Building Energy Simulation Using the Finite Element Method

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Abstract

An overall objective of energy efficiency in the built environment is to improve building and systems performances in terms of durability, comfort and economics. In order to predict, improve and meet a certain set of performance requirements related to the indoor climate of buildings and the associated energy demand, building energy simulation (BES) tools are indispensable. The website the of U.S. Department of energy (Energy.gov 2012) provides information on about 300 building software tools from over 40 countries for evaluating energy efficiency, renewable energy, and sustainability in buildings. Commonly used within these tools are: Zonal approaches of the volumes, assuming uniform temperatures in each zone and 1D modeling of the walls. Due to the rapid development of FEM software and the Multiphysics approaches, it should possible to build and simulate full 3D models of buildings regarding the energy demand. Because BES and FEM have quite different approaches the methodology of this research is very important: Step 1, start with a simple reference case where both BES and FEM tools provide identical results. Step 2, add complexity and simulate the effects with both tools. Step 3, compare and evaluate the results. The full paper includes the following results. For step 1, a very suitable reference case was found at the current International Energy Agency Annex 58 (2012). It concerns a test box with overall dimension 120x120x120 cm³. Floor, roof and three of the four walls are opaque, one wall contains a window with opening frame. Details of the overall geometry with the exact dimensions can be found in Figure 1. We started to build a 3D model of the opaque test box, heavy weight, ACH=0 using COMSOL. In order to compare the COMSOL 3D FEM model with the HAMBase (HAMLab 2012) lumped model, an equivalent heat conduction of the air is used in COMSOL instead of CFD. The distribution in the test box is simulated using Dutch weather data. Figure 2 shows the 3D dynamics snapshots of the isosurfaces. Figure 3 shows the comparison of the simulated mean indoor air temperature using COMSOL (blue line) and HAMBase (green line) during the first month. The verification result is satisfactory. We conclude that for the reference case COMSOL produces identical results as a BES model. The latter is very promising for studying the other required steps of methodology. Preliminary results will be shown in the full paper. Furthermore, the presented results are a first step towards more complex 3D FEM simulations including CFD, window, ventilation and radiation. In principle all variants can be simulated in 3D using COMSOL, with the notification that the CFD modeling could become quite time consuming. The 3D modeling allows to virtually place sensors in the test box that produce simulated 'measured' data. This is left over for future research.

Reference

1. HAMLab (2012), http://archbps1.campus.tue.nl/bpswiki/index.php/Hamlab
2. Energy.gov (2012), http://energy.gov/

Figures used in the abstract

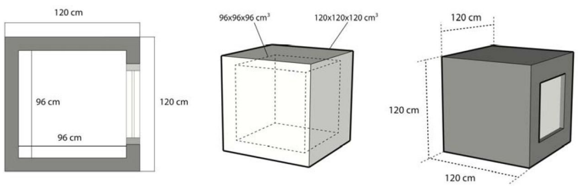

Figure 1: The reference case, a test box.

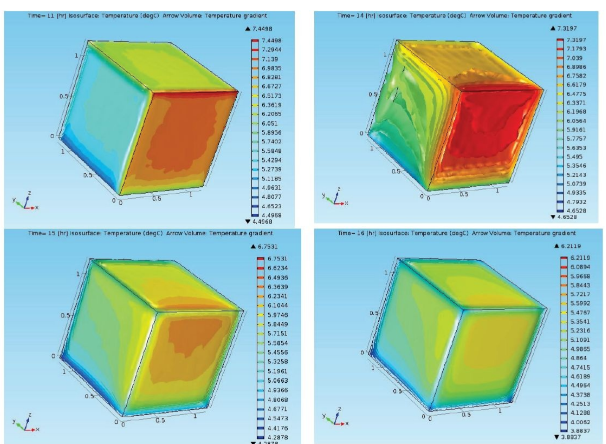

Figure 2: Isosurfaces of the dynamic temperature distributions.

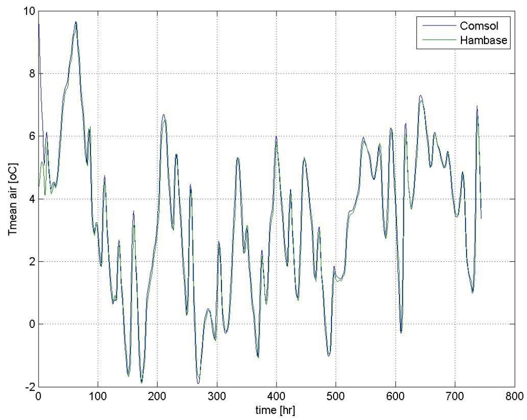

Figure 3: The verification FEM vs BES (blue: COMSOL; green: HAMBase).