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APPROACHES TO CLASSIFICATION OF REDUCTION METHODS OF LOW FREQUENCY NOISE AND VIBRATION OF POWER PLANTS

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***Abstract**: The importance of the problem of low-frequency noise and vibration reduction now may be considered as urgent. Increased influence of low-frequency noise and vibration may cause both human health problems and equipment damage. Power plants (internal combustion engines, compressors, heat-exchanges etc.) are one of the main low-frequency noise and vibration sources. The principles of classification of methods of power plants low-frequency noise and vibration reduction are suggested. Author is proposing energetic approach, according of which all the methods and arrangements of reduction may be classified as passive (adaptive and non-adaptive), active and hybrid passive-active. The classification is illustrated by the different examples, including constructions of mufflers and dampers, some of which are developed by author.*

***Keywords:** industrial low frequency, noise, vibration, classification, reduction*

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1. INTRODUCTION

Presently noise and vibration impact to the population and to equipment operation in industrial and domestic conditions is increasing every year [10, 14, 16 etc.]. Inadmissible noise levels affection to the housing estates leads to cities population disease growth. It is well known, that the strongest impact produced by noise effects on man is in frequency range from 1000 to 4000 Hz (middle- and high frequencies). But for industrial town environment the most strong noise impact to the city population is first of all caused by low frequency noise (from 20 to 300 Hz). Analysis of population complaints confirms it [16 etc.]. Low frequency noise is spreading for a long distances without significant absorption. Low frequency vibration may cause professional illnesses of workers and workers disease, negative impact to environment and to the health of inhabitant on the territory near to industrial enterprises. Intensive vibration during exploitation of power plants and mechanical noise may cause reduction of attention and increasing of number of mistakes during work.

Among of the main low-frequency noise and vibration sources in conditions of urban territories are:

- Transport (especially automobile internal combustion engine intake and exhaust systems);
- Industrial enterprises and equipment (compressors, ventilators, pumps, mechanical noise etc.);
- Urban and domestic noise sources (noise from offices, shops, stadiums etc; noise generated by office and domestic ventilation systems, TV, broadcasting, musical equipment, human speech etc.).

Analysis of scientific research is showing that power plants of different kinds (compressors, automobile internal combustion engines, pumps, ventilators, heat-exchanges, stationary engines etc.) are one of the main low-frequency noise and vibration sources in conditions of urban territories.

This paper is devoted to developing approaches and principles of classification of methods of power plants low-frequency noise and vibration reduction.

2. DISCUSSION OF THE APPROACHES TO CLASSIFICATION OF REDUCTION OF POWER PLANTS LOW FREQUENCY NOISE AND VIBRATION REDUCTION METHODS

Generally, the classification of low-frequency transport noise and vibration reduction may be based on the variety principles. In Tab. 1 approach to systematization of criteria and types of classification of methods of power plants low-frequency noise and vibration reduction is shown, proposed by the author of this paper.

N	Criteria of classification	Types of classification	Examples
1.	The general way of power plants low-frequency noise & vibration reduction	Reduction in the source of generation Reduction on the ways of propagation Individual means of protection	Noise mufflers Acoustic barriers Electrodynamics anti-noise headphones
2.	The spatial kind of low-frequency noise & vibration source reduction	One-dimensional (ducts) Two-dimensional (plane surfaces) Three - dimensional Reduction inside of enclosed volume Reduction in open space	Gas pressure pulsations compensator in compressor pipeline Compensation of low-frequency noise spreading through the windows inside of buildings Reduction of low frequency noise and vibration from industrial equipment in working place Compensation of low-frequency noise inside of automobile passenger compartment Compensation of low-frequency transport noise in open space of living territory
3.	Periodicity of low-frequency noise & vibration generation	Periodical Non-periodical	Internal combustion engines (ICE) intake & exhaust mufflers Traffic noise barriers
4.	Completeness of low-frequency noise & vibration sources reduction	Reduction of single source Reduction of several sources Complex reduction	Automobile ICE exhaust noise muffling Automobile ICE intake & exhaust noise muffling Complex automobile low-frequency noise & vibration reduction
5.	The kind of noise & vibration source spectrum	Broadband noise Narrowband (tonal) noise Broadband vibration Narrowband (tonal) vibration	Noise inside of building ICE intake & exhaust noise active mufflers Vibration dampers Resonators
6.	The kind of transport	Aircraft low-frequency noise and vibration Separate automobiles, motorcycles Noise of automobile transport flows Trolleybuses Railway transport, trams Metro transport Water transport Submarines Pipeline transport Military transport Space transport	Reduction of noise and vibration by mufflers, vibration isolation etc. Noise mufflers, vibration mounts Noise reducing road surfaces Acoustic barriers Acoustic barriers Underground vibration isolation Ship diesel engines noise muffling Vibration dampers inside of submarine Pipeline vibration reduction mounts Active noise & vibration reduction inside of tank Active vibration reduction

Tab. 1: Systematization of criteria and types of classification of methods of power plants low-frequency noise and vibration reduction

Let us consider more detailed the criteria of classification.

For the **general way of low frequency noise and vibration reduction** the classical approach is to subdivide the methods and means of noise and vibration reduction on the general way (in the source of generation and on the ways of propagation) and on the meaning of reduction methods (collective and individual protection). As collective methods of protection acoustic barriers may be considered, as individual – electronic headphones.

The spatial distribution of low-frequency noise & vibration sources has a great significance when choosing the way of reduction. Low-frequency noise in ventilation ducts (one-dimensional spatial distribution) may be efficiently cancelled by active noise control. Two-dimensional vibration e.g. we may find in the case of vibrating surface. Three-dimensional noise & vibration sources are in automobile passenger compartment (the case of enclosed space) or transport noise from the several highways (the case of open space). The most complicated case is three-dimensional broadband noise & vibration cancellation.

According to **periodicity of low-frequency noise & vibration generation** it should be noted that mainly low-frequency noise and vibration source radiate periodical sound. E.g., intake or exhaust noise of automobile internal combustion engine is caused by piston periodic operation and acoustic waves propagating in intake or exhaust ducts due to flow pulsations, so it has the periodical mechanism of generation. One of the main vibration sources of piston compressors pipelines are low-frequency gas pressure oscillations (pulsations) [8, 9].

Completeness **of low-frequency noise & vibration sources reduction** here is meaning how many low frequency noise or vibration sources have been cancelled. The simplest case is reduction of single source. For example, it may be reduction of automobile internal combustion engine intake low frequency noise by the active system [13, 15].

Reduction of several sources may be illustrated as following. Automobile internal combustion engine radiate both intake and exhaust noise. If reduced it separately by active mufflers strong coherent low-frequency sound radiation near to the air-suctioning pipe and exhaust pipe may appear. Combined control of ICE intake & exhaust noise is suggested in some General Motors patents [17 et al].

The kind of **low-frequency noise & vibration** spectrum may be very differs for different kind of transport or transport systems. E.g., for some cases in order to reduce significantly external engine noise it is enough often to reduce noise only for one or two harmonics [11, 15].

The kind of **transport** presently may be widely subdivided, e.g. aircrafts, automobiles, motorcycles, railway transport, trams, pipeline transport etc. Of course, every different kind of transport requires the separate approach when choosing the method of cancellation.

Sure, the described above systematization of criteria and types of classification of methods of power plants low-frequency noise and vibration reduction is not complete and we may add further some new suggestions for classification.

3. ENERGETIC APPROACH TO CLASSIFICATION OF REDUCTION OF POWER PLANTS LOW FREQUENCY NOISE AND VIBRATION REDUCTION METHODS

According to energetic approach it is suggested to classify power plants low frequency noise and vibration reduction methods as passive, adaptive-passive, active and hybrid active-passive.

Passive methods are traditional and admit that passive elements do not add energy to the system. They may absorb energy or change the impedance of the source such that undesirable energy is not created. Classical passive noise control example – sound absorption and sound isolation. Presently there are significant efforts to increase efficiency of passive control elements. We may either use new materials, or use existing materials in more effective ways (e. g. to absorb energy more effectively). But the negative feature is that passive methods are not sufficiently reduces noise and vibration in low frequency range.

In general passive methods may be subdivided to completely passive and adaptive-passive [1, 5, 14]. Completely passive methods are the most oldest and traditional. E.g., it could be using of absorbing materials or noise barriers. Adaptive--passive methods utilize passive elements which can be tuned such that performance can be optimized over some specified range of conditions. But in this case passive elements again cannot add energy to the system. Adaptive-passive solutions are the most efficient for narrowband applications. For example, the adaptive Helmholtz resonators described by Lamancusa [5] would be used for control of narrowband sound at several running speeds.

Dampers with pliable walls may be considered as adaptive--passive constructions, for example, intake manifold oscillations damper of internal combustion engine [2]. However this construction cannot provide maximal efficiency of oscillations attenuation. Adaptive-passive low-frequency pulsations damper in piston machine pipeline is described in [9]. At least one of the damper walls is pliable. Oscillatory gas movement will extend the walls and all variable flow consumption through the compressor pipeline will be locked within the damper. Another damper construction with pliable capacity is membrane-spring damper [12], where connection between the main and the damper is achieved through the light movable hermetically suspended membrane jointed with elastic high-pliable element, for example, soft spring. Effective pressure impulses attenuation in abutting pipeline occurs due to membrane and spring oscillation and by means of resilient characteristics of spring.

As subclass of adaptive-passive schemes the so-called semi--active control systems may be considered [1, 5]. These systems are built up of passive components with adaptive parameters. However, for semi-active systems the parameters are changed at the same rate as the excitation.

Active noise control systems are capable of putting energy into a system. Classically, these systems use loudspeakers to generate an acoustic wave interfering with the disturbance wave and are making stable system unstable. Active systems are generally relatively complicated compared to passive methods and require a source of power.

Active vibration control (AVC) presently is well developed, especially for transport. For cars AVC may be used for vibrations reduction of engine body, pan, steering wheel, seats etc., see e.g. developments of "Lotus Engineering", "Carl Freudenberg" etc.

Hybrid (active-passive) methods are very promising. It is not the most efficient to implement purely active noise and vibration control systems. In fact most so called active systems are a combination of an active system and passive system, so called active-passive hybrid [4, 6, 7, 14].

4. CONCLUSIONS

The principles of classification of methods of power plants low-frequency noise and vibration reduction are suggested. Author is proposing energetic approach, according of which all the methods and arrangements of reduction may be classified as passive (adaptive and non-adaptive), active and hybrid passive-active. The classification is illustrated by the different examples, including constructions of mufflers and dampers, some of which are developed by author. The classification proposed in this paper is not complete and further we may add some new suggestions for classification. Using of results of this paper may be useful for analyzing and selecting optimal decisions for power plants low-frequency noise and vibration reduction and for further development and application of constructions of pumps plants with reduced vibration levels.

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REFERENCES

[1] Bernhard R.J., Hall H.R., Jones J.D. Adaptive-Passive Noise Control. Proc. of "Inter-Noise 92" Congress, 1992, pp.427-430.
[2] Cortemiglio C., Piron M. Absorbeur de pulsations pour le collecteur d'alimentation d'un moteur a combustion interne. Appl. Patent France N 2579667, 1986.
[3] Hansen C.H., Snyder S. D. Active Control of Noise and Vibration. 1997, Cambridge University Press UK. P:1267.
[4] King S.P., Staple A.E. Minimization of Helicopter Vibration Through Active Control of Structural Response. Technical Report, Westland Helicopter Ltd.
[5] Lamancusa J.S. An Actively Tuned, Passive Muffler System For Engine Silencing. "Noise-Con 87" Conference, 1987, pp.313-318.
[6] Mechel F.P. Hybrider Schalldämpfer. German Patent Application No. 40 27 511 C1. Filed: August 30, 1990. Patented: October 2, 1991.
[7] Möser M. Aktive Kontrolle einfacher, selbsterregter Resonatoren. Acustica, Vol. 69, pp.175-184, 1989.
[8] Ogarkov A.A., Vassiliev A.V., Voltchonkov V.I. About the experience of low-rotated piston compressor units vibration reduction. Proc. of the 29 International Congress on Noise Control Engineering "Inter-noise 2000", Nice, France, 2000 August 27-30, Volume 6, pp.3932-3936.
[9] Starobinsky R.N., Vassiliev A.V., Krokhin V.N., Voltchonkov V.I., Desyatkin A.M. Pressure oscillations damper for the suction system of piston machine. Invention certificate 1789748, Russia, 1993.
[10] Tan Y., Guan R., Zhang Z. Performance of accelerated oscillator dampers under seismic loading. Advances in Mechanical Engineering, 2018, 10 (4).
[11] Vassiliev A.V. Compact active noise control units for automobile intake low-frequency noise attenuation. Proc. of "ACTIVE 97" International Symp., Budapest, Hungary, August 21-23 1997, p.587-594.
[12] Vassiliev A.V. Membrane-spring damper of low-frequency gas dynamic pulsation - Proc. of "Transport noise and vibration" International EAA/EEAA Symposium, Tallinn, 1998, pp.43-46.
[13] Vassiliev A.V. Automobile engine low frequency noise reduction by complex using of active noise control method: Proc. of "ISMA 25" the International Noise and Vibration Conference, Leuven, Belgium, September 13-15 2000, Vol.1, pp.37-44.
[14] Vasilyev A.V. Development and approbation of methods and technical solutions of reduction of vibration of power plants and joining mechanical systems. Procedia Engineering. 2015. Vol. 106. pp. 354-362.
[15] Vasilyev A.V. Automobile internal combustion engine low frequency noise reduction using active noise control solutions. Journal "Akustika", Czech Republic, Volume 34, November 2019, pp. 113-117.
[16] Vasilyev A.V., Approaches to the estimation of ecological risk during the impact of acoustical pollutions. "Ecology and Industry of Russia", Moscow, 2018, Vol. 22, N3, pp. 25-27.
[17] Yuan Y. (General Motors, USA): Active Noise Control System for Attenuating Engine Generated Noise. US Patent No. 5,222,148. Filed: April 29, 1992. Patented: June 22, 1993. and: US Patent No. 5,321,759. Filed: April 29, 1992. Patented: June 14, 1994.

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