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# Design of Ultrasonic Technology to Improve the Efficiency of Car Exhaust Gas Cleaning System

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**Abstract.** The article investigates the problem of harmful emissions into the environment from vehicles with internal combustion engines. It describes the application of ultrasonic action for cleaning exhaust gases in order to reduce their toxicity and reduce emissions into the atmosphere. The experimental stand of ultrasonic muffler is presented, as well as the results of research confirming the effectiveness of ultrasonic action. Preliminary calculations are developed and a 3D model of the ultrasonic muffler design is created, which represents an innovative solution for improving the exhaust gas cleaning system.

**Keywords:** internal combustion engine, exhaust gas cleaning system, car muffler design, ultrasonic gas cleaning, ultrasonic emitter

## Introduction

In today's world, road transport plays a significant role in people's daily lives, providing mobility and comfort. However, along with its benefits, it also brings significant negative consequences for the environment [1,2]. Automobiles with internal combustion engines, widespread throughout the world, are the main source of emissions of harmful substances that pollute the atmosphere and threaten human health [3,4]. This problem is particularly acute in large cities and on motorways where vehicle concentrations are high.

Exhaust gases contain hundreds of different components, many of which are toxic and lead to various chronic and severe diseases [5,6]. The existing method of internal combustion exhaust gas purification is not always reliable during long-term vehicle operation due to the limited service life of catalytic converters [7,8]. A promising approach to improve the efficiency of exhaust gas cleaning can be the application of various industrial methods such as adsorption, absorption, filtration, electropulse and ultrasonic cleaning [9,10]. However, not all of these methods can be effectively applied in exhaust gas cleaning systems due to the nature of automotive engines. To solve this problem, innovative approaches to improve the environmental friendliness of automobiles are needed. One of the promising solutions is the improvement of the exhaust gas cleaning system with the help of ultrasonic action.

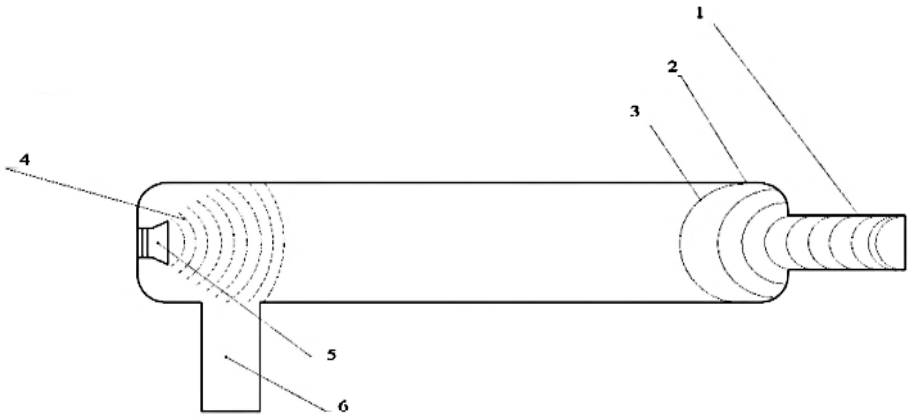
Ultrasonic impact on gas is an effective method of cleaning based on the use of elastic vibrations of high frequency. This method can significantly increase the degree of exhaust gas cleaning by intensifying the process of coagulation of toxic particles [11, 12]. The use of ultrasound also allows for a more effective impact on aggressive impurities, which makes it promising for integration into the design of a car muffler [13,14].

## 2. Methods and Experiments

The scientific group of the Department of "Transport equipment and Logistics Systems" of Karaganda Technical University has developed an experimental stand of ultrasonic muffler, consisting of a metal case and having a total length of 2 metres and a diameter of 108 mm. This stand was made to conduct research to determine the effectiveness of ultrasonic impact on exhaust gases from cars in order to reduce their toxicity and reduce emissions into the atmosphere (Figure 1).

**Fig. 1.** – Experimental stand of ultrasonic muffler

A chematic diagram of a full-sized Ultrasonic Vehicle Muffler Stand is shown in Figure 2.




1 - exhaust gas inlet; 2 - muffler body; 3 - pressure from the side of the engine manifold; 4 - ultrasonic wave; 5 - ultrasonic emitter; 6 - exhaust pipe.

**Fig. 2.** – Schematic diagram of a full-sized Ultrasonic Vehicle Muffler Stand

The stand consists of ultrasonic equipment, namely an ultrasonic generator and an ultrasonic emitter (Figure 3).

**Fig. 3.** – Ultrasonic equipment of the experimental stand

Experimental research was carried out in the laboratory of the department of "Transport Equipment and Logistics Systems". Experiments on ultrasonic car muffler were conducted with and without ultrasonic equipment for a minute each, at different crankshaft speeds (1200, 1400, 1600 rpm) on the car VW Passat B3 with an engine capacity of 1800 cc. and the use of petrol as fuel. After 60 seconds of muffler operation without and with ultrasonic action, gas analyser readings were taken. The exhaust gas was directed to the ultrasonic muffler through the inlet pipe under pressure, depending on the values of engine crankshaft speed. In the muffler, when the ultrasonic equipment was switched on, the exhaust gas was affected by ultrasonic waves of longitudinal direction. This resulted in ultrasonic intensification of the coagulation and exhaust gas cleaning processes by increasing the particle size at the particulate gas collection point. The purified exhaust gas was discharged through the outlet pipe.

## 3. Results and discussion

The experimental results are summarised in Table 1.

**Table 1.** Experimental results

| Indicators | Engine crankshaft speed (rev/min) | | | | | |
|---|---|---|---|---|---|---|
| | 1200 | | 1400 | | 1600 | |
| | Without ultrasound | With ultrasound | Without ultrasound | With ultrasound | Without ultrasound | With ultrasound |
| Oxygen ($O_2$), % | 17,11 | 17,41 | 17,75 | 17,97 | 18,23 | 18,36 |
| Carbon monoxide (CO), % | 0,31 | 0,22 | 0,36 | 0,32 | 0,51 | 0,47 |
| Gas moisture (%) | 46 | 51 | 53 | 56 | 57 | 58 |

Based on the results obtained, graphs of changes in oxygen, carbon monoxide and gas moisture indices as a function of changes in engine crankshaft speed were drawn up (Figures 4-6).

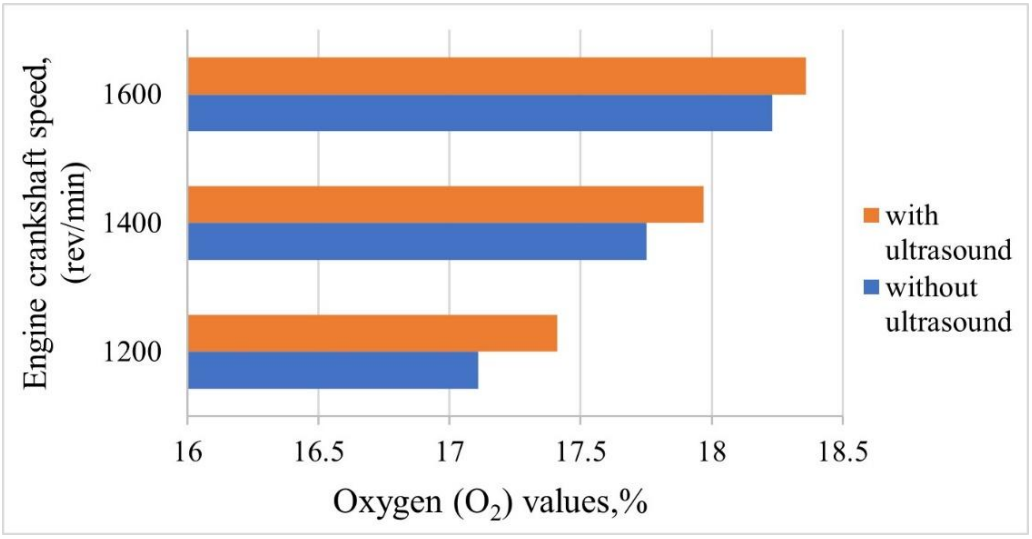



**Fig. 4.** – Changes in oxygen values ($O_2$) without exposure and with ultrasound

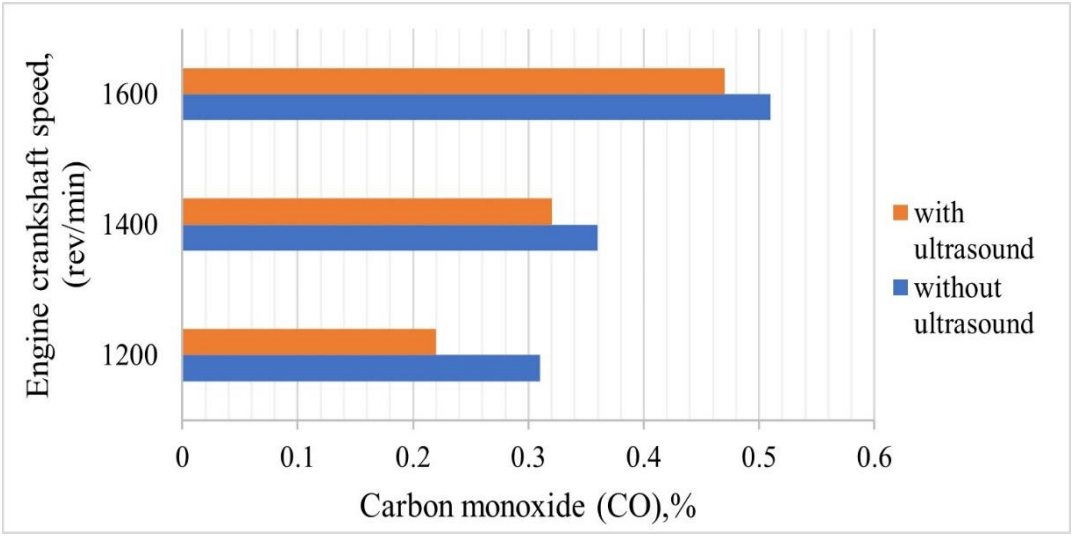



**Fig.5.** – Changes in carbon monoxide (CO) without exposure and with ultrasound

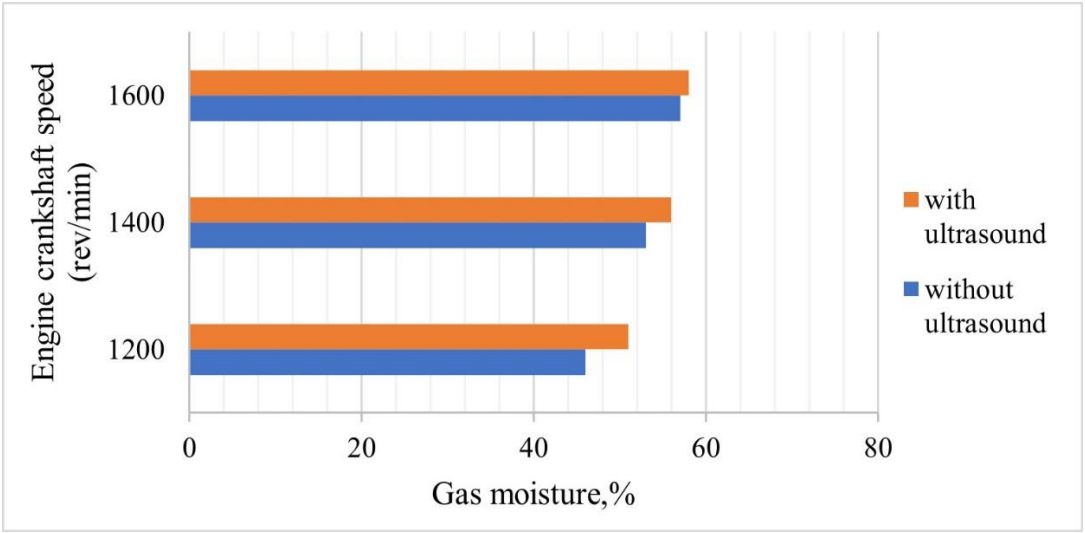



**Fig.6.** – Changes in gas moisture without exposure and with ultrasound

According to the graphs in Figures 4-6, the effect of ultrasound on the gas leads to a decrease in carbon monoxide content and an increase in oxygen content and moisture content. These changes are due to the mechanical effect of ultrasound on the gas molecules. The increase in the rate of coagulation between harmful gas particles caused by the effect of ultrasound promotes exhaust gas cleaning, resulting in an increase in oxygen and a decrease in carbon monoxide. In addition, the ultrasonic effect also increases the temperature of the gas, resulting in an increase in its moisture content. These indicators indicate the effectiveness of ultrasonic action on the exhaust gas and makes it possible to develop ultrasonic mufflers for the exhaust gas cleaning system of internal combustion engines.

Based on the experimental results obtained, which confirmed the feasibility and applicability of ultrasound for cleaning exhaust gases, we developed the design of ultrasonic muffler. Preliminary calculations of the main parameters of its design were carried out, the results of which are presented in Table 2.

**Table 2.** Main design parameters of the ultrasonic muffler

| № | Design parameters | Units of measurement | Values |
|---|---|---|---|
| 1 | Muffler volume | $m^3$ | 0,015 |
| 2 | Muffler length | m | 0,4 |
| 3 | Muffler diameter | m | 0,21 |

According to the obtained calculated values of the main design parameters of the ultrasonic muffler, its 3D model was developed (Figure 7).

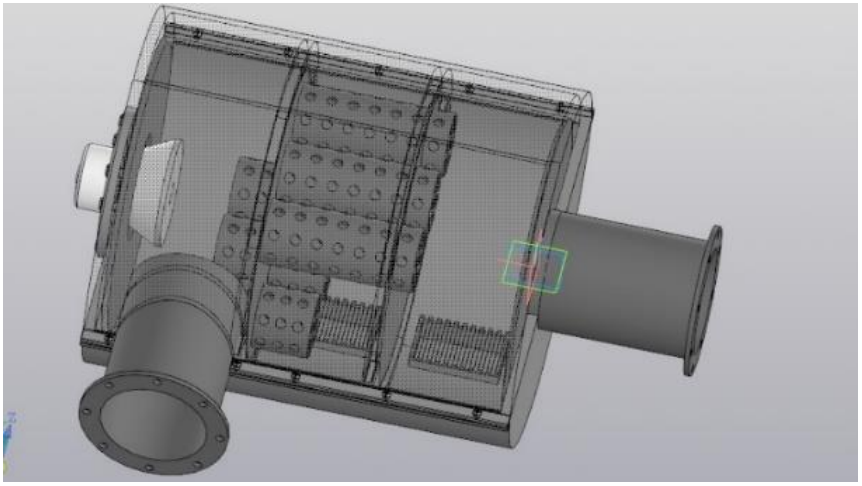


**Fig.7.** –3D model of the ultrasonic muffler design

The presented "3D model" of the ultrasonic muffler is a general design solution to improve the operation of the exhaust gas cleaning system of internal combustion engines.

**Conclusion**

On the basis of the conducted research, a conclusion was formed about the significant potential of ultrasonic impact to reduce the toxicity of exhaust gases and reduce their impact on the environment. Experimental results show that the application of ultrasound helps to increase the oxygen content and humidity in the gas stream, as well as reducing the concentration of carbon monoxide, which indicates the effectiveness of ultrasonic action. Predagayuemaya design ultrasonic muffler is an innovative solution, the use of which is appropriate for modernising the design and improving the operation of exhaust gas cleaning systems in cars with internal combustion engines. In general, the results of research confirm the prospects of application of ultrasonic technology in the automotive industry in order to reduce the negative impact on the environment.

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