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ScienceDirect

Energy Procedia 112 (2017) 650 – 655

Energy Procedia

Sustainable Solutions for Energy and Environment, EENVIRO 2016, 26-28 October 2016, Bucharest, Romania

Study and experimental validation of a zonal model for a sitting manikin thermal plume

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Abstract

A simplified sitting thermal manikin was used for the investigation of the thermal plume with the zonal method. The modeling was realized under free convection, with no ventilation system in the room. The thermal manikin was placed in a 3.53x3.53x2.52 (LxlxH) experimental chamber with different ambient temperatures. The zonal model was realized using the simulation environment SPARK. The manikin's temperature was different for different body parts. The body was divided into three parts, from the temperature point of view – head, body and legs. The thermal manikin's surface was 1.95 m^2. The results of the zonal model were compared with the results obtained during the experimental campaign at the climate chamber of the CAMBI laboratory and with the CFD predictions for the same geometry. The study showed that the zonal model is capable to predict in a good manner the velocity and temperature field of the thermal plume.

Peer-review under responsibility of the organizing committee of the international conference on Sustainable Solutions for Energy and Environment 2016

Keywords: zonal models, SPARK; Thermal Plume

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Peer-review under responsibility of the organizing committee of the international conference on Sustainable Solutions for Energy and Environment 2016
doi:10.1016/j.egypro.2017.03.1132

1. Methods

1.1. Description of the studied configuration and the boundary conditions

The enclosure is presented in figure 1 and the dimensions are those of the experimental chamber, 3,53m x3,53m x 2,52m for axis X,Y and Z. The chamber has no ventilation system so there is no air flow that exits the room. The only heat source is the occupant so the air will heat up as time passes. The manikin is a simplified representation of the human body in a sitting position. The is made from parallelepiped boxes linked to each other.

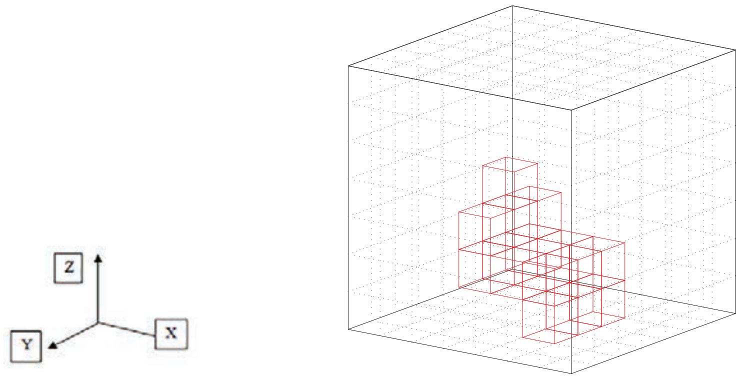

Fig. 1. Placement and shape of the manikin used for the numerical model and in the experiments

The height of the sitting manikin is 1.35m. The total body surface is 1,93 m2. The width of the torso is 38cm and the length 62cm. The medium temperature inside the room is initially 26°C but it has raised due to stratification. For the walls the imposed temperature is 27.3°C. The human body temperature varies from: 35°C for the head , 32°C for the torso and 30°C for the legs. Inside the chamber there was no movement so the circulation of air is due to the heating of the air and to the accessional forces.

1.2. Zonal method and experimental model

The zonal method consists in dividing the enclosure in a number of control volumes of macroscopic size, called cells. Inside the cells the air temperature and density are supposed to be homogenous, while the pressure varies [7]. The air is behaving like a perfect gas. For each cell we apply the mass and energy conservation laws. The flow that crosses the interface between two cells depends on a pressure gradient and can be found using the following relation:

$$\dot{m}_{i,j} = C_d \rho_{i,j} wh \left(\frac{2}{\rho_{i,j}}\left|\Delta P_{i,j}\right|\right)^{\frac{1}{2}} x signe \left(\Delta P_{i,j}\right) \quad (1)$$

Where ΔPi,j=(Pi-ρigzi) – (Pj-ρjgzj)
mi,j- mass flow; Cd–empirical coefficient l- discharge coefficient ;ρi,j–volumetric mass of the fluide upstream according to the sign of (ΔPij);w –transversal dimension of the; dz–differential element; ΔPij –static differential pressure ;zi -height of the center of the zone “i”;
To characterize the ambient inside the cells, we will use mass balance equations for dry air and for water vapors as well as the energy balance [8].
Dry air balance inside ”i” cell :

$$\sum_{u=1}^{6} m_{\dot{au}_{u\to i}} = 0 \ (2)$$