

SUMMARY
of dissertation for academic degree of Doctor of Philosophy (PhD)
in specialty 6D071300 – Transport, Transport Equipment and Technology
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Developing Methodology of Calculation and Design of a Device for The
disposal of Exhaust Gases of City Buses

Relevance

In large cities with a large traffic flow, there is an acute problem of internal combustion engines of vehicles pollution with exhaust gases. In the area of bus stops, at intersections, where there is a large congestion of public transport vehicles, the most intense air pollution with combustion products occurs, and accordingly the highest concentration of toxic and polluting components of exhaust gases is recorded, which negatively affects human health. A significant part of city buses are equipped with diesel engines, the main toxic component of the exhaust gases of which are nitrogen oxides and the polluting component is soot containing the benzpyrene carcinogen [1]. In addition, solid soot particles smaller than 2.5 microns in size and especially ultrafine solid particles can cause not only broncho-pulmonary but also neurological diseases including migraine, headache, cerebro-cardiac stroke, Alzheimer's disease, Parkinson's disease and other forms of dementia [2, 3, 4].

The greatest emission of soot occurs during start-up, engine warm-up and with increasing the engine load, for example, when starting off, accelerating, driving uphill due to the intake of a larger amount of fuel, which contributes to its uneven micro-distribution over the volume of the combustion chamber. A part of the fuel burns immediately after evaporation from the surface of the droplets and increases the concentration of soot in exhaust gases.

In the world practice, there is a tendency to consider soot as a secondary material resource (carbon black) with its use for the needs of the tire industry.

Exhaust gas recovery is mainly considered as recirculation and utilization of thermal energy from exhaust gases of internal combustion engines. There are also developments of scientists on the use of exhaust gases in agriculture as a fertilizer.

There is a known method of cleaning gases of industrial enterprises by coagulation of suspended fine particles due to ultrasonic action on the environment, which also allows utilizing them. However, there are no studies and calculation methods that would allow applying this method for cleaning and utilizing exhaust gases from internal combustion engines of vehicles and, in particular, city buses.

In this regard, the development of a device for ultrasonic cleaning and utilizing exhaust gases of city buses during starting, warming up the engine, stopping and starting off is an urgent task.

The purpose of the work is establishing the dependences that allow developing a calculation methodology and design of a storage device for ultrasonic

cleaning and utilizing exhaust gases from internal combustion engines of city buses.

To achieve this purpose, it is necessary to solve the following tasks:

- to give a comparative analysis of the automobile mufflers design;
- to analyze the cleaning methods and the composition of the exhaust gases;
- to select the option of cleaning and utilizing the exhaust gases of city buses;
- to develop and to study a mathematical model of the process of utilization of exhaust gases from internal combustion engines;
- to develop experimental equipment and to confirm analytical results;
- to propose a design and to develop a methodology of calculating the exhaust gas utilization system for internal combustion engines of city buses.

The object of study is the process of cleaning and utilizing exhaust gases.

The subject of the study is a device for ultrasonic cleaning and utilizing exhaust gases from internal combustion engines of city buses.

Research methods: mathematical modeling, laboratory experiment, correlation analysis, theory of experiment planning.

Scientific novelty. In the work for the first time:

- the possibility of using ultrasonic mufflers with a capacitive chamber for utilizing exhaust gases from internal combustion engines of city buses has been confirmed;

- the dependences of the coagulation coefficient for deposition of solid particles of exhaust gases in the storage tank of the device for utilizing exhaust gases of city buses with and without ultrasonic action have been established;

- the hypothesis of a close correlation between the processes of enlargement and sedimentation of exhaust gas particles and the degree of its transparency in the storage tank of the device for ultrasonic cleaning and utilizing exhaust gases of internal combustion engines of city buses has been confirmed;

- experimentally, the dependences of changing the light transmission and light absorption capacity of the exhaust gas on the settling time of solid particles with and without ultrasound, as well as the coagulation coefficient on the settling time of solid particles in the storage tank of the device for ultrasonic cleaning and utilizing exhaust gases of the internal combustion engine of city buses have been obtained;

- the dependence of the rate of changing the coagulation coefficient of solid particles on the time of their deposition in the storage tank of the device for ultrasonic cleaning and utilizing exhaust gases of the internal combustion engine of city buses has been obtained.

The practical significance consists in developing a method of calculating a storage device for utilizing exhaust gases of city buses.

Scientific provisions for the defense are as follows:

1. Ultrasonic action on exhaust gases in a closed container accelerates 3-4 times the processes of hydrodynamic coagulation.

2. A mathematical model based on the kinetic theory of gases determines the value of the soot mass depending on the initial gas mass, coagulation coefficient and exposure time.

3. Provisions on the relationship between the coagulation coefficient and the degree of gas transparency.

The author defends:

1. Schematic diagram and method of utilizing exhaust gases by a storage device for ultrasonic cleaning exhaust gases from internal combustion engines of buses.

2. Developed mathematical model and methods of its study.

3. The proposed design of the storage device for city buses.

4. Calculation methodology and terms of reference.

The validity and reliability of scientific provisions, conclusions and results is confirmed by the correctness of the problem statement, the adequacy of theoretical and experimental research.

The author's personal contribution consists in setting tasks, developing research methods, developing and analyzing the mathematical model that allows determining the main parameters of a device for cleaning and utilizing exhaust gases from city buses, proposing design options for systems of utilizing exhaust gases from internal combustion engines and design solutions for installing an ultrasonic cleaning device and utilizing exhaust gases on the example of a bus, developing technical specifications for the experimental design of an ultrasonic system for cleaning and utilizing exhaust gases of internal combustion engines.

Implementation of the work results. Design options and the calculation methodology for a device for utilizing exhaust gases of city buses, which allows establishing rational parameters of ultrasonic devices for cleaning and utilizing exhaust gases from internal combustion engines of city buses, have been transferred to Bus Park No. 3 LLP in 2021.

The developed experimental research methodology is presented in the methodological guidelines for students, master and doctoral students.

Information of publications

The main provisions of the dissertation were published in 19 scientific papers including 2 articles in the Scopus database, 3 articles recommended by the CCES, 1 article included in the RSCI abstract base, 6 theses of international scientific and practical conferences. 2 patents for a useful model, 1 certificate of state registration of copyright object and 4 certificates of entering information into the state register of protected by copyright objects.

Conclusions

The work contains new scientifically based results, the use of which provides a solution to an important applied problem.

The paper draws the following conclusions:

1. The classification performed and comparative analysis of automobile mufflers made it possible to conclude that there are no effective devices for

utilizing exhaust gases of urban transport equipped with internal combustion engines.

2. The analysis of the methods of cleaning and the composition of the exhaust gases of internal combustion engines substantiates the need for their disposal due to ultrasonic action.

3. There has been described the physical essence of the process of coagulation of exhaust gases under the effect of ultrasound consisting of ortho-kinetic and hydrodynamic coagulation, the understanding of which is necessary for the development of a mathematical model of the process of ICE exhaust gases utilization.

4. There has been developed and studied a mathematical model of the process of utilizing ICE exhaust gases that is based on the formula of the molecular-kinetic theory of gases. The resulting dependence, taking into account the counting concentrations of gas and soot particles, which vary with time and the coagulation coefficient, makes it possible to determine the amount of deposited soot and to determine the efficiency of cleaning exhaust gases with an ultrasonic device.

5. On the basis of the proposed hypothesis of a close relationship between the content of soot particles in the suspended state and the light transmission capacity of a certain volume of gas, the concept of illumination is introduced as a parameter for assessing the content of soot particles in the suspended state.

6. An experimental storage-type ultrasonic device has been developed, which makes it possible to measure the light transmission capacity of the volume of gas in the device by the illumination parameter E and, on the basis of the data obtained, to determine the change in the concentration of soot particles in suspension, the coagulation coefficient in time without ultrasound and with ultrasound.

7. Experiments have been carried out on the developed experimental equipment and the results obtained by the analytical method have been confirmed. At this, the error of the average values of the experimental data in comparison with the theoretical has been 16.9 % without ultrasound and 14.23 % with ultrasound.

8. Design options for the use of the effect of ultrasonic cleaning of exhaust gases from internal combustion engines of buses and other transport equipment, which determine the directions of further promising scientific research, have been proposed.

9. A method of calculating capacitive equipment has been developed, which makes it possible to determine the main design parameters of ultrasonic cleaning systems for exhaust gases of internal combustion engines.

10. The terms of reference for the design of a system for ultrasonic cleaning and utilizing exhaust gases of internal combustion engines of city buses have been developed.

11. The performed calculation of the ecological and economic efficiency of devices for ultrasonic cleaning and utilizing exhaust gases of internal combustion engines of vehicles shows the effectiveness of using ultrasonic devices for cleaning exhaust gases. At the same time, the annual economic effect from reducing environmental damage for buses of a large class produced in the CIS will be

32,829 tenges, for buses of a large class of foreign production 24,536 tenges per bus.