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Method of Thermal Processing of Biomass With Heliopyrolysis Device

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Abstract: The article discusses the issues of ensuring the temperature regime in the reactor of the pyrolysis plant and the saving of thermal energy for private needs, as well as the analysis of the thermal performance of the plant. As a result of applying a solar concentrator to this type of pyrolysis device, a temperature of 300-500 °C can be obtained. This allows to reduce the private energy consumption for the pyrolysis process by up to 30%.

Key words: heliopyrolysis, concentrator, pyrolysis reactor, biomass, alternative fuel, temperature, time.

INTRADUCTION

The depletion of underground fuel reserves is increasing access to renewable energy sources. The constant production of heat and electricity from renewable energy sources, such as biomass and solar energy, contributes to the constant depletion of natural fuels and the solution of various environmental problems. In our country, the potential for the use of solar energy is high, and in about 270-300 sunny days of the year (2700-3000 hours) radiant energy can be used effectively for various purposes. The technical potential of solar energy in the country is three times more than the amount of energy received from all energy sources for current consumption. In world practice, the use of solar energy for lighting, heating, cooling, ventilation, heating and electricity generation is established. It is important to use solar concentrators for use in technological processes that require high temperatures from solar energy.

MAIN PART

Low energy density is a major problem in the use of biomass. By using solar energy, biomass can be converted to heliopyrolysis fuel. In this process, concentrated solar radiation is a source of high-temperature thermal energy for biomass heliopyrolysis. As a result of this combination, three types of fuels are obtained from biomass: liquid, gaseous and solid alternative fuels. One of the main challenges of today's rapidly developing solar energy industry is to improve the technical and economic performance of solar devices that contain light-reflecting elements, as well as the efficient use of solar concentrators that collect solar energy at one point. Typically, their paraboloid types are widely used in the development of solar concentrators. The preparation of these types of paraboloid concentrators is somewhat difficult. This requires the development of simple structures to design window systems that collect solar radiation into a single point.

In the design process of heliopyrolysis devices, it is important to calculate the heat balance of the bioreactor to determine the heat energy consumption for biomass processing. Thermal processing of biomass requires a certain consumption of thermal energy in the reactor. The given heat energy maintains its temperature regime during biomass processing. To evaluate the energy efficiency of biomass processing, it is necessary to study the heat balance of the reactor. Mathematical modeling of the heat balance of the reactor solves important problems of energy saving and optimization of the heliopyrolysis reactor. The total heat input to the bioreactor, the ratios between the useful heat used and the heat losses in it, are represented by the thermal equilibrium of the reactor.

The pyrolysis reaction takes place inside a stainless steel reactor. The main components of a solar pyrolysis system are a reactor, a parabolacyllican solar concentrator, and a condenser. The schematic diagram of the proposed heliopyrolysis device is shown in Figure 2. The reactor is heated from the outside by means of parabolacylindrical solar concentrators together with a continuous heating system. Parabolacylindrical solar concentrators are used as a heat source to heat the reactor. As a result, using this combined device allows to obtain heat at a temperature of 180 °C.

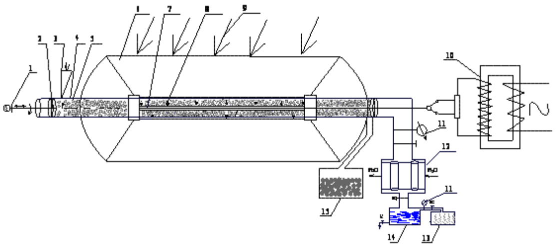

Figure 2. 1-rotating mechanism; 2-piston; 3-bin for loading raw materials; 4-reactor; 5-raw material; 6-solar parabolic cylindrical concentrator; 7-thermoelectric heater; 8-thermocouples; 9-sun rays; 10-current transformer; 11-flow meter; 12-condenser-refrigerator; 13-gas holder; 14-container for storing oil-like substances; 15-capacity for charcoal.

To create the desired temperature, the temperature at which the biomass is placed in the reactor and the amount of heat required to heat it to the pyrolysis temperature are determined. The amount of heat required to heat the loaded biomass to the temperature of the pyrolysis process is determined as follows, kJ,

$$Q_{\text{под}} = M_b c_b (t_b - t_s) \tag{1}$$

where M_b – is the mass of biomass, kg; c_b – - average specific heat capacity of biomass, kJ / (kg·°C); t_b – biomass temperature, °C; t_s – the same loaded, °C.

Heat losses in a bioreactor are determined by the temperature of the processed biomass and the outside temperature of the reactor surfaces, the area of the heat exchange surfaces of the biomass and the outside air, and the thermal conductivity of the reactor wall. The amount of heat lost as a result of heat transfer to the environment through the reactor wall, kJ,

$$Q = KF(t_a - t_b) \tag{2}$$

where K – is the heat transfer coefficient, kJ/(m^3·h·°C); F – is the surface area of the reactor heat exchange, m^3; t_b – is the temperature of the biomass in the reactor, °C; t_a – ambient temperature, °C.

The heat transfer coefficient is determined by the formula:

$$K = \frac{1}{\frac{1}{\alpha_1 d_1} + \frac{1}{2\lambda_{\text{CM}}} Ln\frac{d_1}{d_2} + \frac{1}{2\lambda_{\text{ИЗ}}} Ln\frac{d_{\text{ИЗ}}}{d_2} + \frac{1}{\alpha_2 d_2}} \tag{3}$$

Table 1. Calculation of the thermal balance of the reactor

№	***Mass, kg***	t_{d1}, °C	t_{d2}, °C	***Q₁, kJ***	K, W/m^2×K	F, m^2	Q_2, kJ	dQ, kJ
1	100	20	450	77400	0,3	2,512	4665,6	72734,4
2	50	20	450	38700	0,3	2,512	4665,6	34034,4
3	25	20	450	19350	0,3	2,512	4665,6	14684,4

Heat consumption during solar and electrical pyrolysis of biomass is determined as follows. In the direct experiment, the fuel consumption is 300-600 kg/t (9-18 GJ/t), in addition, solar heliopyrolysis uses process steam with energy of 8-16 GJ/t to convert products into liquid fuel [1,2,3,4,5].

When solar radiation W_s = 800 ÷ 950 W/m^2 and wind speed ϑ = 4 ÷ 5 m/s, the temperature of the biomass rises to 180 °C over time. Initially, the temperature was assumed to be 18 °C when the biomass was loaded into the reactor. Determining the thermal efficiency of a device The total energy consumption received by the concentrator is determined as follows:

$$Q_{\text{в}} = W_h \cdot S_o \cdot R_o \cdot R_a \cdot \sigma \tag{4}$$

where S_o – is the total surface of the reflecting surface of the device, $R_o = 0{,}78$ is the reflection coefficient, $R_a = 0{,}81$ is the absorption coefficient of the beam-absorbing surface, $\sigma = 0{,}85$ is a factor that takes into account the design of the device, the tracking system of the solar system and the properties of the reflecting surface.

The total direct flux of solar radiation according to per year is $W_h = 2000$ kW·s/m^2. Considering this, the thermal energy that can be achieved by a concentrator with dimensions of 1,2 x 1,5 m is,

$$Q_g = W_h \cdot S_o \cdot R_o \cdot R_a \cdot \sigma = 2000 \cdot 1000 \cdot 60 \cdot 60 \cdot 1{,}8 \cdot 0{,}78 \cdot 0{,}81 \cdot 0{,}85 = 7 \cdot 10^9\ Joul$$

CONCLUSION

This means that the installation of heliopyrolysis devices allows to obtain energy from 1 har per surface up to $7 \cdot 10^9$ Joules per year. The heat energy produced by the device can be compared with the combustion heat of combustion of 1 kg of conventional fuel is 29,3 MJ or 7000 kcal (heat released when burning 1 kg of coal). When we convert the annual energy received from 1 m^2 of the device into ordinary fuel, it saves $7 \cdot 10^9/29.3 \cdot 10^6 =$ 238 kg equivalent conditional fuel.

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