

Reduction of external noise of mobile energy facilities by using active noise control system in muffler

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Abstract. The paper describes a method for the reducing emission of low-frequency noise of modern automotive vehicles into the environment. The importance of reducing the external noise of modern mobile energy facilities made in Russia is substantiated. Standard methods for controlling external noise in technology are of low efficiency when low-frequency sound waves are reduced. In this case, it is in the low-frequency zone of the sound range that the main power of the noise emitted by the machinery lies. The most effective way to reduce such sound waves is to use active noise control systems. A design of a muffler using a similar system is presented. This muffler allowed one to reduce the emission of increased noise levels into the environment by 7-11 dB and to increase acoustic comfort at the operator's workplace by 3-5 dB.

1. Introduction

The development and creation of environmentally friendly mobile energy facilities is one of the most important tasks of the machine-building industry in Russia. At present, environmental and ergonomic properties of automotive tractor equipment are among the main indicators of its quality. The best mobile energy facilities made in Russia are practically not inferior to foreign ones in terms of technical characteristics. However, in terms of such indicators as environmental friendliness, ergonomics and safety, Russian technology falls behind foreign analogues for decades. It should be noted that the main ecological indicators of technology are the toxic emissions of exhaust gases, external noise and vibration.

The reason for the technological gap of mobile energy facilities made in Russia for acoustic characteristics is not only in the production technology, but also in the absence of well-coordinated work of state standardization services. Since the early 1970s the norms of external noise have been constantly tightened in all developed countries, and hence the external noise emitted by the equipment has been decreasing until the mid-90s. The external noise of cars has decreased over the years by 10-15 dBA. But this process has slowed down for the last 20 years [3][4].

Among the main sources of noise pollution of the environment caused by mobile energy facilities, the noise of the exhaust process is especially tremendous. For most modern samples of autotractor technology, this type of external noise is dominant. Most of the sound power of a given source is in the low-frequency region of the spectrum [5]. This means that the most intense impact on people directly interacting with mobile energy facilities is provided by low-frequency sound. It can be concluded that reducing the noise of the exhaust process by improving the characteristics of mufflers in the low-frequency region is an urgent task. As it is known, there are two large categories of mufflers



- passive (without own sources of acoustic energy) and active types. Figure 1 shows the classification of exhaust suppressors.

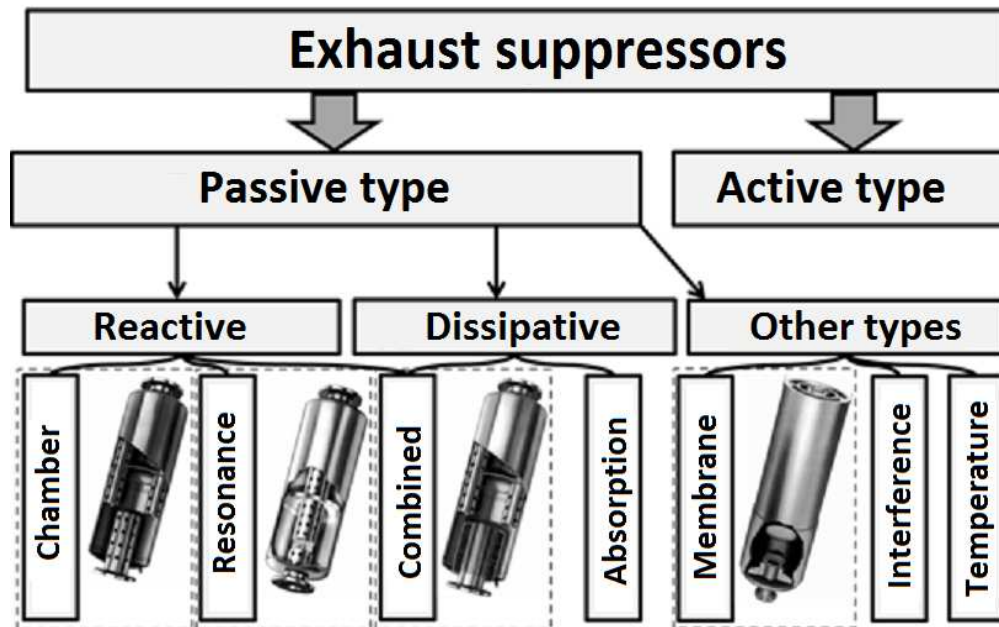


Figure 1.
Classification
of exhaust
suppressors

This article presents a way to reduce the level of exhaust noise which has proved its effectiveness.

2. The method and device description

At present, considerable experience has been accumulated in the design and preliminary calculation of the effectiveness of passive noise – reducing mufflers [2]. A large number of scientific works and publications have been devoted to this subject. A great deal of works have also been dedicated to the practical investigation of the effectiveness of various kinds of noise suppressors of passive type. The main disadvantage of passive noise suppressors is the low efficiency of all types of these noise suppressors with low-frequency noise reduction [6].

For these purposes, the most promising direction is the use of an active noise cancellation system in the muffler. Noise suppressors with these systems refer to active type mufflers. The work of the simplest noise cancellation system with the direct connection is as follows (Figure 2) [4].

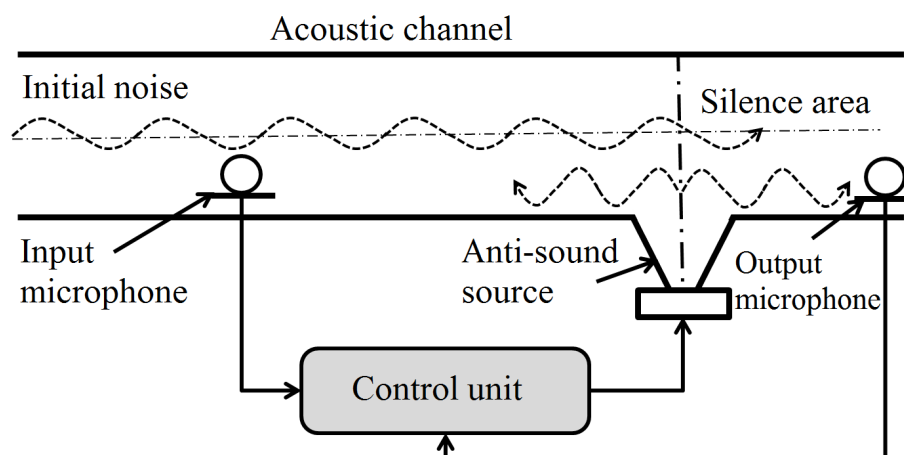


Figure 2. The
simplest active noise
reduction system

The input microphone installed in the acoustic channel on the propagation way of the original noise detects noise and provides a proportional input signal to the control unit, which processes it according

to the embedded algorithm and generates a control signal. When it is formed, the control unit also uses the signal received from the output microphone located in the zone behind the source of the anti-sound. The control signal is fed to the source of the anti-sound, which generates an additional sound wave in the channel. In this case the signal from the output microphone becomes minimal. As studies show, such a system can effectively reduce noise levels in the propagation of plane waves through channels in the frequency range up to 500 Hz [1].

On the basis of the Voronezh State Agrarian University named after Emperor Peter I the design of an active type suppressor was developed to realize this system (Figure 3).

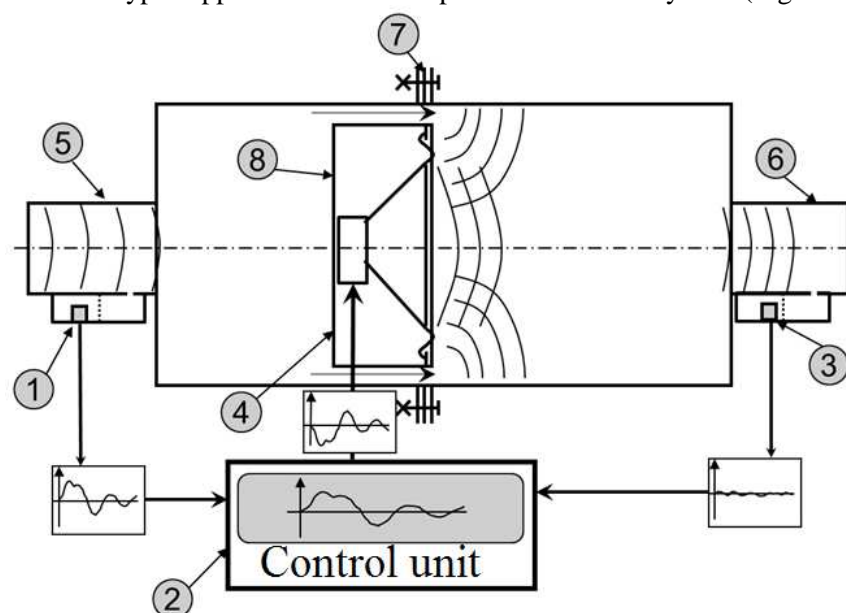


Figure 3. Operation of the noise cancellation system in the suppressor:

1 - reference signal indicator; 2 - control unit; 3 - residual signal indicator; 4 - loudspeaker; 5 - front part of the body; 6 - back of the case; 7 - support plate; 8 - the protective cover of the speaker.

The muffler operates as a conventional two-chamber reactive noise suppressor in conjunction with an active noise cancellation system, the operation of which is described above.

To determine the effectiveness of this silencer, it was installed on the tractor Belarus-1221. During the tests the time characteristics of the main noise sources of this model of tractors were also recorded for a different degree of engine load, and their contribution to the formation of both external and internal sound fields was determined. The general view of the tractor equipped with measuring equipment is shown in Figure 4.

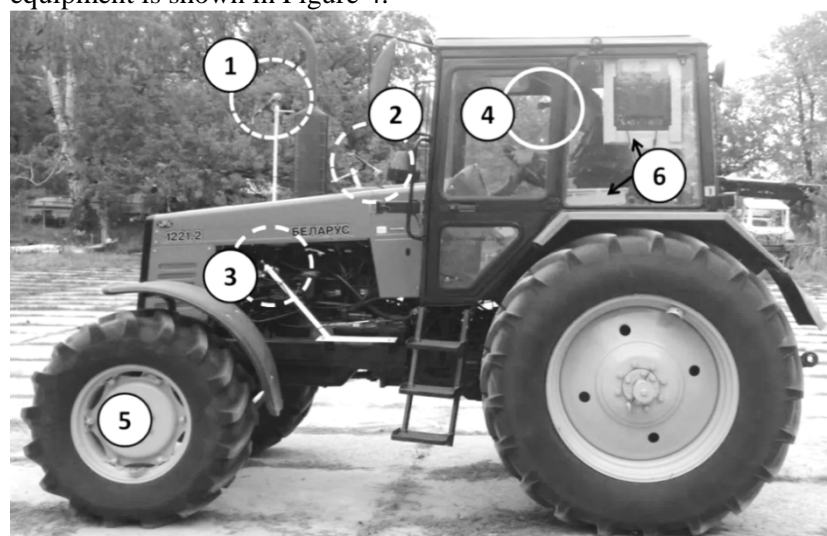


Figure 4. Equipment location on the tractor:

1 - microphone fixing the noise of the release process; 2 - microphone fixing the noise of the intake process; 3 - microphone fixing the structural noise of the engine; 4 - microphone fixing the noise inside the cabin; 5 - tractor Belarus-1221; 6 - monitor and system unit of a personal computer.

3. Results

The average results of SPL measurements in the tractor cab with an average load of the engine are shown in Figures 5-6.

One can see from Fig. 5 that for octave bands with average geometric frequencies from 250 to 4000 Hz, there is a stable excess of SPLs established by sanitary standards.

At the same time, it can be seen from Fig. 6 that for an area of low frequencies, the experimental muffler effectively reduces the SPL to the LS-75 (Limit Spectrum 75 is noise norms in the Russian Federation) values set. However, in the middle frequency zone, there is also a discrepancy in sanitary standards.

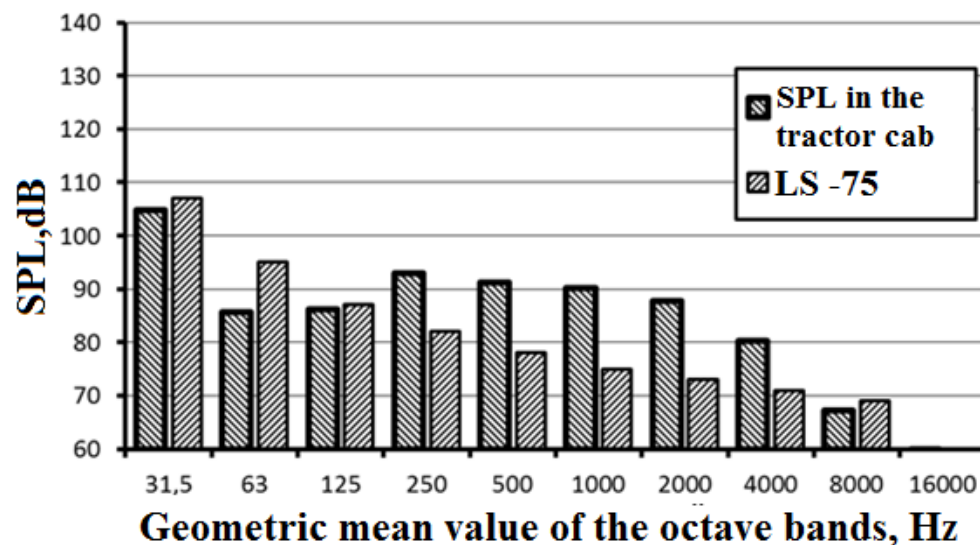


Figure 5. SPL in the tractor cab when using a serial suppressor

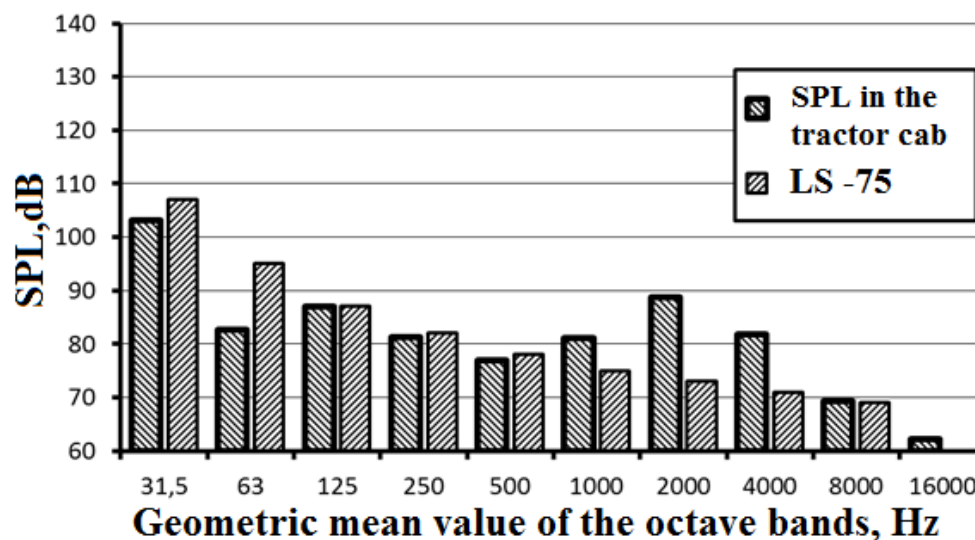


Figure 6. SPL in the tractor cab during field testing using an expert silencer

4. Conclusion

According to the results of tests carried out, low frequency components up to 500 Hz predominate in the spectrum of the external noise of the tractor. As the hook force increases from 0 to 34 kN, an increase in SPL by 5-15 dB is typical for all types of tested mufflers. At the same time, there is no stable interconnection in the mid- and high-frequency range.

A comparative evaluation of the effectiveness of the use of a serial and experimental noise suppressor has shown that the proposed design allows reducing the internal noise in the cabin by an average of 3.5 dB in the octave band of the low-frequency band, for the external noise – by 7.11 dB. At the same time, there is no noticeable difference in the mid- and high-frequency range.

Thus, the use of noise suppressors of active type in the mobile energy facilities design allows one to reduce the emission of increased noise levels into the environment by 7-11 dB and to increase the acoustic comfort at the operator's workplace by 3-5 dB.

References

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