CHAPTER VI
CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

In this study, the non-thermal gliding arc discharge was found to exhibit an attractive alternative to potentially activating reactant molecules for initiating the natural gas reforming reactions at near room temperature and atmospheric pressure. The series of experiments were performed under the different feed gas systems with the variation of feed flow rate or residence time in order to determine the effects of the presence of CO_2, C_2H_6, and C_3H_8 gases in natural gas on the plasma methane reforming. These feed gas systems includes pure methane, CH_4/He, CH_4/C_2H_6/He, $CH_4/C_2H_6/C_3H_8$/He, and $CH_4/C_2H_6/C_3H_8/CO_2$. The various products of hydrogen, carbon monoxide, and gaseous hydrocarbons (C_2, C_3, and C_4) were produced under the studied conditions. The results revealed that the presence of other gas components had remarkable influences on not only the process performance but also the chemical pathways and the plasma characteristics. In comparisons all feed systems, the highest methane conversion and product yields, as well as the lowest specific energy consumption was found in the $CH_4/C_2H_6/C_3H_8/CO_2$ feed system, primarily resulting from the ability of CO_2, an oxidative gas, in extracting H atom from molecules of hydrocarbons via the dehydrogenation reactions. An increase in applied voltage increased methane conversion, product yields, and reduced energy consumption, in contrast to the effect of input frequency. Increasing applied voltage and decreasing frequency increases the number of energetic electrons in the discharge zone. Moreover, an appropriate amount of added O_2 (either pure oxygen or air) to the simulated natural gas increases the number of oxygen-active species, which plays a dominant role in H-abstraction from hydrocarbon molecules over CO_2, due to the fact that itself O_2 is well-known for being a stronger oxidant than CO_2. This lead to the increases in conversions, product yields, and product selectivities, particularly in an oxygen-rich feed system, as compared to the results of the feed without adding oxygen. Apart from being as a significant source of oxygen species, the use of O_2 acting as an oxygen source of partial oxidation also can reduce the

consumed energy of system and minimize the carbon formation. Because the partial oxidation reaction is exothermic, however the CO_2-containing natural gas reforming reaction is endothermic. Thus, the combined CO_2-containing natural gas and partial oxidation requires less energy consumption and the carbon deposit is minimized. In addition, the addition of oxygen was found to increase the production of synthesis gas. For the combined CO_2-containing natural gas and partial oxidation, air was found to be preferentially used as an oxygen source instead of pure oxygen for the reason that the use of air provides better process performance; in addition, air is much cheaper than pure oxygen.

Furthermore, the use of microreactor in non-thermal plasma technology is a feasible approach to control the temperature in the plasma reactor. The reforming reaction of methane was carried out using the gliding arc plasma microreactor in the absence and the presence of catalyst. The main products of the methane reforming were acetylene and hydrogen. In the sole plasma system, increasing input power, electrode gap distance, and reactor width enhanced methane conversion in contrast with the effect of increasing feed flow rate. But, however, the temperature distribution in the sole plasma system insignificantly affected the reaction performance. In contrast to the combined plasma–catalyst system, the closer distance between the catalyst and plasma zone showed the higher methane conversion, meaning that the configuration of microreactor was crucial to control the temperature distribution within the plasma microreactor.

6.2 Recommendations

The recommendations for future work are as follows:

1. The effect of stage number (number of plasma reactors) should be investigated to optimize the process performance.
2. Adding steam should be a practical way to get higher syngas production and to improve the overall reaction performance of natural gas reforming.
3. Various catalyst types are recommended to test under both the conventional gliding arc reactor and the gliding arc microreactor with and without partial oxidation.

4. To clearly understand about the gliding arc characteristics, a high voltage probe should be used to measure the electrical parameters at high-side voltage instead of low-side voltage, and to be able to observe the waveforms of gliding arc discharge from a digital oscilloscope.
5. To study the plasma reaction mechanisms including plasma kinetics, the optical emission spectroscopy (OES) should be used to detect radical species of the reactions. In addition, mathematical modeling of plasma-chemical reactions should be concerned.