The Impact of the Damper Blade Position on the Generated Noise and Pressure Losses in Plenum Box with Swirl Diffusers

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Abstract

The article presents the effect of setting the throttle in the plenum box with swirl diffuser on the generated noise and the pressure losses. The sound power levels of the source was determined using the precision method in the reverberation room in accordance with the PN-EN ISO 3741:2011 standard. The examination was carried out for damper blade position set vertically and horizontally for full opening and at a 45 degree angle in both directions. In order to confirm the universality of the conducted experiment, the tests were carried out for two different face swirl diffuser with different shapes of air control blades and holes in the plate and for different flow rates. The multi-criteria optimization methods were used to select the best throttle position.

Keywords: HVAC, noise emission, sound power level, pressure loss, optimization

1. Introduction

The Polish standard PN-N-01307:1994 specifies the limit values for noise at workplaces due to its nuisance determined. It states that the equivalent sound level A for administrative rooms, design offices for theoretical work, data processing and other similar purposes should not exceed 55 dB [1]. One of the sources of noise in this type of rooms is ventilation [2, 3], mainly from grilles and diffusers [4, 5].

Smaller flow resistance in ventilation systems allows you to use less powerful fans. It allows to save money on purchase of a fan and reduce electricity expenses. In the case of a company with an extensive ventilation system, this can result in a large saving of money.

Manufacturers of ventilation products use various solutions to mount the damper blade in the plenum box, often without wondering if it is the best, because no such

studies have been carried out. The purpose of the tests is to check which damper blade position in the box is better, vertically or horizontally, and which setting direction it is better for a given setting. The noise and flow resistance were taken into account as the criterion of the best location.

2. Test object

The test object is insulated plenum box with dimensions of 600 x 600 mm and 380 mm height with two different swirl diffusers. The diffusers differed in the construction of the air control blades and the tilt angle in the plate. The diffuser A has a smaller tilt angle, fin under the blades and air guides. The blades from the B diffuser are smooth. A visual comparison of diffusers and blades is shown in Figure 1. All air control blades were set in one direction - the swirl was set to the right. The measurements were carried out for three volume flows: 600, 1000, 1400 m3/h. During measurements, the damper position and direction in the plenum box were changed, as shown in Figure 2. Set damper blade in vertical and horizontal directions for full opening and 45 degrees in both directions.

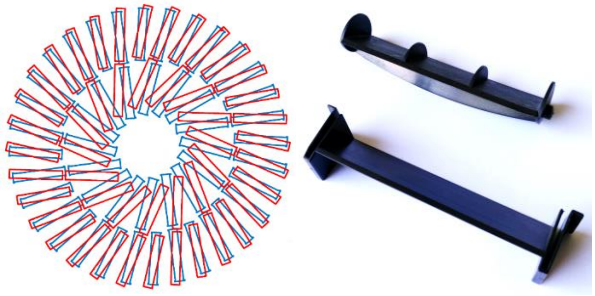

Figure 1. Differences in the shape of swirl diffusers holes and air control blades (blue holes and up blade form diffuser A, red holes and down blade from diffuser B)

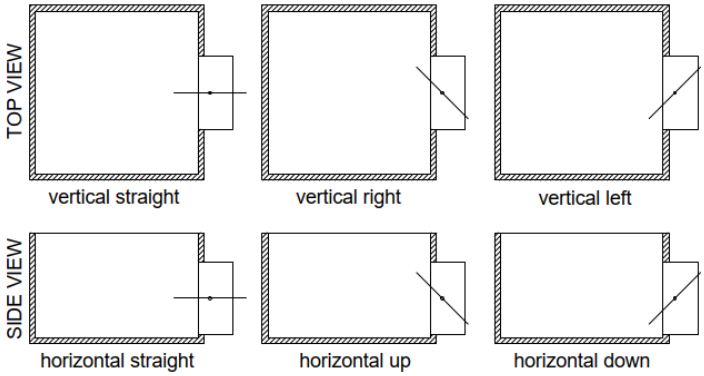

Figure 2. Tested damper blade position in plenum box was tested during measurements

3. Experiment

The measurements were made in a reverberation room (Figure 3) with a volume of 237.0 m^3 and an area of 231.5 m^2 which non-parallel walls. The diffusers connected to the centrifugal fan through three absorption silencers with a total length of 3.3 meters outside the chamber.

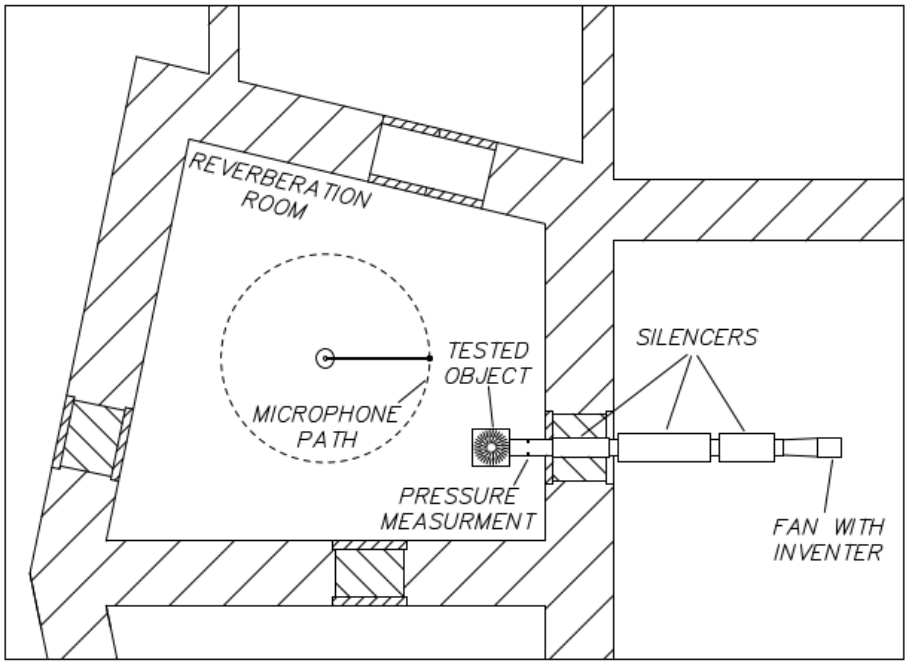

Figure 3. Reverberation room scheme

The volumetric flow was set by changing the rotation frequency of the fan motor. For this purpose, a three-phase inverter was connected to the motor. Flow velocity were measured using the Testo 420 balometer.

The static pressure drop on the expansion box together with the front plate was measured 300 mm on the channel in front of the damper in four evenly located points around the circumference and the environment. A differential electronic pressure transducer was used for this. The tested object in the reverberation room is shown in Figure 4.

Figure 4. Plenum box with swirl diffusers under test

The noise generated is determined by sound power, measured and calculated in accordance with PN-EN ISO 3741:2011 "Acoustics - Determination of sound power levels and acoustic energy levels of noise sources based on sound pressure measurements - Precision methods in reverberation chambers" [6]. The Nor 140 measuring set with the Nor850 software and the Nor265 rotary table was used for the measurements. The sound pressure was measured at twelve uniformly spaced points in a circle with a radius of 1.7 meters (circumference 10.7 m). Measured in 1/3 octaves in the range from 50 Hz to 10,000 Hz. The measurement time is set to 15 seconds. Shorter measurement time had no effect on standard deviation, and more points measurements reduced them. And in the case of background measurement time set to 30 seconds to determine the background correction K_1. Background noise measured for a stand without flow. Reverberation was measured for four omnidirectional loudspeaker settings with three microphone settings every 120 degrees. All calculations of the sound power level were made using a previously made calculation sheet.

Before and after all measurements were made, the background level was measured and calibrated using the Bruel & Kjaer 4231 calibrator. After measuring each setting, the temperature, relative humidity and atmospheric pressure necessary for calculating the sound power were recorded.

4. Results

The results of measurements and calculations of the sound power level correlated with curve A and pressure loss are presented in the form of graphs for three volume flows in the Figure 5.

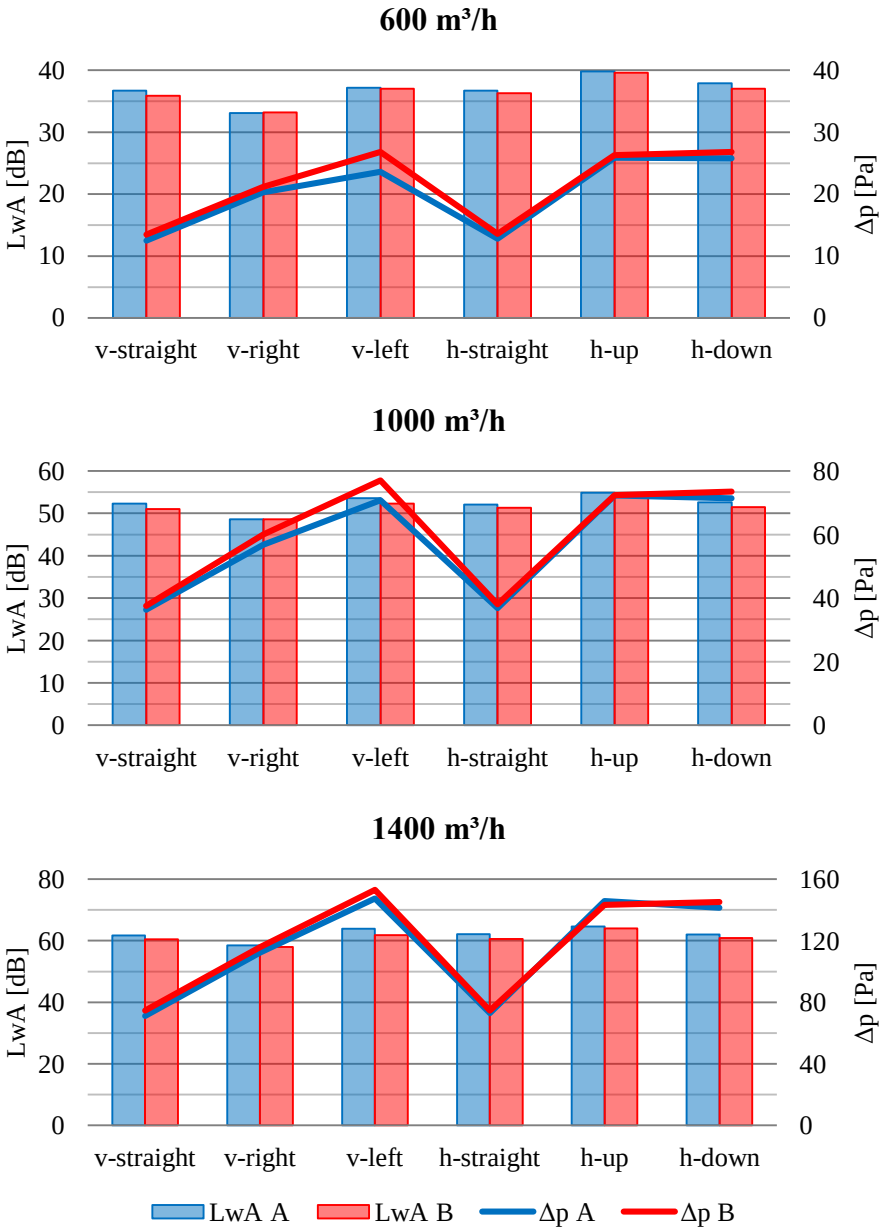

Figure 5. Results of measurements of sound power and pressure losses for various damper blade position in plenum box, volume flow and swirl diffusers (v means vertical and h horizontal)

The spectrum of the sound power level for the volume flow 1000 m^3/h air diffuser B for various damper blade settings is shown in Figure 6. The right throttle setting reduces the noise level for medium and high frequencies. Changing to the left direction increases the high frequency levels. The down adjustment is similar to that for full opening, and turning to the up increase the noise levels in the whole range.

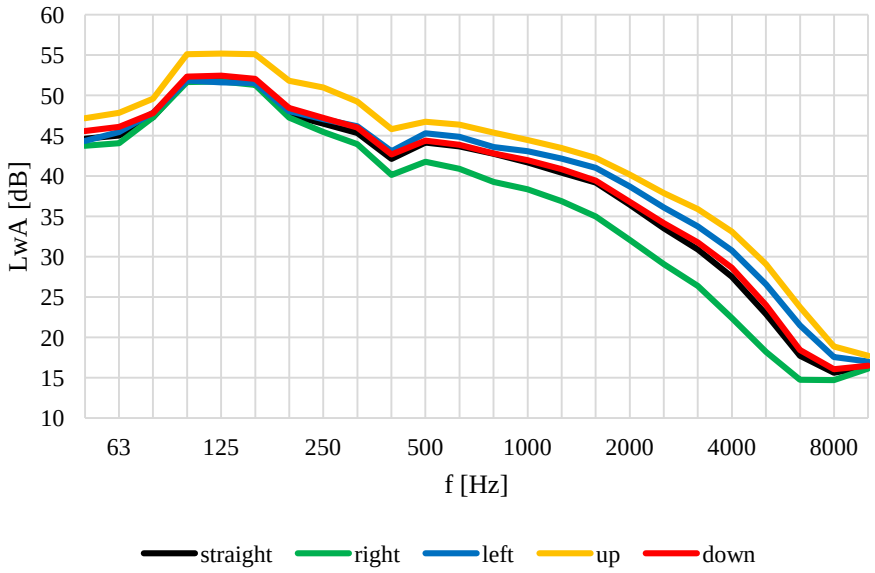

Figure 6. Acoustic power level spectrum for different blade settings with diffuser B and volume flow 1000 m3/h

Because values have different units and are of different order and scope, normalization is necessary [7]. The following formula was used for this purpose, which normalizes the value from 0 to 1 in a dimensionless form.

$$x_{\text{norm}} = \frac{x - x_{\text{min}}}{x_{\text{max}} - x_{\text{min}}} \tag{1}$$

Where x_{min} and x_{max} are the largest and smallest value of x.

To determine the best point considering both parameters, we used the formula

$$F_{\text{glob}} = \sqrt{L^2_{\text{wA-norm}} + \Delta p^2_{\text{norm}}} \tag{2}$$

This pattern determines the distance from the ideal point, which consists of the minimization of the component parameters.

The results of normalization and the global objective function calculations are presented in Table 1.

Table 1. Results after normalization and calculation of the global function

swirl diffuser	**A**			**B**		
600 m³/h						
	$L_{wA\text{-}norm}$	Δp_{norm}	F_{glob}	$L_{wA\text{-}norm}$	Δp_{norm}	F_{glob}
vertical-straight	0.54	0.00	0.54	0.42	0.00	0.42
vertical-right	0.00	0.58	0.58	0.00	0.58	0.58
vertical-left	0.61	0.83	1.03	0.59	1.00	1.16
horizontal-straight	0.54	0.02	0.54	0.48	0.01	0.48
horizontal-up	1.00	1.00	1.41	1.00	0.96	1.39
horizontal-down	0.72	0.99	1.22	0.59	1.00	1.16
1000 m³/h						
	$L_{wA\text{-}norm}$	Δp_{norm}	F_{glob}	$L_{wA\text{-}norm}$	Δp_{norm}	F_{glob}
vertical-straight	0.59	0.00	0.59	0.41	0.00	0.41
vertical-right	0.00	0.57	0.57	0.00	0.57	0.57
vertical-left	0.79	0.96	1.24	0.64	1.00	1.19
horizontal-straight	0.56	0.01	0.56	0.47	0.01	0.47
horizontal-up	1.00	1.00	1.41	1.00	0.88	1.33
horizontal-down	0.63	0.98	1.16	0.50	0.91	1.04
1400 m³/h						
	$L_{wA\text{-}norm}$	Δp_{norm}	F_{glob}	$L_{wA\text{-}norm}$	Δp_{norm}	F_{glob}
vertical-straight	0.52	0.00	0.52	0.42	0.00	0.42
vertical-right	0.00	0.54	0.54	0.00	0.53	0.53
vertical-left	0.89	1.00	1.34	0.63	1.00	1.18
horizontal-straight	0.59	0.02	0.59	0.43	0.00	0.43
horizontal-up	1.00	0.98	1.40	1.00	0.88	1.33
horizontal-down	0.57	0.92	1.09	0.48	0.90	1.02

5. Conclusions

Setting the damper blade in the plenum box with swirl diffusers not only affects the pressure loss, but also the noise emitted. This allows to increase the comfort of work and reduce costs by reducing the flow resistance.

Due to the noise, the best position of the damper blade is to close it in accordance with the swirling of the air control blades - in this case to the right. Appropriate setting

can give over 6 dB less noise. To achieve the lowest possible pressure loss, open the damper blade completely.

According to the method of multi-criteria optimization, it is best to fully open the damper, very close to the minimum there is a damper blade position to the right (less noise, but greater pressure losses).

Vertical throttle mounting is better than horizontal. In terms of noise emissions and pressure losses. Regulation in accordance with the swirl (in this case the right) is better. If the damper is set horizontally, it is better to regulate it by directing it down - pressure losses are similar, but it is quieter.

All the above-mentioned applications are independent of the volume flow and the front of the diffuser.

Appropriate mounting of the damper in the expansion box by the manufacturers and its proper control by the users allows to improve flow properties.

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