STUDY OF A COMBINED DEVICE TO REDUCE THE TOXICITY OF EXHAUST GASES OF DIESEL ENGINES, AGRICULTURAL TECHNOLOGY

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ABSTRACT:

This study was aimed to reduce the toxicity of exhaust gases from diesel engines used in agriculture. Indicators are provided for a technical assessment of the efficiency of exhaust gas cleaning for diesel engines that have a significant impact on agricultural crops. A scheme for the installation of a common device to reduce the exhaust toxicity of diesel engines on the YaMZ-238 engine was described during the test and a research methodology is presented. The main results obtained during the improved toxicity testing device installed on the ULTZ-700 tractor are given with the YaMZ-238 engine, which fully reflects the efficiency of cleaning emissions. The reliability graphs are designed to characterize cleaning efficiency, and the experimental formulas obtained are given. Technical and economic assessment techniques are provided for exhaust gas rates, which apply to the developed device to reduce toxicity. As a result, the main conclusions of the study were formulated.

Keywords: environment, internal combustion engines, secondary afterburner, operating efficiency, cleaning means.

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دراسة لجهاز تقليل سمية غاز العادم في محركات الديزل المستخدمة للتكنولوجيا الزراعية

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المستخلص

يستخدم الجهاز للحد من سمية غازات العادم من محركات الديزل المستعملة في العمليات الزراعة. حيث يتم تحديد مؤشرات لإجراء تقييم تقني لفعالية تنظيف غاز العادم لمحركات الديزل التي لها تأثير كبير على المحاصيل الزراعية. وقد تم وصف مخطط تركيب جهاز شائع للحد من سمية العادم لمحركات الديزل على محرك YaMZ-238 أثناء الاختبار وتقديم منهجية بحث وعرض النتائج الرئيسية التي تم الحصول عليها خلال جهاز اختبار السمية المُحسّن والمثبت على جرار ULTZ-700 بمحركYaMZ-238 ، والذي يعكس تمامًا كفاءة انبعاثات التنظيف. وقد رسمت التصاميم البيانية الموثقة لتمييز كفاءة التنظيف، ويتم إعطاء الصيغ التجريبية التي تم الحصول عليها. يتم توفير تقنيات التقييم الفني والاقتصادي لمعدلات غازات العادم، والتي تنطبق على الجهاز المطور للحد من السمية. نتيجة لذلك ، تمت صياغة الاستنتاجات الرئيسية للدراسة.

الكلمات المفتاحية: البيئة، محركات الاحتراق الداخلي، الاحتراق الثانوي، كفاءة التشغيل، وسائل لتنظيف.

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INTRODUCTION

The beginning of the third millennium is marked not only by the rapid development of transport and small energy but also by the continuing growth of the anthropogenic impact of piston engines on the environment (5). Tilling is one of the main processes that take place on the soil to break the surface layer and create suitable conditions that allow water and air to penetrate (18). Diesel engines are one of the primary sources of energy for mobile vehicles and can also be used as stationary or mobile power sources (1). Reducing the toxicity standards associated with the negative impact of exhaust emissions of diesel engines requires. Also, the development of new and developed ways, and means to reduce the toxicity of exhaust gases with a high degree of purification and long-life service, as well as minimal fuel impact and economic indicators of diesel engines used in Agriculture. Carbon monoxide pollution is a global concern (19). The use of technology in agriculture entails consequences that adversely affect the environment. The prevention and minimization of these consequences are one of the important tasks of “greening” the agricultural sector (5). There are many ways and means of reducing exhaust emissions (5). One of the ways to clean the exhaust gases of diesel internal combustion engines (ICE) is to install additional technical means in the exhaust system that provide physical and chemical cleaning of exhaust gases. This method of reducing toxicity allows, without significant changes in the design of the internal combustion engine, to provide a sufficiently effective purification of exhaust gases from toxic components. An analysis of recent advances in the design of exhaust gas converters for diesel internal combustion engines, published in domestic and foreign scientific journals, shows that it is more efficient to use combined cleaning agents that allow a high degree of purification of exhaust gases from a complex of toxic substances (4).

MATERIALS AND METHODS

Description of the cleaning device

In the Tambov State Technical University (TSTU) at the department "Automotive and agricultural technology" developed a combined device to reduce toxicity (KUST) of exhaust gases of diesel ICEs (14). The device comprises a housing (Figure 1), in which a layer of catalyst 1 is placed, consisting of the upper 2 and lower 3 parts. The lower part is connected through pipe 4, in which the ejector 5 is installed, with the exhaust system of the engine. At the entrance to the lower part of the housing, a diffuser 6 is installed, and a filter trap 7 with a metal grid 8 is screwed on the bottom, which is sealed with a gasket 9. There is a turnkey nut 10 on the bottom of the sump to make it easier to unscrew. Between the upper and lower parts of the case, an electrical coil 11 is installed, having a ceramic case mounted through sealing gaskets 12. The coil is connected by wires 14 to the control unit 13. Catalyst layer 1, consisting of buried granules (active mass consists of aluminum - 10%, copper - 1.5%, nickel - 1.5%, the rest is porous material FTS-5), is located between the input 15 and the output 16 grids. A compensating element 17 in the form of a bimetal coil spring is installed between the input lattice of the catalyst and the electric spiral housing. The upper and lower parts of the body are bolted together. In the upper part of the case, there is a confused 18, which has two nozzles, one of which is the output 19, connected with the atmosphere, and the other, L-shaped 20, and is connected with the cavity of the input nozzle 4. The principle of operation of the KUST is based on the secondary afterburning of exhaust gases. Secondary afterburning is the direction of the particles in the flow of exhaust gases that have passed through the neutralizer to a repeated cleaning cycle.

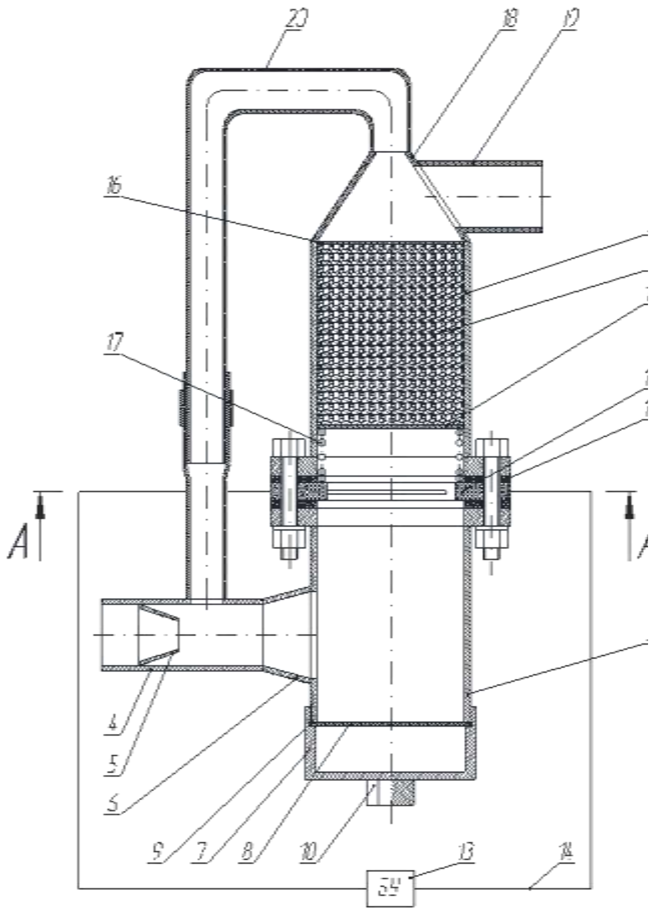


Figure 1 .General view of the diesel KUST
1 - catalyst bed; 2 - the upper part of the body; 3 - the lower part of the body; 4 - pipe; 5 - ejector; 6 - diffuser; 7 - sump filter; 8 - metal mesh; 9 - gasket; 10 - a nut; 11 - electric spiral; 12 - sealing gaskets; 13 - control unit; 14 - electrical wires; 15 - entrance lattice; 16 - output grid; 17 - bimetallic coil spring; 18 - confuser; 19 - outlet pipe; 20 - L-shaped nozzle

When the engine is running, the exhaust gases through the exhaust system enter the inlet 4 of the device and, when passing through the ejector 5, are accelerated, thereby creating a vacuum in the cavity of the confused 18. Then the gases enter the diffuser 6, in which they are distributed throughout the lower part of the housing 3. The heavy fractions of the exhaust gas and condensate are deposited in the filter-settler 7. The gas flow passes through the electric coil 11, which allows raising the exhaust gas temperature, thereby contributing to the afterburning of soot particles. Cleaned soot from exhaust gases penetrates through the restrictive inlet grill 15 into the catalyst bed 1, in which, due to chemical oxidation reactions, the products of incomplete combustion contained in the exhaust gas, namely CO, CxHy, NOx to the final toxic-safe components (CO2, H2O, N2). Purified exhaust gases are directed through the output grate 16 into the confused 18. Due to its conical shape and vacuum created in its cavity, part of the exhaust gas enters the L-shaped nozzle 20 and enters the inlet nozzle 4, where it mixes with the newly received exhaust gases and undergoes a secondary cleaning cycle. The rest of the exhaust gas flows through the outlet 19 to the atmosphere. As a result of thermal expansion, under the influence of high exhaust gas temperatures, in the body of the device, the volume of catalyst granules 1 increases, causing the input grid to shift. In this case, a cylindrical spring 17 made of bimetallic material, reacting to an increase in temperature assumes such a position that it prevents the appearance of free volume in the zone of the catalyst bed 1, and at the same time, preventing the input grid from compressing the granules excessively, to avoid sintering and destruction. the effectiveness of the exhaust gas cleaning process can assess, the developed device introduced two specific indicators: the quality of exhaust gas cleaning and the energy intensity of the device. The specific indicator of the quality of exhaust gas cleaning characterizes the proportion of neutralized toxic components per kilogram of fuel per unit of time, and is defined as the ratio of the degree of exhaust gas purification to the mass fuel consumption:

$$q_{\Delta G} = \frac{\left(\frac{G_{ОГ}^{вход} - G_{ОГ}^{вых}}{G_{ОГ}^{вход}}\right)\cdot 100\%}{G_T} \quad \text{, \% / (kg / h)} \quad (1)$$

Where $G_{ОГ}^{вход}$ = is the mass flow rate of exhaust gas at the entrance to the KUST, kg/h;

$G_{ОГ}^{вых}$ = A mass flow rate of exhaust gas at the outlet of KUST, kg / h;

G_T = Mass fuel consumption, kg /h.

=The specific energy consumption indicator of the device characterizes the energy loss in the neutralizer per kilogram of fuel per unit of time, and is defined as the ratio of the degree of change in exhaust gas pressure in KUST to mass fuel consumption:

$$q_{\Delta p} = \frac{\left(\frac{p_{ОГ}^{вход} - p_{ОГ}^{выход}}{p_{ОГ}^{вход}}\right)\cdot 100\%}{G_T} \quad \text{, \% / (kg / h)} \quad (2)$$

Where $p_{ОГ}^{вход}$ = is the pressure of exhaust gas at the inlet to just, Pa?

$p_{ОГ}^{вых}$ = exhaust pressure at the output of the KUST, Pa. g/m^3

Theoretically, the change in the exhaust gas flow rate in the KUST excluding condensed gases is determined by the amount of exhaust gas neutralized in the catalyst per unit time:

$$\Delta G = k(T) \cdot \frac{\Delta C}{t} \cdot \rho \cdot \frac{\pi \cdot D_p^2 \cdot H_p}{4}$$

Where $k(T)$ = is the chemical reaction constant?

ΔC = Change in the concentration of exhaust gas, in fractions;

t = Time of chemical process, h

ρ = exhaust density, kg / m^3;

D_p = Diameter of the reactor, m;

H_p = Reactor height (height of the catalyst bed).

The theoretical pressure loss in the device is determined by the formula:

$$\Delta p = \xi_{ОБЩ} \cdot \frac{\rho \cdot \upsilon}{2}$$

Where $\xi_{ОБЩ}$ = the total coefficient of gas-dynamic resistance of the device;

υ = The average speed of exhaust gas in KUST, m / s

Thus, by entering indicators, we can talk about the assessment of the effectiveness of the exhaust gas neutralizer

The effectiveness of the exhaust gas converter characterizes the operation of the device and shows how many times the specific degree of exhaust gas purification from the toxic components exceeds the specific degree of backpressure increase in it and is determined by the ratio of the cleaning quality indicator (1) to the energy intensity indicator (2):

$$Э_{КУСТ} = \frac{q_{\Delta G}}{q_{\Delta p}}, \ \frac{\%/(кг/ч)}{\%/(кг/ч)} \qquad (3)$$

There are two possible options for the KUST EG performance indicator, which are used to evaluate the operation of the device:

1. $Э_{КУСТ} > 1$ = means, the degree of reduction of toxic components exceeds the degree of increase of the back pressure in KUST, that is, the device works effectively

2. $Э_{КУСТ} \leq 1$ =in this case, the indicator of energy intensity is equal to or higher than the indicator of the quality of cleaning, that is, the device is not effective.

To test the theoretical model of the efficiency of the device at the Department of Automotive and Agrarian Equipment of the TSTU, tests were carried out on an experimental KUST (Figure 2) installed on a ULTZ-700 tractor with a YMZ-238 engine (Figure 3).

Figure 1 . General view of the experimental KUST

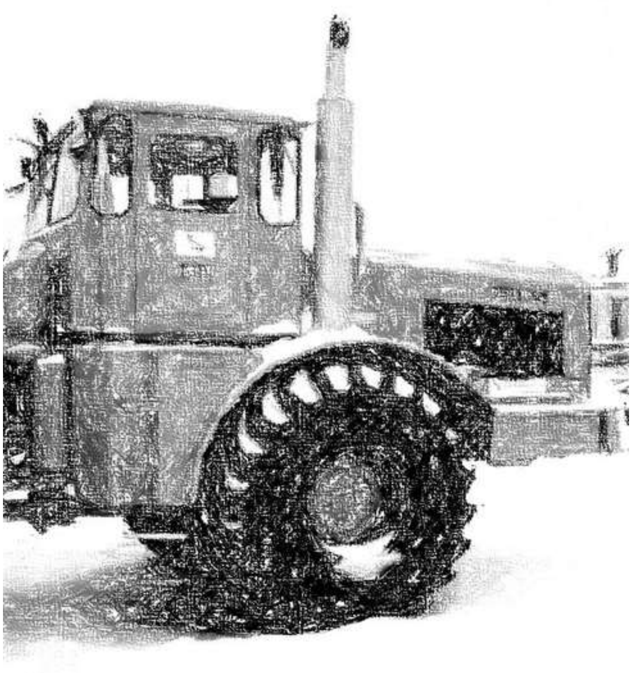
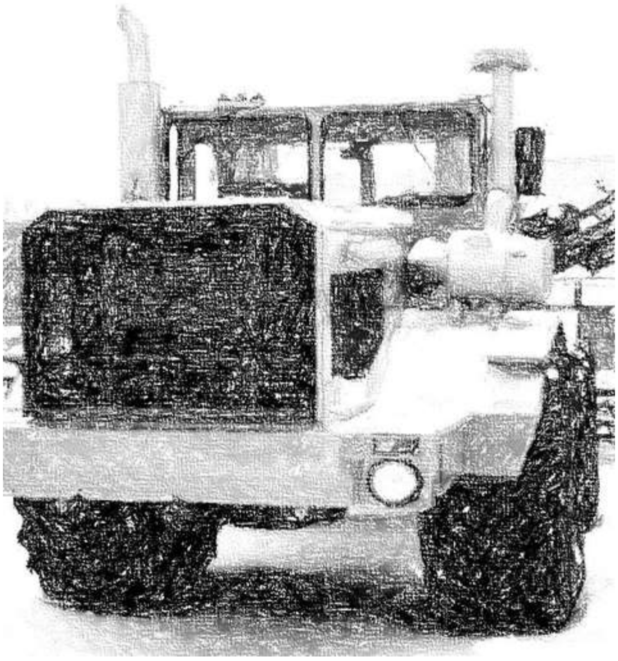


Fig 2 . side view

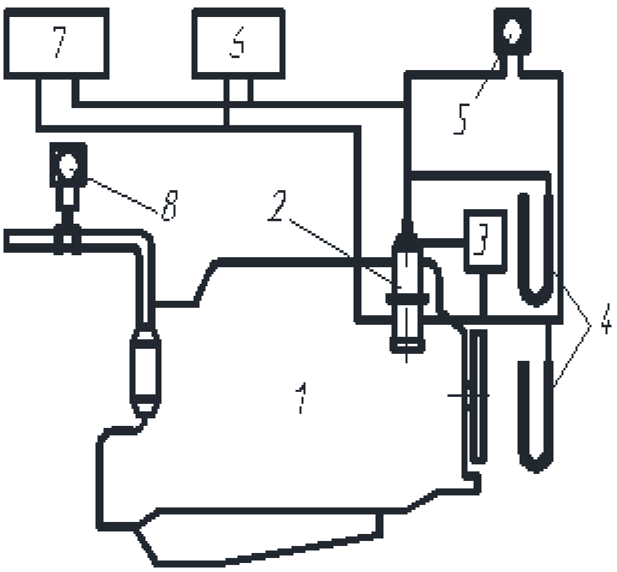


- front view

Figure 3 . KUST installed on the ULTZ-700 tractor

Description of the trial setup

When conducting research on the stand, the parameters of the engine under load were determined. The scheme of connecting the devices to the engine is shown in Figure 4.



1 - engine YMZ-238; 2 - experimental KUST; 3 - temperature meter ITP-2; 4 - piezometers; 5 - exhaust gas flow meter; 6 - TESTO-350 gas analyzer; 7 - Infrakar 1 smoke meter; 8 - fuel meter "Port-1"

Figure 4 . scheme of connecting devices to the internal combustion engine

The neutralizer contains a triple-action nickel-containing catalyst, which does not contain precious metals, developed by the Research Institute of Chemistry of Saratov State University, which is a granule with a deposited catalyst 5 mm in diameter each (15). A 12V battery provides the electrical supply of the electrical coil for the after-treatment of exhaust gas in the neutralizer with a capacity of 60 Ah. The operating voltage of the electric chrome spiral is 11.8 V; the electrical resistance is 3 ohms. Thermal energy supplied to the exhaust stream from a 46-watt electric heater. The experimental data were processed on a personal computer using the application programs Statistical 6.0 and Mathcad 15.0**.**

RESULTS AND DISCUSION

The results of the research are presented in Table 1. The study of the dependences of changes in the fuel and economic indices of the YaMZ-238 diesel with the experimental KUST with a change in its load conditions allows one to evaluate the influence of the design parameters of the studied structure on the diesel performance (traction, speed, fuel efficiency, etc.) (16,10). The results of exhaust toxicity studies are presented in fig. 5, 6 and 7.

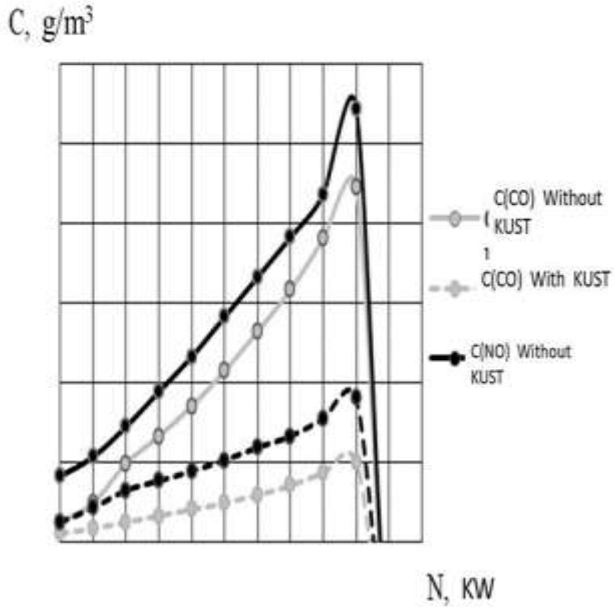


Figure 5. Dependence of CO and NOx concentrations in the exhaust gas on engine power

Table 1 . The results of experimental studies

N, kW	, kg / h	$p_{OГ}$ Pa	T, °C	$G_{OГ}$, kg / h	$C(CO)$, g / m3	$C(CH)$, g / m^3	$C(NO_X)$, g / m^3	$C(C)$, g / m^3	$C(O_2)$, %
				Without KUST					
15	10,2	$23{,}6\cdot10^3$	250,2	358,6	0,092	0,006	0,121	0,0066	18,2
30	11,6	$26{,}5\cdot10^3$	308,6	486,3	0,104	0,007	0,133	0,0085	18,1
45	12,5	$28{,}5\cdot10^3$	375,1	592,1	0,129	0,008	0,152	0,0107	17,8
60	14,9	$36{,}6\cdot10^3$	421,7	695,2	0,146	0,009	0,174	0,0131	17,5
75	16,7	$43{,}4\cdot10^3$	485,3	846,1	0,165	0,012	0,196	0,0156	17,1
90	18,4	$54{,}7\cdot10^3$	532,3	981,3	0,187	0,016	0,221	0,0184	16,8
105	21,6	$69{,}5\cdot10^3$	583,9	1086,5	0,212	0,021	0,246	0,0216	16,4
120	26,5	$80{,}6\cdot10^3$	632,6	1153,2	0,238	0,026	0,271	0,0248	15,8
135	30,2	$94{,}7\cdot10^3$	663,1	1217,6	0,270	0,032	0,298	0,0281	15,2
150	36,8	$106{,}6\cdot10^3$	698,6	1285,3	0,303	0,038	0,352	0,0310	14,7
				with KUST					
15	10,2	$25\cdot10^3$	269,1	357,8	0,085	0,005	0,092	0,0024	18,1
30	11,7	$28\cdot10^3$	357,2	472,3	0,088	0,006	0,101	0,0027	18,0
45	12,6	$30\cdot10^3$	408,8	565,1	0,092	0,007	0,112	0,0030	17,7
60	15,0	$38\cdot10^3$	442,3	667,9	0,096	0,008	0,118	0,0034	17,5
75	16,9	$45\cdot10^3$	496,7	815,7	0,100	0,009	0,124	0,0039	17,0
90	18,7	$56\cdot10^3$	544,1	910,3	0,104	0,011	0,131	0,0044	16,5
105	21,9	$71\cdot10^3$	597,5	983,5	0,109	0,013	0,139	0,0049	15,9
120	27,0	$82\cdot10^3$	655,8	1047,1	0,115	0,015	0,146	0,0055	15,3
135	30,5	$96\cdot10^3$	709,2	1106,9	0,123	0,018	0,157	0,0061	14,8
150	37,1	$108\cdot10^3$	736,0	1196,9	0,130	0,022	0,170	0,0067	14,5

Analysis of changes in the concentration of carbon monoxide (CO) (Figure 5) shows that with an increase in power, the concentration of CO increases from 0.092 g/m3 to 0.303 g / m3 (per kW) due to incomplete combustion of the fuel and a decrease in the processing time. The concentration of carbon oxides at the KUST output is 15–57% lower than at the inlet, especially in the area of high engine loads and at high exhaust temperatures, which contributes to better combustion of carbon oxides. The regression equations are:

-Without KUST

$$C_{CO}(N) = 0{,}079 + 7{,}986 \cdot 10^{-4} \cdot x + 4{,}529 \cdot 10^{-6} \cdot x^2$$

$$C_{NO}(N) = 0{,}11 + 6{,}75 \cdot 10^{-4} \cdot x + 5{,}875 \cdot 10^{-6} \cdot x^2$$

With KUST

$$C_{CO}^{КУСТ}(N) = 0{,}083 + 1{,}209 \cdot 10^{-4} \cdot x + 1{,}246 \cdot 10^{-6} \cdot x^2$$

$$C_{NO}^{КУСТ}(N) = 0{,}088 + 4{,}307 \cdot 10^{-4} \cdot x + 6{,}566 \cdot 10^{-7} \cdot x^2$$

Analysis of changes in the concentration of nitrogen oxides (Figure 5) shows that with increasing load on the internal combustion engine, their concentration increases almost linearly and has the highest value at maximum load, and at high load conditions (kW) the NO_x concentration increases more sharply. This is because the under burning of fuel occurs with an increase in the power of the internal combustion engine and a decrease in the coefficient of excess air, which contributes to the formation of nitrogen oxides. From Figure 5 it follows that the KUST EG more effectively operates with loads of more than 40%.

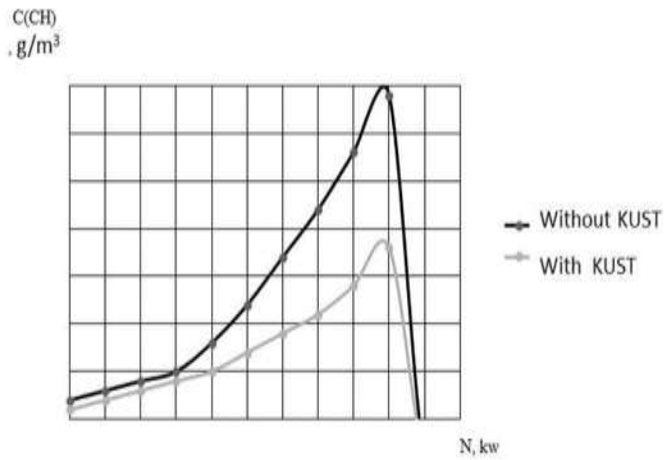


Figure 6. Dependence of hydrocarbon concentration in the exhaust gas on engine power

Figure 6 shows that the concentration of hydrocarbons in the exhaust gas with increasing engine load increases from 0.006 g /

m3 to 0.038 g / m3 (at kW), that is, CH emissions at maximum power are six times higher than at minimum load. This type of dependence is explained by an increase in fuel consumption, and, accordingly, an increase in the number of hydrocarbons released during the combustion of fuel in the combustion chamber (9).

The regression equations are:

Without KUST

$$C_{CH}(N) = 6{,}567 \cdot 10^{-3} - 5{,}485 \cdot 10^{-5} \cdot x + 1{,}785 \cdot 10^{-6} \cdot x^2$$

With KUST

$$C_{CH}^{КУСТ}(N) = 5{,}35 \cdot 10^{-3} - 6{,}212 \cdot 10^{-6} \cdot x + 7{,}576 \cdot 10^{-7} \cdot x^2$$

The dependence analysis (Figure 7) shows that with an increase in the load on the engine, the tillage is the largest consumable energy of the tractor (3), the concentration of soot in the exhaust gas increases almost linearly. This is due to the combustion of fuel in the combustion chamber. The concentration of soot increases from 0.007 to 0.031 g / m3 (4.5 times) without KUST and from 0.002 to 0.007 (3.5 times) from KUST. At the output of the KUST, depending on the increase in load, the concentration of soot varies in a smaller range, since in the high-temperature zone soot burns out better.

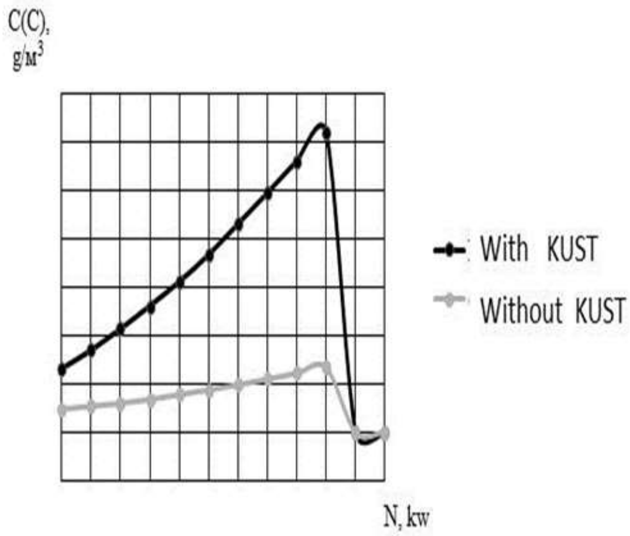


Figure 7. The dependence of the concentration of soot in the exhaust gas from the load of the engine

The dependence of the concentration of soot from the power of the internal combustion engine are:

- Without KUST

$$C_{CH}(N) = 6{,}567 \cdot 10^{-3} - 5{,}485 \cdot 10^{-5} \cdot x + 1{,}785 \cdot 10^{-6} \cdot x^2$$

- With KUST

$$C_{CH}^{КУСТ}(N) = 5{,}35 \cdot 10^{-3} - 6{,}212 \cdot 10^{-6} \cdot x + 7{,}576 \cdot 10^{-7} \cdot x^2$$

Table 2 shows a comparison of the content of toxic substances in the exhaust gas of the engine YMZ-238, obtained during the research, with the standards (12).

Table 2. Comparison of the content of toxic components in the exhaust gas of diesel internal combustion engines with regulatory

Toxic component	Regulations			DVS YMZ-238	
	Euro -III	Euro -IV	Euro -V	Without KUST	With KUST
CO, g / kW · h	2,10	1,50	1,50	3,71	1,48
CH, g / kW · h	0,66	0,46	0,26	0,46	0,25
NOx, g / kW · h	5,00	3,50	2,00	4,31	1,94
C, g / kW · h	0,127	0,08	0,08	0,38	0,076

Analyzing table 2, it can be said that the use of an exhaust gas neutralizer makes it possible to comply with Euro-V standards for all toxic components (13). The average degree of purification of exhaust gases from harmful substances is: for CO - 60%, for CH - 45%, for NOx - 55% and for soot - 80%. Thus, experimental studies of changes in the concentrations of toxic components have shown that the developed KUST effectively reduces the emissions of the main toxic components with exhaust gases and the degree of efficiency changes depending on the operating mode of the engine.

Feasibility Study Device

The feasibility study of the exhaust gas-cleaning device for internal combustion engines allows establishing the economic effect of the adopted structural and technological solutions, as well as to conclude that it is advisable to use exhaust gas neutralizers with optimized geometrical parameters. Justification of cleaning devices is carried out by determining the economic effect of putting it into operation or improving its design (for example, optimization of geometric parameters). The economic effect of these measures can only be indirect, since the introduction of an exhaust gas-cleaning device is not a direct source of income, but helps to minimize costs by increasing the fuel-efficiency of engines (11,17). The annual economic effect for engines equipped with exhaust gas neutralizers is determined by the formula (4):

$$Э_г = \Delta З_T - \Delta З \quad . (4)$$

where $\Delta З_T$ is the change in costs under the item "Fuel" as a result of the introduction of a new exhaust gas cleaning device or an upgraded, rub

$\Delta З$ - change in costs associated with the production and operation of a new exhaust gas-cleaning device or an upgraded, rub

In addition, the payback period of the events under consideration is not a few important factors, since the positive economic effect should correspond to the rational payback, that is, the payback period Device limit must not exceed, which, from efficient engine operation, ranges from 2 to 5 and years (7).

Therefore, the payback period for the introduction of the engine exhaust gas-cleaning device is determined by the formula (5)

$$T_{ок} = \frac{\Delta З_П}{\Delta З_T} \quad . (5) \qquad (5)$$

The change in the cost of production and operation of the exhaust gas-cleaning device is defined as the difference in costs for a new or modernized and currently used by the formula (6):

$$\Delta З = З_{НОГ} - З_И \quad . (6) \qquad (6)$$

Where $З_{НОГ}$ - the cost of production and operation of a new or upgraded exhaust gas neutralizer (FOG) engines, rubles;

$З_И$ - The cost of production and operation of the used converter, rub. If it is absent, the costs are zero (15).

$$З_{НОГ} = З_П + З_Э \qquad (7)$$

Where $З_П$ - the annual cost of production of FOG, RUB;

$З_Э$ - Annual costs of operating the exhaust gas-cleaning device, rub.

$$З_П = З_П^{уд} \cdot D_p \cdot n \qquad (8)$$

Where $З_П^{уд}$ = specific annual costs for the production of one leg, rub / m. When calculating the unit costs are taken according to the consumer price index (2).

D_p = The diameter of the catalyst reactor for the purification of exhaust gas, m. In calculations for the FOG m;

n - The number of devices of this type.

$$З_Э = З_Э^{уд} \cdot \frac{G_{ОГ}^{н}}{\rho} \cdot \Delta p \cdot T_н \cdot n \qquad (9)$$

Where $З_Э^{уд}$ = specific annual costs of operating one exhaust gas cleaning device, rub / kW · h. When calculating the unit costs are taken according to the consumer price index (13).

$\rho_{ОГ}$ = exhaust gas density, kg / m^3.

Δp = Pressure loss in the exhaust gas-cleaning device, kPa;

$T_н$ = The daily time of the unit of equipment.

The change in fuel costs when installing the LEG instead of the device used for the year is determined by the formula (10):

$$\Delta З_T = (G_T - G_{T_{НОГ}}) \cdot W \cdot n \cdot Ц_T \qquad (10)$$

Where G_T = hourly fuel consumption base, kg / h;

$G_{T_{НОГ}}$ = Hourly fuel consumption when installing the LEG, kg / h;

W = Engine operating time for a year, engine hours;

$Ц_T$ = Price of diesel fuel, rubles/kg.

As a result, in order to conduct a feasibility study of a new or modernized FOG, it is necessary to determine the annual economic effect and payback period of measures for introducing exhaust gas cleaning devices into the engine design, and because of the obtained conclusion to conclude the rationality and feasibility of their implementation.

Findings

In the theoretical and practical study of the combined exhaust emission reduction device, the following main conclusions were obtained:

1. The specific indicator of the quality of exhaust gas cleaning by the device was calculated, which contributes to reducing the impact on agricultural crops at work which was $q_{\Delta G} = 1{,}52$ %/(kg/h); the specific indicator of energy intensity KUST was calculated, which was $q_{\Delta p} = 0{,}0221$ %/(kg/h); the technical efficiency of the device was proved $Э_{КУСТ} = 68{,}8$, which showed that KUST is used effectively;
2. KUST leads to an increase in exhaust gas temperature by an average of 5.5%, fuel consumption by 1.1% and a decrease in exhaust pressure by 2.4%;
3. The degree of purification of exhaust gases from harmful substances is: for CO - 60%, CH - 45%, for NOx - 55% and for soot - 80%. The use of the device allows complying with Euro-V norms for all toxic components;
4. The method of determining the economic efficiency of the use of KUST and other similar devices allows us to establish the feasibility of use.
5. The annual economic effect of the KUST installation on one tractor is 393 rubles. Moreover, the use of KUST on diesel engines with a power of 150-220 kW is economically feasible

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