Development of Performance Evaluation Techniques for Biomass Gasification Power Generation System

Background

Development of biomass utilization technologies has been increasingly needed toward prevention of the global greenhouse effect and creation of the recycling-oriented society. Biomass gasification can increase options for combination with various power generation systems using gas engines, gas turbines, fuel cells and/or others to enhance power generation efficiency, and also can open the door to examining power generation system configurations meeting site conditions, such as kinds of collectable biomass, plant capacity, etc. Feasibility study on various power generation systems combined with gasification of various kinds of biomass inevitably requires application of adequate techniques that can estimate and evaluate gasification efficiency, power plant thermal efficiency, etc.

Objectives

Objectives of this research project are to elucidate experimentally gasification reaction characteristics of various kinds of biomass, to establish reaction models and thereby to develop a series of assessment techniques that can estimate and evaluate gasification efficiency, power plant thermal efficiency, etc.

Principal Results

1. Elucidation and modeling of gasification reaction characteristics of various kinds of biomass

By using reaction rate measuring devices such as thermogravimetry (TG), drop-tube-furnace (DTF), etc., gasification reactivity of various kinds of biomass was elucidated (Fig.1). Gasification reaction rate of biomass varied widely depending on its kind and it was, therefore, necessary to determine kinetic parameters of reaction rate experimentally. Random pore model equation frequently used for coal gasification reaction proved to be incapable of representing correctly changes in reaction rate of biomass gasification. Parameters expressing changes of pore structure were improved so as to meet experimental results (Fig.2). Then the improved reaction rate model proved to be applicable to various kinds of biomass.

2. Estimation of biomass gasification efficiency

By reflecting the reaction rate model developed as described in the above section 1 to the “one dimension gasification simulation tool” developed by the CRIEPI, it became possible to estimate gasification performances, such as gas temperature, gas composition, calorific value of generated gas, carbon-conversion efficiency and cold-gas efficiency, for any gasification systems with specified gasifying agent, heat loss and residence time (scale) (Fig.3).

3. Development of techniques for performance analysis and evaluation technology for various power generation systems using biomass

By reflecting the results of gasification efficiency estimation to “General-purpose program for analysis of thermal efficiency of power generation systems (EgWin[*1])” developed by the CRIEPI, it became possible to analyze heat balance and material balance in various power generation systems including combined gas and steam turbine cycles, fuel cells, and gas engines. Table 1 shows an example of analytical data of power generation performance for a combined cycle power generation system integrated with 240 T/D scale woody biomass gasification shown in Fig.4.

As shown above, development of each reaction model corresponding to each of biomass kinds has made it possible to estimate gasification efficiency and power generation performance in response to requirements for plant capacity, power generation system configuration, etc. and to make prior evaluation of various power generation systems in response to applicable kinds of biomass. A part of this research project was carried out as contracted with NEDO/Electric utilities.

Future Developments

The CRIEPI intends to extend and systematize applicable kinds of biomass, to elucidate and model tar formation-decomposition mechanisms posing problems at biomass utilization, and further to develop comprehensive evaluation techniques for biomass power plants.

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References
M. Ashizawa et.al., 2005, “Study on biomass IGCC power generation system - Survey of existing power generation systems and evaluation of plant performance -”, CRIEPI Research Report M04507(in Japanese).
S. Kajitani et.al., 2005, “Study on gasification reactivity of biomass carbide - Investigation of gasification reaction rate equations and analysis of gasification reaction rate of rice husk carbide -”, M04007 (in Japanese).

*1 : Eiichi Koda, Toru Takahashi, “Development of general-purpose software to analyze the steady state of power generation systems”, Energy Conversion and Management 43, pp1407-1416, 2002

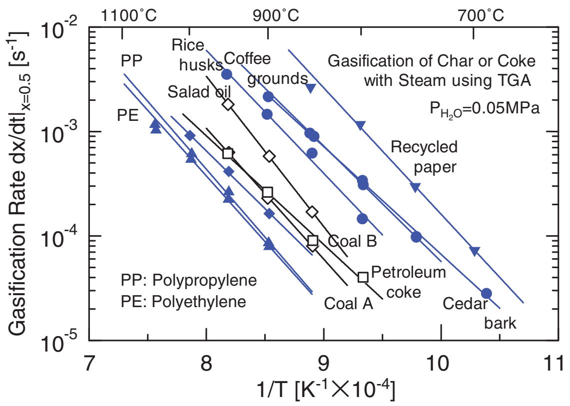


Fig.1 Gasification reactivity of various kinds of biomass

1/T on the abscissa axis is expressed in inverse number of temperature value. Temperature scale is given on the upper abscissa axis for reference. These graphic data prove that the reaction rate is greatly different depending on the kind of biomass.

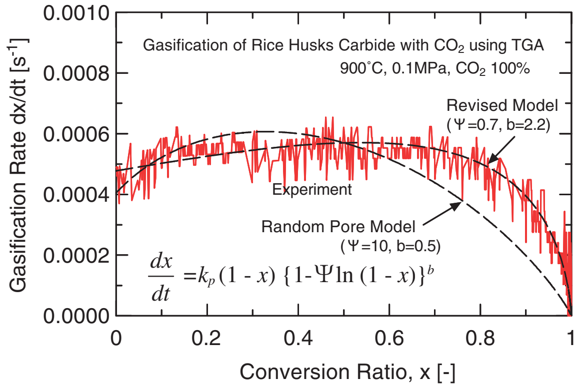
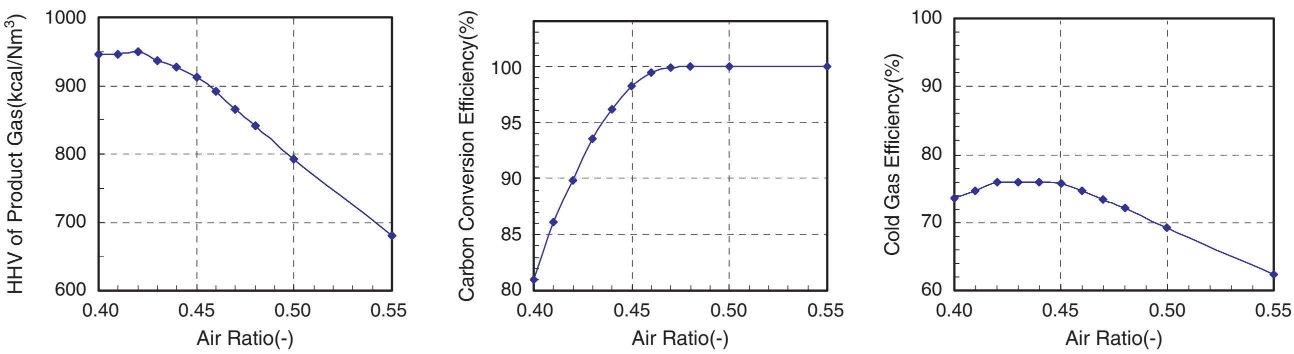


Fig.2 Correlation by improved reaction model

It is possible to represent changes in reaction rate of various kinds of biomass by improved parameters of terms that express changes of the microporous structure.



a) HHV of Product Gas　b) Carbon Conversion Efficiency　c) Cold Gas Efficiency

Fig.3 Results of gasification efficiency estimation for woody biomass(Japanese cedar)

Formulation of the reaction rate equation based on experimental results of reaction characteristics of biomass makes it possible to estimate gasification efficiency inclusive of composition and calorific value of generated gas, carbon conversion efficiency and cold-gas efficiency by taking air ratio, residencetime and heat loss as parameters.

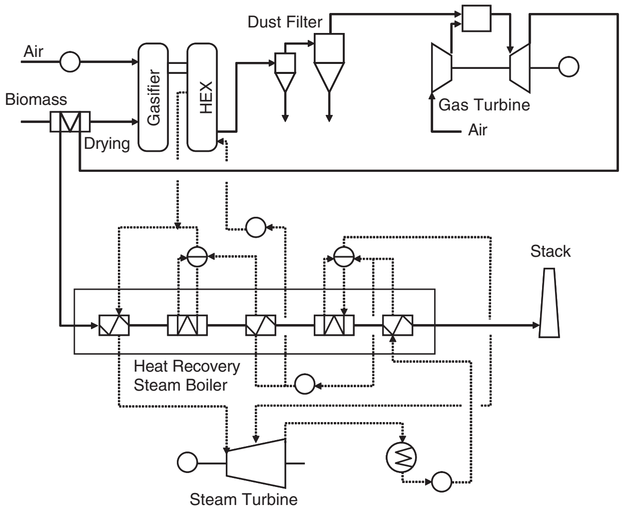


Table 1 An example of analytical data

		240T/D Scale Biomass IGCC
Fuel Feed Rate	t/d	240
(After Drying)	t/d	218
Output	MW	13.53
(GT Output)	MW	7.90
(ST Output)	MW	5.63
Sending-end Output	MW	9.35
Auxiliary Power	MW	4.18
Gross ηth(HHV)	%	36.7
Net ηth(HHV)	%	25.3
Auxiliary Power Ratio	%	30.9

Fig.4 An example of biomass IGCC configuration

It is possible to analyze heat balance and material balance in various power generation systems based on the results of gasification efficiency estimation and by applying “General-purpose program for analysis of thermal efficiency of power generation systems (EgWin)” developed by the CRIEPI.