HELIOPYROLYSIS DEVICE FOR PRODUCING ALTERNATIVE FUELS FROM BIOMASS AND ORGANIC AGRICULTURAL WASTE

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Abstract. The article is analyzes scientific research that presents technologies for processing biomass and agricultural organic waste based on solar energy, providing alternative fuels to solve problems of energy saving for autonomous consumers. We have developed a methodology for conducting experimental studies on the pyrolysis of biomass and organic waste using concentrated solar energy. The results of the scientific research and technical and economic calculations performed showed that the use of a parabolic solar concentrator in pyrolysis installations made it possible to increase the energy efficiency of the installation by 10÷12%.

Key words: solar parabolic concentrator, alternative fuel, biomass energy, organic waste, solar pyrolysis plant, pyrolysis reactor, energy saving.

Аннотация. В статье анализируются научные исследования, в которых представлены технологии переработки биомассы и органических отходов сельского хозяйства на основе солнечной энергии, обеспечивающие альтернативные виды топлива для решения задач энергосбережения автономных потребителей. Разработана методика проведения экспериментальных исследований по пиролизу биомассы и органических отходов с использованием концентрированной солнечной энергии. Результаты научных исследований и выполненных технико-экономических расчетов показали, что использование параболического солнечного концентратора в пиролизных установках позволило повысить энергоэффективность установки на 10÷12%.

Ключевые слова: солнечный параболический концентратор, альтернативное топливо, энергия биомассы, органические отходы, солнечная пиролизная установка, пиролизный реактор, энергосбережение.

Annotatsiya. Maqolada quyosh energiyasi orqali biomassa va qishloq xo‘jaligi organik chiqindilarini qayta ishlash texnologiyasi hamda avtonom energiya iste’molchilarni energiya bilan taminlash uchun ishlab chiqilgan geliopiroliz qurilmasida o‘tkazilgan tadqiqot natijalari keltirilgan. Bundan tashqari maqolada konsentrlangan quyosh energiyasidan foydalangan holda biomassa va organik chiqindilarni piroliz qilish bo‘yicha eksperimental tadqiqotlar o‘tkazish metodologiyasi taqdim etilgan. Amalga oshirilgan ilmiy tadqiqotlar va texnik-iqtisodiy hisob-kitoblar natijalari shuni ko'rsatdiki, piroliz qurilmalarida parabolik quyosh kontsentratoridan foydalanish qurilmaning energiya samaradorligini 10÷12% ga oshirish imkonini berishi aniqlangan.

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Kalit so‘zlar: quyosh parabolik kontsentratori, muqobil yoqilg‘i, biomassa energiyasi, organik chiqindilar, geliopiroliz qurilmasi, piroliz reaktori, energiya tejash.

Introduction

The world pays special attention to the use of solar energy in the production of thermal and electrical energy, lighting and heating of buildings, air cooling and in various technological processes, as well as the issues of saving natural fuel and energy resources. Currently, traditional fuel and energy resources make up 75-90% of the fuel and energy balance in the world [1]. In the 21st century, the energy consumption of existing power plants increased by one and a half times and at the end of 2022 reached ~ 14.5 billion tons in oil equivalent [2]. According to the International Energy Agency, by 2050, energy demand is expected to increase by 3 times. The technologies and systems used in practice for obtaining alternative fuels from biomass require significant consumption of fuel and energy resources. Therefore, the use of solar concentrators for the use of solar energy in technological processes requiring thermal processing of biomass and high temperatures is considered important.

In the Republic of Uzbekistan, certain work is being carried out on the production of alternative types of fuel from biomass, including the introduction of energy-saving technologies and systems based on renewable energy sources (RES), the efficient use of bioenergy plants and increasing their energy efficiency. The Resolution of the President of the Republic of Uzbekistan dated February 16, 2023 “On measures to accelerate the introduction of renewable energy sources and energy-saving technologies in 2023” No. PP-57 outlines important tasks for “the widespread introduction of renewable energy sources in the social sphere, housing and communal services and sectors of the economy, ensuring compensation for energy deficit in the regions of the republic by increasing energy efficiency, comprehensive organization of work in this direction...” [3].

Currently, foreign scientists are conducting a number of studies on the use of solar concentrators in the pyrolysis process. In particular, Morales (Mexico) studied the pyrolysis process using parabolic solar concentrators. However, his studies did not fully examine the practical aspects associated with the position of the sun during the day and seasonal fluctuations in solar radiation [4]. Joarder (Bangladesh) studied a fast pyrolysis system using a parabolic concentrator [5]. Zeng (China) proposed a two-stage parabolic concentrator with a heliostat, equipped with a screen system for regulating the heating rate and temperature of the pyrolysis reactor. In their studies, the effect of temperature (600 ÷ 1000 oC) and heating rate (5 ÷ 45 oC/sec) was studied not on the operation of the system of that period, but on the efficiency and properties of the hard coal obtained as a result

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of this process [6]. Zeitter (Lebanon) created and tested a solar pyrolysis plant with a two-axis tracking system using Fresnel lenses . The study resulted in a temperature of 550 oC and the process of obtaining fuel from household waste by pyrolysis was studied [7]. Seymon Sobek (Poland) conducted experiments to study the fundamentals of the pyrolysis process and the structure of existing solar pyrolysis reactors. To study solar pyrolysis of biomass, a new design of laboratory-scale solar pyrolysis reactors was developed, and solar pyrolysis reactors that also operate from an artificial lighting system were compared with solar pyrolysis reactors that operate continuously using solar energy [8]. As a result of experiments conducted by Venkateshwarlu Chintala (India), the production, processing and use of fuel obtained from biomass were studied. Currently, research is being developed to develop devices for thermochemical processing of biomass using pyrolysis units with a solar concentrator [9-19]. In the Republic of Uzbekistan, research work on obtaining alternative types of fuel from local biomass by pyrolysis was carried out by G.N. Uzakov, R.T. Rabbimov, H.A. Davlonov [20-24]. Despite the positive scientific results achieved, the proposed developments have not yet found practical application in the economic and industrial sectors.

Based on this, the aim of this work is to develop and justify the energy efficiency of a solar pyrolysis plant with a parabolic solar concentrator for obtaining alternative fuels from biomass and organic waste from agricultural production.

Materials and methods

As a result of research in this area, a method of using solar concentrators in the process of biomass pyrolysis, i.e. the heliopyrolysis method, was proposed and an experimental device was created. A parabolic concentrator with a standard diameter d=1,8 m was used as the basis of the solar concentrator. Its reflecting surface was made of 4000 glass mirrors with dimensions of 2.5x2.5 sm^2 (Fig. 1).



Figure 1. Solar concentrator heliopyrolysis device.

Based on the developed process flow chart, an experimental solar pyrolysis plant with a parabolic solar concentrator was created at the scientific testing ground of the Power Engineering Department of the Karshi State Technical University. The experimental solar pyrolysis plant consists of a cylindrical reactor, a condenser-cooler, a gas cleaning system, a parabolic concentrator and a pipe

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system. Based on the results of preliminary experimental tests of the plant, its thermal engineering and design parameters were determined [21-24].

The material balance of various types of biofuel obtained in the process of pyrolysis of biomass and sunflower waste loaded into the reactor of a solar pyrolysis plant with a parabolic solar concentrator was studied in natural conditions using the following method. Before the experiment, product samples with an initial moisture content of 5÷20% and a size of 4÷6 mm were prepared. The mass of the loaded product was measured using electronic scales (Electronic Sf-400), humidity – using a universal digital moisture meter AR971 with an accuracy of ±2%, and the temperature in the reactor was controlled using a Mobile-CASSY 2 thermometer (measurement accuracy: ±3 °C, ±2 %; measurement range: -200 ... + 200 °C / -200 ... + 1200 °C), a Pakkens bimetallic thermometer (measurement accuracy: CL 2.0; measurement range: 0…+500 °C) and a Snegir-700MT thermal imager (measurement accuracy: ±2 °C; measurement range: -20 ... + 700 °C). The intensity of solar radiation was measured using a Photovoltaic Data Logger MacSolar actinometer (illuminance measurement range: 0...1500 W/m^2; temperature measurement range: -40… + 85 °C; temperature measurement accuracy: ±0.1°C).

Results and discussion.

At the first stage, the temperature regime and the possibility of using a solar pyrolysis plant based on a parabolic solar concentrator were studied taking into account the change in incident solar radiation in the conditions of the city of Karshi. By studying the temperature regime of the reactor of the solar pyrolysis plant with a parabolic solar concentrator, the dependence of the yield of alternative types of fuel obtained in the process of solar pyrolysis of biomass and hydrocarbon-containing waste on temperature was studied. The graphs of the change in the temperature field on the surface of the reactor of the solar pyrolysis plant with a parabolic solar concentrator when loading biomass (sunflower waste) into it are presented and analyzed in Figure 3.

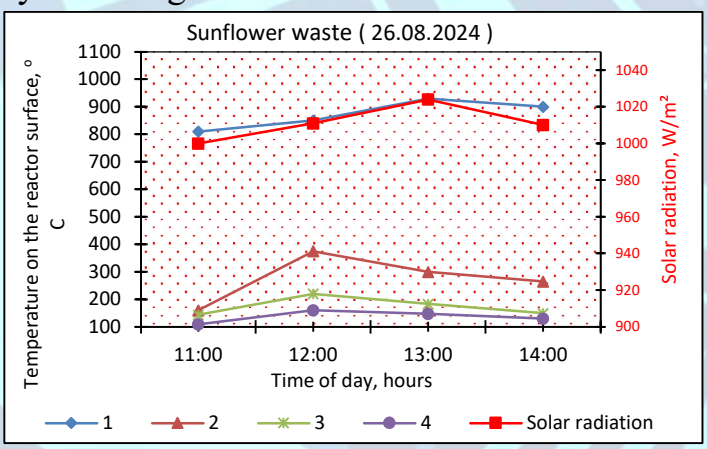


Figure 3. Graph of the dependence of the temperature on the surface of the heliopyrolysis reactor on time and solar radiation

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In addition, during the experiment, the dependence of the amount of energy used for the pyrolysis process on the humidity and size of the biomass loaded into the solar pyrolysis reactor was determined; the results obtained are presented in Figure 4.

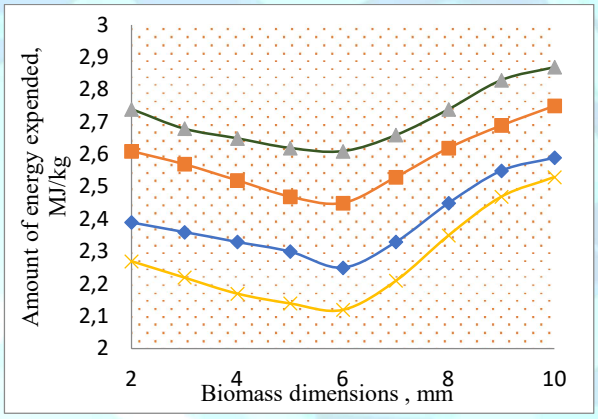


Figure 4. Graph of the dependence of the amount of energy spent on biomass pyrolysis on the moisture content and size of the biomass.

During the experiment it was established that the amount of energy spent on biomass pyrolysis and the duration of the process are reduced as the raw material size decreases to 2÷6 mm. With an increase in the size of the loaded raw material over 6 mm, energy consumption and the duration of the process increased, as a result of which the optimal sizes were selected that correspond to the lowest energy consumption for the implementation of the biomass pyrolysis process. As a result of the experiments, it was substantiated that the optimal geometric size of the raw material, ensuring effective pyrolysis of biomass with minimal energy costs, is 6-8 mm.

Based on the results of the conducted experimental studies, the effect of the humidity of the raw material loaded into the reactor on the pyrolysis process was studied. It was found that with an increase in the humidity of the raw material, the amount of energy spent on the pyrolysis of the biomass increases.

The results of the conducted experimental studies showed that pyrolysis of sunflower waste reaches high intensity in the temperature range of 150-400 °C. The volume of liquid and gaseous fuel released during pyrolysis increases as the temperature rises. At the same time, the analysis of the experimental results showed that the total yield of pyrolysis products depends little on temperature changes in the range of 350-400 ° C. Thus, as a result of pyrolysis of 1 kg of sunflower waste loaded into the reactor during the experiment, 63% biochar, 10% liquid and 27% gaseous fuel were obtained.

The results of the analysis of the material balance of alternative types of fuel obtained by solar thermal processing of various types of biomass and hydrocarbon-

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containing waste loaded into the reactor of a solar pyrolysis plant are presented in Table 1.

Table 1

Results of the material balance

№	Type of loaded raw materials	Weight, m, kg	Initial humidity, %	Initial temperature, t, °C	Solar radiation, $q_r, W/mm^2$	Average temperature in the reactor, t_r, °C	Duration of the process, τ, min	Pyrolysis products		
								liquid, kg	Gaseous, kg	solid, kg
1	Rubber waste	1,0	5	20	984.2	384,3	150	0,20 (20%)	0,35 (35%)	0,45 (45%)
2	Bird droppings	1,0	20	20	945	337,14	180	0,1 (10%)	0,56 (56%)	0,34 (34%)
3	Polyethylene film	1,0	5	19	996	370,6	240	0,55 (55%)	0,45 (45%)	-
4	Coal	1,0	20	21	993	367,1	200	-	0, 54 (54%)	0.4 6 (46%)
5	Plastic bottles	1,0	5	19	1011,2	364,56	180	0,33 (33%)	0,4 (40%)	0,27 (27 %)
6	Plant waste (cotton stalks)	1,0	20	22	1004, 6	391,5	120	0,26 (26 %)	0,4 (40 %)	0,34 (34 %)

During the experiments, a high intensity of pyrolysis of biomass and hydrocarbon-containing waste was recorded in the temperature range of 200-450 °C, and an increase in the volume of liquid and gaseous fuel released during the pyrolysis process was noted as the temperature increased. The analysis of the experimental results allowed us to establish that the total yield of pyrolysis products depends little on temperature changes in the range of 350-450 °C. Thus, as a result of pyrolysis of 1 kg of rubber waste loaded within the framework of the experiment, 45 % of coal, 20 % of liquid and 35 % of gaseous fuels were obtained, from the same amount of chicken manure - 34% of coal, 10 % of liquid and 56 % of gaseous fuels, from polyethylene film - biochar is not released, 55% of liquid and 45% of gaseous fuel were obtained, from plastic bottles – 27 % of coal, 33 % of liquid and

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40 % of gaseous fuel, from plant waste (cotton stems) – 34 % of coal, 26 % of liquid and 40 % of gaseous fuel.

The duration of the pyrolysis process was on average 110-120 minutes. The conducted studies showed that on sunny days in the conditions of the city of Karshi, 3-4 cycles can be performed on the proposed installation.

The analysis of the results of the conducted scientific research and the performed technical and economic calculations showed that the use of a solar concentrator in pyrolysis units allowed to increase the energy efficiency of the unit by 10-12%. It was found that within one year, having processed 1 ton of products using a solar pyrolysis unit with a parabolic solar concentrator, it is possible to obtain 300-350 m^3 of gaseous fuel, 350-400 kg of pyrolysis liquid, and 200-300 kg of solid activated carbon. As a result of using a parabolic solar concentrator in a solar pyrolysis unit, heat savings in the amount of 2340,7 MJ (or 80-85 kg of conventional fuel) were achieved within a year, which was previously spent on the unit's own needs. At the same time, the possibility of generating 24327,25 MJ of thermal energy by using alternative types of fuel obtained using this installation from biomass and hydrocarbon-containing waste has been scientifically substantiated.

Conclusions

The conducted experimental studies show that the developed solar pyrolysis plant with a parabolic solar concentrator makes it possible to compensate for the energy spent on the plant's own needs for the implementation of the cycle in daytime mode, due to solar energy. As a result of the experimental studies conducted on the solar pyrolysis plant with a parabolic solar concentrator, samples of solid, liquid and gaseous fuel were obtained from sunflower waste by the pyrolysis method. During the year, using the proposed solar pyrolysis plant with a parabolic solar concentrator, up to 1 ton of sunflower waste was processed and 270-300 m^3 of gaseous, 100-150 kg of liquid and 550-600 kg of solid alternative fuel were produced. This solar pyrolysis plant with a parabolic solar concentrator is intended for clusters, farms and enterprises growing and processing sunflower.

The analysis of the experimental results allowed us to establish that the total yield of pyrolysis products depends little on temperature changes in the range of 350-450 °C. Thus, as a result of pyrolysis of 1 kg of rubber waste loaded within the framework of the experiment, 45% of coal, 20% of liquid and 35% of gaseous fuels were obtained, from the same amount of chicken manure - 34% of coal, 10% of liquid and 56% of gaseous fuels, from polyethylene film - biochar is not released, 55% of liquid and 45% of gaseous fuel were obtained, from plastic bottles - 27% of coal, 33% of liquid and 40% of gaseous fuel, from plant waste (cotton stems) - 34% of coal, 26% of liquid and 60% of gaseous fuel.

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It has been established that with the help of a solar pyrolysis unit with a parabolic solar concentrator it is possible to obtain 300÷350 m^3 of gaseous fuel, 350÷400 kg of pyrolysis liquid, and 200÷300 kg of solid alternative fuel for household needs of residential buildings of the population and consumers located far from centralized power supply networks (dehkan and farming enterprises). As a result of the practical implementation of the unit, it has become possible to save 917÷1000 kg of equivalent fuel per year.

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