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ACOUSTIC PROTECTION IN DEVICES WITH VACUUM LAYER

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Abstract: *Structures using a vacuum layer for acoustic protection are described. The advantages and disadvantages of using the creation of vacuum to establish sonic flow barriers are demonstrated.*

Keywords: *noise, acoustic protection, vacuum, vacuum layer, permanent magnets.*

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1. INTRODUCTION

Noise refers to negative phenomena existing these days. In terms of its negative impact level, it is comparable with dust, industrial emissions, acid rains, etc. [1] Noise suppression has become the issue of the day since its solution can secure healthy working conditions at the manufacturing site and provide additional resources to improve work performance [2]. One of the means of acoustic protection provided in the paths of noise propagation that is used nowadays is sound-proofing panels with sound protection and acoustic absorption features [3, 4]. In addition to the acoustic parameters of sound-proofing panels such as sound protection and acoustic absorption coefficient, surface density represents an equally important feature [5]. This feature is highly important when calculating the payload existing, for example, in airplanes, cars, space crew vehicles, building industry, and industrial enterprises [6].

However, new solutions are emerging in addition to conventional techniques and approaches applied in acoustic protection. It is generally known these days that sound cannot propagate in vacuum. For example, an experiment with an alarm clock placed under a glass cover is sometimes demonstrated at school. The sound of the alarm clock can be heard when there is air contained under the cover but it disappears when the cover is deaerated. However, vacuum structures have not been widely used as acoustic enclosures up to now. On the other hand, as demonstrated by I.I. Bogolepov, the vacuum layer has a tremendous sound absorption capability [7].

The use of vacuum for acoustic protection purposes was first researched by the famous German acoustician Erwin Mayer [8]. The experiments demonstrated that acoustic protection could not be achieved since the creation of vacuum required the presence of sound bridges or contact areas between walls.

2. REVIEW OF EXISTING STRUCTURES

I.I. Bogolepov attempted to introduce a vacuum layer to the sound-proofing panel design [9]. Fig. 1 illustrates the arrangement of a sound-proofing vacuum panel. A sound-proofing panel consists of two walls, designed as a segment of a sphere with an outer convex surface, which are securely and tightly connected to solid frames with an isolation mount in the form of an elastic sealing that is installed in between the frames. Vacuum is created between the walls. The external atmospheric pressure presses the walls and the frames together very strongly, which results in pressing the sealing.

The analysis of experimental results obtained for this panel demonstrated no distinguishable noise reduction. In addition, the surface density of this sound-proofing vacuum panel is rather high and equals several tens of kilograms per square meter.

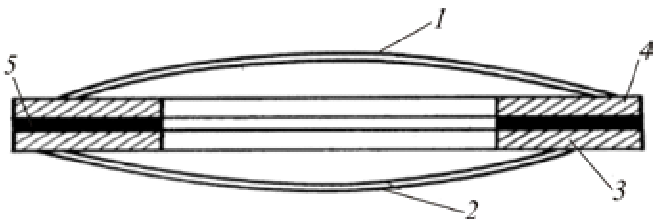

Fig. 1: Sound-proofing vacuum panel. 1 and 2 – walls representing a segment of a sphere; 3 and 4 – metal frames; 5 – elastic sealing

A device with a lower noise level and an acoustic reduction method was created for the same purpose [10]. This device also used the creation of vacuum. This device also features high surface density.

An attempt to reduce the load applied to the sound bridges was made in the „Multilayer heat and sound insulation barrier" structure [11]. Vacuum is created between the parallel walls of this device to increase the wall damping effect and to reduce the acoustic permeability of the entire structure. The performance of this structure is based on the use of electromagnets powered from an external source. All this makes the structure bulky, with high surface density, and hardly suitable for practical use.

3. ORIGINAL DEVELOPMENT OF A DEVICE WITH VACUUM LAYER

Apart from the sound-proofing panels, one of the means of acoustic protection provided in the paths of noise propagation is the personal protective equipment - the ear protectors. They effectively protect the human hearing system from the nuisance of noise.

The authors developed the design for ear protectors that ensured the hearing system protection against broadband noise due to the use of a thin vacuum layer [12]. The vacuum layer is formed due to the use of permanent magnets. An additional function is provided by the ear protectors in this case and that is the relieved stress and headache due to the presence of permanent magnets.

The external configuration of the ear protectors is illustrated in Fig. 2. Fig. 3 shows the view A and Fig. 4 shows the local section I.

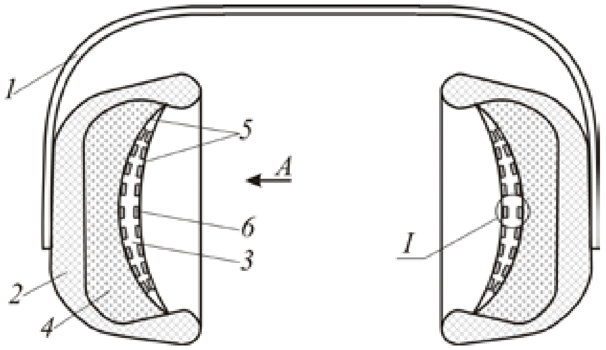

Fig. 2: Ear protector layout. 1 – headband; 2 – earpiece body; 3 – protector; 4 – acoustic absorber; 5 – polymeric plates; 6 – permanent neodymium magnets; I – local section

The configuration of the ear protectors is made up of the headband 1 where the body of the earpiece 2 with the protector 3 is fixed. The acoustic absorber 4 that is made of fiber material and designed for fixing the position of the protector 3 is arranged between the body of the earpiece 2 and the protector 3. The protector 3 consists of the two parallel plates 5 that are made of flexible and elastic pressure-tight polymeric material. Permanent neodymium magnets 6 with the same poles facing the plates are attached to the inner surface of each plate 5. The parallel plates 5 are tightly interconnected along the edge. Permanent vacuum is created between the parallel plates 5.

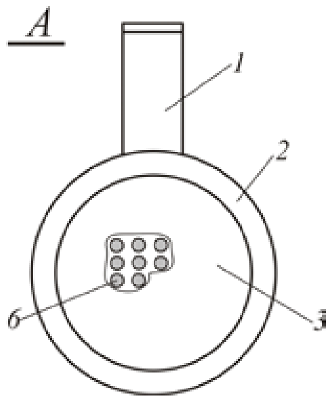

Fig. 3: View A shown in Fig. 2 with local sectional view

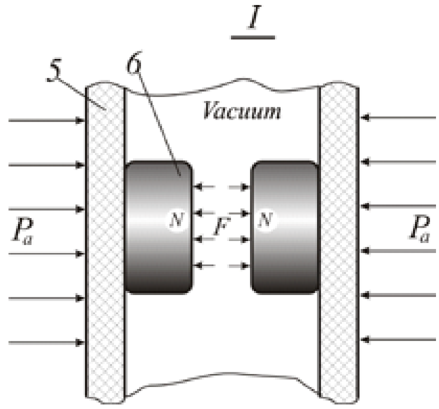

Fig. 4: Local sectional view I shown in Fig. 2. Pa – atmospheric pressure; F – magnetic repulsion force

The operating principle of the ear protectors is described as follows. Using the headband 1, the ear protectors are placed on the person, covering his hearing system with the earpiece body 2. Noise in the form of sonic flows passes through the body 2 virtually without losing any energy and reaches the layer of the acoustic absorber 4 where it is partially absorbed although only across a narrow frequency band. The acoustic absorber 4 does not suppress any broadband noise. The protector 3 ensures the protection of the hearing system against any broadband noise due to the existence of a permanent vacuum inside the protector 3. The thin vacuum layer prevents the transmission of acoustic vibrations from one plate 5 to another. The ability to maintain a thin vacuum layer can be explained by the existing equilibrium between the forces of excess atmospheric pressure exerted on the outer layers of the plates 5 and the repulsion forces existing between the permanent magnets 6 (Fig. 4). The alignment of the permanent magnet positions towards one another can be explained by their identical and symmetrical pattern of arrangement along the internal side of the plates 5. The vacuum layer existing in the protector 3 protects the human hearing system across a broad frequency band, i.e. isolates the person from any broadband noise.

4. CONCLUSION

Vacuum-based acoustic protection devices provided in the paths of noise propagation are described. The advantages and disadvantages of these structures are presented.

The original development of the acoustic protection design using permanent magnets to create a thin vacuum layer is presented.

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