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Study of Biochar Pyrolysis Mechanism and Production Technology

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Abstract：This paper describes the process of biomass pyrolysis to make biochar briefly. Studied the biochar production rate and composition and content of gas under different conditions of temperature and residence time. Meanwhile, the heating value of the combustible gas produced was analyzed. The results showed that: temperature, residence time both have different influence on the pyrolysis process Also proved that 450-500℃ is not only the best temperature for biochar production,but the highest heating value of the combustible gas.It can provide the basis for the furter study of accuracy control and online monitoring of biochar production and improvement of the carbonization furnace.

1 Introduction

The word "biochar" constantly appear in scientific journals and media, in recent years. Biochar is the abbreviation for bio-charcoal, refers to the solid products getting from biomass pyrolysis in hypoxic environment. The method of making biochar is called biomass carbonization technology. biochar is widely used in agriculture, environment, energy and other areas. In agriculture, biochar can improve the soil, enhance soil fertility, increase the yield and quality of grain, promote the sustainable development of agriculture. In environment, it can solve the problem of agricultural and forestry waste pollution and greenhouse gas emissions.and While further processed into activated carbon, can be used for the adsorption of heavy metal pollution, water treatment,etc.

China is a large agricultural country with more than half the rural population. Biomass is the main energy in rural areas, most direct combustion, the average thermal efficiency is lower than 25%. Large excess biomass usually burn directly in the field, not only pollute the environment but also waste of energy. Biomass carbonization technology is an important measure to resolve the problem. Currently, the research on biochar preparation techniques is rare. While, characteristics analysis and study of biomass carbonization process has important theoretical meaning and practical value.

2 Experiment part

Measuring biochar production rate, gas composition and content, etc.of temperature stabilized state(400-800 ℃, step size 50 ℃, carbonization time were: 5min, 10min, 20min)

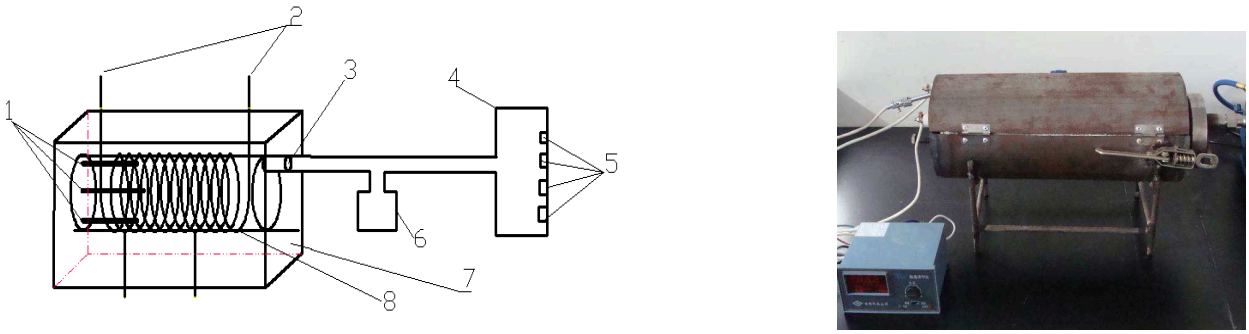
2.1 *Selection of experimental materials*

The carbonization furnace developed in Shenyang Agricultural Uinversity Liaoning Province biochar center can achieve a variety of biomass carbonization, such as; crop straw, rice shell, peanut shell, organic waste.ect.

This experiment selected the single corn straw for a better study on pyrolysis characteristics.
The material from the Shenyang Agricultural Uinversity experimental,field ready for use after natural drying—fragmentation(corn stalks cut into 6cm long or so)
Drying is to reduce the moisture rate of raw material, short the carbonization time and improve the efficiency of the carbonization.
Fragmentation is due to the size limit of the carbonization furnace.It can also promote the carbonization reaction, make carbonizing process more stable.

2.2 *Apparatus and method*

Using the carbonization furnace developed by Shenyang Agricultural Uinversity and data logger.The experimental apparatus are shown in Figure 1.The experimental device is composed of a furnace body and a circuit part which is a temperature control for the whole equipment.
Provide the heat required by carbonization through electric heating.Temperature the inner position by thermocouple connected temperature acquisition logger.To enable accurate temperature measurement , the temperature sensor made of M6*8 spiral shape, drill screw holes on the stove and screw in the feeding tank inside. To understand the temperature distribution in the furnace, design temperature collection points is 3, the temperature sensor using K type thermocouple. Temperature controller and ac contactor is linked together, which is controlled by temperature controller of main circuit open and close shift the ac contactor direct control of main circuit on and off.
Hole is equipped with air bag, gas sensor inside the air bag measuring the concentration of the gas. Sensor uses the input type current sensor , their acquisition module of ADAM - 4018.



1thermocouple, 2 resistance terminal, 3 hole ,4 air bag ,5 gas sensor ,6 tar collecting bottle ,7 hot box ,8 resistance wire

Fig.1 Experimental apparatus

The experimental process

(1)Weigh some raw materials. Connect the carbonization furnace and the data logger. Carbonization furnace is electrified and check all parts of the state.
(2)Set carbonization temperature; put raw materials into the chamber;seal the sealing cover of the chamber; vent opening into the tar collecting container; inser temperature sensor into the chamber;check the wiring insulation condition.
(3)Open the coking furnace main switch, all instruments began to work, enter the stage of carbonization.
(4)Observation data logger temperature change, if the data is not change or with the actual carbonization temperature difference is very big, turn the temperature sensor, and continue to observation data changes. If there is no obvious change, close the switch of coking furnace, stop carbonization, check the coking plant. Otherwise, continue to carbonization.

(5)Reach the coking time, the carbonization furnace switch is closed, the coking chamber are taken from the carbonization furnace, cooling, the biochar removed from the chamber. Prepare the next carbonization.

2.3 *Theoretical study on biomass pyrolysis process Selection of experimental materials*

Biomass is mainly composed of three elements C, H, O, therefore, the molecular formula can be expressed as CxHyOz.At the beginning, the furnace contains a certain amount of air. When reaches a certain temperature, some biomass with the stoichiometric air for complete reaction, some biomass and air incomplete reaction. The reaction equation is:

$$C_xH_yO_z + (x + \frac{1}{4}y - \frac{1}{2}z)O_2 \rightarrow xCO_2 + \frac{1}{2}yH_2O \quad (1)$$

$$C_xH_yO_z + (\frac{1}{2}x + \frac{1}{4}y - \frac{1}{2}z)O_2 \rightarrow xCO + \frac{1}{2}yH_2O \quad (2)$$

After oxygen depleting in the furnace, a series of complex chemical reactions, in which C and H_2O reaction of CO_2 and H_2 in the low temperature region and reaction of CO and H_2 in the high temperature zone.The CO_2 and C reaction of CO then. The reaction equation is as follows:

$CO+H_2O \rightarrow CO_2+H_2$（-41.71KJ/mol） (3)

$C+2H_2O \rightarrow CO_2+2H_2$(-75KJ/mol) (4)

$C+2H_2O \rightarrow CO+H_2$(-131KJ/mol) (5)

$C+CO_2 \rightarrow 2CO$(-173KJ/mol) (6)

$C+2H_2 \rightarrow CH_4$(+75KJ/mol). (7)

Therefore, in theory, the total reaction inside the furnace is:

Biomass+heat → H_2+CO+CH_4+tar+biochar (8)

But in actual pyrolysis, part of CO_2 has not been fully response then out, on the other hand, also generates a small amount of CmHn gas in the reaction. Therefore, the actual reaction can be considered:

Biomass+heat → CO+H_2+CH_4+CmHn+bar+biochar (9)

2.4 *experimental research of biochar production rate effecting by carbonization temperature, carbonization time*

Biochar production rate is studied and the relationship between the carbonization temperature, carbonization time. Set temperature from 400 ℃ to 800 ℃, the step length is 50 ℃, under different carbonization temperature, carbonization for different time. Coking time is respectively: 5 min, 10 min, 20 min.

Calculation of pyrolysis proceeds biochar production rate

According to the experimental procedures stipulated, measure the mass of biochar in turn in the balance after reaching the corresponding conditions.

The rate of biochar can be calculated as follows:

$$Rate\ of\ biochar = \frac{The\ quantity\ of\ biochar}{At\ first\ material\ quantity} \times 100\% \quad (10)$$

According to the calculation results drawing figure 2 as shown.

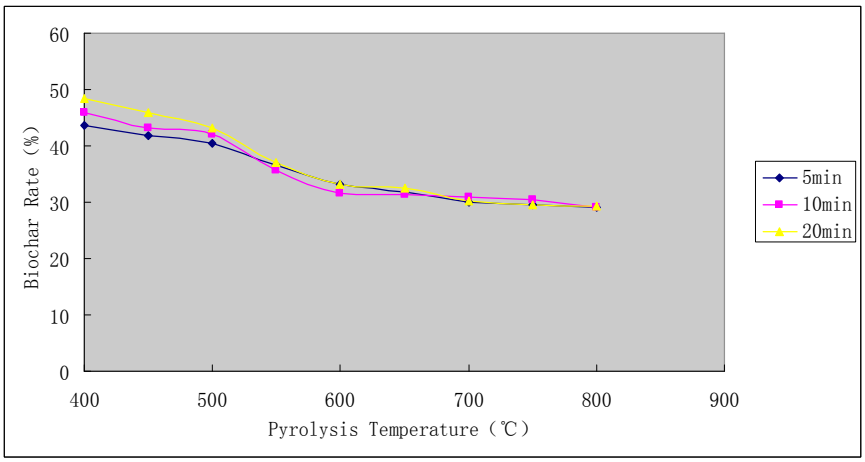


Fig 2 The relationship between biochar production rate and carbonization temperature, carbonization time.

As can seen from chart 1,with the increase of pyrolysis temperature, carbonrate decreased. Carbon rate tends to slow when the temperature is increased further .

When the temperature is below 500 ℃, influence of residence time on the carbon yield is significant. While when the temperature is higher than 500 ℃, the curves approach with different residence time of 5min, 10min, 20min. Long heating time, will make the material ash content increased. Comprehensive analysis, 450 ℃-500 ℃, 15min-30min is more suitable for carbonization conditions.

Figure 3 is biochar obtained under different conditions.

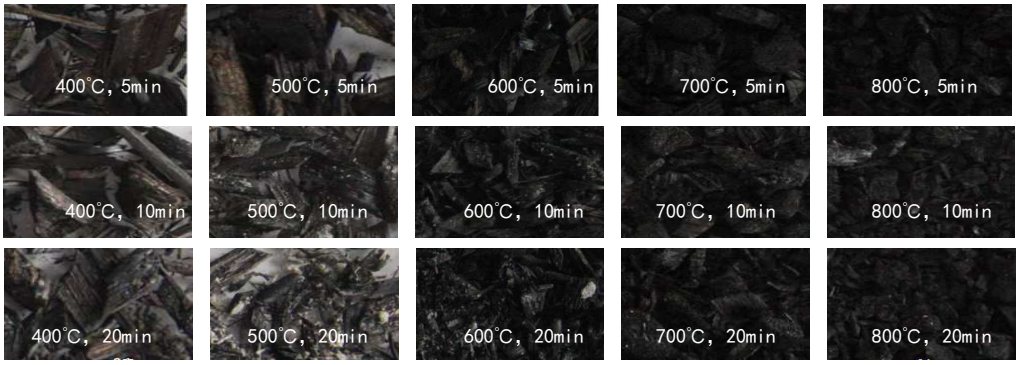


Fig.3 Biochar of different conditions

2.5 *Experimental research on relationship between pyrolysis temperature and gas content*

Use the gas sensor for monitoring gas concentration.And use MCGS7.2 configuration software to realize the real-time data display, data storage and historical data query. According to the data to draw the figure below:

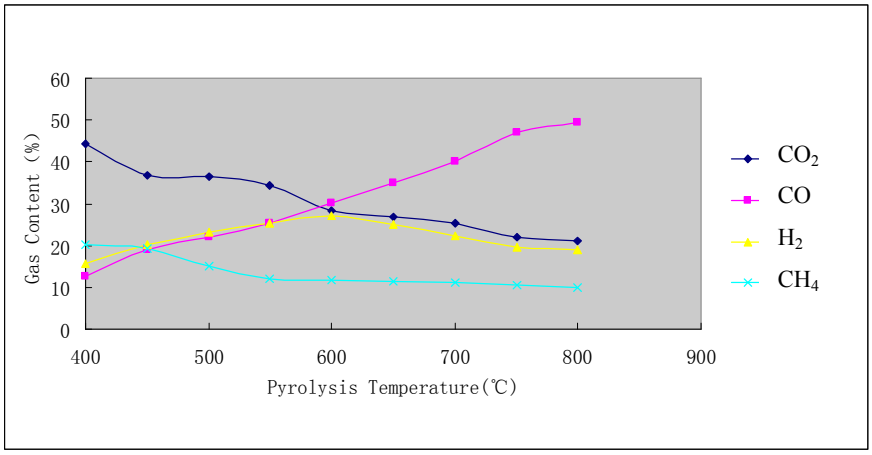


Fig.4 Relationship between pyrolysis temperature and gas content

As can be seen from the figure: pyrolysis temperature plays a decisive role in gas composition distribution. At the temperature of 400-450℃， CO_2 decreased more, then flatten out.CO increased drastically, which fully proves the theory analysis is correct.

2.6 *Combustible gas calorific value analysis*

Gas calorific value is refers to the unit volume of gas combustion contains chemical energy
Mixture total calorific value calculation according to formula (11)

$$Q = 12630P_{CO} + 10780P_{H_2} + 35870P_{CH_4} + 66500P_{C_mH_n} \quad (11)$$

Which Q------ Gross calorific value of mixed gas, KJ/m3

$P_{CO,}P_{H_{2,}}P_{CH_{4,}}P_{C_mH_n}$ --------The corresponding gas volume fraction

According to the type (1-1), calculate the gas calorific value of biomass pyrolysis gas within the range 400-800 ℃. Make chart of gas calorific value trend along with the change of pyrolysis temperaturegas according to the data,as shown in figure 5

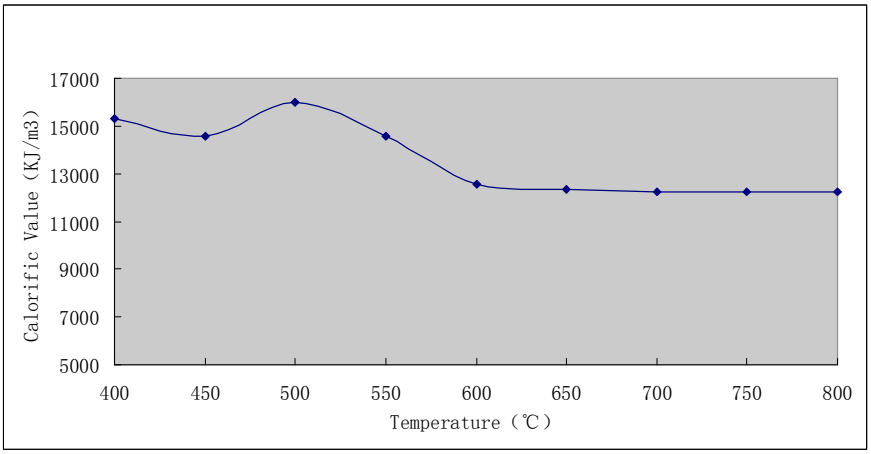


Fig.5 Gas calorific value of different temperature

As can be seen from the chart, gas calorific value roughly from 1.2 to 1, 6 MJ/m3.
With the increase of pyrolysis temperature, gas calorific value first began to rise and then fall, peak in the 450-500 ℃. Therefore, in order to make full use of gas heat value, should choose the carbonization temperature is 450-500 ℃. As it happens, the temperature is suitable for the preparation of biochar.

3 Conclusions and recommendations

(1)Biomass pyrolysis coking process is a complex physical and chemical reaction process.Process of biomass pyrolysis carbonization is a complicated physical and chemical reaction process. The nature of its carbonized product much affected by carbonization conditions. Experimental results showed: 450-500 ℃ is the best temperature for the production of biochar, is also the best temperature of effective use of combustible gas.

(2)The calorific value of combustible gas generated from biomass pyrolysis is high and stable .Therefore, further research on the use of combustible gas has profound meaning.

(3)Accurate control of the various parameters of the pyrolysis process is the bottleneck of biochar preparation process. Therefore, monitoring of the pyrolysis temperature, pressure and main gas compositionand changes,can provide the understanding of the scientific, accurate and convenient biochar carbonization process.

Acknowledgements

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