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著者(和文)	Flabianus Hardi
Author(English)	Flabianus Hardi
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論 文 要 旨

THESIS SUMMARY

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学生氏名： Student's Name	フラビアヌス　ハルディ Flabianus Hardi	指導教員（主）： Academic Supervisor(main)	吉川　邦夫
		指導教員（副）： Academic Supervisor(sub)	高橋　史武

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

Inspired by the positive performance of alkali catalyst during black liquor (BL) gasification process, the integration of the hydrothermal liquefaction (HTL) and gasification was demonstrated as a part of the solution for an efficient second generation biofuel production, improvement of the gasifier performance and diversification of bioenergy. The combined process is foreseen to be independent from pulp mill with BL gasifier and to promote the sustainable "forest waste into energy" by utilizing pine sawdust (from the forest residue) and K_2CO_3 (from the ash of terrestrial biomass). The fundamental on HTL and the feasibility for gasifying the HTL products were explored by conducting experiments on (1) the non-catalytic HTL of pine sawdust, (2) the comparative study on non-catalytic and K_2CO_3-catalytic HTL and (3) the K_2CO_3-catalytic HTL and (4) CO_2 char gasification of the products derived from the catalytic HTL.

In the non-catalytic HTL study, the fundamental of pine sawdust decomposition in subcritical water and the fate of the mass and carbon distributions in the HTL products were investigated. The experimental design and the response surface methodology were used to determine the effects of the reaction temperature (180–260 °C), the reaction time (0–2 h) and the sawdust concentration (9.1–25 wt%) on the biomass conversion, the product yields and the product properties. A high reaction temperature, a low sawdust concentration and a short reaction time favored the biomass conversion and the liquid yields. Moreover, the model predictions were developed to estimate suitable reaction conditions and obtain the product with certain properties which can be useful to strategize the downstream process.

The comparative study on the non-catalytic and the K_2CO_3-catalytic HTL explored the advantages of the alkali catalyst, K_2CO_3. By considering the result from the non-catalytic HTL, the higher temperatures (240, 270 and 300 °C) and a shorter reaction time (30 min) were applied. The K_2CO_3-catalytic HTL improved the biomass conversion and the aqueous product (AP) yield by 15–30% and 18–29%, respectively. The pine sawdust particle size (160–250 µm and 600–710 µm) had no effect on the biomass conversion and the product yields both in the non-catalytic and the catalytic HTL. Eventually, the use of rough sawdust was preferred after considering the economical and technical aspects.

In the K_2CO_3-catalytic HTL of pine sawdust for production of gasification feedstock study, the investigation on the HTL reaction condition that gave high biomass conversion and high AP yield was carried out. The reaction temperature, the sawdust mass fraction and the reaction time were set in the range of 240–300 °C, 9.1–25% and 0–60 min, respectively. The maximum conversion of 83% mass (or equal with 75.2% carbon conversion) and the AP yield of 73.5% mass (or equal with 69.0% carbon yield) were achieved, along with high total carbon and total mass recoveries. The model predictions of biomass conversion, AP yield and gas yield (on mass and carbon basis) were developed using face centered central composite design. According to the models, the biomass conversion and the AP yield had a positive correlation with the reaction temperature and the reaction time, while they had an inverse correlation with the sawdust mass fraction. Therefore, a medium-high temperature, a low sawdust mass fraction and a short reaction time were favorable. Further investigation on the effect of the biomass/water and biomass/K_2CO_3 ratios revealed that both high water loading and high K_2CO_3 loading enhanced the conversion and the AP yield.

The chars of the selected K_2CO_3-catalytic HTL products were gasified in CO_2 atmosphere using a thermogravimetry analyzer. The gasification performance was evaluated based on the char conversion rate, the char reactivity and the activation energy. Prior to gasification, chars were made from the selected K_2CO_3-catalytic HTL products (aqueous product from design center of HTL experiment [APc], aqueous product [AP], solid residue [SR] and the mixture of aqueous product and solid residue [APSR]), black liquor (BL) and the virgin pine sawdust (PS) by the fast pyrolysis. APc, AP, APSR, and BL chars were reactive since they required low temperature to achieve a specific conversion level and this can be advantageous for the low temperature gasification. The activation energies were calculated iso-conversionally by the Kissinger-Akahira-Sunose (KAS), the Flynn-Wall-Ozawa (FWO) and the Starink approximations. The activation energy for APc char (148–326 kJ/mol), AP char (127–567 kJ/mol) and APSR char (215–426 kJ/mol) increased as the fractional conversion increased. Meanwhile, the activation energy of BL char (171–190 kJ/mol) was relatively unchanged with respect to the fractional conversion.

The catalytic HTL of pine sawdust followed by the gasification has been demonstrated. In conclusion, the catalytic HTL process can improve the gasifier feedstock reactivity and decrease the gasification temperature. In the near future, the combined process is expected to drive the efficient and sustainable biofuel production and promote the diversification of biomass feedstock.