

COMPARISON OF LOCAL EXHAUST SYSTEMS CAPTURE EFFICIENCY

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ABSTRACT

The contribution deals with research on capture efficiency of a slot reinforced exhaust system. Designed exhaust hood can work as traditional exhaust system or as reinforced exhaust system (well known as REEXS). Reinforced exhaust system is based on combination of exhaust air and radial supply air, which increases a size of exhaust area. The slot exhaust hood was built into measuring set-up which includes computer measurements of pressures, temperatures and concentrations. A tracer gas method was used for capture efficiency measurements of this system. This method is based on supplying of tracer gas to the space in front of the exhaust hood, which is captured by exhaust hood. We can measure concentrations of captured tracer gas in the exhaust air by multi gas monitor, which is connected to the exhaust part of the entire measuring set-up. We can calculate capture efficiency of the selected system (traditional or reinforced) from these concentrations. Informations about shape and range of efficiency areas are very important for setting up the exhaust hood against the pollution source if we know how pollution behave. This contribution also presents comparison of capture efficiencies measured with different working modes of slot exhaust hood with capture efficiencies of reinforced circle exhaust system at the same volume flow rates of exhaust air and the same values of the ratio of momentum flows of supply and exhaust air.

INDEX TERMS

Slot hood, circle hood, capture efficiency, tracer gas method

INTRODUCTION

Conditions in working place are common and very often mentioned problem all around the world. One of factors that influences conditions in working place is cleanliness of the indoor air. So, it is very important to have a good ventilation system.

Generally, we can divide ventilation into two main parts. Ventilation of civil buildings and industrial ventilation. We can also divide ventilation into another two parts – total ventilation and local exhaustion. General ventilation is often used in civil buildings while local exhaustion is more often used in industry with combination of total ventilation. In this contribution we focused on industrial exhaustion of pollution.

Industrial pollution sources are often very intensive, and despite using various provisions in production in order to reduce them, it is necessary to use also local exhaustion in order to capture leaking pollution directly at the source. Local exhaustion reduces pollution load in the given area, and at the same time decreases total ventilation demands because concentrations of contaminants in exhaust air are much higher than with total ventilation. In place of leakage, the contaminants are captured in the exhaust hoods. It is typical of traditional, commonly used

exhaust hoods, that the air flows in direction to the exhaust opening evenly from all sides. A traditional exhaust hood has to be therefore located as close to the pollution source as possible. Job performance in the place does not often allow locate the exhaust hood immediately next to the pollution source, which results in decrease of the capture efficiency. In such a case it is suitable to use the reinforced exhaust system (REEXS) that represents a combination of air exhaust and supply (Goodfellow and Tähti 2001). With the reinforced exhaust system an appropriate proportion of supply and exhaust air can change the flow pattern in front of the exhaust opening, and therefore help to reach better results of exhaustion.

This contribution compares results of slot reinforced exhaust hood research with results of circle reinforced exhaust hood research from (Patočka S. 2002).

SLOT REINFORCED EXHAUST HOOD

Slot reinforced exhaust hood was constructed and made to measure capture efficiency areas.

There is a design of this exhaust hood with main dimensions in the *Figure 1*. The hood has one slot exhaust opening and a special flange. There are two supply slots on the top of the flange. We can change a width b of these supply slots from $2 \cdot 10^{-3}$ m to 10^{-2} m. A design of the reinforced exhaust hood was constructed with regards to pressure loss and low noise level.

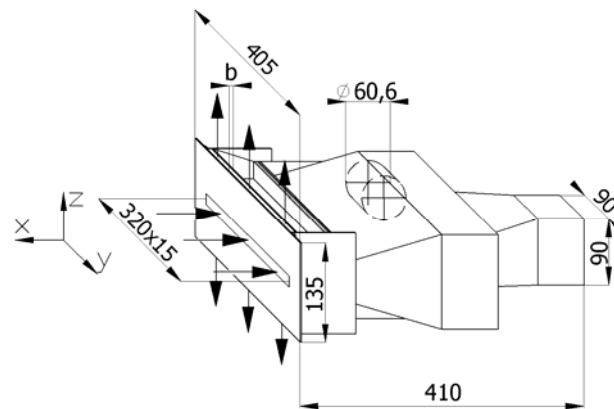


Figure 1. Slot reinforced exhaust hood

We installed the hood to measuring set-up, which allows research of traditional exhaust system and reinforced exhaust system, showed on *Figure 2*. There are three main parts on the measuring set-up. We can supply air by the first part of measuring equipment and exhaust air by the second part of measuring set-up. There are two flow meters, one in the supply air part (position 10) and second in the exhaust air part (position 12) and temperature and pressure sensors needed in this system. We use the pressure transmitters with different ranges (supply air transmitter $0 - 2.5 \cdot 10^3$ Pa and exhaust air transmitter $0 - 20 \cdot 10^3$ Pa) for measuring supply air pressure (position 8) and exhaust air pressure (position 9). The pressure transmitters are connected with measuring module (position 18) and then with communication module (position 17) which communicate with PC. Every temperature sensors are connected to the other measuring module (position 16) which is connected to communication module too. The third part of measuring equipment is for measurement by tracer gas method. There is a bottle with carbon dioxide (position 14), flow meter (position 11), temperature and pressure sensors, porous ball (which simulate pollution source, position 15) and a multi gas monitor (position 6) in this part. A pressure sensor is connected with the third pressure transmitter (position 7) with range $0 - 2.5 \cdot 10^3$ Pa which is connected to the second measuring module (position 16). This module communicates with PC through communication module (position 17).

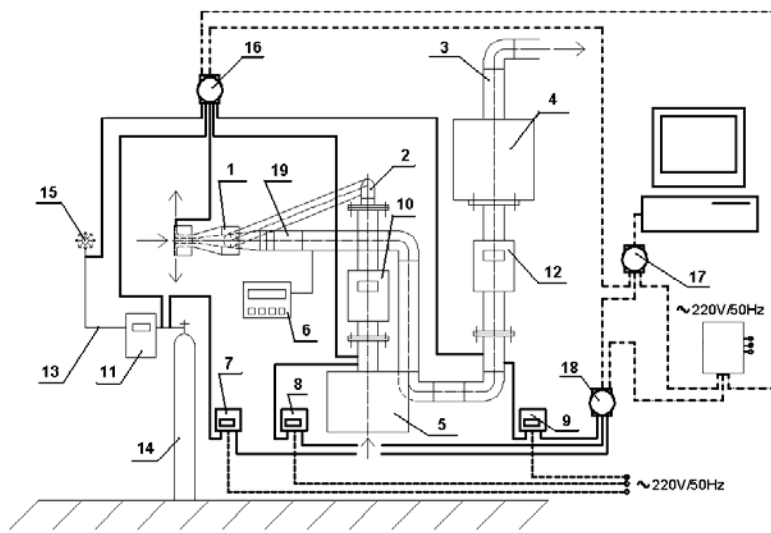


Figure 2. Design of measuring equipment

1-reinforced exhaust hood, 2-supply air ductwork, 3-ductwork for offtake exhaust air to outer area, 4-exhaust ventilator, 5-supply air ventilator, 6-multi gas monitor, 7-tracer gas pressure transmitter, 8-supply air pressure transmitter, 9-exhaust air pressure transmitter, 10-supply air flow meter, 11-tracer gas flow meter, 12-exhaust air flow meter, 13-tracer gas intake pipe, 14- bottle with tracer gas, 15-porous ball, 16- measuring module, 17- communication module, 18- measuring module, 19- whirler



Figure 3. Photo of measuring equipment

Like it was mentioned before, to measure pressure and temperatures we use computer measuring using measuring modules and communication module. The computer communicates with the modules through program which was developed at our University of Technology in Brno at Department of Thermodynamics and Environmental Engineering. This program allows to change the time of measuring period from 0.1 s. For our measurements it is sufficient to use the time period 300 s for temperatures and 5 s for pressures. There is a general view of our laboratory in *Figure 3*.

Basic working parameter, which influences function of the reinforced exhaust hood, is momentum ratio.

We can calculate momentum ratio from this equation:

$$I = \frac{m_s \cdot u_s}{m_{ex} \cdot w_{ex}} \quad (1)$$

where m_s - mass flow rate of the supply air, m_{ex} - mass flow rate of the exhaust air, u_s - velocity of the supply air in supply slot, w_{ex} - velocity of the exhaust air in exhaust opening.

TRACER GAS METHOD

Tracer gas method was used to measure capture efficiency. Tracer gas is supplied by the porous ball, which simulates a pollution source, in front of the hood in this method. Different kinds of gases can be used as the tracer gas like CO_2 , SF_6 , N_2O etc. The main criterion for choosing tracer gas is to have a gas which will not react with surrounding things like the air, parts of measuring set-up etc. Tracer gas also cannot be dangerous for people working in the laboratory with it. Regarding all of these conditions carbon dioxide (CO_2) was chosen as the tracer gas. Another very important thing is the shape of equipment which will supply the tracer gas. On the base of experience from previous experiments porous ball was chosen as a supply gas device. We move porous ball on the selected grid. Another very important device placed in our measuring set-up is whirler. The function of whirler is to mix exhausted air with captured tracer gas by the hood. This allows to measure concentration of tracer gas in exhaust air in one place of exhaust ductwork. On multi gas monitor we can read values of tracer gas concentrations. We measure tracer gas concentration in the exhaust air and tracer gas concentration in the background. We don't have to measure reference concentration because we can control the volume flow of supplied tracer gas. One measurement of concentration take from 20 s to 35 s depending on accuracy. In our case we use 30 s. But there is still one big disadvantage, using tracer gas method we will not receive informations about velocity field in front of the exhaust hood so to get velocities we need to use different method.

We can calculate capture efficiency from the following equation:

$$\eta = \frac{C_{ex} - C_{back}}{C_{ref} - C_{back}} \quad (2)$$

where C_{ex} - tracer gas concentration in the exhaust air, C_{back} - tracer gas concentration in the background, C_{ref} - reference concentration (corresponds with exhausting 100% of supplied gas).

CAPTURE EFFICIENCY MEASUREMENTS

Selected grid of measured points in Cartesian system of coordinates was used to measure capture efficiency. We placed zero of Cartesian coordinates system to the mid point of reinforced exhaust hoods. Width of supply air slots b was $4 \cdot 10^{-3}$ m during measuring capture efficiency. Volume flow rate was chosen with regard to optimal velocity value in the exhaust slot $w_{ex} = 8.0 \text{ m}\cdot\text{s}^{-1}$. Volume flow rate of the exhaust air is $V_{ex} = 0.0417 \text{ m}^3\cdot\text{s}^{-1}$. Capture efficiency areas were measured in vertical plane running through the axis of the exhaust hood for the traditional exhaust mode ($I = 0$) and reinforced exhaust modes ($I = 0.3, 0.6$ and 0.9). There are values of volume flow rate and velocities of supplied air for the slot exhaust hood regarding momentum ratio in *Tab. 1*. We supplied $2 \cdot 10^{-3} \text{ m}^3\cdot\text{s}^{-1}$ of tracer gas which means 650 ppm regarding exhaust volume flow.

Table 1. Values of volume flow rate V_s and velocity u_s of the supplied air regarding momentum ratio I for $V_{ex} = 0.0417 \text{ m}^3 \cdot \text{s}^{-1}$

I	[-]	0	0.3	0.6	0.9
V_s	$[\text{m}^3 \cdot \text{s}^{-1}]$	0	0.015	0.021	0.026
u_s slot	$[\text{m} \cdot \text{s}^{-1}]$	0	5.97	8.36	10.35

RESULTS AND THEIR DISCUSSION

There are capture efficiency areas in the vertical planes running through the axis x in the course of different exhaust modes (see *Table 1*) in the following graphs (*Figure 4*). All capture efficiency areas were measured in the course of $V_{ex} = 0.0417 \text{ m}^3 \cdot \text{s}^{-1}$.

The results were executed by SURFER 7 program which is topographic software for creating maps etc. There were made isolines going through the average of measured points in interval from 50 % to 100 % with the step 5 % by this software. The x is distance from flange of the hood axis wise and y is distance from the vertical plane running through the axis of the set exhaust hood.

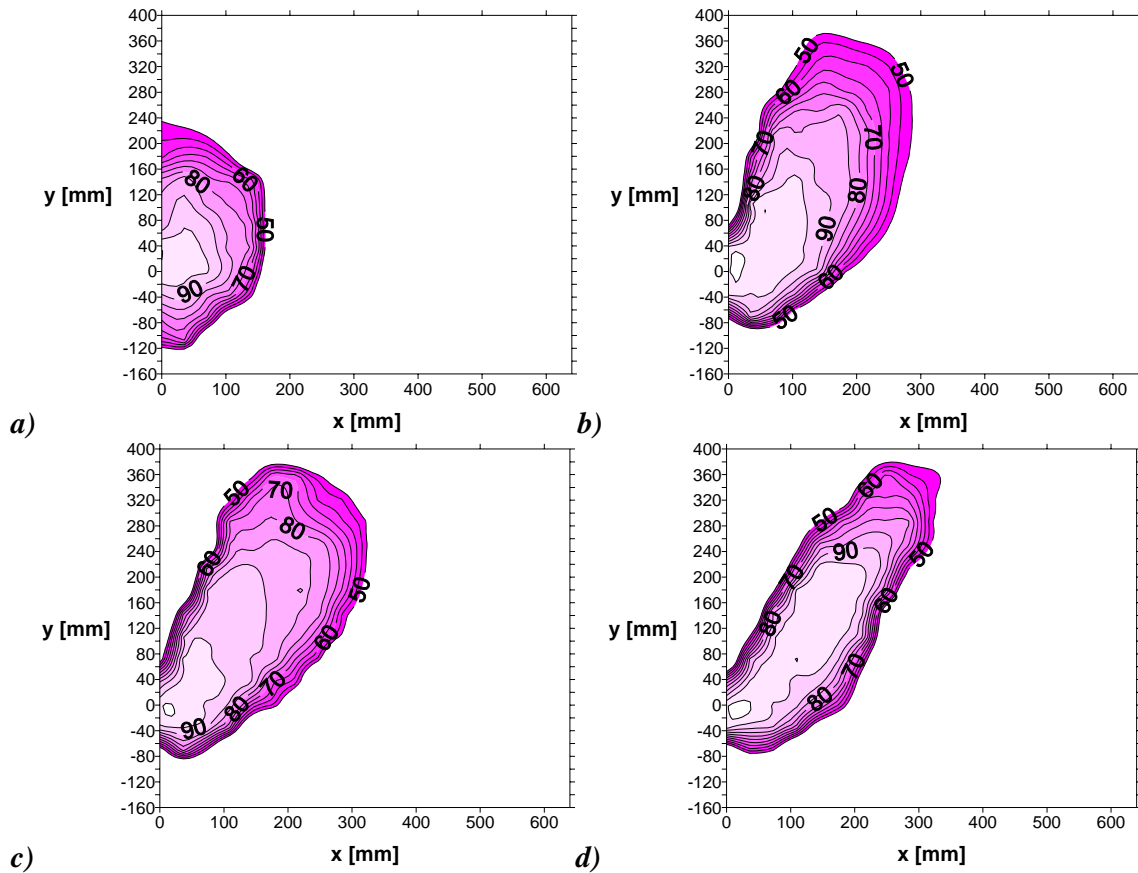


Figure 4. Capture effective areas for the slot reinforced exhaust hood in [%] for $V_{ex} = 0.0417 \text{ m}^3 \cdot \text{s}^{-1}$

a) $I = 0$, b) $I = 0.3$, c) $I = 0.6$, d) $I = 0.9$

From these figures we can see, how design of capture effective areas changes depending on momentum ratio. If momentum ratio $I = 0$, capture effective area is widest but shortest. Areas with higher values of capture efficiency become longer by growing momentum ratio effect. There we can see asymmetries considering to horizontal plane in these graphs. The asymmetric is incurred by density difference effect of the tracer gas and surrounding air. The density of carbon dioxide is $1.88 \text{ kg} \cdot \text{m}^{-3}$ while pressure is $1013 \cdot 10^4 \text{ Pa}$ and temperature 20°C , which means 1.56 times higher than the air when conditions are the same.

From these figures you can clearly see that the range of 90 % isoline, in case of traditional exhausting ($I = 0$), is much shorter than in cases of reinforced exhaust modes of slot exhaust hood.

Results of slot hood capture efficiency research are compared with results of research made previously on the same experimental equipment with circle reinforced exhaust hood (Patočka S. 2002). There is a design of this exhaust hood with main dimensions in the *Figure 5*. The hood has the circle exhaust opening and a special flange. There is a supply slot on the top of the circle flange. A width b of this supply slot can be changed from $4 \cdot 10^{-3} \text{ m}$ to $8 \cdot 10^{-3} \text{ m}$. The exhaust hood has also another two parts – inlet with diameter $63 \cdot 10^{-3} \text{ m}$, placed on the top of the hood and outlet with diameter $80 \cdot 10^{-3} \text{ m}$, placed in the rear of the hood.

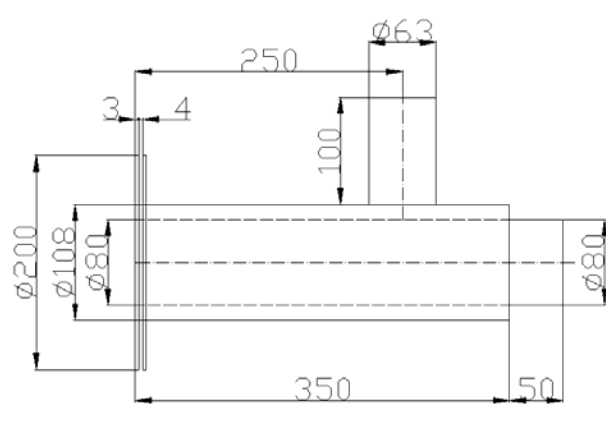


Figure 5. Circle reinforced exhaust hood

We can see from *Figure 6a)* that the range of 90 % capture efficiency isoline for circle traditional exhaust system is $256 \cdot 10^{-3} \text{ m}$ and for 50 % isoline is $424 \cdot 10^{-3} \text{ m}$ while from *Figure 4a)* it is obvious that the range of 90 % capture efficiency isoline for slot traditional exhaust system is $104 \cdot 10^{-3} \text{ m}$ and for 50 % isoline is $184 \cdot 10^{-3} \text{ m}$ which is 2.46 times shorter for 90 % isoline and at the same time 2.3 times shorter for 50 % isoline.

We also can see from *Figure 6c)* that the range of 90 % capture efficiency isoline for circle traditional exhaust system is $405 \cdot 10^{-3} \text{ m}$ and for 50 % isoline is $590 \cdot 10^{-3} \text{ m}$ while from *Figure 4c)* it is obvious that the range of 90 % capture efficiency isoline for slot traditional exhaust system is $162 \cdot 10^{-3} \text{ m}$ and for 50 % isoline is $328 \cdot 10^{-3} \text{ m}$.

The ratio between the circle and slot exhaust hood when $I = 0$ for 90 % isoline is 2.46 and the same ratio for 50 % isoline is 2.3.

The ratio between the circle and slot exhaust hood when $I = 0.6$ for 90 % isoline is 2.5 and the same ratio for 50 % isoline is 1.8.

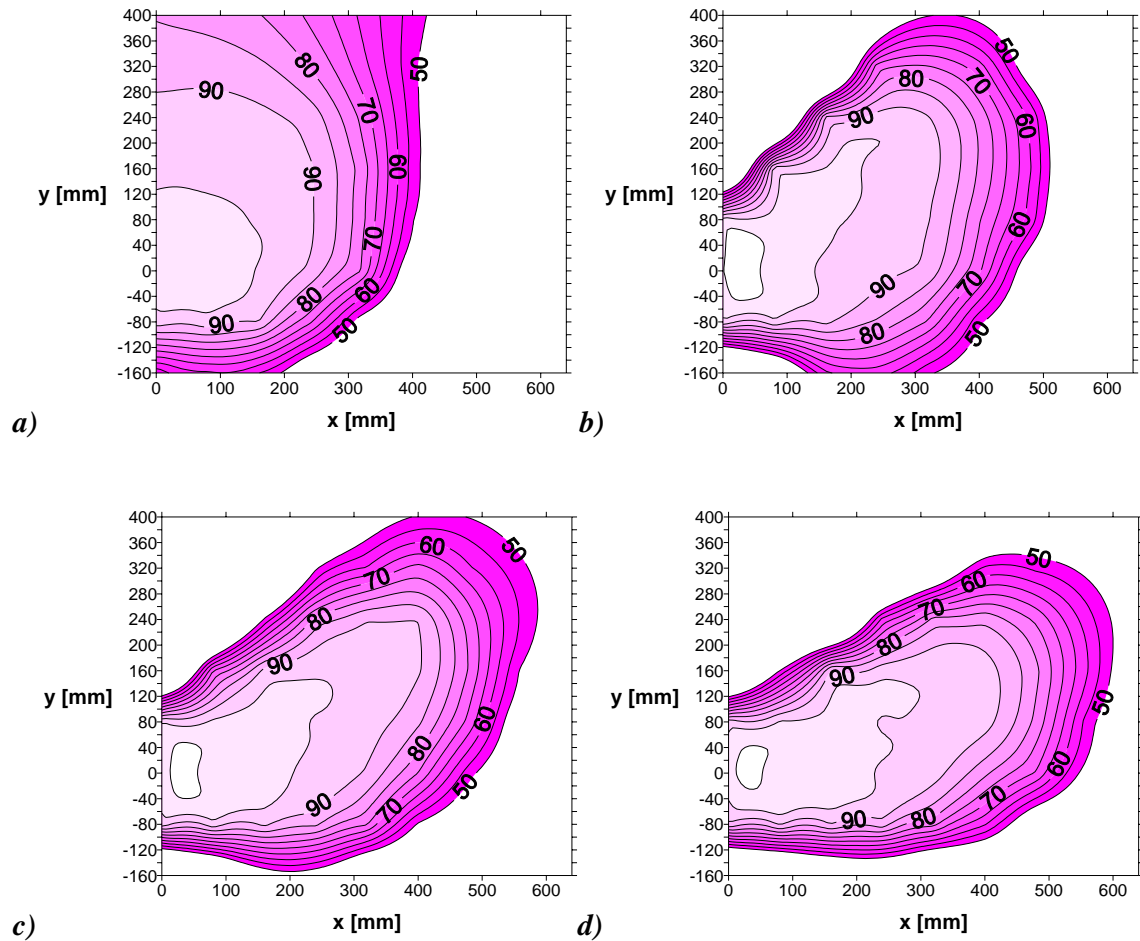


Figure 6. Capture effective areas for the circle reinforced exhaust hood in [%] for $V_{ex} = 0.0417 \text{ m}^3 \cdot \text{s}^{-1}$
 a) $I = 0$, b) $I = 0.3$, c) $I = 0.6$, d) $I = 0.9$

CONCLUSION

There is shown a difference between reinforced exhaust system working with slot exhaust hood and reinforced exhaust system working with circle exhaust hood in this contribution. The slot exhaust hood was constructed and made with regards to pressure loss and low noise level. Results of capture efficiency measurements on horizontal slot exhaust hood were made while different momentum ratios of supply and exhaust air were set. Results showed that the capture effective areas in course of momentum ratio is 0.6 are bigger than in course of momentum ratio is 0.3 and at the same time are the effective areas wider than in course of momentum ratio is 0.9. Results comparison of our measurements with slot reinforced exhaust hood and in literature mentioned measurement results of circle reinforced exhaust hood showed in both cases the same influence of momentum ratios tendency on the capture effective exhaust area. Areas obtained using circle hood are generally bigger than areas obtained using slot hood.

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