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ACOUSTIC ATTENUATION PERFORMANCE OF A ROUND SILENCER WITH THE SPIRAL DUCT AT THE INLET

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The acoustic attenuation performance of a round silencer with the spiral duct at the inlet is investigated. A Finite Element Method was used for a three-dimensional numerical computations in a COMSOL Multiphysics application. A time-harmonic analysis without airflow was used for a frequency range from 10 Hz to 2 kHz. The results show that the spiral duct at the inlet can improve the acoustic attenuation performance of a round silencer. The sound attenuation depends on a spiral lead, an absorbing material and frequency. The transmission loss of investigated acoustic system with spiral ducts is related to an initial acoustic system with circular pipe. The results are shown as a growth of transmission loss $\Delta\mathrm{TL}$ given by an insertion of the spiral ducts. A specific parameter given by relation of the spiral lead s to constant circular duct diameter d is presented as s/d ratio. The value of $\Delta\mathrm{TL}$ is determined by s/d ratio and increases in specific frequencies. An acoustic wave, in those frequencies, is there divided at the outlet of the spiral duct and major acoustic energy goes aside, directly to an absorptive material, and minor acoustic energy goes axially to the silencers outlet. This is the damping effect of the spiral ducts.

Keywords: spiral duct, attenuation, round silencer, numerical computations, FEM.

1. Introduction

The contemporary technical solutions in noise control domain in ventilation, air-conditioning and heat systems are based on typical connections of mufflers with simple pipes of square and circular cross-sections [1, 2]. In the practical point of view this is easy and economic solution, which is no manner of doubt. The main assignment of silencing system is the proper use of constituent elements that the sound attenuation should reach maximum value with generation of relatively low resistance of flowing through medium. This is the mean condition, which must be satisfied to keep the functionality of the system. The change of the shape of a duct connecting noise source with silencer can be effective in an acoustic characteristic of this system. Very important thing is to determinate this effectiveness. In this work there are studied few selected cases of the connections of a round silencer with the spiral ducts at the inlet. The shape of the spiral duct is achieved by an insertion of a screw (helix) shaped blade with ø30 mm mandrel inside a cylindrical duct. This construction is similar to the Archimedes' screw, historically used for transferring water from a low-lying body of water into irrigation ditches – Fig. 1.

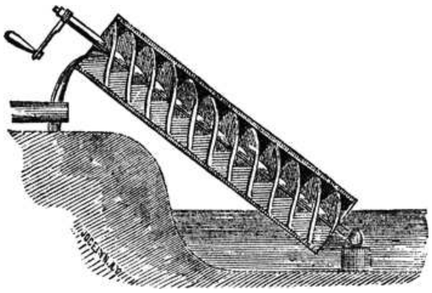

Fig. 1. Archimedes' screw from Chambers's Encyclopedia (Philadelphia: J. B. Lippincott Company, 1875).

For the need of acoustical analysis, the solution presented here is denominated as the spiral duct, already studied in earlier research work of the author [3, 4].

2. Description of investigated silencing system

As it is shown in Fig. 2, at the end of the cylindrical duct, which is the inlet of the silencer, is placed: one turn of the helix shaped blade of 5 mm thickness with ø30 mm cylindrical mandrel in axis of the cylindrical duct, which forms the spiral duct. The mandrel covers about 5.8% of a total cross-sectional area of the cylindrical duct. The time-harmonic analysis was done for frequencies f [Hz] in a range from 10 Hz to 2 kHz without correction of A-weighting frequency filter by the use of COMSOL Multiphysics [5] computer application. The different values of the spiral lead s were executed.

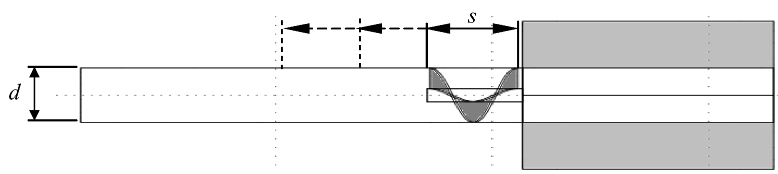

Fig. 2. View of a round silencer with one turn of the spiral duct at the inlet.

In the investigated acoustic system the value of changing spiral lead s is related to a constant value of the cylindrical duct diameter d. The dimensionless value s/d was revaluated from 0.4 to 8 with a step of 0.4. The absorptive round silencer is filled with a porous material of 36736 rayl/m of flow resistivity, which corresponds to 75 kg/m^3 of apparent density of wool with 8 μm of mean fiber diameter [6, 7]. The dimensions of the round silencer are related to the cylindrical duct diameter d, which is the same as an internal diameter of the silencer, and are described as follows: length of the silencer $4.64d$, an external diameter of the silencer $2.72d$.

3. Acoustical performance criteria

The acoustical performance of investigated silencing system was measured in terms of transmission loss TL parameter [2, 3], given by:

$$\mathrm{TL} = 10 \cdot \log_{10} \left[\frac{\dfrac{p_0^2}{2\rho_0 c}}{\dfrac{|p_2|^2}{2\rho_0 c}} \right], \tag{1}$$

where p_0 – maximum amplitude of source sound pressure at the inlet, $p_0 = 1$ Pa, p_2 – maximum amplitude of sound pressure at the outlet, $\rho_0 c$ – characteristic impedance (air density $\rho_0 = 1.24$ kg/m^3, sound speed $c = 343$ m/s).

The parameter of a growth of transmission loss $\Delta\mathrm{TL}$ was specified for a better quality of the presented results and for determination of frequency bands, and is described in equation:

$$\Delta\mathrm{TL} = \mathrm{TL}_{\mathrm{dif}} - \mathrm{TL}_{\mathrm{ini}}\,, \tag{2}$$

where $\mathrm{TL}_{\mathrm{dif}}$ – transmission loss of the silencing system with a different kind of the spiral ducts, $\mathrm{TL}_{\mathrm{ini}}$ – transmission loss reference – TL of the initial silencing system with the cylindrical duct at the inlet.

The transmission loss increases in relation to the silencing system built-up of the round silencer with an empty cylindrical duct at the inlet – Fig. 3.

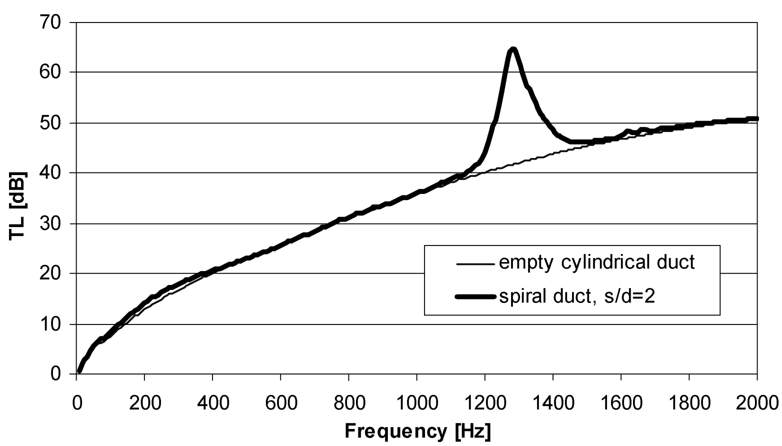

Fig. 3. The transmission loss of the round silencer with an empty cylindrical duct and one turn of the spiral duct with $s/d = 2.0$ at the inlet.

4. Results and discussion

The sound pressure level (SPL) distribution inside the investigated silencing system with the spiral lead to diameter ratio $s/d = 2$ for the highest value of ΔTL in the frequency $f = 1280$ Hz is presented in Fig. 4.

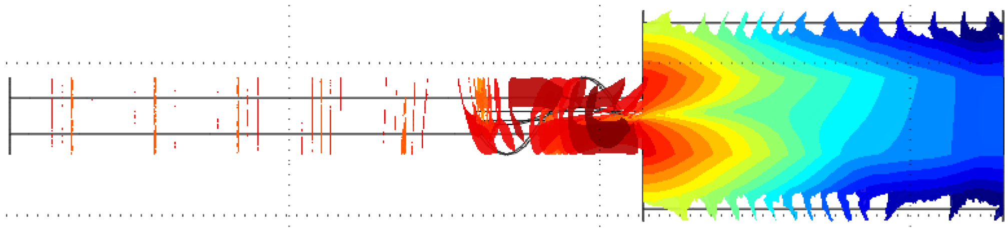

Fig. 4. The sound pressure levels distribution inside the silencing system with $s/d = 2$ for the highest value of the growth of transmission loss ΔTL in frequency $f = 1280$ Hz.

The acoustic wave is divided in such a way that the maximum values of the sound pressure levels are directed sideways, and the minimum values of the acoustical energy are directed axially to the silencers outlet (Fig. 4).

For that kind of sound wave distribution inside the investigated silencing system, air particles included in the acoustic field, which corresponds to the maximum values of SPL, are moving inside the absorptive material. Whereas, the air particles, occur in the acoustic field including the minimum values of SPL, can move axially inside an empty working area to the silencers outlet. That kind of acoustic wave distribution increases the sound attenuation in a specified band of frequency, which can be determined by the spiral duct geometry.

For a better analysis of presented results the growth of transmission loss ΔTL, which arises from the insertion of the one spiral turn into the cylindrical duct at the inlet of the round silencer, is shown in Fig. 5.

The results of the numerical computations indicate that in the examined silencing system the spiral duct placed at the inlet of the round silencer increases his acoustic attenuation performance. The attenuation depends on the spiral lead s and frequency f. The applicable range of this solution starts from the spiral lead to diameter ratio $s/d = 8$, but in that case we can observe the growths of transmission loss in small quantities. When the spiral lead s steps up to infinity $(s \rightarrow \infty)$ the $\mathrm{TL}_{s\rightarrow\infty}$ of the silencing system with spiral duct equals the TL of the silencing system with the empty cylindrical duct. However when the spiral lead s steps down to zero $(s \rightarrow 0)$, the TL of the silencing system goes to zero too, $\mathrm{TL} \rightarrow 0$.

In case when the spiral lead s is twice bigger than the cylindrical duct diameter d, $s/d = 2$, the growth of transmission loss ΔTL increases in the frequency range from 1.2 kHz to 1.4 kHz and reaches the maximum value (about 20 dB) in the frequency $f = 1280$ Hz.

The results presented in Fig. 5, show that the spiral ducts can cause different sound attenuation for different frequency ranges. The range and the level of the growth of

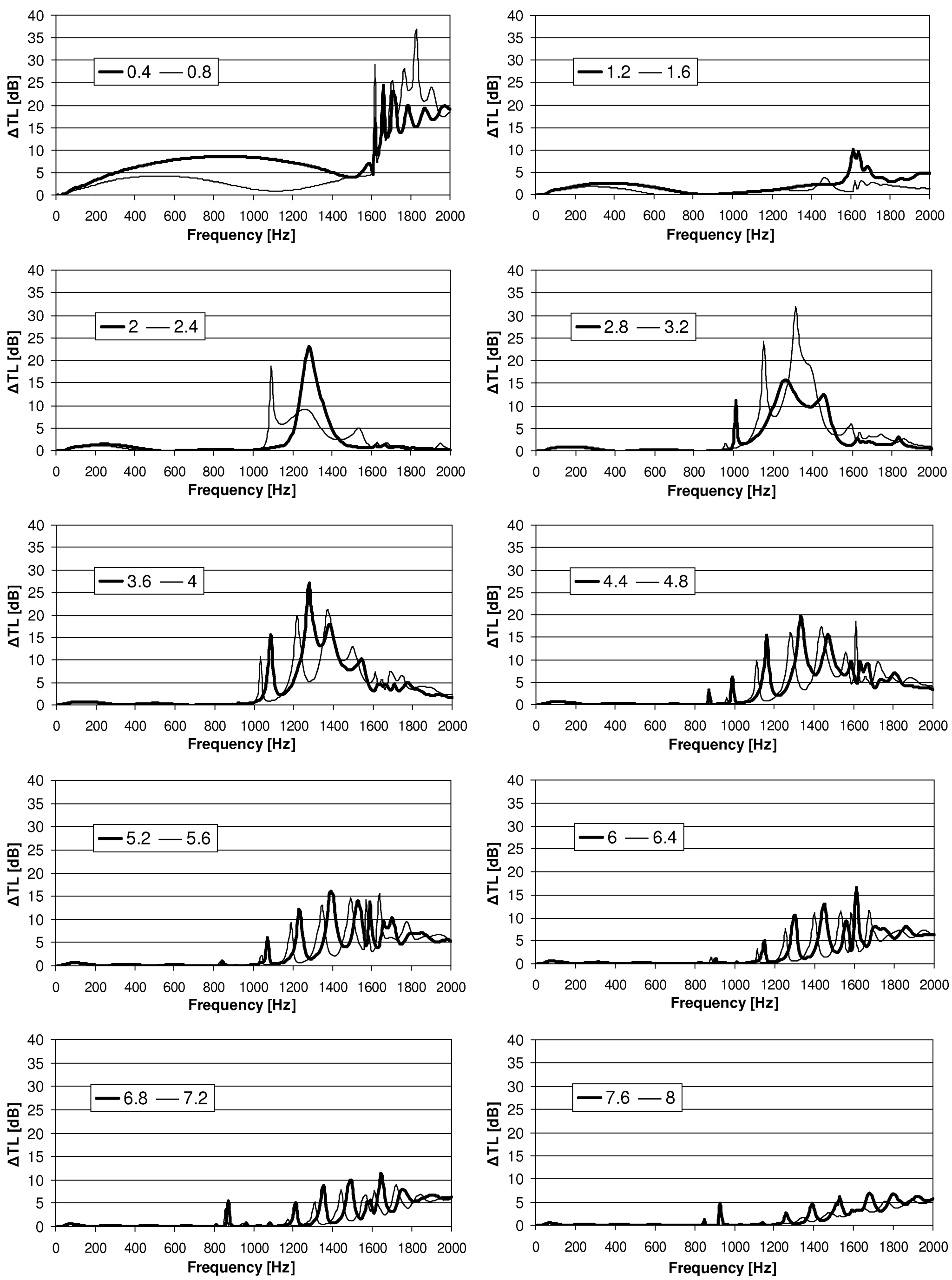

Fig. 5. ΔTL with different spiral lead to diameter ratio s/d.

transmission loss $\Delta\mathrm{TL}$ depend on the geometrical specification of the spiral duct, what will be the issue of author's further research work.

5. Conclusions

The characteristic dimension of the duct – length – states the main difference between the typical ducts (circular or rectangular) and the spiral ducts. In case of the simple ducts the normal frequencies can be calculated directly from the largest longitudinal and cross-sectional dimensions. For the spiral ducts the situation is more complicated and needs more research work, because the largest dimensions cannot be specified solidly, and the propagating sound wave undergo a deformation. Although the deformed sound wave causes physical phenomenon and increases the sound attenuation. The value of $\Delta\mathrm{TL}$ is determined by s/d ratio and increases in a specific frequencies. Acoustic wave in those frequencies is divided at the outlet of the spiral ducts and the major acoustic energy goes aside, directly to the absorptive material, and minor acoustic energy goes axially to the silencers outlet. This is the damping effect of the spiral ducts.

Aknowledgment

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