UDC 621.43.068

METHOD FOR INCREASING THE EFFICIENCY OF INTERNAL COMBUSTION ENGINE EXHAUST GAS RECIRCULATION SYSTEMS USING OZONE

O. Lymar, *PhD;*
D. Marchenko, *PhD;*
O. Steblyuk, *student;*
L. Orlovsky, *student*
Mykolayiv National Agrarian University

Bypassing part of the exhaust gases allows you to change the chemical composition of the fuel-air mixture, reduce the content of free oxygen in the combustion chamber. The efficiency of exhaust gas recirculation is explained by the presence of such components as water vapor and carbon dioxide in them. These substances have a high specific heat capacity, which helps to reduce the flame temperature in the combustion chamber and, accordingly, reduce the amount of nitrogen oxides in the exhaust gases. The use of up to 10% gas recirculation makes it possible to reduce the content of nitrogen oxides by approximately 30% without a noticeable increase in fuel consumption, although the smoke level increases slightly (by 5-10%).

At the same time, to simultaneously reduce toxicity and smoke level, different, sometimes incompatible measures are required, which significantly complicates the task of reducing harmful substances in exhaust gases, especially diesel engines. One possible solution is to combine a gas recirculation system with the ozonation method.

Ozone technologies aimed at intensifying the combustion process offer a promising approach to compensating for the limitations inherent in conventional methods of reducing the toxicity of exhaust gases emitted by internal combustion engines (ICEs). Traditional exhaust aftertreatment systems, such as catalytic converters, exhaust gas recirculation (EGR), and particulate filters, although effective within certain operating ranges, often exhibit reduced efficiency under transient engine modes, low exhaust temperatures, or fuel quality variations. In this context, the integration of ozone-based technologies represents an innovative pathway for enhancing oxidation reactions both within the combustion chamber and in exhaust gas treatment systems.

Ozone (O_3) is a highly reactive and environmentally friendly oxidizing agent characterized by a strong oxidation potential, significantly exceeding that of molecular oxygen. One of its key advantages lies in the absence of secondary toxic or persistent by-products following its decomposition, as ozone rapidly breaks down into diatomic oxygen after participating in oxidation reactions. Owing to these properties, ozone has found widespread application in various industrial and environmental fields, including drinking and wastewater treatment, removal of dissolved metal salts, deodorization of liquids, sterilization processes, and air purification systems employing modern ozone generators.

Under natural conditions, ozone in its pure form exists primarily in the upper layers of the atmosphere, where it plays a critical role in absorbing harmful ultraviolet radiation. Near the Earth's surface, ozone is inherently unstable and decomposes rapidly into oxygen molecules, actively oxidizing surrounding substances in the process. This natural oxidative mechanism contributes to the removal of unpleasant odors, volatile organic compounds, and suspended particulate matter from the air. Ozone is particularly effective in neutralizing odors originating from household chemicals, combustion products, industrial gases, essential oils, and aromatic hydrocarbons such as benzene. Furthermore, it reacts efficiently with hazardous compounds including hydrogen sulfide, carbon disulfide, and certain halogenated substances, such as Freon-12, converting them into less harmful components.

An important additional benefit of ozonation is its pronounced biocidal effect. During the ozonation process, pathogenic bacteria, viruses, fungal spores, and other microorganisms are destroyed due to oxidative damage to their cell membranes and internal structures. This property makes ozone-based air purification especially valuable for applications in medical facilities, public buildings, transportation systems, and industrial environments with high sanitary requirements. Upon completion of the oxidation and disinfection reactions, residual ozone decomposes into molecular oxygen, thereby enriching the treated air and eliminating the need for secondary neutralization procedures. One of the advanced methods for gas purification and in situ ozone generation involves the use of a nanosecond streamer corona discharge. In this technique, contaminated air or exhaust gas is passed through a specially designed reaction chamber subjected to high-voltage electrical pulses of extremely short duration. The pulse parameters are carefully selected to prevent electrical breakdown of the chamber while ensuring the formation of an intense pulsed corona discharge. This discharge manifests as a multitude of thin, luminous plasma channels known as streamers. Within the streamer development zone, a high concentration of energetic electrons is generated. These electrons collide with gas molecules, initiating a complex set of physicochemical reactions, including ionization, excitation, and dissociation. As a result, a wide spectrum of chemically active species is formed, such as atomic oxygen, hydroxyl radicals, and ozone molecules. These reactive components play a crucial role in the oxidation of harmful exhaust constituents, including carbon monoxide, unburned hydrocarbons, nitrogen oxides, and particulate matter precursors. Consequently, nanosecond streamer corona discharge technology enables efficient gas purification at relatively low energy consumption and without the need for chemical reagents. The combination of ozone generation and non-thermal plasma processes opens new prospects for improving the environmental performance of internal combustion engines. By intensifying oxidation reactions and promoting more complete fuel combustion, ozone-based technologies contribute to reducing exhaust toxicity, enhancing combustion stability, and improving overall engine efficiency. This makes them a promising component of next-generation exhaust gas treatment and combustion enhancement systems.

The use of a pulsed corona discharge for the decomposition of harmful gaseous compounds is a promising method. Experimental studies confirm that in the zone of such a discharge, the destruction of volatile organic compounds occurs, as well as the oxidation of sulfur and nitrogen oxides (NO_x, SO_x) and other impurities characteristic of exhaust gases of internal combustion engines. The main characteristics of the cleaning process are the degree of cleaning and the amount of energy required to process 1 m^3 of gas. When using a pulsed corona discharge, the level of cleaning can reach 90-95% and depends mainly on the amount of energy introduced into the gas. This dependence can be both linear and nonlinear.

References

1. Andreev, A. A., et al. Prospects for the use of ozonation in the exhaust gas recirculation system of internal combustion engines. In the collection: Code "Ozonation": conference materials. Kharkiv: KhNADU, 2020.
2. Pylypenko, O. M., Vasylchenko, V. Yu., and Mylenko, A. L. Environmental indicators of a carburetor engine with fuel ozonation // Bulletin of the Vinnytsia Polytechnic Institute. Vinnytsia, 2009. Issue 5. P. 26–28.
3. Stolyarenko, G. S., Gromyko, A. V. Ozone method for reducing the toxicity of exhaust gases of internal combustion engines // Internal combustion engines. 2005. No. 1. P. 47-52.
4. Marchenko D. D., Lymar O. O., Grigorenko A. O. Ways to improve the reliability of grain harvesting machines to ensure the country's food independence. Food security of Ukraine in the conditions of post-war recovery: global and national dimensions. International forum: reports of participants of the international scientific and practical conference (Mykolaiv, May 28-30, 2025) / Ministry of Education and Science of Ukraine; Mykolaiv National Agrarian University. Mykolaiv: MNAU, 2025. P. 356-358. DOI: https://doi.org/10.31521/978-617-7149-86-5-119
5. Kononov, Y., & Lymar, O. (2025). Investigating the stability of oscillations of rectangular plates in an infinitely long rectangular parallelepiped with an ideal fluid. Eastern-European Journal of Enterprise Technologies, 1(7 (133), 14–21. https://doi.org/10.15587/1729-4061.2025.323200
6. Lymar O., Marchenko D., Khramov M. Use of technological fluids coolants in cutting processing. Food security of Ukraine in the conditions of the war and post-war recovery: global and national dimensions. International forum = Food security of Ukraine in the conditions of the war and post-war recovery: global and national dimensions. International forum : reports of participants of the international scientific and practical conference (Mykolaiv, May 30-31, 2024) / Ministry of Education and Science of Ukraine ; Mykolaiv National Agrarian University. Mykolaiv: MNAU, 2024. P. 90-92. DOI: https://doi.org/10.31521/978-617-7149-78-0-28.
7. Marchenko, D., & Matvyeyeva, K. (2025). Research on the technological process of restoration with electrodiffusion strengthening of the working surfaces of the segments of the headers of combine harvesters. Problems of Tribology, 30(1/115), 100–107. https://doi.org/10.31891/2079-1372-2025-115-1-100-107.