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Optimization of syngas production via methane bi-reforming using CeO_2 promoted Cu/MnO_2 catalyst

Irna Haslina Ibrahim [a], Mohd-Nasir Nor Shafiqah [a], Siti Nor Amira Rosli [a], Hassan Mohamed [b], Joongjai Panpranot [c], Van Cuong Nguyen [e], Sumaiya Zainal Abidin [d,e,*]

[a] Faculty of Chemical and Process Engineering Technology, Universiti Malaysia Pahang Al-Sultan Abdullah, Lebuh Persiaran Tun Khalil Yaakob, Kuantan, Pahang 26300, Malaysia

[b] Institute of Sustainable Energy, Universiti Tenaga Nasional (UNITEN), Putrajaya Campus, Jalan IKRAM-UNITEN, Kajang, Selangor 43000, Malaysia

[c] Department of Chemical Engineering, Faculty of Engineering, Chulalongkorn University, Phayathai Road, Pathumwan, Bangkok 10330, Thailand

[d] Centre for Research in Advanced Fluid & Processes (FLUID CENTRE), Universiti Malaysia Pahang Al-Sultan Abdullah, Lebuh Persiaran Tun Khalil Yaakob, Kuantan, Pahang 26300, Malaysia

[e] Faculty of Chemical Engineering, Industrial University of Ho Chi Minh City, 12 Nguyen Van Bao St, Go Vap, Ho Chi Minh City, Viet Nam

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ABSTRACT

Currently, syngas plays an important role in renewable and sustainable energy production. The idea of manufacturing syngas via bi-reforming methane, which involves the combination of methane (CH_4), carbon dioxide (CO_2), and steam, appears very promising. As a result, the goal of this research is to improve syngas output by improving process parameters in methane bi-reforming using a 3%Ce-15%Cu/MnO_2 catalyst. Optimization analysis was performed using response surface methodology (RSM). The ultrasonic impregnation (UI) method was employed to synthesize the catalysts used in this study. Following that, the catalyst was characterized using several techniques such as Brunauer-Emmett-Teller (BET), X-ray diffraction (XRD), temperature programmed reduction (TPR), temperature programmed desorption (TPD), and temperature programmed oxidation (TPO). The findings of the characterization show that the presence of CeO_2 promoters has a dual effect on the size of CuO crystallites. Firstly, it reduces the size from 19.07 nm to 13.66 nm because to the dilutive effect generated by the inclusion of CeO_2. Second, the presence of CeO_2 promoter accelerates the transition from CuO to Cu^0 metallic phase. Furthermore, the addition of CeO_2 boosts the CH_4 and CO_2 conversion rates by 23.65% and 24.93%, respectively. As a result, the H_2 yield increases significantly when compared to the unpromoted catalyst. The study investigates the influence of process parameters, specifically the reaction temperature (700–900℃), CO_2 ratio (0.2–1), and gas hourly space velocity (GHSV) (16–36 L g cat^{-1} hr^{-1}), on the conversion of CH_4 and CO_2, as well as the H_2/CO ratio. The optimization study finds that the highest conversion rates for CH_4 and CO_2 are 78.32% and 72.45%, respectively, when the reaction temperature is 800 °C, the CO_2 ratio is 0.6, and the gas hourly space velocity (GHSV) is 26 L g cat^{-1} hr^{-1}. The optimum conditions result in the highest syngas ratio of 1.77. The results of the optimization are then assessed using the mean errors. The H_2/CO ratio, as well as the average errors for CH_4 and CO_2 conversions, are discovered to be 0.15%, 0.95%, and 0%, respectively.

1. Introduction

The depletion of fossil fuel resources has spurred an initiative to harness natural resources for producing sustainable and eco-friendly energy fuels using advanced and efficient methods. In this context, natural gas has emerged as an economical and environmentally friendly energy source due to its wide availability and high energy density (Al-Fatesh et al., 2023a). Additionally, it predominantly contains methane, which can be converted into viable hydrocarbons, oxygenates, and synthetic fuels through various direct and indirect routes (Ateka et al., 2022). Direct processes involve selective oxidation of methane, methane aromatization, and high-temperature methane coupling. On the other hand, indirect methods focus on upgrading methane to intermediate products like syngas (a mixture of CO and H_2) through partial

* Corresponding author at: Centre for Research in Advanced Fluid & Processes (FLUID CENTRE), Universiti Malaysia Pahang Al-Sultan Abdullah, Lebuh Persiaran Tun Khalil Yaakob, Kuantan, Pahang 26300, Malaysia.

E-mail address: sumaiya@umpsa.edu.my (S.Z. Abidin).

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