

ABSTRACT

to thesis for the degree of Doctor of Philosophy (PhD)

in the training area: 8D071 – Engineering,

the educational program: 8D07102 – Transport, transport equipment and technologies

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DEVELOPMENT AND RESEARCH OF METHODS OF MAINTENANCE AND OPERATION OF A CAR USING ULTRASOUND

Urgency of the thesis. This thesis has been prepared within the State program of the infrastructural development of the Republic of Kazakhstan “Nurly zhol” for 2020-2025, for the degree of Doctor of Philosophy (PhD) in the training area: 8D071 - Engineering, the educational program: 8D07102 - Transport, transport equipment and technologies.

Tens of millions of automobiles are counted in the world. When the technological development is increased in the auto transport industry, the complexity of automotive systems is also enlarging. Thus, it leads to the new types of malfunctions and problems.

An automobile is a complex set of components and parts consisting of the following systems: engine, transmission, running gear, electrical equipment, cooling and heating system, fuel system, exhaust system, ignition system, lubrication system and braking system.

The transmission system, engine, running gear and frame are continuously being advanced with the major automobile companies.

However, some systems can be updated outside of the automobile plants. They include the auto cleaning of radiators and the exhaust gases in the muffler.

The analysis showed the efficiency to use the ultrasound to clean the contaminated parts, indoor gases and liquids. The ultrasonic acoustic coagulation develops the cavitation when exposed to liquid, and it forms the coagulation of large particles when exposed to the gas.

To date the auto radiator tubes are cleaned mechanically and chemically. Both of these approaches are unsafe for the radiator parts. A new approach of the radiator cleaning without these disadvantages should be required, e.g., the radiator cleaning by cavitation of the liquid in tubes using the ultrasound.

The successful studies have been done on the cleaning of exhaust gases from the petrol-engine automobiles. The assessment criterion was a coagulation coefficient (soot formation) in the muffler under the action of an ultrasonic wave. Due to the difference in the operation principle of the petrol and diesel engines,

i.e., different pressure and used fuel, the obtained results were not quite correct for the diesel-powered engine.

The scientific and practical results on the radiator cleaning by cavitation have been not found before. The results are not enough to clean the exhaust gases of the diesel-powered engine.

Therefore, the establishment of dependencies, which define the cleaning process of the radiator tubes and exhaust gases of the diesel-powered engine by the ultrasound, is relevant.

Hypothesis of this research is a feasible theory about possibility of the cleaning of radiator tubes in the cooling system by the cavitation of liquid, and the cleaning of exhaust gas in the muffler by the coagulation of its particles generated under the action of the ultrasonic waves.

The purpose of this research is to establish dependencies which define the cleaning processes of the auto radiator tubes and exhaust gases in the muffler of the diesel-powered engine using the ultrasonic wave.

The purpose of this research led to the following research **objectives**:

- malfunctions, approaches of the cleaning, cooling liquids and cooling systems in automobiles;
- designs, neutralization systems of exhaust gases and the ecological standards for the diesel-powered automobiles have been analyzed;
- the research results on the action of the ultrasonic wave with liquid and gaseous media have been analyzed;
- the theoretical and experimental studies of the cleaning approach of the radiator tubes in the cooling system by cavitation generated in the liquid medium due to the ultrasound have been done;
- regression equation has been established for mass of removed scale crust and the rate of liquid flow from tubes versus the ultrasound exposure time.
- dimensionless coefficients, which determine the efficiency of the radiator cleaning process, have been substantiated;
- the mathematical model of the cleaning of the exhaust gases in muffler of the diesel-powered engine has been developed and researched;
- the experimental researches of reduction of toxicity and smokiness of exhaust gases of a diesel-powered automobile using the ultrasound has been done.
- the technological maps and technical specifications have been developed; the economic efficiency has been calculated.

Research methods. Methods of the mathematical statistics, mathematical analysis, planning and processing of the experiment have been applied in this thesis.

The scientific novelty is caused by the fact that

- regression dependences linking the mass of removed scale crust from radiators with the ultrasound exposure time, liquid temperature and pulp consistency have been established experimentally;

- the efficiency coefficients for the cleaning of radiators have been presented and established depending on pulp consistency, the mass of removed scale crust and flow rate of the liquid before and after ultrasound exposure;

- it has been experimentally determined that the smokiness of the exhaust gas was decreased under the action of the ultrasound; the oxygen content was increased; and the linking parameter was enlarged;

-the dimensionless similarity coefficients, which determine the dynamic and kinetic characteristics of the process, have been established as a result of the development and research of the mathematical model of coagulation of exhaust gases of the diesel-powered engine;

- efficiency coefficient of the cleaning process depending on the number of revolutions of the engine shaft has been proposed.

The scientific provisions submitted for the defense:

- an intensive cavitation removing the scale crust from walls of the tubes takes place under the action of an ultrasonic wave in a radiator filled with warm water with a temperature of about 60 C°;

- dependences of efficiency coefficients of the cleaning process characterizing increase in mass of scale crust and speed of liquid movement in radiator on ultrasound exposure time;

- dependence of smokiness of exhaust gas on engine speed before and after the ultrasound exposure;

- dimensionless coefficients describing the ratio of the dynamic friction of gas particles in the turbulent and laminar modes, the speeds of gas movement in these modes and power ratio of ultrasound of 100 W, internal combustion engine of 120 kW

The author defends:

1. The cleaning approach of radiator tubes of automobiles by the ultrasonic action;

2. The cleaning approach of exhaust gases of diesel-powered engine in a muffler by ultrasound;

3. The obtained experimental results;

4. Mathematical model of gas particle motion in the muffler of an automobile;

5. The obtained similarity coefficients for the cleaning processes of radiators and gas in the muffler;

6. The developed technical maps for the cleaning of the radiators of the auto cooling system by the ultrasound and the technical specification for designing of the cleaning system of exhaust gases of the diesel-powered engine.

Research objects are the radiator of an automobile and the cleaning system of the exhaust gases of the diesel-powered engine.

Research subject is the cleaning process of the radiators of the auto cooling system and exhaust gases of the diesel-powered engine using the ultrasound.

The practical significance is development of a technological map for the cleaning of radiator tubes by the ultrasound and the technical specifications of equipment for the cleaning of the exhaust gases of diesel-powered engines in the muffler;

The research results have been transferred to INSTITUTE GRADIENT PROJECT LLP.

Summary

The operation and maintenance of automobile systems equipped with internal combustion engine have been analyzed in the first chapter on the literature and patent sources. Based on the analysis, the author selected systems to modernize the operation and maintenance of the automobiles. The analytical review of the ultrasonic systems and comparison of the ultrasonic and electric pulse approach of the cleaning of exhaust gases has been made. The analysis of the state of the issue and analytical review has been concluded with setting of the research objectives.

In the second chapter the author analyzed the design, malfunctions and cleaning approaches of for the cooling system and radiators. The physical essence of the cleaning process of radiator tubes using ultrasound has been given. The author designed and manufactured an experimental setup, made an experimental study and analyzed the results of the development and research of the cleaning approach of radiators of the auto cooling system using the ultrasound.

The third chapter of the thesis is devoted to research the ultrasonic cleaning process of the exhaust gases of diesel engine. The author reviewed the design and operation of the diesel-powered engine, systems for neutralization of exhaust gases from diesel-powered engines. The physics of the ultrasonic coagulation process has been demonstrated. The mathematical coagulation model of exhaust gases of diesel-powered engine has been developed. The author created a design to reduce the toxicity of exhaust gases of diesel-powered engine. The experiment and analyses of the obtained results have been performed. An experimental unit has been developed and manufactured.

The fourth chapter describes the implementation of the research results. The author proposed maps for maintenance of automobile radiators using the ultrasound and technical specifications of equipment for the cleaning of exhaust gases of diesel-powered engine in the muffler, and he calculated the economic efficiency of the approach of maintenance for the cleaning of radiators of the cooling system using the ultrasound. The conclusion describes the brief conclusions based on the results of the thesis research.

Personal contribution of the defender of thesis.

The research has been done by the author personally, including, the author analyzed the cleaning approach for radiators of the cooling system of the internal combustion engines, and he performed a comparative analysis of the design of mufflers of diesel-powered engines. He developed and researched the mathematical

model of the operation of an ultrasonic auto muffler. He created an experimental stand for the cleaning of radiator tubes using the ultrasound and the auto muffler for a diesel-powered engine to confirm the obtained results analytically. He obtained and compared the analytical and experimental dependencies describing the operation of the cleaning of radiator tubes and muffler for a diesel-powered engine using the ultrasound.

Publications and approbation of the research. The main provisions of the thesis have been published in 11 scientific papers including 3 articles in the Scopus database and having non-zero impact factor, 5 articles recommended by the Committee for Quality Assurance in the Field of Science and Higher Education of the Ministry of Science and Higher Education of the Republic of Kazakhstan, 2 abstracts of the international scientific-practical conferences. A useful model patent “Approach of gas purification” was obtained.

Many aspects of the research have been reported and discussed in the form of the oral reports at the international, republican and university scientific conferences:

In the International scientific and practical conferences (Saginov’s readings of No. 14 and No.15);

In the article of “Studying the Process of Transport Equipment Cooling System Ultrasonic Cleaning” in the journal “KOMUNIKACIE” included in the Scopus database, 3rd quartile, percentile on Transport 43, in the section of the journal of “Automotive in Transport”, <https://doi.org/10.26552/com.C.2022.4.B288-B300>, the author developed an experimental installation for the ultrasonic cleaning of auto radiators; he performed an experimental study and obtained positive results on possibility of the cleaning of the auto radiator tubes using the ultrasound.

In the article of “Ultrasonic unit for reducing the toxicity of diesel vehicle exhaust gases” in the journal of “KOMUNIKACIE” included in the Scopus database, 3rd quartile, percentile in Transport 43, in the section of the journal of “Automotive in Transport”, <https://doi.org/10.26552/com.C.2022.3.B189-B198>, the author developed an ultrasonic muffler for diesel internal combustion engines; he conducted an experimental study and obtained positive results on the cleaning of diesel exhaust gases by the ultrasound.

In the article of “Researches of the ultrasonic cleaning process of the exhaust gases of internal combustion engine” in the journal of “Bulletin of L.N. Gumilyov Eurasian National University. Technical science and technology series”, the author conducted an experimental study.

In the article of “Development of a methodology for experimental studies to determine the optimal operating modes of an ultrasonic muffler” in the journal of “Bulletin of KazATC”, section “Transport, transport engineering”, the author conducted an experimental study to improve the cleaning system of exhaust gases of internal combustion engines through the installation of the ultrasonic transducer in the muffle.

Structure and scope of the thesis. The thesis consists of introduction, 4 chapters and conclusions presented on 147 pages of printed text, contains 76 figures, 24 tables, a list of used sources of 187 titles, 3 annexes.

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Research results and main conclusions. The thesis contains the new scientifically substantiated results, and their application provides the solution of an important applied problem, i.e. development of the cleaning approaches of radiators of the auto cooling system and exhaust gases of diesel-powered engines through the action of the ultrasonic wave.

The following conclusions have been drawn as a result of this research:

1. Hypothesis of the efficiency of the ultrasound for the cleaning of the radiator tubes of the engine cooling system has been confirmed.
2. The designs, malfunctions, cleaning approaches of the auto cooling system;
3. The designs, neutralization systems of exhaust gases and ecological standards for diesel-powered automobiles have been analyzed;
4. The research results on the action of the ultrasonic waves on the liquid and gaseous media have been analyzed;
5. It has been established that 40% of failures of internal combustion engines are due to the malfunction of the cooling system.
6. Regression dependences of the mass of removed scale crust from the radiator tubes versus the ultrasound exposure time and liquid temperature have been experimentally obtained;
7. The rate of fluid flow through the radiator tubes after the ultrasonic exposure and the liquid density has been increased;
8. Air-saturated liquid by barbotage increased the cleaning efficiency, i.e. the cavitation in the tubes enlarged;
9. Dimensionless coefficients of efficiency process determined by the ratios of mass of scale crust, a flow rate of liquid and pulp consistency to the initial values have been proposed and determined;
10. The mathematical model of the cleaning of exhaust gases in the muffler under laminar and turbulent gas flow has been developed and researched;
11. Dimensionless coefficients determining the influence of turbulence and amplitude speed of gas particle motion on the efficiency process have been proposed;
12. The technical maps have been developed for the cleaning of radiators of the auto cooling system by the ultrasound;

13. The technical specifications for design of the cleaning system of diesel engine exhaust gases have been developed;
 14. The economic effect has been calculated.
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