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Invited Paper

OPTIMIZATION OF NOISE AND VIBRATION PROTECTION APPROACHES IN MOVABLE COMPRESSORS

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ABSTRACT

The reduction of noise of movable compressors (MC) is a problem of great importance in Russia. Today most leading foreign compressor-manufacturing firms produce MC in sound-proofed varieties. Different methods can be used for the noise and vibration reduction of compressors depending on their types, such as: installation of sound-proofed enclosures, mufflers, sound buffles, sound-absorbing and vibration-damping constructions, etc. Each approach when used separately or together with the others can provide a reduction in the noise to the noise limit. Therefore the designer always faces the problem of choosing the optimum approach. In this paper authors solved the problem of optimization of the noise and vibration protection approaches by choosing the noise reduction procedures using the cost and efficiency criteria for a given noise limit at a specified point.

INTRODUCTION

At designing of specific technical systems, in particular movable compressors, one of major problems is minimization of the designing and manufacturing costs of a serial sample to achievement of design specifications. In this case such parameter is a noise, radiated by MC. In practice usually for this purpose are used experimental tests of large number of variants of a general-arrangement schemes and installation of separate noise control elements, that results in increasing of the designing costs and does not ensure the obtaining of optimum result.

THEORY

All variety of MC design performance, depending on the noise radiation formation can be resulting to seven main design schemes. [1]

The authors with use of the acoustical statistical theory have developed mathematical models of an expected noisiness calculations in according to this schemes.

It is possibility for each of the design schemes with elaborated mathematical models to conduct the parametric analysis and optimization of a MC noise reduction complex even at the stage of designing.

For example, for the designed MC scheme, having in under-enclosure space an obviously prevailing source, for noise decreasing it is necessary to place it in the additional enclosure-capsule and the exhaust engine is directed downwards on a reflecting surface. [2,3]

The expected noisiness in a specific point from a prevailing source under enclosure can be calculated by the following equation, in dB:

$$L_{enc}^{SP} = L_{W_{sour}} + 10\lg S_{enc_1} + 10\lg \bar{S}_{enc_2} + 10\lg\left[\frac{\chi_1}{4\pi r_{sour}^2} + \frac{4\psi_1}{B_{enc_1}}\right] + 10\lg\left[\frac{\chi_2}{4\pi r_{enc_1}^2} + \frac{4\psi_2}{B_{enc_2}}\right] - \overline{SI}_{enc_1} - \overline{SI}_{enc_2} - k\lg\frac{R}{r_0} - 11, \qquad (1)$$

where $L_{W_{sour}}$ is the total sound power spectrum of main movable compressor sources, dB; S_{enc_1} is the total area of the first enclosure panels, m^2; $\bar{S}_{enc_2} = \sum_{(i)} \left(\beta S_{enc_2}\right)_i$ is the specific area of the second enclosure, m^2; $S_{enc_{2i}}$ is the area of i-th panel of the second enclosure, m^2; β_i is the coefficient which takes into account arrangement of the enclosure panel in respect to the specific point; $B_{enc_i} = A_{enc_i} / \left(1 - \bar{\alpha}_{enc_i}\right)$ - is the acoustic constant of the i-th enclosure, m^2; χ_1, χ_2 - are the coefficients which takes into account influence of the nearest objects in the acoustical field for the first and second enclosures; ψ_1, ψ_2 are the coefficients which takes into account of sound field diffusion disturbance inside the first and second enclosures; r_{sour} is the distance from geometrical center of a source to the panel of the first enclosure, m; r_{enc_1} is the distance from geometrical center of the first enclosure to the panel of the second enclosure, m; $\overline{SI}_{enc_i} = 10\lg\left(1/\overline{\tau}_{enc_i}\right)$ is the specific sound isolation of the i-th enclosure; $k = 10$ when $R = 1$ m and $k = 20$ when $R = 7.5$ m; R is the distance from geometrical center of the second enclosure to the specific point, m.

The expected noisiness in a specific point from the exhaust engine takes into account a sound, coming in this point directly from the exhaust, and the sound reflected from a reflecting surface and is calculated by equation, in dB:

$$L_{exh}^{SP} = L_{W_{exh}} + 10\lg\left[1 + \frac{\left(1-\alpha_{surf}\right)S_{surf}R_{exh_1}^2}{2\pi R_{surf}^2 \quad R_{exh_2}^2}\right] + DI_{exh} - 20\lg\frac{R_{exh_1}}{r_0} - 11, \quad (2)$$

where $L_{W_{exh}}$ is the sound power spectrum of the exhaust engine, dB; R_{exh_1}, R_{exh_2} are the distances from the exhaust pipe to the specific point and to the geometrical center of the specific reflecting surface accordingly, m; R_{surf} is the distance from the geometrical center of the specific reflecting surface to the specific point, m; S_{surf} is the area of surface, enveloping around on distance of one meter from the reflecting surface, m^2; α_{surf} is the sound absorption coefficient of the reflecting surface; DI_{exh} is the exhaust direction index; $r_0 = 0.2$ m for the exhaust engine.

The total sound pressure level in the specific point can be calculated by equation, in dB:

$$L_{SP} = 10\lg\left(10^{0.1L_{enc}^{SP}} + 10^{0.1L_{exh}^{SP}}\right). \quad (3)$$

The conducted parametric analysis resulting defining ranges of the natural and geometrical characteristics changing of noise control elements, to evaluate the contribution of separate components included in calculating equations. [4]

From the point of view of optimization such analysis lets develop set of the extreme problem plans for each of the schemes.

The second stage of an optimization problem is developing of criterion function. Usually as such function are used the cost characteristics of researched object. It is difficult to develop a cost function in an obvious view for MC. However it is clear that sample cost is determined by quantitative and qualitative ratios of materials used at manufacturing sound isolating enclosure and muffler. Therefore as criterion function in the given problem expediently to use specific area mass of sound isolating enclosure. This mass in turn depends on the same geometrical and physical parameters, as L_{SP} (see equation (3)).

CONCLUSION

Thus the problem of optimization of a MC noise control complex is resulting to a problem of non-linear programming. In such problem the analytical expressions of an expected MC noisiness of the various schemes represent itself as the limitations-equalities. Moreover for each of the design schemes are added the limitations-inequalities connected with technological and construction design features For the solution of such problems the modern instrument of non-linear programming, advanced in last two decades, is effectively used.

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