PAPER REPORT- 2

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Paper Title: Advanced exergy analysis and optimization of a CO_2 to methanol process based on rigorous modeling and simulation

Paper link:
https://www.sciencedirect.com/science/article/abs/pii/S0016236122017860

Summary:

Motivation:
This study focuses on catalytic hydrogenation of CO_2 to methanol, exploring the process's thermodynamic performance using advanced exergy analysis for effective improvement measures and parametric optimization. The main contributions include material and energy flow modeling, conventional and advanced exergy analyses, and identifying effective improvement measures for the CO_2 to methanol process.

Contribution:
The study underscores the significance of efficiently utilizing CO_2 for carbon neutrality. It specifically focuses on producing green methanol and green hydrogen, highlighting their potential to cut carbon emissions and tackle storage challenges. The advanced exergy analysis of the CO_2 to methanol (CTM) process reveals a 46.55% improvement potential, primarily addressing endogenous exergy destruction. Proposed strategies aim to decrease avoidable exergy destruction, potentially resulting in a 14.78% reduction in total exergy destruction and a 4.91% increase in exergy efficiency.

Methodology:
To quantify the real improvement potential and interdependencies among the components and the whole CTM process, the workflow for the advanced exergy analysis of the CTM process, The approach involves a five-stage process, beginning with Rigorous modeling and simulation and then the Conventional exergy analysis, Advanced exergy analysis, Key parameters optimization and lastly Development of improvement strategies.

Conclusion:
The study employed advanced exergy analysis to evaluate the improvement potential and interactions in the CTM process. The findings indicated a total exergy destruction ratio of 33.38%, with endogenous exergy destruction constituting 94.47%, emphasizing irreversibility within components as the primary cause. The study recommended reducing avoidable exergy destruction in specific components, leading to a substantial decrease in total exergy destruction

and an increase in exergy efficiency after optimization, while also suggesting future advanced exergoeconomic analysis to address potential economic implications.

Limitations:

First Limitation:
Limited Improvement Potential: Despite efforts to optimize the CTM process, only 46.55% of the exergy destruction can be realistically reduced. The remaining 53.45% is deemed unavoidable due to technical or economic constraints. This implies that there are inherent limitations that prevent further significant improvements.

Second Limitation:
Trade-off with Production Cost and Equipment Investment: It acknowledges that the optimization efforts, while improving exergy efficiency, may lead to increased production costs and equipment investment. This introduces an economic feasibility challenge, indicating that achieving thermodynamic effectiveness might result in an economically infeasible CTM process.

Synthesis:

To achieve carbon neutrality, it is strategically important to convert CO_2 into green hydrogen and green methanol as efficiently as possible. Despite thermodynamic obstacles, the CTM method has prospective uses in the large-scale manufacture of green fuels that are in line with international efforts to reduce carbon emissions. The use of energy from renewable sources presents a viable resolution to the problems associated with hydrogen storage and transportation. The study highlights the necessity of sophisticated exergy analysis and offers suggestions for improvement to lower unnecessary exergy destruction and raise overall efficiency. Possible domains encompass improving analytical techniques, executing plans at the industrial level, and evaluating financial feasibility. When taken as a whole, these developments may have a significant influence on sustainable energy systems and global efforts to achieve carbon neutrality.