

Chapter 8. Conclusion and Recommendation for

Further Research

8.1 Conclusion

The Supercritical Water Gasification (SCWG) reaction system has been successfully modified and investigated for various liquid type feedstocks with excellent performance of hydrogen yield. The modifications in the reactor geometry include titling the reactor 75° from vertical position and adding the air-cooled tube. The small inclination of the reactor and condenser (15° from horizontal position) is having purpose to facilitate the gaseous products which separate at subcritical condition without bothersome the liquid flow due to the small inclination applied. The air cooled tube uses outside air as cooling media, provide the gradual temperature decrease and avoid rapid heat transfer which was resulting in unstable of gas-liquid flow in previous system (the 1st generation SCWG). In addition, the improvement of hydrogen yield resulted from the additional of air cooled tube because the presence of air cooled tube give the additional time for the reactant to react and process further.

The apparatus performance was investigated with various feedstocks. Two apparatus were introduced, the 2nd generation SCWG and the 3rd generation SCWG while the 1st generation SCWG was explained in a glance. The 1st generation and 2nd generation SCWG have the same reactor dimension while the

reactor volume of the 3rd generation SCWG is 6 times. The detail experiments were done using isooctane (as model compound of gasoline) and glucose (a model compound of biomass). In addition, the various feedstocks from hydrocarbon with one carbon number until ten carbon number are gasified and compared under similar operating condition. There are several things which can be concluded:

1. The non-catalytic gasification is possible in supercritical water, produces high yield of hydrogen at high temperature ($>700^{\circ}\text{C}$)
2. The investigation of experiment variable confirmed the Le-Chatelier principles that the hydrogen yield increases at higher temperature (as endothermic characteristic reaction) and lower feed concentration. The residence time and oxidant totally depend on other variables such as concentration and temperature.
3. The gaseous yields were close with the equilibrium prediction even without addition of any catalysts; possibly because the water gas shift (WGS) reaction is favored at high temperature with high excess amount of water. The presence of air-cooled tube gives gradual temperature decrease; seems act as high temperature water gas shift (HTS) and low temperature shift reaction (LTS) system such as conventional steam reforming (SR) process, producing very low carbon monoxide (CO) yield.
4. The longer the hydrocarbon chain, the more difficult it is to be reformed.

5. The energy efficiency calculation shows that the efficiency of the system can be increased by heat recovery system with the utilization of long chain hydrocarbon feedstock, higher HHV of feedstocks and higher feedstock concentration.
6. Even though n-decane ($C_{10}H_{22}$) has higher carbon number, it is easier to be reformed compare to isooctane (C_8H_{18}). It might be because n-decane is a straight chain hydrocarbon while isooctane is a branch type hydrocarbon which is easier to polymerize. Meanwhile further research need to be conducted.
7. Comparing the experiment result and equilibrium prediction of methanol, isooctane and n-decane, it is reported that the experiment results have higher hydrogen yield, lower carbon monoxide and lower methane yield compare to predicted value. It shows that water gas shift reaction is dominant and methanation reaction is suppressed.

8.2 Recommendation for Further Research

The further research recommendation should address the limitation of the reaction system which did not optimize the energy utilization especially for heating. In details, the recommendation for further research can be explained as below:

1. Improve the energy efficiency by optimizing the heating source used. It is recommended to use other heater source such as burning some portion of gaseous product. Another way is to design the heat recovery system which facilitate the gradual temperature decrease without interfere the gas-liquid flow rate stability
2. Investigate the real liquid type biomass feedstock such as crude glycerol, bioethanol, bio-oil or real gasoline/ diesel instead of model compound.
3. Investigate the effect of hydrocarbon structure (straight, branch, aromatic) to the gaseous product in details.
4. Perform the kinetic study of noncatalytic gasification in supercritical water using this reactor system.

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