Thermal comfort in residential/office rooms using PUF insulation: experimental and sensitivity study

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Supplementary Material

The **CHT-CFD code** based on the Boussinesq approximation has been developed to perform the conjugate heat transfer study for a closed room with natural convection. This is an open-source code that can be freely downloaded and the code can be edited/extended as per the user's requirement and can be used for educational and research purposes.

The details of different functions/subroutines are described below:

- **main.f:** This is the main function of the code, which calls different subroutines required for the calculation. The outer iterations are also being performed in this function.

- **init.f:** reads the grid file (grid.out), input parameters file (daten) and calculates the non-dimensional numbers (e.g. Rayleigh number), initial temperatures in non-dimensional form, initial time step, etc.

- **start.f:** initialize the solution domain with an initial guess of u, v, w, p, θ at the beginning of the calculation.

- **start.f:** initialize the solution domain with the previously calculated values of u, v, w, p, θ at the restart of the calculation.

- **energySolid.f:** computes the temperature field of the solid zone (room walls and roof) by solving the conduction equation, as given below[1]:

$$\frac{\partial \theta}{\partial t} = \frac{1}{\mathrm{Pr_s}} \left[\frac{\partial^2 \theta}{\partial x^2} + \frac{\partial^2 \theta}{\partial y^2} + \frac{\partial^2 \theta}{\partial z^2} \right]. \tag{1}$$

- **conti.f:** correct the velocity fields based on the pressure correction and for this purpose, the continuity equation is solved, as given below:

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0. \tag{2}$$

[1]Refer to the main paper for further details of the symbols used in the equation.

- **energy.f:** compute the temperature field of the fluid zone (indoor air) by solving the energy equation, as given below[2]:

$$\frac{\partial \theta}{\partial t} + \frac{\partial (u\theta)}{\partial x} + \frac{\partial (v\theta)}{\partial y} + \frac{\partial (w\theta)}{\partial z} = \frac{1}{\mathrm{Pr}} \left[\frac{\partial^2 \theta}{\partial x^2} + \frac{\partial^2 \theta}{\partial y^2} + \frac{\partial^2 \theta}{\partial z^2} \right] + \mathrm{S}. \tag{3}$$

- **bcc.f/bcns.f/bct.f:** the boundary conditions for continuity, momentum, and energy equations are being used through the subroutines bcc.f, bcns.f and bct.f respectively.

- **otpt.f:** save the output data files during the computation as well as after the convergence is achieved.

- **nseqcp.f:** compute the velocity components (u, v, w) by solving the X, Y and Z-direction momentum equations, as given below:

$$\frac{\partial u}{\partial t} + \frac{\partial (uu)}{\partial x} + \frac{\partial (vu)}{\partial y} + \frac{\partial (wu)}{\partial z} = -\frac{\partial p}{\partial x} + \left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2} \right), \tag{4}$$

$$\frac{\partial v}{\partial t} + \frac{\partial (uv)}{\partial x} + \frac{\partial (vv)}{\partial y} + \frac{\partial (wv)}{\partial z} = -\frac{\partial p}{\partial y} + \left(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} + \frac{\partial^2 v}{\partial z^2} \right), \tag{5}$$

$$\frac{\partial w}{\partial t} + \frac{\partial (uw)}{\partial x} + \frac{\partial (vw)}{\partial y} + \frac{\partial (ww)}{\partial z} = -\frac{\partial p}{\partial z} + \left(\frac{\partial^2 w}{\partial x^2} + \frac{\partial^2 w}{\partial y^2} + \frac{\partial^2 w}{\partial z^2} \right) + \mathrm{Gr} \times \theta. \tag{6}$$

- **grid.out:** three-dimensional grid used to define the computational domain in the present study.

- **daten:** this input file contains all the input parameters required to initialize and perform the calculations, as described below:

  1. **irest:** 0/1 to start/restart the code,
  2. **stab:** stability factor used to calculate Δt,
  3. **itamax:** maximum number of iterations,
  4. **epsi:** initial limits for residuals,
  5. **stat:** factor to control the maximum number of internal iterations,
  6. **xL_ref:** characteristic length (room length) in m,
  7. **x_Nu:** kinematic viscosity of the air,
  8. **xks:** thermal conductivity of the walls,
  9. **T_floor:** floor temperature,
  10. **T_Roof:** outside roof temperature,
  11. **T_North:** north wall inside temperature,
  12. **T_South:** south wall inside temperature,
  13. **T_East:** east wall inside temperature,
  14. **T_West:** west wall inside temperature,
  15. **T_Ceiling:** inside roof temperature.

[2]Refer to the main paper for further details of the symbols and non-dimensional numbers used in the equation.

- **header:** this input file defines all global variables used in the present study.
- **iwrite:** this input file contains the input controls, which can be used to make some changes during the computation without stopping the computation.