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Experimental study of the swirling flow effect on the efficiency of the local ventilation system

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Abstract. The paper presents the results of an experimental study of the local ventilation system. It is shown that the use of radially swirled counter-flow jet leads to significant increase in the efficiency of gas removing. This fact is confirmed by the flow visualization for different operating regimes of the device (with and without swirling). The velocity distribution along the central axis of the device was also measured. It is also shown that the use of swirling flow leads to significant increase in the velocity of removal flow. Study of the system operating parameters for different direct and counter flow ratio was carried out.

1. Introduction

Presently one of the topical problems in industrial enterprises is cleaning the air against gases, smoke, or dust pollutions. The most effective way is to remove environmentally harmful substances in the immediate area of the source of the emission in order to prevent the distribution of the pollution throughout the buildings. One of the disadvantages of using local ventilation systems is their high energy consumption. The main costs in this case are associated with the pumping of large volumes of exhaust air, which should provide the necessary velocity for capturing harmful emissions.

The existing methods for increasing the efficiency and cleaning area of the ventilation hood are distinguished by two main operation principles: mechanical and air-jet [1] shielding. The most promising way is using shielding by swirling ring jets [2-4]. Their advantages include small dimensions, low energy consumption and efficient removal of environmentally harmful gaseous or aerosol products from the operator's breathing zone without interfering with the process. Increasing the ventilation efficiency is achieved by creating a radial open counter-flow vortex jet. As a result of the flow swirling, an area of reduced pressure (vacuum), into which harmful emissions are sucked from a larger volume and then removed to ventilation system, is formed on the axis of the exhaust hood. In paper [5], the swirling flow is created by a rotating swirler, it leads to a significant complication of the device operation, which requires engine installation. In works [6], a solution to the problem of the vortex suction of air was proposed on the basis of a stationary blade swirler installed in an annular channel parallel to the main exhaust duct. On the basis of these principles, an experimental setup was designed and an experimental study of its efficiency was carried out.

2. Experimental methods

The experiment was conducted on an open aerodynamic setup. The model presented in Fig. 1 was proposed as the test sample. This model was based on the device described in [6]. The parts of the aerodynamic model were manufactured using a 3D printer (Fig. 1a). To create a counter-flow vortex jet, the air with velocity U_s is injected through the inlet 1 into the annular channel 2, then after passing the swirler 3 it becomes swirled and enters the room (Fig. 1b). A stationary 12 blades swirler was used to create the swirling flow. Simultaneously, the air is removing from the room through pipe 4 with velocity U_v.

Figure 1. The photo of the experimental setup.

The air flow in the experiment was created using a blower MT 04-T2S-2.2, the flow rate was regulated by a frequency converter VESPER E2-8300-002H. Air flow control was performed by the ultrasonic flowmeter IRVIS-PC4M, whose error is not exceeded one percent of the measured volume. Visualization of the flow patterns were carried out using a smoke generator, the recording was conducted by a high-speed video camera with a frequency of 1000 frames per second. The velocity distribution along the axis of the hood channel was measured using a one-component thermo-anemometer.

3. Results

In the course of the work, an experimental study of the swirling flow effect on the efficiency of local gas removal was carried out. Figure 2 represents the flow pattern for two different cases: without creating a swirling flow (Fig. 2a) and with creating a radially swirled counter-flow (Fig. 2b). In both cases, air is removed from the pollution zone at a flow rate Q_v = 124 m^3/h through the central channel. In the second case (Fig. 2b) air is injected through the annular channel at a same flow rate Q_s = 124 m^3/h.

Creating a radial-swirled flow significantly increases the flow suction intensity. It is evident from the analysis of the flow patterns. This fact is confirmed by the results of measurements, which are presented in Fig. 3. The plots show the velocity distribution along the central axis of the hood channel at different distances. It can be seen that the use of the swirling flow leads to a significant increase in the velocity along the central axis of the device, which, in turn, leads to more effective gas removal.

a

b

Figure 2. Visualization of the flow structure (Q_s/Q_v= 1)

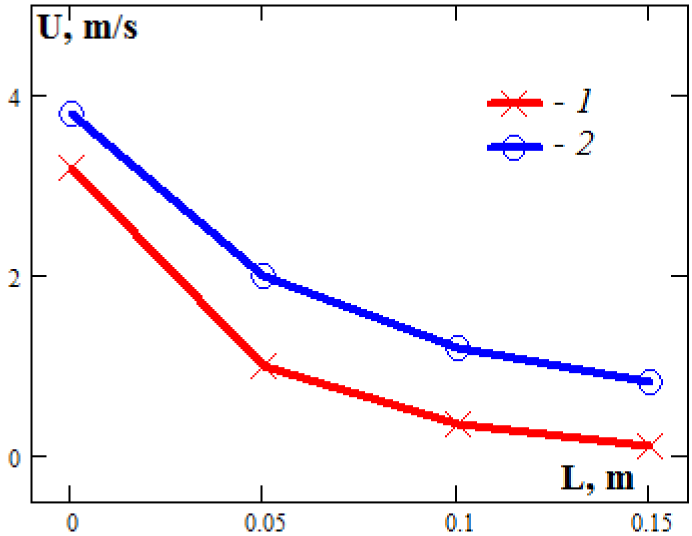

Figure 3. Velocity distribution along the central axis at the different distance from the ventilation channel *(1- with swirled flow, 2- without swirled flow)*

Also the effect of different air flow rate fed through the swirler was investigated. Figure 4 represents the experimentally obtained velocity distribution along the central axis of the hood channel with different air flow ratios. The flow through the extract duct, in turn, remains constant. It can be seen from the plots that an increase in the air flow through the swirler leads to an increase in velocity along the axis of the hood channel. Due to that fact, we can regulate the operating modes of the ventilation device by changing the flow ratio.

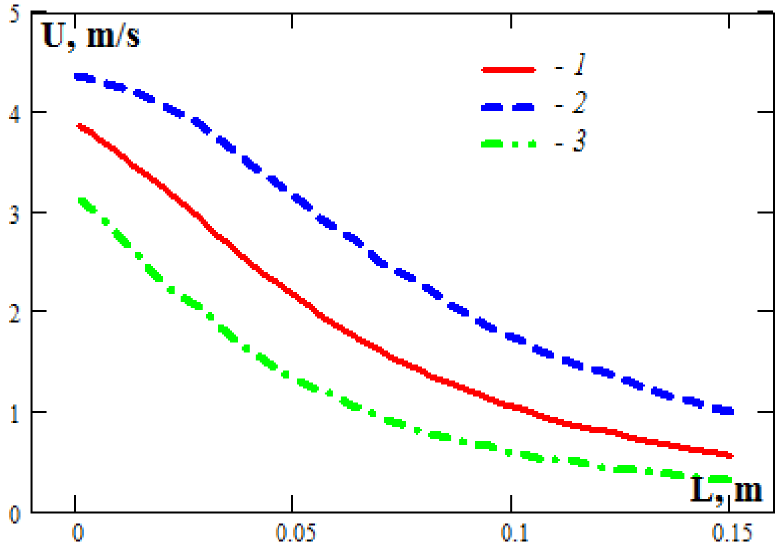

Figure 4. Velocity distribution along the central axis at the different distance from the ventilation channel *(1 – Q_s/Q_v= 0.5; 2 – Q_s/Q_v= 1; 3 – Q_s/Q_v= 2)*

4. Conclusions

In the work, an experimental study of the local gas removal system based on the shielding of the flow by radially-swirling annular jets was carried out. An open aerodynamic facility was constructed and assembled. A series of experiments were conducted to investigate the effect of swirling flow on the operation of the device. By means of flow visualization it is shown that increasing the velocity along the axis of the hood channel by swirling increases the device efficiency. This fact is confirmed by experimental velocity measurements.

The study of the effect of the amount of air supplied through the annular channel on the operating modes of the device was also carried out. It is shown that the efficiency of the local ventilation system can be regulated by changing the flow rate. In future, the vortex suction will be optimized using PIV-technique, in order to improve further the efficiency of the device.

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