学　位　論　文　概　要

題　目　　Supercritical water gasification of sewage sludge with phosphorus recovery

(リン回収を伴う下水汚泥の超臨界水ガス化)

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In the following decades, biomass will play an important role among other renewable energy sources globally as it is already the fourth largest energy resource after coal, oil, and natural gas. Sewage sludge is considered as a promising biomass source due to the abundant amount produced from the wastewater treatment plant. The thermochemical or biochemical conversion looks to be a good promising technology to convert biomass to obtain gaseous, liquid or solid biofuels. Among them, gasification is desirable as the product can be used for all kinds of useful energy such as heat, transportation, and electricity. In terms of wet biomass, conventional gasification is not recommended, due to high drying cost and the need for more energy. Therefore, the appropriate technology, such as supercritical water gasification, has attracted tremendous attention. Supercritical water gasification (SCWG) is an innovative and effective destruction process for the treatment of organic compounds. This process does not require drying, as well as takes place in a few minutes.

Many researchers employed batch reactors for supercritical water gasification process. To the best of author's knowledge, gasification of wet biomass such as sewage sludge by using continuous reactor is still limited. By employing a continuous reactor, pressure can be constantly controlled, and reaction kinetics is easily elucidated, and it is more precise compared with the batch reactor.

Because only a few studies have been investigated in the gasification characteristics of sewage sludge in supercritical water, this study firstly attempted to elucidate the gasification efficiency as well as the behavior of phosphorus during SCWG. Sewage sludge was gasified under supercritical conditions by using a continuous flow reactor. An SS316 steel tube with a length of 12 m and the inner diameter of 2.17 mm was used as the reactor. The reaction temperature was varied from 500 to 600 °C, and the reaction pressure was fixed at 25 MPa. The residence time was also varied in the range of 5–60 s. The effect of temperature and residence time on the composition of product gas was investigated. A model of the reaction kinetics for SCWG of sewage sludge was developed. The kinetic reaction rates were determined by the least square of error (LSE) method that gave the best fitting of the calculated values and the experimental values.

Phosphorus behavior in supercritical water gasification of sewage sludge was also studied, and its behavior together with sewage sludge gasification characteristics was studied. The kinetics of phosphorus conversion in subcritical and supercritical water was also investigated. The effect of temperature and residence time were elucidated in this study. Organic phosphorus was converted into inorganic phosphorus in less than 10 s. First-order reaction and the precipitation rate in proportion to oversaturation was proposed.

Supercritical condition requires high temperature which will affect the morphological structure of sewage sludge. Consequently, the effect of hydrothermal treatment (HT) on the morphological structure of sewage sludge as well as the release of organic compounds inside the cell and its kinetic behavior was studied. HT damaged the sewage sludge cell structure, thereby releasing the cell contents and consequently increasing the total organic carbon in the liquid phase.