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COMPUTATIONAL AND EXPERIMENTAL INVESTIGATIONS OF A SOUND PRESSURE LEVEL DISTRIBUTION AT THE OUTLET OF THE SPIRAL DUCT

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This paper describes a computational and experimental investigations of a sound pressure level distribution at the outlet of the spiral duct. A finite element method was used to compute a three-dimensional numerical models in a COMSOL Multiphysics computer application. Both, numerical and experimental models of the spiral duct were placed solidly in a circular duct and they were approximately of the same size with a mandrel placed axially. For experimental investigations of sound pressure distribution, the measurements were carried out in a square plane, about 16 cm per 16 cm, perpendicular to the mandrel's axis and placed at a distance of 2.5 cm from the outlet of the spiral duct. The nearest surroundings of the outlet of the spiral duct was covered by an absorptive material. As the computational outlet surroundings was set up an empty air volume with a boundary conditions of a characteristic impedance of the air. This gives the same conditions as an anechoic chamber. It is presented that computational model is very similar to experimental one. Specific sound pressure level distribution at the outlet of the spiral duct is presented as computed and measured experimentally. This comparison shows good agreement between experimental and numerical results and it reveals great potential for applications as a newly discovered acoustic band stop filter – the spiral duct.

Keywords: spiral duct, sound attenuation, experiment, numerical computations, FEM.

1. Introduction

There are several papers which describe an acoustic attenuation properties of different types of spiral ducts [4–8]. These include numerically computed in a COMSOL Multiphysics computer application [2] the acoustic performance parameters, such as the transmission loss (TL) [4–6], the noise reduction (NR) [7], and the insertion loss (IL) [8]. A numerical investigations of a round silencer with the spiral duct at the inlet [4] shows that the spiral duct can improve the sound attenuation performance. There was shown the sound pressure level (SPL) distribution at the outlet of the spiral duct inside the round silencer. The damping effect of the spiral duct was described as the SPL distribution inside a round muffler where the maximum values of the SPLs are directed sideways, and the minimum values of the SPLs are directed axially to the silencers outlet. It must be added that this phenomenal SPL distribution gives the highest TL at a resonance frequency of the spiral duct. In reference [5] can be found a comparison of the spiral duct and Helmholtz resonator – well known acoustic band stop filter (BSF) [7–13]. Here [5] the spiral duct seems to be a better sound attenuator than Helmholtz resonator in analyzed frequency range and in described acoustic system – circular duct. It is very important information in fact that newly discovered resonant element (spiral duct) can be used as an alternative substitution of Helmholtz resonator. The spiral duct has also a better acoustic attenuation performance, when applied to a large diameter circular ducts, when typical BSF do not work effectively.

Reference [2] showed, that numerically computed and studied, phenomenal SPLs distribution at the outlet of the spiral duct and Helmholtz resonator are very similar to themselves. This is a great basis to compare with experiment the SPL distribution at the outlet of the spiral duct achieved by a finite element (FE) simulation.

2. Experimental and numerical models

A three-dimensional (3D) FE numerical investigation of the spiral duct models have been studied in authors earlier research works [4–8]. Due to that in this paper is a time to present a general model parameters. Both, numerical and experimental models of the spiral duct are placed solidly in a circular duct (Fig. 1a, c) and they are approximately of the same size (Fig. 1a, b) with a mandrel placed axially, as described in references [1–3]. The circular duct dimensions for experimental and numerical models are: duct diameter $d = 125$ mm, duct length $l = 1.02$ m. The spiral lead s to a constant circular duct diameter d is represented as dimensionless s/d ratio, which equals 2 for investigated numerical model, and $s/d = 2.04$ for experimental model. Other spiral duct dimensions are: mandrel's diameter $\varnothing 30$ mm, thickness of the spiral profile 5 mm. It is possible that the real model may have some geometrical inaccuracy, because its spatial dimensions were not made and measured with high precision technique. Although the real model is quite well done in authors opinion, as presented in Fig. 1b, c. Finally it is good to say that the spiral profile is hand made by the first author and it has a surface with good reflective properties. Numerical model of the spiral duct was connected to the cylindrical duct and it has similar conditions to the experiment. As the computational outlet surroundings an empty air volume with a boundary conditions of a characteristic impedance was set up [2, 7, 8]. This gives the same conditions as an anechoic chamber. The investigated models of the spiral duct were placed in the same position in experiment and numerical simulation. Hence, the comparison of the resulting SPLs distribution presented in Sec. 3 is possible.

a) b) c)

Fig. 1. View of the investigated models: a) 3D FE numerical model of the spiral duct; b) real model of the spiral profile with a mandrel; c) real model of the spiral duct connected to the sound source with $1/2''$ microphone unit placed in a measurement plane.

3. Measurements and results

For experimental investigations of SPL distribution, the measurements were carried out in an approximately square plane, about 16 cm per 16 cm, perpendicular to the mandrel's axis and placed at a distances of 2.5 cm from the outlet of the spiral duct. The spiral duct was connected to a sound source, as it is presented in Fig. 1c. The sound source has generated a harmonic sound wave accordingly to the resonance frequency of the spiral duct. The nearest surroundings of the outlet of the spiral duct was covered by an absorptive material. Measured resonance frequency for investigated experimental spiral duct was $f_r = 1255$ Hz, and the resonance frequency of numerically computed model was $f_r = 1290$ Hz. Also in Fig. 2 the commonly used parameter to compare characteristics of ducts radiation can be expressed as *ka*, where $k = \omega_r/c$, $\omega_r = 2\pi f_r$ is the angular frequency, $c = 343$ m/s is the speed of sound in air, and a is the distance in meters. A Brüel&Kjær $1/2''$ microphone unit type 4190-C-001 was mounted on a tripod and connected to a Brüel&Kjær PULSE platform. Only resonance frequency was read by the use of Fast Fourier Transform (FFT) analysis type 7770. The measurements of SPLs [dB] distribution at the outlet of the spiral ducts placed solidly in the same position inside the circular duct are presented in Fig. 2b and computed SPLs [dB] are shown in Fig. 2a. The SPLs were measured in a square plane with a step of 1 cm line by line.

To draw in Fig. 2b SPLs isolines, there was used a linear interpolation among measurement points. In comparison both figures, Fig. 2a and Fig. 2b, computed and measured, respectively, it can be proposed about their similarity. However, looking for very high similarity of these figures one should take into consideration two things: discretization and interpolation. Instead of that it can be seen that both pictures present the same

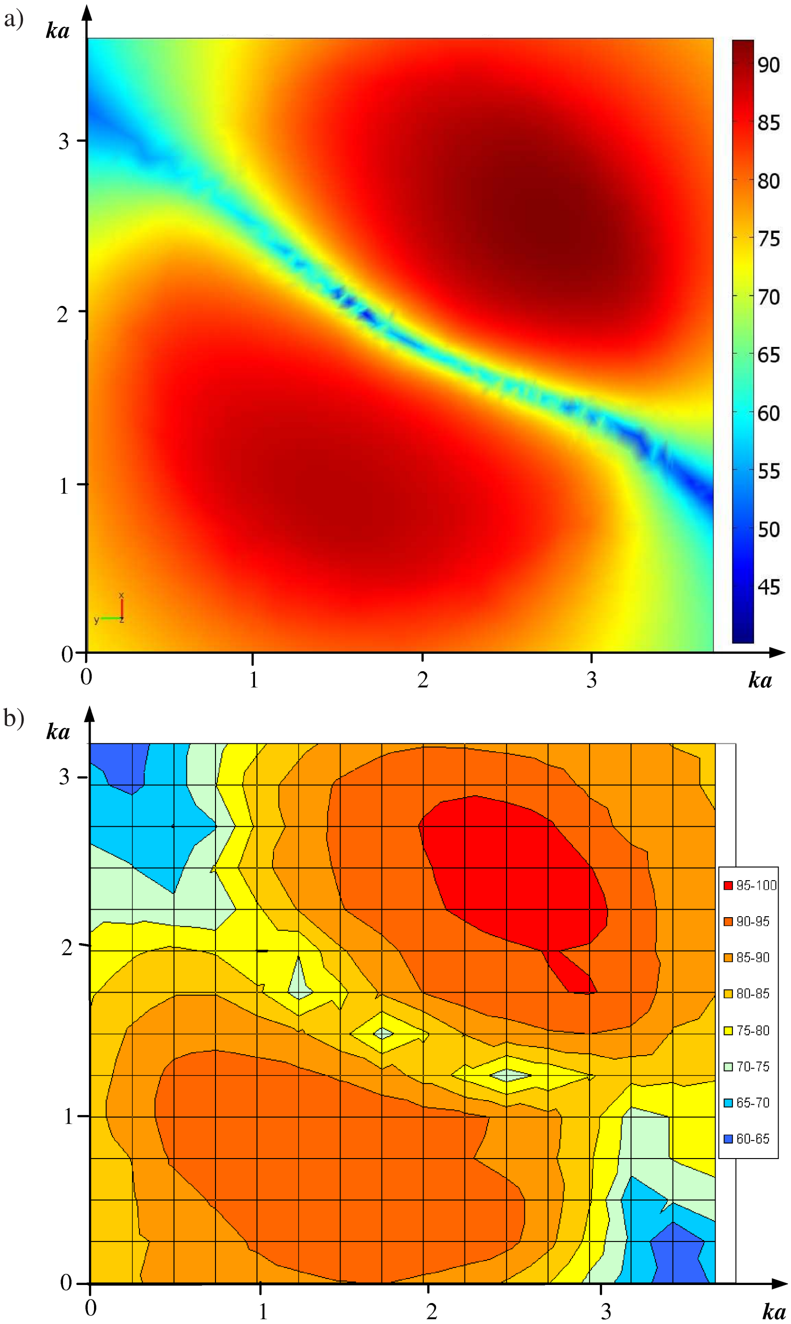

Fig. 2. SPLs [dB] distribution at the outlet of the spiral ducts for the resonance frequency f_r in a square measurement plane (256 cm^2) perpendicular to the duct axis at the distance of 2.5 cm: a) 3D FE numerical simulation $f_r = 1290$ Hz, $s/d = 2$; b) experiment $f_r = 1255$ Hz, $s/d = 2.04$. Circular duct dimensions: $d = 125$ mm, $l = 1.02$ m; spiral duct parameters: mandrels diameter ∅30 mm, thickness of the spiral profile 5 mm.

acoustical phenomenon, which obviously have a local character. It can be observed that in predominant part both SPLs distributions, numerical and experimental, are very similar. Accordingly, this phenomenal coincidence of numerical and experimental results takes place in a case of other distances from the radiating outlet of the spiral duct.

4. Conclusions

The SPLs distribution at the outlet of the spiral ducts, investigated in this paper, shows good agreement between experimental and numerical results and it reveals great potential for applications for a newly discovered acoustic band stop filter. It can be observed from Fig. 2 that the SPLs are distributed in such a way that both, numerical and experimental, measurements indicated higher SPL at right-top corner of the figure. The SPLs distribution depends on the spiral duct profile localization, which was in the same position in experiment and simulation. Performed measurements show that authors earlier research works [4–8], which carried out on the base of numerical simulations, can be considered as correct for practical applications. It is very important information for future research works, which firstly should be supported on numerical investigations and after that, there should be performed validative experiment.

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