ANNALS of Faculty Engineering Hunedoara – International Journal of Engineering

Tome XII [2014] – Fascicule 2 [May]
ISSN: 1584-2665 [print]; ISSN: 1584-2673 [online]
a free-access multidisciplinary publication
of the Faculty of Engineering Hunedoara

1. Ondřej PECH, 2. Milan PAVELEK

INFLUENCE OF THE WORKBENCH ON THE CAPTURE EFFICIENCY OF POLLUTANTS OF THE AABERG EXHAUST HOOD

1. Faculty of Mechanical Engineering, Brno University of Technology, Brno, CZECH REPUBLIC

Abstract: This paper focuses on investigations of capture efficiency of pollutants with the use of the reinforced slot exhaust system (REEXS), which is known as the Aaberg exhaust hood. It is a traditional slot exhaust hood equipped with an air supply jet that intensifies exhausting along the axis of the exhaust hood. By an adjustment of the air supply quantity, the reinforced exhaust hood can operate in traditional or reinforced modes. Two main cases were investigated – the first was with a free space in front of the slot exhaust hood, the second case was with the workbench at the level of the lower edge of the exhaust opening. Influences of the workbench were investigated for the same air velocity in the exhaust opening and with different momentum flux ratios of supplied and exhausted air flows. In both the cases the capture efficiency was measured by the tracer gas method. The carbon dioxide was used for that purpose. From measurements of the capture efficiency it was concluded that the use of the workbench has a positive influence on the capture efficiency area.
Keywords: pollutants, reinforced slot exhaust system (REEXS), air supply quantity

1. INTRODUCTION

To capture pollutants at their source local exhaust ventilation (LEV) can be used, which reduces the load of pollutions in the area, simultaneously decreases demands on the general exhaust ventilation (GEV) because the concentration of contaminants in local exhaust air is much higher than with a GEV. The main component of LEV is a traditional or reinforced exhaust hood. In case of traditional exhaust hood the air flows in the direction to the exhaust opening evenly from all sides but its capture efficiency of pollutants rapidly decreases with an increasing distance from the source of pollutants.

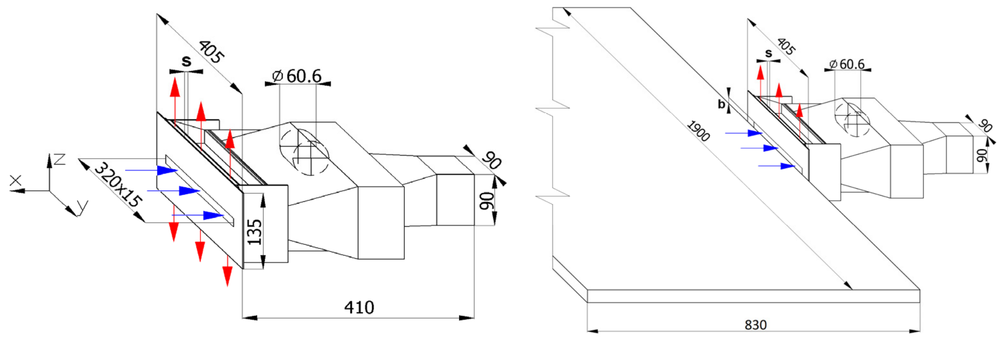

Figure 1. Reinforced slot exhaust hood and reinforced slot exhaust hood with workbench

A traditional exhaust hood has to be therefore located as close to the source of pollutants as possible which is not always technically or technologically practicable. Possible alternative is the use of the local ventilation system called the Aaberg exhaust hood [1], which is also known as Reinforced Exhaust System (REEXS). This is a traditional exhaust hood equipped with high velocity air supply jets that intensifies exhausting along the axis of the exhaust hood. The reinforced slot exhaust hood is shown in Figure 1. With a suitable momentum flux ratio between supplied and exhausted air flows, the shape and range of the effective exhaust area is possible to be partially changed and better results of exhaustion reached.

2. EXPERIMENTAL SETUP

In the research the reinforced slot exhaust hood (Figure 1), designed at Department of Thermodynamics and Environmental Engineering, Brno University of Technology, was used. The hood has one slot exhaust opening with the width b of 15 mm and a special flange with two supply slots on its long side edges. The width s of supply slots can by adjusted between 1 mm and 8 mm. In the investigated cases it was set to 4 mm and the lower supply slot blocked off, when measuring with the workbench. This exhaust hood enables operating in different modes which depends on the operating parameter I established by Hylgård [5] for the Aaberg exhaust hood as the ratio between the momentum flux supplied and the exhausted air. This operating parameter can be determined as follows,

$$I = \frac{\dot{m}_s w_s}{\dot{m}_{ex} w_{ex}} \tag{1}$$

where w_s and w_{ex} represents the mass flow of the supply air and the mass flow of exhaust air, respectively, w_s and w_{ex} are the velocities of the supply air and the exhaust air at the slot openings, respectively. When the operating parameter is set to I = 0, it works as the traditional exhaust hood. In the case of nonzero value of the operating parameter, it works as the reinforced exhaust hood. It was shown that the higher the momentum fluxes ratio the higher the suction effect of the hood [4].

For testing and research of exhaust hoods, the measuring setup was designed and assembled at our department. The scheme of measuring setup is illustrated in Figure 2. This measuring setup consists of three main parts: exhausting (positions 2, 3, 4, 5 in Figure 2) and air supply (positions 6, 7, 8) both connected to the exhaust hood (position 1) and the tracer gas supply part (positions 9, 10, 11, 12). The workbench (position 27) with the dimension in the x axis of 830 mm and in the y axis of 1,900 mm was used.

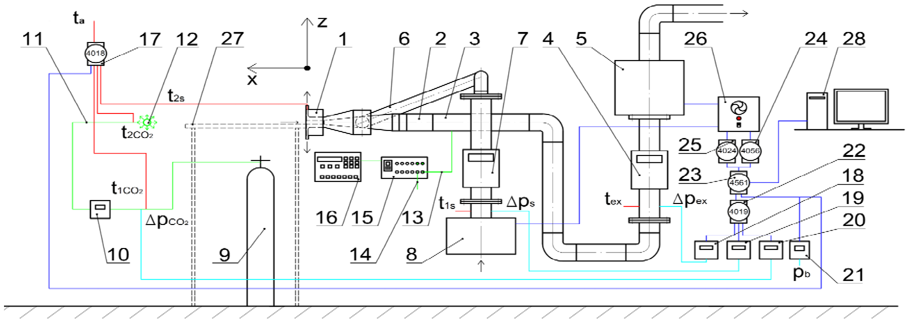

Figure 2. – Scheme of the measuring setup. 1 – reinforced exhaust hood, 2 – whirler, 3 - section for measuring concentrations, 4 – exhaust air flow meter, 5 – exhaust ventilators, 6 – supply air duct, 7 – supply air flow meter, 8 – supply air ventilator, 9 – pressure cylinder with tracer gas, 10 – tracer gas flow meter, 11 – tracer gas intake pipe, 12 – porous ball, 13, 14 – teflon tubes for gas sampling, 15 – multipoint sampler, 16 – multi gas monitor, 17 – temperature measuring module, 18 – exhaust air pressure transmitter, 19 – supply air pressure transmitter, 20 – tracer gas pressure transmitter, 21 – barometric pressure transmitter, 22 – converting module, 23 – communication module, 24 – relay output module, 25 – analogue output module, 26 – triac regulators, 27 – workbench, 28 – PC

The measuring setup includes measurements of pressures and temperatures in the duct in front of the flow meters. Also the barometric pressure and temperatures in the air supply slot, in the pipe in front of the porous ball for supplying the tracer gas and ambient temperature are measured. For the measurement of concentration of the tracer gas at the background and at the exhausting duct the multi-gas monitor (position 16) with the multipoint sampler (position 15) are used.

3. CAPTURE EFFICIENCY MEASUREMENTS

The capture efficiency of the exhaust hood was investigated for the traditional exhaust mode (I = 0), and the reinforced exhaust modes (I = 0.3, 0.6, and 0.9). Two cases of measurements were considered: the case with free space in front of exhaust hood and the case with the workbench situated at the bottom edge of the exhaust slot opening. In the first case the air was supplied by the upper and lower slot openings. In the second case the air was supplied only by the upper slot opening. The velocity magnitude in the exhaust slot opening was chosen to $w_{ex} = 8.0\ m\ s^{-1}$ according to the literature [3].

For the capture efficiency measurement of the reinforced exhaust system the tracer gas method was used. As the tracer gas the carbon dioxide (CO_2) was used. The tracer gas was supplied to the selected place in front of the exhaust hood by the small porous ball with the diameter of 30 mm, which simulates an omnidirectional pollution source. The porous ball moves in the selected grid in the vertical plane (x – z) running through the axis of the exhaust hood located in the Cartesian coordinates system (x, y, z). Its origin was placed to the midpoint of the exhaust slot opening of the reinforced exhaust hood. The distance between measuring points of the grid in the x axis was between 45 mm and 90 mm, and in z axis between 30 mm and 90 mm. In every point of the grid the air samples were taken from the exhaust duct behind the whirler (position 2 in Figure 2) and from the background, and the concentrations were analysed by the multi-gas monitor. The capture efficiency of the exhaust hood from the given place in the area can be then determined by the equation

$$\eta = \frac{C_{ex} - C_{back}}{C_{ref}} \tag{2}$$

where C_{ex} and C_{back} represents the concentration of the tracer gas in the exhaust air and in the background, respectively, and C_{ref} is a reference concentration which corresponds to the absolute capture of the supplied tracer gas.

The measured data of the capture efficiency of pollutants with free space in front of the reinforced slot exhaust hood was gain from previous research [2] at our department.

4. RESULTS AND DISCUSSION

The capture effective areas from the capture efficiency measurement by the reinforced slot exhaust hood with free space in front of and over the workbench with different exhaust modes (I =0, 0.3, 0.6 and 0.9) are shown in Figure 3. The capture effective area is defined as an area where the capture efficiency does not drop below the level of 50 %. Graphs are made in dimensionless coordinates related to the width of exhaust slot opening b = 15 mm. In figures the isolines going through the average of measured points with the step 10 % are made.

Fig. 3 illustrates the essential difference in the shape of the capture effective area for different values of the operating parameter I. It also shows the significant difference in the size and shape of the individual capture effective areas.

In the case of exhausting from the free space in front of the exhaust hood with the operating parameter I = 0 (position 1A in Fig. 3), the capture effective area is the widest but shorter in comparison to other settings of operating parameter I (case of positions 1B, 1C, 1D). With the increasing value of the operating parameter I, the capture effective area becomes longer but its width becomes smaller. It is also possible to see the considerable asymmetry in the capture effective area with respect to the horizontal plane running through the hood axis. This asymmetry is mainly caused by a significant difference between the density of the used tracer gas (CO_2) and the density of air.

In the case of exhausting over the workbench in front of exhaust hood with operating parameter I = 0 (position 2A in Fig. 3), the capture effective area is much higher but the area of high capture efficiency (greater than 80 %) is shorter in comparison to other settings of operating parameter I (case of positions 2B, 2C, 2D). With the increasing value of the operating parameter I, the capture effective area comes near to the board of workbench and becomes longer with a compact shape.

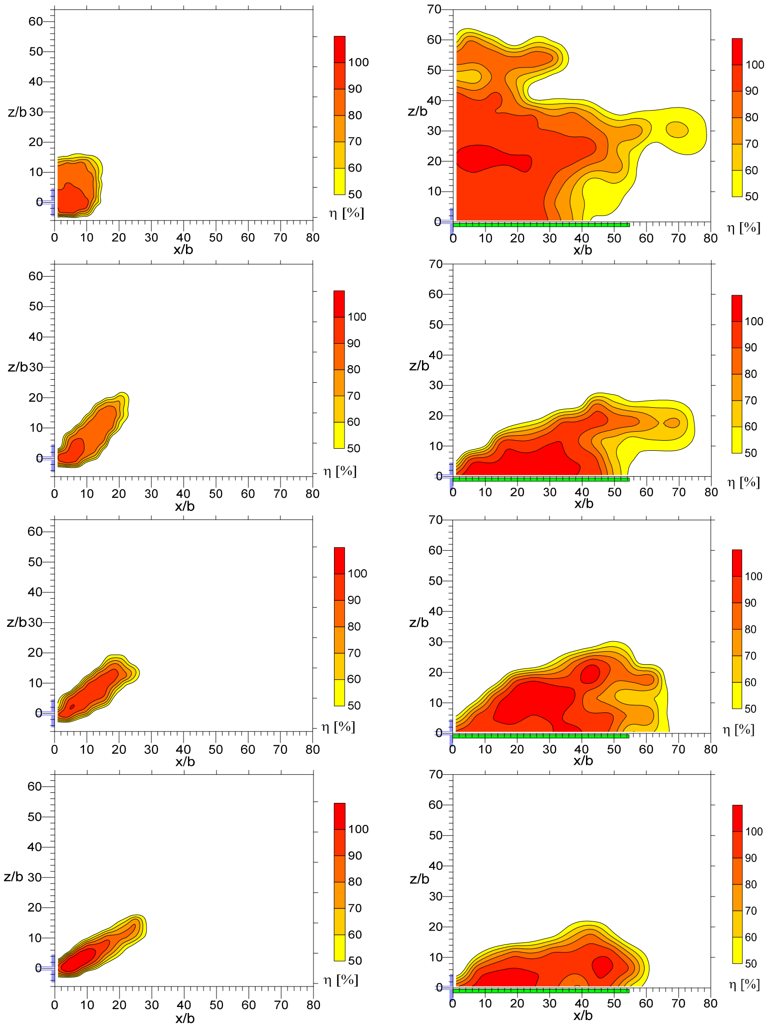

Figure 3. – Capture efficiency in the vertical plane x – z running through the axis of the exhaust hood. 1 – exhaust hood situated in free space with operating parameter A) I=0; B) I=0.3; C) I=0.6; D) I=0.9 2 – exhaust hood situated over the workbench with operating parameter A) I=0; B) I=0.3; C) I=0.6; D) I=0.9

When the results of both cases are compared the significant difference in dimensions of the capture effective areas is evident. This is mainly caused by a significant difference between the density of the used tracer gas (CO_2) and the density of air. In the second case the tracer gas falling down is partially stopped by the workbench and then exhausted by the exhaust hood. With the increasing distance of measuring points of grid from the exhaust hood (axis x) and from the workbench board (axis z), not all the falling tracer gas is stopped by the workbench and then partially exhausted by the exhaust hood because the tracer gas could be carried a side by the developed flow in the room.

5. CONCLUSION

A difference between the reinforced slot exhaust system working in the free space and the reinforced slot exhaust system working in a combination with the workbench was observed. During capture efficiency measurements on the horizontal reinforced slot exhaust hoods, the influence of the operating parameter I (the ratio between the momentum flux of supplied and the exhausted air flows) on the design of capture effective areas was evaluated. Results of the measurement show that when the workbench is used, significantly larger capture effective areas are achieved when pollutions with a higher density are exhausted. Increasing the value of operating parameter I, the area of a high capture efficiency (greater than 80 %) becomes longer but its height becomes smaller.

Acknowledgements

The research leading to the presented results was supported by the Brno University of Technology project FSI-J-13-2042 for young researchers.

References

[1] AABERG C.P.: Plant for Ventilation of Rooms, More Particularly in Stables, United States Patent & Trademark Office, US patent 3401621, 1968.
[2] BOUZEK V: Capture efficiency of reinforced slot exhaust hood, Master's thesis, Brno University of Technology, p.50, Brno (in Czech), 2004.
[3] CHYSKY J., and HEMZAL K.: Ventilation and air conditioning – Design guidebook 31, Bolit, Brno (in Czech), 1993.
[4] GUBLER D.: REEXS Optimization of Operating and Design Parameters, PhD Thesis, Swiss Federal Institute of Technology, 2002.
[5] HYLGÅRD C. E., Aerodynamic control of exhaust, International Conference on Air Distribution in Ventilated Spaces ROOMVENT 1987, Stockholm, Sweden, 1987.