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Possibilities of the Sound Insulation Increase for Power Equipment at Low Frequencies

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Abstract *- A method and design for improving the noise insulation of operating equipment in the low-frequency range from 15 to 20 Hz by order of magnitude (up to 20 dB) have been considered. It has been experimentally shown that the design provides a difference in airborne noise levels (AN) inside and outside the sound insulating casing of the order of 15 - 20 dB at frequencies from 20 to 100 Hz and over 20 dB at higher frequencies. The possibilities of using such a casing in real conditions, taking into account the need for holes for equipment air cooling, and ways to further increase its efficiency have been discussed.*

Keywords - *air noise, sound insulation, sound absorption, frequency, frequency range, damping, noise reduction.*

I. PROBLEM FORMULATION

Airborne noise (AN) is one of the production factors, which are most difficult to eliminate. Analysis of the scientific publications [1]-[2] shows that today there are two main ways to reduce the AN. The first is to decrease it in the source, for example, by reducing vibration, speeds of working processes and working environments. The second method is protection against noise, reducing the AN along the path of its transfer from the source. It is subdivided into noise insulation and noise absorption [3]. Noise insulation involves the placement of screens and casings around the noisy equipment to prevent the spread of the AN. Noise absorption uses means of vibrational energy dissipation of AN, which are placed on the walls and inside the premises with the equipment, on the casings and screens surface. Usually, noise insulation and noise absorption are used together.

It is also necessary to mention methods of active noise (and vibration) suppression. They use emitter control systems to create ‘Anti-sound’, which reduces the AN initial values at specified points in the surrounding space (‘Anti-sound’ technology [4], or active noise insulation). They are usually applied locally to suppress the AN at the operator's location (for example, active headphones). No mentioning of AN active suppression for large industrial installations, with the exception, perhaps, of the scientific publication [4], has been found. It is possible to use active vibration damping of the airborne noise source to reduce it.

The use of noise insulation and noise absorption is complicated due to their low efficiency at low frequencies less than 100 Hz. Quite often, it is not even given for these frequencies (Fig. 1). This is partly due to the fact that the AN influence on the human ear is weakened in the low-frequency zone, which is why correcting filters are introduced in the AN measurements, and the measurements are given in dB (A), where the low frequencies are corrected. However, there are low-frequency, high-power AN sources, which require noise reduction. For example, these are low-speed fans of modern dry ventilated cooling towers and air condensers, turbine generators at power plants with a speed of 50 (60) Hz and 25 Hz.

II. SOUND INSULATING CASING, EFFECTIVE AT LOW FREQUENCIES

The maximum achievable efficiency of a sound insulating casing is defined as the efficiency of a mass obstruction in the path of sound transfer. At normal sound incidence to the surface of the obstacle, the efficiency Δm is defined as

$$\Delta m = 10 \lg (1+a^2) \quad (1)$$

Where $\pi = f\, m / \rho_0 c_0$, ρ_0, c_0 - are density and speed of sound in air, m is the mass per unit of the casing surface, f is the frequency. Fig. 2 shows the Δm frequency dependences for various m. To obtain the efficiency of more than 20 dB at frequencies above 20 Hz, a mass barrier of the order of 80 kg/m2 is required. In the case of diffuse sound incidence, the efficiency decreases to the value Δdm (Fig. 2):

$$\Delta dm = 10 \lg (a^2/\ln(1+a^2)) \quad (2)$$

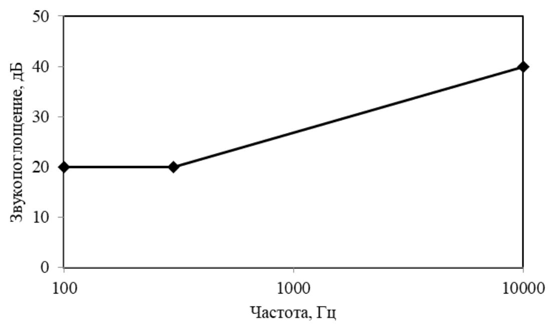

Fig. 1. A typical dependence diagram of the sound insulation efficiency on frequency

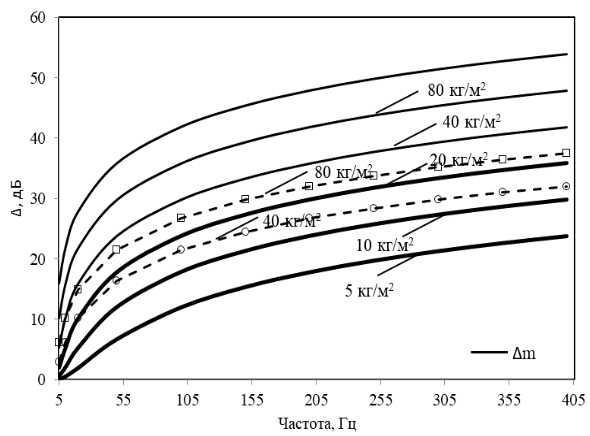

Fig. 2. The efficiency of the mass barrier Δ m at the normal 1 and diffuse 2 sound incidence

The presence of resonances in the casing leads to a decrease in its sound-insulating efficiency, calculated according to the law of masses (1, 2). At resonances, it becomes transparent to sound and can even amplify it. An increase in damping in the casing material favourably affects its efficiency on resonances but cannot eliminate their negative consequences.

It has been proposed to make the casing massive enough, but at the same time pliable, so that its first resonant frequency should be noticeably below 10 Hz. Then, at frequencies above the first resonance, the casing stops and effectively dampens the noise, working as a massive obstruction.

III. THE CONSTRUCTION OF A LOW-FREQUENCY SOUND-INSULATING CASING

The construction of the casing is based on a pliable material such as rubber, on the plates of which a set of massive metal plates are attached, as shown in Fig. 3. Along the perimeter, the plates are attached to a rigid wooden frame, as shown in Fig. 4 for the studied experimental model. The linear mass of the casing plates was about 40 kg/m2, the frequency of the lowest resonance of the plates was about 9 Hz.

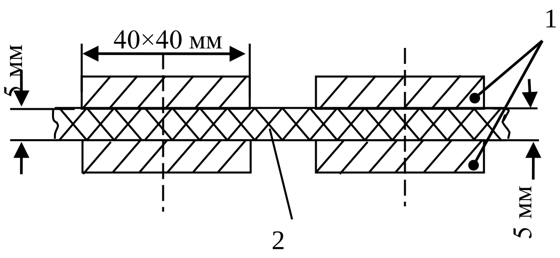

Fig. 3. Construction (cross-section) of an experimental low-frequency sound-insulating casing: 1 - metal plates; 2 - rubber sheet;

Fig. 4. General view of an experimental sound-insulating volume (a cube with sides of 1 m) with a low-frequency casing (metal plates mounted on a rubber sheet) with the top cover removed and with a sound column installed inside.

IV. TEST RESULTS OF THE MODEL

A comparison of the AN levels inside and outside the sound insulating casing model (shown in Fig. 4 and installed in a laboratory room) is shown in Fig. 5. The AN reduction due to the sound insulation is from 15 to 30 dB at frequencies from 10 to 100 Hz and about 30 to 40 dB at higher frequencies. A slight decrease in the sound-insulating ability of the casing model at frequencies of the order of 40, 110, 160 and 260 Hz is due to the resonances of the casing frame, to which the sound-insulating plates are rigidly attached, shown in Fig. 3. Therefore, it is advisable to further investigate the option of attaching the plates to the frame through low-frequency vibration isolation to reduce the effect of frame resonances on sound insulation.

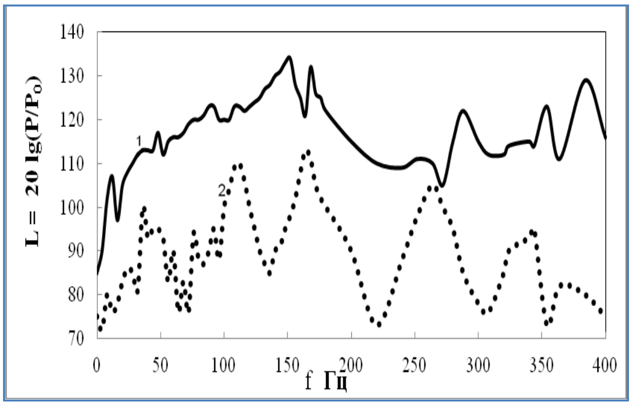

Fig. 5. Reducing airborne noise in a room using an experimental low-frequency sound-insulating casing shown in Figs. 2 and 3. Curve 1 - airborne noise levels inside, 2 - outside of the sound insulation.

V. THE DESIGN OF THE SOUND INSULATING CASING AT THE POWER FACILITY

The casing model in Fig. 4 has been made without holes (sealed). In the case of sound insulation at a real power facility, holes in the casing may be required for the passage of pipelines for various purposes, shafting and, in some cases, holes to cool the equipment with the ambient air. However, it is known that even small holes can significantly reduce the effectiveness of sound insulation. Sealing (minimizing gaps) at the points of pipelines and shafting passage through the casing does not cause fundamental difficulties, except that the pipeline itself can be AN source by transferring AN from a sound-insulated object.

The area of the cooling air holes must provide the required airflow, calculated from the heat balance, and maybe unacceptably large. The solution is to install sound attenuators in these holes, for example, of a plate type, with the required total area. The length of the attenuators should be selected to ensure the required amount of noise suppression. Such a design of a sound insulating casing has been shown in Fig. 6 for a brush apparatus of a power plant turbine generator.

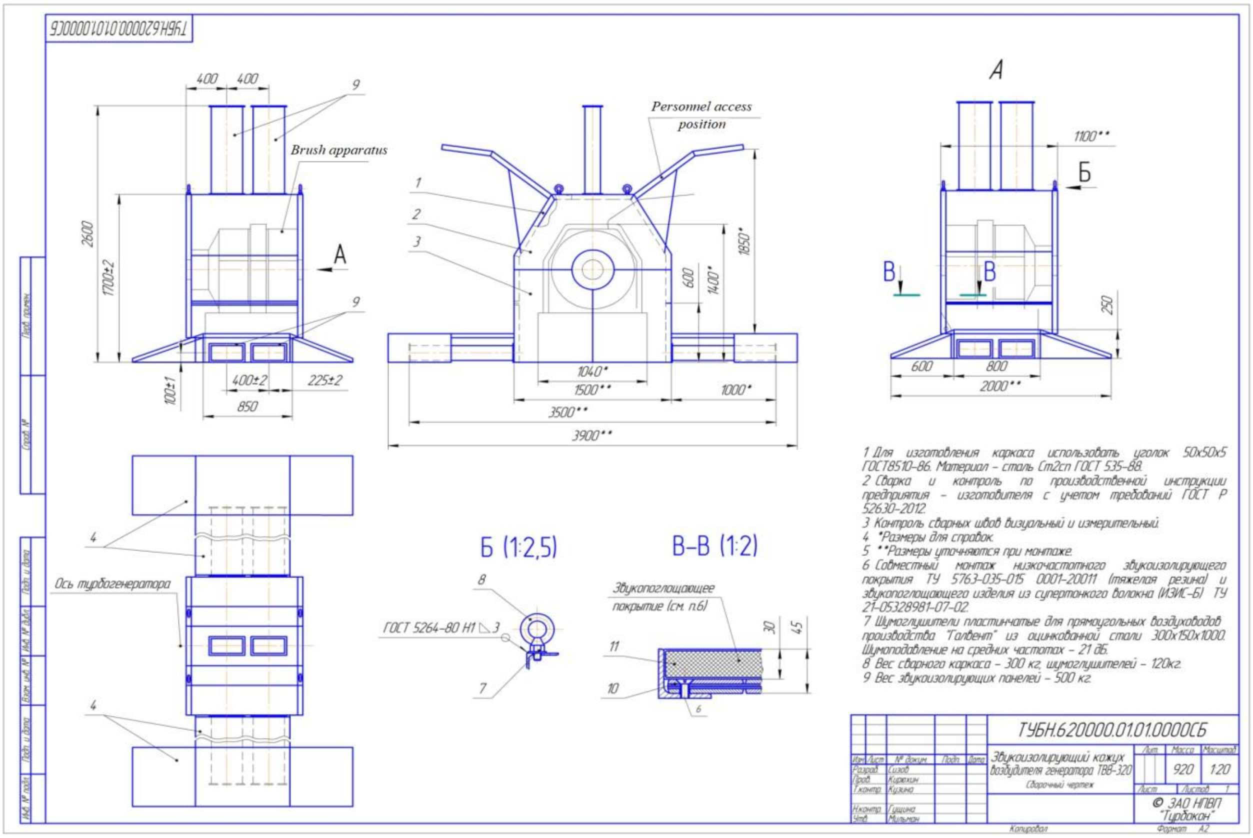

Fig. 6. The sound insulating casing of a brush apparatus of a power plant turbine generator

The structure of the sound-insulating casing of the exciter includes a frame pos. 1 with hinged flaps (2 pcs.) to provide access for service personnel to the brush apparatus. Sheets of a low-frequency sound-insulating coating are attached to the frame. A sound-insulating covering made of super-thin basalt fibre can be additionally installed inside the casing. Along the axis of the brush apparatus, holes for the shaft exit are provided in the endplates of the casing.

Cooling air circulation inside the casing and noise suppression in the air circulation holes is ensured by the installation of plate suppressors pos. 9 with a rated efficiency of more than 20 dB. Four suppressors for cooling air intake are located horizontally at floor level - two on each side of the brush apparatus and two - vertically on top of the casing to ensure the removal of heated air by its natural circulation under the influence of thermal pressure. Suppressors located at floor level are protected from damage by service platforms. It is possible to install fans at the outlet of the suppressors to increase the cooling efficiency.

VI. CONCLUSIONS

A design for improving the sound insulation of equipment in the low-frequency range from 15 to 20 Hz has been proposed and experimentally studied. It has been experimentally shown that the design provides a difference in airborne noise levels (AN) inside and outside the sound insulating casing of the order of 15 - 20 dB at frequencies from 20 to 100 Hz and over 20 dB at higher frequencies. An increase in the efficiency of sound insulation of the considered structure can be obtained due to vibration isolation of the frame plates, frame beams damping and an increase in the linear mass of metal plates.

An example of a design based on such a casing is shown for the brush apparatus for the excitation of an electric generator with noise suppression devices in the holes for air cooling.

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