A novel process for syngas production via CO_2 capture and chemical looping

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Highlights

- Design and simulation of a CO_2-based pathway for syngas production
- The new pathway eliminates the need for external heat supply through heat integration
- The novel process competes with reverse water-gas shift in terms of conversion and selectivity

1. Introduction

Syngas ($CO+H_2$) is a versatile intermediate in the petrochemical industry that can be used for the production of various products, such as alcohols, olefins, and even plastics (indirectly). Steam or dry reforming of methane (SMR or DRM) and gasification are the conventional methods of producing syngas. The issue with these processes is that although they produce a syngas of high purity, they have a high temperature and energy demand which translate into high production costs and a significant carbon footprint [1–3]. The United Nations Environment Programme stated that global GHG emissions should be reduced by 30-55% by 2030 in order to achieve the goals of the Paris Agreement [4]. Therefore, in an effort to be more sustainable, syngas production should be integrated into the world of circular economy.

One pathway involves the indirect production of syngas via reverse water-gas shift (RWGS). This process converts CO_2 into CO and some other by-products. The addition of H_2 to CO generates syngas.. However, the low conversion of CO_2, coupled with by-product formation, decreases the efficiency of the process. Additionally, this process relies on high temperatures and pressures, implying a high demand for energy.

To combat the high energy demand of this reaction, and to avoid any side reactions, chemical looping is a promising technique that can be incorporated. Therefore, this work aims to present a combination of chemical looping and carbon capture, known as chemical looping reverse water-gas shift (RWGS-CL) that has the potential to improve the efficiency of syngas production, while minimizing its environmental impact.

2. Methods

The main objective of this work is to develop an economically viable process to produce syngas with zero or negative CO_2 emissions, based on CO_2 capture and utilization, before converting it into different products. The process is first simulated in Aspen Plus version V12.1. Captured carbon dioxide and hydrogen (from electrolysis) are introduced to a chemical looping system comprised of three reactors, where CO_2 is converted to CO and hydrogen is converted to water. Carbon monoxide is then mixed with H_2, and depending on the desired molar ratio, syngas can then be converted into different chemical products. Figure 1 showcases a simplified block flow diagram of the proposed system.

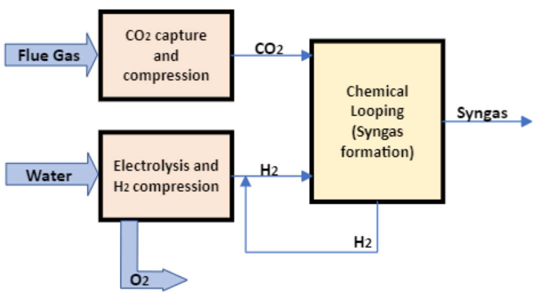

Figure 1. Simplified schematic of proposed process.

Heat integration network (HEN) design was conducted in Aspen Energy Analyzer V12.1 to optimize and minimize the energy demand of the system. A comparison between traditional RWGS and the novel process is also provided.

3. Results and discussion

Simulation results were obtained and compared to traditional RWGS in terms of energy demand, conversion of CO_2, and selectivity to CO [5]. The results of the RWGS-CL include results after heat integration design.

Table 1. Comparison of different parameters between RWGS and RWGS-CL

	Temperature	CO_2 conversion	CO selectivity	Energy Demand
Traditional RWGS	750 °C	69.1 %	85.1 %	1.1 MW
RWGS-CL	Adiabatic	79.2 %	74.5 %	-1.9 MW

As seen from Table 1, the new pathway provides higher conversion and selectivity compared to the traditional RWGS pathway. The new design is adiabatic compared to the high temperature requirement of 750°C. This, however, increases the heating demand for the system. Therefore, to combat this, heat integration is performed. The negative energy demand implies that no heat is needed by the system; instead, heat is generated. This waste heat can be converted into steam, to supply heat demand to any upstream or downstream units, or it can be converted to electricity to supply the demand for the process.

4. Conclusions

The results proved that this new process is more efficient than RWGS in terms of conversion and selectivity. The incorporation of heat integration eliminated the heating demand, and instead, the process is now capable of supplying heat or electricity to downstream units. By eliminating the demand from syngas production and applying the waste heat to other purposes, energy demand is reduced, and so are GHG emissions.

Further studies are necessary to assess the validity of the process, such as life cycle assessment and techno-economic analysis. Additionally, the data should be compared to different syngas production pathways to obtain a well-rounded idea of the benefits of RWGS-CL.

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Keywords

CO_2 utilization; chemical looping; process intensification; syngas production