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STUDY OF THE PROCESS OF ELECTRIC PULSE CLEANING OF INTERNAL COMBUSTION ENGINE EXHAUST GASES

Abstract: The paper presents the results of experiments carried out on the developed equipment, which makes it possible to study the parameters of exhaust gas purification by electric pulse. The general structure of the electric-pulse cleaning stand with moving electrodes, the description of the principle of its operation is given. The analysis of the results of the experiments makes it possible to draw a conclusion about the effectiveness of electric-pulse purification of exhaust gases and determine the optimal modes of operation of electric-pulse equipment of the designed systems of internal combustion engine exhaust gas purification.

Keywords. Internal combustion engine, exhaust gases, toxicity, electric pulse, cleaning

Introduction.

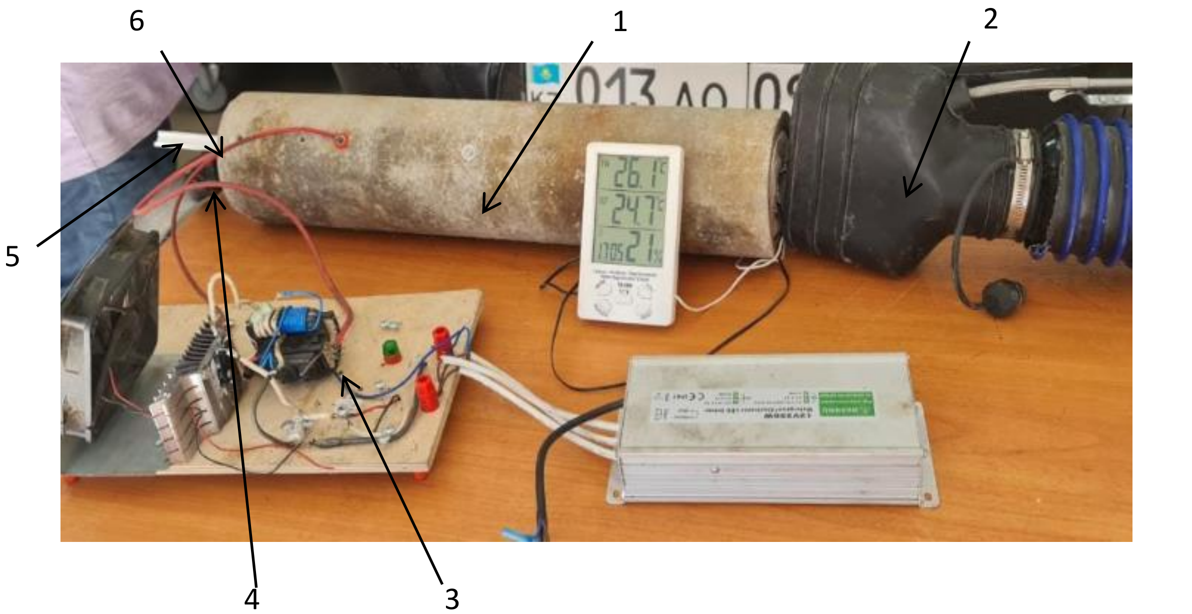
One of the significant sources of environmental pollution is motor transport equipped with internal combustion engines. Exhaust gas includes many chemical compounds, numbering more than 300 components. The most toxic components of internal combustion engine exhaust gases are nitrogen oxides, soot, hydrocarbons, carbon monoxide, hydrocarbons, etc. [1,2] There are several ways to clean the exhaust gases. The most widespread are the methods of catalytic neutralization, which are quite effective, but at the same time one of the most expensive [3,4]. Therefore, there is a necessary to find alternative methods of purification of exhaust gases of internal combustion engines. Known method of gas purification by electric impulse, the operating principle of which is based on generation of static charges, well-proven in the industry when cleaning gases from suspended particles [5,6,7]. The aim of the study was to determine the parameters of electric-pulse purification of exhaust gases depending on the mode of engine operation and the distance between the electrodes. Scientific novelty lies in determining the dependence of the efficiency of the electric-pulse method for cleaning of exhaust gases of internal combustion engines on the design parameters of electric-pulse equipment.

Materials and methods.

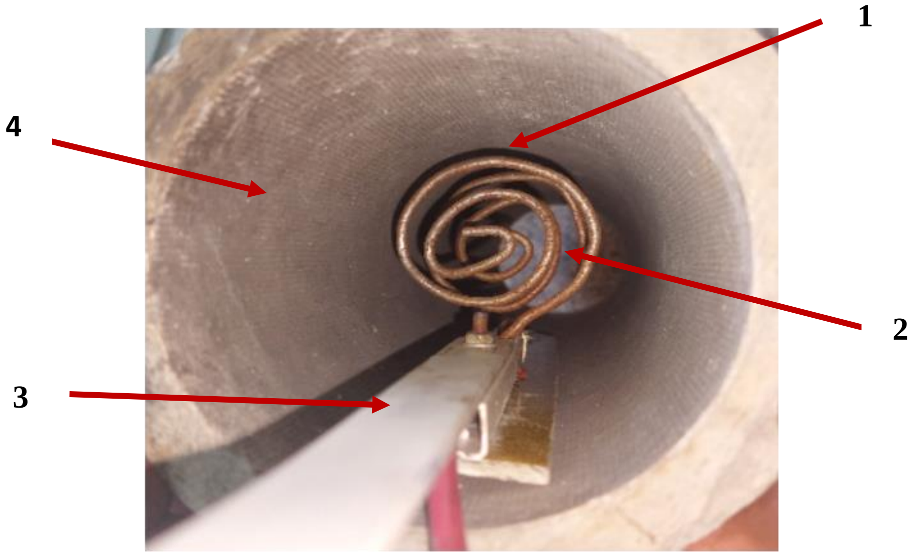
We have developed an electric pulse cleaning bench with moving electrodes (Figure 1), which allows to take a number of indicators of the content of substances in exhaust gases at different crankshaft speeds and distances between the electrodes [8].

Installation (Figure 1) consists of a cylindrical body 1, made of asbestos, which has low electrical conductivity; inlet 6 and outlet 2 holes for the passage of exhaust gases; high voltage generator 3; batten rail 5 to change the distance between the electrodes.

Location of spiral electrodes inside the electropulse unit is shown in Figure 2. On a special bar rail 3 (Figure 2) are mounted two electrodes 1, 2 (Figure 2), to which from the generator 3 (Figure 1) by high-voltage wires 4 is fed an electric current of high voltage. Exhaust gas entering through the inlet opening 2 in the experimental setup is exposed to an electric field of high voltage. As a result, shock ionization and changing of the exhaust gas composition take place. The purified gas exits into the atmosphere through the exhaust port 3.



1 - cylindrical body; 2 - exhaust port; 3 - high voltage generator; 4 - high- voltage wires; 5 - bar-rail to change the distance between the electrodes; 6 - inlet port
Figure 1 - Stand for electric pulse cleaning with moving electrodes



1 - anode; 2 - cathode; 3 - rail to change the distance between the electrodes; 4 - inside surface of the unit body
Figure 2 - Arrangement of spiral electrodes inside the electropulse stand:

The tests were conducted in three stages:
- the first stage, in which the toxicity of the exhaust gases at 700 rpm was determined;
- the second stage, in which the toxicity of the exhaust gases at 1400 rpm was determined;
- the third stage, in which the toxicity of the exhaust gases at 1900 rpm was determined.

At each stage in determining the toxicity of the exhaust gas using a gas analyzer, the values of the excess air ratio λ, oxygen content O_2, % vol, carbon dioxide CO_2, % vol, hydrocarbons HC, ppm vol, carbon monoxide (carbon monoxide) CO, % vol were determined.

The plan of the experiment [9] is presented in Table 1.

Table 1 - Plan of the experiment

Stage	Operations
1	2
Preparatory Stage	1. To start the internal combustion engine and wait until the coolant is at operating temperature
	2. To connect the diagnostic complex to the vehicle
	3. To connect the experimental bench to the silencer of the car
The first stage (at 700 rpm)	4.Measure the toxicity of exhaust gases at 700 rpm of the engine crankshaft
	5. To reset the gas analyzer to zero
	6. To set the distance between the electrodes R=0.002 m
	7.Turn on the experimental bench and measure the toxicity of exhaust gases
	8.Reset the gas analyzer to zero
	9. To set the distance between the electrodes R=0.004 m
	10. Turn on the experimental bench and measure the toxicity of exhaust gases
	11. To reset the gas analyzer to zero
	12. To set the distance between the electrodes R=0.006 m
	13.Turn on the experimental bench and measure the toxicity of exhaust gases
	14.Record and process the results
The second stage (at 1400 rpm)	15.Increase the engine speed to 1400 rpm of the engine crankshaft
	16. Measure the toxicity of exhaust gases at 1400 rpm of the engine crankshaft
	17. To reset the gas analyzer to zero
	18. To set the distance between the electrodes R=0.002 m
	19. Turn on the experimental bench and measure the toxicity of exhaust gases
	20. To reset the gas analyzer to zero
	21. To set the distance between the electrodes R=0.004 m
	22. Turn on the experimental bench and measure the toxicity of exhaust gases
	23. To reset the gas analyzer to zero
	24. To set the distance between the electrodes R=0.006 m
	25. Switch on the experimental bench and measure the toxicity of exhaust gases
	26. Record and process the results
Stage Three (at 1900 rpm)	27. Increase the engine speed to 1900 rpm of the engine crankshaft
	28. Measure the toxicity of exhaust gases at 1900 rpm of the engine crankshaft
	29. To reset the gas analyzer to zero
	30. To set the distance between the electrodes R=0.002 m
	31. Turn on the experimental bench and measure the toxicity of exhaust gases
	32. To reset the gas analyzer to zero
	33. To set the distance between the electrodes R=0.004 m
	34. Switch on the experimental bench and measure the toxicity of exhaust gases
	35. To reset the gas analyzer to zero
	36. To set the distance between the electrodes R=0.006 m
	37. Turn on the experimental bench and measure the toxicity of exhaust gases
	38. Record and process the results

Results and discussions.

Table 2 shows the results of the first stage of the experiment conducted on a gasoline engine at engine crankshaft speed n=700 rpm without the effect of the electric pulse and with the effect of the electric pulse at different values of the interelectrode distance R.

Table 2 - Results of the first stage of the experiment, conducted on a gasoline engine

Measured parameter	Engine speed, n=700 rpm			
	Without exposure to an electrical impulse	Distance between electrodes, R=0,002 m	Distance between electrodes, R=0,004 м	Distance between electrodes, R=0,006 м
λ	1,134	1,395	1,304	1,300
O_2, % vol	2,97	6,42	5,34	5,29
CO_2, % vol	12,45	10,22	10,86	10,83
HC, ppm vol	280	236	241	252
CO, % vol	0,298	0,256	0,268	0,281

The second stage of the experiment yielded the data shown in Table 3.

Table 3 - Results of the second stage of the experiment, conducted on the gasoline engine

Measured parameter	Engine speed, n=1400 rpm			
	Without exposure to an electrical impulse	Distance between electrodes, R=0,002 m	Distance between electrodes, R=0,004 м	Distance between electrodes, R=0,006 м
λ	1,065	1,069	1,055	1,211
O_2, % vol	1,81	1,89	1,64	4,05
CO_2, % vol	13,4	13,11	13,25	11,53
HC, ppm vol	209	206	211	180
CO, % vol	0,445	0,476	0,493	0,374

As a result of the third stage of the experiment we obtained the data shown in Table 4.

Table 4 - Results of the third stage of the experiment, conducted on the gasoline engine

Measured parameter	Engine speed, n=1900 rpm			
	Without exposure to an electrical impulse	Distance between electrodes, R=0,002 m	Distance between electrodes, R=0,004 м	Distance between electrodes, R=0,006 м
λ	1,020	1,018	1,030	1,020
O_2, % vol	0,95	0,93	1,11	0,98
CO_2, % vol	13,71	13,71	13,64	13,65
HC, ppm vol	187	194	187	193
CO, % vol	0,535	0,559	0,466	0,566

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According to the experimental data obtained, plots of changes in the measured parameters of the exhaust gas analyzer without and with the influence of an electric field of high voltage as a function of the inter-electrode distance R at various engine crankshaft speeds n were plotted. The zero value of R corresponds to the values of the measured parameters without the influence of the electric pulse. The change in the excess air coefficient λ as a function of the interelectrode distance R at different n is shown in Fig. 3.

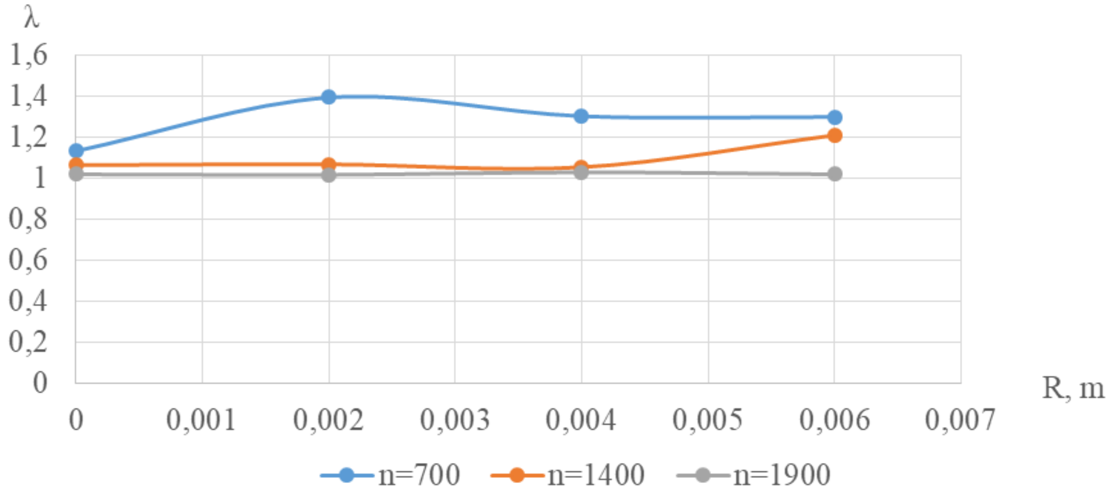

Figure 3 - Dependence of the excess air ratio λ on the interelectrode distance R at different n

The parameter λ in the optimal case of fuel combustion should have a value close to one. An increase in the "lambda" parameter indicates that the mixture is depleted and the oxygen is not burned completely. This refers only to the case when the composition of the exhaust gases is measured in the silencer without switching on the electric pulse equipment [10]. When exposed to the pulse λ in the best case should increase, because as a result of ionization the value of oxygen increases and the content of harmful gases decreases.

The change in the oxygen content O_2, %vol in the composition of the exhaust gas from the interelectrode distance R at different n are shown in Fig. 4.

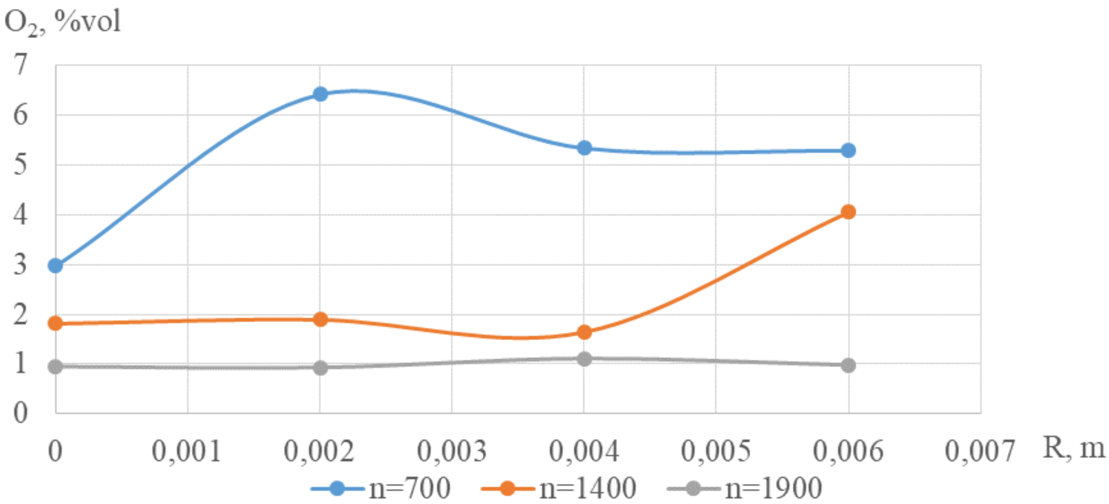

Figure 4 - Dependence of the oxygen content O_2, %vol in the exhaust gas on the interelectrode distance R at different n

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Figure 4 shows that the maximum oxygen content is at 700 rpm at a distance of 0.002m between the electrodes. At 1400 and 1900 rpm at a distance of 0.006m.

Plots of the carbon dioxide CO_2 content, %vol in the exhaust gas from the interelectrode distance R at different n are shown in Fig. 5.

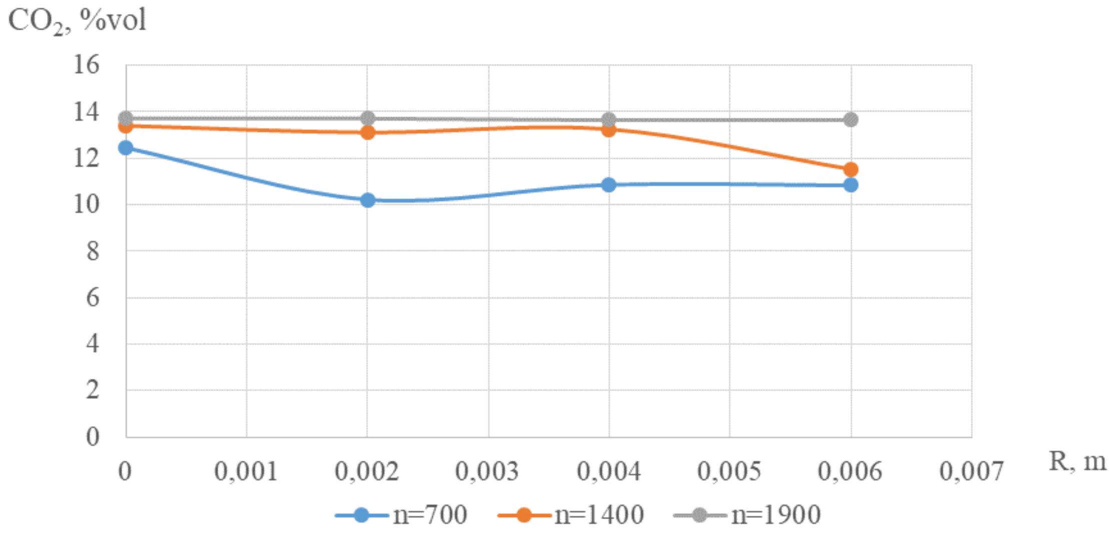

Figure 5 - Dependence of carbon dioxide CO_2 content, %vol in the exhaust gas from the interelectrode distance R at different n

Figure 5 shows that the point of minimum carbon dioxide content at 700 rpm is observed at a distance of 0.002m between the electrodes. At 1400 and 1900 rpm at 0.006m.

Plots of dependence of HC hydrocarbons content, %vol in the exhaust gas composition on the interelectrode distance R at different n are shown in Fig. 6

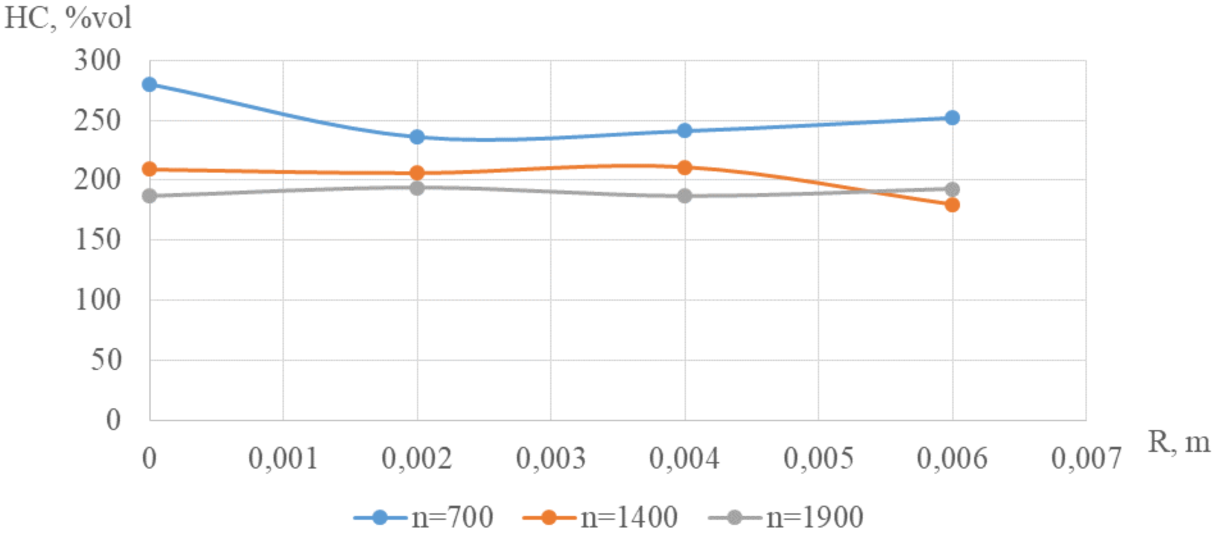

Figure 6 - Dependence of HC hydrocarbons content, %vol in the exhaust gas composition on the interelectrode distance R at different n

Figure 6 shows that the point of minimum hydrocarbon content at 700 rpm is observed at 0.002m, at 1400 rpm at 0.006m, and at 1900 rpm at 0.004m.

Plots of the dependence of carbon monoxide CO, %vol in the exhaust gas composition on the interelectrode distance R at different n are shown in Fig. 7.

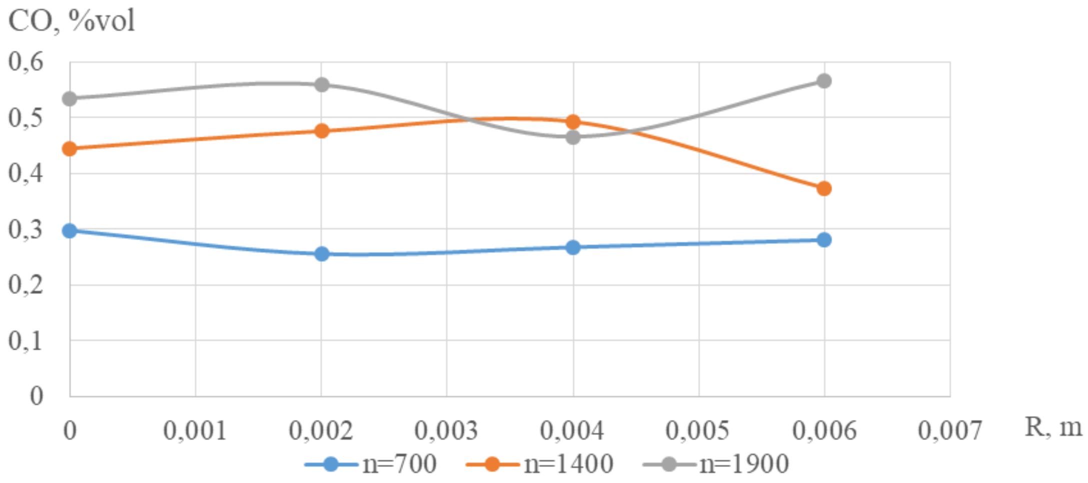

Figure 7 - Dependence of carbon monoxide CO, %vol in the exhaust gas on the interelectrode distance R at different n

Figure 7 shows that the point of minimum carbon monoxide content at 700 rpm is observed at 0.002 m, at 1400 rpm at 0.006 m, and at 1900 rpm at 0.004 m.

Conclusions.

From the analysis of the dependencies shown in Figures 3 - 7, it follows that there is a tendency to increase the content of carbon dioxide and carbon monoxide simultaneously with an increase in engine crankshaft speed. While the content of oxygen and hydrocarbon, on the contrary, decreases with increasing revolutions. The decrease in hydrocarbons is explained by the fact that there is better combustion of fuel, with enough oxygen.

After switching on the electric pulse, with a distance of 0.002m between the electrodes at 700 rpm of the crankshaft, a sharp increase in oxygen (by 116.16%), a decrease in carbon dioxide (by 21.82%) and carbon monoxide (by 14.09%) and hydrocarbons (by 15.71%) is observed. It follows that the distance between the electrodes of 0.002m is optimal at 700 rpm, as the analysis of histograms shows that the values are minimum for all three harmful gases, and maximum for harmless oxygen. At crankshaft speed n=1400 rpm, the greatest reduction in carbon monoxide CO and HC hydrocarbons is observed at R=0.006 m, and at n=1900 rpm - at R=0.004 m.

The results obtained are necessary to establish the modes of effective operation of electric pulse equipment when designing promising systems for the purification of combustion engine exhaust gases.

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ІШКІ ЖАНУ ҚОЗҒАЛТҚЫШЫНЫҢ ПАЙДАЛАНЫЛҒАН ГАЗДАРЫН ЭЛЕКТРОИМПУЛЬСТІ ТАЗАРТУ ПРОЦЕСІН ЗЕРТТЕУ

Аңдатпа. Мақалада пайдаланылған газдарды электр импульсімен тазарту параметрлерін зерттеуге мүмкіндік беретін әзірленген жабдықта жүргізілген эксперименттердің нәтижелері келтірілген. Жылжымалы электродтары бар электр импульстік тазалау стендінің жалпы құрылғысы, оның жұмыс принципінің сипаттамасы берілген. Эксперименттердің нәтижелерін талдау пайдаланылған газдарды электр импульстік тазартудың тиімділігі туралы қорытынды жасауға және жобаланған пайдаланылған газдарды тазарту жүйелерінің электр импульстік жабдықтарының оңтайлы жұмыс режимдерін анықтауға мүмкіндік береді.

Түйінді сөздер. Ішкі жану қозғалтқышы, пайдаланылған газдар, уыттылық, электр импульсі, тазалау.

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ИССЛЕДОВАНИЕ ПРОЦЕССА ЭЛЕКТРОИМПУЛЬСНОЙ ОЧИСТКИ ОТРАБОТАВШИХ ГАЗОВ ДВИГАТЕЛЯ ВНУТРЕННЕГО СГОРАНИЯ

Аннотация. В статье приведены результаты экспериментов, проведенных на разработанном оборудовании, позволяющем исследовать параметры очистки отработавших газов электроимпульсом. Дается общее устройство стенда электроимпульсной очистки с подвижными электродами, описание принципа его работы. Проведенный анализ результатов экспериментов позволяет сделать вывод об эффективности электроимпульсной очистки отработавших газов и определить оптимальные режимы работы электроимпульсного оборудования проектируемых систем очистки отработавших газов ДВС.

Ключевые слова. Двигатель внутреннего сгорания, отработавшие газы, токсичность, электроимпульс, очистка.

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