FORECAST OF THE PROPERTIES OF A COLD VERTICAL WALL JET COMING FROM A FAN COIL

D. Marchal, P.J. Vialle

Centre Technique des Industries Aérauliques et Thermiques
27-29 Boulevard du 11 Novembre 1918
69603 Vileurbanne Cedex, FRANCE

ABSTRACT

The study of the flow in a room cooled by a fan-coil pointed out how the form of air flow and comfort could be influenced by the characteristics of the cold jet blowing out. It is based both on practical experiment and on numerical simulation using CFD code. Combining these methods allowed a large number of configurations to be studied, in association with different conditions for the appliance.

Using the results in combination enabled a relation to be established between the problem data, the device characteristics and the comfort conditions obtained. A simple rule was derived from this, which can be used in air-conditionning premises, in order to make the right choice or scaling of the air-conditionning appliance depending on its conditions of use.

KEYWORDS

Comfort
Mixing ventilation
Numerical simulation
Full-scale experiments

SYMBOLS

f: width of the fan-coil unit supply grille (m)
l: length of the fan-coil unit supply grille (m)
g : gravity acceleration (ms^{-2})
h' : distance between the blowing plane and the ceiling (m)
V : air blowing velocity (m/s)
β air volume coefficient of expansion (K^{-1})
Δt : temperature difference between intake and blowing (K)
ν: kinematic viscosity (m^2/s)
Re : Reynolds number
Fr : Froude number

INTRODUCTION

To cool inhabited premises that are subject to heat loads, cold-air ventilation is generally used. Cold air is denser than ambient air and tends to fall, making it difficult to distibute to every places where it is needed. To remedy this difficulty, the property of air jet to adhere to the walls, called Coanda effect, is resorted-to. The good performance of the cooling system is so, strongly dependent of the characteristics of the jet blowed out by the fan-coil. This is again more significant if the fan-coil is located at the basement of a window. Due to the low position of the blowing plane in this case, the jet has first to go upward what is opposite to its inclination to fall down.

The work discussed here is designed to define the conditions that has to fulfill the flow blowed out of a fan-coil located at the basement of a window, in order to assume a good comfort. It is based on both experiment and numerical simulation, the latter being used as a means of extending the scope of the experimental results. The study achieves a non-dimensional presentation of the results, which can be used in many situations for practical design of appliances.

METHODS

First part of this work [1] consisted in experimentations performed in a test chamber with scope for varying the heat loads and the operating conditions of the fan coil installed. Two types of measurements were taken : measurements relating to the flow of the cold air jet from the device, and the measurements of the velocities and temperatures in the occupied area of the room. The latter measurements enabled to characterize the usual criteria to be used to describe the comfort of the occupants, particularly the ADPI criterion [2], which takes into account both the homogeneousness of temperature and the lack of excessively ventilated areas. The experimental work covered an important number of situations, albeit limited by the dimensions of the test chamber and the air-conditionning appliance chosen. It has also enabled the accuracy of the numerical simulations performed with a CFD code (FLUENT) to be verified for a number of cases, as regards both the velocity and temperature profiles in the air jet and the velocity and temperature fields in the occupied zone.

Three dimensionnal numerical simulation was then used to explore a large number of situations which may arise in practice. Every cases studied concerned empty, oblong rooms with heat loads applied, on the one hand by conduction through the upper part of the building-front against which the fan coil is installed (glazing), and on the other hand to the greatest extent, by internally-generated heat assumed to be uniformly distributed in the occupied zone. The study consisted of systematically varying the parameters listed in table 1, which shows the interval explored, representing some twenty configurations.

Variable (unity)	Minimum value	Maximum value
room length (m)	3.0	6.0
room width (m)	2.5	4.5
room height (m)	2.5	3.5
thermal load (W)	650	1600
l (m)	0.5	1.2
f (m)	0.03	0.1
α jet angle (°)	-30	30

Table 1 Variation range for the parameters studied

In each of these cases, several simulations were performed in which the blowing velocity of the fan coil (assumed to be vertical and uniform) was varied simultaneously with the corresponding temperature, so as to compensate the heat load in order to achieve always the same air-intake temperature (25°C). This exploration of each configuration was so conducted as to highlight the variations of the comfort criterion (ADPI).

RESULTS

Numerical part

The synthesis of the results obtained after the parametric study pointed out the ability to link the comfort criterion ADPI to a non dimentional number X defined in the following way :

$$X = \frac{1}{\mathrm{Re}(f).Fr^2(h')} \quad (1)$$

this is the reciprocal of the product of two usual non-dimentional numbers :

- Reynolds number relating to the width f of the supply grille of the device :

$$Re = \frac{f.V}{\nu} \qquad (2)$$

in which V and ν refer to the blowing velocity and kinematic viscosity of air respectively; and

- the Froude number relating to the heigt h' to which the jet has to rise :

$$Fr(h') = \frac{V}{\sqrt{h'.g.\beta\Delta t}} \qquad (3)$$

Figures 1 and 2 diagrams, relating to a vertical uniform jet (α = 0) show how the ADPI indice varies versus the X number, for a constant heat load and different values of the dimensional parameters of the case regarded : width f of the supply grille (figure 1) or h' height (figure 2).

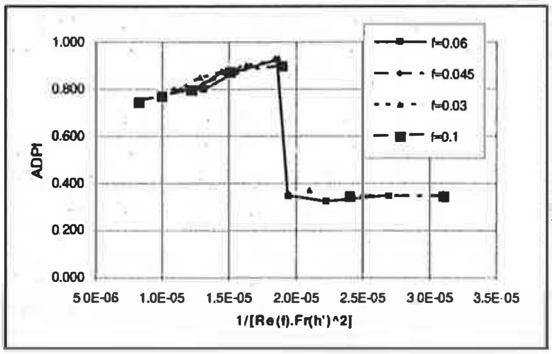

Figure 1 Variation of the X parameter for different values of the grille's width f.

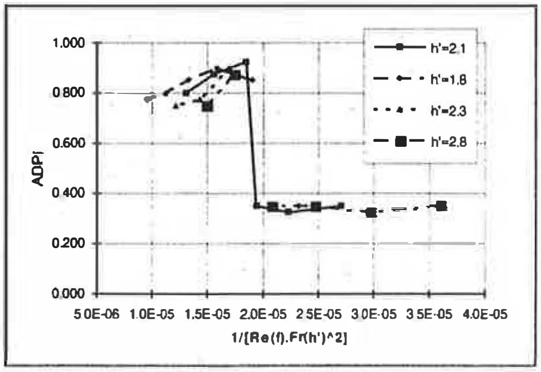

Figure 2 Variation of the X parameter for different values of the h' height

The choice of this expression of X, of which value increases when the temperature difference is increased at the expense of velocity, is designed to account satisfactorily for the effects of inertia, diffusion and gravity, which involve forces, the relationships of which taken in pairs are represented by the Reynolds and Froude numbers. The rapid change of the ADPI criterion from 0.9 to 0.3 around a value for X of $1.9.10^{-5}$ corresponds to the transition between the two flow situations described in the figures 3 and 4.

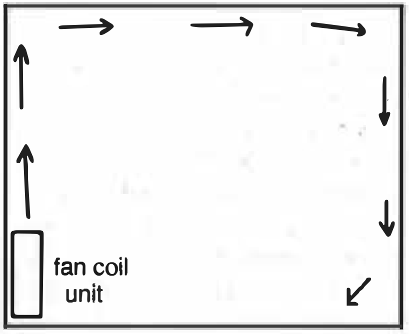

Figure 3 Sketch of the flow situation with good comfort conditions

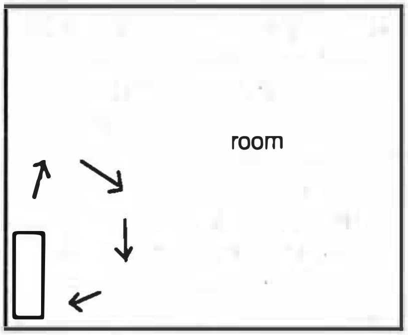

Figure 4 Sketch of the flow situation with bad comfort conditions

In figure 3 ($X < 1.9.10^{-5}$) the jet blowed out of the grille has a sufficient energy to reach the ceiling and then surround with cooled air the occupation zone, wich implies a satisfying comfort; at the opposite on the figure 4 ($X > 1.9.10^{-5}$) the jet falls

Experimental study on the air flow characteristics of air-conditioned office rooms.
ROOMVENT 96, 17th-19th July 1996, Nagoya, Japan

[2] Method of testing for room air diffusion. ANSI/ASHRAE 113-1990, American National Standards Institute, 1990.