Development of High-efficiency Gasification Technology for Biomass & Waste – Study on Operating Condition for High Thermal Efficiency and Stability Controlling Tar Formation –

Background

For the reduction of CO_2 emission and the construction of circulative society, the effective utilization technology of biomass and waste is expected. If the gasification technology with high thermal efficiency and flexibility for various biomass is developed, the biomass utilization can be promoted [*1]. In order to resolve the problems at high moisture content and low grindability, CRIEPI is developing the high-efficiency carbonization and gasification system for various biomass.

Objectives

Pyrolysis and gasification reaction of typical biomass samples are characterized to develop the prediction model for the performance of a gasifier. The gasification systems for various fuels are investigated using this prediction model, and operating conditions [*2] for high thermal efficiency and stability are clarified for biomass and waste (Table 1).

Principal Results

1. Clarification of pyrolysis and char gasification reactivity of typical biomass sample

(1) The pyrolysis tests using the atmospheric Drop Tube Furnace (DTF) showed that tar, which was often the cause of trouble in the operation, formed much at less than 900℃, while tar was decomposed completely at high temperature over 1200℃.

(2) The char gasification tests of Japanese cedar bark with carbon dioxide at high-temperature conditions as in entrained flow gasifiers using the Pressurized DTF (PDTF) showed that the char gasification rate was from 10 to 100 times as high as that of coal chars (Fig.1). It can be said that high reactivity of Japanese cedar gasification maintains if temperature of the gasifier is decreased 100℃ or 300℃ lower than that of the coal gasifier.

2. Investigation of gasification system and operating condition for high thermal efficiency and stability

The prediction model to predict gasification performance from gasification rate was established. Following results were obtained using this model.

(1) If the carbonization and gasification system (Fig.2), in which the carbonizer is the pretreatment facility and biomass is decomposed into carbide and volatile gas including moisture, is adopted, even cedar chip with a lot of moisture (40%) can be stably gasified at high efficiency (Fig.3).

(2) When the volatile gas at carbonizer is much like cedar tip (volatile ratio = 90%), it is necessary that oxidizing agent is fed to gas reforming part to maintain gasifier temperature to decompose tar in the carbonization and gasification system (Fig.3).

(3) In the case of waste, ash content is high and the volatile gas is not much (volatile ratio = 60%). Air should be fed only to the combustor in two-stage gasifier to operate stably at high efficiency and to melt ash to discharge from the gasifier as clean slag (Fig.4).

(4) It was clarified that the high-efficiency and stable operating condition range can be applied to various biomass and waste with different volatile ratio (Fig.5).

From the above-mentioned result, the foresight to achieve 30% of gross thermal efficiency with less than 40% moisture content biomass was obtained.

Future Developments

The experimental verification of gasification performance and the establishment of high-efficiency and stable operating technology will be carried out using our carbonization and gasification experimental facility, which is being constructed in CRIEPI, to promote the utilization of biomass and waste

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Reference

・S. Kajitani et al., March 2004, Basic characterization of gasification reactivity of biomass from agriculture or forestry for high-efficiency utilization, CRIEPI Report, W03020 (in Japanese)

・K. Kidoguchi et al., July 2004, Development of high thermal efficient gasification technology of biomass and waste - Proposal of gasification method by calculation for forecasting gasification performance -, CRIEPI Report, W03026 (in Japanese)

*1：K. Ichikawa et al., The trend of woody biomass power generation technologies and research subjects for practical use, CRIEPI Report, W02026 (in Japanese)

*2：The necessary condition:Carbon conversion efficiency is more than 99.5% and cold gas efficiency is more than 75% for high-efficiency utilization. Combustor exit temperature is less than 2000℃ for heat residence of gasifier wall. Gasifier exit temperature is more than 1100℃ to decompose tar. When ash content is high, combustor gas temperature is more than 1600℃ to melt ash.

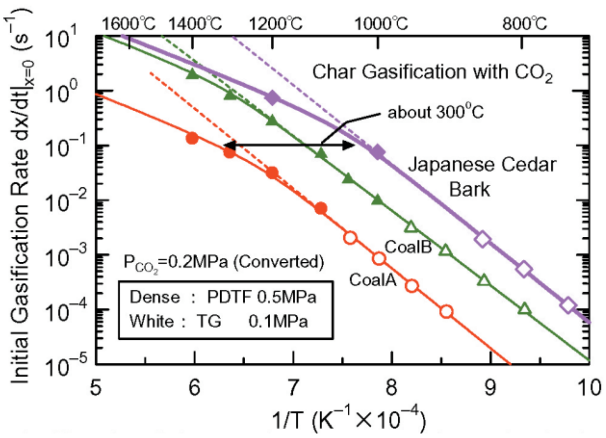

Fig.1 Results of char gasification rate analysis of cedar bark

Char gasification rate of Japanese cedar bark was analyzed using the TGA and PDTF. As a result, the char gasification rate was from 10 to 100 times higher than that of coal chars.

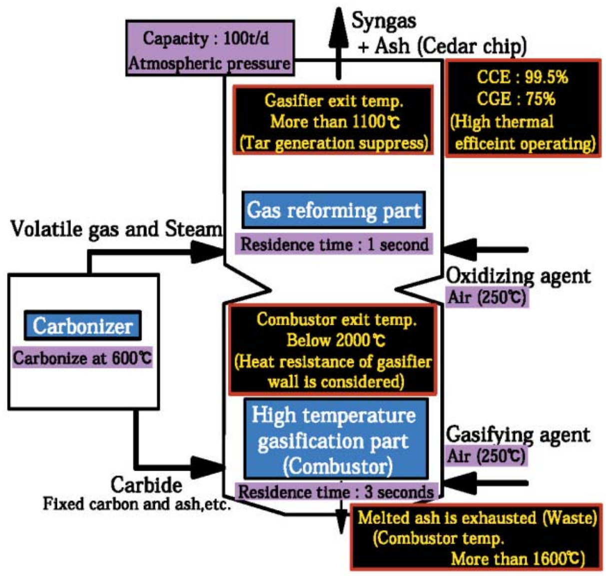

Fig.2 Schematic of carbonization and gasification system

The operating condition for high thermal efficiency and stability in the carbonization and gasification system was examined.

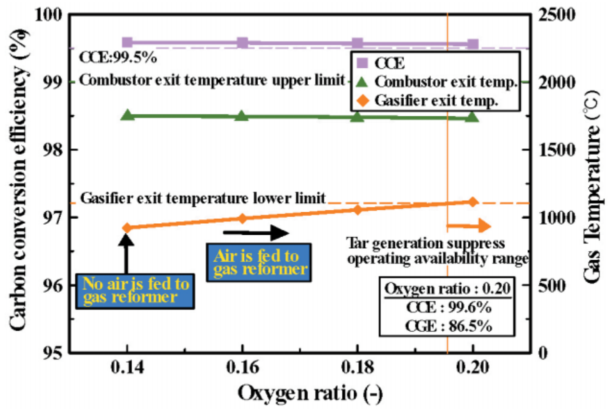

Fig.3 Gasification performance in carbonization and gasification system (Cedar chip, Combustor oxygen ratio = 0.56, Air is fed to gas reformer)

When cedar chip is gasified, it is necessary that oxidizing agent is fed to gas reformer to maintain gasifier exit temperature to decompose tar.

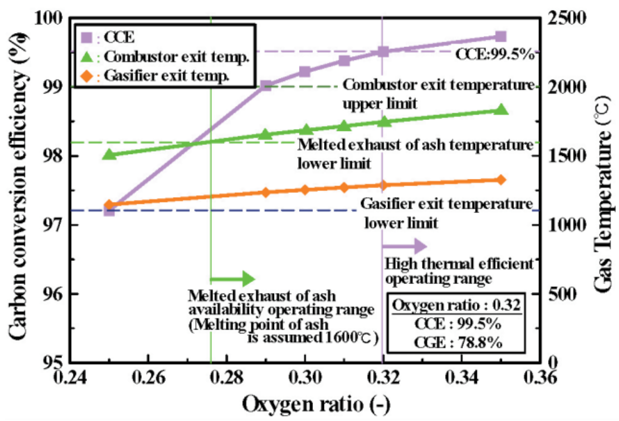

Fig.4 Gasification performance in case of Waste

Waste is gasified at high thermal efficiency and ash is molten, feeding air to only combustor in two-stage gasifier.

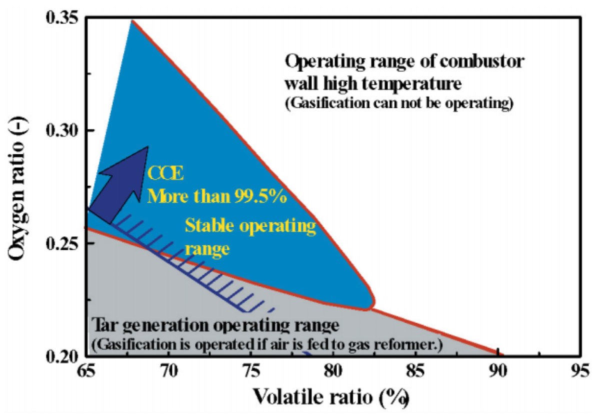

Fig.5 Operating condition range for high thermal efficiency and stability when volatile ratio is changed.

The high-efficiency and stable operating condition range can be applied to various biomass and waste with different volatile ratio.

Table 1 Properties of examined biomass

Item	C	H	O	N	S	Cl	Fixed carbon	Volatile matter	Ash	Moisture
Cedar chip	13.73	6.19	42.81	0.10	0.01	<0.01	6.07	53.84	0.09	40.00
Waste	41.42	5.33	21.79	1.49	0.14	1.07	9.78	61.45	5.38	23.39

wt% (wet base)

Definition

$$\text{Oxygen ratio} = \frac{\text{Oxygen flow rate}}{\text{Theoritical oxgen of fuel}}$$

$$\text{Carbon conversion efficiency (CCE)} = \frac{\text{Carbon flow rate in product gas}}{\text{Carbon flow rate in fuel}} \times 100$$

$$\text{Cold gas efficiency (CGE)} = \frac{\text{Calory in product gas}}{\text{Calory in fuel}} \times 100$$

$$\text{Volatile ratio} = \frac{\text{Volatile gas from carbonizer} - \text{Moisture in fuel}}{\text{volatile matter in fuel}} \times 100$$