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SOUND ATTENUATION OF LOUVERED NOISE BARRIERS FOR INDUSTRIAL EQUIPMENT

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ABSTRACT

An industrial equipment is often noise source in urban spaces and disturbs people everyday activities. The usual way to reduce noise level is application of barriers surrounding the equipment. On the other hand, any obstacles can interfere with the normal operation of the equipment, for example, they can block the air flow. Therefore, the barrier should provide both significant sound attenuation and sufficient ventilation. For this reason, the louvered noise barriers are used in practice to protect residential areas and other noise sensitive spaces. In the paper we study their sound attenuation performance in dependence on acoustic properties of the louvre blades. It is shown that the rigid blades are not so effective because sound energy penetrates through the barrier, whereas the dissipative louvre blades reduce sound more effective. In addition, we consider the other two boundary conditions for the louvers. It is found that the reactive impedance shows the highest performance at low frequencies.

Keywords: *simulation, impedance, diffraction, noise control*

1. INTRODUCTION

Technological and industrial equipment for various purposes continues to be one of the major sources of man-made noise in buildings and surrounding areas. Exposure to elevated noise levels reduces acoustic comfort and has a negative impact on human health, leading to physiological and psychological consequences. These factors highlight the need for effective noise reduction measures, making this an important area of focus in architectural and building acoustics.

One of the issues is shown in Fig. 1. Dry coolers are placed on the roof and emit noise around. To reduce noise radiated downwards the equipment is surrounded by a heavy brick barrier. The noise level on the lower floors and on the ground is appropriate, whereas on the upper floors the noise acts directly on the windows and terrasses and its level is still too high. It is impossible to cover the equipment with a solid roof, as this would prevent ventilation. Therefore, a ventilated barrier is required, and a louvered-type noise barrier can be used to achieve this.

The sound attenuation of louvered barriers has been studied [1-6], and this research continues these investigations. In this paper we focus on the acoustic properties of louvers. Using simulation, we study the attenuation of sound transmitted through the barrier depending on the acoustic impedance of the louvre surfaces.

Figure 1. Dry coolers on the roof.

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2. LOUVERED NOISE BARRIERS

2.1 Sound diffraction by barriers

Sound attenuation by barriers is usually calculated using a classical diffraction theory [7]. The sound transmitted through the louvered barriers with a finite height can be divided into two components (Fig. 2). The first component T_1 is the sound that propagates around the upper edge of the barrier. The second component T_2 is the sound that penetrates through the barrier. By separating these two components, we can simplify the diffraction problem. The transmission coefficient T_1 can be found using the known results of diffraction by a rigid finite barrier. The calculation of the transmission coefficient T_2 can be fulfilled for the infinite louvered barrier. This approach allows us to focus on the second component of the transmitted sound and find the parameters of the barrier for maximum sound attenuation.

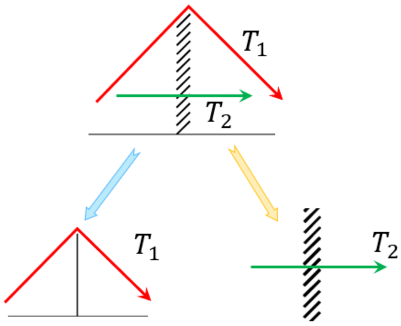

Figure 2. Simplification of the problem of sound diffraction by the louvered barrier.

In this paper, we examine the infinite louvered barrier and investigate the impact of its acoustic properties on sound attenuation.

2.2 Attenuation of sound transmission

The formulation of the sound diffraction problem by an infinite louvered barrier is illustrated in Fig. 3. The louvers are rectangular in shape with dimensions of h and L, with a spacing of H between the edges of the louvers. The inclination angle of the louvers is denoted by α. These four geometrical parameters completely define the barrier.
Acoustic properties of the louvers are described by the impedance Z normalized to ρc, where ρ is a density of the medium and c is a sound speed. All louver surfaces have the same acoustic impedance.
The incident sound is a harmonic plane wave with the wavenumber $k = \omega/c$, where ω is frequency. We are interested in the sound field behind the barrier.

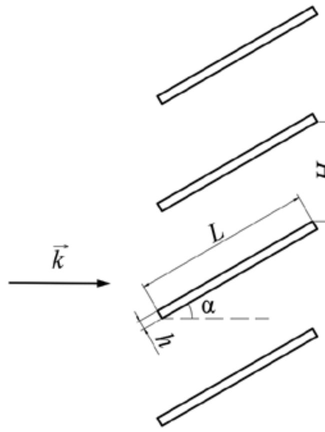

Figure 3. Formulation of the diffraction problem.

If the sound energy density of the incident wave is E_1 and the sound energy density behind the barrier is E_2, then the sound attenuation due to the barrier is determined as

$$T = 20\lg\frac{E_1}{E_2}. \quad (1)$$

We will use simulation to calculate the sound attenuation coefficient T.

3. SIMULATION

The scheme of the numerical experiment is shown in Fig. 4. We consider a two-dimensional case with a rectangular domain of dimensions 20 x 10 m. One side of the domain is a plane oscillating at frequency ω with a velocity normal to that side. All other sides of the domain have the impedance $Z_0 = 1$ and slightly reflect sound waves. Therefore, the oscillating side acts as a source for a plane wave.
A louvered barrier is placed in the middle of the domain. Each louver has dimensions $h = 0.05$ m and $L = 1$ m. The distance between the louvers edges is $H = 0.45$ m, resulting in a period of 0.5 m for the structure. The parameters h, H and L are fixed in this experiment, while the inclination angle α can take on different values. The impedance of the louver surfaces will be changed as well.
A probe domain is a rectangular area located behind the barrier. The sound energy density is calculated in the entire simulation domain without the barrier, and E_1 is the average of this value over the probe domain. To calculate the sound energy density E_2 with the barrier, the same process is followed, but with the addition of the barrier. The sound attenuation of the barrier is then found using Eqn. (1).

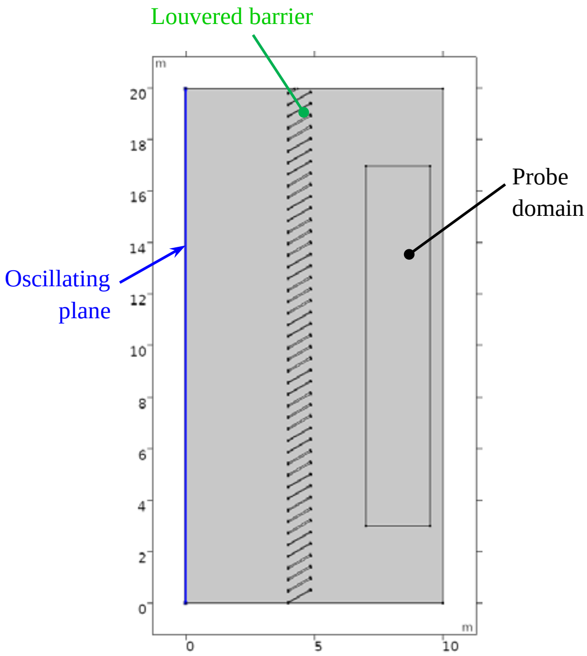

Figure 4. Scheme of the numerical experiment.

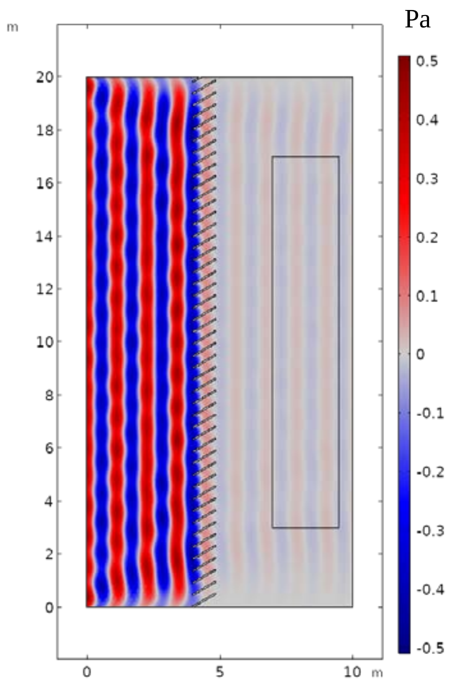

Figure 5. Sound pressure at 300 Hz with Z =1 and α = 30°.

Fig. 5 shows an example of calculating the sound pressure field at 300 Hz with the incilnation angle α = 30° and the surface impedance Z = 1. The sound field appears to be a set of the plane waves with slight distortions caused by reflections from the boundaries of the calculation domain. We can see that the transmitted wave has a smaller amplitude in comparison with the incident one. Therefore, the barrier effectively attenuates sound.

The following calculations of T are made in a similar way for different values of the louver impedance. We will use the frequency range 100-1000 Hz with a step size of 100 Hz.

3.1 Rigid surface

The first issue we consider is the louvers with the rigid surfaces. The standard boundary condition is $\partial p/\partial n = 0$, where p is the sound pressure, n is a normal to the surface. The sound attenuation defined by Eqn. (1) for the inclination angles α = 0, 30°, 60° is given in Fig. 6.

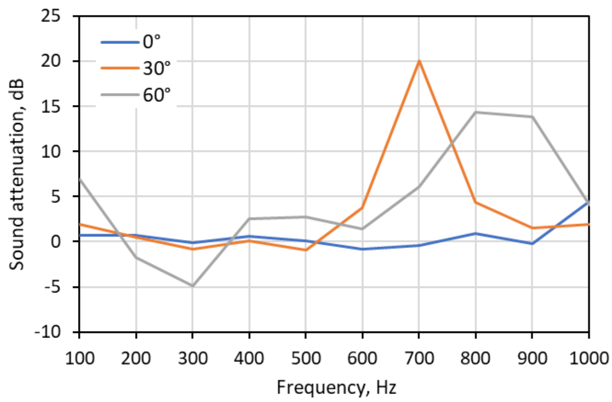

Figure 6. Sound attenuation for the rigid louvers.

If the louvers are parallel to the wavevector (α = 0) the sound attenuation is close to zero at all frequencies, whereas the inclined louvers reduce transmitted sound at certain frequencies. But their effect is narrowband, so the rigid louvers are not very effective.

3.2 Absorbing surface

Next type of the louvers is a sound absorber with the surface impedance Z_a = 1. This surface completely absorbs a normally incident sound wave. The calculated sound attenuation is shown in Fig. 7. The barrier reduces sound at all frequencies and the reduction increases with the increase of the angle α.

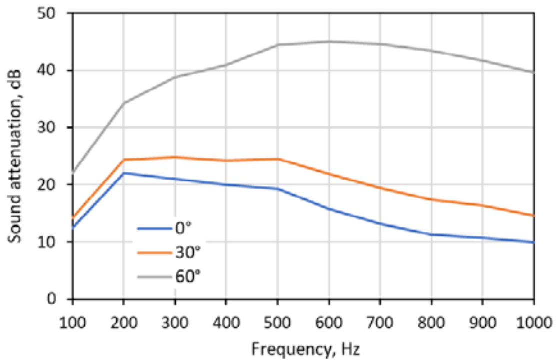

Figure 7. Sound attenuation for the absorptive louvers.

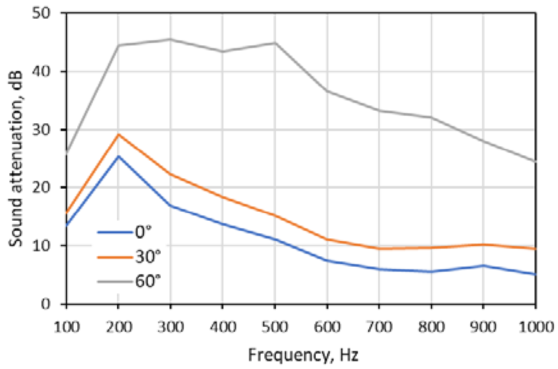

Figure 8. Sound attenuation for the louvers with the Creamer's impedance.

It is important to note that the distance between the louvers changes with the angle α, because the space period *H* is fixed. The distance is *H*cosα, it decreases with increase of α. So, the better attenuation for α > 0 is related to a smaller distance.

The non-inclined louvers have the performance of 10-20 dB in the entire frequency range. The maximum sound attenuation is at frequencies 200-500 Hz. The frequency characteristic resembles the performance of a plate muffler used for ducts [8].

3.3 Cremer's impedance

Sound propagation in a duct has a maximum attenuation coefficient if the duct surfaces have the Cremer's or optimal impedance [9,10]. Using the formula for the optimal impedance derived in [11] we can find it in dependance on the duct width *d* as follows

$$Z_c = kd(0.15 + 0.12i). \quad (2)$$

We can hope that the optimal sound decay in the duct between the louvers will provide a good performance of the sound attenuation by the barrier. At 500 Hz the optimal impedance as given by Eqn. (2) is Z_c = 0.61+0.49*i*. The simulation results for this impedance are presented in Fig. 8. The maximum attenuation for α = 0, 30° occurs at 200 Hz, rather than 500 Hz. It means that the short duct with the length *L* can not be considered as an infinite duct. Anyway, the found effect is comparable to that of the absorbing surfaces, but at high frequencies the sound attenuation is lower.

The large inclination angle as seen in Fig. 7 and 8 provides very high sound attenuation for both the absorptive louvers and the ones with the Cremer's impedance. At all frequencies the effect is greater than 20 dB.

3.4 Reactive impedance

The final type of impedance is a reactive impedance with Re *Z* = 0. The louvers do not dissipate sound energy, but at low frequencies, under certain conditions, all eigenmodes in the gap between the louvers are non-uniform. Above a certain frequency there are uniform modes and sound propagates through the gap. This physical principle allows us to hope that the barrier effectively isolates sound waves at low frequencies.

Fig. 9 shows the sound attenuation for the louvers with the impedance Z_r = –0.1*i*. For α = 0, 30° the barrier reduces the transmitted sound at frequencies below 500 Hz. At higher frequencies sound propagates between the louvers without attenuation. For α = 60° the effectiveness of the barrier is significant up to 1000 Hz.

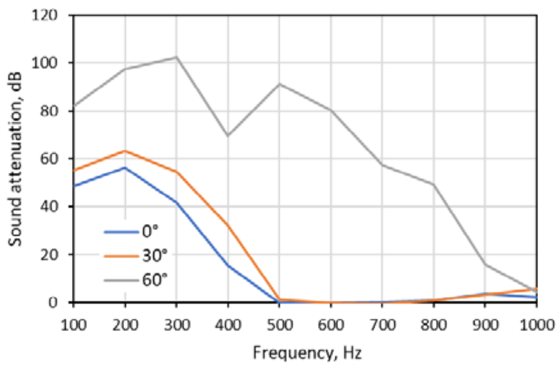

Figure 9. Sound attenuation for the louvers with the reactive impedance.

3.5 Comparison of different impedances

To compare the sound attenuation for different boundary conditions on the louver surfaces, we present the results for $\alpha = 0°$ and three types on the impedance are presented in Fig.10. We can see that the Cremer's impedance has the lowest performance, while the absorptive impedance provides significant attenuation over a wide frequency range. Louvers with reactive impedances have a very high reduction in transmitted wave at low frequencies, but their performance is negligible at higher frequencies.

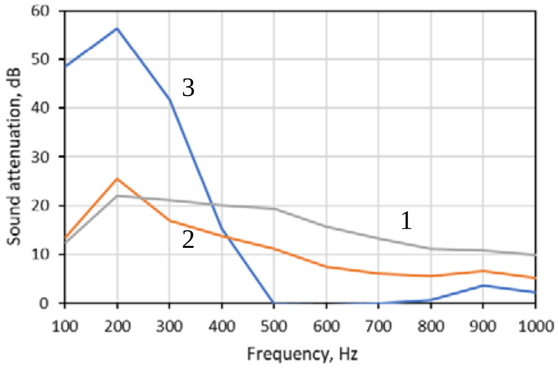

Figure 10. Sound attenuation for the louvers with different impedances for $\alpha = 0°$: 1 – Z_a, 2 – Z_c, 3 – Z_r.

4. CONCLUSION

The findings of this study demonstrate the importance of selecting the acoustic properties of the louvers for designing ventilated barriers. Based on our findings, we can conclude that absorptive louvers can be used for wide-band sound attenuation. Industrial equipment typically emits low-frequency noise, so in this case, louvers with reactive impedance may be more suitable.

To generalize the findings, additional simulations and a theoretical study of infinite louvered barriers are required. The dependence of sound attenuation on the length, thickness of louvers, and the distance between them needs to be investigated in order to determine the optimal parameters for the barrier.

5. REFERENCES

[1] R. Lyons: "Sound insulation of acoustic louvre and open screens," *Build. Acoust.*, vol. 1, no. 2, pp. 105–124, 1994.

[2] G.R. Watts, D.C. Hothersall, K.V. Horoshenkov: "Measured and predicted acoustic performance of vertically louvred noise barriers," *Appl. Acoust.*, vol. 62, pp. 1287-1311, 2001.

[3] E.B. Viveiros, B.M. Gibbs, S.N.Y. Gerges: "Measurement of sound insulation of acoustic louvres by an impulse method," *Appl. Acoust.*, vol. 63, pp. 1301-1313, 2002.

[4] J.L. Horner, S.J. Walsh: "Prediction of the spatial characteristics of higher mode sound transmission through a periodic slit screen," *Appl. Acoust.*, vol. 83, pp. 47-56, 2014.

[5] B. He, X.B. Xiao, X. Zhou, J. Han, X.S. Jin: "Characteristics of sound insulation and insertion loss of different deloading sound barriers for high-speed railways," *Notes on Numerical Fluid Mechanics and Multidisciplinary Design*, vol. 126, pp. 345-352, 2014.

[6] T. Astrauskas, P. Baltrėnas, T. Januševičius, R. Grubliauskas: "Louvred noise barrier for traffic noise reduction," *The Baltic journal of road and bridge engineering*, vol. 16, no. 1, pp. 140–154, 2021.

[7] H. Kuttruff: *Acoustics*. London, New York: Taylor & Francis, 2007.

[8] D.V. Chugunkov, E.A. Zhuravlev, G.A. Seyfelmlyukova, K.C. Fomenko: "Study of the acoustic efficiency of a plate silencer of the original design," *IOP Conf. Ser.: Mater. Sci. Eng.*, vol. 976, 012029, 2020.

[9] L. Cremer: "Theory regarding the attenuation of sound transmitted by air in a rectangular duct with an absorbing wall, and the maximum attenuation constant produced during this process," *Acustica*, vol. 3, pp. 249-263, 1953.

[10] B.J. Tester: "The optimization of modal sound attenuation in ducts, in the absence of mean flow," *J. Sound Vib.*, vol. 27, no. 4, pp. 477–513, 1973.

[11] N.G. Kanev: "Optimum sound attenuation in a rectangular duct with impedance walls," *Acoust. Phys.*, vol. 68, no. 4, pp. 403-407, 2022.