Numerical Analysis of Sound Propagation in Selected Acoustical System with Helicoidal Resonator Placed in Cylindrical Duct With 90 Degree Elbow

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Abstract

This paper concerns to the numerical analysis of transmission loss of selected acoustical helicoidal resonator placed in cylindrical duct close to the elbow. The change of acoustic attenuation performance of helicoidal resonator is observed with the change of the degree of rotation of cylindrical duct elbow. The finite element method was used to calculate the acoustical system in the COMSOL Multiphysics computational environment. The results show that the change of rotation of elbow or rotation of helicoidal profile can change the resonance frequency, and thus the tuning options are extended when applying helicoidal resonators in ducted systems.

Keywords: helicoidal resonator, sound propagation, duct elbow, ducted system

1. Introduction

The most popular ducted systems exist in ventilation systems and exhaust systems, where the transport of medium is needed. For many cases to transport air in ventilation systems the gravitational energy is used, but also in many cases are used fans to deliver the air in a long and curved pipes. The existence of fan means the source of noise, and sometimes it needs to apply the silencer [10, 11]. This paper considers the influence of placing acoustical helicoidal resonator [2-8] close to the 90 degree duct elbow as acoustical band stop filter for silencing specific sounds in a range of frequencies.

2. Description of acoustical system and numerical analysis

Considered acoustical system consist of a cylindrical duct with the diameter d = 125 mm and 90 degree elbow of internal bind radius r_b = 125 mm with helicoidal resonator of constant relationship between helicoidal pitch s to a cylindrical duct diameter d, ratio s/d = 1.976, and constant helicoidal profile thickness g to the cylindrical duct diameter d, ratio g/d = 0.04. The constant value of relationship between mandrel diameter d_t and cylindrical duct diameter d, ratio d_t/d = 0.24, was investigated. The location of 0 degrees rotation consisted in placing the beginning of the helicoidal profile directly at the beginning of the elbow, so that the outer largest radius of the helical profile coincided with the largest radius of the elbow. The numerical computational environment COMSOL Multiphysics [1] was used to solve the three dimensional models by the use of finite element method. The analysed type of medium was air of temperature 20ºC without mean flow. The numerical computations were realized in the frequency domain with the use of timeharmonic pressure acoustics physics. Computed Helmholtz equation [1, 10, 11] with defined boundary conditions, as hard walls with perfect reflection defined for all surface elements of helicoidal resonator, cylindrical duct walls and 90 degree duct elbow walls; and second boundary condition of plane wave radiation defined for inlet (incident pressure p = 1 Pa) and outlet circular surfaces (anechoic termination) of the cylindrical duct with elbow. The model mesh was automatically generated with the rule of minimum five finite elements per wavelength [9] for the highest analyzed frequency. The Transmission Loss (*TL*) [1, 10, 11] was calculated in the range of frequencies from 10 Hz to 2 kHz with the calculation step of 1 Hz.

3. Sound pressure levels distribution and transmission loss

In Figure 1 to Figure 4 are presented the sound pressure levels distribution for four degrees of rotation between helicoidal resonator in cylindrical duct end 90 degree duct elbow for resonance frequencies in acoustical systems.

The interesting distribution of sound pressure levels are observed for all four considered cases, where for the resonance frequency the highest sound pressure levels (dark red colors in Figures 1-4) are placed inside helicoidal resonator, and the lowest sound pressure levels (blue colors in Figures 1-4) are curved and directed to the outlet part of the duct). In Figure 5 are presented transmission losses for four considered cases of the degree change between helicoidal resonator and elbow.

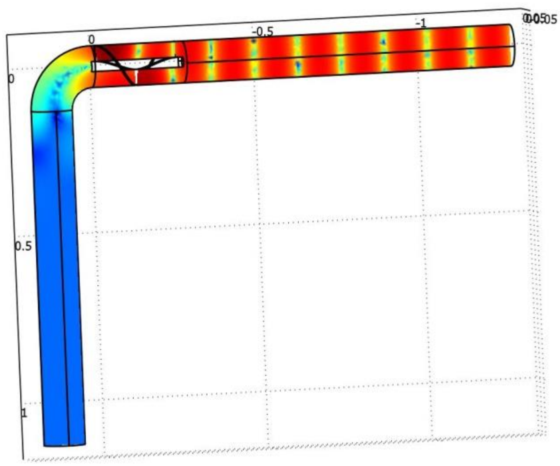

Figure 1. Sound pressure levels distribution for 0 degree of rotation of 90 degree elbow and helicoidal resonator for the resonance frequency 1300 Hz: highest dB levels – dark red colors, lowest dB levels – blue colors

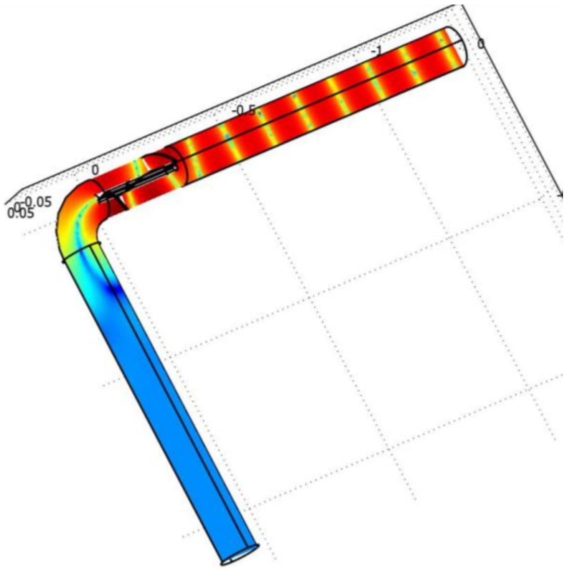

Figure 2. Sound pressure level distribution for 90 degree of rotation of 90 degree elbow and helicoidal resonator for the resonance frequency f = 1330 Hz: highest dB levels – dark red colors, lowest dB levels – blue colors

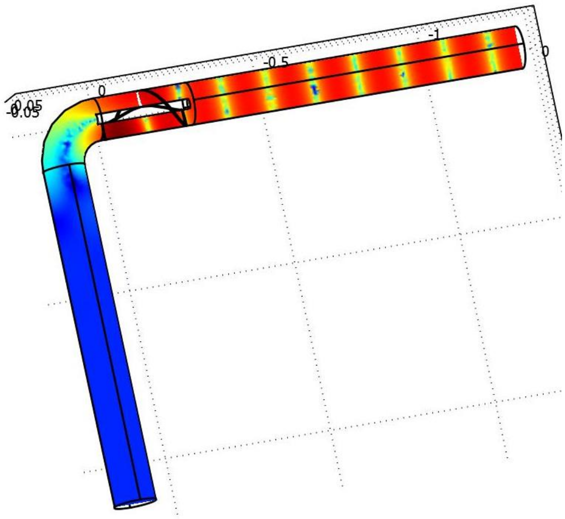

Figure 3. Sound pressure level distribution for 180 degree of rotation of 90 degree elbow and helicoidal resonator for the resonance frequency f = 1270 Hz: highest dB levels – dark red colors, lowest dB levels – blue colors

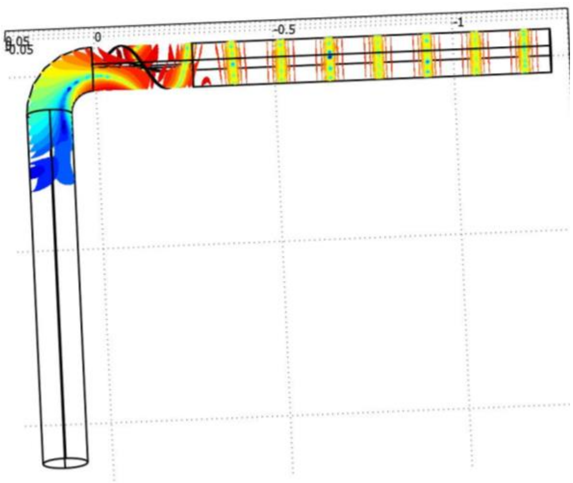

Figure 4. Sound pressure level distribution for 270 degree of rotation of 90 degree elbow and helicoidal resonator for the resonance frequency *f* = 1263 Hz: highest dB levels – dark red colors, lowest dB levels – blue colors

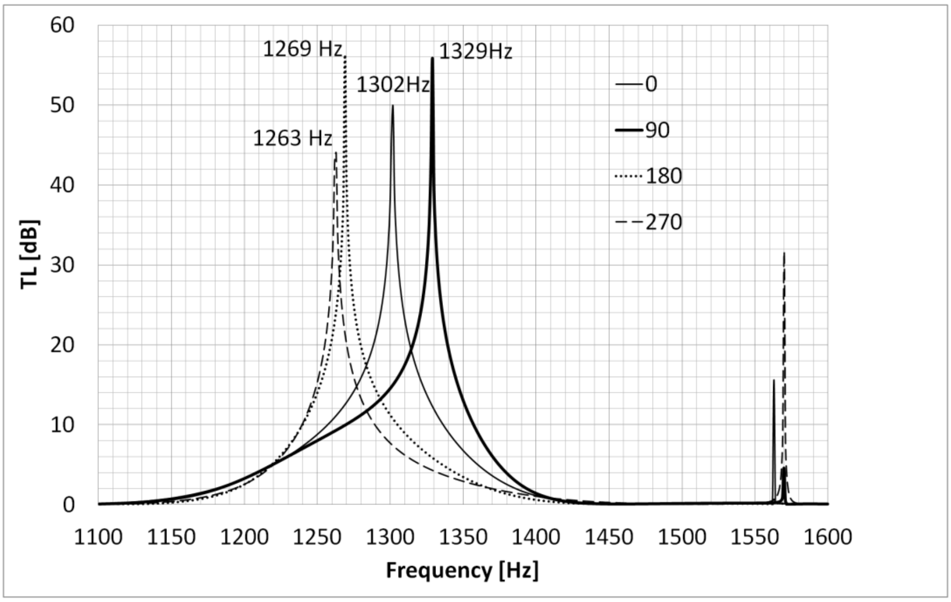

Figure 5. Transmission loss for acoustical systems with helicoidal resonator with *s/d* = 1.976 and 90 degree duct elbow for four types of degrees of rotation

Presented in Figure 5 transmission loss results show that the change of rotation degree between helicoidal resonator with *s/d* = 1.976 and 90 degree duct elbow causes the change in resonance frequency of such acoustical system. The biggest difference between resonant frequencies equals almost 70 Hz. The value of *TL* didn't change a lot and is higher than 40 dB for all cases. The biggest asymmetrical distribution of *TL* values in frequency domain in relation to the resonance frequency are obtained for 90 and 270 degrees of rotation between elbow and helicoidal resonator.

4. Conclusions

This paper described the acoustical numerical analysis of the change of rotation degree between 90 degree duct elbow and selected helicoidal resonator with *s/d* = 1.976 in the cylindrical duct with diameter *d* = 125 mm. The change of sound propagation and acoustic attenuation performance of helicoidal resonator was observed with the change of the degree of rotation of duct elbow. Transmission loss results showed that the change of rotation degree between helicoidal resonator and duct elbow causes the change in resonance frequency of such acoustical system. The biggest difference between resonant frequencies equaled about 70 Hz. In other way, in practical ducted systems it only needs to change the rotation of helicoidal resonator helicoidal profile to tune the resonance frequency.

Acknowledgments

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