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A spectral analysis method to study indoor flows

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INTRODUCTION

When air is introduced into a closed room, turbulent fluxes are produced due to several causes: a significant velocity gradient, density differences between the incoming air and the environmental air, existence of obstacles, etc. The turbulent flux makes easier the transport of physical properties as momentum, heat, humidity and concentration of substances in the air. In many applications it is important the study of the turbulent mixing of air incoming into an enclosure, as well as the change among magnitudes associated with that mixing[1].

The spectral analysis is a statistical tool that is often used to study turbulence. This method allows a temporal or spatial series to be transformed in a set of values in the frequency or wavenumber space, and in this way it is possible to break down the energy of movement in the scales associated with each frequency. We have based on this idea to present in this work important results of a study of spectral analysis to improve the knowledge of the behaviour of indoor air movements [2].

DESCRIPTION

We have developed an experimental model consisting of a composition of three grids of sensors (velocity and temperature) to measure indoor air. The display of the grids was in an appropriate way for a cell or simple enclosure, similar to an isolate room. In the experiment, air is introduced through a window, in a controlled way, and got out by an orifice performed in the opposite wall to the window [3]. The cell was borrowed from the Institute of Renovable Energies of CIEMAT, located in LECE-PSA (Solar Platform of Almería, Spain).

It was used hot-wire anemometers (HWA), a sonic anemometer (SA) and, also, thermocouples (TC), to measure in very short temporal scales. From the experimental data it was possible to know the conditions of the incoming air, the turbulent fluxes of momentum and heat, as well as the intensity of turbulence [4].

A preliminary spectral study of u, v and w components of velocity showed decay towards higher frequency, which it is more evident near the boundaries and along the streamwise [5]. This result is similar to that happening in the free atmosphere; therefore one aim of this work is to know the rate of agreement between the spectra for movement indoor and in the atmosphere by means of the respective “inertial subrange”. This would include to obtain the characteristic scales of transference of turbulent energy in the indoor air. On the other hand, from the heat fluxes, the Nusselt number has been calculated for the main flow direction indoor (X direction). We have used the following expression:

$$(Nu)_X \;=\; \frac{\rho c_p H}{k \Delta T}\, \overline{u' T'}$$

where ρ is the density, c_p the specific heat for constant pressure, H a characteristic length, k the thermal conductivity of the air, ΔT the difference of temperature respect a reference and $\overline{u'T'}$ represents the turbulent flux of temperature.

Also, the behaviour of Nu versus the found inertial subrange has been studied.

CONCLUSIONS

Spectral and dimensional analysis of movement indoor air have been performed in order to obtain more information on the energy exchanges along its trajectory, mainly near the jet and depending on the relative position to the boundaries of the cell.

From the experiments and the analysis of this work, it can be underlined the following conclusions: 1) Along the main direction of the flow, u component of velocity, the fitting of maximum value has a slope at a value near –5/3 (the Kolmogorov´s law for the inertial subrange), similarly to the behaviour in the atmosphere. 2) It has been observed a Kolmogorov length scale η, for indoor air of order 10^{-1}mm (wavenumber, k_η = 60 mm^{-1}) and an integral scale L_t = 5.45 m (wavenumber k_{Lt} = 10^3 mm^{-1}). 3) It can be said with a good accuracy, that transfer of kinetic energy from the largest to the smallest scales happens within the interval [10^3, 60] mm^{-1}. This transfer becomes more effective along the main direction of the flow.

Therefore, we can summarize that spectral analysis of velocity components of the turbulent flow introduced into an enclosure, allows to locate those areas where the exchange of momentum and heat is more effective. This corresponds, in this experimental case, to positions of bigger shear in the flow.

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