

# Study on the Characteristics of the Influence of Temperature and Excess air ratio effect on Waste Gasification Syngas

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**Abstract:** In order to optimize the gasification reaction conditions and improve the gasification effect, we studied the effect of temperature and excess air ratio on the distribution of waste gasification gas phase products. First, apple 9.99%, green vegetables 5.58%, flour 4.83% and meat 0.43% were selected as the kitchen components, PS2.3%, PE21.76%, PP3.14%, PET4.09% and PVC0.45% were selected as the plastic components, poplar wood 20.19% as the wood and bamboo components, and 27.21% of the used cardboard boxes as waste paper composition. The results show that the optimum gas chemical condition is that the air equivalent ratio is about 0.2 and the gasification temperature is 800°C. At this time, the combustible component in the gasification synthesis gas accounts for 77.16% of the total volume, the volume fraction of H<sub>2</sub> is 17.95%, the volume percentage of CO is 28.42%, and the volume percentage of CH<sub>4</sub> is 20.66%. The ER range (0.05, 0.27) corresponding to the intersection of CO and CO<sub>2</sub> fold line has practical guiding significance for selecting the best gas chemical conditions (gasification temperature, ER) and improving gasification efficiency.

## 1. Introduction

With the advancement of industrialization, urbanization and the increasing consumption of materials, the amount of urban domestic waste has increased dramatically, posing a serious threat to the ecological environment. In 2016, the amount of garbage removal reached 203 million tons. It is estimated that by 2030, the amount of garbage removal will reach 480 million tons [1]. The composition of domestic garbage is more complicated, mainly composed of kitchen utensils, plastics, wood bamboo, fabric, waste paper, metal and brick clay [2]. The main components of domestic garbage in various cities in China are roughly the same. The main characteristic is that the content of combustible components in domestic garbage can reach about 80% [3].

Municipal solid waste gasification treatment can eliminate the production of dioxins, it has the characteristics of large capacity reduction, complete harmlessness, sufficient resource utilization, and low secondary pollution, and is receiving increasing attention [4]. Pyrolysis and gasification of domestic waste has been reported [5,6,7], but there are few related studies on achieving balance and optimization between gasification synthesis gas composition, synthesis gas calorific value and gasification reaction conditions. Therefore, this paper uses the simulated waste as raw material to study the influence of gasification temperature and ER on the gasification characteristics of the waste



on a fixed bed. The most ideal gasification conditions are obtained by analyzing the relationship between the gas phase product composition distribution and the low calorific value of the gasification synthesis gas, thereby improving the gasification effect.

## 2. Experimental

### 2.1. Material

So far, many scholars have made a more detailed study on the content of household waste, which consists of the main kitchen, plastic, biomass, waste paper, fabric, rubber and inorganic materials. According to the related garbage component research literature [3,8], we determine the content of each component of the experimental waste (dry base). The kitchen waste components were purchased from Xi'an Fangxin Group, Yangmu was collected from Qujiang Park in Xi'an, waste paper was express package, and plastics were purchased from Sigma-Aldrich Shanghai Trading Co.Ltd. After all the samples were naturally air-dried and air-dried, they were crushed using a high-speed rotary pulverizer and a sample pulverizer 5E-PC1\*100, respectively, to obtain an experimental material powder. According to the dry component content data in Table 1, the powders of each material were mixed, and then used in a dry container for use. The specific components of the waste, the Ultimate and Proximate analyzes of various components of waste component are shown in Table 1.

Table 1. Percentage of waste components(%),  
the Ultimate and Proximate analyzes of various components of waste

Component	Kitchen				Plastic						Poplar	paper
	Apple	Vegetables	Flour	Meat	PS	PE	PP	PET	PVC			
<b>Percent</b>	9.99	5.58	4.83	0.43	2.30	21.76	3.14	4.09	0.45	20.19	27.21	
<b>C</b>	44.37	38.77	44.3	50.31	88.55	85.86	85.71	62.93	47.58	43.87	40.72	
<b>H</b>	6.30	5.83	6.20	7.14	7.65	13.00	14.29	4.26	5.24	5.80	5.72	
<b>O</b>	48.30	49.43	49.15	27.13	5.32	0.90	--	32.81	--	49.67	52.69	
<b>N</b>	0.43	4.91	0.34	13.71	0.48	0.24	--	--	--	0.15	0.28	
<b>S</b>	0.60	1.06	0.01	1.71	0.20	--	--	--	0.06	0.51	0.59	
<b>Cl</b>	--	--	--	--	--	--	--	--	55.04	--	--	
<b>M</b>	4.37	8.96	9.20	6.90	--	0.10	--	--	0.1	12.80	6.89	
<b>A</b>	1.31	11.03	0.90	2.50	1.49	0.09	--	--	0.03	2.28	9.44	
<b>V</b>	70.74	65.65	72.20	88.10	95.00	98.88	99.95	90.57	92.01	70.50	75.77	
<b>FC</b>	23.58	14.37	17.70	2.50	3.51	0.93	0.05	9.43	7.86	14.41	7.90	
<b>LHV</b>	16.48	13.80	14.55	24.23	37.67	43.83	45.34	21.25	20.38	15.31	13.92	

### 2.2. Gasification experiment

Gasification experiments were carried out in a high-temperature tube type electric furnace, which were produced by Shanghai Jiugong Electric Co. Ltd., model JGL1200, rated voltage 220V, rated power 4KW. The furnace size of the tube furnace is 106\*6cms, its space capacity is 3L, the length of the heating section is 60cm, and three K-type thermocouples are arranged in the heating section, the usual

temperature is 1100°C. The schematic diagram of the gasification experimental device is shown in Figure 1. The gas-phase product detection instrument is a North Fratelli 342A gas chromatograph, and all columns are Carboxen 1000 packed columns. It is detected by a TCD thermal conductivity cell detector using high purity argon as a carrier gas.

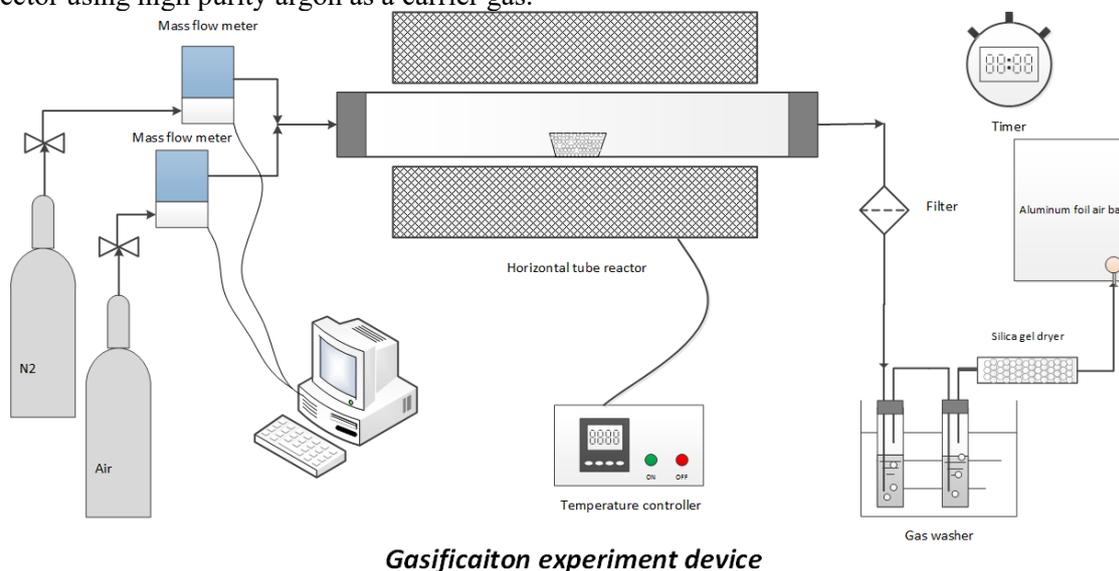


Figure 1. The schematic diagram of the gasification experimental device

### 2.3. Experimental procedure

The paper studied the effect of gasification temperature and air equivalent ratio on the gasification characteristics of waste, ignoring the influence of particle size on gasification. The temperature range is set to 600-900°C, the air equivalent ER is 0.1-0.4, and the waste is about 2 g.

The porcelain boat filled with 2g straw is placed on the outlet of the tube furnace; The inside of the tube is then drained with nitrogen and warmed by a tube furnace temperature control program; When the temperature reaches the gasification test temperature, the ceramic boat is pushed into the high temperature region of the tube furnace by a metal push rod, the mass flow meter on the computer is turned on to control the flow rate of the gasifying agent, and the gasification syngas is collected by the air bag; After the material was reacted for 10 minutes, the gasifying agent was turned off, and the porcelain boat was pushed to the outlet of the tube furnace, and after cooling to normal temperature, the vaporized residual solid was collected.

## 3. Results and discussion

### 3.1. Effect of $T$ on gasification

When the excess air ratio is set to 0.2, it can be observed from Fig. 2 that  $H_2$  and  $CH_4$  in the combustible component gradually increase with the increase of temperature. When the gasification temperature is 600°C, the volume percentages of  $H_2$  and  $CH_4$  are 4.803%, respectively. 12.748%, At a gasification temperature of 900°C, the volume percentages of  $H_2$  and  $CH_4$  were 26.701% and 32.385%, respectively, and the increase in  $H_2$  content was the largest. The CO content decreases firstly and then increases with the increase of temperature, but overall, the volume content does not change much. The minimum volume fraction is 23.449% at the gasification temperature of 700°C, and the volume percentage is 32.38% at 900°C.  $CH_4$  decreased with increasing temperature, and their volume percentages were 3.748% and 1.529% at 700°C and 900°C, respectively. The volume fraction of  $CO_2$  gradually decreased with the increase of temperature, from 39.564% (gasification temperature is 600°C) to 16.34% (gasification temperature is 900°C). The LHV of gasification syngas increased with

the increase of temperature, and increased from 9.59 MJ/Nm<sup>3</sup> (T=600°C) to 14.205 MJ/Nm<sup>3</sup> (T=900°C).

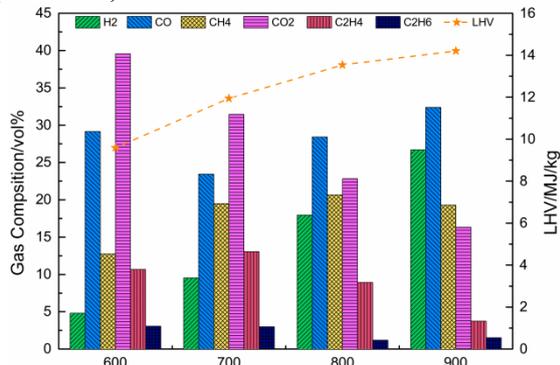


Figure 2. Effect of T on gas product

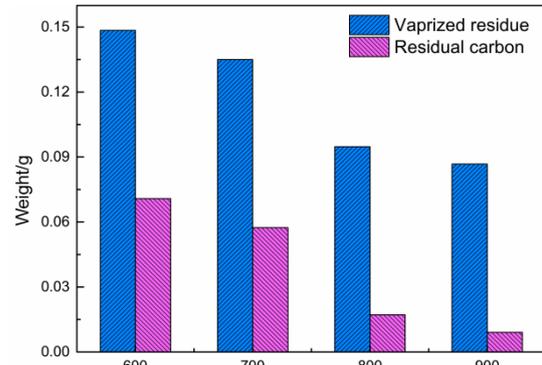


Figure 3. Effect of T on Gasification Residues

From the gas phase products as a whole, the large changes with in gases volume content are H<sub>2</sub>, CO<sub>2</sub>, C<sub>2</sub>H<sub>4</sub> and C<sub>2</sub>H<sub>6</sub>. Only the volume fractions of H<sub>2</sub>, CO and CH<sub>4</sub> increase with temperature. The volume percentage of the remaining three gases (CO<sub>2</sub>, C<sub>2</sub>H<sub>4</sub>, C<sub>2</sub>H<sub>6</sub>) decreases with increasing temperature., and it is inferred that the increase in temperature is beneficial to the transfer of gaseous products of waste to H<sub>2</sub>, CO and CH<sub>4</sub>. It is inferred that the increase in temperature favors the transfer of gaseous products of the waste to H<sub>2</sub>, CO and CH<sub>4</sub>. However, the higher the temperature, the greater the energy required for the gasification equipment. The gasification temperature of about 800°C can ensure that the combustible component content reaches the lowest and the low calorific value is the best, while minimizing the energy required for the gasification equipment. A balance is reached between.

The garbage is placed in a small porcelain boat. When the air passes over the upper surface of the material in the high temperature area of the tube furnace, and the lower surface is less in contact with the air, there is still solid residue in the porcelain boat after the gasification reaction occurs. The solid residue includes not only the ash of the garbage itself, but also residual carbon. It can be seen from Fig. 3 that as the temperature increases, the amount of waste gasification residue is less, that is, the residual carbon content is less. At 700, the residual carbon content is 0.05739 g, accounting for 2.87% of the original material; at 900°C, the residual carbon content is 0.00912 g, accounting for 0.455% of the original material.

### 3.2. Effect of ER on gasification

From the four graphs of Fig.4, the following characteristics can be observed: at the same gasification temperature, the combustible component in the gasification syngas is increased with the increase of excess air coefficient (H<sub>2</sub>, CH<sub>4</sub>, CO, C<sub>2</sub>H<sub>4</sub> and C<sub>2</sub>H<sub>6</sub>) gradually decrease, and the CO<sub>2</sub> content gradually increases; As the gasification temperature increases, the content of combustible components generally increases. The most significant change is H<sub>2</sub>, and the highest reaches 33.19% (gasification temperature is 900°C); Regardless of the degree of gasification temperature, as the ER increases, the low calorific value of the gasification syngas will decrease; In the gasification experiment range, the temperature is 600-900°C, the ER is 0.1-0.4, the CO content is about 30%, and the C<sub>2</sub>H<sub>4</sub> and C<sub>2</sub>H<sub>6</sub> volume percentages are not changed much.

When the gasification temperature is 800°C, it can be observed from Fig. 4(T=800°C) that the content of CO and CO<sub>2</sub> in the gasification synthesis gas is relatively large, accounting for about 50% of the gasification synthesis gas. When the ER is between 0.1 and 0.3, the content of C<sub>2</sub>H<sub>4</sub> and C<sub>2</sub>H<sub>6</sub> does not change much. The content of H<sub>2</sub> decreases from 26.22% to 10.34%, the decrease rate reaches 60.56%, and the CO<sub>2</sub> content increases sharply. When ER is greater than 0.3, the contents of H<sub>2</sub>, CH<sub>4</sub>, C<sub>2</sub>H<sub>4</sub> and C<sub>2</sub>H<sub>6</sub> are stable, and their volume content percentages are 9.31%, 16.55%, 9.98% and 1.16%, respectively. The CO content is decreasing, and the CO content is decreased to 14.95% and the largest

decrease. In addition, as the ER increases, the low calorific value of the gasification syngas decreases from 15.43 MJ/Nm<sup>3</sup> to 9.504 MJ/Nm<sup>3</sup>.

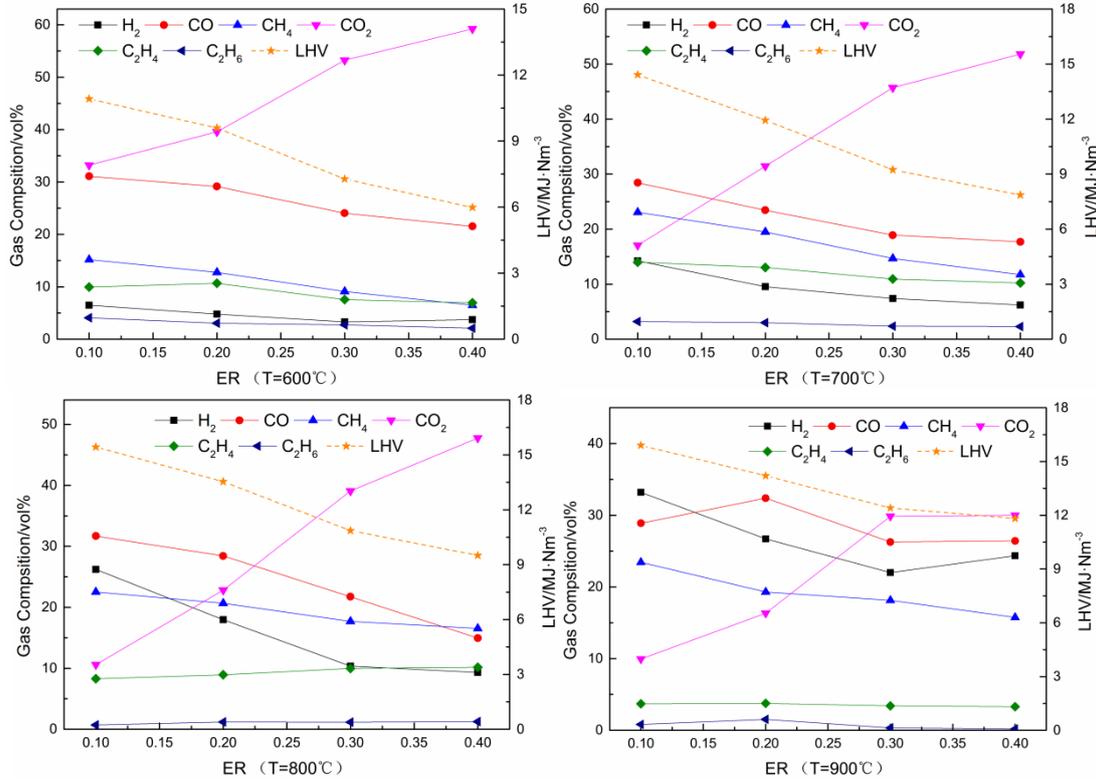


Figure 4. Effect of air equivalence ratio on gasification characteristics

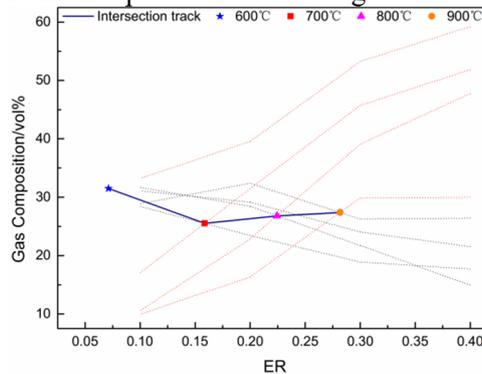


Figure 5. Migration of CO and CO<sub>2</sub> at different temperatures and air equivalence ratios

From Fig.4, we can find a very interesting phenomenon: under different gasification temperatures, the CO and CO<sub>2</sub> content trends show a similar symmetry arrangement, and there is an intersection point between the two broken lines; The point of intersection occurs when the gas volume content changes, and if one gas content decreases, the other gas must show an increasing trend. At different gasification temperatures (600, 700, 800, and 900°C), the line graphs of CO and CO<sub>2</sub> will intersect at one point. The interpolation calculus method is used to obtain the coordinates of the corresponding ER for the four working conditions. As the gasification temperature increases, the point moves toward the direction in which the ER increases, and it can be seen from Fig. 5 that the ER range is (0.07, 0.28). When the ER is about 0.2, the straw air gasification is favorable. The combustible components in the gasification synthesis gas have a larger proportion and higher quality, so this point is for selecting the best gas chemical condition (T, ER), improving gasification efficiency has practical significance.

#### 4. Conclusions

In this paper, straw air gasification experiments were carried out on a tube furnace to study the effects of T and ER on straw gasification residue and gasification synthesis gas composition. The results show that when the gasification temperature is 800 °C and the ER is between 0.1 and 0.3, the content of C<sub>2</sub>H<sub>4</sub> and C<sub>2</sub>H<sub>6</sub> does not change much. The content of H<sub>2</sub> decreases from 26.22% to 10.34%, the decrease rate reaches 60.56%, and the CO<sub>2</sub> content increases sharply. When ER is greater than 0.3, the contents of H<sub>2</sub>, CH<sub>4</sub>, C<sub>2</sub>H<sub>4</sub> and C<sub>2</sub>H<sub>6</sub> are stable, and their volume content percentages are 9.31%, 16.55%, 9.98% and 1.16%, respectively. The CO content is decreasing, and the CO content is decreased to 14.95% and the largest decrease. In addition, as the ER increases, the LHV of the gasification syngas decreases from 15.43 MJ/Nm<sup>3</sup> to 9.504 MJ/Nm<sup>3</sup>. Through the tube furnace gasification experiment, the best working condition for waste gasification is that the air equivalent ratio is about 0.2 and the gasification temperature is 800 °C.

At this time, the residue after the gasification of the garbage air accounts for 2.87% of the original waste, the combustible component of the gasification synthesis gas accounts for 77.16% of the total volume, the volume percentage of H<sub>2</sub> is 17.95%, and the volume percentage of CO is 28.42%, CH<sub>4</sub> The volume percentage is 20.66%. In the actual gasification process, the intersection of CO and CO<sub>2</sub> should be referenced first, and the optimal gas chemical condition is selected as the ER corresponding to the intersection.

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