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Kinetic and experimental validation of optimised feed ratio bi-reforming process over a Ni/MgAl₂O₄ catalyst

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ABSTRACT

Bi-reforming of methane (BRM) is integrating dry reforming and steam reforming reactions, offers a promising pathway for simultaneous utilisation of CO₂ and CH₄ to produce syngas with tunable H₂/CO ratios suitable for downstream Fischer–Tropsch and methanol synthesis [1, 2]. However, optimisation of feed composition and reliable kinetic validation under industrially relevant conditions remain critical challenges, particularly with respect to catalyst stability and carbon mitigation. In this study, a comprehensive kinetic and experimental validation of an optimised feed-ratio bi-reforming process over a Ni/MgAl₂O₄ catalyst is presented.

The Ni/MgAl₂O₄ catalyst was synthesised by an incipient wetness impregnation (IWI) route and evaluated in a fixed-bed reactor over a wide range of CO₂/CH₄/H₂O feed ratios, temperatures (800–900°C), and gas hourly space velocity (GHSV). Experimental results demonstrate that optimisation of the steam-to-carbon and CO₂-to-CH₄ ratios enables enhanced syngas productivity with stable H₂/CO ratios close to unity, while significantly suppressing carbon deposition compared to conventional dry reforming operation. Under optimised conditions, the bi-reforming process achieved up to ~33% higher CO₂ utilisation per mole of CH₄, alongside improved methane conversion and sustained catalytic stability [Figure 1].

A mechanistic kinetic model for bi-reforming was developed, considering steam methane reforming, dry methane reforming, and the water-gas shift reaction using the Langmuir–Hinshelwood–Hougen–Watson model, with consistency ensured over the temperature range investigated in this work. Kinetic parameter estimation was carried out using nonlinear least-squares regression, incorporating a temperature-centred approach to reduce parameter correlation. The resulting parameter set was further evaluated against physicochemical and thermodynamic consistency criteria, while statistical robustness and parameter identifiability were assessed to ensure statistically consistent and reproducible parameter estimation, thereby enabling their subsequent use in reactor design modelling and optimisation. The combined experimental–kinetic approach provides valuable insights into reaction pathways governing

BRM over Ni-based catalysts. Overall, this work establishes a validated framework for feed-ratio optimisation in bi-reforming, demonstrating the potential of Ni/MgAl₂O₄ catalysts for efficient, low-carbon syngas production and offering practical guidance for scale-up toward electrified and industrial reforming systems.

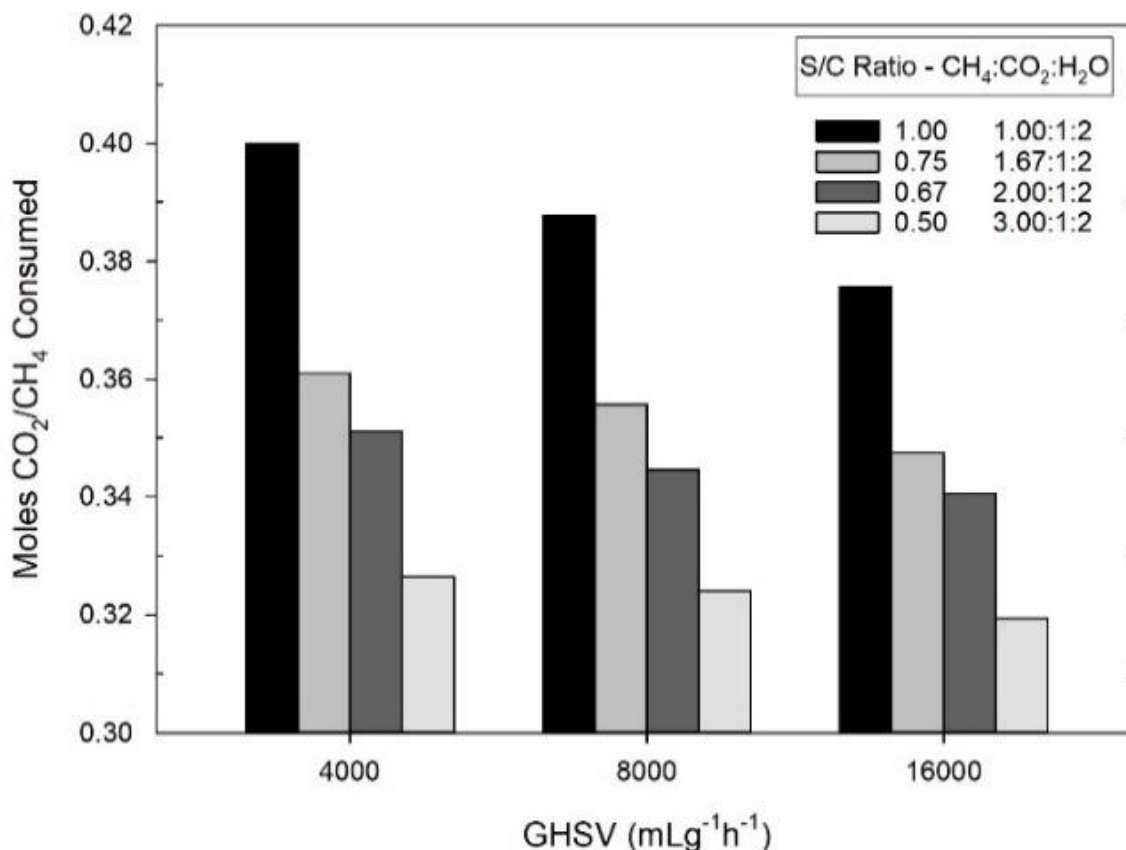


Figure 1: Moles of CO₂/CH₄ consumed for Ni/MgAl₂O₄ catalysts with a GHSV range of 4000-16000 mLg⁻¹h⁻¹ and S/C of 1.00, 0.75, 0.67 and 0.50.

KEY WORDS

Bireforming; Ni-based catalyst; Syngas; Kinetic validation; LHHW model; Catalyst stability

BIOGRAPHY

Dr Mohammad Shakir is a Research Associate at the WA School of Mines, Curtin University, Perth, Australia. His research focuses on decarbonisation, CO₂ utilisation, catalytic reforming of greenhouse gases, sustainable aviation fuel production, and electrified reactor technologies. He has extensive experience in catalyst synthesis, reaction engineering, process optimisation, and industry-linked research translation. Dr Shakir has published in reputable journals and presented his work at leading international conferences. His current work is directed toward developing advanced catalytic systems and scalable low-emission processes for syngas, hydrogen, and sustainable fuel production to support the global energy transition.

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