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DEVELOPMENT OF A TECHNOLOGY FOR COMPLEX PROCESSING OF DECOMPOSITION PRODUCTS OF LIQUID ORGANIC WASTE IN AN ELECTRIC ARC

In the modern world, the continuous increase in population leads to a rise in resource consumption. However, the consumption of both non-renewable and renewable sources results in an increase in the amount of waste. In the present research, the plasma gasification of selected solid municipal waste was studied as a method of plasma chemical processing. As a result of the conducted experiments, high-calorific synthesis gas, which can be used for various purposes, was obtained from the waste. In addition, the slag derived from the process can be used in the construction industry and road building.

Keywords: waste, utilization, plasma chemical processing, plasma gasification, high-calorific synthesis gas, slag, plasma reactor

Introduction

In the early periods of human existence, waste did not accumulate to levels that could cause negative changes in the environment. However, population growth and scientific-technical progress have led to such a large amount of waste entering the environment that it exceeds the capacity of natural ecosystems. The problem worsens as increasing amounts of substances that are difficult or impossible to decompose through natural processes are produced. Each person living on Earth uses approximately 20 tons of various natural resources annually to meet their needs for food, clothing, shelter, and daily requirements. Global mineral extraction doubles every 15 years. Accordingly, the volume of waste increases, which can be conventionally divided into industrial and household waste [1-4].

At present, there are many different methods for the utilization of industrial and household waste. At the initial stage, part of the waste is recycled, but the majority is subjected to various disposal and neutralization methods. Each method has its own advantages and disadvantages and is used depending on the chemical composition, physical properties of the waste, and the degree of its harmful impact on surrounding ecosystems [5, 6].

The purpose of the present research is to study the plasma chemical processing of waste through the application of plasma gasification technology. Carbon-based solid municipal waste was selected as the main research object.

Methodology of the experiment

The plasma-chemical process flow diagram for recycling household waste is based on plasma waste gasification technology, which produces high-calorific synthesis gas ($CO + H_2$) with a yield of up to 90% vol. and a calorific value of 8-14 MJ/m^3. The use of syngas as a fuel in power boilers, gas turbine units (GTUs), and new-generation electric generators based on

solid oxide fuel cells enables the generation of thermal and/or electrical energy with an efficiency exceeding that of existing thermal power plants. High temperatures in the plasma reactor's reaction zone (1300-1500 ºC) inhibit the formation of carcinogenic substances (dioxin, furans) and ensure the production of liquid slag, followed by granulation, with inert properties, allowing its use in the construction and road construction industries.

The proposed installation includes a shaft-type plasma furnace with a plasma torch, a system for cooling and cleaning exhaust gases, a device for cooling and granulating slag, a gas and water supply system for the plasma torch and the furnace casing.

The characteristic composition of the carbon-based waste taken as the research object is as follows: paper and cardboard – 34.3%; food waste – 21.2%; glass – 2.05%; iron oxides – 3%; plastic mass – 13.2%; wood – 5.1%; leather, rubber, and other combustible materials – 16%; textiles – 2%; calcium carbonate – 2%. The chemical composition of the raw material used is shown in Table .

Table

Chemical composition of carbon-based waste (in % (wt.))

C	H	O	N	S	Cl	H_2O	Fe_2O_3	SiO_2	$CaCO_3$
34.15	5.85	6.29	8.16	0.94	5.3	32.31	3.0	2.0	2.0

The calculations were performed in the temperature range of 300–3000 K and at a pressure of 0.1 MPa. For the following initial technological mixtures, the steam and air gasification of carbon-based waste was calculated:

1) 10 kg waste + 4 kg air

2) 10 kg waste + 1 kg steam

The technological scheme of the plasmochemical processing of waste is based on plasma gasification technology. The scheme includes a plasma reactor, a waste feeding system, service systems ensuring the operation of the electric arc plasmatron, a system for cleaning waste gases in a scrubber, and systems for collecting slag and sludge.

Waste processing capacity: 10 kg/hour

Power of the plasma generator: 60–100 kW

Consumption of produced synthesis gas: 20–25 m³/hour

Temperature of waste gases: 1200–1300°C

Results and discussion

The technological scheme of the plasma chemical processing of waste is based on plasma gasification technology, which makes it possible to obtain high-calorific synthesis gas ($CO + H_2$) with a yield of up to 90% (by volume) and a heating value of 8–14 MJ/m³. Using synthesis gas as fuel in boilers, gas-turbine units, and next-generation solid-oxide fuel-cell-based electric generators allows the production of thermal or electrical energy with higher efficiency compared to that generated in existing thermal power plants.

The high temperature (1300–1500°C) in the reaction zone of the plasma reactor prevents the formation of carcinogenic substances (dioxins, furans) and ensures the formation of molten slag. This slag can later be granulated and used in road construction and the construction industry.

Air with a consumption rate of 12 kg/hour is used as the plasma-generating gasifying agent. The power of the plasmatron is 72 kW. After heating the reactor for 15 minutes, 20 waste briquettes with a total mass of 8 kg are sequentially fed through the pipes. Under the influence of the air plasma torch, an average temperature of 1600 K is achieved in the chamber, during which the organic portion of the waste is gasified, while the inorganic

portion melts and forms slag inside the reactor. The produced synthesis gas is continuously discharged from the system through the cooling and purification unit. After the plasmatron is switched off and the reactor is cooled, the molten mineral residue of the waste is removed from the reactor.

Depending on the composition of the waste, it is possible to obtain from 0.8 to 1.4 Nm^3 of dry synthesis gas from 1 kg of waste. Its calorific value may vary from 6000 to 14000 MJ/Nm^3. The composition of the obtained synthesis gas (in vol%) is as follows: H_2 – 50–55%; CO – 30–35%; CO_2 – 5–7%; N_2 – 5–7%.

As a result of the analysis, the slag was found to have the following composition (in %(wt.)): Fe_3C – 63; $CaSiO_3$ – 21; SiO_2 – 13; Fe – 3. The carbon content in the slag sample was experimentally determined to be 2.8 wt%, which corresponds to the degree of waste carbon gasification. The difference between the experimental and theoretical values of the carbon gasification degree is 9%. No harmful impurities were detected in the gaseous or condensed products of plasma gasification. The specific energy consumption for the gasification of waste in the plasma reactor ranged from 2.25 to 4.5 kWh/kg. In the calculation, the energy consumption for air-plasma gasification of carbon-containing waste was 1.92 kW h/kg. Such a significant discrepancy between the calculated and experimental values of specific energy consumption for the process is explained by the fact that in thermodynamic calculations the minimum possible energy consumption in an isolated thermodynamic system is determined without taking into account the exchange of heat and work with the environment. In practice, both the plasma reactor itself and the plasma torch are characterized by significant heat losses into the environment with cooling water. In addition, the experimental specific energy consumption takes into account the energy consumption for preheating the reactor before feeding carbon-containing waste. In the second and subsequent cycles of processing carbon-containing waste, there will be no additional costs for preheating the reactor. In this case, the discrepancy between the experimental and calculated values of specific energy consumption for plasma gasification of carbon-containing waste will be about 15%.

Result

Thus, the conducted research has shown that during plasma gasification of waste in air and steam environments, the maximum yield of synthesis gas is obtained at temperatures of 1600–1800 K. During air–plasma gasification, it is possible to obtain high-calorific synthesis gas with a concentration of 82.4% (CO – 31.7%, H_2 – 50.7%), while during steam–plasma gasification, synthesis gas with a concentration of 94.5% (CO – 33.6%, H_2 – 60.9%) can be produced. The specific heating value of the synthesis gas obtained during air gasification is 3410 kcal/kg, while that of the gas obtained during steam gasification is 4640 kcal/kg.

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РАЗРАБОТКА ТЕХНОЛОГИИ ДЛЯ КОМПЛЕКСНОЙ ОБРАБОТКИ ПРОДУКТОВ РАЗЛОЖЕНИЯ ЖИДКИХ ОРГАНИЧЕСКИХ ОТХОДОВ В ЭЛЕКТРОДУГЕ

РЕЗЮМЕ

Ключевые слова: отходы, утилизация, плазменно-химическая обработка, плазменная газификация, высококалорийный синтез-газ, шлак, плазменный реактор

В современном мире непрерывный рост населения приводит к увеличению потребления ресурсов. Однако потребление как невозобновляемых, так и возобновляемых источников энергии приводит к увеличению количества отходов. В данном исследовании изучалась плазменная газификация отдельных твердых бытовых отходов как метод плазмохимической обработки. В результате проведенных экспериментов из отходов был получен высококалорийный синтез-газ, который может быть использован для различных целей. Кроме того, шлак, образующийся в результате этого процесса, может использоваться в строительной промышленности и при укладке дорог.

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MAYE ÜZVİ TULLANTILARIN ÇÖKMƏ MƏHSULLARININ ELEKTRİK QÖVSÜNDƏ KOMPLEKS EMALI TEXNOLOGİYASININ İŞLƏNİB HAZIRLANMASI

XÜLASƏ

Açar sözlər: tullantılar, utilizasiya, plazmokimyəvi emal, plazmalı qazlaşdırılma, yüksək kalorili sintez-qaz, şlak, plazma reaktoru

Müasir dünyada əhalinin getdikcə artması resurs istehlakının getdikcə artmasına səbəb olur. Bununla belə, həm bərpa olunmayan, həm də bərpa olunan mənbələrin istehlakı tullantıların miqdarının artmasına səbəb olur. Mövcud tədqiqat işində sınaq obyekti götürülmüş bərk məişət tullantılarının plazmalı qazlaşdırılması yolu ilə onların plazmokimyəvi emalı prosesi tədqiq edilmişdir. Aparılmış tədqiqatlar nəticəsində tullantılardan müxtəlif məqsədlər üçün istifadə oluna biləcək yüksək kalorili sintez-qaz alınmışdır. Bundan başqa prosesdən alınan şlakdan tikinti sənayesində və yolların çəkilməsində istifadə etmək olar.

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