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Simulating the complete HAMSTAD benchmark using a single model implemented in Comsol

A.W.M. van Schijndel*, S. Goesten, H.L. Schellen

Eindhoven University of Technology, P.O. Box 513 5600MB Eindhoven, Netherlands

Abstract

Benchmarks are important tools to verify computational models. In the research area of building physics, the so-called HAMSTAD (Heat, Air and Moisture STAnDardization) project is a very well known benchmark for the testing of simulation tools. In contrast to earlier work where we used multiple (Comsol) models, in this paper we simulated all five subtasks of the benchmark by using a single model implemented in Multiphysics software Comsol 5.2a. We conclude that the single model provides satisfactory results on all parts of the benchmark and is therefore applicable for a wide range of HAM problems.

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1. Introduction

Multiphysics tools for modeling heat and moisture transport in constructions, might encounter numerical problems. Especially the multi-layered mixed moisture transport (i.e. vapour and water) part can be tricky to solve.

In 2000, the European Union initiated the HAMSTAD (Heat, Air and Moisture STAndards Development) project on standardization procedures and certification in the field of heat, air, and moisture transport in building constructions [1,2]. In the total of five different benchmarks were developed. Amongst others van Schijndel [3,4] developed several models using Comsol to simulate parts of HAMSTAD benchmarks. Although the results were already satisfactory at that time, it did not contain all benchmarks so far. Moreover, for each benchmark a separate model was developed. With this paper, we revisit the HAMSTAD benchmarks using the latest version of Comsol (5.2a) and present a

* Corresponding author. Tel.: +31 40 247 29 57.

E-mail address: A.W.M.v.Schijndel@tue.nl

complete updated overview of all five benchmarks *for a single model*. The latter is the most important innovation. The main benefit is that this single model can be used for a wide range of HAM problems. Due to space limitations, only the most important results are included in this paper. We refer to HAMLab webpage [6], where all models and a detailed reports [5,7] are available.

2. The physics behind the model and implementation of the material properties and boundary functions

The heat and moisture transport can be described by the following PDEs using LPc as potential for moisture transfer.

$$\begin{aligned} C_T \frac{\partial T}{\partial t} &= \nabla \cdot (K_{11} \nabla T + K_{12} \nabla LPc) \\ C_{LPc} \frac{\partial LPc}{\partial t} &= \nabla \cdot (K_{21} \nabla T + K_{22} \nabla LPc) \end{aligned} \quad (1)$$

With:

$$\begin{aligned} LPc &= {}^{10} \log(Pc) \\ C_T &= \rho \cdot c \\ K_{11} &= \lambda \\ K_{12} &= -l_{iv} \cdot \delta_p \cdot \phi \cdot \frac{\partial Pc}{\partial LPc} \cdot Psat \cdot \frac{M_w}{\rho_a RT}, \\ C_{LPc} &= \frac{\partial w}{\partial Pc} \cdot \frac{\partial Pc}{\partial LPc} \\ K_{22} &= -K \cdot \frac{\partial Pc}{\partial LPc} - \delta_p \cdot \phi \cdot \frac{\partial Pc}{\partial LPc} \cdot Psat \cdot \frac{M_w}{\rho_a RT}, \\ K_{21} &= \delta_p \cdot \phi \cdot \frac{\partial Psat}{\partial T}, \end{aligned} \quad (2)$$

Where t is time [s]; T is temperature [°C]; Pc is capillary pressure [Pa]; ρ is material density [kg/m³]; c is specific heat capacity [J/kgK]; λ is thermal conductivity [W/mK]; l_{iv} is specific latent heat of evaporation [J/kg]; δ_p vapour permeability [s]; φ is relative humidity [-]; Psat is saturation pressure [Pa]; $M_w = 0.018$ [kg/mol]; $R = 8.314$ [J/molK]; ρ_a is air density [kg/m³]; w is moisture content [kg/m³]; K is liquid water permeability [s]. The implementation of material and boundary functions was done by using MatLab. These functions are used to convert measurable material properties such as K, φ, δ_p and λ which are dependent on the moisture content into PDE coefficients which are dependent on the LPc and T. This is schematically shown in Figure 1 Left. For each material and at each point the vapour pressure can be calculated using similar corresponding functions.

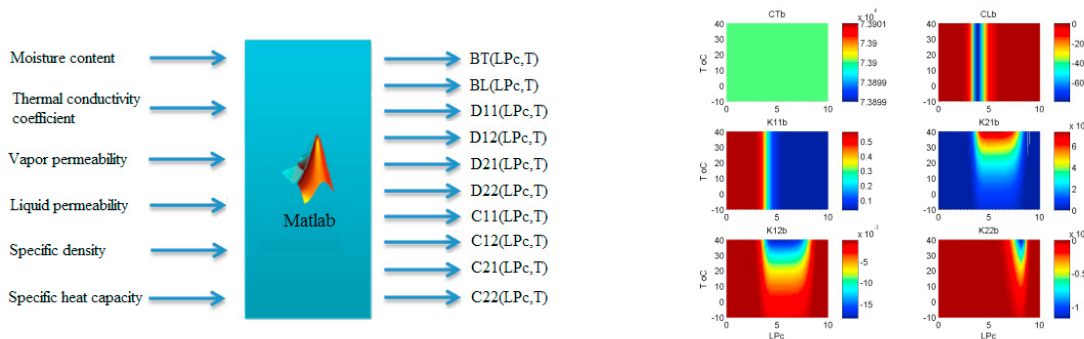


Fig. 1. Left: The conversion from measurable material properties into PDE coefficients. Right: PDE coefficients C_T , C_{LPc} , K_{ij} as functions of LPc and T calculated from the provided HAMSTAD benchmark no.1 material properties for insulation

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