C1 Building Blocks for Future Chemistry
DGMK Conference October 11-13, 2023, Dresden

Process Intensification Strategy Demonstrated by Innovative DME Synthesis

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Abstract

Dimethyl ether (DME) is a promising PtX energy vector with multiple applications in different sectors. Its thermophysical properties promote DME as an additive and replacement for fossil LPG. DME is also an oustanding and environmentally benign hydrogen carrier with an excellent hydrogen capacity of 26.1 wt.-%. The conventional DME production process has the disadvantage of a large number of process steps and high external heat demand. A promising alternative is DME synthesis via reactive distillation, where DME is removed in-situ from the chemical equilibrium, allowing complete conversion of the feedstock and product purification in a single process step [1]. This process alternative results in fewer unit operations and lower maintenance requirements and can also enable an energy self-sufficient process without external heat requirements [2]. The DME reactive distillation implies a reaction in liquid phase at significantly lower reaction temperatures than in the conventional gas phase synthesis. Consequently, in a previous publication of our group several catalysts for the liquid phase DME synthesis were screened and a kinetic model of DME synthesis on two different ion exchange resins was derived based on fixed bed profile reactor measurements [3].

The target of this work was the transfer of the reaction kinetics from a laboratory scale reactor to the actual process conditions in a reactive distillation column on a more industrially relevant scale in a DN50 pressure distillation column. Starting from both pure and crude methanol feed, the production of purified DME in a single unit operation was succesfully demonstrated. Multiple experiments were carried out, examining the influence of reflux ratio and WHSV and the gas phase composition was determined on multiple positions along the column using FT-IR spectroscopy. By modeling the system and comparing the theoretical reaction rate according to kinetic models with the actual measured distillate stream, the transfer of the kinetic model from the laboratory reactor towards the process conditions of a reactive distillation column could be succesfully validated.

With the validated kinetic model, industrial-scale reactive distillation process configurations were simulated in Aspen Plus V12. Besides the stand-alone reactive distillation column, process configurations with a complementing side- or pre-reactor were analyzed and optimized with regard to minimum total production cost and it was shown that the best reactive distillation process can reduce the production cost by 40 % compared to the conventional DME process.

References

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