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Enhanced process Integration of entrained flow gasification and combined cycle: modeling and simulation using Aspen Plus

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Abstract

Energy recovery from black liquor can be performed through gasification process at temperatures above the melting point of the inorganic chemicals. Complementing the experimental research, this study was conducted in Aspen Plus software to simulate thermodinamic modeling of detail process for gasification and combined cycle in an integrated system power plant. Mass and energy balances were examined to quantify process performance. The unrecoverable energy in a single process will be utilized in other processes. The combination of these technologies is expected minimizing the total exergy destruction the throughout system. Kraft black liquor was used as sample during process calculation. The proposed integrated-system shows a high energy efficiency. A significant positive energy harvesting from black liquor can be achieved for further development.

Keywords: black liquor gasification; energy recovery; modeling; integrated system

1. Introduction

Energy recovery from biomass can be performed through thermochemical or biochemical route. Generally, thermochemical conversion, especially gasification, shows faster conversion rate and higher

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conversion efficiency [1]. The production of charred matter prior gasification always involves a thermochemical conversion process.

It is an essential reaction step in any combustion or gasification process. Furthermore, to achieve high total power generation efficiency from biomass, an integrated gasification and combined cycle (IGCC) has been developed with some advantages of high carbon conversion, high power generation efficiency and low environmental influence [2].

Since the power block of an IGCC plant is similar to that of a natural gas combined cycle (NGCC) plant, the efficiency of the latter is a natural reference for the IGCC plant. Currently, NGCC efficiencies are approaching 60%. Depending on configuration, some of the produced heat may or may not be recovered. Either way, a significant efficiency penalty or exergy loss arises because heat is a lower quality energy form than chemical energy.

Since black liquor is obtained from existing kraft process, an approach is needed to produce the desirable black liquor. One method to produce black liquor is using hydrothermal liquefaction (HTL) prior biomass gasification. This study is a preliminary effort to investigate the feasibility of an integrated system for power generation from gasification and combined cycle employing an existing black liquor as fuel resource.

2. Overall proposed system

2.1. Overview

Fig.1 shows the conceptual diagram of the overall proposed integrated system. The proposed integrated processes consist of gasification and combined cycle. The black liquor is flown to gasification module which are converted to syngas consisting of hydrogen, methane, carbon monoxide, etc. The produced syngas flows to the combined-cycle-based power generation comprising combustor, gas turbine, heat recuperator and steam turbine. Moreover, a high temperature raw syngas from the gasifier module is recycled and utilized for pre-heating in combined cycle process.

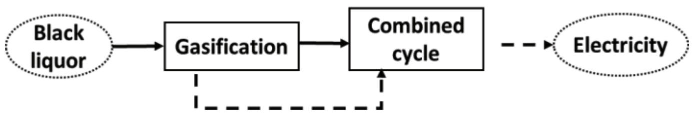

Fig.1. Conceptual diagram of the proposed integrated system

In the gasifier, black liquor pyrolysis, volatile combustion and char gasification reactions take place subsequently to produce the syngas. Hot syngas flows to heat recovery module to preheat the steam for combined cycle process. Subsequently, syngas will be cleaned up, removing the particulates and Sulphur. The clean syngas is then used as fuel for combustion, creating a high temperature pressurized gas to rotate the gas turbine. As the temperature of the flue gas from the gas turbine is still high, the rest of the heat will be utilized basically to generate steam in heat recovery steam generator (HRSG) which is used to rotate the steam turbine to generate the electricity.

2.2. Aspen plus modeling

The simulations of the integrated system were based on the mass-energy balance and chemical equilibrium. The integrated plant design is modeled with Aspen Plus V8.8, a simulation tool which can calculate material flow and energy balances. The stream for biomass were specified as a non-conventional