CHAPTER VIII
CONCLUSIONS AND RECOMMEDATIONS

8.1 Conclusions

The experimental results of the present study showed that the corona discharge is a challenging technique to approach high efficiency in producing synthesis gas from methane instead of conventional processes. The results obtained can be concluded as follows:

1. Reactant conversions increased with input power, input voltage, gap width at constant voltage, and oxygen content in feed stream but decreased with increasing flowrate and gap width at constant power.
2. The optimum frequency for high reactant conversions was found at a different frequencies depending on the operational conditions. The power factor decreased with increasing frequency due to the lag between current and voltage waveforms.
3. This study confirms that active oxygen is an important factor to enhance methane conversion and energy efficiency in the discharge reactor.
4. Carbon dioxide conversion was always lower than methane conversion in carbon dioxide reforming with methane under the studied conditions because the dissociation energy of carbon dioxide (5.5 eV) is higher than the dissociation energy of methane (4.5 eV) and carbon dioxide can be produced during the reaction, so the net carbon dioxide conversion becomes lower.
5. In this study, ethane was found to be a primary product formed at short residence times and low current and energies. The coupling of methyl radical increased with increasing methane to oxygen feed mole ratio due to increasing probability of an activated methane species reacting with another activated methane.
6. The hydrogen to carbon monoxide mole ratio in the effluent stream was not sensitive to applied voltage, power, frequency, gap width or flowrate.

The only parameter that strongly effects the hydrogen to carbon monoxide mole ratio is the feed gas composition.

7. Current, electron production rate, does not depend on the composition of the feed mixture and flow rate, but increases with increasing power, input voltage, and with decreasing gap width and frequency.
8. Corona discharge favors to be operated at room temperature rather than elevated high temperatures.
9. The presence of Pt/ZrO_2 or Pt/KL in the studied discharge reactor did not show the synergetic effect on the synthesis gas production from methane. Moreover, the conversions of methane and carbon dioxide in the presence catalyst were usually lower than in the absence of catalyst while the oxygen conversion was higher because oxygen can be activated by the catalysts at a much lower temperature than methane and carbon dioxide.
10. The methane conversion dropped dramatically but the oxygen conversion increased with addition of ethane to the feed gas. Ethane conversion was higher than methane conversion by more than 5 times due to the fact that ethane has a lower net energy for hydrogen abstraction. Consequently, the $CH_4/Air/C_2H_6$ system has a lower specific energy consumption than the CH_4/Air system.
11. The less energy was consumed to convert methane under the plasma environment with nitrogen as a diluent compared to helium, indicative of a third body effect.
12. The sinusoidal and square waveforms to generate the plasmas gave negligibly different results of all conversions, the product distribution, and current but to obtain the same power, the applied voltage had to be higher in the case of the square wave compared to the sine wave because the power factor is lower.
13. Adding water-vapor in the feed gas mixture of methane and oxygen greatly enhanced the conversions of methane and oxygen and improved the energy efficiency in an oxygen-lean system but not in an oxygen-rich system.

14. The simultaneous carbon dioxide and steam reforming with methane produced higher methane conversion and the CO/C_2 ratio than only steam reforming or carbon dioxide reforming.

8.2 Recommendations

The corona discharge is a very complicated system. There are several aspects involving corona discharge to be needed to clarify. The recommendations for future work are expressed as follows:

1. The power, power factor, voltage, current and frequency were measured in the current study, however, all parameters were measured at low side voltage. The more accuracy data should be obtained if all parameters are measurable at high side voltage.
2. To understand clearly about plasmas, the mechanism of plasma reaction is one of the most interests to be studied.
3. In this study the results showed that frequency had only small effect on reactant conversions, product distributions, and energy efficiency. Ultra high frequency range should be investigated.
4. Finding the way to prove that corona discharge is more economical than conventional processes is very beneficial for real application.
5. Wire and plate corona reactor was used in this study. Other configurations of reactor and other types of electrodes as well as multi-stage plasma system should be considered to obtain high reactant conversions and high synthesis gas selectivity including increasing plasma reactor volume and decreasing carbon formation. In addition, other types of low temperature plasmas such as microwave discharge should be investigated.
6. Low temperature plasmas are non-equilibrium, which are very useful for initiate chemical reactions at a low temperature. The application of low temperature plasmas is not only for producing synthesis gas but also other reactions especially for air pollution control.