But-1-ene hydroformylation in a continuous gas-phase membrane reactor: road to industrial application

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Abstract

Since its discovery by Otto Roelen in 1938, hydroformylation grew to become one of the largest industrial chemical processes utilizing homogeneous catalysts at more than 10 million metric tons of products annually [1]. One of the major challenges for industrial operation is the efficient and complete recycling of the expensive Rh catalyst. Developments in the field of catalysis that allowed the immobilization of a homogeneous catalyst on a solid support gave rise to supported liquid phase (SLP) catalysis. Being a bridge between homogeneous and heterogeneous catalysis, SLP showed great potential in improving current industrial processes significantly.
Investigations on this catalytic system demonstrated the employment of rhodium and biphephos (bpp) ligand with the amine additive sebacate as a liquid phase to catalyze but-1-ene hydroformylation to aldehydes. [2, 3] The catalyst system showed superior performance with selectivities reaching 60% toward n-pentanal and exceptional regioselectivity with linear to total aldehyde ratio of 99%. Given the high reactivity of the formed aldehydes, their consecutive reaction toward aldols must be suppressed for continuous gas-phase SLP catalysis.
Recently, we successfully developed a membrane reactor approach that combined reaction and separation into a single operating unit. A monolithic structure of silicon carbide was coated with polydimethylsiloxane (PDMS) then directly impregnated with the SLP catalyst system. This polymeric membrane layer facilitated the selective separation of the reaction products resulting in n-pentanal rich permeate stream.
In this contribution, we demonstrate this approach with a continuous membrane reactor set-up. The results from kinetic investigations and stability studies were used to implement a membrane reactor model within Aspen Custom Modeler (ACM). This ACM model has been used to scale up the hydroformylation process by a factor of 500. The demonstration reactor will be implemented in a production plant of Evonik in Marl, Germany.

References:
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