



# Gasification of oil palm residues (empty fruit bunch) in an entrained-flow gasifier

Tomoko Ogi<sup>a,\*</sup>, Masakazu Nakanishi<sup>a</sup>, Yoshio Fukuda<sup>a</sup>, Keigo Matsumoto<sup>b</sup>

<sup>a</sup> National Institute of Advanced Industrial Science and Technology, Onogawa 16-1, Tsukuba, Ibaraki 305-8569, Japan

<sup>b</sup> Nagasaki Research and Development Center, Mitsubishi Heavy Industries Ltd., 5-717-1, Fukabori-machi, Nagasaki 851-0392, Japan

## ARTICLE INFO

### Article history:

Received 14 September 2009

Received in revised form 15 February 2010

Accepted 30 August 2010

Available online 17 September 2010

### Keywords:

Empty fruits bunch (EFB)

Gasification

Entrained-flow gasifier

Bio-fuel

Solid residue

## ABSTRACT

Empty fruit bunch (EFB) biomass, one of the most abundant biomass residues in Southeast Asia, was gasified using H<sub>2</sub>O (steam) or H<sub>2</sub>O + O<sub>2</sub> as a gasification agent in an entrained-flow gasifier at 900 °C. During gasification with H<sub>2</sub>O alone, the EFB gasification rate was >95% (C-equivalent), and hydrogen-rich gas with a composition suitable for liquid fuel synthesis ([H<sub>2</sub>]/[CO] ≈ 1.8–3.9, depending on the [H<sub>2</sub>O]/[C] ratio) was obtained. The gasification rate improved (to >99%) when O<sub>2</sub> was added to H<sub>2</sub>O; however, under these conditions, the gas composition was less suitable for liquid fuel synthesis (the amount of [CO<sub>2</sub>] increased, the amounts of [CO] and [H<sub>2</sub>] decreased, and the [H<sub>2</sub>]/[CO] ratio decreased). Nevertheless, the [H<sub>2</sub>]/[CO] ratio was sufficient (~2) for liquid fuel synthesis. We also performed thermogravimetric (TG) analysis of EFB using a thermobalance specially designed for analysis of feedstock in the presence of O<sub>2</sub>, H<sub>2</sub>O, or both. TG analysis suggested that EFB decomposed easily, especially in the presence of H<sub>2</sub>O and/or O<sub>2</sub>. The results obtained from TG analysis and gasification agreed well. In gasification, the tar yield was low (<0.1 wt.%), and the tar was composed mainly of six compounds, including naphthalene; these results suggest that the primary tar decomposed and that gasification proceeded quite well. The yield of solid residues was low, and the soft, yellow residues, which partially adhered to the gasifier wall, were composed mainly of ash. These solid residues would require treatment in a large-scale gasifier.

© 2010 Elsevier Ltd. All rights reserved.

## 1. Introduction

In 2002, biomass was first approved as a renewable source of energy by the Japanese government, and targets for the introduction of biomass were set. The target values were revised in 2006, at which time bio-fuel (also referred to as liquid bio-fuel), which is fermented or synthesized from biomass and used for vehicles, was first nominated. According to the government scenario, more than 0.5 million kl of bio-fuel will be introduced every year up to 2010, and the yearly amount will gradually be increased until 2030 [1]. Although bioethanol is the main gasoline substitute in use at the moment, biodiesel fuel will also be introduced after 2020. Among them, second-generation bio-fuels, such as liquid fuel synthesized catalytically from gasified biomass, are expected (and required) to become the main substitutes for petroleum diesel fuel.

The production of bioethanol by fermentation of food biomass, such as sugarcane and grain (corn and wheat) unexpectedly led to an increase in global food prices and raised ethical problems with converting food to energy. Therefore, technologies for bioethanol production from non-food biomass or lignocellulose, such as wood and agricultural residues, by means of pretreatment–saccharifica-

tion–fermentation are being aggressively studied. However, the energy conversion rates for these materials are low because of the three main components of lignocellulose (cellulose, hemicellulose, and lignin), only cellulose undergoes fermentation. Technologies for fermenting xylan, a type of hemicellulose, are under development but are not yet in practical use. On the contrary, gasification and catalytic liquefaction rapidly convert various kinds of whole biomass to gaseous or liquid fuel with high conversion rates and, consequently, have the potential to become practical, high-efficiency processes.

Gasification technology itself has been developed well thus far. According to the World Gasification Database (2007), existing world gasification capacity was 56,238 MWth of syngas output from 144 operating plants and about 400 total gasifiers [2]. Details of feedstock showed coal was dominant (30,835 MWth, 54.8% in total), then was petroleum 18,454 MWth, 32.8%. Biomass/wastes had very low share of 2.0%. Products of coal gasification were FT liquids and chemicals (49%, 32% respectively), on the other hand, products of biomass/wastes were gaseous fuels and power. It is necessary to develop biomass gasification from now, basing and modifying on coal gasification.

Many types of gasifiers have been studied; the main types include fixed-bed, rotary kiln, fluidized-bed, and entrained-flow gasifiers. Small-scale gasifiers are already in practical use for the generation of electric power and the cogeneration of power and

\* Corresponding author.

E-mail address: [t-ogi@aist.go.jp](mailto:t-ogi@aist.go.jp) (T. Ogi).

heat. Power generation or cogeneration requires gas with a high calorific value, but control of the gaseous components is unnecessary because the gas is combusted. To reduce both initial and operational costs, an air-blown gasifier is usually used, and the gas produced contains 30–50% nitrogen. Gasifiers developed for power generation and cogeneration thus far have been fixed-bed and fluidized-bed types [3,4].

In contrast, for the catalytic synthesis of liquid fuel, both the gaseous components and the impurities must be controlled. Because liquid fuel and other chemical products are usually synthesized from  $H_2$  and CO, the ratio of  $H_2$  to CO has to be controlled to suit the desired products; for example, the ideal  $[H_2]/[CO]$  ratio for the synthesis of methanol and Fischer–Tropsch synthesis oil is  $\sim 2$ . Even though  $N_2$  gas is inert, it increases the energy required for compression and decreases the energy efficiency of the gasifier. In addition, the amount of impurities that deactivate the catalyst must be reduced; for example, the sulfur content must be  $<1$  ppm [5,6].

Fluidized-bed and entrained-flow gasifiers are commonly used for liquid fuel synthesis and chemical production. The entrained-flow gasifier has many advantages; for example, it has a simple structure, no catalyst is required, the tar yield is low, control of the gaseous components is easy, and various kinds of biomass are available as feedstock.

As mentioned before, the entrained-flow gasifier was initially developed for gasifying coal, and now for coal gasifiers are operated, such as GE Energy, Shell, and Lurgi, in large scales of a few thousand ton/day in the world. In Japan, two demonstration plants are now in operation; an oxygen-blown, two-stage spiral-flow gasifier is used in an integrated coal gasification fuel cell combined-cycle plant under the Coal Energy Application for Gas Liquid & Electricity (EAGLE) Project, and an air-blown entrained-flow gasifier is used in an integrated coal gasification combined-cycle plant in Nakoso [7–9]. Co-gasification of coal and biomass using an entrained gasifier also has been developed and demonstrated, adopting for the integrated gasification combined-cycle plants. The content of biomass to coal is as low as 3–10 wt.%, so coal gasification is the base in principal, however, modifications are required. There have been few reports on the co-gasification using an entrained-flow gasifier, basic research about co-gasification reactivity of coal and woody biomass is reported [10].

In biomass (alone) gasification using an entrained-flow gasifier-liquid fuel synthesis process, two cases are well known in the world. One is a black liquor gasification-DME synthesis by CHEMREC Co. Ltd., in Sweden [11,12], the other is a two-stage gasification of woody biomass –FT synthesis by CHOREN and Shell Co. Ltd., in Germany [13]. The former is gasification of liquid material and the latter is the two-stage gasification, in which wood is pyrolyzed at lower temperature to produce carbonized solid material at 1st stage, then the carbonized material is gasified at higher temperature in an entrained gasifier at 2nd stage. Both gasification processes have been developed by companies and are now on demonstration and/or partially commercialization stages, and the final target scales planned are very large, as large as a few thousand ton/day scale, almost equal to scale of coal gasification. So collection of feedstock biomass would be one of the most important key factors. In general, amounts of biomass are estimated to about 50–100 ton/day, up to 200 ton/day at most, so gasification process suitable for biomass scale should be developed.

As the composition and characteristics of biomass are quite different from those of coal, the gasifier and the plant would also have to be modified for biomass gasification from the following points. The oxygen and fixed carbon contents of biomass are respectively about 45 wt.% and 20–25 wt.%, whereas those of coal are respectively 2–20 wt.% and 50–85 wt.%. The  $[H]/[C]$  ratio for biomass is 1.7–2.1, which is higher than that of coal (0.5–0.85). Therefore, biomass is more degradable compared to coal and the gasification

temperature for biomass is lower than that for coal (1300–1600 °C). In biomass, gasification temperatures are reported at 650–1200 °C with and without catalyst, but we consider better to gasify biomass at temperatures of 700–1000 °C (without catalyst case) from both points of energy balance and cost. Because higher temperature consumes much more energy, especially when using steam as a gasification agent, and equipments durable and suitable at high temperatures above 1000 °C become very expensive. Biomass, not like coal, is not expected to contract a large scale and should be treated in energy- and cost-effective conditions.

As part of the High-Efficiency Bioenergy Conversion Project sponsored by the New Energy and Industrial Technology Development Organization, we have been studying the gasification of biomass in an entrained-flow gasifier and clarifying suitable conditions for synthesizing liquid fuels. On the basis of fundamental research, Mitsubishi Heavy Industries Ltd., (MHI), Chubu Electric Power Corporation, and our group at the National Institute of Advanced Industrial Science and Technology (AIST) developed a test plant operating at 2 ton/day for the study of woody biomass gasification and liquid fuel (methanol) synthesis (Fig. 1) [14,15]. In this system, steam and oxygen were used and biomass was partially oxidized to give heat for gasification. In Japan, another group (Sakai at NIAS; Nagasaki Institute of Applied Science's group) has performed gasification using an entrained type reactor [16]. In their system, steam alone is used as a gasification agent and other gasification agent (such as oxygen) cannot be introduced, and heat is supplied from outside of a gasifier (external heat supply system), therefore, it is impossible to make up in a large scale (maximum scale is about 1 ton/day scale at most). The latter is the system suitable for locally distributed in small-scale system and is different from our system.

Using the relatively large scale plant, we also investigated the possibility of recycling the char and analyzed the gasification kinetics [17,18]. We developed a small-scale entrained-flow gasifier and used it to gasify various kinds of biomass; we found that the gasification characteristics depended on the gasification conditions and the feedstock biomass [19–21].

In the current study, we gasified empty fruit bunch (EFB) biomass, the waste from fresh fruit bunches of the oil palm. In South-east Asia (Malaysia and Indonesia), the production of oil from palm has increased year by year and amounts of discharged EFB have also increased in large quantities. Now most of the EFB are left, however these are promising candidates for bio-fuel production.



Fig. 1. Entrained-flow gasifier test plant (2 ton/day) at Kawagoe, Japan.

Download English Version:

<https://daneshyari.com/en/article/6642634>

Download Persian Version:

<https://daneshyari.com/article/6642634>

[Daneshyari.com](https://daneshyari.com)