Journal of Physics: Conference Series

PAPER • OPEN ACCESS

Examining capture velocity in local exhaust ventilation utilizing a purpose-built workstation

To cite this article: S Szekeres 2024 *J. Phys.: Conf. Ser.* **2911** 012005

Examining capture velocity in local exhaust ventilation utilizing a purpose-built workstation

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Abstract: HVAC systems play a pivotal role in determining the overall energy consumption of industrial production halls and workshops, thereby emphasizing the necessity to optimize ventilation levels. Consequently, there is a paramount need to devise systems that strike a balance between energy efficiency and functional efficacy. This article elucidates a comprehensive investigation into the capture velocity of local exhaust ventilation (LEV) through the utilization of a purpose-built workstation within a controlled laboratory environment. The workstation, characterized by a 900 mm width and 450 mm depth worktop, was strategically outfitted with an exhaust duct proximal to the pollutant source, aligning with the operational objectives of the LEV system. The worktop was partitioned into square sections to facilitate precise documentation and subsequent reevaluation. Controlled fresh airflow was supplied through a duct positioned above the worktop. The study primarily centered on evaluating air velocity and turbulence intensity. Diverse configurations were experimented with at specified measurement nodes, and to avoid air extraction from behind the exhaust duct, a back sheet panel was installed. The results unequivocally demonstrated that the incorporation of a back sheet augmented capture velocities, underscoring its efficacy in enhancing LEV performance. These findings significantly contribute to advancing our comprehension of LEV efficiency and underscore the imperative of thoughtful design considerations and operational adjustments to ensure effective containment of contaminants within the operation environment.

1. Introduction

Local exhaust ventilation (LEV) has an important role in the industrial, especially in the manufacturing facilities where during the production or the technological processes harmful contaminant are being released. In industries where airborne contaminants pose occupational health risks, LEV systems play a pivotal role in safeguarding worker well-being by capturing and removing contaminants to maintain adequate air quality in the occupied zone [1, 2]. Apart from LEV, both exhaust ventilation and displacement ventilation or mixing ventilation are also used [3]. Although numerous ventilation systems are intend to supply fresh air but are not effective at removing contaminants [4]. If only a small area around a worker needs to be treated, personal ventilation can be used as well [5, 6, 7]. Designing a high-quality ventilation system is a difficult and complex task, as pollution can exist in various states, such as gas, solid, or liquid, and in particles of all sizes [8]. To capture and remove enough pollutants to ensure a safe working environment, it is crucial to know the total amount of contaminants released and the type of pollution [9]. In an office building, pollution is mainly released by the workers and can be transmitted to one another. Increased ventilation decreases the incidence of airborne infectious diseases [10]. Additionally, pressure differences between spaces can contribute to the spread of pollutants [11]. Capture efficiency assessments have been conducted in various operational conditions, however, a universally applicable methodology has yet to be established [12].

Although capture efficiency is a crucial aspect of exhaust systems, existing studies do not thoroughly examine capture velocity, even though increasing it could potentially improve overall capture efficiency [13]. This article delves into a detailed examination of LEV efficacy within a purpose-built workstation environment. Central to the study was the evaluation of air velocity and turbulence intensity, with diverse configurations tested at specified measurement nodes. To mitigate the risk of unintended air extraction, a back sheet panel was incorporated. The results of our investigation unequivocally underscore the efficacy of this design modification, as evidenced by augmented capture velocities. These findings not only advance our understanding of LEV efficiency but also emphasize the critical importance of thoughtful design considerations and operational adjustments in ensuring effective containment of contaminants within industrial work environments.

2. Materials and method

For the analysis of the capture velocity in local exhaust ventilation a purpose-built workstation was used. The workstation was set up in the Air-Ventilation and Air-Conditioning Laboratory. The measurements were conducted in a laboratory setting, making them easy to replicate. During the measurements calibrated Testo [14] instruments were used (see Figure 1). A turbulence intensity probe sensor was utilized to measure the prevailing air velocities and turbulence at the workstation. Turbulence intensity is calculated by the instrument according to standard EN ISO 7730 [7] and given in percentage. Each measurement lasts 3 minutes, with the results representing the average velocities collected from the recorded data. The instrument records data every second during the measurement.

Figure 1. Measuring instruments [13]

The velocity in the plane of the exhaust duct (later referred to as face velocity) was set between 1 m/s and 10 m/s using a probe with a diameter of 100 mm, the same as the duct's diameter. The workstation's worktop measures 900 mm in width and 450 mm in depth. The worktop was segmented into squares with sides measuring 150 mm each, as shown in Figure 2.

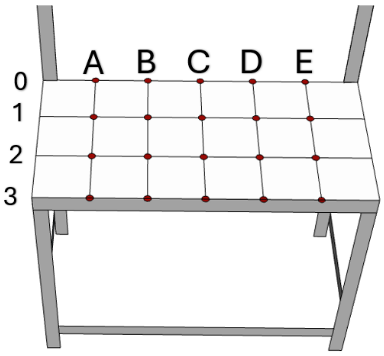

Figure 2. Measurement reference points

Each node represent a reference for the measurements, total 20 reference points. The horizontal lines can be described with numbers while the vertical ones with letters. This allows for precise and repeatable measurements every time and easy documentation. By using this grid and reference point system, you ensure that any measurements taken on the worktop are consistent and can be easily repeated. For example, the four reference points in the center of the worktop can be described as follows: C0, located in the middle of the far side of the worktop, 450 mm away from both side edges. Next point is C1, which is 150 mm away from C0 (the edge of the worktop) and 450 mm away from both side edges. Next point is C2, which is 300 mm away from C0 and 150 mm away from C3. Besides the exhaust duct, a supply duct was installed above the worktop to deliver fresh air into the breathing zone near the workstation. This airflow is set to 40 m^3h-1, meeting the required fresh air supply per person for moderately heavy physical work [15]. On the exhaust duct which is centrally positioned within the worktop two different attachments, mounting boxes were connected. Both attachments are the same width as the worktop (900 mm). Both are 200 mm high and 120 mm deep. Initially a grill was placed in the center of the mounting box, see Figure 3.

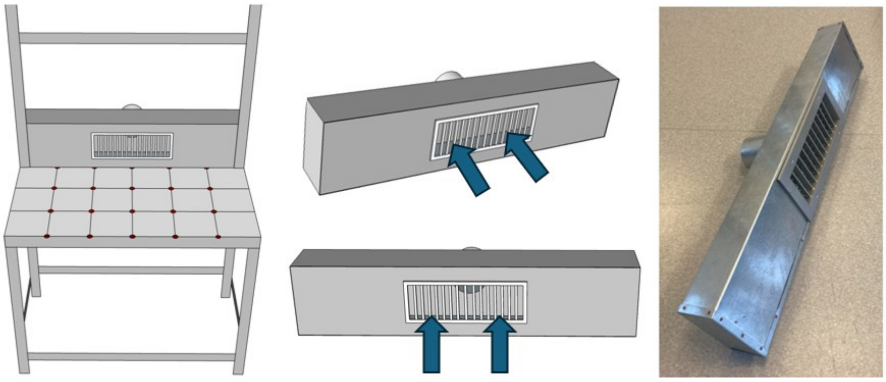

Figure 3. Mounting box with grill

Following that, a mounting box of the same size was used with slot suction (see Figure 4).

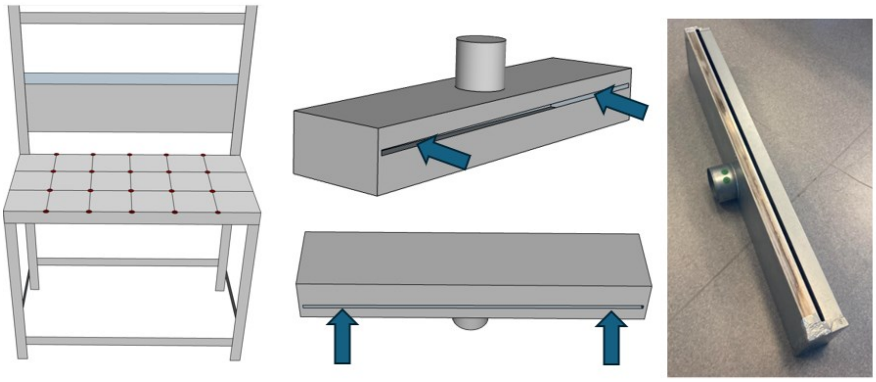

Figure 4. Mounting box with slot suction

The area of the slots on the grills was same as the area of the slot used in the second setting and both similar to the area of the 100 mm diameter exhaust duct. As the grill was 300 mm wide only reference points measured were in lane B, C and D as the capture velocities in side lanes A and E were negligible. After measuring all the points, a back sheet panel was installed with the slot suction setting to prevent suction from behind the workstation. This sheet alone increased the capture velocity, thereby enhancing efficiency.

3. Results and discussion

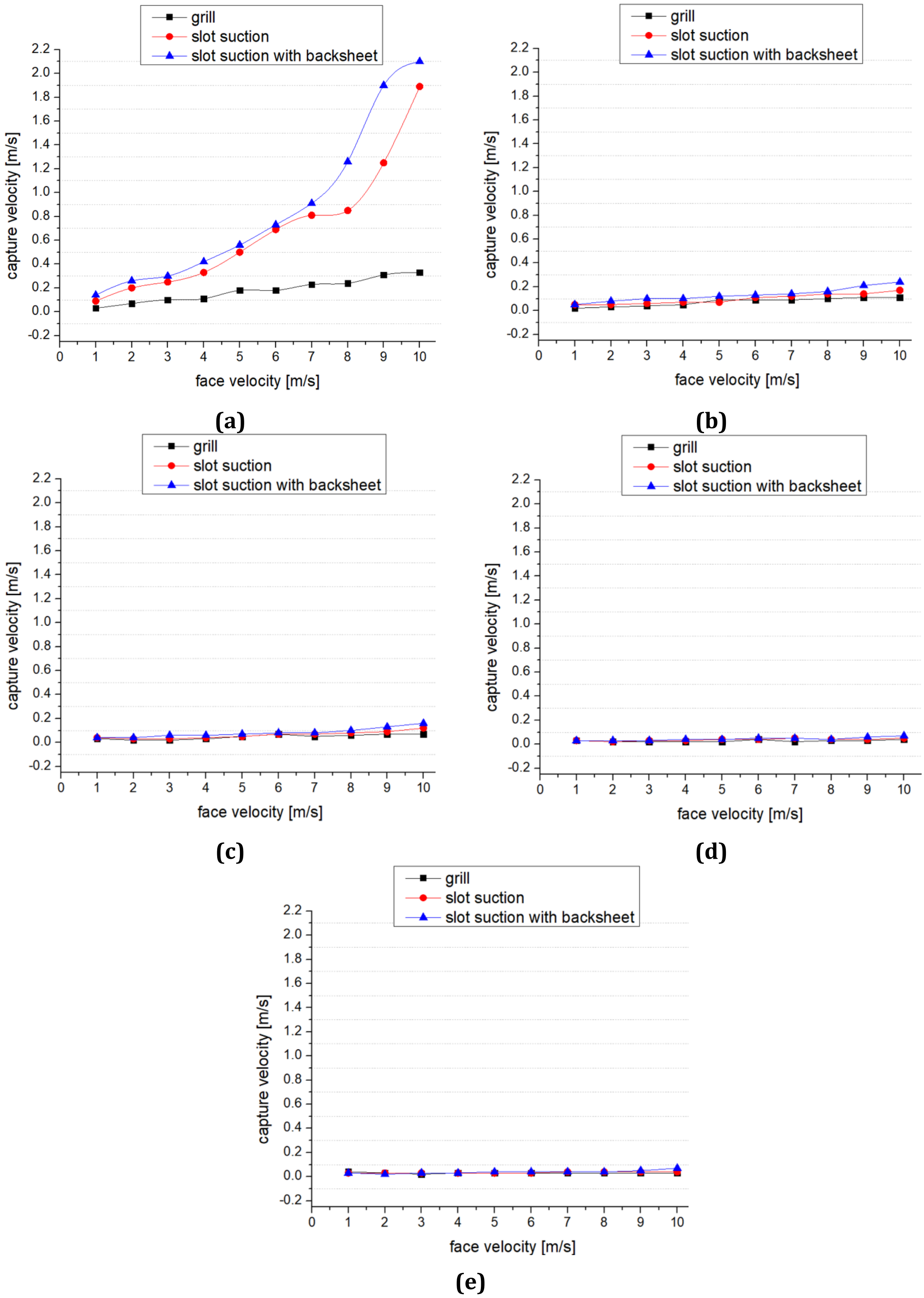

Figure 5. Capture velocities at face velocity set from 1 m/s to 10 m/s at 50 mm from the exhaust (a), 100 mm (b), 150 mm (c), 300 mm (d), and 450 mm (e) measured at lane C

After starting the measurements, it was observed that beyond a distance of 150 mm from the exhaust, the capture velocity was negligible as can be seen in Figure 5. Therefore, additional measurement points were established at 50 mm and 100 mm. Figure 5 also shows that the grill exhaust was weaker than the slot suction and also indicates that after installing the back panel, the capture velocity of the slot exhaust increased. The results measured at the face of the exhaust were not displayed on the diagram because they were significantly higher than the others, rendering the remaining results unassessable.

As can be seen in Figure 6, increasing the face velocity from 5 m/s to 10 m/s did not result in significant changes for the grill exhaust system. This suggests that grill exhaust systems may have a limited capacity to enhance capture efficiency through increased face velocity alone, whereas for the slot suction exhaust system, it nearly quadrupled, showing a substantial improvement. However, this is true at the 50 mm measurement point, while at 100 mm and 150 mm the increase was less noticeable, it only nearly doubled. At 300 mm and 450 mm, it remained almost unchanged.

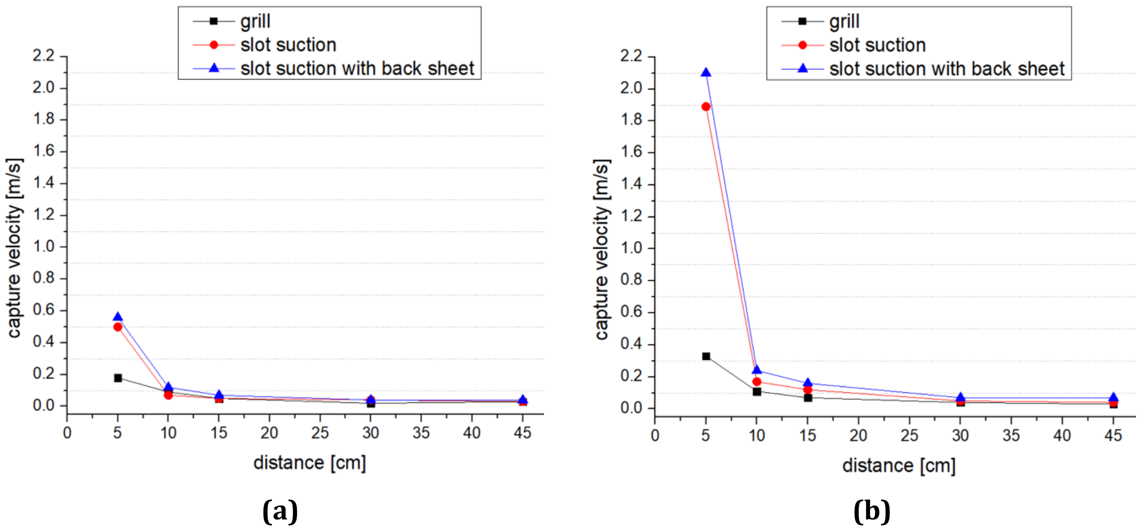

Figure 6. Capture velocities at 5 m/s face velocity (a), and at 10 m/s face velocity (b) measured at lane C

4. Conclusions

The study demonstrated that the installation of a back sheet panel with slot suction significantly increased the capture velocity, thereby enhancing the overall efficiency of the exhaust system. This suggests that modifications to the physical setup of ventilation systems can have substantial impacts on their performance. Measurements indicated that beyond a distance of 150 mm from the exhaust, the capture velocity became negligible. This finding underscores the importance of positioning the exhaust. The comparison between grid exhaust and slot exhaust systems revealed that the grill exhaust was less effective. The slot suction, particularly after the installation of a back panel, showed improved capture velocity, highlighting its potential superiority in certain applications. The research highlighted the critical role of capture velocity in the effectiveness of exhaust systems. Higher capture velocities were associated with better removal of airborne contaminants, emphasizing the need for careful design and assessment of ventilation systems in environments where air quality is crucial. The findings have important implications for occupational health, as enhanced capture efficiency can lead to significant reductions in airborne contaminants. This can contribute to safer working environments, particularly in industries where exposure to pollutants poses health risks.

Acknowledgments

Project no. TKP2021-NKTA-34 has been implemented with the support provided by the Ministry of Innovation and Technology of Hungary from the National Research, Development, and Innovation Fund, financed under the TKP2021-NKTA funding scheme.
The presented research was supported by the Ministry for Culture and Innovation, through the National Research, Development and Innovation Office. New National Excellence Program, code ÚNKP-23-3-II

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