

Research Of The Temperature Regime Of The Heliopyrolysis Process

Almardanov Hamidilla Abdiganievich

PhD, Karshi state technical university

Abstract. The article analyzes the temperature regime in the reactor of the pyrolysis device and the saving of thermal energy consumed for the specific needs of the device, as well as the thermal technical indicators of the device. The article also proposes a heliopyrolysis system with a solar concentrator to provide heat to the pyrolysis reactor. As a result of the use of a solar concentrator in this type of pyrolysis device, it is possible to obtain a temperature of 400-700 °C. As a result, it allows reducing the specific energy consumption for the pyrolysis process by up to 30%. The objectives of this computational and theoretical research on the heliopyrolysis process are mainly aimed at an approximate assessment of their thermal efficiency, taking into account the degree of optimization of thermal technical parameters.

Keywords: heliopyrolysis, concentrator, pyrolysis reactor, biomass, heat content, enthalpy, solar radiation, thermal efficiency, alternative fuel, temperature, heat transfer coefficient, time.

Introduction

Scientific research is being conducted around the world to produce heat and electricity from solar energy, to light buildings, to heat them, to cool them, and to ventilate them. The use of solar concentrators for technological processes requiring high temperatures is an important area of research [1-8].

Pyrolysis is a method of converting organic waste and biomass into steam-gas by heating it in an airless environment and then cooling it to produce gaseous, liquid, and solid hydrocarbon products [9,10].

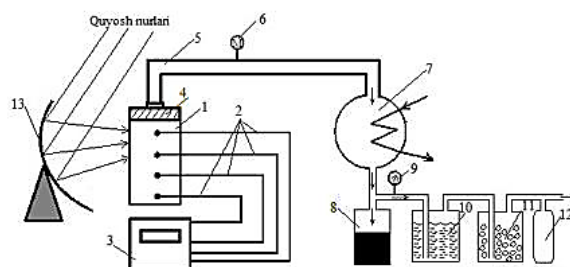
One of the methods of thermal-chemical processing of biomass is pyrolysis, which, in comparison with the combustion method, produces liquid, gaseous and solid alternative fuels from organic waste in a shorter time of 3-3.5 hours. Pyrolysis devices have the ability to simultaneously generate three types of alternative fuels and heat energy (hot water) and electricity. These devices significantly reduce the amount of "greenhouse" gases emitted into the environment [11-14].

The biomass pyrolysis process is a high-temperature thermochemical process, in which the average temperature regime is 500÷700 °C. Ensuring the temperature regime in the reactor of the pyrolysis device and saving thermal energy spent on the device's own needs is an urgent issue. As a result of the use of a solar concentrator in the pyrolysis device, it is possible to obtain temperatures of 400-700 °C. As a result, it allows reducing the private energy consumption for the pyrolysis process by up to 30 % [15-18].

Maintaining the temperature regime in the pyrolysis plant reactor is one of the main problems. Because to maintain the required temperature regime (350÷500 °C) in the reactor, energy (heat) must first be supplied. Usually, coal, natural gas or electricity are used as energy sources for the processes carried out in a traditional pyrolysis plant [19,20].

Materials and methods

The article examines the temperature dependence of the products produced during the heliopyrolysis of biomass and hydrocarbon waste. To study the temperature regime of the pyrolysis process, a schematic diagram of the heliopyrolysis reactor was created (Fig.1). The experimental heliopyrolysis device consists of a tubular reactor, a condenser-cooler, a gas holder, a gas cleaning system, a parabolic concentrator, and a piping system [21].



1 – reactor; 2 – thermocouple; 3 – Mobile-CASSY 2 thermometer; 4 – boot lid; 5 – steam-gas pipeline; 6 – manometer; 7 – condenser-cooler; 8 – condensing unit; 9 – gas consumption measuring device; 10 – water filter; 11 – activated carbon filter; 12 – gas holder; 13 – parabolic concentrator.

Fig.1. Schematic diagram of the reactor of the heliopyrolysis device.

Heliopyrolysis of biomass and hydrocarbon waste was carried out in laboratory conditions according to the following methodology. Before the start of the experiment, samples of biomass and hydrocarbon waste (rubber) with an initial moisture content of 5÷20 % and a size of 4÷6 mm were prepared. The mass of biomass and hydrocarbon waste loaded into the heliopyrolysis reactor was measured on an electronic scale (Electronic SF-400), and the moisture content was measured with an accuracy of ±2 % using a digital universal moisture meter AR971. The heliopyrolysis reactor (1) is made of a steel pipe with a diameter of 0,16 m, a height of 0,2 m and a useful volume of 0,003 m³. When the density and moisture content of biomass or organic waste are known, up to 1 kg of raw material can be loaded into the reactor.

To increase the initial reactor loading the lid (4) opens and biomass is loaded. Heliopyrolysis reactor parabolic solar the concentrator (13) is installed in the focus. The biomass is heated and converted into a vapor-gas mixture. The resulting vapor-gas mixture passes through the pipe (5) to the condenser (7) and is cooled and condensed with cold water. The condensate of the vapor-gas mixture (pyrolysis liquid) goes to the condensing unit (8) and here the gaseous fuel released from the biomass passes through a water filter (10) and an activated carbon filter (12) and is collected in a gas holder.

The temperature regime of the heliopyrolysis process in the experiment was parabolic solar was produced using a concentrator. The heating rate of the loaded raw material was 5÷10 °C/min. The temperature regime in the reactor was controlled by a Mobile-CASSY 2 thermometer (measurement accuracy: ±3 °C, ±2 %; measurement range: -200 ... +200 °C/-200 ... +1200 °C), a bimetallic thermometer Pakkens (measurement accuracy: CL 2.0; measurement range 0.... +500 °C) and a thermal imager Snegir-700MT (measurement accuracy: ±2 °C; measurement range -20.... +700 °C). The temperatures at characteristic points along the height of the cylindrical reactor were recorded using a Mobile-CASSY 2 thermometer.

Measurements were taken at points 0.25h; 0.5h; 0.75h; 0.95h along the reactor height. (Fig.2) The average temperature in the reactor was determined as follows:

$$t_{aver} = \frac{t_1 + t_2 + t_3 + t_4}{4} \quad (1)$$

where t_1, t_2, t_3, t_4 – are the temperatures at characteristic points of the reactor surface, °C.

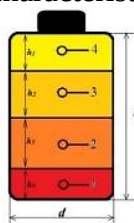


Fig.2. Scheme of measuring temperatures at characteristic points of a heliopyrolysis reactor.

The formation of combustible gas, high-calorie pyrolysis liquid, and solid fuel was observed as a result of heliopyrolysis of biomass and hydrocarbon waste. The solid and liquid products formed in the process were weighed using an electronic balance. Thus, the results of experimental studies on the pyrolysis of biomass and hydrocarbon waste show that the amount of pyrolysis products released depends on the process temperature, moisture content and granulometric composition of the feedstock.

In this study, the dependence of temperatures at different points in a heliopyrolysis reactor on the value of solar radiation and the type of raw material loaded was analyzed [22].

Results and discussion

The experiments show that the heliopyrolysis method has a number of advantages over other traditional biomass pyrolysis methods, and is an energy-efficient and environmentally friendly method. The intensity of sunlight depends on the climatic conditions of the area and its position relative to the horizon, which allows for uniform heating of the surface of the heliopyrolysis reactor using solar concentrators. Table 1 presents the results of temperature changes at characteristic points of the reactor when various biomass and hydrocarbon wastes are loaded into the heliopyrolysis device.

Table 1
Heliopyrolysis reactor temperature study results (rubber waste)

T/r	Time	Incandescent solar radiation, q_r , W/m^2	External air temperature $t_{t,x}$, °C	Reactor different at the points temperatures, t_r , °C				In the reactor average temperature, t_{aver} , °C
				1	2	3	4	
1	11 ⁰⁰	970	31.3	735	285	170	145	333.75
2	12 ⁰⁰	1015	33.4	801	315	180	150	361.5
3	13 ⁰⁰	1030	34.6	995	390	202	183	442.5
4	14 ⁰⁰	1020	34.9	970	400	255	192	454.25
5	15 ⁰⁰	970	35.4	903	375	231	162	417.75
6	16 ⁰⁰	950	36.5	865	325	215	150	388.75
7	17 ⁰⁰	935	35.8	734	310	201	137	345.5

Parabolic sun concentrator heliopyrolysis device reactor temperature of the area change
The graphs are presented in Fig.3. and analysis was done .

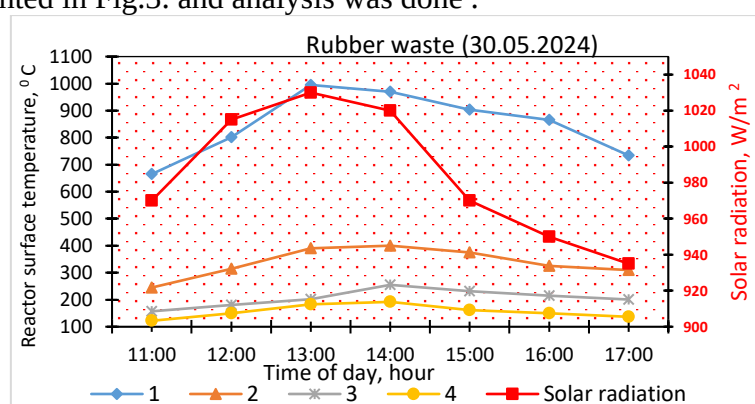


Figure 3. Parabolic sun concentrator heliopyrolysis device reactor temperature of the area change graph.

The experiments were conducted with hydrocarbon waste (rubber waste). Based on this, the heliopyrolysis reactor was initially loaded with rubber pellets with a particle size of 4÷6 mm and a moisture content of 5%. It was found that at an external temperature of 35 °C and a solar radiation value of 970 W/m², the average temperature inside the reactor was 394.3 °C, and the process lasted 150 minutes.

Conclusion

Based on experiments conducted to study the process of obtaining alternative fuels in a heliopyrolysis device, the following conclusions were reached.

1. An experimental solar concentrator heliopyrolysis device for biomass pyrolysis was created and initial pilot tests were conducted.
2. Studies conducted on the developed parabolic solar concentrator heliopyrolysis device show that on sunny days, the temperature regime of 300÷500 °C required for biomass pyrolysis in the device's reactor can be created without using traditional fuels. As a result, it has become possible to save fuel and energy resources consumed for private needs in traditional pyrolysis devices by using solar energy.

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