NUMERICAL AND EXPERIMENTAL DEVICE FOR LOCAL CONTROL OF VENTILATION

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ABSTRACT

Local control of ventilation in large buildings is considered to be a main issue in energy savings regarding the huge energy losses that are usually induced by such large volumes. An efficient ventilation system and the development of local control ventilation strategies could prevent large buildings from having an unsuited or overvalued ventilation and reduce significantly the energy consumption. Considering the issue of developing such strategies, both pollutant dispersal and heat transfer models, based on Computational Fluid Dynamics codes, have been developed in Science Buildings Laboratory (LASH) in Lyon. The models are used for numerical tests of established control ventilation strategies, while an added experimental device allows to perform experimental validation.

KEYWORDS

Indoor Air Quality, Large Buildings, Local Control of Ventilation, Experimental Set-up, CFD, Modeling.

INTRODUCTION

The ventilation systems should be thought today so as to adapt the airflows to the real occupation of premises, in order to have better control on the energy consumption due to the renewal of indoor air, while maintaining an acceptable level of indoor air quality to ensure both comfort and hygiene of occupants. Large buildings are considered then, because of their highly intermittent and localized activies, to be the ones on which the reductions of the energy consumptions could be the highest, if they were equipped with ventilation systems adapted to the real needs (Barbat, 2000). A local control of ventilation within the large volumes allows to reduce significantly the energy spending related to unsuitable and overvalued airflows in the areas of very low occupation.

Regarding the development of future strategies of local control of ventilation, pollutant dispersal and heat transfer numerical models and an experimental device were realized to be afterward able to test and validate such strategies.

The ventilation's control should ensure a satisfactory indoor air quality and an acceptable internal comfort for the occupants. The setting of the algorithms of control will base themselves then on the precise knowledge of several characteristic parameters of air quality and comfort. The thermal comfort will be estimated by the indicator PMV, presented as an effective indicator allowing to integrate all the main parameters of comfort (Bruant, 1997), while the indoor air quality will be characterized by the concentration in pollutant CO_2. The choice of the CO_2 as a characteristic parameter is justified by the fact that, being given the office activity that is practised within the experimental premise, the occupants appear then as the main source of pollution, because of their metabolic activity. Carbon dioxide becomes then the main pollutant of indoor air and the control of its content, directly linked to the occupation of the premise, allows to ensure good indoor air quality (Woods et al, 1982, Liddament, 1996).

The aim thus was at first to elaborate a numerical model of the experimental premise that was able to calculate for the entire volume all the parameters defining the indicator PMV, to characterize thermal comfort, as well as the dispersal of the CO_2, for evaluating indoor air quality. At the same time as the development of the model, the setting of an experimental device was made to allow to test and validate the model, and to perform field testing on the strategies of local control ventilation developed.

EXPERIMENTAL PREMISE PRESENTATION

A premise of the Building Sciences Laboratory (LASH) was used for the setting of the experimental device. This premise presents all the geometrical characteristics allowing to consider it as a large building, as well as a complete ventilation and warming/cooling system with an air distribution network perfectly adapted to the field testing of strategies of local of control ventilation developed.

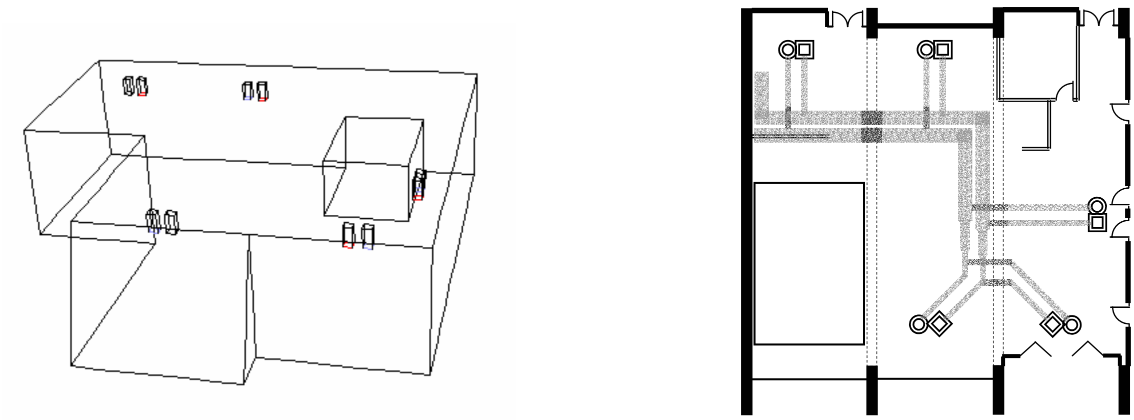

Figure 1 : Visualization of experimental premise

The premise appears as a large volume with horizontal dimensions of 16 m on 15 m, and a height under ceiling of 4,35 m, for an approximate volume of 950 m^3. It is equipped with two fans, one blowing fan and one extracting fan, for a maximum airflow of 6000 m^3/hour each, and with reversible hot air pumps, allowing to change the temperature of blowing, and so that the indoor thermal conditions. The air distribution network consists in 5 pairs of extracting and blowing diffusers distributed on the entire volume (cf. Figure 1).

NUMERICAL MODELING

A global heat transfer and pollutant dispersal model of the experimental premise described above has been developed to allow numerical testing of the local control of ventilation strategies established.

Heat transfer modeling

The heat transfer model was developed using the Computational Fluid Dynamics code given by FLUENT®.

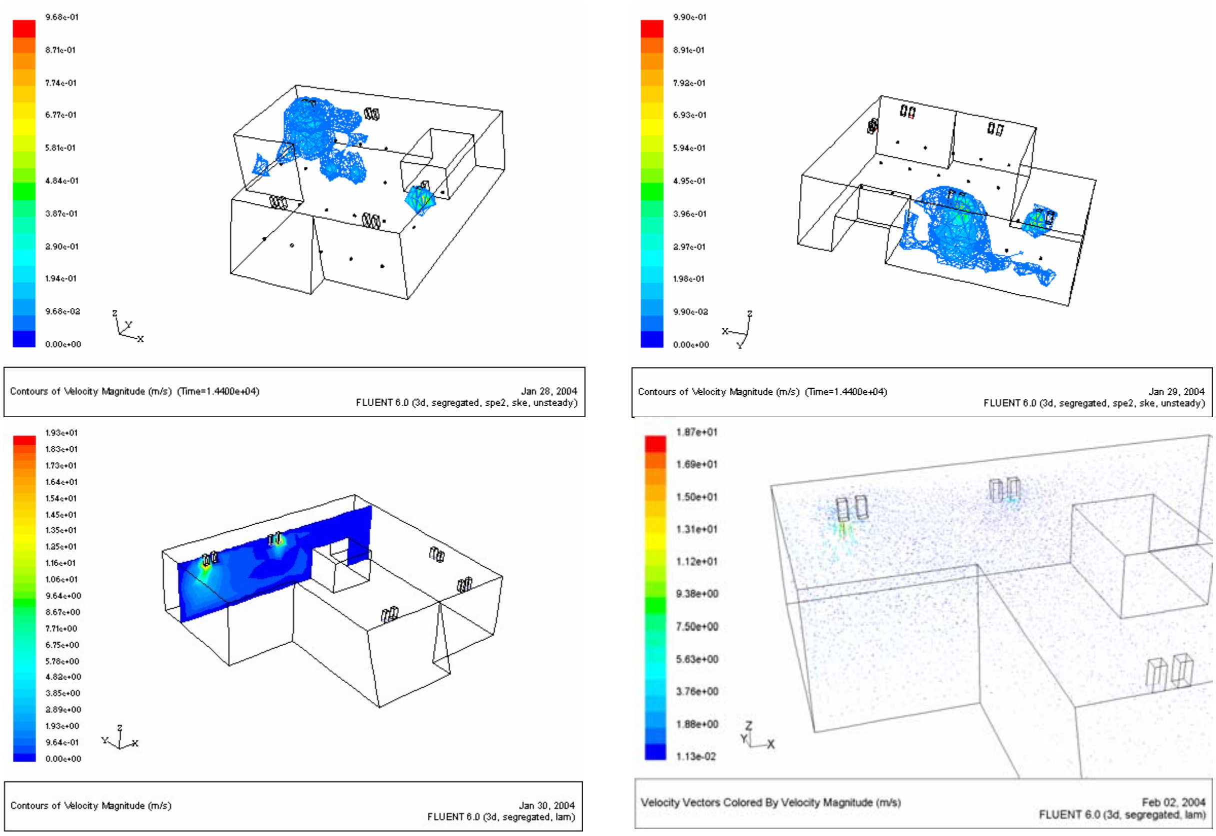

Figure 2 : Visualization of simulations realised with FLUENT

The building's geometry was simplified in a way to improve the performances, in terms of calculation's time, of the heat transfer model. Some geometrical features, having a small effect on air distribution inside the premise, were so abolished during the geometrical modeling. In the same way, the geometrical peculiarities linked to the blowing and extracting diffusers of the air distribution network were minimized so that they could have been simply modeled.

It was then necessary to proceed in a set of campaigns of experimental measures to calibrate the model, and in the second time, to validate it. The model so developed allows henceforth to determine the airflow, as well as the temperature distribution and the relative moisture content inside the entire volume of the experimental building (cf. Figure 2).

Pollutant dispersal modeling

Once the heat transfer model validated, a parallel model of dispersal of pollutant was developed, to provide, from knowledge of occupation inside the premise, the dispersal of the pollutant within entire volume. Even there, the model was established from the CFD code FLUENT.

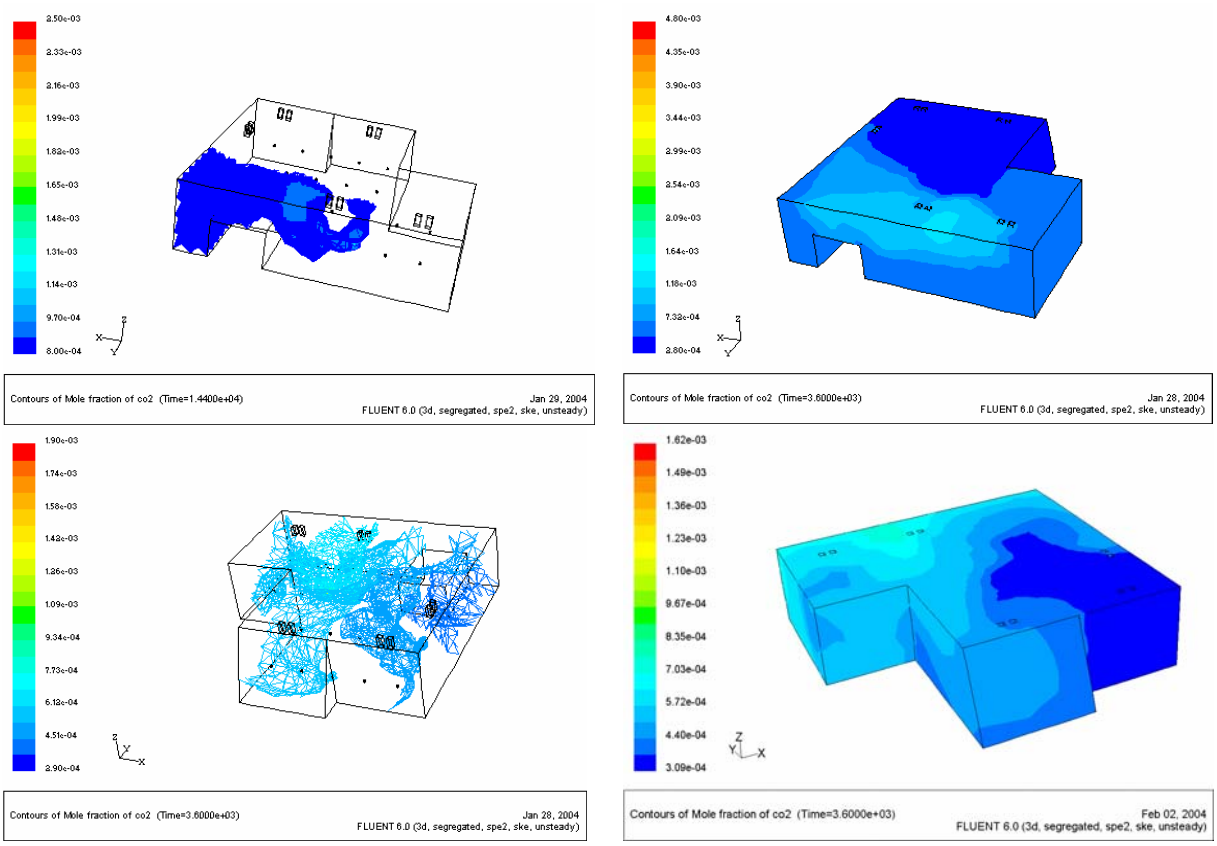

Figure 3 : Visualization of CO_2 dispersal inside the experimental premise

The pollutant that was considered to assess the indoor air quality inside the building is the CO_2. This pollutant was chosen considered the activities practised inside the premise, which are primarily office activities. The occupation (number and position of occupants) was translated into terms of carbon dioxide production, on the basis of the information provided by the guide of the AIVC (Liddament, 1996). It is henceforth possible, thanks to this model, to determine, from information of occupation and activity, the dispersal of the CO_2 inside the experimental building (cf. Figure 3).

EXPERIMENTAL SET-UP

While developing numerical models, an experimental device was conceived to perform experimental measurements to validate the models, and also to perform, afterward, tests of local control of ventilation strategies in a real situation. The premise was so equipped with a complete system of acquisition and command, automatically piloted.

Acquisition and command centre

A cockpit was installed in the experimental premise, in order to have a control over the whole device. The network of air distribution and air treatment is linked to an acquisition and command system giving information from sensors positioned within the premise, and controlling many device, such as fan's speed or VAV's opening. A PC computer is so installed and equipped with an acquisition card presenting analogical and digital functions, and being able to be used in several applications to automate and control equipments. The acquisition and the command is made by means of a user interface developed with Labview program.

Acquisition system

The acquisition system of the experimental device supplies all the information used in the local control of ventilation strategies. In the case of our study, the system consists in video cameras installation that can provide images of the premise used for the determination of the occupation, as well as in different sensors. A set of 5 cameras IP provides video images of entire volume. These images are analysed through a computer program that sends back information concerning the occupation. Afterward, this information is translated into terms of pollution source, and will be used for field testing. A set of sensors so allows to get back information about temperature, relative humidity, CO_2 level, and air velocity within the premise. Experimental measures of all these parameters allowed to calibrate, then to validate the numerical model developed beforehand.

Command system

The command system's user can have control on many device composing the air distribution and air treatment network. He so has the control on the speeds of both blowing and extracting fans, air blown temperature, and the openings of VAV of every diffuser of the air distribution network thanks to motors installed on VAV. The chosen motors, of type LMC24-SR-F, from brand Belimo, give the opportunity of a flexible command, from an analogical signal 0-10V. It allows to vary the opening of VAV from 0 to 90 °, and consequently the airflow in all the diffusers of the network from 0 to 100 %. The control of the airflows at the extremities of the air distribution network is an essential constituent of the local control of ventilation. All these commands allow to have a complete control on ventilation's system of the experimental premise.

The experimental device so developed allowed, by the continuous acquisition of data on various parameters of indoor air, provided by numerous sensors, to make the validation of the numerical models developed beforehand. It will afterward be used to apply and test in real situation the future strategies of local control of ventilation.

CONCLUSION

The experimental and numerical device which was conceived in the Building Sciences Laboratory (LASH) in a suitable experimental premise is now efficient for tests of strategies of local control of ventilation. The numerical models of pollutant dispersal and heat transfer developed allow numerical tests of the strategies, while the experimental device, with a complete acquisition and control centre, allow to perform field testing for future validation of the developed strategies.

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