Design of an aqueous phase reforming process demonstration unit for the production of green hydrogen from organics-laden residual waters

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Area 1.3 Biorefineries
Syngas Platform Technologies

Highlights

- First APR process demonstration unit
- Upscaling by a factor of 666
- Process up to 44 l/h of residual water
- Product gas contains up to 75 vol% H_2

Introduction

Aqueous phase reforming (APR) describes the conversion of oxygenated hydrocarbons dissolved in an aqueous phase to hydrogen and carbon dioxide [1].

$$C_nH_{2y}O_n + n\,H_2O \rightleftharpoons n\,CO_2 + (y+n)\,H_2$$

When applied to residual waters from biorefineries, it offers the possibility to valorize the organic compounds present in these effluents. Since research to date has only focused on bench-scale investigations, a lab-scale unit was built to prove the feasibility of APR at a larger scale.

Materials and Methods

The process demonstration unit (PDU) built for this endeavor (see Fig. 1) is fully automated and able to process up to 44 l/h of residual water in a continuous manner.

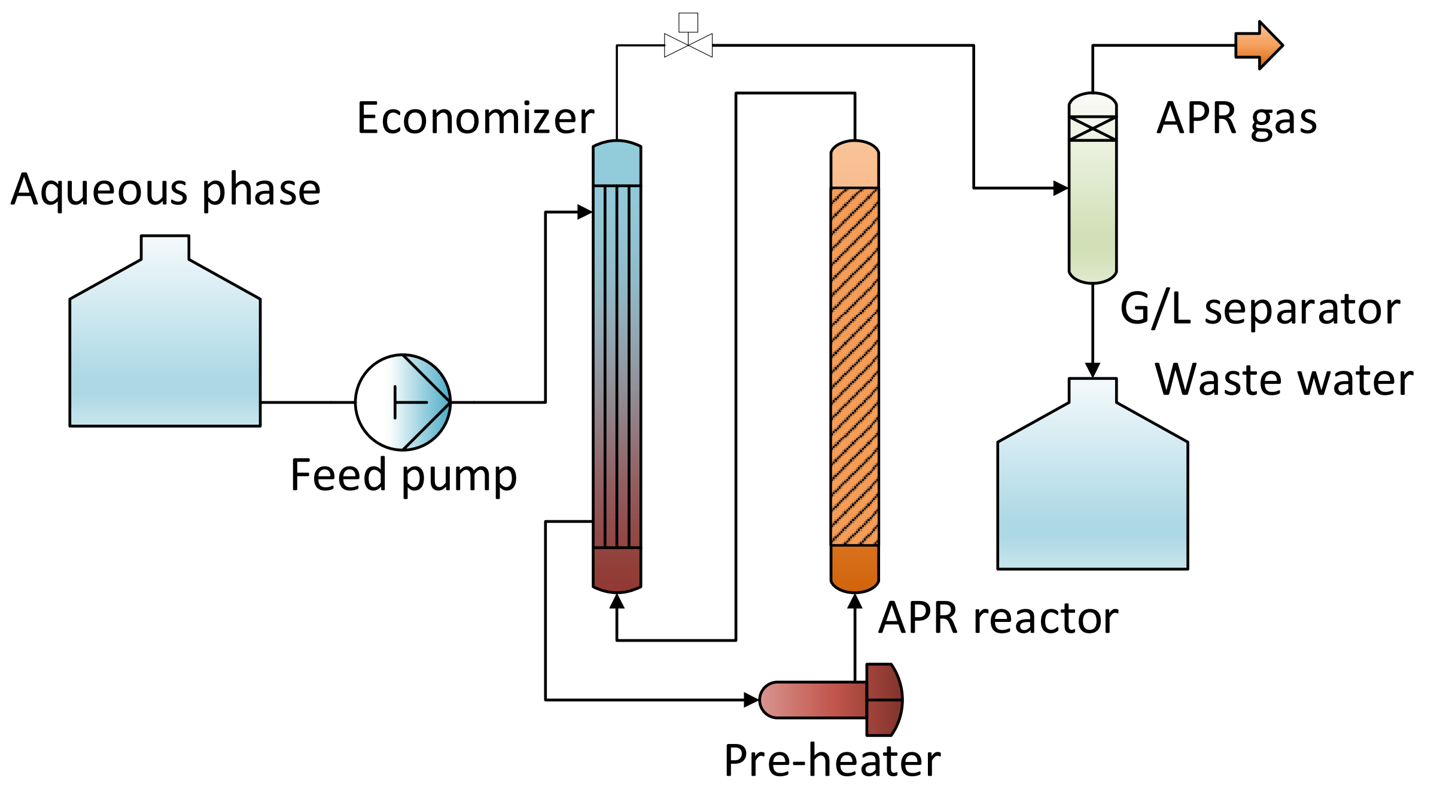

Fig. 1. Process flow diagram of the APR PDU

The plant is designed to process residual waters derived from lignin-rich hydrothermal liquefaction, which typically contain carboxylic acids, alcohols, ketones, polyalcohols, aromatics and aldehydes [2]. The first experiments, however, were conducted using a 0.5 wt% glycolic acid solution. Further experiments were conducted with a synthetic aqueous phase mixture composed of five model compounds selected to resemble residual water obtained from hydrothermal liquefaction [2]. The composition used was 0.16 wt% glycolic acid, 0.19 wt% lactic acid, 0.18 wt% acetic acid, 0.42 wt% methanol and 0.05 wt% glycerol. The reactor used for reforming the aqueous phase was a fixed bed reactor with an internal diameter of 70.1 mm. It was filled with 666 g of a 5 wt% Pt/C catalyst. A temperature of 250 °C, a pressure of 52 barg and a WHSV of 0.283 and 0.575 $g_{org}/(g_{cat}\cdot h)$, respectively, were selected as the operating conditions.

Results and Discussion

The PDU was operated successfully with both a glycolic acid solution and a synthetic aqueous phase mixture. The experiment with the glycolic acid solution yielded a product gas flow rate of 156 Nl/h while that with the synthetic aqueous phase mixture resulted in a gas flow rate of 154 Nl/h. The product gas of both experiments (see Fig. 2) largely consists of H_2 and CO_2 with small amounts of CH_4 and CO. The increased CH_4 content for the synthetic mixture is due to the presence of more challenging to reform compounds in the feed [3].

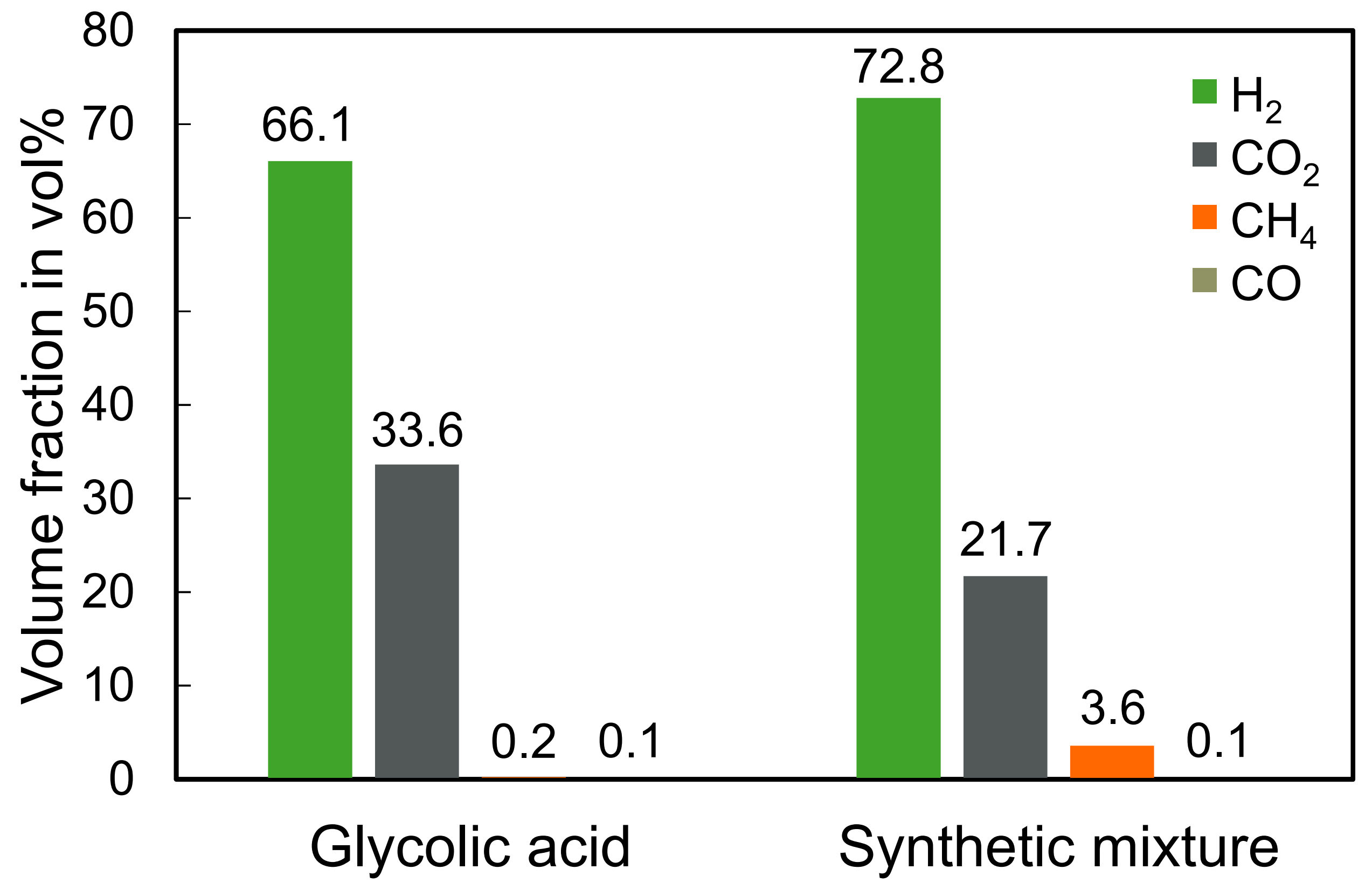

Fig. 2. Product gas composition

Successful operation of the APR PDU proves that an upscaling of the APR process from bench scale to larger scales is possible from a process technological standpoint. Furthermore, demonstrating that the process works flawlessly with a continuously-operated fixed bed reactor instead of a batch-operated stirred-tank reactor is an important step to prove the industrial viability of APR.

References

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