*Journal of Engineering Physics and Thermophysics, Vol. 78, No. 2, 2005*

# EXPERIMENTAL STUDY OF THE ELECTRIC DISCHARGE SYSTEM FOR LOWERING THE TOXICITY OF EXHAUST GASES OF THE D-243 DIESEL ENGINE

**S. A. Zhdanok, G. M. Vasil'ev,**
**V. A. Vasetskii, and A. N. Kartashevich**

UDC 537.525

*The results of the experimental studies of a full-scale plasmachemical system for lowering the toxicity of exhaust gases of the D-243 diesel engine are presented. It has been shown that under nominal operating conditions of the D-243 engine the device decreases the content of soot by more than 95% and lowers the concentration of nitrogen oxides by 24% under combined conditions of discharge power supply and at a value of the specific energy input up to 2.5 W·h/m*$^3$.

One of the main directions in increasing the ecological indices of modern automobiles and tractors is the application of a complex of measures for additional physicochemical cleaning of exhaust gases from toxic components in the process of discharge. These measures are realized in practice by using special gas cleaners installed in the discharge system. Of the known gas-cleaning techniques, the most promising for mobile machinery equipped with internal combustion engines is the use of electric discharge systems for lowering the toxicity of exhaust gases that are capable, at moderate energy inputs, of providing a high degree of cleaning gas flows from both aerosol particles and toxic gaseous components without using the expensive materials (platinum, palladium) used in catalytic cleaners.

The volt-ampere characteristics of the electrode system of the plasmachemical reactor for the D-243 engine at various temperatures of the flow of exhaust gases are given in Fig. 1.

Consider the results of experimental studies of the operating efficiency of the plasmachemical system [1–3] depending on the value of the voltage powering the reactor and the energy input into the discharge for different operating conditions of the engine (Fig. 2). The obtained characteristics permit establishing a relation between the value of the voltage powering the reactor and the degree of cleaning exhaust gases as well as determining the highest possible degree of cleaning the exhaust gases of the D-243 diesel by the proposed electric discharge system depending, in the first place, on its constructional arrangement and the concentration of soot in the exhaust gases of the diesel.

At some critical voltage (6.5–8 kV) on the electrode system of cleaning gases from soot, the soot content does not decrease at all or decreases insignificantly (by 1–2%). As the voltage on the electrode system is increased, the content of soot in the exhaust gases begins to decrease monotonically. At a voltage exceeding 14–15 kV, the reactor goes to the saturation regime. Further increase in the voltage is pointless because, in so doing, the specific energy input markedly increases with a small additional value of the degree of cleaning. An increase in the discharge powering voltage from 15 to 17 kV for the nominal discharge of gases leads to an increase in the power approximately from 320 to 520 W (by a factor of 1.6), while the degree of cleaning increases approximately from 92 to 95%. Obviously, to obtain a higher degree of cleaning with a moderate specific energy input into the discharge (up to 0.5 W·h/m$^3$), it is necessary to increase the time of treatment of the flow of exhaust gases in the discharge chamber of the reactor.

The results of the experimental investigations to determine the efficiency of decreasing the concentration of nitrogen oxides at pulsed powering of the plasmachemical reactor and in the regime of nominal power of the engine are given in Fig. 3. The efficiency of cleaning exhaust gases from nitrogen oxides in the pulse streamer corona plasma increases with increasing amplitude and frequency of the powering voltage. In so doing, it has a maximum (50–60%) determined by the proceeding of back reactions, since in the course of experiments no binding agents were added to

A. V. Luikov Heat and Mass Transfer Institute, National Academy of Sciences of Belarus, 15 P. Brovka Str., Minsk, 220072, Belarus. Translated from Inzhenerno-Fizicheskii Zhurnal, Vol. 78, No. 2, pp. 189–191, March–April, 2005. Original article submitted October 14, 2004.

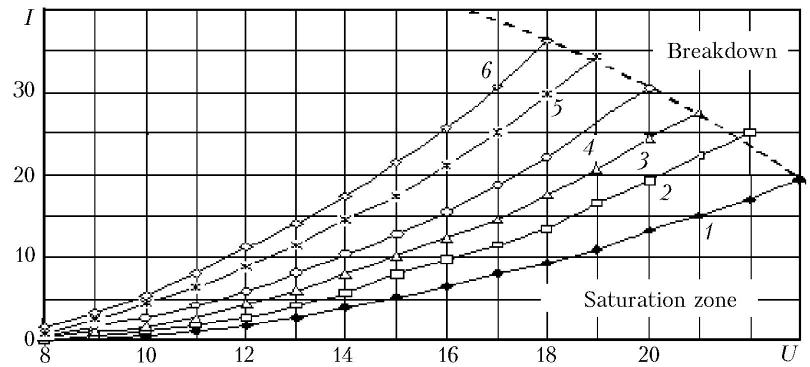


Fig. 1. Volt-ampere characteristics of the plasmachemical reactor taken at various temperature values of the flow of exhaust gases: 1) 25; 2) 140; 3) 220; 4) 300; 5) 390; 6) 400°C [1) air; 2–6) exhaust gases]. *I*, mA; *U*, kV.

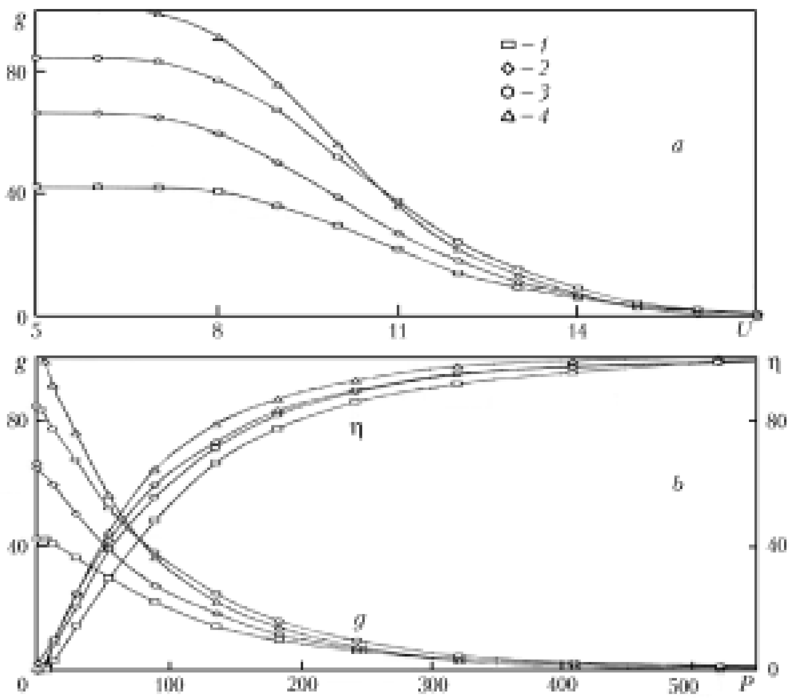


Fig. 2. Efficiency of cleaning exhaust gases from soot by the plasmachemical reactor as a function of voltage (a) and power (b) of the corona discharge: 1) $G_{e.g}$ = 652; 2) 506; 3) 475; 4) 386 $m^3$/h. η, %; *g*, mg/$m^3$; *P*, W; *U*, kV.

the reaction products. The maximal level of $NO_x$ decomposition corresponded to a specific energy input into the discharge of ~13.1 W·h/$m^3$.

At pulsed powering of the reactor no cleaning of exhaust gases from solid particles occurs or there is an insignificant decrease in the quantity of soot in exhaust gases (by 2–5%). This value corresponds to the quantity of soot burning out in the plasma of the interelectrode gap of the device, since soot deposits on the electrode surface are not formed in this powering regime.

The results of the experimental investigations aimed at decreasing the concentration of nitrogen oxide in combined powering of the plasmachemical reactor (for complete discharge of gases in the regime of nominal power of the diesel) are presented in Table 1.

The basic parameters are: specific energy input — up to 2.3 W·h/$m^3$; the smoke of exhaust gases after the discharge chamber was in the limits of 1–3%.

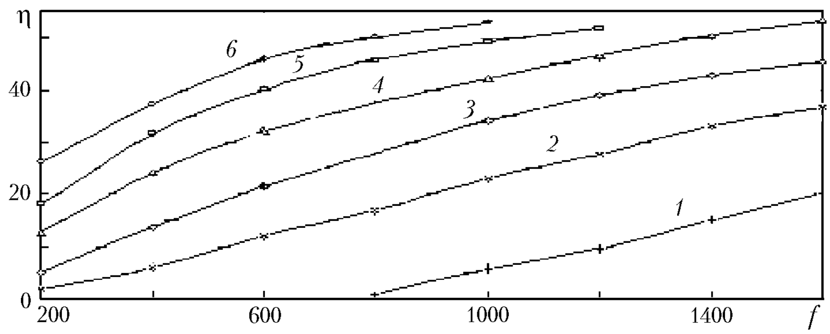


Fig. 3. Efficiency of cleaning exhaust gases from nitrogen oxides in the pulsed discharge plasma as a function of the powering voltage amplitude and the pulse repetition frequency: 1) *U* = 12, 2) 14; 3) 16; 4) 18; 5) 20; 6) 22 kV. η, %; *F*, Hz.

TABLE 1. Efficiency of Decreasing the Concentration of Nitrogen Oxides in Combined Powering of the Electric Discharge System

| Pulse frequency, Hz | Voltage, kV | | Decrease in the concentration of nitrogen oxides, % |
|---|---|---|---|
| | pulse | d.c. | |
| 300 | 20 | 5.4 | ~10 |
| 400 | 20 | 6.9 | ~16 |
| 500 | 19—20 | 7.2 | ~25 |

The obtaining of a high degree of cleaning is hindered by the influence of back reactions of the kind $NO_2 + O \rightarrow NO + O_2$. Moreover, in the mixture containing oxygen and water there appears an additional channel of destruction of active radicals in the reaction $O + OH \rightarrow O_2 + H$. The reaction rate constant at a temperature of $100^oC$ is equal to $1.7 \cdot 10^{-11}$ $cm^3 \cdot sec^{-1}$. At a concentration of radicals of $10^{16}$ $cm^{-3}$ the characteristic time of their mutual recombination will be $\sim 6 \cdot 10^{-6}$ sec. The oxidation time of NO in the reaction $NO + OH \rightarrow HNO_2$ (the reaction rate constant is $1 \cdot 10^{-11}$ $cm^3 \cdot sec^{-1}$) under the same conditions is $\approx 10^{-5}$ sec. Thus, under certain conditions the radicals O and OH obtained upon the dissociation in the pulsed discharge can be used ineffectively, which should lead to an increase in the energy expenditure for cleaning exhaust gases from NO at large energy inputs into the discharge and equal concentrations of O and OH.

## CONCLUSIONS

1. On the basis of the analysis of the experimental studies made we can note the following main advantages of the plasmachemical method of cleaning exhaust gases of diesel engines: possibility of realizing complex cleaning of exhaust gases from soot and toxic gaseous components with low specific energy expenditures for the gas-cleaning process; simple constructional arrangement and absence of expensive materials (platinum, palladium) that are used in the systems of catalytic cleaning; absence of expendable structural elements subject to salvaging; possibility of unifying the structural elements and creating module systems for all standard sizes of diesel engines.

2. At the present time, the use of plasmachemical reactors in mobile and stationary machinery operating in closed rooms or in rooms with limited air exchange can become the most expedient. Moreover, they can find wide application in the discharge systems of city buses and other kinds of automobiles and tractors.

## NOTATION

$G_{e.g}$, discharge of exhaust gases, $m^3/h$; *g*, soot concentration, $mg/m^3$; *f*, pulse repetition frequency, Hz; *I*, discharge current, mA; *P*, power, W; *U*, discharge voltage, kV. Subscript: e.g, exhaust gases.

**REFERENCES**

1. G. M. Vasil'ev, A. N. Kartashevich, and A. A. Sushnev, Characteristics of the plasma reactor in a flow of exhaust gases of a diesel engine, *Izv. Belor. Inzh. Akad.*, No. 2 (14), 7–12 (2002).
2. J.-O. Chae and G. M. Vasiliev, Development and investigation of electric discharge plasma and chemical systems for lowering soot content and toxicity of diesel exhaust gases with a working volume of up to 5 liters, in: *Proc. Joint Int. Plasma Symp. of 6th APCPST, 15th SPSM, OS 2002 & 11th KAPRA*, 1–4 July 2002, Jeju Island, Korea (2002), Contributed papers, p. 142.
3. J.-O. Chae, G. M. Vasiliev, and E. M. Vassilieva, Electric discharge plasma-chemical system for lowering the soot content and toxicity of diesel exhaust gases with a working volume of up to 5 liters, in: *Proc. VI Int. School-Seminar "Nonequilibrium Processes and Their Application,"* 31 August–5 September 2002, Minsk, Belarus (2002), Contributed papers, pp. 137–142.