A Total System Optimization Study of Waste Pyrolysis and Gasification Process for Electric Power Generation

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In Japan, Waste Power Generation or Waste-To-Energy (WTE) Technology has been widely applied as the main waste handling technology because of its sanitation, disposal volume reduction, and obtainment of electric energy from the waste. However, in the conventional typed WTE, the efficiency level has been as low as 10 %. Therefore, the R&D works has been performed as the governmental projects from FY1991 to 1999 with efficiency level of 30%, which we call High Efficient Conventional Typed WTE. Along with that project, another R&D work regarding the Gasification WTE technologies has been performed as two projects. One is called Pyrolysis (or Partial Gasification or Cracking) and Combustion Typed WTE Technology performed from FY1998 to 2000, which has good tendency for medium-sized capacity such as more than 200t/d. And the other is called as Pyrolysis and Gasification (or Reforming) Typed WTE Technology performed from FY2001 to 2003, which has good tendency for smaller sized capacity such as less than 200t/d. This paper presents some test results obtained in the project of the Gasification and Reforming Typed WTE.

1. Introduction

The energy policy in Japan leads the Waste-To-Energy (WTE) to the top among new energy sources in terms of capacity of 4,170 MW, or 5,520 Ml in oil equivalent, by FY2010. This national goal accounts for almost 30% of the total new energy capacity. This capacity will supply 1% of the nation-wide primary energy supply in FY2010. Thus the development of WTE is quite promising. In FY2001, the actual installed capacity of the WTE was 1,400 MW (2,150Ml in oil equivalent) which accounted for only 0.33% in the primary energy supply. To achieve the above goal, the installed capacity must be three times as much as FY2001 level by FY2010. New Energy and Industrial Technology Development Organization (NEDO), one of governmental R&D centers, has been conducting the technology development, known as High Efficient Conventional Typed WTE since FY1991, supported by the Ministry of Economy, Trade and Industry (METI). These efforts aimed at increasing the efficiency of WTE, in which we established a technology for improving the efficiency from FY1991 to FY1999, by conducting demonstration plant tests. The demonstration tests proved that newly developed super-heater (SH) materials could ensure the furnaces' operating reliability as well as high efficiency under steam conditions of 500°C and 9.8 MPa pressures.

From FY1998 to 2000, we developed "the Waste Pyrolysis and Combustion Typed WTE" with Ash Melting Technologies in order to meet the legal requirement on melt resultant ashes for preventing dispersion of pollutant as well as the political requirement for more efficient power generation. The total system optimization study shows that the gross power efficiency of 30% is achievable by employing those new technologies to 600 t/d scale municipal solid waste (MSW) facility. On the other hand, we have started the development of “the

Waste Pyrolysis and Gasification Typed WTE ” since FY2001 as a three years project. The preliminary feasibility study showed that this system would be suitable for small and medium scale of MSW facilities less than 200 t/d. The present technology development project aims at not only improving generation efficiency but also reducing the concentration of dioxin emissions and achieving economic efficiency in terms of construction costs. The following targets are defined for 100 t/d scale facility after developed:

- Gross power generation efficiency: 25% (Generation capacity: about 2500 kW)
- Net power generation efficiency: 14%
- Gas engine generating efficiency: 36%
- Concentration of dioxins emission: < 0.01 ng-TEQ/m^3_N
- Economic efficiency: construction and operating costs should be lower than or equal to the levels attained by the conventional technologies.

2. Development of The Pyrolysis and Gasification Typed WTE

The Waste Pyrolysis and Gasification Typed WTE having direct power generation such as gas fired engine instead of steam turbine are proposed and studied. The Pyrolysis and Gasification Typed WTE is similar to the Waste Pyrolysis and Combustion Typed WTE up to the process of melting the ash content of the residue at a high temperature. However, the un-burnt carbon, tar, and other substances from the pyrolysis reactor which is operated about 500-600 °C are further gasified in the gasification and reforming reactor under the high temperature around 1,000-1,500 °C. The suitable conditions of gasification and reforming to obtain high efficient are different according to the type of reactor and oxidizer (air or oxygen).

2.1. Feature of the Pyrolysis and Gasification Typed WTE A waste gasification system can generate electric power by a gas engine (GE), etc., expecting to get higher efficiency than the steam turbine system, especially in small size facilities. In addition, the system is expected to be the next-generation technology with much less impacts on environment. In the gasification process, the system exhaust gases are cleaner than conventional systems by suppressing synthesized DXN, decomposing DXN and their precursors. Besides the combustible component of the syngas which consists mainly of H_2 and CO while its incombustible component mainly comprises N_2 and CO_2, it is conceivable that the gas can be used as chemical feedstock for production of hydrogen, methane, methanol, and etc. The calorific value of produced gas ranges from 5,020 kJ/m^3_N to 10,550 kJ/m^3_N. Compared with town gas with a calorific value of about 46,000 kJ/ m^3_N, that of the syngas is very low. However, a basic combustion test recently conducted on a single-cylinder gas engine found that the pre-combustion chamber, pilot oil-ignited gas engine would be able to maintain stable combustion with high efficiency.

2.2. Tasks Involved in High-Efficient Pyrolysis and Gasification Typed WTE In order to establish the Pyrolysis and Gasification Typed WTE as a high-efficient power generation technology suitable for relatively small sized WTE with reducing adverse environmental impacts, efforts are needed to realize the concept. Reflecting the above situation, NEDO also began R&D project to develop High Efficient Pyrolysis and Gasification WTE Systems supported by METI, from FY 2001 to 2003 for three years project.

As in the case of the development of pyrolysis and combustion project, actual development works are being performed by the cooperation of some manufactures in Japan. Figure 1 shows the main development items of the project, which features are described as follows.

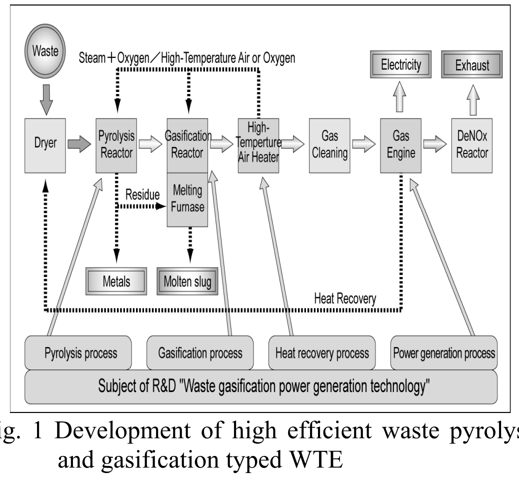

Fig. 1 Development of high efficient waste pyrolysis and gasification typed WTE

(1)Optimization of Thermal Decomposition Process

Considering the lack of data on the thermal decomposition characteristics of waste composition in a reduction atmosphere in a high-temperature range (> 1000 °C), efforts are needed to experimentally identify these basic characteristics and develop a technology for optimizing of a pyrolysis reactor using fluidized bed type and rotary kiln type reactor, and gasification process including gas reforming process with ash melting process (by Mitsubishi Heavy Industries Ltd. for Fluidized Bed Type and NGK Insulators Ltd. for Rotary Kiln Type,).Figures 2 and 3 show the typical examples obtained by those test results respectively.

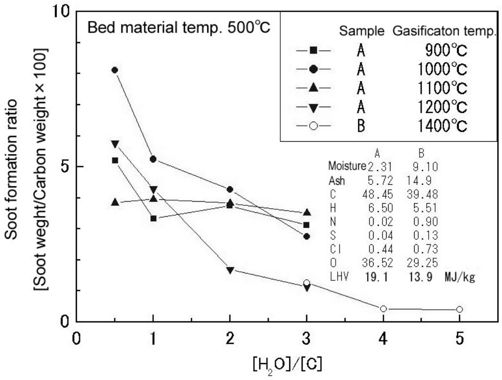

Fig. 2 Soot formation

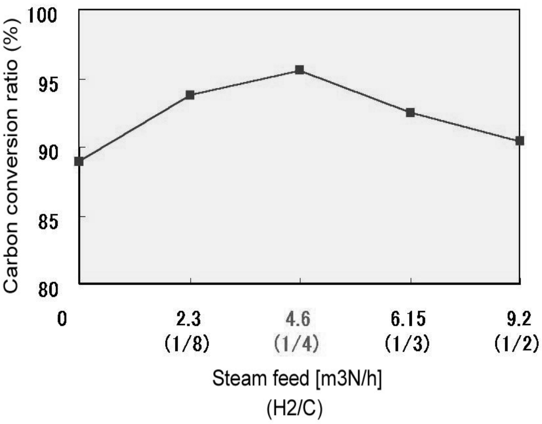

Fig. 3 Carbon conversion ratio

(2)Optimization of Sensible Heats Recovery System

In the existing waste pyrolysis and gasification systems, sensible heat of produced gas are cooled rapidly, and high temperature exhaust gas from gas engine are not utilized to the full extent, resulting in the involving a significant calorific power loss. The high-efficient power generation requires the development of a technology to recover those sensible and waste heats in such a form in which these heats can be effectively used for the waste drying, waste gasification and reforming processes or power generation process (by Toshiba Corporation). Figure4 shows typical example of test results.

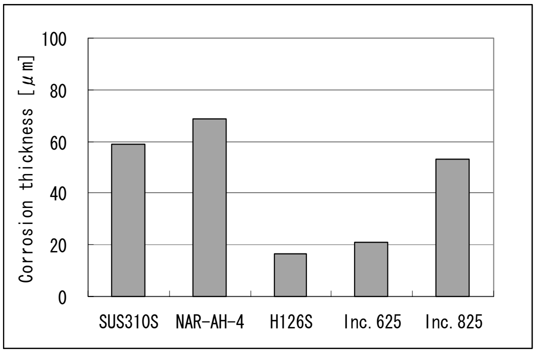

Fig. 4 Corrosion thickness

(3)Development of Low Calorific Value Gas Firing High Efficient Engine

Syngas is a low-calorific-value gas of which major combustible components are H_2 and CO, as stated earlier in this paper. There are sufficient records on the use of liquefied natural gas and other high-calorific-value gases for power generation by gas engine, gas turbine or some other system. But a low-calorific-value gas with the combustible components mentioned above has seldom been used for power generation. Therefore, to find experimentally optimal, stable combustion conditions for the gas at gas engine facilities, its serviceability as plant fuel should be demonstrated by a series of long-term tests. As a result of the preliminary test and evaluation study of various gas engine types, micro-pilot-fuel oil ignited type lean burn gas engine using pre-combustion chamber is selected to be developed (by Sumitomo Metal Industries, Ltd., and IHI-Niigata-Gendoki). Figure 5 shows typical example of test result.

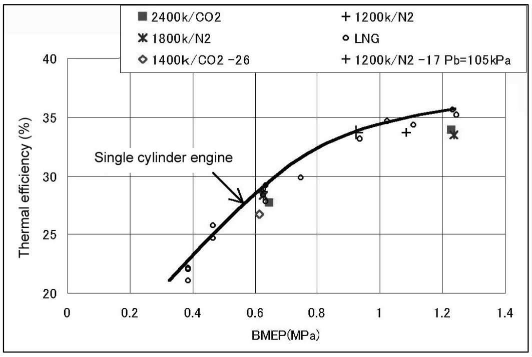

Fig. 5 Gas engine efficiency.

(4)Study On Optimization of Waste Treatment including Waste Gasification Technology

Study on optimization of waste treatment including waste gasification technology has shown diverse potentials. A practical feasibility study (FS) are being conducted on these potentials, which include, for example, not only the small scale sized WTE application but also the use of the system as a peak-load power source or as a supply source of external fuel and chemical raw materials. (by the Institute of Applied Energy) Figure 6 and 7 show some results obtained in the FS.

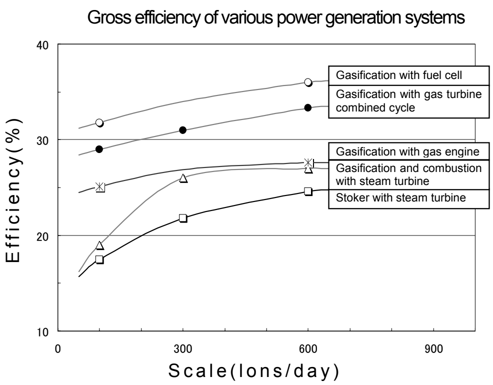

Fig. 6 Gross efficiency

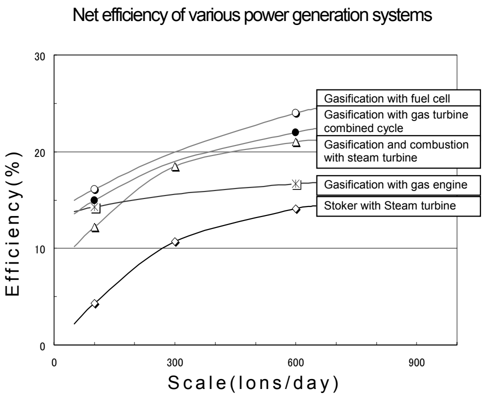

Fig. 7 Net efficiency

3. Conclusions

The High-Efficient Conventional Type WTE and Pyrolysis and Combustion Type WTE are entering upon the commercialization stage. Meanwhile, continued efforts are exerted to push on the development of the Waste Pyrolysis and Gasification Type WTE as a next-generation system, which is considered to have an advantage in meeting some conditions of users including, among others, its suitability for relatively small-sized facilities. The Waste Pyrolysis and Gasification Type WTE has not only excellent characteristics as a waste-to-energy system in attaining high efficiency and reducing adverse environmental impacts but also has diverse potentials from the viewpoint of recycling raw materials, especially for chemical products.

We would like to express our sincere acknowledgment to officials of the Ministry of Economy, Trade and Industry for their continuous support to this project. This project has been collaborated with several manufacturers mentioned in this paper. We are deeply grateful to their cooperation and efforts to conduct these R&D works.

References and Notes

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