INVESTIGATION OF THE AIR FLOW FIELD IN FRONT OF THE REINFORCED SLOT EXHAUST HOOD

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ABSTRACT

The paper deals with the investigation of air flow field in front of the reinforced slot exhaust hood with the workbench at the level of the lower edge of the exhaust opening. The reinforced exhaust hood, which is also known as the Aaberg exhaust hood, is the traditional 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. The investigation was made for the fixed air velocity in the exhaust opening and with three different momentum flux ratios of supplied and exhausted air flows. The air flow field was measured by six hot bulb thermo-anemometric sensors with the diameter of 3 mm in the vertical plane running through the axis of the exhaust opening. An obvious extension of the velocity plane in the reinforced modes was observed from the results of air velocity measurements.

KEYWORDS

Industrial ventilation, REEXS, exhausting, slot exhaust hood, velocity measurement.

1 INTRODUCTION

In industrial production different pollutants are generated from technologies. These pollutants are mostly unhealthy, and therefore the ventilation is necessary. The ventilation systems can be divided into two groups according to the air exchange rate inside a ventilated space. The first group is called the global ventilation systems and these systems control the pollution level by supplying the fresh air into the whole ventilated space. The second group is called the local ventilation systems. These systems capture pollutants at their source and reduces the load of pollutions in the area and simultaneously decrease demands on the global ventilation because the concentration of contaminants in the local exhaust air is much higher than that in global ventilation. The main part of local exhaust systems is an exhaust hood which can be traditional and reinforced. In the case of the traditional exhaust hood the air flows evenly in the direction of the exhaust opening from all the sides but its capture efficiency of pollutants rapidly decreases with an increasing distance from the source of pollutants. The traditional exhaust hood has therefore to be located as close to the source of pollutants as possible which is not always technically or technologically practicable. It is also possible to use the **Re**inforced **E**xhaust **S**ystem – REEXS invited by (Aaberg, 1977) which uses the reinforced exhaust hood. It is a traditional exhaust hood equipped with an air supply inlet that intensifies exhausting along the axis of the exhaust hood, see Fig. 1. With the suitable momentum flux ratio between supplied and exhausted air flows, the shape and the range of the effective exhaust area are possible to be partially changed and better results of exhaustion can be reached as shown in (Pech & Pavelek, 2012) and (Pech & Pavelek, 2013).

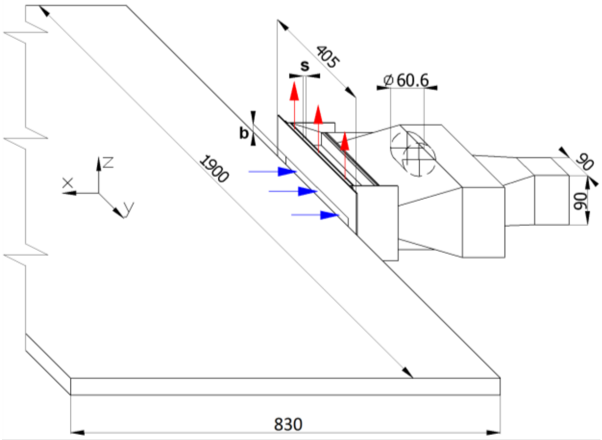

Figure 1: Reinforced slot exhaust hood with workbench

2 MEASUREMENT 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 the width was set to 4 mm and the lower supply slot was blocked.

This exhaust hood enables operating in different modes which depend on the operating parameter *I* established by Hylgård (Hyldgård, 1987). For the Aaberg exhaust hood, the operating parameter is defined as the ratio between the momentum flux of supplied and the exhausted air. This operating parameter can be determined as follows,

$$I = \frac{\dot{m}_s \cdot w_s}{\dot{m}_{ex} \cdot w_{ex}}, \quad (1)$$

where $\dot{m}_s$ and $\dot{m}_{ex}$ represent 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 $I = 0$, the exhaust hood works as the traditional exhaust hood. In the case of nonzero value of the operating parameter, the exhaust hood works as the reinforced exhaust hood. Gubler (Gubler, 2002) and others shown that the higher the momentum flux ratio the higher the suction effect of the hood.

For testing and research of exhaust hoods, the measurement setup (Figure 2) was designed and assembled at our department. For measuring it is possible to use the tracer gas method (to determine the exhaust efficiency), the method of velocity measurement in front of the exhaust hood or the flow visualization method with smoke or helium bubbles.

Figure 2: Measuring setup in variant with workbench

The scheme of measurement setup is illustrated in Figure 3. It consists of three main parts: exhausting (positions 2, 3, 4 in Figure 3) and air supply (positions 5, 6, 7), both connected to the exhaust hood (position 1), and the velocity measurement part (positions 8, 9).

The workbench (position 19) with the dimension in the *x* axis of 830 mm and in the *y* axis of 1,900 mm was used. The measurement setup includes measurements of pressures and temperatures in the duct in front of the flow meters. Also the barometric pressure, ambient temperature and the temperature in the air supply slot are measured. For the measurement of velocity magnitude the velocity data logger (position 6) with six hot bulb thermo-anemometric sensors (position 8) are used.

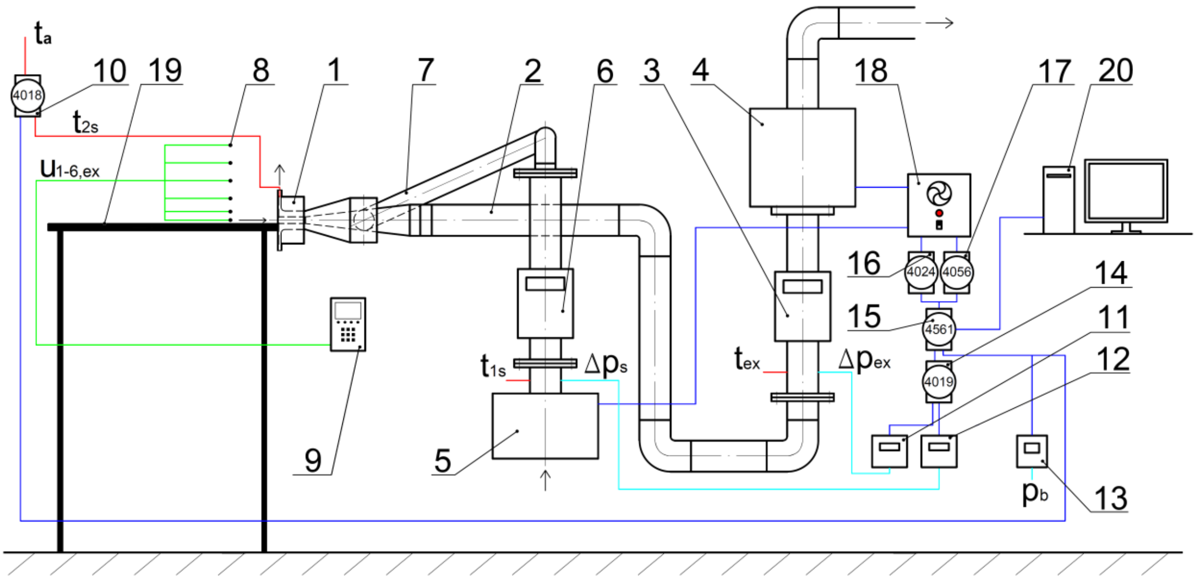

Figure 3: Scheme of the measurement setup

1 – reinforced exhaust hood, 2– exhaust air duct 3 – exhaust air flow meter, 4 – exhaust ventilators, 5 – supply air ventilator, 6 – supply air flow meter, 7 – supply air duct, 8 – thermo-anemometric sensors, 9 – velocity data logger, 10 – temperature measuring module, 11 – exhaust air pressure transmitter, 12 – supply air pressure transmitter, 13 – barometric pressure transmitter, 14 – converting module, 15 – communication module, 16 – relay output module, 17 – analogue output module, 18 – triac regulators, 19 – workbench, 20 – PC

3 VELOCITY MEASUREMENTS

The velocity field of the exhaust hood with the workbench situated at the bottom edge of the exhaust slot opening was investigated for the traditional exhaust mode ($I = 0$), and for the reinforced exhaust modes ($I = 0.3$, 0.6, and 0.9). The air was supplied only through the upper

slot opening as shown in Figure 1 and its velocity magnitude was set according to the operating parameter. The velocity magnitude in the exhaust slot opening was chosen to w_{ex} = 8.0 m/s according to the literature (Chysky & Hemzal, 1993).
For the velocity measurement of the reinforced exhaust system the constant temperature anemometry with six hot bulb sensors with the diameter of 3 mm was used. The hot bulb sensors move 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 measured points of the grid in the x axis was between 15 mm and 30 mm, and in z axis between 15 mm and 45 mm.

4 RESULTS AND DISCUSSION

The velocity fields from the velocity measurement by the reinforced slot exhaust hood situated over the workbench with different exhaust modes (I = 0, 0.3, 0.6 and 0.9) are shown in Figure 4. The graphs are made in dimensionless coordinates related to the width of exhaust slot opening b = 15 mm.

Owing to the nature of contaminants and to background air movements, the velocity in front of the hood must exceed a minimum velocity, known as the capture velocity, in order to draw the contaminated air into the exhaust inlet. Under normal practical conditions the capture velocity is typically of the order of 0.25 m/s, see Høgsted (Høgsted, 1987), (Saunders & Fletcher, 1993), or (Gubler, 2002). Hunt (Hunt & Ingram, 1992) defines the effective suction area, from which the air is drawn into the exhaust inlet and successfully removed from the workplace, as the area bounded by the line of constant velocity.

In the case of exhausting with the operating parameter I = 0 (position A in Figure 4), the capture velocity field is shorter in a comparison to other settings of the operating parameter I (cases of positions B, C, D). With the increasing value of operating parameter I, the capture velocity field becomes longer. In reinforced modes (cases of positions B, C, D) can be also seen the supplying air flow.

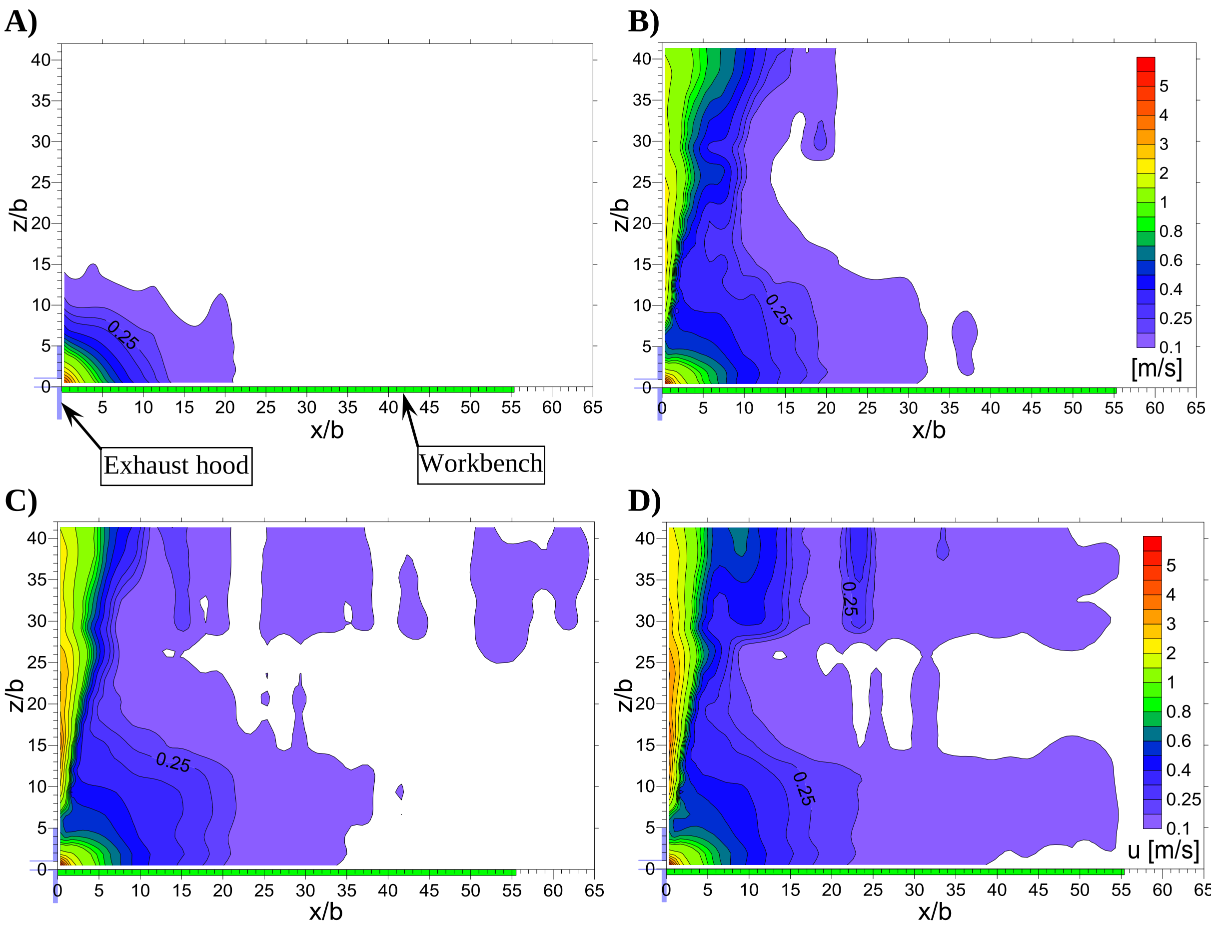

Figure 4: Velocity field in the vertical plane x – z running through the axis of the reinforced slot exhaust hood situated over the workbench with operating parameter A) I = 0; B) I = 0.3; C) I = 0.6; D) I = 0.9

In the Figure 5 there are pictured the velocity magnitudes in the axis of the reinforced slot exhaust hood with different operating parameters I. In this figure the capture velocity

$u = 0.25$ m/s is also drawn. As can be seen from the figure the effective suction area is shortest ($x/b = 12.0$) in traditional mode ($I = 0$). In reinforced exhaust modes the effective suction area in the axis of the reinforced slot exhaust hood is longer: in case with $I = 0.3$ its length equals to $x/b = 16.8$, with $I = 0.6$ to $x/b = 17.6$ and with $I = 0.9$ is its effective suction area is extended to $x/b = 17.7$. However, the experimentally obtained differences in the length of the effective suction area between variants with operating parameter $I = 0.6$ and $I = 0.9$ were so small that they fell into the uncertainty range of the measurements.

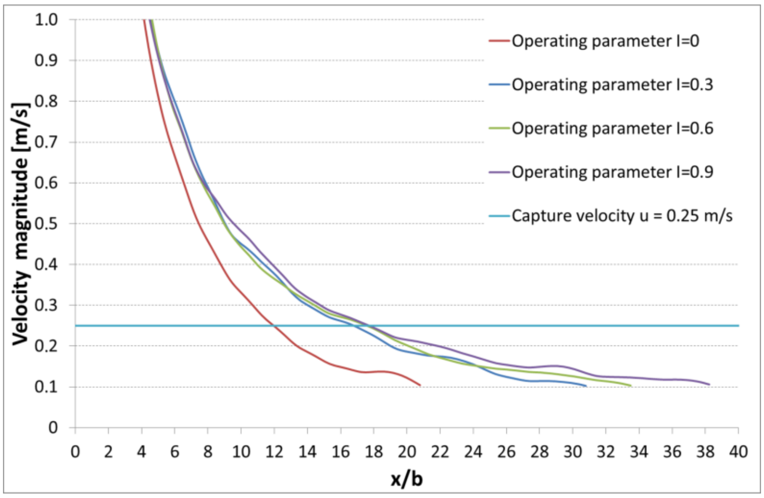

Figure 5: Velocity magnitude in the axis of the reinforced slot exhaust hood with different operating parameter *I*

5 CONCLUSIONS

The difference between velocity fields in front of the traditional slot exhaust hood and the reinforced slot exhaust hood situated over the workbench was observed. The velocity magnitude in the axis of the reinforced slot exhaust hood with different operating parameters *I* (the ratio between the momentum flux supplied and the exhausted air flow) was compared with the capture velocity in order to determine the length of the effective suction area. The results of the measurement show that in reinforced mode the effective suction area becomes longer in comparison to the traditional mode. With the increasing value of operating parameter *I* from 0.3 to 0.9, the effective suction area becomes longer but the difference is not as significant as in the case of comparison between traditional and reinforced modes.

6 ACKNOWLEDGEMENTS

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