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COMPARATIVE ANALYSIS OF GASEOUS FUELS COMBUSTION HEAT

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Abstract. *The estimation of the calorific value of gaseous fuels such as pyrolysis gas, biogas, landfill gas, natural shale gas was done. The results showed that the calorific value of pyrolysis gas was comparable to the calorific value of biogas and shale gas.*

Key words: *calorific value, pyrolysis gas, biogas, shale gas, utilization of tyres.*

СРАВНИТЕЛЬНЫЙ АНАЛИЗ ТЕПЛОТЫ СГОРАНИЯ ГАЗООБРАЗНЫХ ТОПЛИВ

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Аннотация. *Проведена оценка теплотворной способности газообразных топлив, таких как пиролизный газ, биогаз, свалочный газ, природный сланцевый газ. Полученные результаты показали, что теплотворная способность пиролизного газа сопоставима с теплотворной способностью биогаза и сланцевого газа.*

Ключевые слова: *теплотворная способность, пиролизный газ, биогаз, сланцевый газ, утилизация шин.*

ПОРІВНЯЛЬНИЙ АНАЛІЗ ТЕПЛОТИ ЗГОРЯННЯ ГАЗОПОДІБНИХ ПАЛИВ

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Анотація. *Проведено оцінку теплотвірної здатності газоподібних палив, таких як піролізний газ, біогаз, звалочний газ, природний сланцевий газ. Отримані результати показали, що теплотвірна здатність піролізного газу є порівняною з теплотвірною здатністю біогазу і сланцевого газу.*

Ключові слова: *теплотвірна здатність, піролізний газ, біогаз, сланцевий газ, утилізація шин.*

Introduction

The problem of energy independence is an important one in energy policy of Ukraine and many countries. This is directly related to the sharp rise in price obtained while crude oil and petroleum products processing.

In this regard there arises the necessity to create technologies and equipment for getting heat and electricity based on renewable and therefore cheaper and readily available raw materials.

Methods and technologies allowing to obtain energy from recycled materials as well as domestic and industrial wastes (waste wood, agricultural production) whose value now is around 10 times lower than the cost of petroleum products are being widespread in the world. They are used to solve environmental problems like waste utilization and maintaining clean and healthy environment and economic problems of reducing scarce energy resources exploitation. [1]

Analysis of publications

The replacement of natural gas with alternative energy source, namely: pyrolysis gas, landfill gas, biogas and natural shale gas is one of the examples of rational and relevant solution of the problem of energy dependence on traditional fuels.

Technologies of waste utilization with secondary products such as flammable gases have long been used in the developed European countries and the United States of America [2].

There were done many proposals of pyrolysis installations last years in Ukraine.

Main indicators of some pyrolysis installations were analyzed by us and presented in table 1.

Table 1 The amount of products formed by pyrolysis installations

Installation	Power, (*t*/day)	Productivity per day, *t*		
		slag	liquid	gas
ECO-2006	4	0,8	2,9	0,7
Alpha	3	1,4	0,98	0,16
Biodiesel	1	0,5	0,3	0,05
Green Power	1	0,45	0,25–0,3	0,1–0,15
Pyrotex	5	1,35	2,75	0,9
Antval	3	0,9	1,8	0,3
Antval	7	2,7	4,2	1,8
Konstanta	6	1,42	1,92	1,1

As it is seen from the Table 1and earlier researches [3, 4] the power of installation, output of goods (slag, liquid and gas), physical and chemical characteristics varied at different installations.

Installations manufacturers have said that all three products are commercial goods and pyrolysis gas is similar in properties to natural gas. Pyrolysis gas is used for industrial processes at installations and it remains are burned [4].

There is no unified view of the possible use of the pyrolysis products as follows from previous studies. In the previous work I was analyzed the environmental and economic assessment of pyrolysis liquid [5].

The purpose and problem statement

The purpose of this paper is to give a comparative analysis of the calorific value of different types of alternative fuels including pyrolysis gas formed at various Ukrainian installations and to determine the possibility of their practical use.

Objectives of the work include:
– Calculation of calorific value of pyrolysis gas;
– Calculation of calorific value of alternative gaseous fuels such as landfill gas, biogas, natural shale gas, coke oven gas;
– Comparative analysis of properties of different alternative gaseous fuels. And compare their calorific value to calorific value of natural gas.

Comparative analysis of gaseous fuels combustion heat

The equation D.I. Mendeleyev to calculate the calorific value of gases was used [6].

This formula includes the volume of gases and heat of their combustion. Only those components emitting heat during combustion were considered, gases such as CO_2, N_2, O_2 and water vapor are the ballast, and their presence leads to decrease at combustion temperature.

$$Q = 358CH_4 + 640C_2H_6 + 915C_3H_3 + \\ +1190C_4H_{10} + 1465C_5H_{12} + 126,5CO + \\ +107,5H_2 + 234H_2S\left(\frac{\text{KJ}}{\text{m}^3}\right). \quad (1)$$

$$Q = 398CH_4 + 700C_2H_6 + 995C_3H_8 + \\ +1285C_4H_{10} + 1575C_5H_{12} + 126,5CO + \\ +107,5H_2 + 257H_2S\left(\frac{\text{KCal}}{\text{m}^3}\right). \quad (2)$$

Where Q – calorific value of gas, KJ/m^3, KCal/m^3;
C_nH_m – hydrocarbon content in the gas, %;
CO – content of carbon oxide in the gas, %;
H_2S – content of hydrogen sulfide in gas, %;
H_2 – content of hydrogen content in gas, %.

The calorific value of alternative gaseous fuels such as landfill gas, biogas, pyrolysis gas and shale gas has been calculated for comparative analysis. That is why these waste utilization technologies are used in Ukraine today. Results of calculation are presented in Table 2.

As it is seen from Table 2 the calorific value of alternative gaseous fuels is substantially (2–5 times) lower than that value of standard fuel – natural gas.

Table 2 Comparative analysis of various gases combustion heat

Company		Gas composition, %			Net Calorific Value, m^3
		CH_4	H_2	CO	
NATURAL GAS					33 080
PYROLYSIS GAS					
South-Ural Ltd.		7	25	18	7 470,5
Iron Ltd.	min	5	15	15	5 300
	max	10	20	25	8 892,5
Neroaera	min	33	12	11	14 495,5
	max	45	28	18	21 397
Energy Ltd.		24	17	4	22 734,7
A ALPHA – UKRAINE Ltd.		35	18	4	29 154,3
Energomash Ltd.		38	82	47	28 364,5
SHALE GAS					
Linde Group	min	14	25	10	8 964,5
	max	17	40	20	12 916
BIOGAS					
Mediana PM Ltd. Russia	min	50	0		17 900
	max	80	1		28 747,5
Euro diesel Ltd. Ukraine	min	40	0		14 320
	max	75	1		26 957,5
LANDFILL GAS					
Gengas OY	min	40	0		14 320
	max	70	1		25 167,5
TIS Eco	min	50	0		17 900
	max	75	1		26 957,5
Nedra Luganska Ltd.	min	40	0		14 320
	max	60	1		21 587,5

Calorific value of pyrolysis gas can be almost the same as the calorific value of natural gas, but may be 6 times less.

The value ranges from 5 250 to 29 155 kJ/m^3. Pyrolysis gas with the lowest calorific value of 5 300 kJ/m^3 (Iron Ltd.) can only be used for industrial process at installations.

The calorific value of pyrolysis gas by the Alpha Energy and Energomash Ltd. installations is comparable and exceed the shale gas combustion heat in 2 times. This suggests that the pyrolysis gas can be used in the same sectors of the economy that natural shale gas.

It is known that Ukraine possesses substantial reserves of shale gas and it is intensive development being planned coming years [7].

Recently, biogas is used both in Europe and the United States of America as a substitute for natural gas. As it is seen from Table 2 the calorific value of pyrolysis gas is close to the calorific value of biogas.

So, the practical use of pyrolysis gas prevents the small volume of its formation at pyrolysis plants with capacity from 1 to 7 tons/day. The volume of gas does not exceed 2 t/day.

It is known that Alpha Ltd. offers installations of tire recycling capacity of 20 ton/day, with the pyrolysis gas amount of 5 t/day in Ukraine. In this case the pyrolysis gas can be used for industrial purposes.

Conclusion

After completing this work we have the following results:

– It has been proved that the calculated calorific value of pyrolysis gas is 2–6 times lower then the calorific value of natural gas;

– It was found that the calorific value of pyrolysis gas is comparable to the calorific value of biogas, and exceed 2 times the calorific value of the shale;

– Ukraine releases installations which can produce 100 ton of pyrolysis gas a day. Pyrolysis gas from such installations can be applied in economy fields using biogas, landfill gas and shale gas.

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