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Development of a Novel Process for the Large-scale Production of OME Fuels from Formaldehyde and Methanol

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Abstract

Polyoxymethylene dimethyl ethers (OME) are oxygenates of the general structure $H_3C\text{-}O\text{-}(CH_2O)_n\text{-}CH_3$. They are environmentally benign alternative fuels which strongly reduce the soot formation in diesel engines [1,2]. Synthesis routes for the production of OME are based on synthesis gas via the methanol route which enables the flexible use of both traditional (coal, natural gas) and renewable raw materials (biomass, CO_2). The production of OME can thus be perfectly adapted to a changing raw materials landscape. Presently, processes for the production of OME require the use of expensive intermediates as feedstock such as methylal and trioxane [3]. This contribution presents the conceptual design of a novel OME process which employs cheaper feedstocks with high production capacity: methanol and aqueous solutions of formaldehyde. After the OME reactor, OME of the desired chain lengths (n = 3−5) and water are separated from the reactive multi-component mixture (formaldehyde+water+methanol+methylal+OME) which shows a liquid phase split and several (reactive) azeotropes. A wide range of physico-chemical property data, including reaction kinetics and various phase equilibria, are determined experimentally. Based on these measurements a comprehensive model for describing the various data is developed. Using model-based conceptual design methods, a process concept consisting of a synthesis reactor, product purification, and purge of coupled product is developed. An optimized operating point obtained by process simulations is verified in lab-scale experiments including the continuous operation of a reactive distillation column. The novel process is compared with pre-existing OME processes and shown to be beneficial in both CAPEX and OPEX.

[1] Lumpp B, Rothe D, Pastötter C, Lämmermann R, Jacob E (2011) Oxymethylene ethers as diesel fuel additives of the future. MTZ, 72(3), 34-8.

[2] Härtl M, Gaukel K, Pélerin D, Wachtmeister G (2017) Oxymethylenether als potenziell CO2-neutraler Kraftstoff für saubere Dieselmotoren Teil 1: Motorenuntersuchungen. MTZ, 78(2), 52-59.

[3] Burger J, Ströfer E, Hasse H. (2013) Production process for diesel fuel components poly (oxymethylene) dimethyl ethers from methane-based products by hierarchical optimization with varying model depth. Chem. Eng. Res. Des., 91, 2648-2662.