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The characteristics of gasification for combustible waste

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Abstract

With the increasing environmental consideration and stricter regulations, gasification of waste is considered to be more attractive technology than conventional incineration for energy recovery as well as material recycling. The experiment for combustible waste mixed with plastic and cellulosic materials was performed in the fixed bed gasifier to investigate the gasification behavior with the operating conditions. Waste pelletized with a diameter of 2~3cm and 5cm of length was gasified at the temperature range of 1100~1450℃. It was shown that the composition of H_2 was in the range of 30~40% and CO 15~30% depending upon oxygen/waste ratio. Gasification of waste due to thermoplastic property from mixed plastic melting and thermal cracking shows a prominent difference from that of coal or coke. It was desirable to maintain the top temperature up to 400℃ to ensure the mass transfer and uniform reaction through the packed bed. As the bed height was increased, the formation of H_2 and CO was increased whilst CO_2 decreased by the char-CO_2 reaction and plastic cracking. From the experimental results, the cold gas efficiency was around 61% and heating values of product gases were in the range of 2800~3200kcal/Nm3.

Key Words : waste gasification, fixed bed gasifier

1. Introduction

Landfill disposal of waste is becoming environmentally less desirable, both because of land wastage and seepage of toxic decomposition products out of landfill areas. Then a number of alternative technologies for waste disposal have been proposed and are being evaluated. These include technologies for incineration and gasification. As conventional incineration has problems of dioxins and final disposal of burnt ash, and is low-efficiency heat application, waste gasification has been proposed as an alternative solution for waste destruction with energy recovery.

Gasification disposal is a process that carbon contained within combustible material is oxidized partially and gasified in high-temperature reduction atmosphere, using steam and oxygen as gasification agent. The key components in gasifier product gases include H_2, CO, CO_2 and CH_4. Also gasification is distinguished from pyrolysis that combustible material is volatilized by heating in inert atmosphere.

The reason used to gasification technology at waste disposal is that it has been proven alternative technology to solve problems of combustion control and aftertreatment due to formation of pollutant emissions during heat recovery from combustible material. Also gasification technology is possible to dispose various wastes and is advantage economically for high-efficiency of energy recovery. Waste gasification processes developed at the present internationally are 'SVZ' process[1,2], 'Thermoselest' process[3] and 'SIEMENS' process[4]. Characteristic of waste gasification distinguished from coal/coke gasification is that waste is heterogeneous. For this reason, waste gasification require preprocessing such as carbonization and molding to achieve homogeneity of waste.

To select gasifier type with characteristics of feedstock is very important, because gasification performance is different with components of feedstock. Waste is a complex mixture of varying components, which makes characterization difficult. This is due to geographical and seasonal variation. However, for simplicity, waste can be considered to be comprised of varying proportion of lignin or cellulose derived material (paper, wood, straw, etc.), polymer derived material and inorganic material (ceramics, metal, glass, etc.). Lignio-cellulosic materials tend to loose volatiles and produce chars of graphitic ordering with high reactivities and large surface areas. They are common precursor materials for activated carbons[5]. Most commonly occurring non-crosslinked polymers, undergo a fluid phase before pyrolysis, although there are certain exceptions such as highly crosslinked resins[6]. They tend to produce carbons with much greater graphitic ordering, low reactivity and low surface areas. Therefore biomass or wood waste is frequently used fludized-bed reactor. On the other hand waste to include polymer is used rotary kiln or fixed-bed reactor.

Major factors to optimize operating condition of fixed-bed gasifier are reactant ratio, reaction temperature, and definition of draft ability for uniform dispersion of oxygen in packed bed. In this work, waste gasification was performed to evaluate characteristics of producing syngas with the holdup of waste, oxygen/waste ratio and bed height in small-scale fixed-bed gasifier.

2. Experiment

Feedstock was molded in extruder at 200℃ after combustible waste crushed into 5mm or less in size is mixed homogeneously. Feedstock is a diameter of 30mm and a length of 50mm as shown in Fig. 1. The high heat value (HHV) was determinated using ASTM standards[7] and value was obtained 6,500kcal/kg. Elemental and proximate analysis of feedstock is shown Table 1.

Fig. 1. Pelletized waste sample

Table 1. Elemental and Proximate Analysis(wt.%)

Proximate analysis (wt%)	
Volatile	79.58
Fixed carbon	5.66
Ash	13.43
Moisture	1.33
Elemental analysis (wt%)	
Carbon	51.60
Hydrogen	8.15
Nitrogen	0.80
Sulphur	0.12
Oxygen	24.96

Experimental work was carried out in fixed-bed gasifier with an inside diameter of 150mm and total height of 1100mm. Inside wall of gasifier is consisted of alumina refractory and temperature of gasifier is monitored using K-type thermocouples each placed at 200mm, 450mm and 700mm in the reactor wall. feedstock was fed at the top of the gasifier by feeding system, composed of a lock hopper. A nitrogen flow was used to help the waste feeding and to avoid the back flow of the gas. Oxygen for gasification, LPG and air for preheating gasifier were fed at the bottom gasifier by blow lance. For evaluating draft ability of oxygen in packed bed, pressure was measured at the top and bottom gasifier and pressure drop was determined. The syngas to be left the gasifier, passing through a cyclone to remove particulate. Afterward, the gas was introduced in CO, CO_2 and CH_4 on-line analyzers, whose information allowed controlling the process. The syngas was also analyzed by gas chromatography for a complete determination of its composition. Slag recovered in a quenching system. A schematic diagram is shown in Fig. 2.

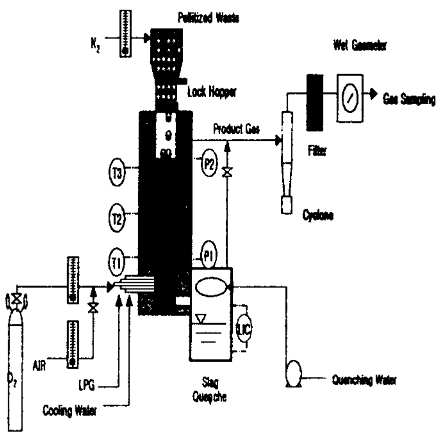


Fig. 2. Schematic drawing of fixed bed Gasifier

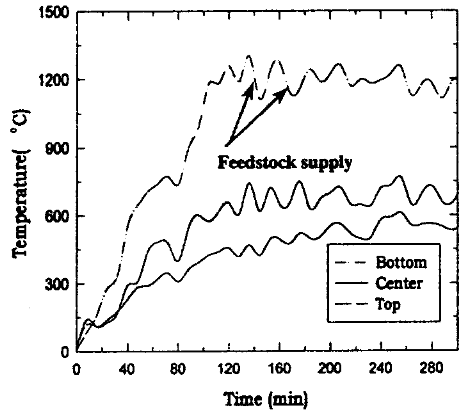


Fig. 3. Temperature distribution during reactor preheating and gasification

For preheating gasifier, 3kg cocks were packed in lock hopper and gasifier. cocks were ignited by using a LPG preheating burner. Afterward, cocks were periodically fed in gasifier by using lock hopper, for keeping constant bed height and the bottom of gasifier was preheated by 1200℃. Before complete combustion of cocks, feedstocks were fed and mixed firing and the height of packed bed, the amount of feedstock and oxygen were controlled for gasification reaction.

3. Results and Discussion

3.1. Effect of the feed amount and periodic

Temperature measured at thermocouples each placed in the reactor wall is shown in Fig. 3. The temperature were decreased because air ratio were decreased when preheating cocks or feedstock was fed in gasifier and in course of time gradually increased. However, with gradually decrease of packing amount by combustion of feedstock, temperature measured at bottom of gasifier were increased and thereafter the temperature were gradually decreased. Then optimum feeding amount and periodic of feedstock was determine 0.3kg, 15min through preliminary test.

3.2 Effect of material content in feedstock

As shown in Fig. 4, fixed-bed gasifier have countercurrent mass flow that the feedstock and reactive material flow in opposite directions. When feedstock is fed at the top of the gasifier, The initial combustion reaction step (3)-(4) occur and thereafter With feedstock heating by high temperature combustion gas, the secondary pyrolysis step (1)-(2) occur in an oxygen starved atmosphere.

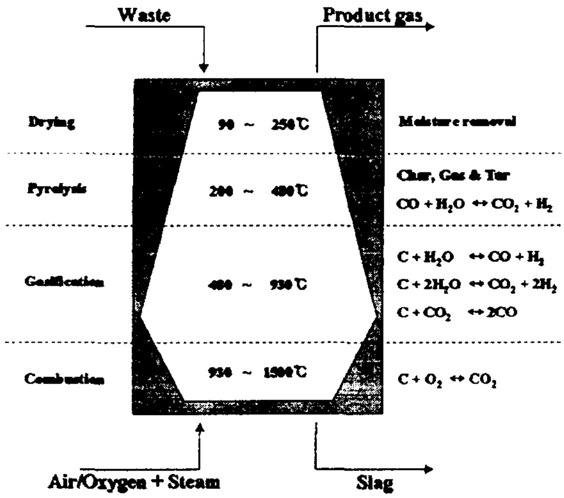


Fig. 4. Schematic drawing of fixed bed gasification

$$Waste(Cellulose) \rightarrow Char(C) + VM \quad (1)$$

$$Waste(Plastic) \rightarrow nC_nH_m \quad (2)$$

$$C + O_2 \rightarrow CO_2 \quad (3)$$

$$C + \tfrac{1}{2}O \rightarrow CO \quad (4)$$

TGA and DTG curve obtained for feedstock and key components are reported in Fig. 5 and Fig. 6. Two main distinct weight loss steps characterize the TGA and DTG curve. the first, at temperatures around 180℃, is caused by degration of cellulosic materials. and the second, in a temperature range between 350 and 450℃, is due to degradation of plastics.

The gasification reactions of the remaining carbonaceous residue occur with steam and CO_2. Because char-gas reaction is endothermic reaction, gasification temperature has to keep highly.

$$C + CO_2 \rightarrow 2CO \quad (5)$$

$$C + H_2O \rightarrow CO + H_2 \quad (6)$$

$$C + 2H_2O \rightarrow CO_2 + 2H_2 \quad (7)$$

$$C + 2H_2 \rightarrow CH_4 \quad (8)$$

That pyrolysis of plastic is that bond brakage occurrs throughout the plastic molecule structure, which hence decomposes into plastic small molecular radical and atom. As is shown in Fig.7, gasification with feed material produce syngas with different gas composition. The obtained results seem to show that the CH_4 concentration produced by PE gasification is more than by mixed waste gasification. With increase of plastic content in feedstock, the reason of increasing CH_4 concentration produced by gasification is not that CH_4 is produced by methanation but that by cracking. Component analysis of recovery materials by dust collector is reported in Table 2. The obtained result seem that it is soot to involve more carbon concentration than feedstock and that to be increased concentration methane or soot of syngas relate to temperature at upside of gasifier.

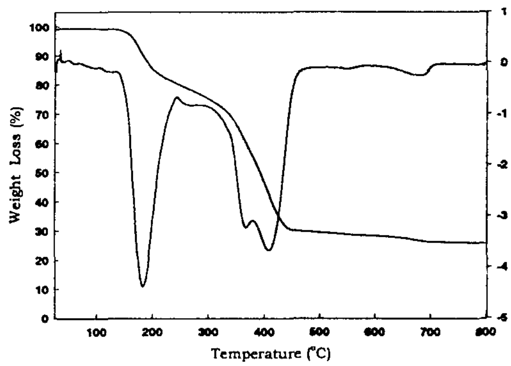


Fig. 5. Thermogravimetric analysis for combustible waste

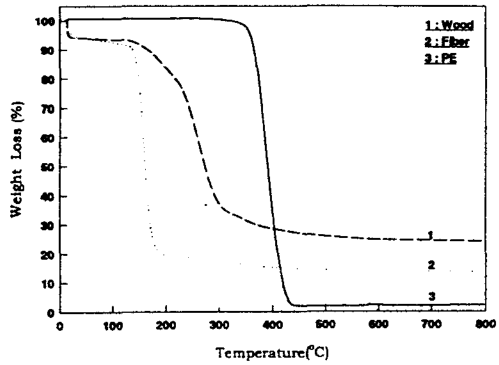


Fig. 6. Thermogravimetric analysis for key components of combustible waste

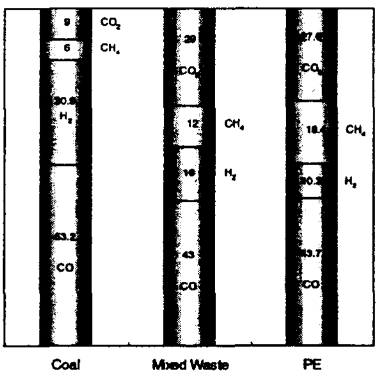


Fig. 7. Gas composition with feed material

Table 2. Dust Analysis (wt.%)

Proximate analysis (wt%)	
Volatile	6.94
Fixed carbon	77.78
Ash	0.39
Moisture	14.89
Elemental analysis (wt%)	
Carbon	65.40
Hydrogen	12.10
Nitrogen	0.10
Oxygen	21.93

3.3 Effect of O2/waste ratio and temperature

It was also studied the effect of O2/waste ratio on gas composition. To ensure a constant residence time, the mass flow rate of waste was kept constant in all test runs and only the oxygen flow rate was changed.

As shown in Fig. 8, with increase of oxygen flow rate, the temperature of inside gasifier was increased and rapidly was increased until O2/waste ratio is 0.4(kg/kg). This result mean that the increase of O2/waste ratio favours the exothermic reaction (3) and (4), which cause the reactivity of waste to be high and leads to a higher conversion and gasifier temperature.

When packed bed is constant height (500mm), gas composition change with respect to the O2/waste ratio is presented in Fig. 9. As shown in Fig. 9, the CO concentration is maximum value when the O2/waste ratio was about 0.35~0.45. This effect was due to the formation of CO through char-CO_2 reaction that CO_2 produced at combustion zone rise to gasification zone and thereafter react on pyrolysed char.

If Oxygen was more increased, the formation of char was decreased and the formation of CO_2 was increased. Therefore, when O2/waster ratio was above 0.45, it was shown the result that concentration of H_2, CH_4 and CO produced by char-gas reaction was decreased.

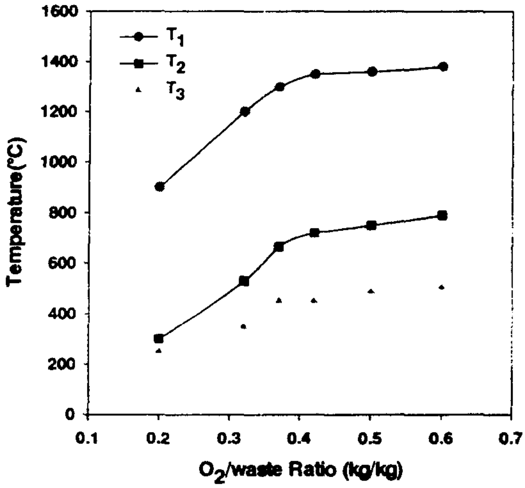


Fig. 8. Bed temperature with the oxygen/waste ratio

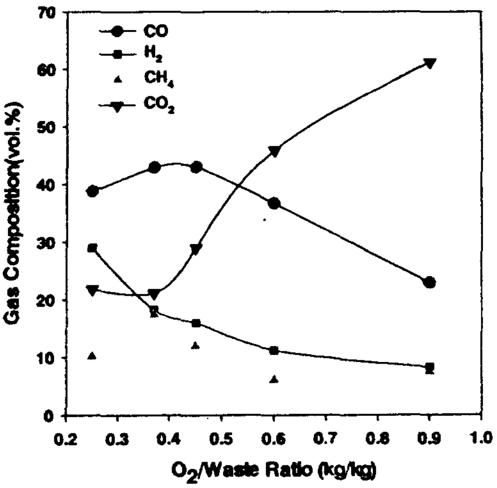


Fig. 9. Gas composition with the oxygen/waste ratio

If plastic is not pyrolysed and cover on surface packed bed to melting condition, the O2 and steam fed from lower part of gasifier and syngas is difficult to pass through packed bed. Then channeling and pressure drop is occurred. Waste and gasification agent should be contacted uniformly but if draft ability for uniform dispersion of oxygen in packed bed is not defined, it is difficult to occur gasification reaction.

With temperature change at top of packed bed, operation condition was evaluated. feedstock is heated by risen syngas and bond to reactor wall. this results was that gasification operation was difficult if temperature measured at top of packed bed was kept below 400℃.

3.4 Effect of bed height

The formation characteristic of syngas with bed height is shown in Fig. 10. With increase of bed height, it was shown the result that concentration of H_2, CH_4 and CO was increased. The effect was due to increasing residence time of gas and char. The results were that gasification operation was difficult if bed height was kept above 700mm.

3.5 Cold gas efficiency

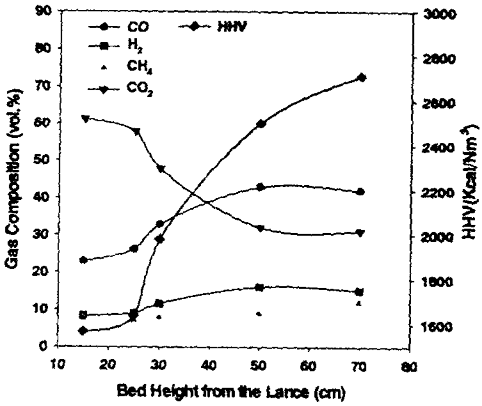
With change of oxygen amount and temperature, product amount of syngas was 1~1.8NL/g (waste basis) and cold gas efficiency was 61% when O2/waste ratio was about 0.4~0.5. The results is reported in Fig. 11

4. Conclusion

From the experimental gasification of waste molded to pellet type in 30kg/day fixed-bed gasifier, the following conclusions were obtained :

1. With feeding amount and periodic of feedstock, gasification temperature and composition of syngas

was changed and feedstock was fed on 0.3kg, 15min in experimental gasification.



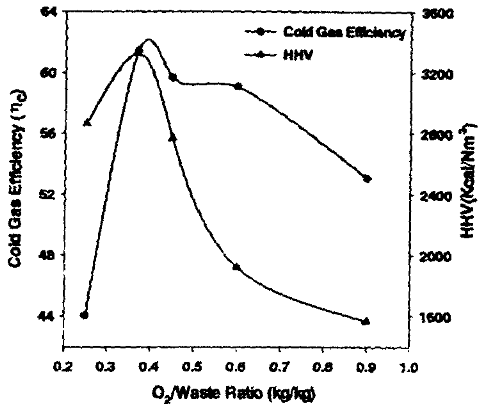


Fig. 10. Gas composition with the bed height

Fig. 11. Heating value and cold gas efficiency with oxygen/waste ratio

2. Plastic of waste influence gas composition and draft ability and CH_4 produced by PE gasification is more than by coal or cellulose gasification. The reason is that CH_4 is produced by cracking of plastic. Also, For defining draft ability from plastic melting, temperature measured at top of packed bed was kept above 400℃.

3. With increase of oxygen flow rate, the temperature of inside gasifier was increased and temperature of gasifier rapidly was increased until O2/waste ratio is 0.4(kg/kg). The CO concentration is maximum value when the O2/waste ratio was about 0.35~0.45. This effect was due to the formation of CO through char-CO_2 reaction that CO_2 produced at combustion zone rise to gasification zone and thereafter react on pyrolysed char.

4. With increase of bed height, concentration of H_2, CO and CH_4 was increased. Operation of gasification was difficult due to pressure drop of oxygen if bed height was above 700mm.

5. The amount of syngas was 1~1.8NL/g (waste basis) and cold gas efficiency was 61% when O2/waste ratio is about 0.4~0.5.

Acknowledgement

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