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R&D (Research and Development) on distributed power generation from solid fuels

Kunio Yoshikawa *

Department of Environmental Science and Technology, Tokyo Institute of Technology, 4259 Nagatsuta, Midori-ku, Yokohama 226-8502, Japan

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Abstract

Technical demonstration of an innovative small-scale gasification and power generation system for solid fuels such as wastes and biomass are described which is known as the STAR-MEET (steam/air reforming type multi-staged enthalpy extraction technology) system. In this system, a fixed-bed pyrolyzer combined with a high temperature reformer using a high temperature steam/air mixture is employed. From the experimental results using various solid fuels, it has been demonstrated that the injection of high temperature steam/air mixture into the pyrolysis gas effectively decomposes tar and soot components in the pyrolysis gas into CO and H_2, and almost dust and tar free clean reformed gas can be generated. This gasification system generates low-BTU gas from solid fuels. Power generation experiments using a small, dual fueled (20% light oil gas + 80% low-BTU gas) diesel engine demonstrated high thermal efficiency around 30% and low emission (especially NO_x). For the early commercialization of STAR-MEET systems, three classes of facility, which are different in capacity are under development. The current demonstration status is described.

Keywords: Gasification; Distributed power generation; Solid fuel

1. Introduction

Many types of gasification and power generation technologies are studied and developed for thermal recycling of unutilized solid fuels like wastes and biomass in the world such as reported in Kiran [1], Rapagna [2], Morris [3] and Slapak [4]. We are developing a relatively smaller sized and distributed type of solid fuel gasification and power generation system, known as the STAR-MEET (steam/air reforming type multi-staged enthalpy extraction technology) process that can be installed at distributed locations to minimize the cost of transportation and treatment of solid fuels. In this system, solid fuels are pyrolized in the fixed-bed gasifier and the pyrolysis gas is reformed by a high temperature steam and air mixture to maximize the efficiency of the gasification process. The reformed gas is purified to become a low-BTU fuel gas, which is available for power generation by the dual fuel type diesel engine. In this paper, performance of the plants in several size types are compared theoretically and experimentally to clarify the technical feasibility and scaling factor of the system.

* Tel.: +81 45 924 5507; fax: +81 45 924 5518.
E-mail address: yoshika@depe.titech.ac.jp (K. Yoshikawa).

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2. System

Fig. 1 shows a typical system flow of the STAR-MEET system. Solid fuels are fed into a fixed-bed pyrolyzer using a continuous feed device. Thermal energy for pyrolysis of the solid fuels is supplied from the partial combustion of char at the bottom of the pyrolyzer or melting furnace. Residual ashes are extracted from the bottom of the pyrolyzer in the form of calcinated ashes or from the melting furnace in the form of molten slag. Pyrolysis gas contains H_2, CO, CH_4, N_2, CO_2, O_2, light hydrocarbons and tar.

In the reformer, tar and soot components are reformed with high temperature steam in the following endothermic reactions;

$$C_nH_m + nH_2O \rightarrow nCO + (n + m/2)H_2 \quad (1)$$

$$C + H_2O \rightarrow H_2 + CO \quad (2)$$

These reactions are activated under the condition of high temperature over 800 °C. To sustain this temperature, high temperature air is used for partial combustion of the pyrolysis gas. Main components of the reformed gas are H_2, CO, CO_2, N_2, CH_4 and gaseous hydrocarbons such as C_2H_2.

High temperature steam and air are produced from a high efficiency heat exchanger with hot gas from a furnace burning low-BTU fuel gas. The thermal energy of the reformed gas is used for making saturated steam and hot air for the pyrolysis stage. Impurities such as HCl, H_2S, etc. in the reformed gas is removed in the purifier, which is a scrubber (wet) type and/or a dry type such as a dust filter or an impurity adsorption device. The recovered fly ashes are supplied into the pyrolyzer again, and the condensed water originated from the moisture in the solid fuels and the steam supplied for reforming is adequately treated and discharged. Finally, this purified fuel gas is pressurized by a suction blower and used as a fuel for a dual fuel type diesel engine with power generator and for the low-BTU gas-burning furnace with a heat exchanger.

3. Plant types

The STAR-MEET system can be adapted to various sizes of plant. Typical plant specifications of three sizes are summarized in Table 1. Each type of plant has already been designed, constructed and tested to prove the availability and performance of the STAR-MEET system.

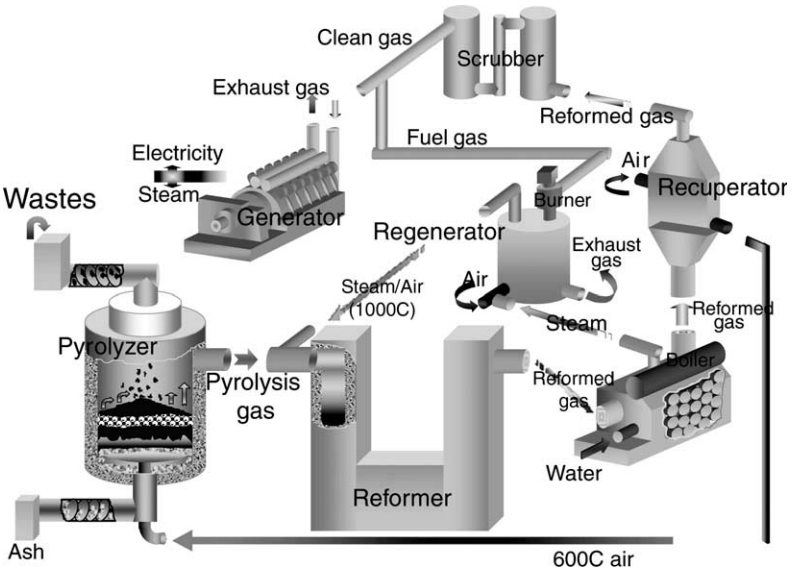

Fig. 1. STAR-MEET system.