Energy Conversion and Management 286 (2023) 117049

Contents lists available at ScienceDirect

Energy Conversion and Management

journal homepage: www.elsevier.com/locate/enconman

Optimal retrofitting of MCH-Toluene dehydrogenation system: Energy and technoeconomic analysis

Muhammad Anas Maqbool [a,1], Javed Khan [b,c,1], Muhammad Haris Hamayun [a,2], Faisal Ahmed [b,2,*], Murid Hussain [a,2]

[a] Department of Chemical Engineering, COMSATS University Islamabad, Lahore, Pakistan
[b] Process and Energy Systems Engineering Center-PRESTIGE, Department of Chemical Engineering, COMSATS University Islamabad, Lahore, Pakistan
[c] Department of Chemical Engineering, University of Massachusetts Amherst, Amherst, USA

ARTICLE INFO

Keywords:
LOHC
MCH-Toluene system
Heat integration
Teaching learning self-study optimization
Technoeconomic analysis

ABSTRACT

The rapid consumption of fossil fuels and the decline of conventional energy sources are diverting the world energy demand towards clean and sustainable energy. Hydrogen gas is under consideration for past few years as the clean energy source. But hydrogen itself is facing storage and transportation issues, and liquid organic hydrogen carriers (LOHCs) are the viable potential option to meet this need of the hour. Methylcyclohexane-toluene (MCH-Toluene) is one of the most appropriate LOHCs as compared to any other. Several studies in the past have focused mainly on the sensitivity analysis or the effect of catalysts on different operational parameters such as conversion of the reaction, but according to the best of authors' knowledge, the MCH-Toluene dehydrogenation system has not yet been rigorously optimized to reduce the total energy demand of the system. This study first unfolds the process configuration modification of the MCH-Toluene dehydrogenation system for its retrofitting based on heat integration. This retrofitted MCH-Toluene dehydrogenation system is then rigorously optimized to present an optimal process with respect to energy demand. A fast converging and consistent optimization approach named teaching learning self-study algorithm is used to achieve maximum potential thermodynamic performance of the proposed retrofit. The optimization of the system results in the total energy demand of the system reduced by the 6.07% as compared to the base case. The economic evaluation shows that the total investment required for MCH-toluene system and the total annual operating cost are reduced from $ 2.67 million and $ 2.42 million in the base case to $ 1.36 million and $ 1.6 million in this case, respectively. The levelized cost of hydrogen product is decreased from 1.6 $/kg H_2 in the base case to 1.08 $/kg H_2 in this study. As this method is reliable and efficient to reduce the total energy demand of the system, it could be more beneficial and helpful for the process engineers in the future.

1. Introduction

As the world's population growing along with rising living standards, the demand for energy is expected to rise substantially in the future [1] as energy is the basic requirement to derive every aspect of life. Today's modern life depends upon such sources of energy which must be rich in abundance, easy to utilize, and have good content of energy. It is a driving force in the bodies of all living creatures, propelling vehicles and lighting this dark universe. Our planet is dealing with a significant energy crisis, which is driving up the global energy demand. In this scenario, fossil fuels are still considered the major source of energy among various renewable and sustainable sources such as hydel power generation, wind energy, hydrogen energy, and renewable energy resources. However, the use of fossil fuels is linked with various disadvantages, (1) destroys the natural resources, (2) a continuous increase in carbon dioxide emissions in the atmosphere, which environmentalists believe is to be responsible for climate changes and unexpected global temperatures, (3) significant emissions of the greenhouse gases. The international energy agency has proposed imperative steps to control carbon dioxide emissions. The world's intervention is currently being

* Corresponding author.
E-mail address: faisalahmed@cuilahore.edu.pk (F. Ahmed).
[1] The two authors contributed equally as the first author.
[2] The three authors have the same contribution to this study.

https://doi.org/10.1016/j.enconman.2023.117049
Received 9 February 2023; Received in revised form 7 April 2023; Accepted 11 April 2023
Available online 26 April 2023