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Biomass Pyrolysis Fuel Research of the Technology about Heating Through Heat-carrier

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Abstract

With the rapid development of biomass pyrolysis fuel technology, the technology about heating through heat-carrier as an important part of biomass pyrolysis fuel process is also to mature. However, since there is a relatively great temperature difference after carrier heating, the biomass pyrolysis products and oil production rate are affected ultimately. Therefore, this article first introduces several kinds of biomass pyrolysis fuel technology about heating through heat-carrier, and then leads to a design of a fine temperature control device through analysis and comparison to keep the initial temperature difference within ±10 ℃ for the carrier in main reactor so that it can satisfy the temperature demand of biomass pyrolysis and promote the industrialization of biomass pyrolysis fuel.

Keywords: *Biomass pyrolysis fuel technology, Heating technology, Fine temperature control device, Carrier, The initial temperature difference*

1. Research Status of Biomass Pyrolysis Fuel Technology about Heating Through Heat-carrier

It is an indisputable fact that China is confronted with the shortage of oil resources and serious energy security issues. China's annual oil demand will reach 560 million tons in 2020 with foreign dependence rising to over 65% [1]. Meanwhile, China enjoys abundant biomass resources, yet about 400 million tons of straws, 300 million tons of forest wastes, 300 million tons of sand shrubs and many other biomass resources have been abandoned [2]. Therefore, the major practical problem in China's energy, environmental protection and sustainable development area is to accelerate the speed of research on converting the abundant agricultural and forestry residues into bio-combustible fuel efficiently and economically. Biomass fuel technology has far-reaching strategic significance. During this process, adequate heat is required, which mainly comes from the heat carrier. In order to ensure the integrity of biomass feedstock and the speed of heating, the carrier in the main reactor needs to be heated to about 560 ℃. Therefore, it is crucial to study heating technology which enables high-speed and efficient carrier heating and controls the temperature of carrier in the main reactor.

With the rapid development and industrialization of biomass pyrolysis fuel technology, biomass pyrolysis fuel equipments have also been developing rapidly, among which the carrier heating device as the key technology of biomass pyrolysis fuel also experienced the progress of carrier from gas to solid.

1.1 Gas Heat-carrier –the Indirect Heating Furnace with Circulating Air-duct

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Figure 1 shows the heating program that the heating device regards air as the carrier to transfer heat. When the operation starts, the heating furnace (5) begins to heat. When the furnace temperature reaches the predetermined temperature, open the fan (6) to start hot-air circulation. During the process that hot air is circulating in the hot-air duct (2), just heat the inner wall of the main reactor to increase the internal temperature of the main reactor. As the rotating cone (3) is also heated to a certain temperature, the heat-carrier will be able to reach the required temperature after several cycles in the main reactor. By Figure 2, the heating furnace (5) uses straws and wood wastes as raw materials for combustion in the initial stage. When the pyrolysis reaction starts, use the non-condensable gas of pyrolysis steam for fuel feed. It will not only solve the sourcing problem of raw materials for heating, but also make full use of recyclable non-condensable gas in order to avoid air pollution.

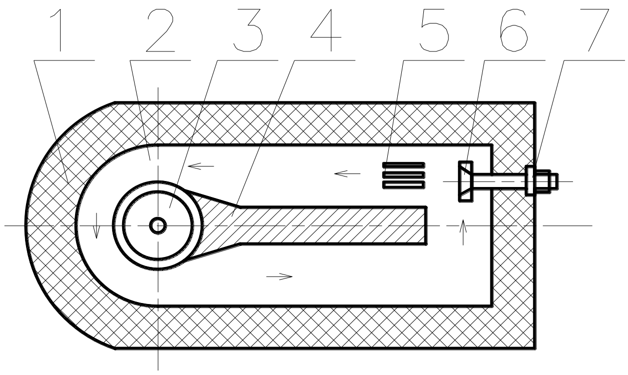

Figure 1. Schematic Diagram of a Heating Furnace with Circulating Air-duct

1. Insulation 2. Hot-air duct 3. Rotating cone 4. Interlayer between hot-air duct 5. Heating furnace 6. Fan 7. Cooling Hinge

During the process, the indirect heating furnace with circulating air-duct reveals some shortcomings such as slow heating rate, long heating time and unstable temperature. Moreover, the fan life is shortened dramatically due to the high operating temperature which is generally above 800 ℃. Thus it is unfavorable for stable production in the long term.

Figure 2. The Real Heating Furnace with Circulating Air-duct

1.2 Solid Heat-carrier –the Direct Heating Furnace

This method is to heat the carrier directly by using the flame from the diesel atomizer burner. The structure is shown in Figure 3. The heat-carrier delivery system brings the carrier into the furnace through the inlet pipe (1), and then the distribution of the carrier becomes thin and uniform since the inverted funnel (4) (whose wall is provided with round holes in a certain size and number) and three tungsten wire meshes (5) have dispersed it. Meanwhile, it is heated directly by the flame of the burner (6) and then flowing out from the outlet pipe (8) through the poly flow cone (7) into the main reactor to pass on the heat to biomass particles. In addition, the tungsten wire meshes play the role of auxiliary heating.

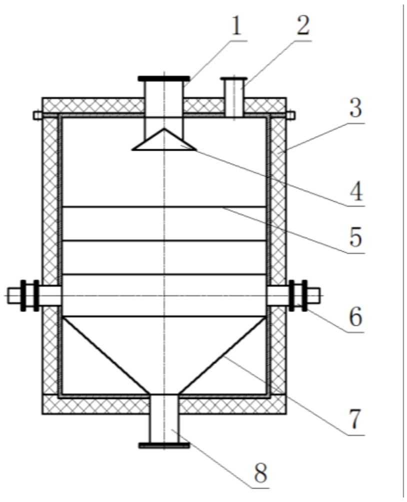

Figure 3. Chart of Direct Heating Furnace

1. Inlet pipe 2. Smoke tube 3. Insulation 4. Inverted funnel
5. Tungsten wire mesh 6. Burner 7. Poly flow cone 8. Outlet pipe

The direct heating furnace (As shown in Figure 4) enjoys the advantages of fast heating rate and short time-consuming since the carrier is heated directly. As the scale of biomass pyrolysis fuel is enlarging, the needed quantity of heat-carrier also increases greatly. However, the three tungsten wire meshes are too compressed, resulting in a considerable amount of the heat-carrier staying on the surface of them and other carrier flowing too fast without adequate heating. Consequently, the recycling of carrier can not be guaranteed because temperature requirement can not be reached.

Figure 4. The Real Direct Heating Furnace

1.3 Solid Heat-carrier – the Compound Heating Furnace

The high-speed and efficient compound heating furnace is mainly composed of an upper furnace and a lower furnace, and its structure is shown in Figure 5. During the carrier-heating process, the hot smoke released by the burner first enters the lower furnace (4) and then moves to the heating pipe (2) of the upper furnace (1) through the connecting conduit (3) between the two furnaces. Carrier goes into the upper furnace through the heat-carrier inlet device (10) and then exchanges heat with the smoke by the heating pipe. Afterwards, carrier moves to the lower furnace (4) to convert heat with the smoke directly. The flow of carrier can be commanded by a flow control valve (8). A tilting baffle (7) is installed at the lower furnace so that the heat carrier can fully contact with the hot smoke.

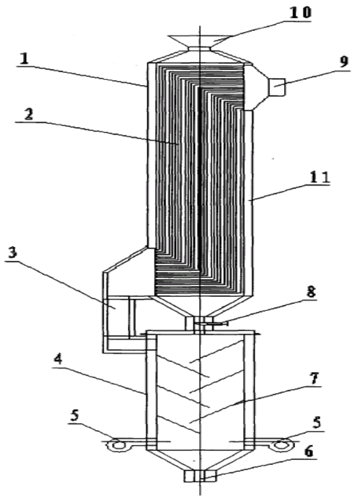

Figure 5. Chart of the Compound Heating Furnace

1. Upper furnace 2. Heating pipe 3. Connecting conduit 4. Lower furnace 5. Burner 6. Heat-carrier outlet device 7. Tilting baffle 8. Flow control valve 9. Flue 10. Heat-carrier inlet device 11. Insulation

The high-speed compound heating furnace (Figure 6) not only improves the heating rate of carrier and the heat utilization, but also meets the need of large biomass pyrolysis fuel equipments for the volume of carrier.

Figure 6. The Real High-speed Compound Heating Furnace

With the further development of biomass pyrolysis fuel technology and the improvement of biofuel quality, the reacting temperature in the main reactor needs to be as accurate as possible, which requires precise control of the carrier temperature after heating. Therefore, it is necessary to design the fine temperature control device.

2. The Design of the Fine Temperature Control Device

2.1 The Basic Principles of Fine Temperature Control Device

The fine temperature control device is installed between the carrier outlet of the furnace and carrier inlet of the main reactor. When the temperature of heat-carrier changes, feedback signals from the thermocouple bring in the condition machine through the analog input, calculated by the PID controller, via I / O output to control the high-frequency power swift so as to regulate the heating temperature of the carrier. (Figure 7)

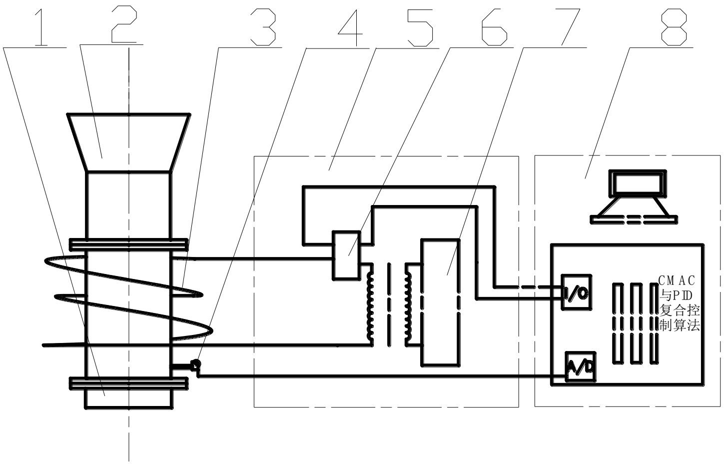

Figure 7. Fine Temperature Control Device

1. IPC 2. high-frequency generator 3. Solid State Relays 4. High-frequency power 5. Thermocouple 6. heating pipe 7. carrier outlet of the furnace 8. carrier inlet of the main reactor

The basic method of the high-frequency heating for carrier is as followings. First put the carrier into the electromagnetic induction coil, then electrify it by some certain alternating current to generate a magnetic field so that some closed induced currents will be produced within the carrier under the effect of electromagnetic induction in the alternating magnetic field. Meanwhile, the surface temperature of carrier will rise since energy from the high-density current on the surface layer of carrier is converted to heat. By Figure 8, the carrier flows into the fine temperature control device through the furnace, shunted by the sand-diversion cone, and eventually goes to the annular drift sand area which is formed by an inner tube and an outer tube. During the process, the fine temperature control device will regulate the temperature of the heat-carrier precisely in order to make the carrier into the main reactor within ± 10 ℃ in comparison with the set temperature.

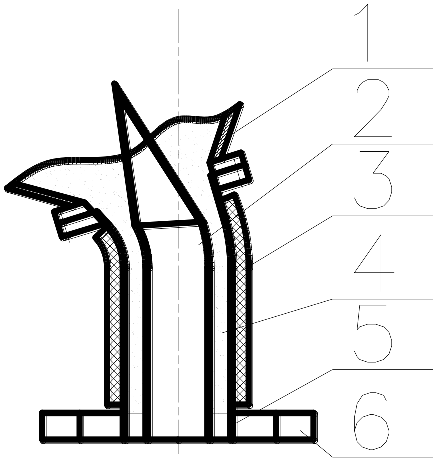

Figure 8. Schematic Diagram of the Fine Temperature Control Device

1. Interface of furnace 2. Inner tube 3 Insulation 4.Carrier 5. Outer tube 6. Flange

2. 2 Calculation of the Fine Temperature Control Device Theory

Known the mixing ratio between the amount of carrier and dry biomass is 1:10. [4] The moisture content of the biomass feedstock is 10%, and the required amount of biomass pyrolysis is 300kg per hour along with the specific heat of carrier as 1.005J / g ℃ and the density as 1500 ~ 1700kg / m3. According to the cracking experiment for pyrolysis fuel equipments, generally the temperature of carrier from the furnace is only about 540℃. In order to achieve pyrolysis temperature, the needed temperature of carrier is 560 ℃ so that the requirement for the amount of heat can be calculated as follows:

$$Q = Cm\Delta t$$

In the formula, Q——the needed quantity of heat for carrier heating, KJ / h;

C——the specific heat capacity of carrier, 0.24cal / g ℃;

m——the mass of the carrier, g;

Δt ——the temperature difference for carrier heating, ℃.

The above shows that the demand for the amount of carrier is $3x10^4$ kg and the temperature difference is 20 ℃. When leading these numbers into the formula, the result is that Q is 60.48 KJ / h. Since the rate of heat loss during the transfer process is 10%, actually the needed quantity of heat for carrier heating is 66.5 KJ / h.

Since the device is connected to the outlet of the furnace, the outlet D_0 is 60mm according to the design. In order to ensure a carrier flow of 2.144kg / s, the inner tube D_1 should be 50mm. The outer tube D_2 can be calculated by the following formula:

$$\frac{1}{4} \times \pi \ (D_2^2 - D_1^2) = \frac{1}{4} \times \pi \, D_0^2$$

The result shows that D_2 is 78mm. According to the Mechanical Design Handbook, D_2 can be set up as 83mm, along with the thermal conductivity λ as 0.45 $w / m \cdot k$ [5].

According to the "Principles of Chemical Engineering", the relationship between the length of tube and the heat is as follows:

$$Q = \frac{2\pi \ \lambda L \Delta t}{Ln \frac{r_1}{r_2}}$$

In the formula, Q——the needed quantity of heat for carrier heating, KJ / h;

Δt ——the temperature difference for carrier heating, ℃.

λ——the thermal conductivity, 0.45 $w/m \cdot k$;
L——the length of tube, mm;
r_1——the radius of the inner tube, mm;
r_2——the radius of the outer tube, mm;

According to the known data, the result shows that L is 1000 mm. In order to ensure a constant temperature rising, a layer of relatively soft asbestos with mica flakes fixed as outer insulation is added to the outer wall of the tube.

3. Summary

This paper describes heating technology during the biomass pyrolysis fuel process, which yields a result that almost all kinds of heating methods are hard to ensure the final heating temperature of carrier to reach 560 ℃, as the heating temperature is generally about 540 ℃. Therefore, a fine temperature control device is designed by analyzing its operating principles, structures and theoretical calculation process. Ultimately, the device can control the initial temperature difference within ± 10 ℃ since the temperature of carrier is increased by 20 ℃.

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