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CASE STUDY OF A MULTIPLE CONFLUENTS JETS SYSTEM IN A VIRTUAL CHAMBER

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Abstract. This article presents a case study of a multiple confluents jets system in a virtual chamber. In this study, it is obtained the behavior of the airflow in an office, simulated by a virtual camera, whose ventilation system is of the horizontal confluent jets type. The ventilation system has an inlet system consisting of four vertical ducts mounted in the corners of the compartment. Each duct has four groups of 32 nozzles, aligned and equally spaced, positioned from the base of the duct close to the floor. Each two groups of nozzles are directed towards each of the walls adjacent to the duct The exhaust system consists of a quadrangular vertical duct mounted close to the ceiling and positioned in the center of the compartment. The study uses a numerical differential model in order to simulate the Computational Fluids Dynamics. Ventilation by horizontal confluent jets creates a horizontal air velocity close to the wall surface as well as the floor surface. With the increase in the exit velocity of the jets, the interactive effect of the confluence of the jets, coming from opposite ducts, in the central area of the wall becomes more evident. The airflow resulting from the interactions of the jets has an upward characteristic towards the exhaust system.

1 Introduction

In this work, a horizontal confluent jet type ventilation process is applied as a Heating Ventilating Air Conditioned system. Some examples of this type of ventilation system were applied in the works of Arghand et al. [1], where the characteristics of the airflow and the levels of comfort obtained were analysed, Karimipanah et al. [2], in which different air distribution systems were studied, and Cho et al. [3], in which confluent jets ventilation and displacement ventilation were comparatively analysed.

The airflow, inside a virtual compartment, is an important parameter to evaluate comfort, due to thermal and air quality conditions, and discomfort conditions such as Draught Risk for the occupants. In this sense, some examples of the use of airflow topologies in real vehicles and virtual buildings were presented in previous works by Conceição et al. [4, 5].

The air velocity is also an important parameter in the comfort evaluation. This variable, when obtained around the occupant, influences the heat exchange by convection between the body and the environment, namely the natural and forced convection [6-8].

Indoor air quality is another condition that is influenced by the air velocity. Air velocity is important because of how it affects the transport of carbon dioxide, whose concentration level gives an indication of indoor air quality [9], and determines the air change rate [10].

The air velocity is a parameter that is used to evaluate the Draught Risk. This index was proposed by Fanger et al. [11], and later adopted by ISO 7730 [7]. An application of this index can be seen in the work by Conceição et al. [12], where the performance of a personalized ventilation system was studied in a virtual classroom.

The numerical study, applied in this work, considers a numerical software that simulate the Building Thermal Modelling [13], and the coupling of the Human Thermal Modelling and the Computational Fluids Dynamics [14].

The purpose of this work is to assess the airflow field within a virtual chamber, whose ventilation system is of the horizontal confluent jet type. The ventilation system used consists of a double inlet system, installed in vertical ducts located in the corners of the room, and an outlet system installed in a duct located near the central area of the ceiling. It is intended to obtain the airflow profile in the region influenced by the confluent jets for four values of the inlet air velocity.

2 Numerical Model

The numerical model is founded on a coupling between Computer Fluid Dynamics and the Human Thermal Modelling. Using Cartesian coordinates, CFD software uses partial differential equations of mass continuity, energy, Navier–Stokes, turbulence kinetic energy and turbulence energy dissipation.

The CFD used is defined by the following:

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- Hybrid scheme in the convective/diffusive fluxes;
- Grid refinement near the surfaces, inlets and outlet, done with 537680 cells;
- Impulsion term in the vertical air velocity equation;
- Wall boundary in the surface proximity;
- Finite volume method in the equation discretization;
- The resolution of equations system done by iterative TDMA (Tri-Diagonal Matrix Algorithm) method.

3 Numerical Methodology

The virtual compartment (Fig. 1) simulated in this work has the following dimensions: 2.7×2.45×2.4 m^3. It has a horizontal confluent jets ventilation system consisting of an inlet system and an exhaust system with the following characteristics:

- The inlet system consists of four vertical ducts of 125 mm in diameter mounted in the corners of the compartment. Each duct has two sets of 32 nozzles aligned on each of its sides facing the adjacent walls and positioned close to the floor (Fig. 2). Each row of nozzles has a length of 200 mm, with a distance between nozzles of 6 mm. Each nozzle has a diameter of 6 mm.
- The exhaust system consists of a quadrangular duct mounted 1.8 m high in the central area of the compartment and connected to the ceiling (Fig. 3).

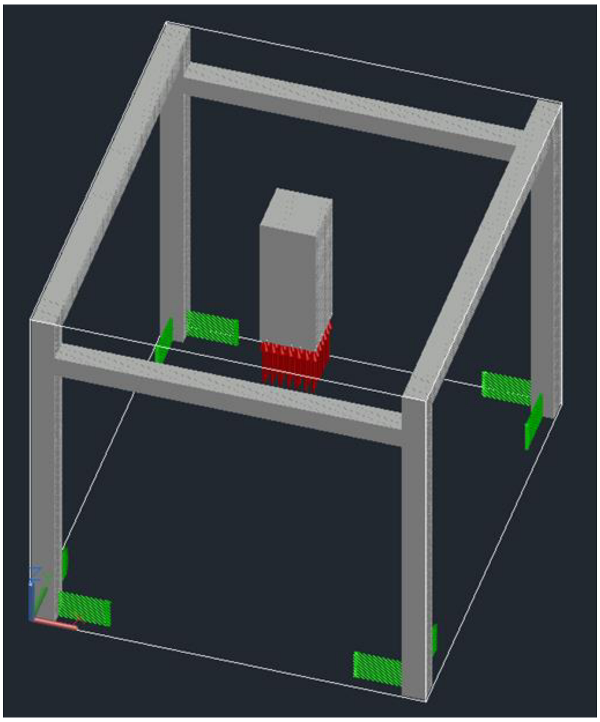

Fig. 1. Design of virtual room provided by a horizontal confluent jets ventilation system: green arrows represent confluent jets in the inlet system and red arrows represent jets in the exhaust system.

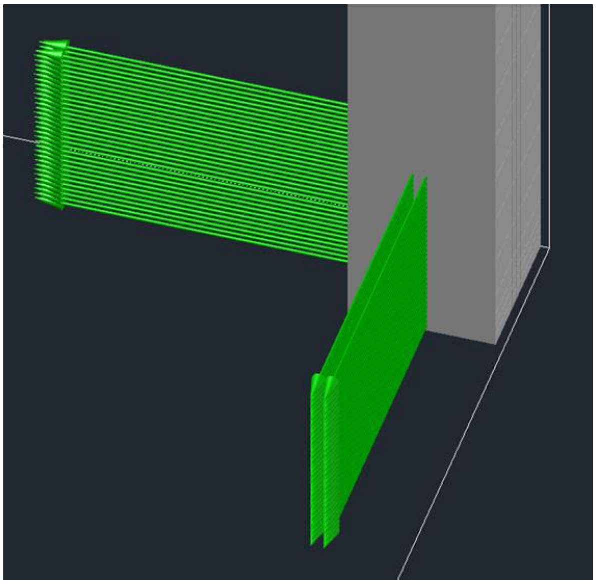

Fig. 2. Detail of the horizontal confluent jets (green arrows) in the inlet of the ventilation system.

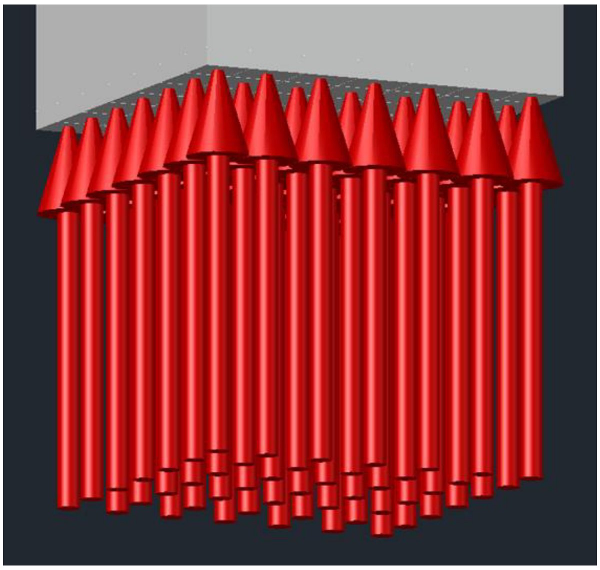

Fig. 3. Detail of the horizontal confluent jets (red arrows) in the exhaust of the ventilation system.

The air velocity is obtained in seven vertical planes, for the distances shown in Table 1, positioned at 0.075 m (in the middle of the two lines of the jets coming from the inlet) in the X direction, and for four inlet air velocities: 2, 3, 4 and 5 m/s.

Table 1. Distances (D) along the Y axis of vertical planes.

Y	D (m)
y1	0.204
y2	0.389
y3	0.597
y4	0.804
y5	1.012
y6	1.219
y7	1.375

4 Results

Fig. 4 to Fig. 7 show the results obtained on the vertical planes defined for the Y distances presented in Table 1 located at 0.075 m in the X direction. Fig. 4 is associated with an inlet air velocity of 2 m/s, Fig. 5 is associated with an inlet air velocity of 3 m/s, Fig. 6 is associated with an inlet air velocity of 4 m/s and Fig. 7 is associated with an inlet air velocity of 5 m/s. Fig. 8 shows on the vertical plane that cuts the exhaust zone at 0.440 m in the X direction. The results were obtained for the Y distances presented in Table 1, and for an air inlet air velocity of 6 m/s.

The results show that the maximum values of air velocity, in general, are higher near the ground. However, in the middle of the wall, in the y direction, the effect of the interaction of the jets coming from opposite directions is noticed because the maximum value of the air velocity occurs at about 0.4 m height of the wall. In general, it can be seen that the air velocity tends rapidly to values between about 0.1 m/s, for an inlet velocity of 2 m/s, and about 0.35 m/s, for an inlet velocity of 5 m/s, from 1.1 m in height. However, in the middle of the wall, it is noticed that the air velocity manages to maintain higher values up to a greater height. Once again the interaction between jets coming from opposite directions is evident.

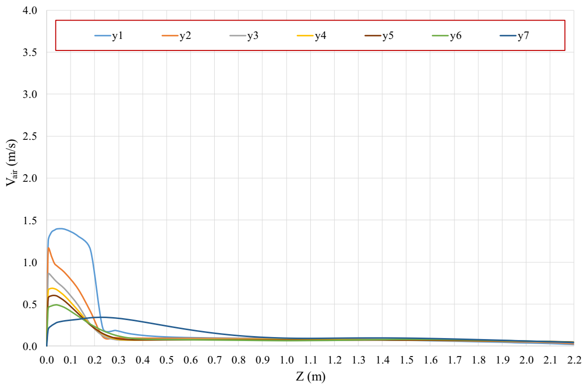

Fig. 4. Air velocity (V_{air}) in vertical plans located at 0.075 m in the X direction, for an inlet air velocity of 2 m/s.

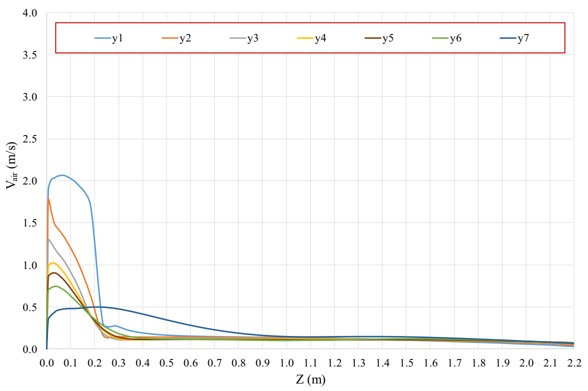

Fig. 5. Air velocity (V_{air}) in vertical plans located at 0.075 m in the X direction, for an inlet air velocity of 3 m/s.

It is also noted that air velocities increase as the outlet air velocity increases and that this effect increasingly occurs at greater heights. The maximum air velocity values then vary between 1.4 m/s, for an inlet air velocity of 2 m/s, and 3.4 m/s, for an inlet air velocity of 5 m/s.

The horizontal confluent jet system thus creates a horizontal air velocity close to the wall surface and close to the floor surface. In the central area of the wall, there is a collision between the jets coming from opposite directions with the consequent spreading of the airflow. The resulting airflow has a horizontal component along the wall and a vertical component along the floor. Furthermore, the airflow has an upward characteristic towards the exhaust system, as can be seen in Fig. 8. Next to the exhaust, the air velocity reaches 1.31 m/s when the exhaust air steps into the extraction duct.

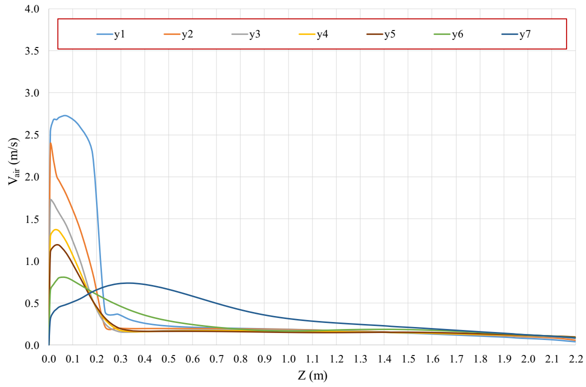

Fig. 6. Air velocity (V_{air}) in vertical plans located at 0.075 m in the X direction, for an inlet air velocity of 4 m/s.

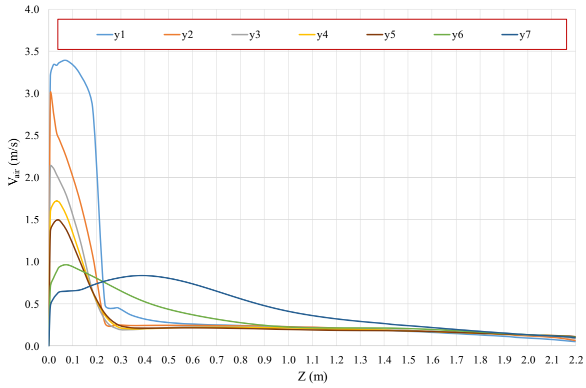

Fig. 7. Air velocity (V_{air}) in vertical plans located at 0.075 m in the X direction, for an inlet air velocity of 5 m/s.

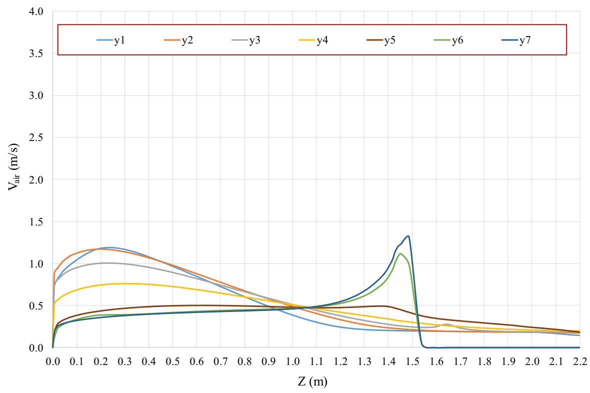

Fig. 8. Air velocity (V_{air}) in vertical plans located at 0.440 m in the X direction, for an inlet air velocity of 6 m/s.

5 Conclusions

The airflow field, within a virtual chamber, created by a horizontal confluent jet ventilation system was analysed in this article. This ventilation system is constituted by an inlet system, installed in vertical ducts located in the corners of the room, and an outlet system installed in a duct located near the central area of the ceiling. The airflow profile was obtained for four values of the inlet air velocity.

The most relevant conclusions are the following:

- This ventilation system provides a horizontal air velocity near the wall surface and near the floor surface;
- In the area located in the middle of the wall, the interaction that occurs between the jets originated by the nozzles located in diametrically opposite ducts can be seen;
- The resulting airflow is seen to take an upward direction towards the exhaust system.

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