

学 位 論 文 の 要 旨

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学位論文題目	Biochar-Assisted Steam Co-Gasification: A Pathway to Enhance Hydrogen-Rich Syngas Generation using Various Biomass Feedstocks (バイオチャー補助水蒸気共ガス化:異なるバイオマス原料を用いた水素リッチな合成ガス生成への経路)		
学位論文要旨			
<p>The urgent need to address climate change and mitigate global warming has prompted initiatives aimed at reducing greenhouse gas (GHG) emissions, especially carbon footprint from the utilization of fossil fuels. The shift to sustainable technology is being encouraged, in which biomass gasification is emerging as a promising alternative source due to its renewability and reduced environmental impact compared to conventional fossil fuel processes. Biomass gasification is a thermal conversion process that can produce environmentally friendly fuels such as hydrogen. However, one significant issue with it is the co-generation of tar, a byproduct that poses problems for operational and environmental aspects. In response, co-gasification with biochar has become a viable strategy for mitigating tar-related issues. This approach involves blending various types of raw biomass materials with biochar to create synergistic effects that enhance the processes of tar removal and gas production. This method provides exceptional fuel selection diversity while also improving operating efficiency by utilizing the complementary qualities of different materials. Using a variety of feedstocks in addition to biochar reduces the dependency on a single biomass source with full utilization of locally available resources, thereby reducing transportation costs and promoting regional sustainability. This dissertation focuses on an investigation into the effectiveness of biochar-assisted steam co-gasification for enhancing hydrogen-rich syngas generation using various biomass feedstocks.</p> <p>Firstly, various types of biomass are investigated to determine which one promotes the most positive synergistic effect. Woody biomass such as cedarwood, herbaceous biomass like rice straw and husk, and marine biomass such as seaweed are utilized in steam co-gasification with seaweed biochar—materials known for their ease of decomposition and high amounts of AAEM that could promote syngas generation and reduce tar production. The addition of torrefied seaweed to land-based biomass, such as cedarwood, can increase the overall gas yield due to the positive synergistic effect, particularly with an optimum addition of cedarwood to seaweed biochar with a weight ratio of 1:1. The amount of tar generated during the co-gasification is 11% lower than the predicted result calculated from individual gasifications of cedarwood and seaweed biochar. It is considered that the high content of AAEM species and the high porous structure of biochar contribute significantly to the positive synergistic effect of the co-gasification process. On the other hand, the least favorable combination involves the use of herbaceous biomass, where it is discovered that the high silica content hinders the catalytic</p>			

activity of biochar.

Secondly, in an effort to address the limitations of steam co-gasification with herbaceous biomass, Monster-TUAT1 rice straw, a genetically modified rice plant developed by Tokyo University of Agriculture and Technology (TUAT) with taller and larger stalks, was utilized alongside Giant Miscanthus, a promising energy crop, as the feedstock. Compared to the typical rice straw, Monster TUAT1 exhibits superior steam gasification performance, yielding 1.75 times more hydrogen gas and generating 27.0% less tar. Despite focusing on overcoming the challenges posed by high silica content in Monster TUAT1 through co-gasification with Giant Miscanthus, only a modest enhancement of +6% in hydrogen gas yield is achieved under optimal operational conditions, which is deemed unsatisfactory. Consequently, strategies for enhancement are proposed, including the incorporation of seaweed biochar containing high levels of alkali and alkaline earth species. This approach results in significant improvements, particularly when seaweed biochar is introduced at a level of 50%wt., leading to an increased hydrogen gas yield with a tar reduction to 5.5%. These findings underscore the feasibility of utilizing herbaceous biomass like rice straw in conjunction with strategic co-gasification solutions to address constraints and enhance hydrogen production.

Finally, to explore the potential of using biochar derived from different types of biomass besides marine sources, the biochar produced from Monster-TUAT1 rice straw through pyrolysis at a high temperature of 600°C was mixed with its raw biomass to assess its impact on gasification performance. However, due to the poor characteristics of the raw materials, modification of the biochar is necessary to enhance its catalytic ability during steam gasification. Iron metal precursor, known for its effectiveness in tar reforming and abundant resources, was loaded into the rice straw biochar, creating a highly efficient biochar catalyst. The synergistic effect observed upon the addition of this Fe-loaded biochar is highly satisfactory, resulting in a threefold increase in hydrogen gas yield compared to the scenario involving unloaded biochar/MOS. Furthermore, significant tar reforming activity is observed, leading to minimized tar production, accounting for only 5% of the converted carbon, with a conversion into gas exceeding 90% of the feedstock. By incorporating raw biomass into the steam co-gasification system alongside its enhanced biochar, the range of available gasification feedstocks can be expanded, facilitating the gas yield with minimal tar formation using cost-effective methodologies and materials.

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