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「課程博士用」

学 位 論 文 の 要 旨

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学位論文題目	Development of Small-scale Systems for Power Generation and Hydrogen Production by Biomass Thermochemical Conversion（バイオマスの熱化学的変換による小規模発電と水素製造システムの開発）		

学位論文要旨

World’s energy demand is increasing year by year. The depletion of fossil fuels leads the world to take a glance at renewable sources as the alternative for energy production, which biomass is considered as the most potential one. Thermochemical conversion is viewed as the best way to convert biomass into various convenient energy. However, unlike the fossil fuels, biomass growing and collection limits its large-scale application with low cost. As such, conversion of biomass into energy in a small-scale with the local biomass resource system is more preferable and attractive for its complete and efficient utilization. Meanwhile, during the thermochemical conversion process, various byproduct and impurities such as tar will be generated. It is important to avoid the unwanted byproducts generation and improve the utilization efficiency during the biomass energy system designed and operation. This dissertation, on the one hand, considers the compatibility and synergistic effect existence in various biomass mixture during the thermal conversion process, the co-pyrolysis of various biomass with different properties and co-gasification of their char were experimentally investigated to give a guidance of biomass selection in the two-stage gasification system. On the other hand, advanced small-scale biomass energy systems especially for the power generation and hydrogen production were designed and analyzed. This dissertation includes 7 chapters.

Firstly, compatibility and synergistic effect existence on co-pyrolysis of biomass was investigated to support biomass selection requirement in two-stage gasification system, in which biomass pyrolysis and biochar gasification were conducted separately to reduce tar formation. It was found that less reactive co-pyrolysis biochar could be generated from the biomass with high content of silica species such as rice straw and rice husk since the silica species can react with the AAEM species in woody biomass to form alkali silicate compounds, which always greatly inhibit the gasification rate. In contrast, the gasification of the co-char involving combinations of different woody biomass showed synergistic effect to improve the gasification efficiency since the AAEM contents in woody biomass was stably maintained in the co-char after the co-pyrolysis process. This study provided a guidance for the biomass selection in the application of two-stage gasification system.

Secondly, the performance of a novel separated-type biomass gasification system as further development of conventional two-stage gasification system composed of an auger-type pyrolyzer, a steam tar reformer, an air-steam char fluidized bed gasifier, and a spent char riser-type combustor with circulating heat carrier particles for small-scale power generation was

investigated. Herein, the system performances based on two typical biomass pyrolysis processes, i.e., slow and fast pyrolysis process, were analyzed in details. It is found that the cold gas efficiency of the system had a range of 71.7-73.8% from slow to fast pyrolysis. This study offered a new viewpoint on addition of steam tar reforming process in the conventional two-stage gasification system could not only solve the tar formation problem in gasifier, but also increase the overall system performance.

Thirdly, a new concept of chemical looping process combined with a steam tar reforming process for the hydrogen production from biomass feedstock was proposed and simulated. The system consisted of a biomass pyrolysis unit, a steam tar reforming unit, and a biochar chemical looping unit for hydrogen production (CLH) with a heat circulation design to achieve an auto-thermal operation condition. As such, the overall system can generate a total of 6.9 kg/h of H2 and net power of 58.3 kW simultaneously from 100 kg/h feeding rate of woody biomass. The hydrogen production efficiency of this novel system was obviously higher than other reported biomass hydrogen production systems. Herein, the combination of two types of hydrogen production units boosted the system efficiency. It is expected to provide a new way for the effective hydrogen production from biomass.

Finally, a small-scale combined heat and power (CHP) system combining a biomass direct chemical looping combustion (BDCLC) and organic Rankine cycle waste heat recovery (ORC-WHR) was proposed and simulated. The BDCLC unit produced 170.2 kWe power whereas the ORC-WHR unit generated additional 21.0 kWe. As such, the system produced 191.2 kWe total power from 1000 kWth biomass input. Moreover, this system applied two evaporators in the ORC-WHR unit to recover the heat from two reactors in the chemical looping combustion process for the additional power generation. Therefore, it has the potential for the small-scale power generation using the biomass resource.

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