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論 文 要 旨

THESIS SUMMARY

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要旨（英文 800 語程度）
Thesis Summary (approx.800 English Words)

In this study we recognized the potential utilization of biomass CO_2 gasification as a compatible method for bioenergy with carbon capturing and storage (BECCS). CO_2 gasification produced high purity of CO and CO_2 mixture so that the combustion product with O_2 can be sequestrated in a simple process and/or recycled back to gasifier as gasifying agent. To more deeply investigate and optimize this potential, the following three parts were studied in this thesis.

First, the effect of steam replacement by CO_2 for producing nitrogen-free producer gas was investigated in a lab-scale downdraft gasifier. The results showed that substitution of steam with CO_2 would generally lower the H_2 yield and enhance the CO yield. A positive effect of the CO_2 mixing ratio on the thermal efficiency of the gasifier was observed at the temperature of 850°C and above. For the indirect gasification (without O_2 supply), the highest thermal efficiency of the gasifier (52%) was gained under the CO_2-only atmosphere at 850 °C. For the direct gasification (with O_2 supply), the highest thermal efficiency (60%) was gained under the CO_2-O_2 atmosphere at 950° C. This calculation result shows that the gasification process with CO_2 as a gasifying agent and a heat carrier, especially in the direct gasification process, is potentially be more efficiently utilized in the N_2-free producer gas production than steam. The kinetics and diffusional limitations of CO_2-char reaction were significant at the reaction temperature of 750°C. At the reaction temperature of 850°C and above, the limitations were less so that the experimentally obtained cold gas efficiencies of CO_2-O_2 gasification results were close to the equilibrium prediction.

Next, the operability and the performance of the CO_2-O_2 gasification in a pilot scale downdraft gasifier

were examined. The CO_2-O_2 gasification was stably operated for around 70 minutes in a pilot scale downdraft gasifier under 0.6 - 1.6 CO_2/C ratios and around 0.4-0.6 equivalence ratio. The progress of CO_2 to CO conversion was mainly occurred through the CO_2-char reaction and the dry reforming was indicated by the less significant decrease of the CO fraction than the increase of the CO_2 fraction in the producer gas as the CO_2/C ratio increased. Owing to the dilution effect of unreacted CO_2, the lower heating value (LHV) of the producer gas was decreased by the increase of the CO_2/C ratio. Nevertheless, LHV of the producer gas of CO_2-O_2 gasification is still higher than those of air gasification even at the comparable amount of O_2 diluent in the gasifying agent. CO_2-O_2 gasification did not bring significant improvement of the H_2/CO ratio compared with air gasification that implied the suitability of its producer gas for heat and power generation fuel gas. A statistically significant effect of the CO_2/C ratio was hardly observed on the cold gas efficiency of the gasifier. However, the cold gas efficiencies of CO_2-O_2 gasification were consistently higher than those of air gasification at the examined CO_2/C ratio range.

Finally, the CO_2 recycled biomass gasification system was proposed and optimized using the thermal equilibrium model that was adjusted with the experimental results. With 900˚C applied turbine exit temperature (TET), the beneficial effect of CO_2 recycling was only significant at the gasifier temperature of 750ºC and it was less at the gasifier temperatures of 850ºC and 950ºC. This is because the recycled CO_2 temperature was not so high to give a substantial amount of heat to the gasifier with the target temperature of 850ºC and above. On the other hand, our previous finding showed that 750ºC might be too low to expect the optimum performance of CO_2 gasification because of the kinetic and physical limitations. Performance optimization of the system was then conducted by varying the applied TET in the range of 900 ˚C -1000 ˚C that is fixed by the application of the turbine inlet temperature (TIT) in the range of 1000˚C -1200˚C. 850˚C gasifier temperature was set as the basic condition. The gasifier efficiency was more significantly increased by the CO_2 recycle ratio increase in the systems with the higher applied TET. Additionally, the combination of TET and TIT that is corresponded in a certain pressure ratio was importantly determining the turbine efficiency and eventually the system efficiency. The turbine efficiency was significantly increased by the pressure ratio increase to around 2.3 and moderately decreased afterwards. Under the examined conditions, the optimum condition for gaining the highest system efficiency, 38.14 %, is under 0.6 recycle ratio with

applied TET and TIT of 1000°C and 1200°C. The proposed system produced 11.93 % higher efficiency and exhausted -484 gCO_2/kWh CO_2 emission than the conventional air gasification. In addition, the exhausted CO_2 is in the form of high purity CO_2 stream which is suitable for sequestration or further utilization. Thus, considering the carbon neutrality of biomass feedstock, the system potentially implement the carbon-negative power generation with the intensity around -484 to -1372 gCO_2/kwh.