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Lab-scale 반응기에서 RPF 열분해 가스의 가스화에 의한 합성 가스의 생성에 대한 연구

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Production of synthesis gas by gasification of pyrolyzed gas of RPF in a lab-scale reactor

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Key words : gasification(가스화), pyrolyzed gas(열분해 가스)

Abstract : This paper provides RPF (Refuse Plastics Fuel) gasification characteristics for generating synthesis gas in gasfying reactor which was design in lab-scale. This research is carried out as an immediate work for making pyrolysis gas from RPF into energy resource. This study is consisted of experimental and numerical. The numerical study was accomplished from RPF pyrolysis data, and predicted the maximum operating conditions by STANJAN and FLEUNT. Based on results of STANJAN, it is found that the maximum point of $O_2/O_{2,stoich}$=20-30, which is used as injection point of O_2. Experiment results shows that CO and H_2 were increased but THC was decreased as temperature was increased. It is estimated that the cracking of cracking of THC into CO and H2 is happened at a high temperature. It is observed that as steam was injected, production of CO and H2 were increased, then, H2 is dependent on the amount of injectionsteam.

1. Introduction

Because of global economic growth, there is an increasing need for energy(1). The production of high value-added petrochemicals is dependant on availability of H2 and CO (synthesis gas)(2)

Synthesis gas is a major intermediate raw material for further product synthesizes. The growing demand for downstream products is the driving force for synthesis gas manufacture (3).

The generation of synthesis gas may be categorized into two different types of processes from a point of used feedstock. One is based on like natural gas or high hydrocarbons, and the other is solid fuel such as coal, biomass, municipal solid waste (MSW), refuse derived fuel (RDF), refuse plastic fuel (RPF) and so on(4,5). Natural gas and high hydrocarbons will remain the major feedstock for manufacture of synthesis gas due to its lower investment(3). However, it is estimated that usage of other solid fuels is more and more important. It is reported that coal reserve is about six times more than that of fluid hydro carbons, and it will become a major source for synthesis gas production in the near future (3). Especially, coal gasification has received a great deal of attention since the integrated gasification combined cycle (IGCC) was successfully developed (6). MSW (7), RDF (5), RPF (4), biomass (8) and so on as well as coal are focused on as the new potential energy.

The pyrolysis and cracking or gasification produces products that may serve as alternative sources of energy and chemical raw materials, such as synthesis gas and char. In recent, many studies on them have been conducted out in the laboratory

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scale. Chen investigated experimentally the partial oxidation of two different high-volatile pulverized coals in a tube furnace (6). Song et al. investigated the co-gasification of coal and natural gas using a laboratory scale fixed bed reactor (3). Yuehong et al. compared the lab-scale experimental measurement on the co-gasification process with ASPEN Plus simulator (9). Kajitani et al. gasified two coal chars with carbon dioxide or steam using a Pressurized Drop Tube Furnace (PDTF) (10). Binlin et al. investigated the kinetics for modeling pyrolysis through a thermogravimetry analysis under isothermal conditions between 300 and 600℃(4). Dominguez et al. studied the feasibility of performing the dying, pyrolysis, and gasification of wet sewage sludge in a single process at high temperature(11). Praharso et al. examined the kinetics of iso-octane steam reforming as a function of iso-octane and steam partial pressure at various temperatures(12).

Based on our previous studies, this paper provides cracking or reforming characteristics of pyrolysis gases of RPF at various operating conditions in a small scale gasifying reactor.(4,13) It is estimated that our study provide the possibility concerning availability of RPF as new regenerating energy.

2. Experiment

2.1 Materials preparation

Samples of RPF were prepared system to obtain the pyrolysis gas. The proximate analysis was carried out using the method described by American Society for Testing and Materials (ASTM) D5142. The ultimate analysis was conducted using an elementary analyzer (EA1110, CE instrument). The caloric value of the sample (LHV) was obtained by the Dulongs equation

$$LHV = HHV - 600(9H+W)$$

where

$$HHV = 8100C + 34000(9H-O/8)+2500S$$

The characteristic of RPF samples are summarized in Table 1.

2.2. Experimental set up

Fig. 1 shows a schematic of the experimental apparatus. It primarily consists of TGA (thermogravimetric analysis) and gasifying reactor. In the previous study, Dou et al. investigated the kinetics of refuse plastic fuel (RPF) through our TGA.(1) The present study used gases from TG furnace for the feed gas. The composition of the gas, which was measured by gas chromatography instrument, is shown in Table 1. The gasifying reactor with 50 mm in ID and 450 mm in length is made of a dense alumina ceramic tube. A tubular electric furnace was used to heat and maintain the gasifying reactor at the required temperature within 1100℃.

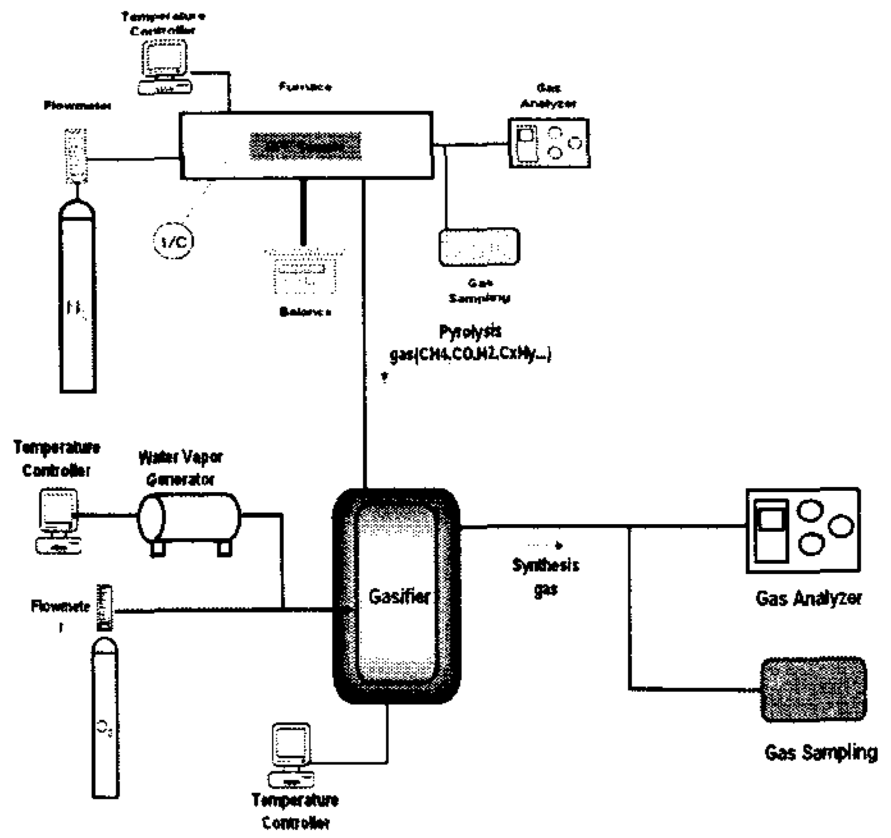

Fig.1. a schematic diagram of the experimental apparatus.

Table 1 Concentrations of pyrolysis gas compounds

Species	Molecular formula	Mole fraction (%)
Ethylene	C_2H_4	26.817
Methane	CH_4	22.108
Carbon monoxide	CO	9.346
Carbon dioxide	CO_2	8.447
Hydrogen	H_2	6.732
N-Butane	C_4H_{10}	5.355
Ethane	C_2H_6	5.327
1,3-Butadiene	C_4H_6	3.528
Benzene	C_6H_6	3.457
1,3-Pentadiene	C_5H_8	2.952
N-Pentane	C_5H_{12}	2.108
1-Pentene	C_5H_{10}	1.195
Propane	C_3H_8	0.914
1-Hexene	C_6H_{12}	0.309
Cyclopropene	C_8H_8	0.169
Ethylbenzene	C_8H_{10}	0.141
Other		1.096
Total		100

2.3 Experimental procedure

The pyrolysis gas, which was generated at the isothermal condition in TGA, was carried to the gasifying reactor for the cracking experiments. After the gasifying reactor should be heated to high temperature (1100K-1400K), the concentrations of syntheses gas by the injection of oxygen and steam were analyzed. The pyrolysis gas at the inlet of gasifying reactor was carried out at 100 L

min^{-1}.

The purpose of the current study is to investigate the effect of cracking pyrolysis gas in a tube furnace and to evaluate the reaction performance of the pyrolysis gas at various operating conditions.

Selecting a standard oxygen amount as is needed to evaluate the performance of gasifying reactor. Based on the simplified species and the complete combustion mechanism, as following, the amount of synthesis gas is calculated through STANJAN, which is chemical equilibrium calculator, in the range of $O_2/O_{2,stoich}$10~50%. Fig.2 presents the profile of the mole fraction with the ratio of $O_2/O_{2,stoich}$.

- $C_2H_4+3O_2 \rightarrow 2CO_2+2H_2O$
- $CH_4+2O_2 \rightarrow CO_2+2H_2O$
- $CO + 1/2O_2 \rightarrow CO_2$
- $H_2+1/2O_2 \rightarrow H_2O$
- $C_4H_{10}+13/2O_2 \rightarrow 4CO_2+5H_2O$
- $C_2H_6+7/2O_2 \rightarrow 2CO_2+3H_2O$

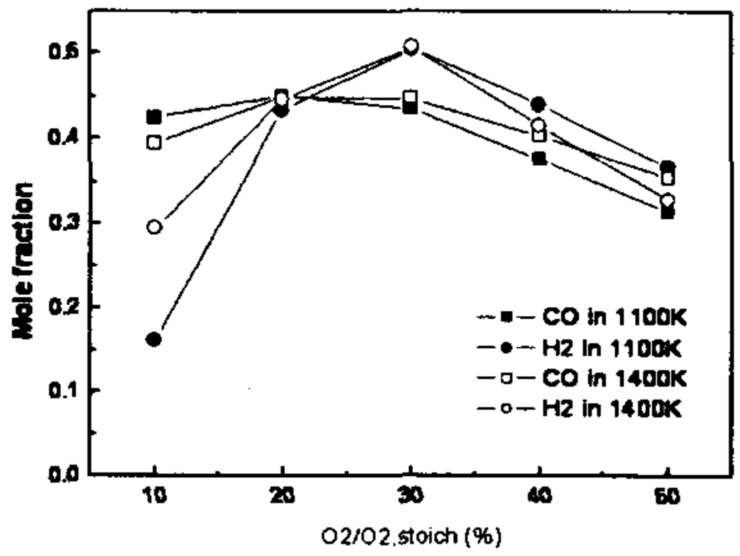

Fig.2 Mole fractions of CO and H_2 for various $O_2/(O_2)_{stoich}$

The amount of oxygen was injected at 0.4 L min^{-1}($O_2/O_{2,stoich.}$=30%),which was the maximum condition of synthesis gas(H2,CO) calculated by using the free energy minimization method, which is based on the principle that at equilibrium the change in free energy is zero and the total free energy of the system is minimum. The steam is injected at 483K from the steam generator.

In the following studies, we select the operating range of the $O_2/O_{2,stoich}$ as the 30% based on the result of Fig. 2.$^{(6)}$

3. Results and discussion

3.1. Effect of temperature on yield of synthesis gas

Fig.3 shows the gasification of pyrolyzed gas as well as pyrolysis of RPF, comparing with only pyrolysis. As shown in Fig.3, It is observed that synthesis gases are increased and THC is decreased, when pyrolyzed gas of RPF is gasified in a lab-scale reactor.

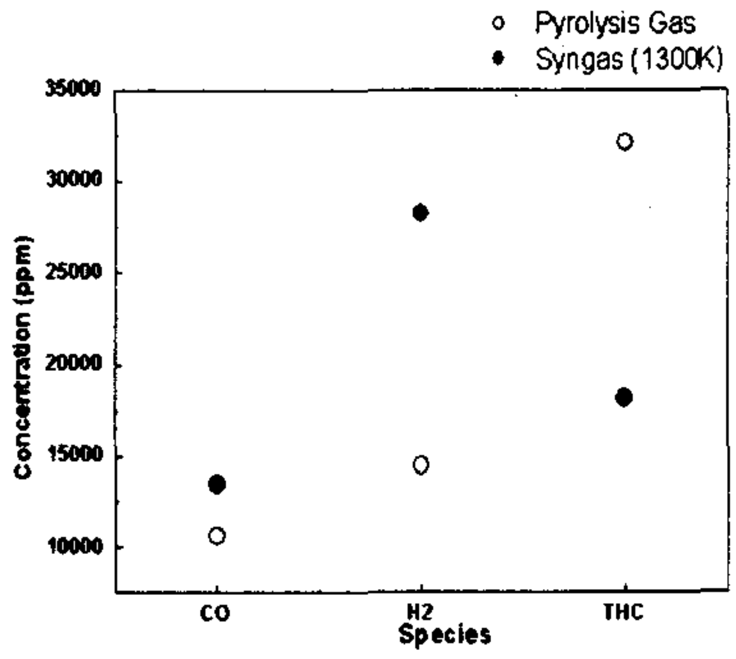

Fig. 3 Concentration of Pyrolysis gas and Cracking gas

Fig. 4 shows the profiles of the concentration of CO, H2 and THC at various wall temperatures. THC is decreased gradually from 1200K as temperature is increased. It is observed that that the gasification was happened.

The concentration of H2 is increased until 1300K, but higher wall temperature represents the decrease in H2. It is considered that additional heating condition makes the reaction into H2O from H2 more active.

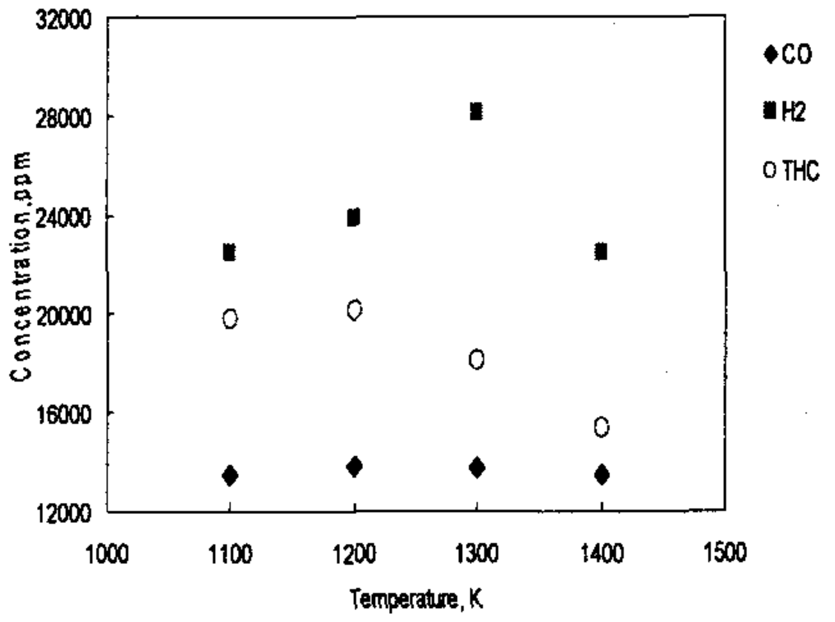

Fig. 4 Concentration of synthesis gas at different temperature

3.2. Effect of steam amount on yield of synthesis gas

Fig 5 shows the trends of concentrations of each gas with injection rates of steam. With the increase of temperature, the concentration of THC is decreased while the concentration of H2 and CO is increased. Increasing rate of H2 is more than CO. This result shows that a portion of THC is conversed into syngas.

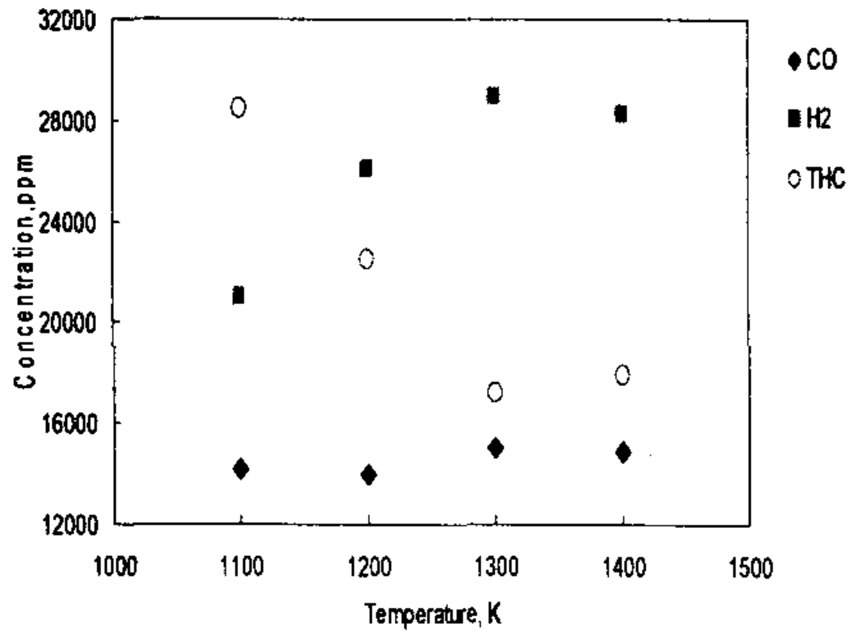

Fig. 5 Concentration of synthesis gas at various temperatures in steam injection

Fig. 6 and Fig. 7 show effect of steam injection in this experiment. When the temperature is below is 1200K, gasification of pyrolyzed gas is little, but the gasification is improved with above 1200K. This shows that gasification with steam injection should be considered with temperature.

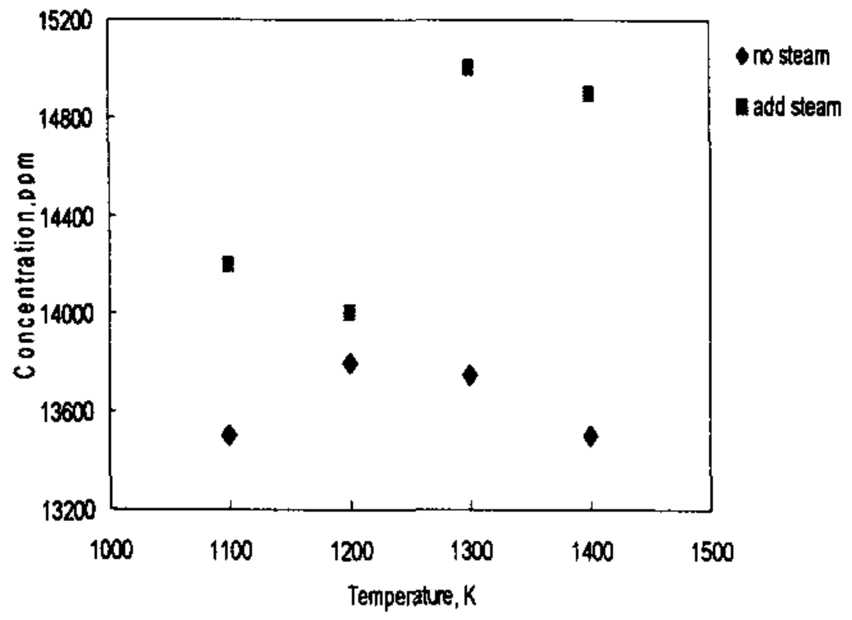

Fig. 6 Comparison of measured CO composition at various temperature

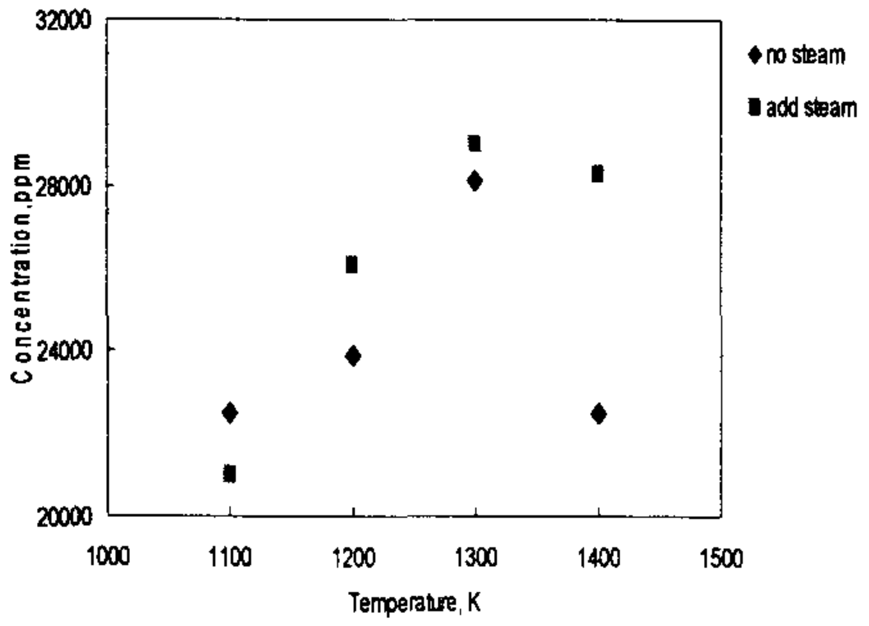

Fig. 7 Comparison of measured H2 composition at various temperatures

Fig 8 shows the experimental results of H2 comparing with calculation by Fluent. It is found that the trend is the same. It is considered that two results have similar trend.

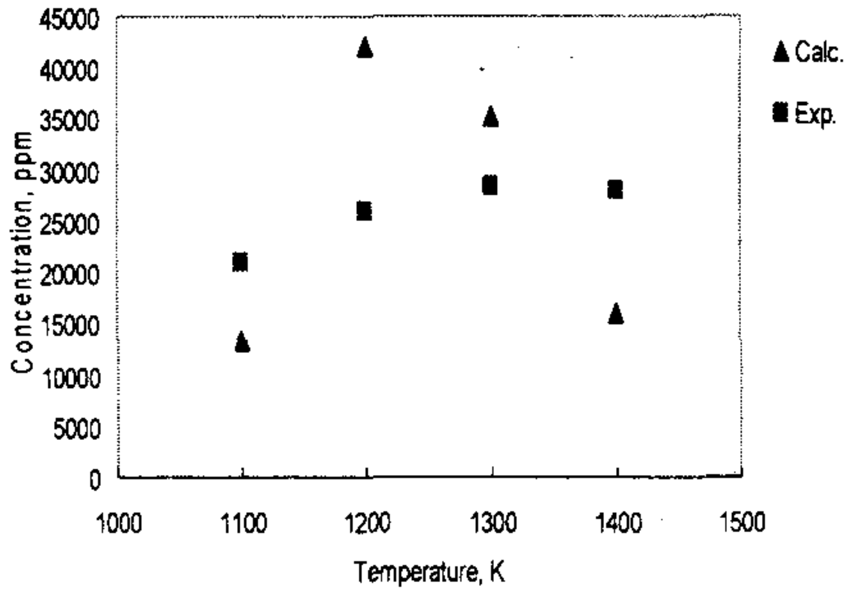

Fig. 8 Comparison of measured and calculated of H2 at various temperatures

4. Conclusions

This study has examined the characteristics of lab-scale reactor and its optimum operating conditions through gasification of pyrolyzed gas of RPF, as following:

1) As pyrolyzed gas of RPF went through reactor, THC was decreased, but CO and H2 were increased. It is estimated that gasification of THC into CO and H2 was happened.
2) As steam was injected, the effect of steam injection was observed in this experiment
3) Experimental and calculation results have similar trend.

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