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INTENSIFYING THE SONIC FLOW IN THE AUSCULTATION DEVICE

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***Abstract**: The design of an auscultation device with a mechanical sonic flow densifier is presented. The relationship associating the sonic flow amplification level with the auscultation device dimensions is obtained.*

***Keywords:** acoustic field, sonic flow density, ray optics, parabolic reflecting surface, simulation*

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1. INTRODUCTION

Auscultation (auscultare – to listen) refers to a research method based on the perception of sounds that are naturally produced by the human body, which are perceived by direct or indirect – using a certain solid body — contact between our ear and the body surface.

Auscultation became a diagnostic technique thanks to the French scientist René Laënnec (1781-1826) who was a talented clinical surgeon, anatomic pathologist, and lecturer at a medical school in Paris.

Auscultation deals with very faint sounds produced by our body, which propagate in the air only slightly or do not propagate at all. Therefore, whenever there is at least a thinnest layer of air between the ear and the body surface, we are unable to hear any sounds but begin to perceive them as soon as there is a continuous connection established through a solid body between the ear and the sound-producing body.

An attempt was made to create a sound-reflecting surface of a given profile for obtaining the required acoustic field [1, 2, 3]. This resulted in creating a sound reflecting surface with parabolic shape [4].

A large number of auscultation devices have been developed up to date. For example, there is a commonly known auscultation device [5] comprising a sound receiver designed as a thin-walled spherical membrane that is confocally connected with a spherical recess in the housing, rigidly connected with the housing along the perimeter, and provided with radial stiffeners. The weakness of the above device is that with this design the sound receiver will reduce the sonic flow generated by the target of research and, therefore, receive incomplete information on the condition of that target.

In the auscultation device [6] comprising a hollow-type head that is equipped with a spring-driven block with its installation mechanism and an elastic plug. In addition, a variable pressure source is used, which is designed as an elastic hemispherical cap that is tightly connected with the head. The weakness of this device is the complexity of its design, which reduces the sonic flow and compromises its informational component.

The most advanced auscultation device [7] is a device with an installed parabolic reflector, acoustic sensor, and electronic module using galvanic cells as a source of electrical power. The weakness of this device is the complexity of the structure that contains such elements as the acoustic sensor and the electronic module using galvanic cells as a source of electrical power. Every element consists of multiple simple parts and failure of any part will result in the failure of the entire device. Therefore, the reliability of the device is generally low. In addition, the acoustic sensor is arranged within the focus of the parabolic reflector. The presence of the acoustic device in the singular domain distorts the acoustic field generated by the target of research and, as a result, the received information is not comprehensive enough.

2. PROBLEM STATEMENT

The authors developed a patented structure for auscultation purposes [8]. The technical result of applying the proposed invention is based on the fact that the device has a simplified design and its reliability is improved due to the missing electrical power sources and electronic devices. The received acoustic information is of higher quality due to the fact that the pattern of the sonic flow generated by the target of research is not distorted within the singular domain but densified and identically reflected from the surface of the reduced parabolic reflector because the sonic flow intensifies as a result of its densification.

The general configuration of the sonic flow densifier for auscultation is presented in Fig. 1. Fig. 2 illustrates the device part comprising a parabolic reflector and a reduced parabolic reflector with a schematic diagram of sonic flows reflected from solid surfaces according to the ray theory.

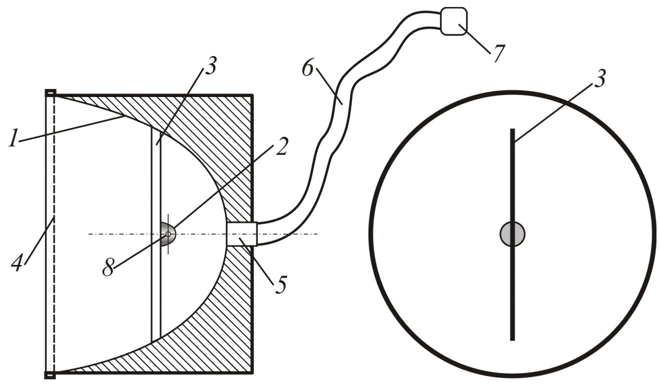

Fig. 1: General arrangement of the sonic flow densifier for auscultation purposes. 1 – parabolic reflector; 2 – reduced parabolic reflector; 3 – support; 4 – protective shield; 5 – center hole; 6 – sound duct; 7 – earpiece; 8 – parabolic reflector focus point

The mechanical sonic flow densifier for auscultation purposes comprises the parabolic reflector 1 and the reduced parabolic reflector 2 arranged in such a way that their foci match. The reduced parabolic reflector 2 is fixed to the support 3. The protective shield 4 is mounted on the parabolic reflector 1. The center hole 5 is provided at the center of the parabolic reflector, which is linked with the flexible tubular sound duct 6 fitted with the earpiece 7. Focus 8 represents the focus of the parabolic reflector 1 and the reduced parabolic reflector 2 at the same time.

The operating principle of the sonic flow densifier for auscultation purposes is described as follows. The parabolic reflector is mounted on the surface of the object whose internal parts must be inspected. Generated sonic flow perpendicular to the object surface passes through the protective shield 4 and reaches the surface of the parabolic reflector 1 (Fig. 1).

According to the ray theory, the sonic flow is reflected from this surface and directed to the focus 8. As it travels, the sonic flow reaches the surface of the reduced parabolic reflector 2. It is also reflected from this surface and, based on the ray theory, the reflected sonic flow is directed in parallel to the original sonic flow generated from the surface of the target of research (Fig. 2). In this case, the pattern of the acoustic flow generated by the surface of the target of research is maintained when such flow is reflected from the reduced parabolic reflector 2. The sonic flow reflected from the reduced parabolic reflector 2 is several times as dense as the original sonic flow and, therefore, louder. For this reason, the acoustic information passing to the researcher via the flexible tubular sound duct 6 and the earpiece 7 will be of good quality and have a high information value.

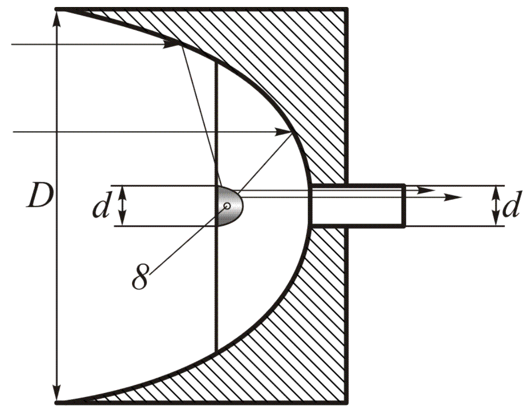

Fig. 2: Arrangement of the sonic flow densifier. D – entry sonic flow diameter; d – exit sonic flow diameter and reduced parabolic reflector diameter; 8 – parabolic reflector focus point

Fig. 2 illustrates the diagram showing relative positions of parabolic sound-reflecting surfaces provided that their foci match. The relationship associating the sound amplification level at the exit section with the sound energy density at entry and exit sections must be established. The originality of the problem is involved in proposing a technique that is practically suitable and requires no differential problem statement.

3. DEVELOPING BASIC RELATIONSHIPS

The density of sonic flow $\boldsymbol{\varepsilon_1}$ at the entry section with area equal to

$$S_1 = \frac{\pi}{4}(D^2 - d^2) \tag{1}$$

is calculated using the formula [9]

$$\varepsilon_1 = \frac{I_1}{c} \tag{2}$$

where
$\boldsymbol{I_1}$ is the intensity of sonic flow at the entry section and
$\boldsymbol{c}$ is the acoustic speed in the air.

The density of sonic flow at the exit section with area equal to

$$S_2 = \frac{\pi}{4}d^2 \tag{3}$$

is calculated using the formula

$$\varepsilon_2 = \frac{I_2}{c} \tag{4}$$

where
$\boldsymbol{I_2}$ is the intensity of sonic flow at the exit section.

The sonic flow amplification factor in the auscultation device will be

$$k = \frac{\varepsilon_2}{\varepsilon_1} \tag{5}$$

Taking into account (2) and (4), we shall obtain

$$k = \frac{I_2}{I_1} \tag{6}$$

On the other hand, the amplification of sound will be calculated using the formula

$$\Delta L = 10 \cdot lg\left(\frac{I_2}{I_0}\right) - 10 \cdot lg\left(\frac{I_1}{I_0}\right) \tag{7}$$

where
I_0 is the limit value of sound intensity perceivable by the human ear. By making certain transformations

$$\Delta L = 10 \cdot lg\left(\frac{k \cdot I_1}{I_0}\right) - 10 \cdot lg\left(\frac{I_1}{I_0}\right)$$
$$\Delta L = 10 \cdot lg(k) + 10 \cdot lg\left(\frac{I_1}{I_0}\right) - 10 \cdot lg\left(\frac{I_1}{I_0}\right)$$

we shall obtain

$$\Delta L = 10 \cdot lg(k) \tag{8}$$

However, taking into account the values of sonic flow intensity

$I_1 = \frac{W}{S_1}$ and $I_2 = \frac{W}{S_2}$

where
W is the power of sonic flow passing through the auscultation device. It is assumed in this case that the power level remains constant both at the entry and at the exit sections.

Then the relationship (6) based on (1) and (3) will be as follows:

$$k = \frac{D^2}{d^2} - 1 \tag{9}$$

By substituting (9) into (8), we shall finally obtain the target value

$$\Delta L = 10 \cdot lg\left(\frac{D^2}{d^2} - 1\right) \tag{10}$$

4. EXAMPLE OF DETERMINING SOUND AMPLIFICATION

Formula (10) allows to determine the level of sound amplification in the auscultation device at different relationships between the diameters at entry and exit sections. The calculation data are shown in Tab. 1.

Tab. 1 shows that even at a sufficiently low relationship $^D/_d$ we obtain observable sound amplification when using a mechanical sonic flow amplifier in the auscultation device.

$\frac{D}{d}$	ΔL, dB(A)	$\frac{D}{d}$	ΔL, dB(A)
4	11,8	10	19,9
5	13,8	12	21,5
8	18,0	15	23,5

Tab. 1: Values of sound amplification in the auscultation device. The values are given in relative units

5. CONCLUSION

The arrangement of the mechanical sonic flow densifier in the auscultation device is presented. The operating principle of the auscultation device is described. The relationship associating the level of sound amplified by using a mechanical sonic flow densifier with the auscultation device parameters is obtained.

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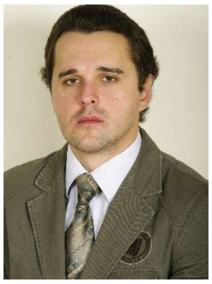

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