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5톤/일 고정층 가스화기를 이용한 바이오매스, RPF 가스화 특성 연구

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Gasification Characteristics of Biomass and RPF in a 5ton/day Fixed Bed Gasifier

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Key words : Gasification(가스화), Fixed bed(고정층), RPF(RPF), Biomass(바이오매스)

Abstract : With the increasing environmental consideration and stricter regulations, waste gasification is considered to be more attractive technology than conventional incineration for energy recovery as well as material recycling. The experiment for combustible waste was performed in the fixed bed gasifier to investigate the gasification behavior with the operating conditions in a 5ton/day fixed bed gasifier. The experiments of operation with 10-50 hours were carried out to determine the effects of bed temperature and oxygen/waste ratio on the syngas composition, calorific value and carbon conversion. The calorific values of the produced syngas decreased with an increase of bed temperature because combustion reaction more actively happened. The syngas composition of wood waste gasification is CO: 34.4%, H_2: 10.7%, CH_4: 6.0%, CO_2: 48.9% and that of RPF is CO: 33.9%, H_2: 26.1%, CH_4: 10.7%, CO_2: 29.2%. The average calorific values of produced gas were about 1,933kcal/Nm^3, 2,863kcal/Nm^3, respectively.

1. Introduction

The amount of waste generated domestically is about 0.25 million ton/day, and 0.17 million ton/day of waste generated has been recycled and the others (0.07 million ton/day) have been incinerated or reclaimed in Korea. The combustible waste trend in Korea is shown in Fig. 1. The combustible waste is mostly consisted of materials derived in polymer resin, plastic materials, biomass, and so on. Incineration might be used for reducing combustible wastes and heat recovery, but there are many environmental problems and limits of application. Therefore gasification treatment of combustible wastes might be one of options to replace incineration method. Also it would be applied for various fields after purification of produced gas.[1]

Waste gasification technologyis 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 syngas from gasifier include H_2, CO, CO_2 and CH_4. And it could occur free from production of pollutants such as SOx, NOx, dioxin and others. General applications of produced syngas are the power generation and raw material of chemical compounds such as methanol. However the waste gasification processes have not been introduced into domestic industries because of excessive initial capital cost, the difficulty of choice of a suitable gasification process, low economic efficiency, and so on.[2]-[4]

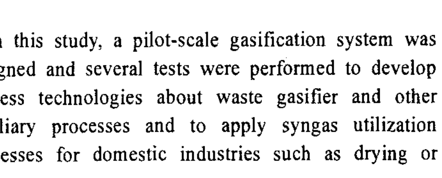


Fig. 1 Origin of combustible wastes in Korea

In this study, a pilot-scale gasification system was designed and several tests were performed to develop process technologies about waste gasifier and other auxiliary processes and to apply syngas utilization processes for domestic industries such as drying or melting process. Alsothe gasification characteristics of woodwaste and RPF(refuse plastic fuel) have been determined in the pilot plant. Especially, the effects of bed temperature, oxygen/waste ratio on the gas composition of produced gas, carbon conversion were analyzed

2. Experiments

Municipal combustible waste of which 70% is consisted of biomass such as pulp and wood have been almost collected at the state of being not separated and so it has been reclaimed or incinerated. However, the property of industrial waste from specific factory is more uniform. And RPF from industrial waste pelletized with a diameter of 2~3cm and 5cm of length and wood waste from construction field were was selected as the object material in this study.

The proximate analysis and elemental analysis of wood waste and RPF are shown in Table 1 and their calorific value is 4,520 and 6,250kcal/kg, respectively.

Table 1 Proximate and elemental analysis of biomass and RPF

		Wood waste	RPF
Calorific value (kcal/kg)		4,520	6,250
P. A (wt.%)	Water	21.7	4.2
	C.M.	74.5	83.5
	Ash	3.8	12.3
E. A (wt.%)	C	46.53	56.20
	H	5.75	7.67
	N	0.25	0.61
	S	0.11	0.00
	O	43.51	16.20

The gasification characteristics of wood waste and RPF have been determined in a 5ton/day fixed bed gasifier(1.2m I.D. and 2.8m high) and schematic diagram of the gasification process are shown in Fig. 2. The fixed bed gasifier was consisted of air compressor, oxygen tank, flow control system, gasifier, cyclone, heat exchanger, solid/gas separator, water fluidized bed reactor and blower and the details can be found elsewhere.[4]

To preheat gasifier from room temperature to gasification temperature, LPG burner, wood and cokes were used. After the bed temperature arrived at gasification temperature, the bed temperature was maintained by controlling feeding rate or oxygen rate. To capture soot or unburned carbon from the gasification reaction, solid/gas separator and water fluidized bed have been used. The experiments were carried out to determine the effects of bed temperature (500-1,000°C), oxygen concentration (0-21vol%) and solid/oxygen ratio (kg/h of woodchip and RPF/kg/h of oxygen, 0-15) on the gas composition, calorific value and cold gas efficiency of the produced gas.

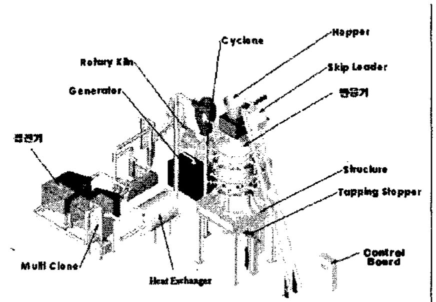


Fig. 2 Schematic diagram of 5ton/day fixed bed gasifier

3. Result

TGA curves obtained for feedstock are described in Fig. 3. Two main distinct weight loss steps are characterized following as ; the first at temperatures around 180℃, is caused by degradation of cellulosic materials andthe second in a temperature range between 350 and 450℃, is due to degradation of plastics.

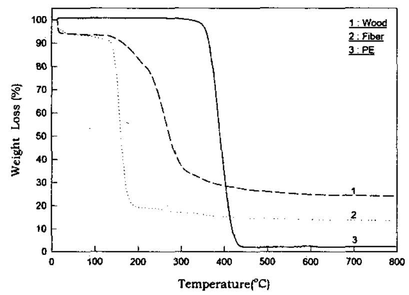
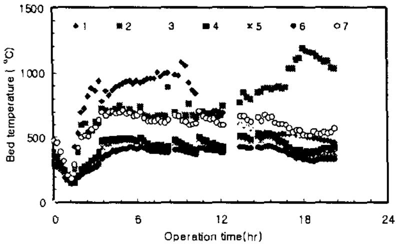


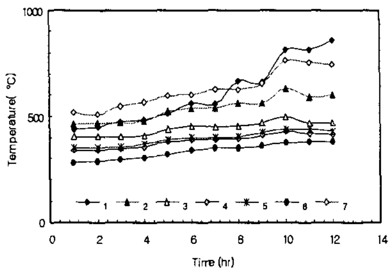
Fig. 3 TGA for key components of combustible waste

The key point of 5ton/day pilot plant design might be the basic design related with reactor and kinetics. Therefore the calculation of reactor size was performed by using experimental results of the lab-scale fixed bed gasifier.[5] Also it was assumed that 4 reaction steps such as drying, pyrolysis, gasification and combustion would occur one after the other.

In the gasification experiments of wood waste and RPF, the temperature profiles of the gasifier system are shown in Fig. 4. In this figure temperature 7 is the inside temperature of gasifier at the height of 2.7m above the bottom and the others are refractory wall temperatures (1: 0.3m, 2:0.7m, 3:1.0m, 4:1.5m, 5:2.0m, 6:2.5m). As can be seen in Fig. 4, the bed temperatures of RPF were more stable than that of wood waste due to low water content and higher calorific value. However the bed temperature of woodchip is higher than that of RPF because of cokes to be used for preheating materials.



(a) Woodchip



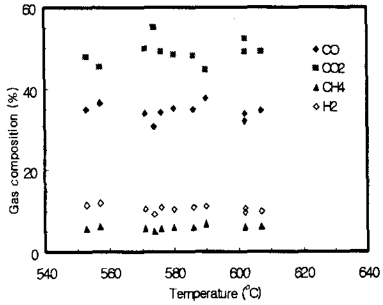
(b) RPF

Fig. 4. Temperature profile in the gasifier

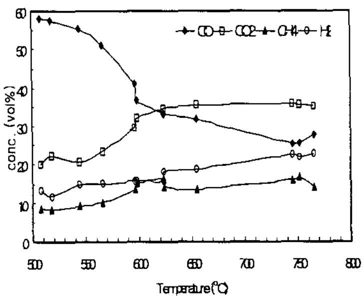
In the experiments of using only woodchip, the bed temperature of woodwaste gasification was lower than that of RPF. At the other experiments the bed temperature of RPF gasification was over 1,000°C due to higher calorific value and lower water content.[4]

The effect of bed temperature on gas composition and calorific value of woodchip are shown in Fig. 5. At this experiment, the feed rate of solid was 100-140kg/h and the oxygen rate was 24-30Nm^3/h. The heat needed for gasification reaction was derived from the combustion reaction of some of wood waste and RPF, so the composition of $CO_2$was higher than steam gasification. Also CO_2 concentration of wood wastegasification was higher than that of RPF because the shift reaction might occur.

The average syngas composition of gasification of wood waste is CO: 34.4%, H_2: 10.7%, CH_4: 6.0%, CO_2: 48.9% and that of RPF is CO: 33.9%, H_2: 26.1%, CH_4: 10.7%, CO_2: 29.2%. The calorific values of produced gas of wood waste and RPF are 1,933kcal/Nm^3, 2,836kcal/Nm^3, respectively. At the wood waste experiment, the weight fractions of gas, liquid and solid product were 89.6, 4.8 , 5.6, respectively.



(a)Wood waste



(b) RPF

Fig. 5. Effect of bed temperature on gas composition

The effect of bed temperature on caloric value of produced syngas is shown in Fig. 6. As shown in Fig.5, the sum of CO and H_2 gas concentration from wood waste and RPF gasification were over 40%. These values are lower than other gasification results used steam gasification reaction because partial oxidation reaction was occurred in this reactor.[4] Also the caloric value of produced syngas decreased with an increasing bed temperature because the combustion reaction becomes larger than gasification reaction. At the experiments of RPF, the effect of bed temperature on calorific value shows the same trend as seen in the plot.

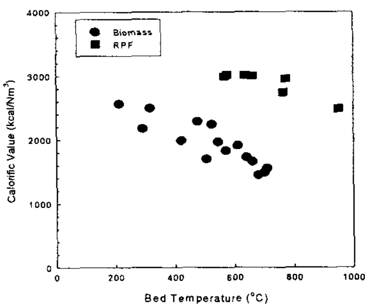


Fig. 6. Effect of bed temperature on calorific value of the produced gas

The syngas heating value with oxygen/waste ratio is shown in Fig. 7. Inthe RPF gasification experiments, the maximum value was 3,100kcal/Nm^3 at oxygen/waste ratio near 0.2. In the wood waste gasification experiments, maximum calorific value was 2,300kcal/Nm^3 at solid/oxygen ratio 0.12. It might be caused by different shape and components from test samples. From experimental results, the cold gas efficiencies of RPF gasification were calculated about 60%.

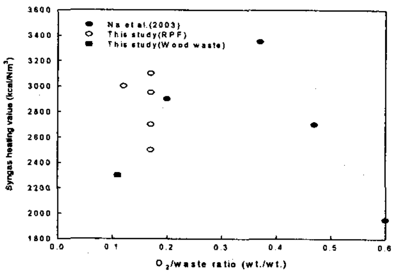
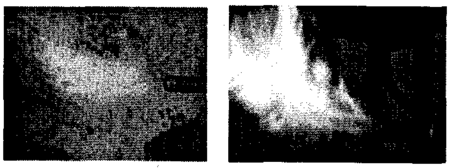


Fig. 7. Effect of RPF/O_2 ratio on calorific value of the

The photographs of syngas combustion are shown in Fig. 8. As can be seen in Fig. 8, the flame with oxygen input is more vigorous and stronger than that with air input.[5] However the syngas from air-blown gasification could be used via lean gas burner, stirring engine and so on.

If 10 wt% of domestic combustible waste was used for resources in waste gasification processes, the production quantities of synthesis gas could be 1.38×10^{9}Nm^3 from the data based on this study. If synthesis gas from wastes gasification was used for power generation, the production cost could become about 23won/kWh, so the waste gasification process might have suitable economic value.



(a) Air (b) Oxygen

Fig. 7. Photograph of flame in burner

4. Conclusion

The gasification characteristics of combustible wastes, such as wood waste and RPF, have been determined in a 5ton/day fixed bed gasifier (1.2m I.D. and 2.8m high).

The calorific values of the produced gas decreased with an increase of bed temperature because combustion reaction more actively happened. The average gas composition of partial oxidation of woodchip is CO: 34.4%, H_2: 10.7%, CH_4: 6.0%, CO_2: 48.9% and that of RPF is CO: 33.9%, H_2: 26.1%, CH_4: 10.7%, CO_2: 29.2%.

The average calorific values of produced syngas were about 1,933kcal/Nm^3, 2,863kcal/Nm^3, respectively. The maximum calorific values were 3,100, 2300kcal/Nm^3 because of different shape and components.

From the burning test, it was proved that syngas from combustible waste gasification can be easily utilized for drying or melting process and power generation by applying gas engine system.

Acknowledgments

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References

[1] Lee, S. H., Choi, J. G., Lee, J. G., Kim, J. H., 2004, "The effects of heating rate on pyrolysis of agricultural wastes," J. Korea Society of Wase Management, Vol. 21, No. 5, pp. 465-471.

[2] Kurkela, E., Stahlberg, P., Laatikainen, J., Simell, P., 1993, "Development of simplified IGCC-processes for biofuels: Supporting gasification research at VTT," Bioresource Technology, 46, 37.

[3] Ko, M.K., Lee, W.Y., Kim, S.B., Lee, K.W. and Chun, H.S., 2001, "Gasification of food waste with steam in fluidized bed," Korean J. Chem. Eng., 18, 961.

[4] Kim, J.H., 2003, "Process development of manufacturing synthetic gas and recycling raw material from combustible wastes by gasification," *Industrial Waste Recycling R&D program*, Ministry of Science and Technology, Korea.

[5] Na, J.I., Park, S.J., Kim, Y.G., Lee, J.G. and Kim, J.H., 2003, "Characteristics of oxygen-blown gasification for combustible waste in a fixed-bed gasifier," *Applied Energy*, 75, 275.