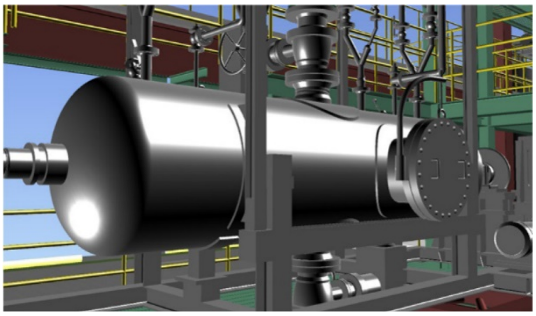
Development of High Efficiency Biomass Recovery and Recycling System for Municipal Waste



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Toward the establishment of a resource recycling society, there is a growing need in the waste treatment sector for separately collecting, to the extent possible, biomass such as kitchen waste (food waste) and paper from waste and recycling it. However, it is not easy to separately collect biomass from waste containing plastics, metals, etc., and it has become a challenge in the promotion of recycling. Mitsubishi Heavy Industries, Ltd. (MHI) Group is advancing the development of technologies for facilitating the separate collection of biomass resources from waste that had to be incinerated due to the difficulty in separate collection and converting them into recyclable materials. The overview and features of this system are introduced in this report.

1. Introduction

The amount of municipal solid waste generated in Japan in 2020 was 41.67 million tons, the breakdown of which is 11.65 million tons of domestic waste such as household waste and 30.02 million tons of commercial waste from supermarkets, convenience stores, restaurants, etc.(1). About 60% of municipal solid waste (dry weight basis) is biomass resources such as kitchen waste and paper, but since municipal solid waste contains plastics, metals, etc., biomass resources are not separately collected and recycled but are mostly incinerated at present(2). In addition, there is an issue that although power generation with boiler and heat utilization are conducted in many waste incineration plants in Japan, the energy recovery rate is low because kitchen waste contains a lot of water. In the light of such situations, in 2019, the Ministry of the Environment referred to the importance of developing “the function as a regional energy center by efficiently recovering waste energy” and producing methane gas through “promotion of the recycling of waste and the utilization of biomass”(3).

Looking at the world, the EU plans to substantially increase biomethane production to 35 billion m^3 in 2030 in the Fit for 55 package and the REPowerEU, which is a plan to respond to the Russia-Ukraine crisis, and the State of California in the United States has also set the biomethane procurement target for utilities to be about 2 billion m^3 by 2030(4). Thus, with the risks involved in energy security and the price increase of natural gas in addition to the increasing requirements for decarbonization of energy, there has been a rapidly growing interest in utilizing biomethane that can be domestically procured. In Japan as well, which depends on imports for its energy, the expansion of utilization of biomethane will be a significant challenge in the achievement of carbon neutrality in 2050.

Against such a backdrop, the MHI Group is advancing the development of a high-efficiency biomass recovery/recycling system that facilitates the easy separate collection of highly contaminated biomass resources from municipal solid waste containing various materials such as plastics and metal and converts them into materials having properties suited to produce methane

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gas at a high energy recovery rate.

2. Overview of high-efficiency biomass recovery system

The basic configuration of this system is shown in **Figure 1**.

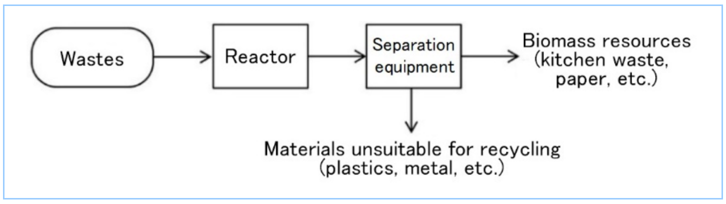

Figure 1 Basic system configuration

This system consists of a reactor for hydrothermally processing waste at a constant temperature and pressure and a separation equipment for separating reaction products into biomass resources such as kitchen waste and paper and materials such as plastics and metal that are unsuitable for recycling.

The reactor has a function of processing waste under appropriate reaction conditions (i.e., temperature, pressure and reaction time) set up for finely granulating only biomass resources while maintaining the original shapes of unsuitable materials so that waste can be easily separated into biomass resources (i.e., kitchen waste and paper) and unsuitable materials.

One example of treated products from a simulated waste (domestic waste) is shown in **Figure 2**. As seen in the figure, plastics such as garbage bags have their original shapes, while biomass resources such as kitchen waste are broken into small pieces like sawdust. These reaction products are separated by a general separation equipment, so a high recovery of biomass resources can be easily collected.

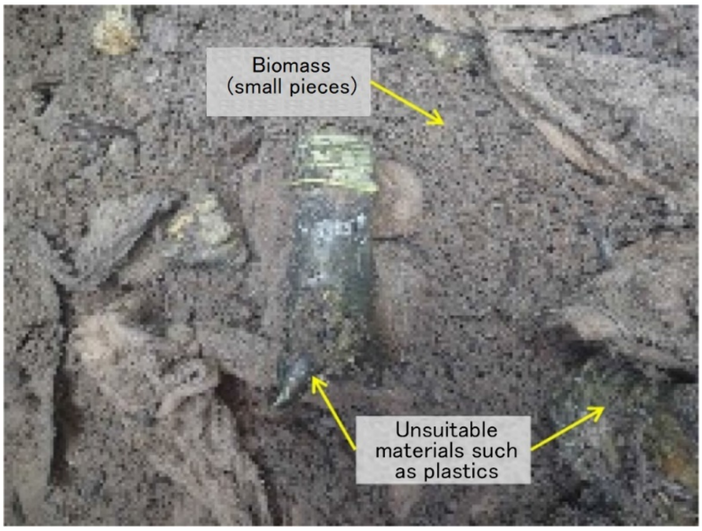

Figure 2 Treated products from simulated waste sample (one example)

This system adopts batch-type processing in which feeding to the reactor, treatment and discharge are repeated. When the system is automatized by being interlocked with a waste charging/discharging conveyor and a separation equipment for treated materials, labor saving in the operation can be realized.

3. Effects on energy recovery when combined with methane fermentation process

The system previously introduced in Chapter 2 can achieve the following effects when combined with methane fermentation process.

3.1 Increased biogas generation by improvement of recovery and decomposition rate of biomass resources

When this system is applied, a high recovery rate of biomass resources can be achieved as described above. In addition, the decomposition rate of paper, trees, plants and crop residue, which were considered to have a slow reaction rate in producing methane gas, is increased, resulting in an increase in biogas generation. From laboratory test results, it is estimated that for municipal solid waste containing about 60% biomass resources (dry weight basis), when the high-efficiency biomass recovery system and wet fermentation are applied in combination, the biogas generation will be 1.2 to 1.3 times larger than that of the conventional method which consists of crusher, separator and dry fermentation (**Figure 3**).

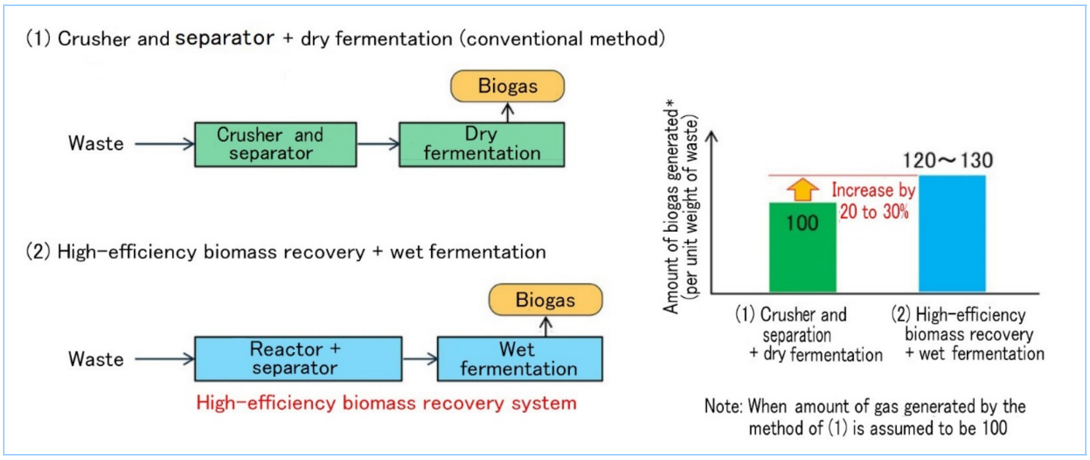

Figure 3 Comparison of biogas generation between methane fermentation process methods (one example)

3.2 Contribution to stable operation of methane fermentation process and small footprint

When waste having a large variety of properties and shapes is supplied, methane fermentation sometimes becomes unstable due to fluctuations in the input load and changes in the reaction rate. There is an issue in the methane fermentation process that it is difficult to keep stable operation. The biomass resources treated by this system are broken into small pieces and have homogenized properties and shapes. Therefore, the input load into a fermenter and the reaction rate are stabilized and the operation management of methane fermentation can be simplified.

Furthermore, as the operation of methane fermentation is stabilized, a thermophilic (high-temperature) fermentation method can be applied. In thermophilic fermentation where the temperature is around 55℃, the reaction rate is higher than that in mesophilic fermentation around 37℃ and the retention time in a methane fermenter can be reduced by half. Therefore, the capacity of the fermenter can be reduced by half and can be made compact.

3.3 Rationalization of wide-area waste management by reducing waste in volume and rendering waste harmless and odorless

Biomass resources treated and collected by this system are broken into small pieces, thereby being reduced in volume as well as being rendered harmless and odorless through heat treatment and sterilization. For example, in the wide-area and intensive management of municipal solid (household) waste treatment which has been recommended by the government, there may be a case where a transfer station to a waste incineration plant is required. When this system is applied, (1) production of methane gas from biomass resources can be completed at a transfer station and the waste transportation load is substantially reduced and (2) separated unsuitable materials such as plastics and metal are rendered harmless and odorless by heat treatment and can be transported to a waste incineration plant in a relatively hygienic state (**Figure 4**).

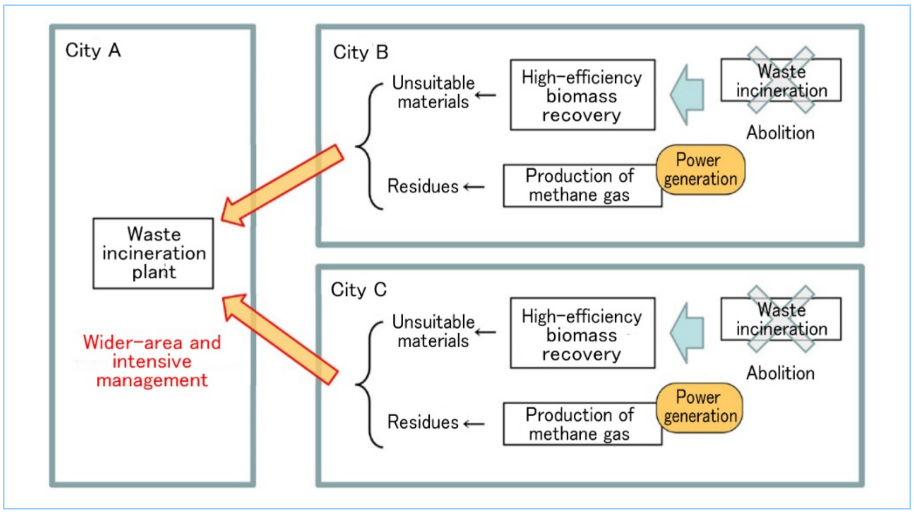

Figure 4 Image of application of this system in wide-area management of municipal solid waste

3.4 Increase in energy recovery and reduction of CO_2 emissions by 20% by hybrid treatment with waste incineration

This system can be also applied to hybrid treatment with incineration and methane fermentation combined, as shown in **Figure 5**, which is being introduced as a new municipal solid waste treatment method. With the energy recovery through methane production from biomass resources and power generation by gas engine as well as the power generation efficiency being improved by the increased heating value of waste through incineration of plastics separated as unsuitable materials, the increased energy is obtained even after the energy required for this system is deducted.

The CO_2 emissions reduction effects for municipal solid waste were compared between (1) the incineration treatment (conventional method) and (2) the hybrid treatment with incineration by application of this system. The respective net CO_2 emissions in (1) and (2) were calculated as follows: obtaining the total of the CO_2 emissions derived from plastics in waste and the CO_2 emissions to which the electric power consumption at a plant was converted with the assumed CO_2 emission factor of the electric power system; converting the electric power obtained from power generation to the amount of CO_2 emissions reduced; and subtracting the amount of CO_2 emissions reduced from the obtained total CO_2 emissions to calculate the net CO_2 emissions for each of (1) and (2). The calculation result is shown in **Figure 6**. (2) Hybrid treatment is expected to reduce CO_2 emissions by about 20% due to an increase in energy recovery compared to (1) incineration treatment.

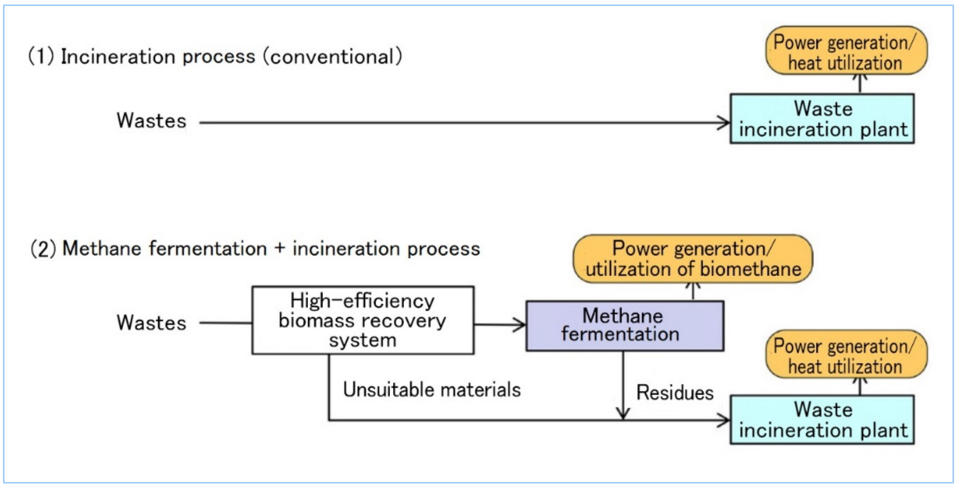

Figure 5 System flow of hybrid treatment with this system applied (one example)

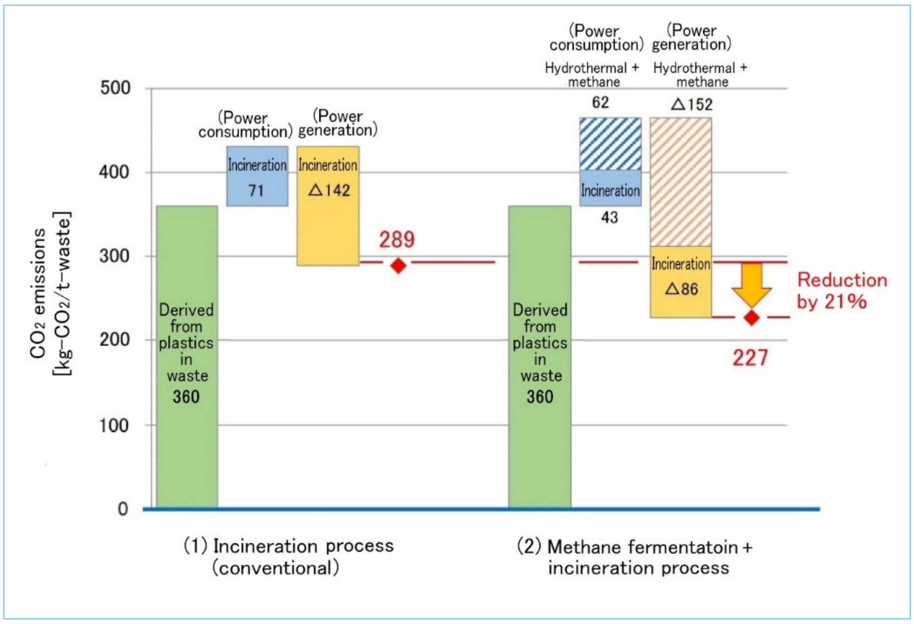

Figure 6 CO_2 emissions calculation result

4. Conclusion

We devised a treatment system that can easily collect biomass resources such as kitchen waste and paper from waste containing plastics, metal, etc., and convert them to materials having properties suitable for recycling. In combination with methane fermentation process, this system can increase the collection rate and decomposition rate of biomass resources from waste, producing an effect of increasing the biogas generation amount. Going forward, we will contribute to solving global environmental issues and realizing a resource recycling society by providing this system widely to domestic and overseas private companies and local governments.

References

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