

Building a physical model of acoustic air pollution reduction process for brick manufacturing enterprises

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Abstract. The article is devoted to the study of the air acoustic pollution reduction process for brick manufacturing enterprises based on the physical and energy approach based on the theory of dispersed systems. The authors performed physical modeling of the process taking into account the properties of all the objects taking part in it at each stage and the features of the space in which it is implemented. Based on the constructed model, a mathematical description of the probability of the process and its effectiveness is obtained.

1 Introduction

According to statistics and long-term observations, it is noise that is one of the most aggressive components of an urbanized environment that have a negative effect on a person in the process of his labor [1]. A complex of specific symptoms and pathological disorders due to the impact of high levels of noise on the human body in scientific and educational literature is found under the definition of noise disease [2, 5, 11, 15]. This disease is attributed to a number of occupational diseases, to which workers of construction, engineering and other enterprises are exposed, the activity of which is accompanied by radiation of noise. Workers exposed to noise most often complain of headaches, which may have different intensities and localizations, dizziness with a change in body position, memory loss, increased fatigue, drowsiness, sleep disturbances, emotional instability. Despite the intensive development of industries and introduction of new production technologies that can reduce the percentage of human involvement in the process, the number of people employed at work under the influence of increased noise levels increases annually [7, 9]. Analysis of working conditions at enterprises of various sectors of the economy allows us to conclude that construction workers are more often than others affected by the negative influence of noise in the course of their work. At the present stage of economic development of society, the construction industry is a large industrial complex that provides not only the production of building materials and structures, but also the construction of facilities for various purposes. The activities of all segments of the

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construction industry are accompanied by intense noise emissions. That is why the study of noise generation in construction and search for new noise control systems are becoming increasingly important tasks [8, 12]. However, often in practice some of the most common methods and means of protection against industrial noise are used, the effectiveness of which can be estimated as the difference in sound pressure levels before and after the introduction of a technical measure. This approach cannot provide highly effective noise reduction in each individual case, since it is unified in nature and does not take into account the features of the process of acoustic pollution of the air, depending on the noise source and the space in which the process is implemented.

2 Methods

Noise reduction system should be developed taking into account all the physical parameters of the process of reducing acoustic pollution of the air. Physical modeling allows to take into account features of the process of reducing acoustic pollution for each individual case, taking into account all the parameters and characteristics that affect the formation, radiation and propagation of a sound wave from a noise source in the space under consideration [2].

Earlier, we developed a physical model of the process of acoustic air pollution for the clay brick workshop of the molding department, since it is the process of molding clay mass in the SMK-506 vacuum screw press that is accompanied by intense radiation of noise and requires development of an integrated system to reduce it. Physical modeling of the inverse process - reduction of acoustic pollution of the air was carried out on the basis of the constructed model, using basic principles of the physical and energy approach based on the theory of dispersed systems. This approach was described in detail and applied by us when studying the process of dust removal of air, which in this article acts as an analogue when studying the process of acoustic pollution [3-5].

3 Results

When considering the "acoustic field" system from the point of view of the theory of dispersed systems, we consider the air medium as a dispersion medium, and a sound wave as an analog of the dispersed phase. At the same time, the process of reducing air pollution is considered as a sequential process of the impact of "additional" dispersed systems on the "source" and "intermediate". The main goal of each stage is to reduce the concentration of the dispersed phase in the "initial", "intermediate" and "residual" dispersed systems.

During implementation of the process of reducing air pollution at different stages, various objects take part: technological equipment, technological raw materials, industrial premises, industrial premises air, industrial site territory, industrial environment air, etc. The properties and characteristics of each object participating in the process of air pollution must be taken into account when modeling. Figure 1 presents a physical model of the process of reducing acoustic pollution of the air, taking into account the stages of internal and external propagation of a sound wave.

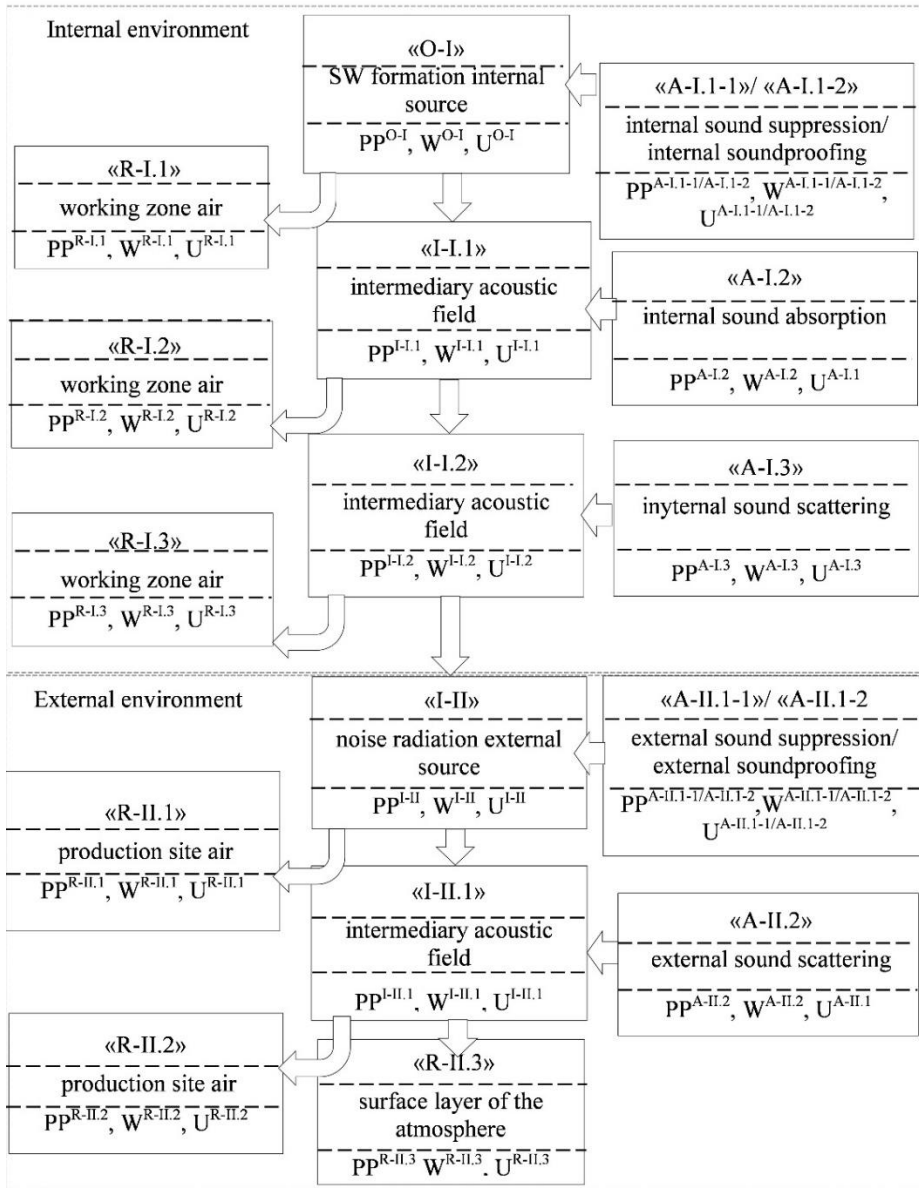


Fig. 1. Physical model of the process of acoustic air pollution.

The internal source of formation of sound waves “O-I” in the molding department of the clay brick workshop is the SMK-506 screw press engine. By making oscillations, the source of the formation of sound waves causes oscillations of the particles of the medium adjacent to it with the same frequency that determines the “internal” radiation of the sound wave into the air of the production room.

At the stage of formation of sound waves, depending on the parameters of the source of formation of the sound wave, nature of behavior and parameters of the properties of the dispersion medium, a process of waves cancellation is organized, in which the sound wave

attenuates, or the process of sound insulation, which consists in reducing the sound power along the propagation path of sound waves. In this case, means and methods can be used as an additional disperse system, which make it possible to organize the process of attenuating the strength of a sound wave at the stage of its formation before radiation begins in the internal volume of the production room. An example of such systems can be both individual resonators and resonator systems placed directly at the source of sound wave generation [6-9]. As soundproof fences, walls, ceilings, partitions, glazed openings, windows, doors can be considered. This is also achieved by using soundproof fencing, soundproofing booths and control panels, soundproof shrouds and acoustic screens. As materials for soundproof fencing, concrete, reinforced concrete, brick, ceramic blocks, wooden paintings (for the manufacture of doors), glass, etc. are used [10]. As a result of the interaction of "O-I" and "A-I.1-1"/"A-I.1-2" two acoustic fields are formed:

1. "I-I.1" an intermediate acoustic field, characterized by a reduced level of sound pressure, in case of compliance with the MAL directed to the working area and not requiring further action aimed at the destruction of sound waves;

2. "R-I.1" an acoustic field, which is sound waves with a certain reduced level of sound pressure remaining in the air of the working area.

In case of non-compliance with MAL at the stage of emission of sound waves into the internal volume of the production room, a sound absorption process is organized in which the sound wave energy partially dissipates into the heat wave, as a result of friction losses in the sound absorber. Sound absorbers act as an additional disperse system "A-I.2" interacting with "I-I.1", which, as a rule, are made of porous materials with an incomplete structure, since the friction losses in them are most significant. In the process of interaction of the acoustic field "I-I.1" with the specially created "I-I.2" in order to achieve absorption of the sound wave, two acoustic fields are formed:

1. "I-I.2" an acoustic field, which is sound waves with a certain reduced level of sound pressure, directed either directly to the working area (if MAL is observed) or to the sound wave scattering zone;

2. "R-I.2" an acoustic field, which is sound waves with a certain reduced level of sound pressure remaining in the air of the working area.

Further, at the stage of internal propagation of the sound wave, the process of their forced scattering is implemented, which ensures the achievement of standard values of the parameters of acoustic pollution. Basis of this method is a change in the directivity of the radiation of sound waves, which is possible under the conditions of directional radiation. In this case, the directed sound wave can be oriented in the opposite direction from the working place.

In the process of forced scattering of sound waves "I-I.2", the acoustic field interacts with the previously prepared "A-I.3" acoustic field. As a result of this interaction, with the aim of its maximum destruction, two acoustic fields are formed:

1. "R-I.3" an acoustic field, which is represented by the minimum number of sound waves, the sound pressure level of which must correspond to MAL in the internal volume of the room;

2. "I-II" an acoustic field that, through door and window openings, extends into an external volume outside the production building and enters the air of the industrial site.

At the stage of external radiation of the sound wave, the processes of their sound insulation and partial sound absorption are also organized. To effectively protect urban areas from acoustic pollution, acoustic screens are used that are installed in the path of sound wave propagation. Most often they are a structure containing a foundation base, a basement, a bearing base, transverse struts, longitudinal profiles and sound-reflecting or sound-absorbing panels, in some cases it is proposed to use both types of panels [13-16].

As a result of the interaction of "И-II" and the acoustic field "A-II.1", two sound fields are formed:

1. "R-II.1" an acoustic field, which is represented by a reduced number of sounds:

$$P_{(RAP)} = 1 - (1 - P_{RAPPR1}) \cdot (1 - P_{RAPIS2}) = 1 - [1 - (1 - P_{SS/Sl}) \cdot (1 - P_{SA}) \cdot (1 - P_{SSC})] \cdot [1 - (1 - P_{Sl/SA}) \cdot (1 - P_{SS})] \quad (1)$$

The formula characterizes the probability of the implementation of the process of reducing acoustic pollution of air (P_{RAP}), as a set of probabilities of physical processes of reducing acoustic pollution inside the production room (P_{RAPPR1}), including sound suppression and sound insulation ($P_{SS/Sl}$), sound absorption (P_{SA}), sound scattering (P_{SSC}), as well as reducing acoustic pollution of industrial site air (P_{RAPIS2}), including sound insulation and sound absorption ($P_{Sl/SA}$) and sound scattering (P_{SS}).

Probability is the result of implementation of the process, but when considering both the process of acoustic pollution and the process of reducing acoustic pollution, the main role is played by the parameters of the properties of the sound wave and the surrounding space. And the relationship between probability and property parameters is expressed by the concept of efficiency.

Based on the probabilistic description of the process of reducing acoustic pollution (1), we can conclude that the effectiveness of each stage of the process is adequate to the concept of the probability of its implementation, so we can identify the following relationship:

$$E_{E(RAP)} = 1 - [1 - (1 - E_{E(SS/Sl)}) \cdot (1 - E_{E(SA)}) \cdot (1 - E_{E(SSC)})] \cdot [1 - (1 - E_{E(Sl/SA)}) \cdot (1 - E_{E(SS)})] \quad (2)$$

where $E_{E(SS/Sl)}$, $E_{E(SA)}$, $E_{E(SSC)}$, $E_{E(Sl/SA)}$, $E_{E(SS)}$ are effectiveness of the implementation of the processes of sound suppression, sound insulation, sound absorption and sound scattering in internal and external environments, respectively.

At the same time, considering the effectiveness of the process of reducing air pollution, it should be noted that its quantitative description is possible only on the basis of considering the effectiveness of each of its stages. In turn, the effectiveness of the implementation of each subsequent stage depends on the correctness of the selected measures to reduce acoustic pollution.

The concept of the effectiveness of the implementation of the process of acoustic pollution of the air in the framework of the physical and energy approach has been singled out by us as one of the resulting parameters, on the basis of which parametric dependencies can be derived that will allow calculating the effectiveness of systems to reduce acoustic pollution of air.

4 Discussion

Thus, the studies carried out allowed to study the essence of the process of acoustic pollution of air at brick manufacturing enterprises as part of the physical and energy approach.

The physical model we constructed for the process of reducing acoustic pollution of air and a mathematical description of the physical nature of the process, as well as the effectiveness of its implementation, can be the basis for the formation of environmentally efficient and energy-efficient noise reduction systems.

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