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Experimental results of gasification of waste tire with air in a bubbling fluidized bed gasifier

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HIGHLIGHTS

- ▶ Lower ER values result in higher CH_4 concentration and LHV.
- ▶ Four bed materials are tested to verify the change of LHV with ER.
- ▶ Bed temperature significantly changes the LHV.
- ▶ The LHV–ER relation is different for various ER regions.
- ▶ Three correlations are produced to find LHV in the ER range of 0.15–0.60.

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ABSTRACT

Waste tire can be thermochemically disposed to solve environmental problems and to produce energy. Gasification is one of the methods to obtain a product gas with a high calorific value. The product gas is a potential resource for electrical energy production. This paper presents the experimental results of gasification of waste tire in a fluidized bed under air atmosphere. The effects of equivalence ratio (ER), gasification temperature and bed material particle size on the composition of the product gas are investigated. The equivalence ratio is varied in the range of 0.15–0.45. The composition of the product gas is determined with an online gas analyzer which measures CO, CO_2, CH_4, H_2 and O_2 components. The lower heating value (LHV) of the product gas is calculated by using the gas composition measurements. Lower ER values result in lower CO_2 concentrations, higher CH_4 and H_2 concentrations and higher LHVs. This study shows the importance of gasification temperature at low ER values, produces data points for four bed material particle sizes to verify the relation between LHV and ER, and proposes generalized correlations for different ER ranges.

1. Introduction

Waste tires need to be disposed in order to eliminate significant environmental problems. Waste tire has higher heating value, higher volatile content and lower ash content than coal and biomass. Therefore, scrap tire is a good candidate for a thermal disposal application. Among different thermochemical conversion techniques, gasification process is used to obtain a gaseous product from solid fuel. The gaseous product is called product gas or synthesis gas. The product gas can be used to generate electrical energy by using a fuel cell, gas turbine or gas engine. In addition to the product gas, a solid product is also generated during the gasification of waste tire. The solid product, which is also called char yield, can be used as a carbon source in industrial process and synthesis.

Many researchers studied various aspects of different methods, such as combustion, pyrolysis and gasification, on the disposal of waste tire. Singh et al. [1] performed experiments in a down fired combustion facility to reburn and co-fire the pulverized tire rubber together with pulverized coal. They found that the reburning of tire reduced NO emission up to 80%. They also found that the co-firing of tire with a lower volatile coal provided greater NO removal than that with a higher volatile coal. Ko et al. [2] performed design and economic analysis of a processing facility to produce activated carbon for two different feedstocks: Waste tire and coal. They found that waste tire was better than coal to produce activated carbon.

Williams et al. [3] pyrolyzed scrap tire in a fixed bed reactor under nitrogen atmosphere. They studied the effects of pyrolysis temperature and heating rate on the compositions and properties of the derived gases, pyrolytic oils and solid char. Lee et al. [4] investigated the effects of different parameters on pyrolysis of waste tire in a fluidized bed reactor. The feed rate of tire did not affect the pyrolysis performance. However, the oxygen concentration,

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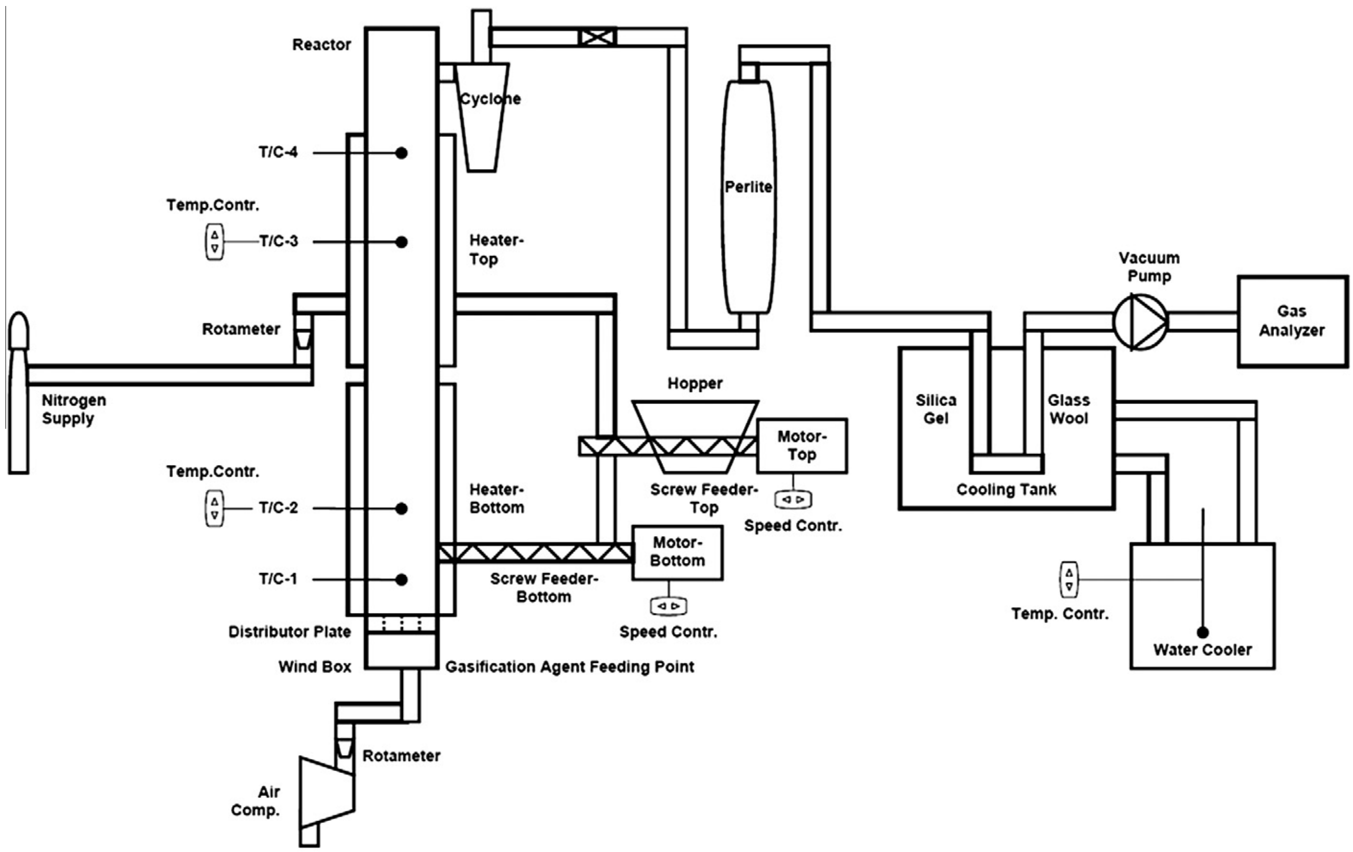

Fig. 1. Schematic diagram of the experimental facility.

pyrolysis temperature and fluidizing velocity affected the pyrolysis performance.

Chang [5] studied pyrolysis of waste tire by using a thermal gravimetric analyzer under nitrogen atmosphere for the temperature range of 200–800 °C. The degradation rate of tire increased with the increase in temperature but this effect was weak above 400 °C. Dai et al. [6] used a circulating fluidized bed reactor to study the effects of temperature, residence time and heating rate on pyrolysis of waste tire under air atmosphere. The oil yield in pyrolysis process increased with the increases in temperature and heating rate.

Zabaniotou and Stavropoulos [7] pyrolyzed waste tire in a wire mesh microreactor under helium atmosphere and reported that the pyrolysis char presented higher reactivity with steam than CO_2. Song and Kim [8] compared gasification and co-gasification processes in an internal circulating fluidized bed with a draft tube. The lower heating value of the gasification of tire was higher than that of the co-gasification of tire and sewage sludge. Galvagno et al. [9] separately gasified refuse derived fuel, poplar and tire in a bench scale rotary kiln under steam atmosphere. The rotary kiln reactor facilitated the gasification of refuse derived fuel which has a highly heterogenous structure. Among the three wastes studied, the scrap tire generated the highest hydrogen, methane, ethylene and ethane compositions.

Bubbling fluidized bed is one of the appropriate technologies to gasify waste tire to generate product gas and char at industrial scales. However, there are limited studies on gasification of tire in a fluidized bed in the literature.

Leung and Wang [10] studied the effects of tire feed rate, tire particle size and equivalence ratio on gasification of waste tire in a fluidized bed under air atmosphere. They performed many experiments by changing the ER in the range of 0.07–0.42. However, the gasification temperature decreased with decreasing ER, and the decrease was significant below 0.30.

Xiao et al. [11] investigated the effect of gasification temperature on gasification of waste tire in a fluidized bed under air atmosphere. For the temperature range of 700–800 °C, the gasification temperature slightly changed the LHV. However, for the temperature range of 400–700 °C, the effect was significant. Therefore, the temperature of 700 °C was the threshold value. Although they maintained a constant gasification temperature of 700 °C, they carried out tests only at three values of ER: 0.2, 0.4 and 0.6.

Leung and Wang [10] and Xiao et al. [11] examined many important parameters for the gasification of waste tire with air in fluidized bed. However, the study of Leung and Wang [10] suffered

Table 1
Proximate analysis, ultimate analysis and calorific value of the tire sample.

	Original basis	Dry basis
Proximate analysis (wt.%)		
Moisture	0.68	0.00
Volatile matter	63.78	64.21
Ash	6.63	6.68
Fixed carbon	28.95	29.11
Ultimate analysis (wt.%)		
Carbon	79.55	80.10
Hydrogen	7.99	7.97
Nitrogen	0.15	0.15
Sulfur	2.47	2.49
Oxygen[a]	2.53	2.62
HHV (kcal/kg)	8865	8926
LHV (kcal/kg)	8469	8531

[a] By difference.