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IBP REPORT 507

37 (2010) NEW RESEARCH RESULTS IN BRIEF

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THE VEPZO MODEL – VELOCITY PROPAGATING ZONAL MODEL

QUICK ESTIMATION OF AIRFLOW PATTERN AND TEMPERATURE DISTRIBUTION IN CONFINED SPACES

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OBJECTIVE

The aim of zonal models is to perform quick simulations of the airflow pattern and temperature distribution in rooms. Therefore an air volume is subdivided into several discrete zones (see Fig. 1), typically 10 to 100 [1]. In terms of accuracy and needed computational time zonal models are a compromise between the more complex CFD-calculations and the approximation of a perfectly mixed room.

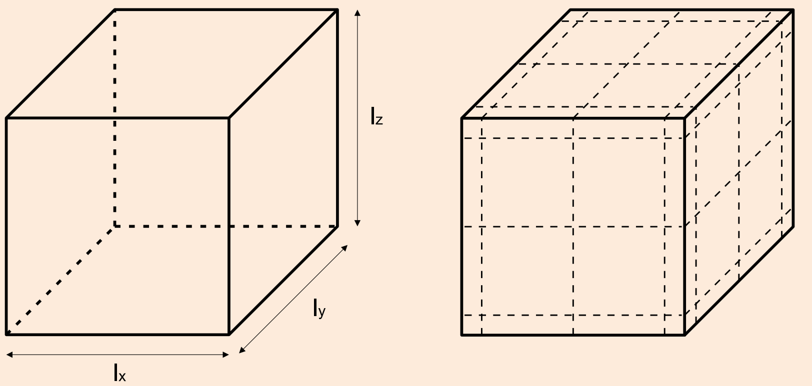
A new formulation of such models has been developed at the Fraunhofer Institute for Building Physics IBP, the velocity propagating zonal model or VEPZO model. The VEPZO model is using the airflow velocity as a property of a zone and a viscous loss model in order to better match the physics of airflow. The model is implemented in "Modelica".

METHOD

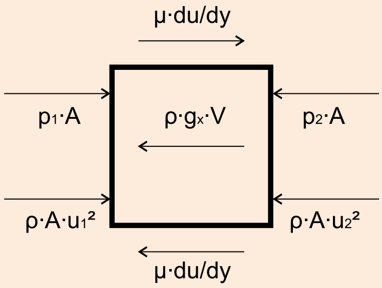
Zonal models consist of two main components: volumes and flows. In the volume model the conservation of scalar quantities like mass, heat and moisture is implemented. The model contains interfaces for airflows and external heat exchanges, e. g. a convective exchange with a wall or a single localised heat source like a computer. It is possible to implement interfaces for other exchanges, like particles or gases, too.

In a VEPZO model the volumes furthermore contain information about the three components of a resulting velocity vector which is determined from the incoming and leaving amount of air on each of the volume's surfaces. This vector as well as the location of the zone in a confined space and the state of the air contained in the volume are sent to the flow model. The latter determines the amount of air exchanged between two adjacent volumes.

References
[1] Boukhris, Y.; Gharbi, L.; Ghrab-Morcos, N.: Modeling coupled heat transfer and air flow in a partitioned building with a zonal model: Application to the winter thermal comfort. Building Simulation, 2009, Vol. 2, pp. 67–74
[2] Wurtz, E.; Nataf, J.-M.; Winkelmann, F.: Two- and three-dimensional natural and mixed convection simulation using modular zonal models in buildings. Int. Journal of Heat and Mass Transfer, 42, 1999, pp. 923–940



1 left: Generic geometry of a room, right: Example of zoning 4 x 4 x 4 zones



2 Forces acting on a flow path in a VEPZO model

For this the resulting forces acting on the flow paths are summed up and the acceleration of the airflow is calculated (see Fig. 2). A viscous term is introduced to be able to model losses. The equation is shown for the x-direction, but applies equivalently to the other Cartesian coordinates.

$$\dot{u} = -\frac{\frac{\Delta p_{1,2}}{\rho} + \Delta(u^2)_{1,2} + g\cdot\Delta z}{\Delta x} + \frac{\mu}{\rho}\cdot\left(\frac{\Delta\frac{\partial u}{\partial y}}{\Delta y} + \frac{\Delta\frac{\partial u}{\partial z}}{\Delta z}\right)$$

The use of an adjusted viscosity similar to the idea of a turbulent viscosity allows to better account for losses along the flow path. A value of 0.001 Pa·s proves to give reasonable results.

RESULTS

The performance of a VEPZO model is compared to the results obtained in a three-dimensional room (l_x x l_y x l_z = 2.6 x 3.6 x 2.55 m³) [2]. The boundary conditions for the simulation are listed in table 1.

Two 4 x 4 x 4 zonings were tested. In the first zoning all directions are equally decomposed. In the second zoning the room is decomposed such that the first and fourth element in each direction is 0.1 m thick (similar to Fig. 1, right). Thus, the space close to the wall is refined whereas the elements in the middle are larger.

The simulation takes approximately 4 s to converge on a normal portable computer. The diagrams in Fig. 3 show that the temperature profiles obtained with the VEPZO model are in good agreement with the conducted experiment and the Fluent-simulation reported in [2]. For the vertical temperature distribution the VEPZO model outperforms the old formulation. The horizontal airflow velocity profile shows that refining near-wall zones enhances the accuracy of the model.

Table 1 Boundary conditions

Surface	Temperature (°C)	Heat transfer coefficient (W/m²·K)
left	25.5	4.1
right	32.0	4.1
front	24.5	4.1
back	24.5	4.1
Floor	24.5	1.0
Ceiling	26.0	5.7

CONCLUSIONS

Overall, the VEPZO model produces results with reasonable agreement to published measurements and simulations. The model allows quick predictions of the impact of the local distribution of heat sources or of temperature gradients along the boundaries of a confined space.

Promising applications are the prediction of local heat accumulation in stratified spaces or condensation at cold surfaces or edges.

Fig. 3: Horizontal temperature profile, vertical temperature profile and horizontal profile of the vertical velocity, evaluated in the middle of the room