Series of split silencers for ventilation systems

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Abstract. The paper is devoted to the prospects of noise reduction in ventilation systems with large cross-section main air ducts. The design schemes of a split silencer for various systems obtained as a result of calculations and experiments are proposed. For a silencer whose split ducts are formed by successive narrowings and expansions the parameters ensuring minimum noise reduction of 7.5 dB and pressure loss of up to 120 Pa are shown and the recommendations for usage in systems where two-phase flows propagate are given. For a silencer whose split ducts contain internal elements the parameters that provide a minimum noise reduction of 10 dB and pressure loss of up to 90 Pa are identified and the recommendation for usage in supply ventilation systems with the required disinfection is presented. For a silencer that combines two sections with oppositely oriented split ducts its applicability in systems without aerodynamic restrictions and with increased acoustic requirements was noted. For additional silencer section composed from Helmholtz split resonators the parameters that ensure even noise reduction are shown and the recommendation for usage in systems without restrictions on the length of the main duct and with increased low-frequency noise reducing requirements is given.

1. Introduction

Calculated and experimental data have shown the prospects of a silencer whose split ducts are formed by stepped partitions (figure 1) in ventilation systems with large cross-section main ducts [1-5].

The device is technological, provides even noise reduction in the normalized frequency range and has advantages associated with the absence of sound-absorbing material in flows containing dust, liquid and infectious agents.

![Figure 1. Split silencer scheme.](image-url)
To simplify designing the silencers in specific systems it is necessary to create a series of split devices. The purpose of the paper is developing the recommendations for the use of split silencers. The problems of determining the acoustic and aerodynamic characteristics of split devices in air ducts of large cross-section were solved.

2. Materials and methods
The silencer was described taking into account not less than one hundred forms of propagating waves \([6-11]\) by the method of equivalent multidimensional chains of four-poles (table 1).

| Components of the model | The scheme of acoustic system | The scheme of equivalent multidimensional chain |
|-------------------------|-------------------------------|-----------------------------------------------|
| Air duct                |                               |                                               |
| The tie between air duct and silencer input |                               |                                               |
| The tie between silencer output and air duct |                               |                                               |
| The element (narrowing, expansion) in the split duct of the silencer |                               |                                               |

Calculations of acoustic characteristics were carried out using Simulink (figure 2).

Figure 2. S-model of the two-split silencer.
The silencer’s S-model contains modules that combine blocks from the library sections of Math, Sources, Links, Signals and Systems, Matrix Inverses and Matrix Operations.

Using the principle of modularity provides the construction of various S-models.

Physical models of split silencer were tested on aeroacoustic stand with fulfilling the similarity theory requirements [12-15].

- Acoustic characteristics of silencers were determined by method of measuring in doubled reverberant chambers with removable elements.
- Aerodynamic characteristics of silencers were determined by method of measuring in pressure duct with the diaphragm.
- The dustiness of the silencer models was tested in flows containing coal dust of 1-20 mg/m³ and sawdust of 1-100 mg/m³.
- The accumulation of liquid impurities in the silencer model was checked in flow with sprayed water.

Silencer’s spark arresting ability was tested in the stand with internal-combustion chamber:

3. Results

Based on characteristics of variants of the silencer which split ducts are shaped by successively alternating narrowings and expansions (table 2) it was found that the expansion ratio of 4 and the lengths change indicator $2^{-0.6}$ provide noise reduction by at least 7.5 dB in the frequency range above 125 Hz and the insertion of pressure loss up to 120 Pa into the system.

In two-phase flows the characteristics of the silencer are stable.

- Traces of solid impurities were observed in the first in the direction of the flow split ducts elements.
- The possibility of removing dust when the ventilator is running were identified.
- The possibility of removing the released liquid impurities when the bottom is tilted in the direction of the flow is revealed.

Sparks on the silencer’s outlet weren’t appeared.

For a silencer whose split ducts have narrowings continued inside the expansions with the distance between slices of 5 mm (table 3) the noise reduction by at least 10 dB in the frequency range of 125-8000 Hz and pressure loss by no more than 90 Pa were detected.

The possibilities of additional split silencer section were considered.

- The silencer that combines two sections with oppositely oriented split ducts (table 4) is characterized by twice the noise reduction compared to a single design and twice the pressure loss.
- The second silencer’s section combining Helmholtz split resonators (table 5) whose tuning frequencies changes in geometric progression with a denominator of $2^{-0.8}$ and the distance between the various tuned resonators is determined by a quarter of the geometric mean sound wavelength allows increasing the efficiency of the silencer in the frequency range of 31.5-125 Hz without significant insertion of pressure loss into the system.
- In silencer’s resonator section a Helmholtz resonator with the highest tuning frequency can be placed between resonators with neighboring lower tuning frequencies so the device can be compact.

4. Discussion

Recommendations for usage of the split structures in specific ventilation systems are shown in the tables 2-5.
Table 2. Silencers composed from split expansion chambers.

| Recommendations | Acoustic characteristics |
|-----------------|--------------------------|
| For systems with dusty flows (in the housing design – rotary walls, filter cavities) | ![Graph showing noise reduction] |
| For systems with flows containing liquid impurities (in the housing design – the slope of the base, the hydraulic gate) | ![Graph showing noise reduction] |

Table 3. Silencers composed from split expansion chambers with inner narrowings.

| Recommendation | Acoustic characteristic |
|----------------|--------------------------|
| For supply ventilation systems (taking into account their disinfection) | ![Graph showing noise reduction] |
Table 4. Two-section silencers with opposite oriented split ducts.

| Recommendation | Acoustic characteristics |
|----------------|--------------------------|
| For systems with high acoustic requirements and without aerodynamic restrictions | ![Graph showing noise reduction vs frequency for single and two-section silencers] |

Table 5. Two-split silencer section contained Helmholtz resonators.

| Recommendation | Acoustic characteristic |
|----------------|--------------------------|
| For systems without length restrictions and with increased requirements to reduce low-frequency noise | ![Graph showing noise reduction vs frequency for resonator section] |

Dimensions of the split silencer will be clarified when designing the specific system.
5. Conclusion
The obtained data allow recommending the series of devices for systems with large cross-section air ducts.

- The split silencer composed from expansion chambers and equipped chambers and equipped with dust and moisture removal elements is effective in exhaust ventilation systems.
- The split silencer composed from expansion chambers with inner ducts is effective in supply ventilation systems.
- The two-section split silencer with opposite oriented ducts is effective in systems with increased acoustic requirements and without aerodynamic restrictions.
- The silencer’s section containing split resonators is effective in systems without dimensional restrictions on the main air duct and with increased low-frequency noise reduction requirements.

References
[1] Williams P, Kirby R, Hill J, Abom M and Malecki C 2018 Appl. Acoust. 131 61–69
[2] Yu X and Cheng L 2015 J. Sound Vib. 33520 229–44
[3] Papini G S, Pinto R L U F, Medeiros E B and Coelho F B G 2017 Appl. Acoust. 125 102–12
[4] de Lima K F, Lenzi A and Barbieri R 2011 Appl. Acoust. 72(4) 142–50
[5] Plitsyna O and Rogova T 2019 Akustika 34 85–7
[6] Cui X B and Ji Z L 2012 Engineering Analysis with Boundary Elements 3(7) 1053–61
[7] Zhu D D and Ji Z L 2016 Appl. Acoust. 112 25–31
[8] Du J, Liu Y, Wang Y and Wang G 2018 Appl. Acoust.s 138 60–71
[9] Fang Z, Ji Z L and Liu C Y 2017 Appl. Acoust.11615 152–163
[10] Yang L, Ji Z L Wu T W 2015 Engineering Analysis with Boundary Elements 61 265–73
[11] Denia F D, Sanchez-Orgaz E M, Martinez-Casas J and Kirby R 2015 Finite Elements in Analysis and Design 1011 46–57
[12] Ahmed A, Noureddine A, Morvan O and Olivier D J. Sound Vib. 459 1148–73
[13] Lee I, Jeon K and Park J 2013 Appl. Acoust. 74(4) 479–84
[14] Yu X, Tong Y, Pan J and Cheng L 2015 J. Sound Vib. 3511 57–67
[15] Langfeldt F, Gleine W and von Estorff O 2018 J.Sound Vib. 417 359–75
[16] Yu X, Lu Z, Cheng L and Cui F 2017 J. Sound Vib. 387 114–26