Experimental Investigation to Process High Water Content Waste to Solid Fuel using Superheated Steam

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Abstract

A practical superheated steam drying system is introduced to process high water content waste to solid fuel. Energy consumption and CO_2 emissions with this system are evaluated and compared with the result from a conventional waste incinerator. In addition, the temperature and the quantity of superheated steam required for material drying are theoretically estimated. Used paper disposable diapers are processed by the drying system as high water content waste. If the solid fuel is used as an auxiliary fuel to generate superheated steam and results in an efficient waste thermal recycle system, the energy consumption and CO_2 emissions become considerably low. As a result, the application of the new superheated steam drying system for processing high water content waste and the obtained solid fuel provide a promising environmentally-friendly waste recycle system.

1. Introduction

Although the drastic increase in world population and economic growth have made human life better, they result in an increase of industrial and municipal wastes, and depletion of natural resources. Especially, high water content waste, such as leftover food and sludge, requires supplementary fuels to boost incineration disposal in order to reduce its capacity. In this process, CO_2 and pollutants emitted from supplementary fuels and electricity are added to the emissions from the waste. Therefore, it is essential to establish a new recycle system to deal with municipal and industrial wastes. In addition, fuel prices have been rising dramatically around the world.

Recently, plastic series waste materials have been considered to be a superior fuel alternative because of their high heat value. In order to reduce fuel consumption by waste processing equipment, a drying system using superheated steam is drawing much attention for use with high water content solid wastes due to its high thermal efficiency [1,2] The dried waste can be converted and made available as solid fuel, called refuse paper and plastic fuel (RPF). In this paper, a material recycle system for processing high water content waste to solid fuel is introduced using a superheated steam drying demonstration system. Then the environmental and thermal advantages of this waste recycle system are compared with conventional waste incinerator features.

2. Characteristics of Superheated Steam

Superheated steam is an atmospheric steam heated to around 100ºC or more. The gas has a high specific enthalpy compared with hot air at the same temperature. Such steam promotes the drying of water content materials by convection, radiation and condensation heat transfer. The condensation heat transfer is a special feature of a superheated steam drying system, which a hot air drying system does not have. In general, superheated steam is available at around 170ºC or more. The steam has characteristic advantages especially valuable for waste processing, such as inactive gas and high heat capacity.

3. Experimental Setup and Method

A multistage superheated steam drying system is employed in this experiment [3]. The designed process capacity of the drying system is 400 kg-waste/h. The initial steam generated by the auxiliary boiler flows into the heat exchanger, where the high temperature gas is supplied from the hot gas generator, and the steam is then superheated. The superheated steam enters the multistage drying chamber. After the chamber is filled with the superheated steam, the waste is supplied to the drying chamber after passing through a crusher to be of a suitable size for drying. The steam dries the waste by convection, radiation and condensation heat transfer. It takes two hours to dry the waste in this system. The steam, together with the moisture from waste, circulates through this system.

The designed capacity of the waste incinerator employed to compare the characteristics of two waste processing systems is 260 kg-waste/h. The wet waste is burnt by a burner, and a blower is introduced to assist the burning. It takes half to one hour to burn up the waste after the supply of waste.

4. Experimental Evaluation Method

In this new drying system, waste, electricity, heavy oil and water are supplied as input, while solid fuel is discharged from the chamber as output. Exhaust gas from heavy oil burning is also emitted. In this experiment, the heavy oil and electricity supplied to the system are calculated as input items of the evaluation condition, while CO_2 emissions from solid fuel, heavy oil and electricity are considered as output items. In this evaluation, the heat obtained from RPF burning is supplied to the required heat source for the hot gas generator. Then the consumption of heavy oil is reduced considerably compared with that of a conventional waste incinerator. Here thermal recycling is achieved in this drying system.

On the other hand, in the conventional incinerator, the waste is supplied to the incinerator and burnt up so as to become ash. In this evaluation, the heavy oil and electricity supplied to burner and blower are calculated as input items in the evaluation. While CO_2 emissions from wet waste, heavy oil and electricity are output items for evaluation.

5. Experimental Results and Discussion

Used solid disposable paper diapers are processed in this experiment. The water content of the wet waste to be processed is 75 wt%. However, the average amount of water content of the wet waste for the incinerator is 63 wt%, because it is difficult to incinerate 75 wt% water content waste.

A huge amount of energy is consumed before and after the waste supply to the drying chamber. It takes 5 or 6 hours before the waste can be supplied to the drying chamber because the temperature within the drying chamber must be increased to more than the condensing temperature of water. Then, 3 or 4 hours are required after supplying the waste to discharge it from the chamber. The energy losses during these periods are significant. Therefore, the evaluation is performed based on the data that are obtained in the steady-state condition from one cycle of operation.

If the RPF is supplied as the heat source of the system, the consumption of heavy oil is reduced to 4% and the total fuel consumption becomes 64% compared with that of a conventional incinerator, where the heat values of the heavy oil and RPF are defined as 39.1 MJ/L and 19.7 MJ/kg-RPF, respectively. Electrical consumption of the drying system becomes lower than that of the incinerator, even though the drying system has a mixing system, a conveyor and a granulator. CO_2 emissions also become lower than with a conventional incinerator. Thus, the total energy consumption and the CO_2 emissions are lower than with an incinerator.

6. Conclusions

The advantages of the new superheated steam drying system to process high water content wet waste are demonstrated. The energy required to process the wet waste to solid fuel and CO_2 emissions is far less than with a conventional waste incinerator, when the solid fuel is used as a heat source in a closed fuel recycle system. As a result, the new superheated steam drying system developed to process high water content waste and obtain solid fuel provides an environmentally-friendly waste recycle system with dramatically less energy consumption.

7. References

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