The Effect of Different Operational Parameters on Biomass(The Pine Wood) Gasification

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Abstract. Biomass gasification gains additional significance each year. For the pursuit of the H₂ content of product gas, selecting air-dried pine wood chips as gasification feedstock, a lot of experimental work is completed in gasifier by altering the operation parameters such as particle size(60mesh,80mesh,100mesh),temperature (700°C,750°C,800°C,850°C,900°C) and steam mass to biomass mass ratio(S/B)(0.7,1.4,2.1,2.8).The effects of operation parameters on the ingredients of product gas are analyzed, which predicts the optional operation parameters for other biomass gasification.

1 Introduction

The traditional energy competition is becoming increasingly acute, the development of renewable energy sources as supplementary to petroleum products attracts the world's attention. Biomass is defined as renewable green energy for its cyclic nature. Biomass resources are widely distributed in nature, which can be used directly or indirectly by converting it into gaseous or liquid fuel[1].Biomass products have a variety of uses depending on its characteristics and the technological process.

In the present study, the gasification using steam as gasification agent has caught an enormous amount of attention for higher ratio of H₂/CO and hydrogen yield. Reams of experimental work is done using a downdraft gasifier with steam[2][3][4][5][6].A lot of numerical work are compared with experimental work[4][7][8][9][10][11][12],however, there is no unitive conclusion. In this study, the experiments made on pine wood chips gasification with steam in gasifier are carried out, adding its conclusions to previous studies.

2 Methods

2.1 Experimental set-up

The overall experiment setup appears in the Fig.1, which contains five equipments:inert atmosphere system,steam generator, biomass gasifier, gas purification system, gas collecting and analyzing device. The inert atmosphere system consists of Nitrogen tank and valve.The steam generator includes steam generator and electric heater. The biomass gasifier is made up

of feeder device, Quartz tube,filter cartridge and PID temperature control system. The washing bottle and drying bottle make up gas purification system. The gas collecting and analyzing system consists of suction pump, infrared gas analyzer and airbag. The resistance wire heating keeps the gasifier at a specific constant temperature, which provides external heat source needed.

Fig.1. Experiment set-up of gasification of biomass

2.2 Parameters and testing methods

The pine wood chips is chosen as the gasification feedstock, are broken into the biomass micron using a small blade mill.By the sieves,60 mesh,80 mesh and 100 mesh pine wood chips are sieved out.

The property of the biomass influences the quality of product gas. Proximate analysis and Ultimate analysis are completed by automatic analyzer MAC-3000A and Vario Micro cube ultimate analyzer. The infrared gas analyzer(Gasboard-3100) is used for product gas analysis.

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2.3 Index parameters

Product gas mainly contains H_2 , CO , CO_2 , CH_4 , N_2 , H_2O . Gas production and calorific value of gas production are opposite index parameters; CO_2 has no contribution to the calorific value of gas; CH_4 has little contribution to gas production; N_2 is inert gas; H_2O is removed during the purification phase, so the main consideration is the content of H_2 and CO . Compared with the property of CO , H_2 has its environmental advantages as a clean fuel and high calorific value which makes it more energy efficient, the ratio of H_2/CO is the most suitable index parameter[2][7][13], which not only reflects the changes of volume, but also reflects the changes of the quality of product gas.

3 Results and discussion

3.1 Proximate analysis and Ultimate analysis

Table 1 Proximate analysis and Ultimate analysis

Proximate analysis (wt %,ad)				Ultimate analysis (wt %,ad)				
FC	A	V	M	C	H	O	N	S
12	12	74	12	43.5	4	39	1	0.5

3.2 The effect of temperature on product gas

In this experiment, the pine wood chips with a particle size of 60 mesh have been selected as the gasification feed stock. The feeding rate maintains at 3g/min, some experiments are completed at temperatures of 700°C, 750°C, 800°C, 850°C and 900°C respectively, the results are shown in Fig.2 and Fig.3

Fig.2. Gas composition at different temperature

Fig.3 The ratio of H_2/CO at different temperature

Fig.2 shows that the temperature changes have a great difference to the ingredients of gasification gas. With the increase of temperature, the proportion of H_2 is leaping growth from 15.5% to 30.5%; the proportion of CO shows a decreasing mode from 54% to 42.5%, the content of CH_4 increases first and then decreases, When the temperature is 800°C, the content of CH_4 is at the highest point, the proportion of C_mH_n and CO_2 have decreased with temperature increasing.

Fig.3 reveals that the ratio of H_2/CO has been growing from 700 to 900°C, however, the increase in each temperature section is not the same, the higher the temperature, the greater the ratio of H_2/CO .

3.3 The effect of particle size on product gas

In this experiment, without gasification agent, some experiments are carried out, maintaining the temperature of the gasifier at 900°C and feeding rate of 3g/min, taking 60 mesh, 80 mesh and 100 mesh pine wood chips as the gasification feed stock. The results are shown in Fig.4 and Fig.5.

Fig.4 Gas composition of different particle size

Fig.5 The ratio of H₂/CO at different particle size

Fig.4 points out that the proportion of CO decreases from 40% to 38%, but the decrease is small as the particle size becomes smaller. The proportion of H₂ have increased obviously from 26% to 33%; The proportion of CH₄ changes insignificantly. The proportion of CO₂ decreases.

After the crushing of the pine wood chips, the cellulose structure is effectively destroyed at the microscopic level. As the crystallinity decreased, the porosity of the particles is increased. On the macroscopic level, the reduction of the particle diameter causes the specific surface area of the biomass particles to react with the surrounding atmosphere increasing, which is also helpful for the heat exchange between the raw material and the surrounding atmosphere, so that the yield of H₂ increases.

According to the Fig.5, the H₂/CO increases almost linearly as the particle size becomes smaller, which appears inflection point when the particle size is 80 mesh. when the particle size is between 60 mesh and 80 mesh, the growth rate the H₂/CO is greater, compared to that the particle size is between 80 mesh and 100 mesh. Considering the cost of broken pine wood chips, the 80 mesh may be the optimal particle size for the gasification of pine wood chips.

3.4 The effect of gasification dose on product gas

In this experiment, steam is picked as gasification agent. Taking 80 mesh pine wood chips as the gasification feed stock, keeping the gasifier temperature 900 °C and feeding rate of 3g/min, the S/B (the ratio of steam mass to biomass mass) are 0.7,1.4,2.1,2.8 respectively. The results are shown in Fig.6 and Fig.7.

Fig.6 Gas composition of different S/B

Fig.7 The ratio of H₂/CO at different particle size

Fig.6 suggests that the content of CO drops by 1.72% from 0.7 to 2.8 of S/B, the content of H₂ grows by 1.61%. The proportion of CH₄ decreases, the proportion of CO₂ increases.

The introduction of steam is conducive to the formation of H₂, but the steam temperature is lower than the ambient temperature, resulting in heat loss, having an impact on heat and mass transfer, Excess steam inhibits the generation of H₂.

Fig.7 demonstrates that the S/B is 1.4, the content of H₂ is highest at 35.94%. Although the sum of the two is highest as S/B is 0.7, which is not much more than it as S/B is 1.4. this experiment shows that the optimal S/B is 1.4.

4 Conclusions

In this study, the focused inspection are the effects of temperature, particle size, and S/B on the composition of product gas. The three parameters have a great difference to gas composition, maybe they are the most important influence factors. Based on the obtained results come from experiments, following conclusions are draw: for the pine wood gasification, the higher the temperature, the better the quality of the product gas, the optional particle size of pipe wood gasification is 80 mesh or 0.17mm, the optional S/B is 1.4.

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