Localization of car engine noise sources

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Abstract. The engine of a vehicle, particularly a passenger car, is one of the main sources of noise radiated into the environment and creates a noise load in residential areas, which has a negative impact on people. Experts in the field of acoustics perform computational and experimental acoustic studies both at the design stage, and at the stage of putting into production and directly operating the engine as part of the car to reduce engine noise. An important stage of acoustic research is the localization of the most intensely radiating noise of systems, mechanisms, nodes and engine parts. The article presents the results of experimental studies on localization of internal combustion engine noise sources of a LADA car. Keywords: car, engine, noise, sound field.

1 Introduction

The engine is the main dominant source of generating and emitting noise energy from the vehicle. The engine acoustic emission is a consequence of the flow and interaction of dynamic disturbances of numerous interrelated and very complex oscillating systems formed by the engine mechanisms and systems. During the compression, combustion and expansion strokes, dynamic deformations of the combustion chamber walls occur, which are transmitted and transformed into corresponding vibrations of the outer sound-emitting walls of the engine body parts. In functioning engine mechanisms, impact dynamic interactions occur between gap-mating contacting parts. For example, such shock dynamic processes occur in the timing mechanism during valve seating and opening in interaction with valve seats, in the crank mechanism – in processes of piston relocation in cylinders, during dynamic interaction of crankshaft pins with supporting main and crank bearings. The mentioned shock processes are transformed into the corresponding vibrating impulses of dynamic excitations and subsequent acoustic radiations of the walls of the housing parts of mechanisms and engine systems (housing noise). The reduction of motor hull noise is discussed in (Deryabin, 2022). An intense noise emitter is also the engine exhaust system, in particular the catalytic converter, usually mounted directly to the exhaust manifold. A large number of scientific articles are devoted to the problem of exhaust noise (Deryabin, Gorina, Krasnov, 2021; Li et al., 2017; Ranjbar et al., 2016; Ranjbar, Kemani, 2016; Zhong, 2020, et al.). A large contribution to the formation of the sound field on the engine side of the car is made by the intake system (Deryabin, 2020; Fesina et al., 2007). When performing research and development work to reduce engine noise, one of the most important tasks is to identify the dominant sound emitters on the engine side. Solving this problem for a particular engine

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model will allow further qualitative acoustic optimization of its design to minimize the level of radiated noise.

2 Materials and methods

Studies of the case noise of a four-cylinder sixteen-valve gasoline internal combustion engine with a working volume of 1.6 l, which has the following maximum indicators of the external speed characteristic: effective power N_e = 78 kW (5000 min^{-1}), effective torque M_e = 132 Nm (3000 min^{-1}) were carried out. The engine was mounted on a test stand located in an acoustic anechoic chamber. Studies of the sources of structural engine noise emission were performed using an automated acoustic holography complex STSF (B&K, Denmark). Automated complex STSF (see Fig. 1) allows to estimate the 3D sound field of the investigated object, including the functions of simulation of sound emission source changes.

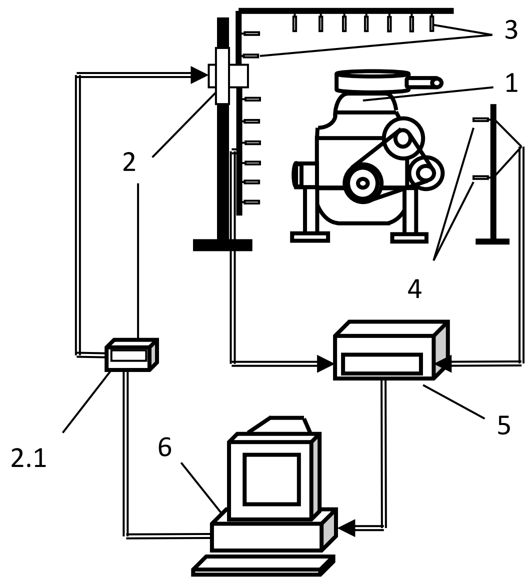

Fig. 1. Scheme of the test equipment to study the acoustic radiation of the engine: 1 – engine; 2 – acoustic robot; 2.1 – engine controller of the acoustic robot; 3 – scanning microphones; 4 – reference microphones; 5 – data acquisition system; 6 – workstation.

A scanning system of an array of reference (4) and scanning (3) microphones is used to obtain a complete description of the source sound field, within a given spatial angle, based on measurements in the flat surface of the microphone array near the stationary sound emission source (1). The number of microphones used and the distance between them are determined by many factors, including the specified (working) frequency range of the sound emission under study, the required measurement detail and the planned test time. Reference microphones provide phase, amplitude, and coherence information. The absolute values of the signal values from the reference microphones are of little importance. The scanning microphones are mounted, depending on the scanning plane, on the horizontal and/or vertical boom of the measuring microphone positioning system (acoustic robot (2)) and automatically scan in a given measuring plane, moving through the control of the acoustic robot motor controller (2.1) and STSF software package. The data acquisition system (5) is a modular system for signal analysis and system analysis. This system consists of from 1 to 64 units or groups, each of which can include up to eight six-channel input modules that are networked together via a master server. The data acquisition system is connected to the workstation (6) via a coaxial cable.

The engine was running at stationary maximum torque speed with the throttle fully open. When assessing the distribution of the sound field of the engine, the sound emitted by the intake system (the gas-dynamic component of the intake noise, which in this case is a background parasitic signal) was diverted from the area where the measuring microphones were installed using a rubber hose with free section placed in the cavity of the intake ventilation nozzle of the acoustic engine box. The exhaust gases removal of the engine with the accompanying process of eliminating exhaust noise was carried out by the technological exhaust system of the stand, consisting of a standard intake pipe with a neutralizer and a box exhaust silencer, the exhaust pipe of which is connected to the technological system of exhaust gas suction. Measurements of the engine sound field were carried out with microphones arranged by special vertical and horizontal stand as part of the positioning system in a rectangular matrix of 1 column x 12 rows (12 microphones in total). Twelve scanning and two reference microphones were used. By moving the microphone stand along the horizontal (X-axis) and vertical (Y-axis) positions, a rectangular measuring area of 1 x 1 m^2 was covered. Sound signals were measured by each microphone in the rack, respectively, in the direction of the noise source along axis Z (axis perpendicular to the studied surface of the engine case) at a distance of 1 m from the source surface.

3 Results

Figures 2-4 show some graphical results of studies of the structural noise of the 1.6 L engine of the Lada car.

The characteristics obtained from measurements from the front of the engine (Fig. 2), in the frequency range of 400 to 3350 Hz (the dominant frequency range in the overall noise level) show that the maximum contribution to engine noise emission from the front at maximum torque is made by the location of the catalytic converter and the belt drive of the alternator.

The characteristics obtained from the left side of the engine (Fig. 3), in the frequency range of 700 to 4000 Hz, show that the maximum contribution to the noise emission of the engine on the left side at maximum torque is made by the catalytic converter.

When examining the sound field emitted from the left side of the engine (Fig. 4), at a frequency of 3080 Hz (bandwidth 70 Hz), a shift of the sound radiation center to the upper right side of the cylinder block (water pump location area) was noted.

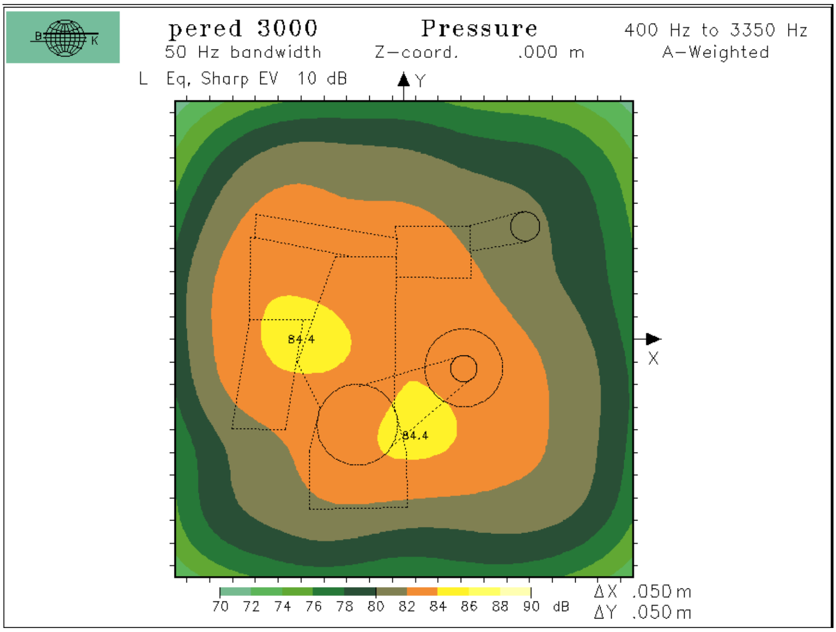

Fig. 2. Map of spatial distribution of sound pressure at the distance of 1 m from the surface of the engine on the front side in the frequency range of 400-3350 Hz.

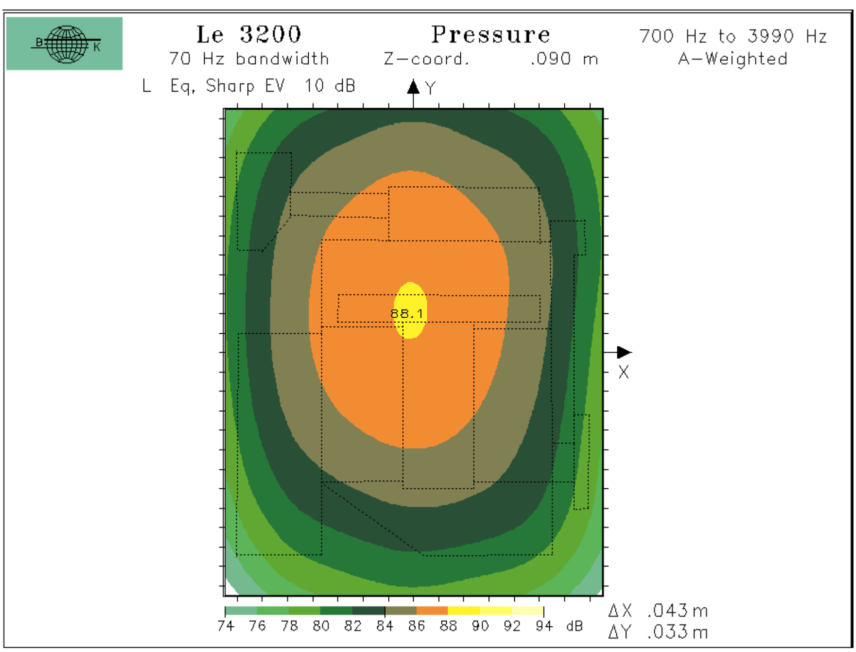

Fig. 3. Map of spatial distribution of sound pressure at the distance of 1m from the surface of the engine on the left side in the frequency range of 700-4000 Hz.

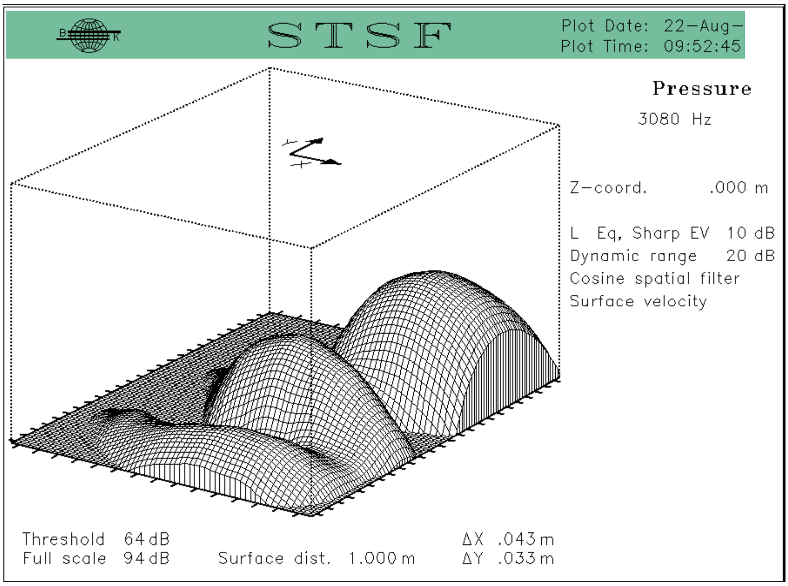

Fig. 4. Map of spatial distribution of sound pressure (in the 3D coordinate system) in the measurement area plane at a distance of 1 m from the surface of the engine on the left side**,** at a frequency of 3080 Hz.

4 Conclusion

Practical use of technology of research and modeling of structural noise sources of a passenger car engine by the STSF method allows to identify (localize) the main areas of increased sound emission of the engine case, to perform quantitative and qualitative assessment (including redistribution of zones and change of areas of maximum sound emission) of various structural measures influence on reduction of its case noise, to model noise attenuation of local sources of structural engine noise. Localization of sources of increased noise in the engine of the Lada car (neutralizer, belt drive auxiliary units, water pump) will allow qualitatively perform fine-tuning of the engine on the acoustic indicators.

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