords— Trickle Bed Reactor; Periodic operation; Gas-phase Reaction; Dryout.

I. INTRODUCTION

Previous work on the periodic operation of a Trickle Bed Reactor (TBR) has demonstrated that for the hydrogenation of alpha methyl styrene (AMS) to cumene on Pd/Al₂O₃ catalyst, reaction rates are increased up to 400% with respect to the steady state results (Castellari and Haure, 1995). In this mode of operation, circulation of the liquid phase is switched on and off while the gas passes continuously through the reactor. Silveston *et al.* (1995) pointed out that due to the complexity of the unsteady operation and the probability of higher costs than the conventional procedure, cycling is recommended if the rate enhancement is at least higher than 100%.

The performance of a TBR under cycling is extremely complex, especially in the case of the gas-limited, liquid volatile, exothermic reaction situation. The performance depends on the switching between wet and dry operation (Gabarain *et al.*, 1997). In the non-wet cycles, wetting of the packing is incomplete. The reaction rate can be greater or smaller than the rate observed over completely wetted packing. This depends on whether the limiting reactant is present only in the liquid phase or in both the gas and liquid phases. If the reaction is gas limited, rates will be higher because the gas reactant can access the catalyst pores from the externally dry area. When the reaction is liquid limited and the liquid reactant is non-volatile, a decrease in the

wetting efficiency will cause a decrease in the reaction rate. But if the liquid reactant is volatile and significant heat effects are also present, then, a gas phase reaction can occur on the dry catalyst resulting in higher rates and temperatures (Al-Dahhan and Dudukovic, 1995). The associated increase in the local reaction rate and the temperature rise may be a feature of concern because it can lead to the formation of uncontrolled hot-spots and the subsequent sintering of the catalyst, runaway conditions and undesirable side reactions, as pointed out by Hanika *et al.* (1975). Proper selection of the cycling variables is strongly recommended to exploit the vaporization phenomena while avoiding related problems.

The occurrence under steady-state conditions of vaporization during reaction in multiphase reactors at the single pellet level is well documented (Hanika *et al.*, 1976; Watson and Harold, 1993, 1994). In particular, Watson and Harold (1993) studied the Pd-catalyzed hydrogenation of AMS (to cumene) and of cyclohexene (to cyclohexane) in a single pellet catalytic reactor. The key difference between the two reactions is the volatility of the less volatile reactant. The experimental data reveal interplay between the exothermic reaction, the endothermic vaporization and internal and external transport processes. For the case of drying with hydrogenation, they observed a departure from traditional drying theory, especially in the initial period due to the influence of the latent heat of vaporization, the heat conduction and the heat generated by the exothermic reaction. In general, hydrogenation accelerates the drying process because the reaction on dewetted sites speeds up the dryout phenomenon. The rate of drying depends on the volatility of the liquid and, if sufficient time elapses such that a fraction of the catalyst becomes exposed to the gas, a much more rapid gas-phase catalytic reaction occurs with an accompanying temperature excursion.

Gabarain *et al.* (1997) have proposed a phenomenological model that explains the events associated with periodic interruption of the liquid phase to a TBR. Experimental and model results compare reasonably well. Cycling deliberately creates hot spots during the “dry” cycles due to the onset of gas-phase reaction and results in higher conversions compared to the conventional

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