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Advancing Environmental Sustainability in Methanol Production through a Techno-Economic and Energy-Efficiency Optimization Approach

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Abstract

The modern world needs green energy and environmentally friendly solutions for the well-being of our ecosystems. As a cleaner production offering a lower carbon footprint, methanol has emerged as a viable option for energy generation and environmental sustainability. Accordingly, multi-objective optimization (MOO) of techno-economic and energy efficiency metrics has been conducted. This MOO involved modeling methanol synthesis from syngas using the Aspen Plus simulator, validated through a literature review. The MOO of methanol production encompasses production cost and energy efficiency objective functions. The optimization process entailed the integration of the Aspen Plus model with MATLAB-NSGA-II evolutionary algorithm, facilitating back-and-forth iterative computation procedures that were conducted until optimal Pareto front solutions were attained. Consequently, the methanol production rate of 233.92 km/hr with 99.999% purity was achieved with Pareto optimal solutions of 74.94% energy efficiency and a production cost of 457.76 $/ton. Furthermore, an Aspen Energy Analyzer (AEA) process heat integration simulation was conducted to assess the methanol synthesis plant's energy consumption and cost reduction.

The AEA analysis revealed significant reductions, including a 94.9% decrease in hot utilities, a 67.18% decrease in cold utilities, a 91.87% decrease in overall utility cost, and zero carbon emissions.This study emphasizes notable reductions in methanol production costs and substantial improvements in energy efficiency, highlighting its potential to advance environmental and energy sustainability within the methanol production plant.

Keywords: Syngas; Modeling; Optimization; Heat integration; Environmental sustainability