Матеріали XXV Міжнародної науково-практичної конференції «Екологія. Людина. Суспільство» пам'яті д-ра Дмитра СТЕФАНИШИНА (12 червня 2025 р., м. Київ, Україна)

Proceedings of the XXV International Science Conference «Ecology. Human. Society» dedicated to the memory of Dr. Dmytro STEFANYSHYN (June 12 2025, Kyiv, Ukraine)

ISSN (Online) 2710-3315
https://doi.org/10.20535/EHS2710-3315.2025.331622

SUBSTITUTION OF FOSSIL FUELS THROUGH THE GASIFICATION OF CARBON-CONTAINING RAW MATERIALS

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Abstract

The study explores technologies based on the gasification of local fuels to advance renewable energy utilization, supporting global and EU goals to increase renewable energy consumption to 40-45% by 2030. The Department of Alternative Fuels Technology at the Gas Institute of Ukraine is developing two key technologies: electricity generation using generator gas in piston power plants and synthesis gas production for chemical applications. A test-industrial installation demonstrated electrical efficiency of 22-24% when operating on fuels such as wood chips, lignite, and sunflower husk pellets. Emission levels (CO and NOx) met or exceeded EURO-5 standards but slightly underperformed against EURO-6. An industrial system with a capacity of 75 kW is currently under testing. In the second focus area, the team optimized gasification conditions (850-950°C) to produce synthesis gas with a [H_2] : [CO] ratio close to 2:1. Experiments with diverse carbon-containing materials, including rubber from used tires, showed potential for high-calorie gas production and waste utilization. Rubber gasification yielded a gas with a lower heating value of 9804 kJ/m³ and produced a coke residue with 85% carbon content. These findings highlight the versatility of gasification technology for generating electricity and producing feedstock for the chemical industry. The developed solutions demonstrate the feasibility of replacing traditional fuels with sustainable alternatives, contributing to both energy security and environmental protection.

Keywords: *gasification, biofuels, renewable resources, synthesis gas.*

In recent decades, the development of the energy industry around the world has been moving towards renewable energy sources. As an example, we can take the European Union directive on the promotion of energy from renewable sources. This directive. Prescribes an increase in the Consumption of energy from renewable energy sources. Up to 40% by 2030. And also calls for. Collective actions by countries to increase this figure to 45% [1].

The Department of Alternative Fuels Technology of the Gas Institute of the National Academy of Sciences of Ukraine is developing 2 technologies based on the gasification process of local types of fuel:

- electricity generation;
- production of generator gas, close in properties to synthesis gas, for further use in the chemical industry.

The main focus of the Alternative Fuels Technology Department is to generate electricity by using generator gas obtained from local fuels at a piston power plant to create autonomous or mobile sources of electrical energy. Figure 1 shows a photograph and a schematic diagram of this installation. The basis of the installation is a periodic gas generator 1. The generator gas cleaning system includes a heat exchanger-cooler 2, a coarse filter 3 and a fine filter 4, after which the purified generator gas enters a generator based on a piston machine 5.

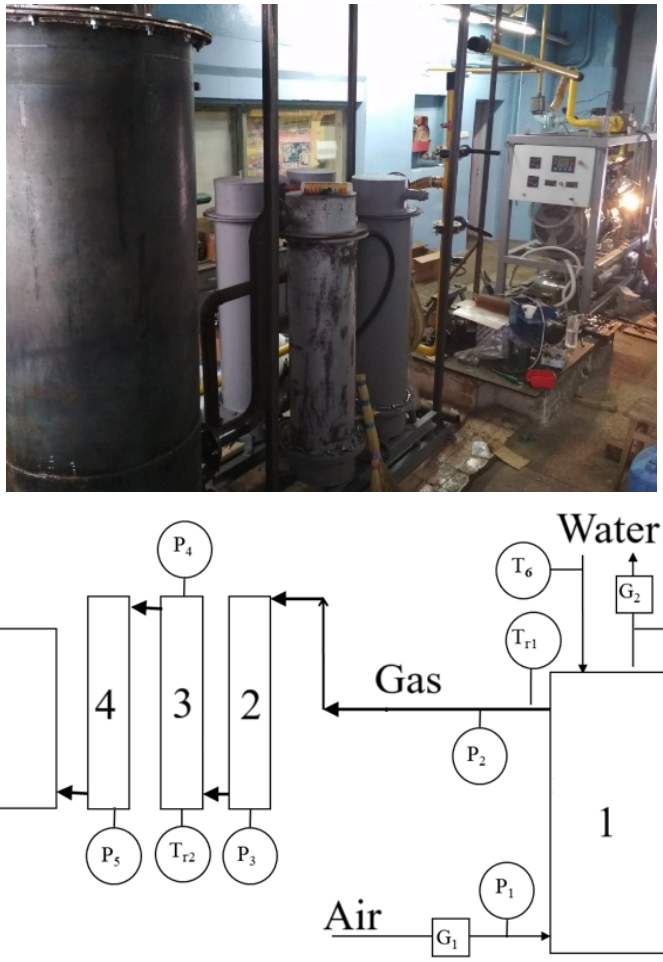

Fig. 1. *Photograph and schematic diagram of a plant for generating electrical energy based on biofuel gasification and using the resulting generator gas i n a piston machine with an electric generator*

Tests conducted on this unit showed the possibility of the unit operating on various types of fuel such as wood chips, sunflower husk pellets, straw, lignite and other. Data obtained during the tests are shown in Fig. 2 and indicate that the electrical efficiency of this unit reaches 22-24% in the optimal mode. The environmental aspect should also be noted: emissions of this unit are CO – 2.58 g/kW*h, and NOx – 0.76 g/kW*h. Which exceeds EURO-5: CO – 4.0 g/kW*h, NOx – 2.0 g/kW*h; but is slightly lower than EURO-6: CO – 4.0 g/kW*h, NOx – 0.4 g/kW*h [2]. Currently, an industrial installation with a capacity of 75 kW for electricity is being tested.

The second area of work of the department is obtaining generator gas with a given ratio of $[H_2]$:[CO].

For the research, design documentation has been developed and a gasification section has been manufactured (Fig. 3) consisting of: gas generator (1), heat exchanger (2), fine gas filter (3). A series of studies was conducted that allowed determining the optimal temperature regimes and fuel/oxygen concentration ratios for regulating the parameters of gaseous gasification products. It was determined that operation in the 850...950°C mode allows obtaining synthesis gas with characteristics [H_2] : [CO] close to 2:1 [3].

The results of gasification of a wide range of carbon-containing resources are presented: lignite, brown coal, rubber from used automobile tires, RDF, wood chips and pellets. Component ratio of acquired gas from conducted experiments presented on Fig. 4.

Results of rubber gasification allowed us to propose this process as a possible one for the utilization of used tires. During the gasification of rubber, high-calorie gas and coke residue are formed, the carbon content of which reaches 85%. Properties of the obtained generator gas when tested on rubber are presented in table 1.

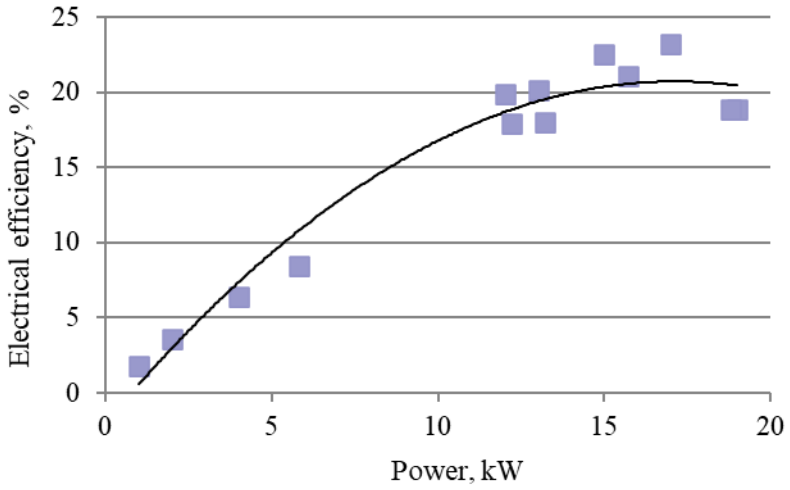

Fig. 2. *Dependence of electrical efficiency on the power of the test-industrial installation*

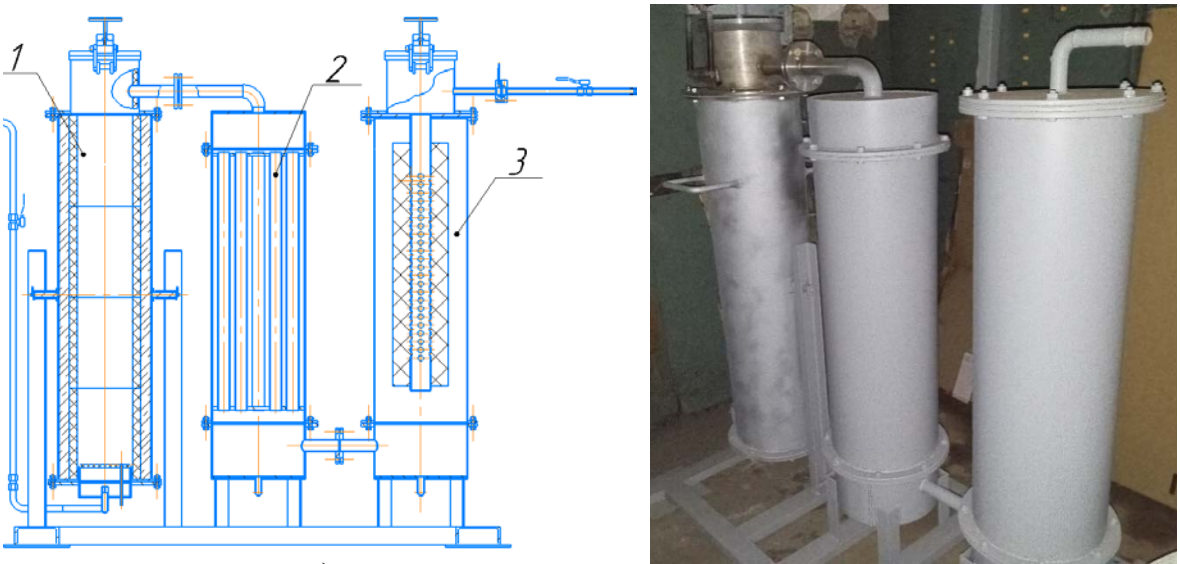

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Fig. 3. *Assembly drawing (a) and working section (b) of gasification*

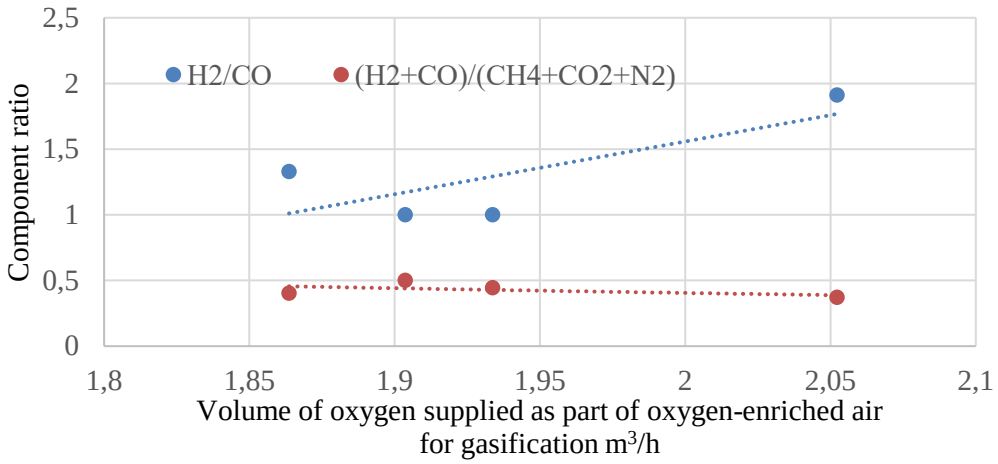

Fig. 4. *Dependence of the ratio of key gas components for the synthesis reaction on the volume of blowing air enriched with oxygen*

Table 1. Title of table in English

Component	**Rubber, %**
H_2	12,59
N_2	56,74
CO	2,49
CH_4	11,65
CO_2	6,00
H_2S	1,22
C_2H_4	4,73
C_2H_2	0,35
C_2H_6	1,25
C_3H_6	0,01
C_3H_8	0,53
iC_4H_{10}	0,42
nC_4H_{10}	0,23
iC_5H_{12}	0,01
neo C_5	0,00
H_2O	1,78
Lower heating value	9804 kJ/m^3

Conclusions

The developed technological solutions involve the use of a periodic gas generator, in which the reverse gasification process is implemented. The results of the research concluded that ehis technology can be used both to obtain electrical energy with indicators close to existing installations on traditional fuel and to obtain generator gas as a raw material for the chemical industry.

References

[1] Directive (EU) 2023/2413 of the European Parliament and of the Council of 18 October 2023 amending Directive (EU) 2018/2001, Regulation (EU) 2018/1999 and Directive 98/70/EC as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652PE/36/2023/REV/2OJ L, 2023/2413, 31.10.2023,
ELI: http://data.europa.eu/eli/dir/2023/2413/oj

[2] Regulation (EC) No 595/2009 of the European Parliament and of the Council of 18 June 2009 on type-approval of motor vehicles and engines with respect to emissions from heavy duty vehicles (Euro VI) and amending Regulation (EC) No 715/2007 and Directive 2007/46/EC and repealing Directives 80/1269/EEC, 2005/55/EC and 2005/78/EC (Text with EEA relevance)
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[3] Mahmoudi, Hamid, Mahmoudi, Maedeh, Doustdar, Omid, Jahangiri, Hessam, Tsolakis, Athanasios, Gu, Sai and LechWyszynski, Miroslaw. "A review of Fischer Tropsch synthesis process, mechanism, surface chemistry and catalyst formulation" Biofuels Engineering, vol. 2, no. 1, 2017, pp. 11-31.
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ЗАМІЩЕННЯ ВИКОПНОГО ПАЛИВА ШЛЯХОМ ГАЗИФІКАЦІЇ ВУГЛЕЦЕВОМІСНОЇ СИРОВИНИ

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Анотація

У дослідженні розглядаються технології, засновані на газифікації місцевих видів палива, для розвитку використання відновлюваної енергії, що підтримує глобальні та європейські цілі щодо збільшення споживання відновлюваної енергії до 40-45% до 2030 року. Відділ технології альтернативних видів палива Газового інституту України розробляє дві ключові технології: виробництво електроенергії з використанням генераторного газу в поршневих електростанціях та виробництво синтез-газу для хімічного застосування. Тестово-промислова установка продемонструвала електричний ККД 22-24% при роботі на такому паливі, як деревна тріска, буре вугілля та гранули з лушпиння соняшнику. Рівні викидів (CO та NOx) відповідали або перевищували стандарти EURO-5, але дещо поступалися EURO-6. Наразі проходить випробування промислова система потужністю 75 кВт. У другій галузі дослідження команда оптимізувала умови газифікації (850-950°C) для отримання синтез-газу зі співвідношенням [H2]:[CO], близьким до 2:1. Експерименти з різноманітними вуглецевмісними матеріалами, включаючи гуму з використаних шин, показали потенціал для виробництва висококалорійного газу та утилізації відходів. Газифікація гуми дала газ з нижчою теплотворною здатністю 9804 кДж/м³ та коксовий залишок з 85% вмістом вуглецю. Ці результати підкреслюють універсальність технології газифікації для виробництва електроенергії та сировини для хімічної промисловості. Розроблені рішення демонструють можливість заміни традиційних видів палива екологічно чистими альтернативами, що сприяє як енергетичній безпеці, так і захисту навколишнього середовища.

Ключові слова: газифікація, біопаливо, відновлювані ресурси, синтез-газ.