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Investigation of integrated biomass pyrolysis and gasification process for green fuel production

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Abstract

The energy production from biomass has been received closer attention due to an increased concern in greenhouse gas emissions from fossil fuel combustion unit. Gasification is a promising technology used to convert biomass to a synthesis gas. Although the gasification process provides a high amount of synthesis gas, it also consumes high energy, especially in an air separation unit (ASU), which is the largest energy consumer in the process. A design of new biomass conversion process offering lower energy consumption is an interesting topic and focused in this study. The integrated biomass pyrolysis and gasification (IBPG) process, for the co-production of synthesis gas and bio-oil, is investigated using the IBPG model developed in Aspen custom modeler. Rice straw is a considered biomass feedstock. The effects of changes in pyrolysis temperature on the IBPG performance, i.e., product distribution and energy consumption, are investigated. The amount of oxygen required to achieve 98% of char conversion at gasifier is found to decrease as the pyrolysis temperature increases, resulting in the decrease of energy required at ASU. The production rate of synthesis gas and bio-oil derived from IBPG process increase as pyrolysis temperature increases due to the increased volatiles. Comparing with the conventional biomass gasification, although the IBPG process offers lower syngas production rate, it provides additional bio-oil as a valued product. Additionally, the lower amount of waste heat released from IBPG process is found. The IBPG process with high pyrolysis temperature offers a high amount of synthesis gas and bio-oil and releases the low amount of waste heat.

Keywords: Gasification; Pyrolysis; Rice straw; Process analysis; Synthesis gas; Bio-oil

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1. Introduction

Increased economic growth results in an increased amount of greenhouse gases emitted from fossil fuel combustion units which lead to the global warming and public health issues. To deal with these problems, energy production from biomass for which carbon neutrality can be assumed has been received closer attention. Gasification is recognized as a promising technology used to convert biomass into synthesis gas which is essential for the synthesis of several chemicals. Although the gasification process provides a high amount of synthesis gas, it consumes a high amount of energy, especially in an air separation unit (ASU), which is the largest energy consumer in the gasification process [1]. A design of new biomass conversion process offering lower energy consumption is an interesting topic.

Pyrolysis is another approach used to convert biomass into energy (i.e., synthesis gas and bio-oil) at a lower temperature than gasification [2]. During biomass pyrolysis, some volatiles, e.g., hydrogen, carbon monoxide, light hydrocarbon and bio-oil, are removed and char is remained. The remaining char can be used as a gasification feedstock to produce additional synthesis gas. As char contains a low amount of carbon, oxygen is less required to carry out the gasification reaction. Consequently, the lower amount of energy is required at ASU. The integrated biomass pyrolysis and gasification (IBPG) process seems to be a new design biomass conversion process offering lower energy consumption which can produce synthesis gas and bio-oil simultaneously. Previously, a study of the integrated pyrolysis and gasification process was restricted by using a coal feedstock [3]; therefore, the present study focuses on the performance analysis of the IBPG process using biomass. Rice straw, the highest amount of biomass residue found in Thailand, is a considered feedstock. The effects of changes in the pyrolysis temperature on the IBPG performance (i.e., product distribution and overall energy consumption) are investigated. Moreover, the performance comparison of the IBPG and the conventional gasification processes is also performed. The simplified diagram of IBPG process represents the involved reactions, the key parameters and the performance indicators, is shown in Fig.1.

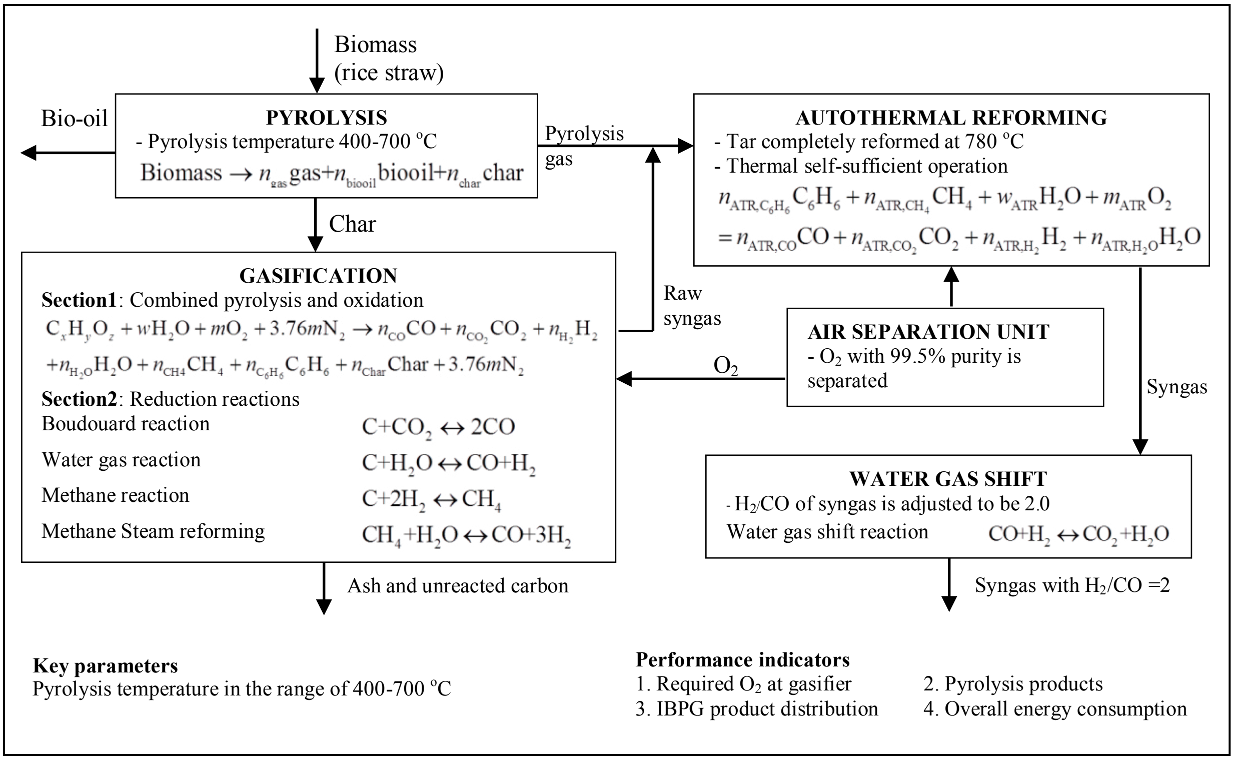

Fig. 1. Simplified diagram of the IBPG process.