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Synthesis gas production using steam hydrogasification and steam reforming

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ABSTRACT

Experimental work has been carried out on the mixed reforming reaction, i.e., simultaneous steam and CO₂ reforming of methane under a wide range of feed compositions and four different reaction temperatures from 700 °C to 850 °C using a commercial steam reforming catalyst. The experiments were conducted for a CO₂/CH₄ ratio from 0 to 2 and a steam to methane ratio from 3 to 5. The effect of CO₂/CH₄ ratio on the exit H₂/CO ratio and the conversions of the reactants indicate that the dry reforming reaction is dominant under increased carbon dioxide in the feed. Steam reforming of typical steam hydrogasification product gas consisting of CO, H₂ and CO₂ in addition to steam and methane has also been investigated. The H₂/CO ratio of the product synthesis gas varies from 4.3 to 3.7 and from 4.8 to 4.1 depending on the feed composition and reaction temperature. The CO/CO₂ ratios of the synthesis gas varied from 1.9 to 2.9 and 2.0 to 3.3. The results are compared with simulation results obtained through the Aspen Plus process simulation tool. The results demonstrate that a coupled steam hydrogasification and reforming process can generate a synthesis gas with a flexible H₂/CO ratio from carbon-containing feedstocks.

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1. Introduction

The efficient commercial production of synthesis gas (a mixture of hydrogen and carbon monoxide) is gaining significant attention as the worldwide interest in synthetic fuels and chemicals is increasing. Synthesis gas (syngas) is a versatile feedstock that can be used in the production of a number of hydrocarbons, including synthetic Fischer–Tropsch (FT) diesel. The required molar ratio of hydrogen to carbon monoxide (referred to as the syngas ratio) varies depending on the desired product and fuel processing technology [1,2]. For example, the production of Fischer–Tropsch diesel fuel may require a H₂/CO syngas ratio from less than one to over two depending on the catalyst and specific technology used [1]. Oxosynthesis and other processes such as dimethyl ether synthesis generally require a H₂/CO ratio of 1 [2]. There are several commercial

technologies available for syngas production depending on the input gas composition; each usually resulting in a specific fixed H₂/CO syngas ratio [3]. Steam methane reforming produces a H₂/CO syngas ratio of four or higher whereas partial oxidation gasification produces a syngas ratio of 1; and autothermal reforming produces a ratio of 2. The composition of the syngas from either gasification processes or syngas production technologies are generally not suited for direct use in the downstream fuel process. In several cases, H₂/CO syngas ratio adjustment techniques such as downstream shift reactors, membrane separators or pressure swing adsorption are employed to meet the ratio requirement [3,6]. This adds cost and complexity to the overall process.

Steam methane reforming is a well known commercial technology and is often a preferred choice for hydrogen production from methane. It has been well established that the presence of

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carbon dioxide in a conventional steam methane reformer feed reduces the product H_2/CO syngas ratio [4–6]. The catalytic reaction of methane and CO_2 is known as dry reforming. There has been considerable interest in the dry reforming of methane since this allows two major greenhouse gases to be utilized simultaneously for the production of synthesis gas. It has been proposed that the CO_2 is shifted to CO and H_2O through the reverse water–gas shift (RWGS) reaction and then H_2O is reacted with CH_4 to produce syngas during the dry reforming [18]. A major disadvantage of dry reforming is the tendency for carbon deposition leading to catalyst deactivation. It has been shown that this problem can be mitigated by the addition of steam to the process [7–9]. Hence the simultaneous steam and carbon dioxide reforming of methane, known as the ‘mixed reforming’ reaction allows some limited control of the H_2/CO syngas ratio while avoiding carbon deposition. Significant research has been done on the mixed reforming reaction [7,10–12]. It has been shown that the presence of carbon dioxide enhances the conversion of methane and can have an influence on the H_2/CO syngas ratio. Other parameters such as temperature, the steam to methane ratio and the type of catalyst can also influence this ratio. These studies have been primarily focused on the use of a small amount of steam to avoid carbon deposition and also to obtain a final syngas ratio of 1 to 2 [4,5,13]. Therefore, these studies have been performed over narrow feed ratios of methane to carbon dioxide and methane to steam.

Our laboratory has shown that the hydrogasification of carbonaceous matter in the presence of steam significantly enhances the rate of methane formation [15]. This process, known as steam hydrogasification, can be used to generate a methane rich gas stream from carbon-containing feedstocks. The steam hydrogasification product gas is ideally suited for reforming to produce synthesis gas due to the presence of a significant amount of methane and unreacted steam. The production of synthetic liquid fuels using syngas from a hydrogasification reactor directly coupled to a reforming process have been successfully demonstrated in our laboratory using several carbonaceous feed stocks [14,16]. The gasifier products from this process also contain significant amounts of CO_2 , H_2 and CO in addition to methane and steam. To our knowledge experimental and modeling results have not been published on mixed reforming of a steam hydrogasification product gas. The effect of H_2 and CO on steam reforming in the absence of CO_2 has been reported in the literature. The effect of hydrogen on the catalytic activity was found to be complex. The methane reforming reaction was inhibited by hydrogen in the relatively lower temperature range of 400–600 °C. At higher temperatures around 700 °C, no inhibition was observed. Numaguchi et al. [21] state that the activity of the catalyst was recovered under most conditions after the stopping of H_2 addition. Lemonidou et al. [13] conducted experiments over a $Ni/CaO-Al_2O_3$ catalyst at atmospheric pressure to study the effect of H_2 and CO presence in the feed. They have reported that at a temperature of 630 °C, the presence of hydrogen inhibits CH_4 conversion and at the same time has a positive effect on the CO_2 conversion. These results are in agreement with the experimental work on Ni based catalysts by Bradford and Vannice [22]. Under the same conditions, Lemonidou et al. also note that the presence of CO has a negative effect on the conversion of CO_2 . This is clearly due to the WGS shift reaction. Overall, CO has an

inhibiting effect on CH_4 conversion. Similar results were obtained on a $Ni/La-Al_2O_3$ catalyst by Olsbye et al. [23].

In contrast, Tsipouriari and Verykios [9] reported that the rate of the reforming reaction was practically unchanged over a Ni/La_2O_3 catalyst in the presence of CO . The same study also concludes that H_2 essentially has no effect on the methane reforming activity of the Ni catalyst, but the rate of conversion of CO_2 to CO due to RWGS was found to increase. Experimental work on the steam methane reforming of typical gasification product gas streams are necessary in order to be able to control the composition of the product syngas.

The objective of the present work is to evaluate the effects of the CO_2/CH_4 feed gas ratio and the process temperature on the mixed reforming reaction under a wide range of steam to methane ratios. The experimental work focuses on the H_2/CO and CO/CO_2 ratios of the product gas of the steam methane reformer. The H_2/CO ratio is an important parameter for further fuel synthesis whereas a higher CO/CO_2 ratio indicates higher energetic product gas stream. All ratios used in the present work are on a mole basis. The feasibility of the combined use of steam hydrogasification and steam reforming to produce a syngas with a highly flexible H_2/CO ratio is evaluated in this paper through experimental and simulation work. This has been accomplished by reforming typical steam hydrogasification reactor (SHR) product gas using a commercial steam reforming catalyst and comparing the experimental results with theoretical calculations.

2. Syngas generation by coupled steam hydrogasification and reforming

Steam hydrogasification is a thermo-chemical process where a carbon-containing solid feedstock is converted into a methane rich gas stream in the presence of steam and H_2 . As mentioned earlier, experimental and simulation work performed earlier have demonstrated that the enhanced methane production from steam hydrogasification can be combined with steam reforming to generate synthesis gas with a flexible H_2/CO ratio from a number of carbonaceous feed stocks. An important advantage of this process is the fact that the final H_2/CO ratio of the synthesis gas can be controlled simply by altering the H_2O/C and H_2/C ratio of the SHR feed, as shown in the next section [25]. The details of this process have been published elsewhere, although a brief description of the technology is presented here [14,17]. Fig. 1 shows a schematic diagram of the process.

The carbonaceous feed such as biomass, coal or biosolids and the water are fed into the steam hydrogasification reactor (SHR) as a slurry along with the H_2 . The slurry feed eliminates the need for drying the feedstock and allows the feed to be pumped in to the reactor [26]. Contaminants such as sulfur, chlorine and other trace metals present in the SHR product gas must be removed since the steam methane reformer (SMR) is a catalytic reactor. This task is accomplished using a warm-gas cleanup unit that operates at a temperature higher than the dew point of water, allowing the unreacted steam to be retained in the product gas stream and hence enabling the process to retain most of the sensible heat in the gas stream. The clean gas stream containing significant amounts of methane and steam is converted into a clean synthesis gas in the steam methane reformer (SMR). The syngas from the SMR can be used in a fuel

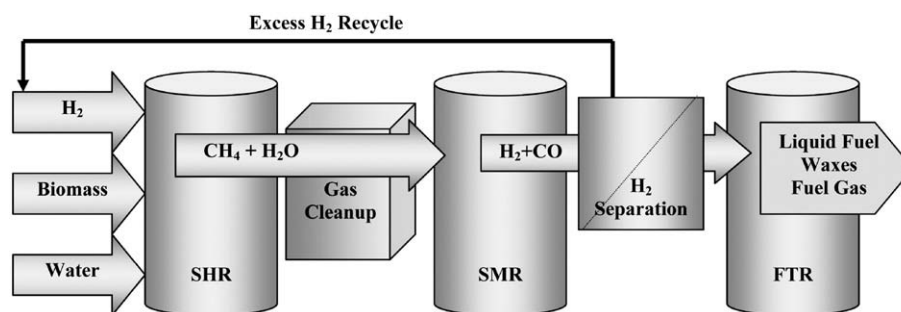


Fig. 1 – Schematic diagram of the coupled steam hydrogasification and reforming process.

synthesis process such as a Fischer-Tropsch Reactor (FTR) to generate synthetic hydrocarbon fuels. The syngas can also be used for power generation if desired. The syngas generated by the SMR has a higher H_2/CO ratio than is normally required for the production of fuels such as the Fischer-Tropsch liquids. The excess H_2 from the syngas is separated using a polymer membrane or a pressure swing adsorption unit and is fed into the SHR as feed, eliminating the need for a separate source of H_2 for the process. It should be noted that the CO_2 can also be removed after the SMR for potential sequestration purposes.

The product gas streams from typical gasification processes contain varying quantities of H_2 , CO , CO_2 , CH_4 , NH_3 , etc. The steam methane reformer requires a steam/ CH_4 ratio of 3 or higher in order to operate efficiently. In addition, the effect of H_2 and CO on the mixed reforming process has not been clearly established in the literature. In order for a steam reformer to produce a synthesis gas of desired composition using the gasifier product as feed, it is necessary to maximize the amount of methane and also to maintain steam/ CH_4 ratio of 3 or higher in the gasifier product gas. Current literature does not have data on the reforming of typical steam hydrogasification product gas streams and hence experimental work is necessary. Two sets of reforming experiments were conducted in this study, each with a feed representing different SHR exit compositions. Table 1 shows the SMR inlet gas flow rates for the two cases. These feed gas compositions were determined using simulation results. The gasifier was operated at 800 °C and 400 psi pressure for Case 1 and at 700 °C and 400 psi for Case 2.

3. Aspen simulations

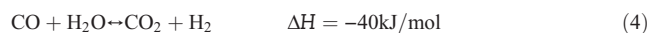
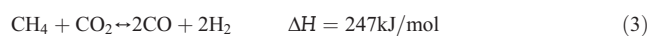
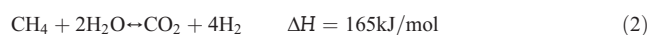
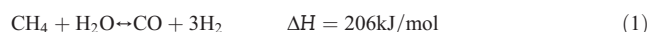
A detailed process model using Aspen Plus has been developed and used to predict process behavior, mass and energy balances. Aspen Plus has the ability to handle non-conventional feed stocks and process streams using built-in process

Table 1 – Input flow rates for SHR product gas reforming tests

Input component	Case 1	Case 2
	Flow rate (cm ³ /min)	Flow rate (cm ³ /min)
CH ₄ (g)	250	270
H ₂ O (l)	0.6	0.7
CO ₂ (g)	160	110
H ₂ (g)	600	360
CO (g)	100	20

models and physical/chemical property databases. A brief description of the original process model used to perform the simulations is given below.

The model simulates the steam hydrogasification block using three units, the decomposition, pyrolysis and gasification. A non-conventional feedstock mixed with water in slurry form was fed into the SHR along with the hydrogen at predetermined H_2/C mole ratio and water/feed mass ratios. The gasification product gas compositions were evaluated through Gibbs free energy minimization. The SMR was simulated using a built-in equilibrium block. The reactions considered in the SMR are given below.



The Fischer-Tropsch reactor block used an external model, which was called by the Aspen Plus through a FORTRAN module. This external model was empirically developed by Hamelinck et al., to predict the selectivity of the Fischer-Tropsch process and has been verified to be in accordance with experimental results performed on cobalt catalysts [24].

As the $H_2O/Feed$ and H_2/C ratios of the SHR feed are varied, the SHR product gas composition changes accordingly. Since

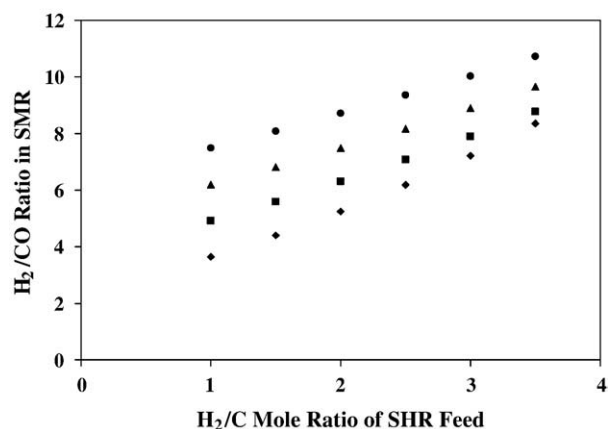


Fig. 2 – Effect of SHR feed ratios on the H_2/CO ratio of the SMR product gas. ♦ — $H_2O/Wood$ of SHR feed = 1, ■ — $H_2O/Wood$ of SHR feed = 2, ▲ — $H_2O/Wood$ of SHR feed = 3, ● — $H_2O/Wood$ of SHR feed = 4.

the SHR product gas stream is fed directly into the SMR after gas cleanup, the SHR feed ratio changes affect the SMR product gas composition [17]. Hence, the H₂/CO ratio of the syngas can be controlled directly by varying the SHR feed. Fig. 2 shows that varying the feed composition of SHR generates a wide range of syngas ratios. In this case, the carbonaceous feedstock was assumed to be wood.

4. Experimental section

A standalone SMR was constructed for these experiments. The packed bed reactor was 61.5 cm long with an i.d. of 0.9 cm and was constructed using inconel alloy. The experimental set up is shown in Fig. 3. A steam generator consisting of a heated coil and a SSI Series I HPLC pump was connected to the reactor inlet. The reactor was heated using two tubular electric heaters and the pressure was controlled using a backpressure regulator. A commercial G-90-0-1 (Sud-Chemie Inc.) steam reforming catalyst was used for all the experiments. The catalyst has a nominal nickel oxide content of 14 wt.% supported on aluminum oxide along with a small amount of calcium oxide. The reaction product gases were passed through a condenser for water removal before being analyzed in real time using a residual gas analyzer. The catalyst in the oxidized state must be reduced before the start of the reforming experiments in order for it to be active. The catalyst reduction was achieved by flowing hydrogen through the catalyst filled reformer at 800 °C. The catalyst needs to be reduced only once and after the reduction, it must not be exposed to air or oxygen. Background tests of steam reforming in the absence of CO₂ feed were performed under atmospheric pressure for a wide range of temperatures before the actual set of experiments were initiated. The purpose of the background experiments was to test the activity of the catalyst and to ensure that the catalyst performance was in compliance

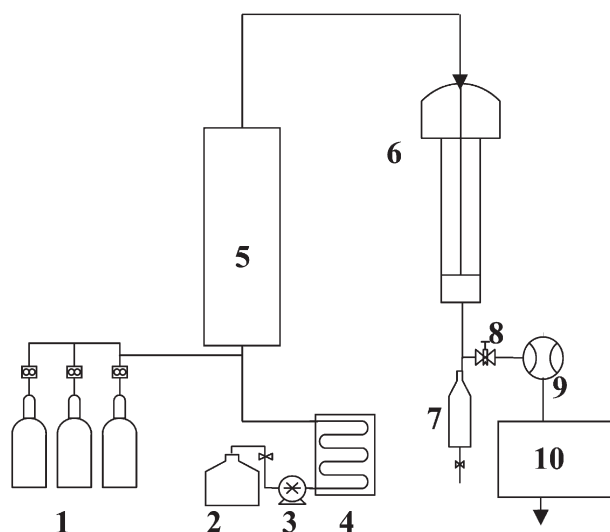


Fig. 3—Block diagram of the steam methane reformer. 1—Gas cylinders and mass flow controllers, 2—water container, 3—pump, 4—steam generator, 5—reactor and heaters, 6—heat exchanger, 7—water condenser, 8—back pressure regulator, 9—dry gas meter, 10—residual gas analyzer and vent line.

with the product and operating manuals. The catalyst performance was found to be satisfactory although the results of these tests are not presented here. The CO₂ feed experiments were conducted for CO₂/CH₄ input ratios of 0 to 2 with a constant steam/CH₄ ratio of 3. A second set of experiments with a constant CO₂/CH₄ ratio of 0.5 was conducted for steam/CH₄ ratios of 3 to 5. The flow rate of methane was fixed at 250 cm³/min (ml/min) for all the experiments. Each specific feed ratio was tested under four different temperatures between 700 °C and 850 °C. The pressure was maintained at 25 psi for all the tests. The catalyst was purged with steam after each test in order to avoid potential carbon deposition.

5. Results and discussion

5.1. Effect of CO₂/CH₄ ratio

The syngas produced by the steam reforming reaction has a theoretical hydrogen to carbon monoxide ratio of 3 according to Eq. (1). The actual ratio is usually higher due to the water–gas shift reaction (Eq. (4)), which is thermodynamically favored only at lower temperatures [18]. The water–gas shift reaction (WGS) proceeds in the reverse direction (RWGS) at higher temperatures. The mole fractions of hydrogen and carbon monoxide through a steam reformer can be expressed in terms of the rate constants of the steam reforming and water–gas shift reactions and the mole fractions of the species [6].

$$y_{\text{H}_2} = \frac{[K_{\text{SMR}}K_{\text{WGS}}]^{0.25}}{[P]^{0.5}} \cdot \frac{[y_{\text{CH}_4}]^{0.25}[y_{\text{H}_2\text{O}}]^{0.5}}{[y_{\text{CO}_2}]^{0.25}} \quad (5)$$

$$y_{\text{CO}} = \frac{[K_{\text{SMR}}]^{0.25}}{[K_{\text{WGS}}]^{0.75}[P]^{0.5}} \cdot \frac{[y_{\text{CH}_4}]^{0.25}[y_{\text{CO}_2}]^{0.75}}{[y_{\text{H}_2}]^{0.5}} \quad (6)$$

Hence, the H₂/CO ratio of the product synthesis gas can be expressed as

$$y_{\text{H}_2}/y_{\text{CO}} = [K_{\text{WGS}}] \cdot \frac{[y_{\text{H}_2}]^{0.5}[y_{\text{H}_2\text{O}}]^{0.5}}{[y_{\text{CO}_2}]} \quad (7)$$

The syngas ratio of the product stream is expected to decrease as CO₂ increases. The H₂/CO and CO/CO₂ ratios obtained from experiment and simulation over a wide range of CO₂/CH₄ feed ratios are compared in Fig. 4. The experimental results are generally in good agreement with the simulation. The theoretical H₂/CO ratio according to Eqs. (1) and (3) decreases from 3 to 1 as the reaction shifts from pure steam reforming to pure CO₂ reforming. However it can be seen from Fig. 4 that the actual ratio decreases from above 5 to 1. As expected, the H₂/CO ratio steadily decreases with increasing amount of CO₂ in the feed.

The decrease in the H₂/CO ratio is caused by an increase of CO₂ reforming and the reverse WGS reaction. It has been reported that the conversion of methane is enhanced by the increase in CO₂ due to the dry reforming reaction, i.e., the methane consumption increases with the increase in the CO₂ partial pressure [13,20]. The results are in agreement with reported trends and are comparable to that of similar studies [4,5], although literature data are not available for the wide

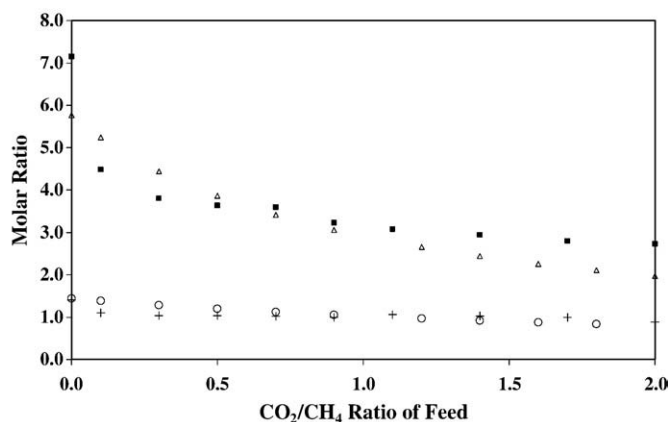


Fig. 4— Effect of CO₂/CH₄ ratio of the feed stream on the H₂/CO and CO/CO₂ ratios of the product synthesis gas. Steam/CH₄ ratio of feed = 3, T = 700 °C, P = 25 psi. ■ — Experimental H₂/CO, Δ — simulation H₂/CO, + — experimental CO/CO₂, ○ — simulation CO/CO₂.

range of CO₂/CH₄ ratios used here. Choudhary and Rajput [5] concluded that the relative composition of steam and CO₂ in the feed has an influence on the final H₂/CO ratio as observed here. The exit CO/CO₂ ratios from the experiments are relatively stable for all the CO₂/CH₄ feed ratios. There was no pressure drop observed across the reactor throughout the course of the experiments, indicating that there was no significant carbon deposition, i.e., coking in the reactor. The tendency for carbon formation depends on the H/C ratio of the feed under given conditions and the results demonstrate that even in the high CO₂ feed experiments, coke formation through methane degradation or the Boudard reaction is avoided by the presence of steam. The equilibrium compositions calculated using the simulation tool are in reasonable agreement with the experimental results as shown in Figs. 4 and 5.

5.2. Effect of steam to methane input ratio

The effect of steam to methane ratio on the H₂/CO ratio of the syngas is shown in Fig. 5. All the experiments were conducted

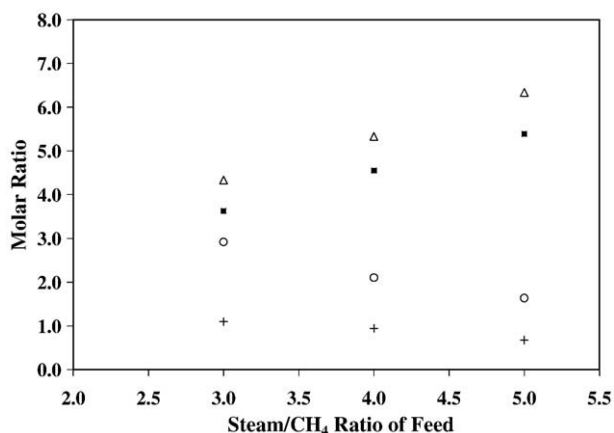


Fig. 5— Effect of steam/CH₄ ratio of the feed stream on the H₂/CO and CO/CO₂ ratios of the product synthesis gas. CO₂/CH₄ ratio of feed = 0.5, T = 700 °C, P = 25 psi. ■ — Experimental H₂/CO, Δ — simulation H₂/CO, + — experimental CO/CO₂, ○ — simulation CO/CO₂.

at a constant CO₂/CH₄ ratio of 0.5. It is recommended that a minimum steam to methane ratio of 2 be maintained for commercial reforming catalysts in order to avoid carbon deposition on the catalyst. The methane reforming reaction is dominant over the dry reforming reaction in the presence of excess steam and as such, the selectivity for hydrogen is higher than that of carbon monoxide. Hence, the H₂/CO ratio increases with the increase in the steam/CH₄ feed ratio. The simulation results are in good agreement with the experimental data. The higher steam/CH₄ ratio also enhances the water-gas shift reaction, as confirmed by the decrease in the CO/CO₂ ratio of the product stream (Fig. 5). The present experimental data have been compared with literature data for experiments conducted under similar conditions. Choudhary and Rajput [5] conducted experiments over a NiO-CaO catalyst, primarily focused on the catalytic activity and the coking tendencies. Effendi et al. [4] have conducted experimental studies of the reforming of a model biogas with a CH₄/CO₂ ratio of 1.5 using a Ni/Al₂O₃ catalyst. The experimental results of these studies have been compared with the present data in Fig. 6. The results of Choudhary and Rajput are in good agreement with the current data, whereas the Effendi et al.

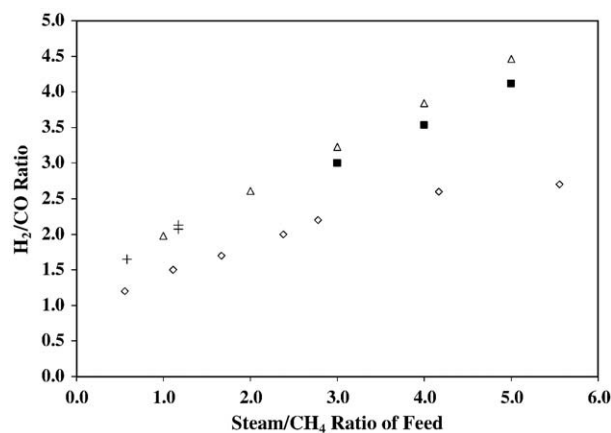


Fig. 6— Comparison with literature data. ■ — Experimental H₂/CO, Δ — simulation H₂/CO, + — H₂/CO data from Choudhary and Rajput [5], ◇ — H₂/CO data from Effendi et al. [4].

data have a lower H_2/CO syngas ratio. This lower H_2/CO syngas ratio is due to the higher CO_2/CH_4 feed ratio and also due to varying feed gas/steam volume ratios.

5.3. Effect of temperature

The changes in the product gas H_2/CO and CO/CO_2 ratios for different temperatures are presented in Fig. 7. It can be seen that the selectivity towards CO increases with increasing temperatures due to the occurrence of the reverse water-gas shift reaction. This results in a reduction of the H_2/CO ratios with increasing temperatures. These trends are in agreement with literature data [4,5]. As expected, the conversion of the reactants also increased with temperature, with methane conversion reaching 100% as the temperature reaches 800 °C and the dry reforming reaction becomes dominant at higher temperatures. Unlike partial oxidation, the H_2/CO ratio of the syngas generated by the mixed reforming reaction changes with changing temperature [19]. Hence, the temperature is an important parameter in determining the H_2/CO ratio of the product gas.

5.4. Steam reforming of steam hydrogasification product gas

As mentioned earlier, experimental data on the reforming of SHR product gas is currently not available in the literature. Although experimental work has been performed on the effects of H_2 and CO on the methane reforming reaction, conclusive data on the effect of the presence of H_2 and CO on the mixed reforming reaction is not available. Hence, it is very important to conduct experimental studies of the reforming of typical gasification product gas streams in order to be able to determine the conditions that will allow the production of a syngas of the desired composition. Two sets of reforming experiments were conducted as part of this study, each with a feed representing different gasifier exit compositions as described earlier. The SHR gasifier simulations were performed using the Aspen Plus software as detailed in Section 3. The results of these simulations were used to determine the

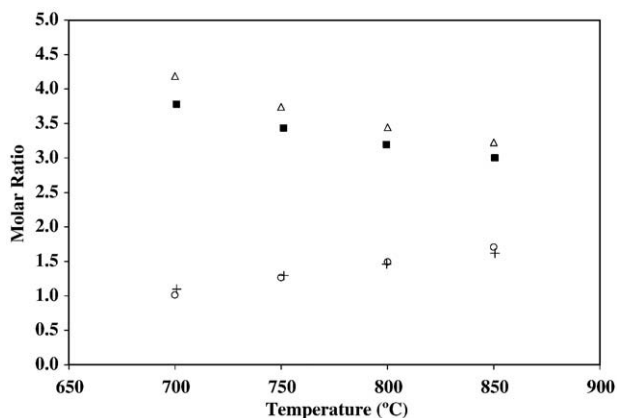


Fig. 7 – Effect of temperature on the H_2/CO and CO/CO_2 ratios of the product synthesis gas. Steam/ $CH_4=3$, CO_2/CH_4 ratio of feed = 0.5, $P=25$ psi. ■ — Experimental H_2/CO , △ — simulation H_2/CO , + — experimental CO/CO_2 , ○ — simulation CO/CO_2 .

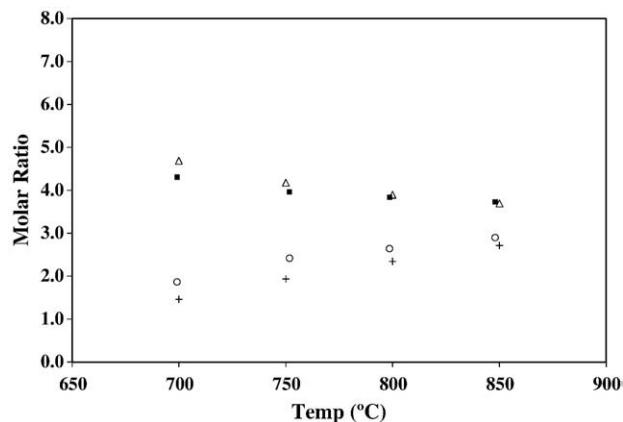


Fig. 8 – Effect of temperature on the reforming of steam hydrogasification product gas — Case 1. Feed steam/ $CH_4=3$, $CO_2/CH_4=0.64$, $H_2/CH_4=2.4$, $CO/CH_4=0.34$. ■ — Experimental H_2/CO , △ — simulation H_2/CO , ○ — experimental CO/CO_2 , + — simulation CO/CO_2 .

feed gas compositions for the reformer. The experimental results along with the experimental conditions are shown in Figs. 8 and 9 and the feed gas compositions are given in Table 1. The reformer feed rates for Case 1 were based on a gasifier simulation performed under 800 °C and 400 psi pressure. The reformer feed rates were based on gasifier operating conditions of 700 °C and 400 psi for Case 2.

It can be seen from Fig. 8 that for Case 1, the H_2/CO ratio of the product synthesis gas varied from 4.3 to 3.7, while the CO/CO_2 ratio from 1.9 to 2.9. Fig. 9 shows that the H_2/CO and CO/CO_2 ratios varied from 4.8 to 4.1 and 2.0 to 3.3 respectively for Case 2 depending on the reaction temperature. These results show that the H_2/CO and CO/CO_2 ratios of the syngas varied considerably depending on the feed composition. The experimental results reasonably agree with that of the simulation results for most of the cases, although there is a difference, especially with respect to the CO/CO_2 ratios, as can be seen in Figs. 5 and 9. These differences may be attributed to the

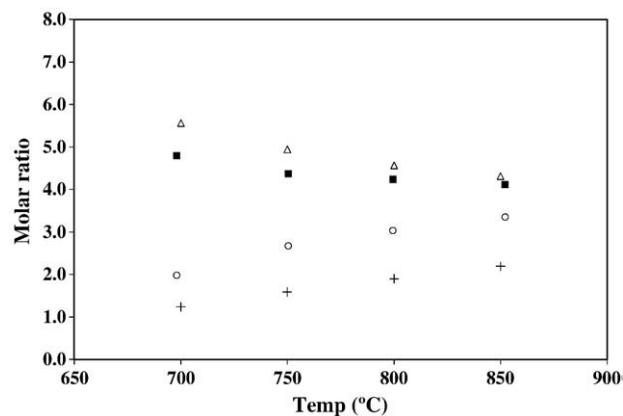


Fig. 9 – Effect of temperature on the reforming of steam hydrogasification product gas — Case 2. Feed steam/ $CH_4=3.2$, $CO_2/CH_4=0.4$, $H_2/CH_4=1.3$, $CO/CH_4=0.07$. ■ — Experimental H_2/CO , △ — simulation H_2/CO , ○ — experimental CO/CO_2 , + — simulation CO/CO_2 .

reactor not operating under ideal equilibrium conditions. These results indicate that a more realistic modeling approach is necessary in order to be able to predict the experimental results precisely. However, developing such a model would be out of the scope of this study. The experimental data did not show any appreciable decline in the catalyst performance or methane conversion during the gasification product gas tests.

6. Summary

This study demonstrates that a steam hydrogasification reactor coupled with a steam methane reactor can be used to produce syngas at a predetermined H₂/CO ratio. The effect of steam/CH₄ ratio, CO₂/CH₄ ratio and the temperature on the mixed reforming reaction has been investigated. It has been shown that temperature and the feed CO₂/CH₄ ratio play a dominant role in determining the product gas H₂/CO ratio. Reforming of typical steam hydrogasification product–gas stream has been performed over a commercial steam reforming catalyst. The gasification product gas compositions were determined through Aspen Plus simulations and similar concentrations were used as the reformer feed. These experimental results have been compared with simulation data. The results demonstrate that the combined use of this gasification process with a reformer can generate a synthesis gas with a predetermined H₂/CO ratio from carbon-containing feedstocks. The synthesis gas H₂/CO ratio can be adjusted to specific values that are desired by different fuel production applications such as Fischer–Tropsch synthesis, dimethyl ether synthesis, etc. The importance of these findings is that the syngas ratio generated from steam hydrogasification can be carefully controlled over a wide range by varying the carbon to water and carbon to hydrogen ratios of the feed.

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