Methods to improve vibroacoustic characteristics of mining machines

A I Podgorny, A V Kudrevatykh, N V Kudrevatykh, A S Ashcheulov and A S Ashcheulova

Federal State Budgetary Educational Institution of Higher Education “T.F. Gorbachev Kuzbass State Technical University”, Vesennya St, 28, Kemerovo, Russia

E-mail ascheulovas@kuzstu.ru

Abstract. At machine-building enterprises, serious attention is paid to the issue of improving the products quality. Noise and vibration are one of the main indicators that characterize the quality, comfort and reliability of machines, so the reduction of noise and vibration level is one of the most important scientific and technical problems of national engineering. Along with the economic aspects, the reduction of machine noise contributes to the ecological state improvement, as well as the working and living conditions of workers. Noise and vibration are one of the most common adverse factors that worsen working conditions in production, construction and transportation.

Numerous medical studies have proven the harmful effects of prolonged high-intensity noise. The rhythm of heart activity changes, blood pressure increases, hearing deteriorates, and the process of fatigue accelerates under the influence of noise. Vibration disease and cochlear neuritis are the most common among occupational diseases and are about 30% of the total number of occupational diseases. Noise is one of the factors that reduce labour productivity; in addition, it can cause accidents and injuries at work. It is established that the noise reduction from 5 to 10 dB can lead to the labour productivity increase by 5%.

The necessity to increase labour productivity, achieve notable social and health effects in order to make work in transport, construction and production more attractive, makes the task to ensure comfortable working conditions, eliminate adverse factors that affect health such as noise and vibration the priority.

In addition, noise reduction in transport and industry is cost-effective. Estimates show that potential economic effect of noise reduction can reach 1-2 billion roubles per year. Noise reduction produced by the machine by 1 dB automatically increases its value by 1% or more on the world market.

In this regard, it is natural that a lot of attention is paid to solving the problem of noise reduction all over the world. In many scientific works, the physical foundations of the radiation nature and sound propagation, the processes of creating noise by various mechanisms, methods for evaluating and measuring sound, methods and means of noise protection are described.

Much attention is paid to noise reduction in mining engineering. However, despite the efforts of scientists, designers, and machine builders, the problem of mining transport noise is currently very relevant. At least 30 to 50% of produced and operated mining machines exceed the existing permissible noise.
Until recently, the attention of researchers and designers in the field of mining engineering was paid to ensuring normal acoustic environment at the operator's workplace. This was due to the traditionally higher noise requirements of the MM operator, the rationing of which is stricter in Russia than abroad. The cabin was used as a method of noise control, which is a reliable mean in terms of vibroacoustic qualities, but structurally complex with a high-cost control, but which effectively reduces noise in the workplace. At the same time, the problem of external noise, which has currently received increasing attention, is still unsolved.

 Attempts to use "passive" methods of reducing external noise by noising over and shielding radiation sources for a number of economic and technological difficulties have not gone beyond the scope of research and have not found wide application in mining engineering.

 In addition, the structure analysis of various road construction machines allowed to conclude that the design and production of road construction equipment is carried out without taking into account its future acoustic parameters, i.e., the machine design does not initially include solutions that allow to obtain the specified acoustic characteristics of the created machine.

 The methods used to combat the noise of already created machines, which do not provide differentiated approach to the study of the process of noise generation and radiation, necessitate the use of expensive and technically complex methods of noise reduction, involving complete isolation of radiation sources or the operator's workplace.

 As practice shows, such methods of noise reduction are quite effective in terms of noise reduction, but are economically unprofitable, difficult to implement in mass production, and inconvenient to operate.

 Therefore, the purpose of this study is to develop methods to predict and reduce the noise of the power units of mining machines at the design stage, as well as in the process of their experimental refinement by acoustic parameters.

 The development, tuning and exploitation of ‘low-noise’ mining equipment should be based on clear ideas about the causes that lead to machines acoustic radiation, which should serve as a theoretical basis for specifying the requirements for machines design, as well as the principles of mining machines design (MMD) with specified vibroacoustic characteristics. Numerous studies in the field of machine noise reduction have established that in all cases, the solution of noise and vibration protection problem of models that came into production and are in operation is economically less feasible than at the design stage. At the same time, the task of developing or selecting a set of measures that provide the specified vibroacoustic parameters at the minimum (in the limit of the minimum possible) costs, taking into account the requirements of manufacturability, convenience and reliability in operation, should be already solved at the earliest stages of machine development. The introduction of methods to reduce the noise load even at the stage of production of mining machines will reduce the harmful effects of vibrations on both a machine operator and equipment reliability. The introduction of the same methods to already operating equipment is not always economically justified and technologically possible, in this regard, it is necessary to develop other methods to improve the machine vibration and noise characteristics. [1, 2, 3]

 The complexity of the processes leading to acoustic radiation, a large number of radiators makes it difficult to obtain an objective picture of mining machines noise generation. The basis of such models is the following basic physical prerequisites: the noise occurs in the source because of the impact or other interaction of parts, during the flow and pulsation of gas flows in the systems and mechanisms of the power unit, during machine unit vibrations on the suspended span under the influence of various power factors. The sound field excited by the source is formed in various conjugate elements of the machine structure. The sound energy is partially reflected or absorbed [4, 5, 6]. The acoustic radiation occurs due to the transfer of the sound energy part from the point of disturbing force application, to the external surfaces of the machine that emit sound. It should be noted that for mining machines, it is the vibration of the external surfaces that is one of the most significant noise sources.

 The practice of dealing with the machine noise has developed two interrelated methods of noise absorption. These are measures aimed at reducing noise in the excitation source and absorption of
acoustic energy in the path of sound waves propagation. Noise reduction in the source is usually achieved by reducing the intensity of the power excitation, as well as reducing the sound conductivity and sound-emitting ability of the radiator. [7, 8, 9] Reducing the intensity of power actions in various sources is achieved in a number of cases due to difficulty to implement design measures aimed at reducing gaps in joints and units, reducing aerodynamic vortices and pulsations, balancing rotating parts, affecting the flow of the working process, etc. Reduction of sound conductivity and sound-emitting ability of the structures is achieved mainly by breaking the synchronism of vibrations of the radiating surfaces, reducing the radiation area, increasing the coefficient of inelastic losses in the parts materials.

Noise reduction in the way of its propagation is achieved by the use of sound insulation, sound absorption, vibration isolation, as well as a number of other means from the acoustics arsenal. [10, 11]

The practical possibilities of modern methods of machine noise reduction are quite wide. Individual measures, as well as their complexity, are able to provide any required reduction in machine noise. However, it is necessary to take into account not only the acoustic efficiency of the measures, but also the economic criteria that determine the ability to solve the problem of achieving the specified vibroacoustic parameters with acceptable material costs.

As practice has shown, this task is the most efficiently solved only if the machine is designed from the initial design stages, taking into account the necessity to obtain, along with the specified performance and efficiency characteristics, the specified vibroacoustic indicators.

At the same time, in relation to mining machines, the priority issue is the design or selection of a power generation system that meets technical and economic requirements of this machine type and provides the required vibration and acoustic characteristics. It should be noted that the possibilities of acoustic improvement of the internal combustion engine design used for mining machines are wider than in vehicle engines. A prerequisite for this is the possibility of a wider variation of the engine parameters in mining transport in order to obtain the required values of sound levels to the detriment of their weight and size characteristics. [12, 13, 14]

Considering this, in order to ensure the specified values of the effective power and vibration-acoustic parameters of an engine, the optimal combination of parameters must be based on the requirements for power generation system of a particular type of mining equipment, taking into account the specifics of their technological functioning. In this situation, it is possible to obtain the specified vibroacoustic parameters of an engine by reducing its rated speed (de-forcing by speed). The reduction in effective power can be compensated by the use of pressure charging.

In addition, for many mining machines, the requirements for weight and dimension are not among the primary ones. Here, the option of restoring the engine power to the required values by increasing the working volume is not excluded. Despite the weight increase, dimensions, and metal consumption, this method of noise reduction has a number of advantages compared to the expensive, structurally complex, as not sufficiently developed method of noising over and capsulating of power units.

One of the most significant reserves for reducing the noise level of mining machines power units is pressure charging. Thus, the use of pressure charging, according to experts, reduces the noise from the combustion process in diesels by 18 dBA and brings its levels to values lower than the levels of mechanical noise, which allows, all other things being equal, to reduce the sound power emitted by the engine by more than half.

The use of gas turbine pressure charging also has a positive effect on the noise levels generated by the exhaust system. The gas turbine in the exhaust system leads to the pulsation smoothing of the exhaust gas flow, which reduces the noise levels of the exhaust process by 10-12 dBA. However, as practice shows, the noise levels of non-muffled exhaust systems, even in the presence of turbocharging, are significant. Therefore, at present, it is accepted and considered reasonable to combat with their acoustic radiation by using autonomous anti-noise devices for this purpose.
Under the existing standards for the noise of mining machines, the acoustic radiation of the exhaust system of the power unit does not significantly affect the external noise, if the acoustic efficiency of the silencer is at least 25 dBA. With the existing noise levels of engines used in mining engineering equal to 120-125 dBA, the noise levels of the exhaust process equipped with a silencer, not exceeding 95 dBA, practically exclude the exhaust system from among the noisiest sources of the machine.

Such muffling characteristics are provided with both reactive silencers and active silencers with sound-absorbing material. The effectiveness of active silencers, in which the sound energy is reduced due to its absorption by the sound-absorbing material, is quite high, but in practice, such silencers are used extremely rarely due to the rapid coking of the sound-absorbing material. In this case, reactive-active silencers are more acceptable.

As practice has shown, for the intake systems of mining machines power units, there is no need to use additional noise silencers, since the air purification systems of diesel engines, made in accordance with the standards requirements, are effective noise silencers.

Reducing the noise and vibration of machines in operation is technically more complicated. In this case, a significant reduction in noise and vibration levels at an operator's workplace is often achieved by using noise and vibration-absorbing coatings of the control cabin, but effective reduction of external noise requires the use of a set of measures, often difficult to implement without changing the machine design significantly.

In this situation, it is possible to solve the question of the possibility and rational strategy for improving the vibroacoustic characteristics of mining machines only on the basis of an analysis of the conditions for the sufficiency of certain influences on the structure in order to reduce the acoustic activity of the most intense sources that form its sound field.

Here, the necessary initial stage of the study of the machine acoustic qualities is the determination of its main contribution sources to the overall picture of radiation. The methodology of such studies should be based on a number of techniques that allow isolating the noise of individual systems and machine units. One of these techniques can be the method of sequential exclusion of sources, the essence of which is to install effective noise suppression structures on individual noise sources, as well as other measures that allow excluding the influence of this source to the overall noise of the machine. The specific content of the methodology is individual for each type of mining equipment.

Based on the assessment of the contribution of each of the sources and the determination of the most intense radiators, the question of appropriate means to influence them, allowing to exclude these sources from the number of the ‘loudest’ ones, is decided.

The practice of noise reduction in mining equipment, as well as in related areas of mechanical engineering, such as autotractor production, has developed a number of typical methods of influencing the most intense sources of machine noise, which, as a rule, are the exhaust system, as well as the internal combustion engine, as an independent source and as the exciter of the design of a vehicle itself. In some cases, they allow to achieve results that meet the requirements of legal documents at low costs and changes in the machine design.
In addition, the most successful design solutions found in the process of finishing measures to improve the acoustic qualities of the design of machines in operation can be used in solving problems of obtaining the specified vibroacoustic characteristics of newly designed machines.

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