Final report on the pilot plant operation for supercritical water gasification of wet biomass

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Abstract. Supercritical water gasification has been developed as gasification technology for wet biomass. This is because the reaction takes place in water, and drying pretreatment is not needed. So far, production of gas and utilization of this producer gas has been discussed. However, devices to use gas such as gas engine or fuel cell are expensive. One possibility is to use heat as final product. To examine the possibility to use heat from supercritical water gasification, the pilot scale plant located in Chugoku Electric Power Co., Inc. was modified, and heat recovery experiment was conducted. To avoid the char production, addition of radical scavenger was also tried. Heat recovery with the efficiency of 24.7 % was achieved and DSS operation for 147 h 30 min in total was successful.

1. Introduction

Supercritical water gasification is gasification in hot compressed water whose temperature and pressure are both above its critical values [1]. It allows rapid decomposition and gasification of wet biomass, and thus has been studied intensively [2-4]. Wet biomass has high moisture content that hindered its use, but supercritical water gasification, utilization of wet biomass is highly expected. However, studies made so far resulted in requirement of expensive apparatus such as gas engine and fuel cell, and its commercialization was not successful. This is because final energy requirement takes the form of electrical or chemical energy. If final energy use is heat, needed apparatus should be much cheaper, and its commercialization should be much easier. To the best of authors’ knowledge, utilization of heat from supercritical water gasification has not been well studied. Thus, the purpose of this study is to verify the possibility of heat use from supercritical water gasification.

2. Experimental

The study should be more demonstrative one. We needed to decide what kind of heat utilization is to be made, first. Then, we conducted long-term operation of the modified pilot plant with shochu residue as feedstock. We added activated carbon catalyst to enhance gasification and radical scavenger to suppress char formation. The detail is shown below.
2.1 Heat generation
There are several possibilities of heat recovery from the process. Burning the product gas is one possibility. However, considering the needs of steam as process heat and that supercritical water gasification effluent has heat that can be used to produce steam by heat exchangers, we equipped a heat exchanger at the exit of the pilot plant of supercritical water gasification whose scale was 1 t-wet/d [5,6]. Water was fed to the heat exchanger to produce steam.

2.2 Feedstock
Shochu residue, which is distillation residue of Japanese distilled liquor shochu, was used as feedstock. As radical scavenger, acetic acid was employed to avoid char formation [7].

2.3 Operation
Reactor temperature and pressure were set at 590 °C and 23.5 MPa, respectively. Feedstock concentration was in the range of 3-5 wt%. Activated carbon catalyst was added by 1.0 wt%, and acetic acid concentration was in the range of 0.1-0.2 wt%. The operation was in daily-start-and-stop (DSS) mode.

3. Results and discussion
3.1 Continuous operation
DSS operation started on Sep. 1, and operation in total of 33 d was successfully conducted. The 33 d included 17 d continuous DSS operation for weekdays from Dec. 1, 2018 through Jan. 1, 2019. It is known that tarry material production results in pressure rise along the heat exchanger, finally causing plugging of it. However, in this run, addition of acetic acid was effective in pressure rise increase in the heat exchanger. This indicates the suppression of tarry material production. Fig. 1 shows one

![Fig. 1 Pressure loss of the heat exchanger](image)
example of daily pressure loss change of the heat exchanger. It is clearly shown that the pressure loss of the heat exchanger is quite stable for the 7 h continuous operation on the day.

3.2 Thermal efficiency
Thermal efficiency for this configuration of plant can be defined as the heat obtained as steam divided by the total supplied heat to the process. The total heat supply to the process is composed of heating value of the feedstock and the heating value of liquid propane gas. Because heat exchanger cannot bring the inlet flow temperature to the reaction temperature, we burned liquid petroleum gas to provide additional heat. It is to be noted that due to the small scale of the plant available in this study, heat loss is rather large, and high thermal efficiency cannot be expected. For the actual plant, product gas should be used instead of liquid petroleum gas, and heat loss should be much lower. In this calculation, however, we did not use the product gas to substitute liquid petroleum gas, and thus heating value of the product gas was subtracted from the heat provided by the liquid petroleum gas. The resulting thermal efficiency was 24.7 %.

4. Conclusion
1 t wet/d pilot plant for supercritical water gasification was modified so that heat recovery could be achieved as steam. By addition of acetic acid, long time operation of 33 d in total could be achieved. The thermal efficiency was calculated to be 24.7 %.

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