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（博士課程）
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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 pulp and paper industries, paper sludge is very difficult to dispose due to its high moisture content characteristic. This objective of this research is to promote Waste-to-Energy practices in the pulp and paper industry by using the hydrothermal treatment to upgrade paper sludge followed by the co-combustion of the hydrothermally treated paper sludge with coal. To realize this goal, A series of experiments, both lab-scale and pilot-scale hydrothermal treatment (HTT), fundamental combustion, basic co-combustion, and practical fluidized bed co-combustion plus attrition tests, have been conducted. The equipment has been selected according to the scheme of each study.

The first main chapter is the "Lab-scale and pilot-scale investigation on hydrothermal treatment of paper sludge for solid fuel production". The paper sludge (Raw-PS) was subjected to HTT under subcritical hydrothermal conditions. In the lab-scale experiment, the temperature conditions were 180, 200, 220, and 240 °C at the pressure around 1.8–2.4 MPa, while it was 197 °C at 1.9 MPa in the pilot plant as the optimum condition. The holding time was 30 minutes in both cases. The hydrothermally treated paper sludge (HTT-PS) was evaluated in regards to its fuel properties, dewatering and drying performances, and mass distribution. Results showed that the higher heating value of the HTT-PS was slightly improved by the HTT. By mechanical dewatering, only 4.1% of moisture in the Raw-PS can be removed while the 200 °C HTT-PS showed 19.5% moisture reduction (5 times better). According to the energy balance of the pilot plant, the recovered energy was significantly higher than the energy input, showing the feasibility of employing HTT to produce alternative solid fuel from paper sludge.

After that, the investigation on combustion characteristics of the HTT-PS was performed as a fundamental combustion study. Combustion behavior of the products and the reference materials, including cellulose, hemicellulose, and lignin, were studied by the thermogravimetric analysis. The HTT-PS from the previous work was used. Major decomposition of paper sludge was devoted to cellulose. The ignition temperature was originally low around 257–271 °C. From the two-stage kinetics study, it was revealed that the activation energy of the treated paper sludge was lower than the original material indicating a higher reactivity and they were in the range of 113–147 kJ/mol.

After the fundamental combustion study, the co-combustion of the HTT-PS with subbituminous coal was investigated. NO emissions were tested by a batch-type fixed bed combustor. The results showed that the NO emissions could be reduced around 26–31% in the combustion test and, therefore, the mixture of coal and HTT-PS yielded lower NO emission compared to the mixture of coal and Raw-PS. Slagging and fouling indices were calculated. The fouling and slagging tendencies of HTT-PS were improved.

Then, a practical co-combustion test was conducted. Fluidized bed co-combustion of Raw-PS and HTT-PS with either low (Lo-Coal) or high reactivity coal (Hi-Coal) was investigated. South African bituminous and Thai subbituminous coals were selected as representative of Lo-Coal and Hi-Coal, respectively. A 110-mm bubbling fluidized bed combustor was used in this study. During the steady combustion tests, the nominal temperature was 850 °C, the fluidization velocity was 0.5 m/s, and the excess air was varied as 20%, 40%, and 60%.

Co-combustion tests were conducted by feeding the sludge at the mixing ratio of 30% and 50% (mass basis) with coal. Results showed that at 30% mixing ratio using HTT-PS instead of Raw-PS could reduce NO_x emission by 3–6% and 9–17% in the case of Lo-Coal and Hi-Coal, respectively, and the loss of unburned carbon could be decreased by 15–18% and 36–53% for Lo-Coal and Hi-Coal, respectively. On the whole, the hydrothermally treated paper sludge showed better performance and would be a better choice compared to the original raw paper sludge.

The effect of HTT on fluidized bed combustion of paper sludge focusing on essential particle comminution phenomena, i.e., the primary fragmentation and the char particle attrition, were investigated. This chapter explains the important findings, i.e., the reduction of unburned carbon by HTT, from the steady burning test. The results showed that all three samples extensively underwent the primary fragmentation. From the char particle attrition, the Sub-C intensely experienced particle rounding off and, after that, became very strong against mechanical abrasive attrition followed by HTT-PS and Raw-PS. In both cases, HTT-PS showed lower amount of fine particles than the original material indicating better combustion performance.

In conclusion, the integrated solution of using hydrothermal treatment to upgrade paper sludge and co-combusting the hydrothermally treated paper sludge will give many positive effects and will be more appropriate than the conventional way of dealing with paper sludge such as landfilling or co-firing the original high water sludge.