Comparison of aerodynamic characteristics for various slot diffusers

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Abstract. The airflow in the room or any space has a significant impact on the proper operation of the entire ventilation system. An appropriate field of air velocity flowing through the entire room allows for climate comfort. That is why it is so important proper selection as well as proper arrangement for the air-supply and air-exhaust elements in the ventilation system. This research study presents an isothermal air stream flowing from two different slot diffusers. The supply airstream was analysed at various volumetric flow rates and the velocity of the supply air stream was measured in accordance with the PN-EN 12238: 2002 standard. In order to evaluate the optimal measuring points and to create an appropriate grid, before starting the experimental measurement smoke tests were carried out which determine the scope and shape of the supply stream. All experimental measurements were performed up-to the location where the supply air stream reaches the limiting speed of 0.2 m/s. As a result of the analysis, the obtained characteristics of two types of slot diffusers were discussed and compared.

1 Introduction

The main task of mechanical ventilation and air conditioning systems is to provide the proper amount of good quality air to the ventilated space. This is done in order to guarantee thermal comfort to users of these rooms [1-3]. To accomplish this task, the installation designer should prepare a thermal energy balance and determine the number of harmful substances and pollutants emitted in the space. However, the correctly determined amounts of air and the selection of high-quality air treatment devices do not guarantee yet the correct operation of the installation. The comfort of users in ventilated building is also determined by the correct arrangement in the air distribution. This means that the appropriate velocity field of air flowing through the entire space has to be ensure [4-6].

Depends on the geographical region ventilation plays also a significant role from the total thermal energy point of view. Heat loss due to ventilation is responsible for about 25-55% total heat loss. Taking into account this fact it has been found [7] that it is hardly possible to obtain primary class energy-efficient building without adequately designed mechanical ventilation system [8].

People spend about 80% of their time indoors. For this reason, air quality and thermal comfort are of primary issue and important aspects of the indoor environment that require particular attention. The forecasts and knowledge regarding indoor climate conditions are crucial for indoor climate optimization, thermal comfort, and energy efficiency [1]. It is known that relative humidity and temperature should be maintained within a range of 40-60% and 20-24^{o}C respectively. Special attention should also be taken to keep the air clean and control its biological as well as chemical composition. Indoor air pressure should also be taken into consideration and airflow without recirculation is preferred.

In the last decade, a large number of studies have been conducted experimental and numerical for this topic. Nielsen [9] analysed case with wall-mounted air supply equipment. In this work, author shows air velocity distributions in the vicinity of a wall. In [10] authors used a simplified method to describe the thermal and flow conditions for 8 various diffuser types: slot diffuser, nozzle diffuser, grille diffuser, round ceiling diffuser, vortex diffuser, square ceiling diffuser, valve diffuser, displacement diffuser. Al-Hamed [11] performed CFD simulation to calculate room ventilation to predict air velocity and temperature for the cases with multiple inlets and outlets located in the ventilated space. Author use with the succeeds the *k-ε* turbulence model. The flow evaluated in that work was verified against experimental data. In [12] authors proposed a method for evaluating boundary conditions at the inlet of a vortex diffuser. They compared experimental visualization with numerical simulations and showed the effectiveness of the proposed method in the case of vortex diffuser. Einberga and Hagstrom [13] shown the results of

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modelling for the case of multi-cone air diffusers. This type of diffuser is often used in industrial application. Authors compared CFD results with experimental measurements. The obtained results showed that the numerical analysis performed using the standard *k*-*ε* model can predict the non-isothermal airflow around the diffuser with good accuracy. Most of the research studies presented in the literature (experimental and numerical) have been carried out in small size spaces. It can be also seen that the studies were carried out randomly on pre-selected diffuser models and there is no comprehensive method for evaluating diffusers, for example, from the point of view of energy consumption. As a result, many problems still persist in relation to making projections on existing numerical and mathematical models, especially for low speed flows characterised by the low Reynolds numbers.

The appropriate evaluation of the air distribution requires a good knowledge of the phenomena related to the air supply flow as well as exhaust air from the ventilated space. The selection of diffuser geometry and arrangement in the space should be based on theoretical foundations and the results of tests and analyses carried out on objects similar to where the system will be implemented. In order to ensure the comfort of people staying in a ventilated space, air velocity and temperature have to be set-up so that the air in the room does not draft or stagnates. It is important that the blown air cover the entire occupied space. Therefore, the velocity and airflow should be analysed in detail already at the design stage, taking into account the impact of all possible factors affecting the distribution of air in the room [14,15].

This work presents an isothermal air stream flowing from two different slot diffusers. The supply airstream is analysed at various volumetric flow rates and the velocity of the supply air stream is measured in accordance with the PN-EN 12238: 2002 standard. In order to evaluate the optimal measuring points and to create an appropriate grid, smoke tests is also carried out.

2 Experimental setup

The measurements were carried out in the thermal technology laboratory located at the AGH University of Science and Technology. The measuring stand was constructed based on the PN-EN 12238: 2002 standard. This standard specifies the test stand and requirements for the room dimensions.

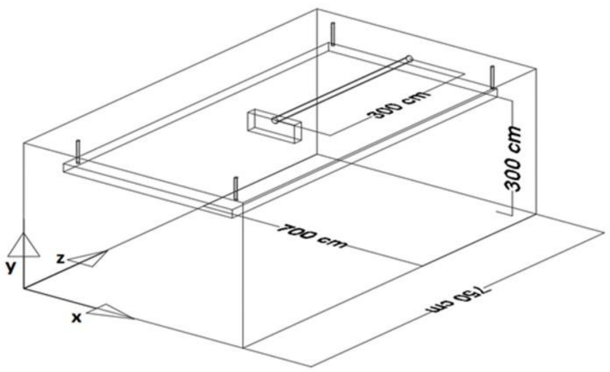

Fig. 1. Dimensions of the laboratory test section.

The room where the measurements were carried out is 7.0 m wide, 7.5 m long and 4.2 m high. A movable suspended ceiling was installed in the room, with diffusers mounted at a height of 3.0 m from the floor. The air was supplied to the expansion box with by duct 160 mm diameter and 3.0 m long (see Fig. 1).

The air was supplied by a radial fan equipped with a inverter enabling change of rotational speed. A measuring orifice was used to determine the value of supply airflow.

In order to determine the range of limiting speed L0.2 (with a value of 0.2 m/s) of the blown stream, the measuring grid presented in Figure 2 was determined. The intersection of the two lines indicates the point where the measurement was taken. The distance between the measuring points was 30 cm horizontally and 15 cm vertically. The first horizontal measuring line was 5 cm below the diffuser. At low values of the supply airflow, the measuring grid was limited most important points.

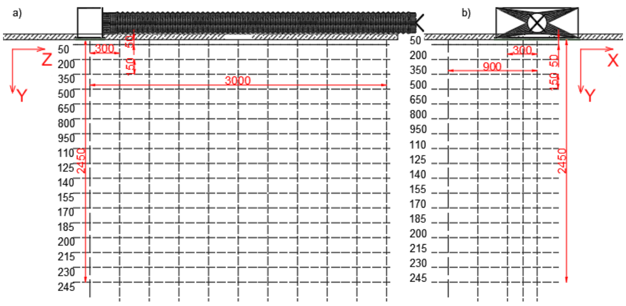

Fig. 2. Measuring grid used (a) side view, (b) front view of the diffuser.

The air velocity was measured using the AirDistSys 5000 measuring system consisting of four SensoAnemo 5100LSF series transducers with measuring probes. The measuring device has a measuring range from 0.05 m/s to 5.0 m/s and accuracy in the range of ± 0.02 m/s ± 1.5% of indication. The measuring system also includes a SensoBar 5301 transducer for measuring and automatic compensation of the influence barometric pressure on the indications of thermoanemometric sensors.

One of the two tested air diffusers was the NSAL series diffuser (Fig. 3). This diffuser is intended for installations with constant and variable airflow. It has 4 rows with 8 individually adjustable rollers. This allows for fine adjustment of the direction of the supply airflow.

Fig. 3. NSAL diffuser photo.

The second diffuser tested was the SLN series diffuser (Fig. 4). This diffuser has four linear slots with adjustable blades allowing for the two-stage setting. Both tested diffusers had the same external dimension of 83 cm x 14 cm and were installed in identical expansion boxes.

Fig. 4. SLN diffuser photo.

For both diffusers, measurements were made in two variants of air deflector settings: downward supply perpendicular to the floor and lateral supply parallel to the ceiling. The diffusers were tested at two different values of the supplied airflow 120 and 480 m^3/h.

3 Results

Figure 5 shows the NSAL diffuser during the smoke test with the outlet set vertically down for two values of the supply air stream. Figure 6 shows the SLN diffuser during the same test and at the same airflow rate. For both diffusers, the blown air stream initially flat as it moves away from the diffuser expands, falling downwards.

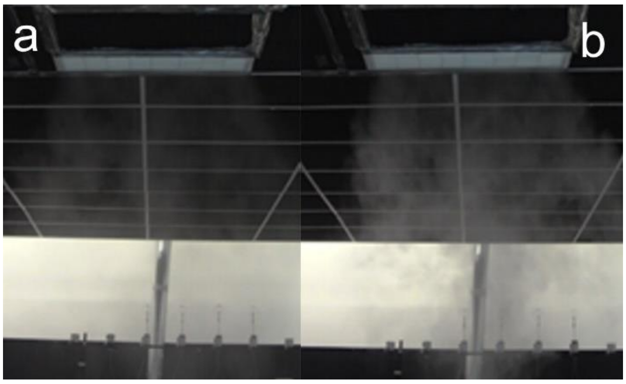

Fig. 5. Smoke test of the NSAL diffuser, with outflow directed downwards, for two air streams: (a) - 120 m^3/h, (b) - 480 m^3/h.

Fig. 6. Smoke test of the SLN diffuser, with outflow directed downwards, for two air streams: (a) - 120 m^3/h, (b) - 480 m^3/h.

Similarly, Figures 7 and 8 show the NSAL and SLN diffusers during the smoke test with the blown air stream parallel to the ceiling. Pictures were taken as before for two different airflow values 120 and 480 m^3/h. Smoke tests were intended to determine the shape and range of the blown streams before the final experimental anemometric measurements.

Fig. 7. Smoke test of the NSAL diffuser with outflow along the ceiling, for two air streams: (a) - 120 m^3/h, (b) - 480 m^3/h.

Fig. 8. Smoke test of the SLN diffuser with outflow along with the ceiling, for two air streams: (a) - 120 m^3/h, (b) - 480 m^3/h.

Figure 9 shows the velocity distributions in the NSAL diffuser axis with the outflow vertically down for different airflow values. As the distance from the supply air outlet decreases, the velocity decreases reaching 0.64 m/s (for flow 480 m^3/h) at the lowest measuring point (2.45m from the diffuser). For the lowest flow rate, the velocity of 0.2 m/s was achieved at a distance of 1.7 m from the diffuser.

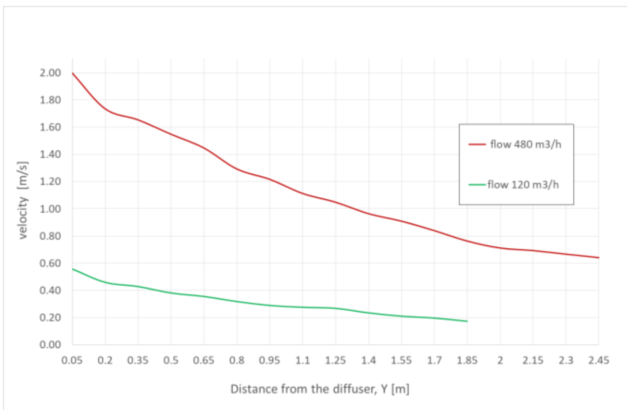

Fig. 9. Distribution of velocity along the NSAL diffuser axis for downflow.

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For comparison, Figure 10 was prepared. It shows analogous velocity distributions but for the SLN diffuser. At the lowest measuring point, 0.55 m above the floor a velocity of 0.28 m/s was recorded (for a stream of 480 m^3/h). While for the 120 m^3/h streams, the airflow velocity at a distance of 1.70 m from the diffuser fell below the limiting velocity and amounted to 0.16 m/s.

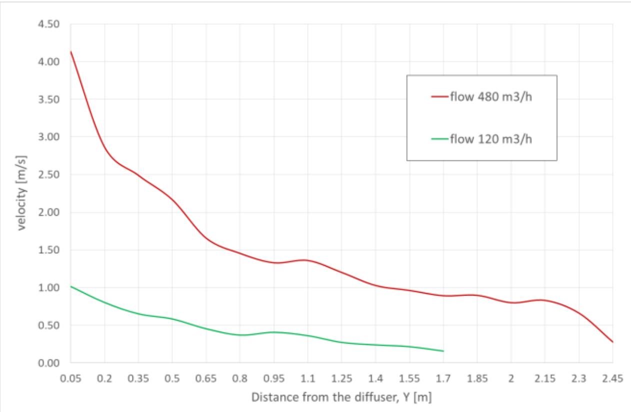

Fig. 10. Distribution of velocity along the SLN diffuser axis for downflow.

Figure 11 shows the limit velocity range 0.2 m/s (L0.2) for 480 m^3/h and 120 m^3/h streams obtained at the NSAL diffuser. The range of the stream relative to the X-axis is characterised by a decrease in width along with the distance from the diffuser. Figure 12 shows the same range statement but obtained for the SLN diffuser. The L0.2 range with a stream of 480 m^3/h in the X-axis was more evenly shaped. However, the ranges for the SLN diffuser reached much larger widths in the X-axis than for the NSAL diffuser.

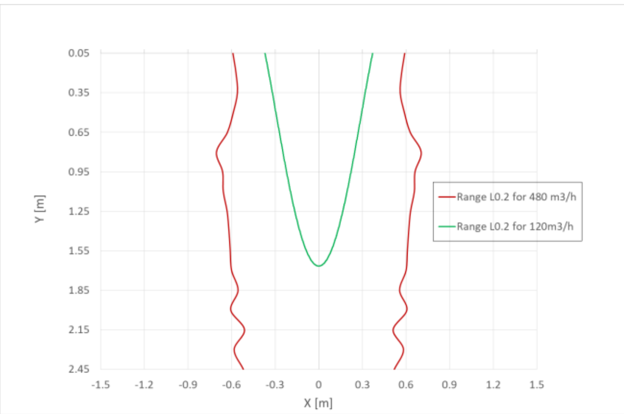

Fig. 11. Range L0.2 of NSAL diffuser flow, with the downward flow, in the X-axis.

A comparison of the measured ranges L0.2 of the tested air diffusers is shown in Figure 13. The graph shows the ranges of the air stream of the tested diffusers with lateral outflow (along with the ceiling) for the 120 m^3/h flow rate. On can infer from this figure that the NSAL diffuser has reached a larger range. The lowest point of the limiting velocity was 2.44 m from the floor at a distance of 3.0 m from the diffuser.

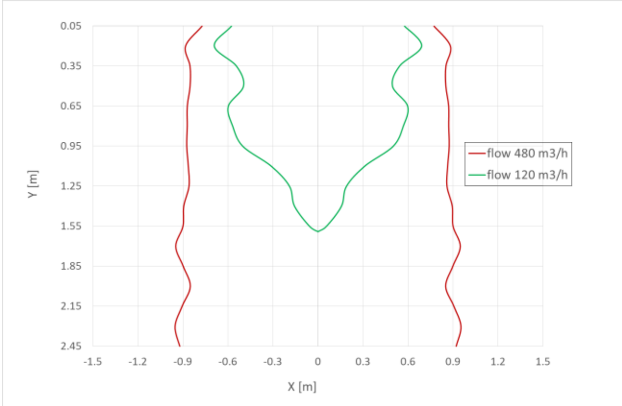

Fig. 12. Range L0.2 of SLN diffuser flow, with downward flow, in the X-axis.

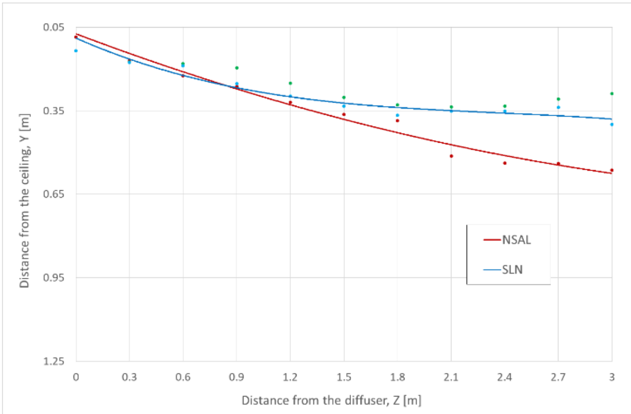

Fig. 13. Comparison of ranges of tested diffusers at 120 m^3/h flowrate, outflow lateral (along with the ceiling).

A similar comparison is shown in Figure 14. It presents the range of air streams supplied by the tested diffusers at a flow value of 480 m^3/h. This time the L0.2 range waveforms are different. NSAL diffuser has reached a much larger range. The lowest range point was 2.12 m from the floor.

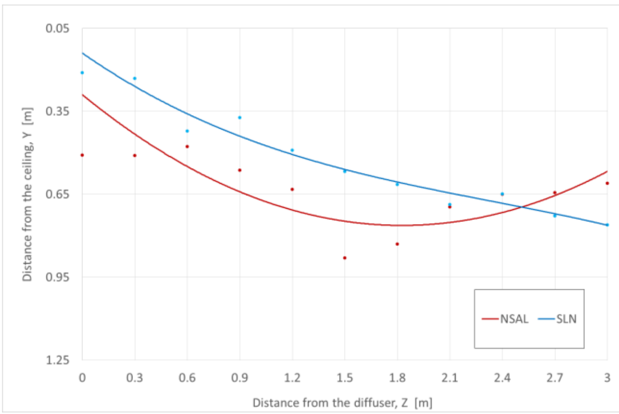

Fig. 14. Comparison of ranges of tested diffusers at 480 m^3/h flowrate, outflow lateral (along with the ceiling).

4 Conclusions

A comparative analysis of the tested slot diffusers for different construction on terms of differences in the air stream range has been done. Referring the results obtained to the conditions that should be ensured in the zone of staying of people, it can be seen that when supplying air to the ceiling direction, both diffusers meet the requirements for the limit of air velocity range 0.2 m/s. However, when the air stream is directed downwards, the limiting speed value is exceeded in the occupied zone ranged from 1.3 to 2.0 m above the floor. Therefore, it can be seen that the knowledge on the stream blown shape through the diffuser is important in the process of designing a ventilation systems.

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