A New Educational Concept for Whole Building Heat, Air & Moisture Simulation

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ABSTRACT

The objective of the paper is to present a new educational concept for improving the accessibility to whole building Heat, Air & Moisture (HAM) simulation models developed in the simulation environment HAMLab. We provided a library of buildings, including the default performances of the buildings themselves, on a website. Students can select the most appropriate building, adapt the input parameters, simulate and evaluate the results. In case a higher resolution is required, two steps explain how to implement respectively advanced controllers and HAM details. The following results are presented: First, a brief overview of the types of buildings, already present at the website; Second, a short description of a developed guideline; Third, the use of the guideline by a case study and Fourth, evaluation of the results. It is concluded that the accessibility to the whole building HAM simulation model HAMLab has been improved by the new concept. Moreover, the website and all HAMLab models are public domain so that every Matlab-user has access to state-of-art HAM building models.

KEYWORDS

Simulation, HAM, modeling, education,

1. INTRODUCTION

It is widely accepted that simulation can have a major impact on the design and evaluation of building and systems performances. Also, the modeling and simulation of whole building heat, air and moisture (further-on called HAM) responses in relation with human comfort, energy and durability are relevant. The International Energy Agency (IEA) has confirmed this relevance by organizing an Annex project that will focus on a holistic approach of HAM transfer between the outside, the enclosure, the indoor air and the heating, ventilation and air-conditioning (HVAC) systems (IEA Annex 41 2006). In this research project the Heat, Air and Moisture Laboratory (HAMLab 2006) is one of the 14 participating simulation tools. An important objective of the mentioned Annex 41 is technology transfer, i.e. the Annex 41 results should be accessible to everybody outside the scientific community. HAMLab is developed using the standard scientific computational tool MatLab/SimuLink. The models developed in this project are research oriented and are not aimed for education and training. The objective is to develop and implement a new educational concept for improving the accessibility to whole building HAM simulation models developed in HAMLab. The methodology was: First, we provided a library of buildings, including the default performances of the buildings themselves, on a website. Second, students can select the most appropriate building, adapt the input parameters, simulate and evaluate the results. At this stage, the students obtain hourly-based values of the indoor climate in each zone of the building. Usually this resolution is sufficient for most educational design projects. Third, in case a higher resolution is required, two more steps explain how to implement more advanced controllers and HAM details. The next results will be presented in more detail: Section 2 presents the current contents of the website. Section 3 provides a short description of the developed guideline and the use of it by a case study; Section 4 presents an evaluation of the results.

2. THE HAM CASES WEBSITE

At this moment the website (HAMcases 2006) is under construction. Currently available on the website are a link to the HAMBase and three demonstration projects by students (office building, dwelling and church). More buildings and english descriptions will be added in near future.

3. GUIDELINE AND CASE STUDY

This Section provides a step-by-step guideline. Each step is divided into a (*D*)escription and (*R*)esult Section and requires more knowledge of the building and systems details as well as the modeling environment. After each step, the simulation results should be evaluated. If the results are not satisfactory due to oversimplification of the model(s) go the next step. Furthermore, we apply the guideline for the following case study (van Schijndel et al. 2003b). In the Walloon Church in Delft a monumental church organ is present which has been restored in the spring of 2000. To prevent causing damage to the organ again, the indoor climate has to meet certain requirements. The main objectives were: (I) Development of a integrated model for simulating the indoor climate, the detailed moisture distributions of wood and the HVAC system. (II) Evaluation of the current setpoint operation strategy of the HVAC system of the Walloon church. (III) Development and evaluation of new strategies including RH control.

Step 0: Selection of a similar building.
(*D*) The first step neither requires Matlab nor specific knowledge of modeling parameters. At the HAMcases website, a web base application provides simulated results of the indoor climates of several building types. For each building type graphical output is presented including time series and statistical information of the temperature, relative humidity (Rh), thermal comfort, heating, cooling and (de)humidification in each zone for a specific period (year, month week). A building should be selected that is most similar to the design.
(*R*) Select a church from the HAMcases website (and download the HAMBase input mfile.

Step 1: Editing/simulating the HAMBase model
(*D*) This step requires software package Matlab and basic knowledge of HAM parameters of the building. After downloading HAMLab (public domain), the selected building of step 0 can easily be simulated by typing the name of building type at the Matlab prompt. The same results as presented at the website occur. The input file is a text file that can be edited to match the design. The model parameters are explained in the same file. The HAMBase model facilitates default systems and controllers. If it is necessary to model more details of the systems and controllers go step 2.

(*R*) Edit the input mfile, using the details of the geometry, material properties and boundary conditions of the church model as provided by (Schellen 2002). The hourly simulated air temperature and relative humidity of one month (December 2000) inside the church is presented in figure 1, together with measured values. We want to include a more detailed controller and a detailed moisture transport model, so we proceed with the next step.

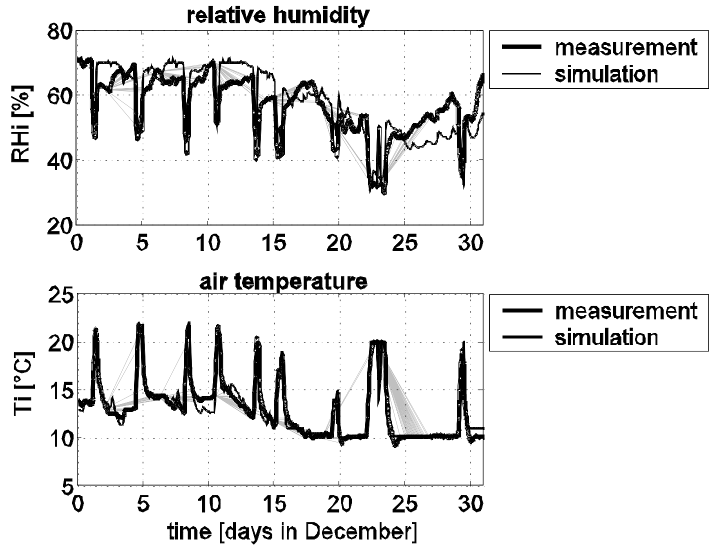

Figure 1. Validation of the HAMBase model. The measured and simulated air temperature and relative humidity of one month (December 2000) are compared.

Step 2: Including detailed systems and controllers

(*D*) This step also requires: SimuLink, included in MatLab, some experience with this tool and basic knowledge of systems and controllers. It is very easy to export the HAMBase model to a SimuLink block. The input/output structure of this block is as follows: for each zone the input consists of a heat and moisture source and the output consists of the air temperature, comfort temperature and Rh. The exported SimuLink model simulates a free-floating situation of the building, where all systems and controller settings of the original MatLab model are ignored. Detailed systems and controllers models can be added in SimuLink in order to simulate a controlled situation of the building. Note that also models mentioned in Step 3 can be used in this stage. If it is necessary to model more details of the constructions or airflow go step 3.

(*R*) After exporting the HAMBase model to SimuLink, a church building model block, with the input/output structure for the church model (containing 2 zones: church and attic), appears in SimuLink The HVAC system is modeled by standard blocks of SimuLink as shown in figure 2.

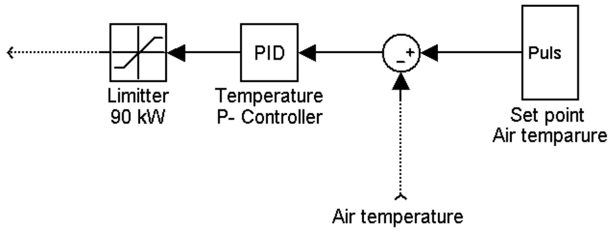

Figure 2. The HVAC system and controller model in SimuLink

The set point of the air temperature is generated by a pulse block with properties: Period: 1 week, start time 04.00 o'clock Sunday, duration: 12 hours, lower value: 10 ^oC higher value 20 ^oC. The input of the PID controller consists of the set point minus the actual air temperature. The settings of the PID controller are: P = 10^7, I=D=0, so in this case it acts like a proportional controller. The output of the controller is limited between 0 en 90 kW. In order to include a detailed moisture transport model, we proceed with step 3.

Step 3: Including detailed HAM/Airflow models

(*D*) This step requires: Beside the Matlab software, a separate toolbox ComSol, experience with this tool and specific knowledge of PDE modeling. To integrate HAM/Airflow models into SimuLink, the next sub-steps are required: (a) Select a ComSol model that is most suitable for the problem. Inspiring models can be found at the ComSol and HAMLab websites; (b) adapt the model, start simulations and evaluate the simulation results. If satisfactory, (c) export the ComSol model to SimuLink using the standard export facility or using S-Functions as shown in (van Schijndel 2003d).

(*R*) Although ComSol is well equipped for solving complex building physics problems (van Schijndel 2003a), the ComSol model in this application is quit simple. The emphasis of this study lies not on the complexity of the individual models but on the complexity of the combination of models. The moisture transport is assumed to be 1D, dominated by vapor transport and is further explained in (van Schijndel et al. 2003b). This ComSol model is exported to SimuLink using the standard export facility. In figure 3 the results of a validation study by Schellen (2002) is presented.

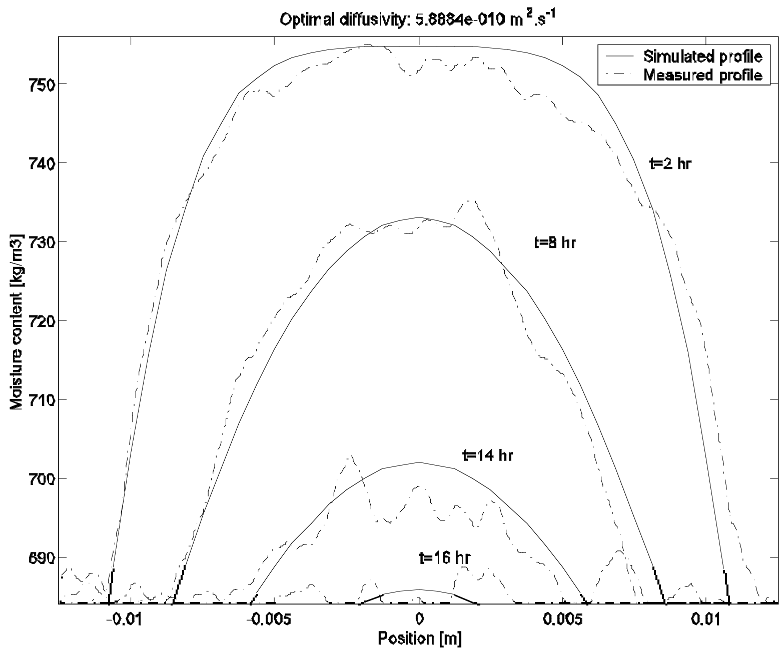

Figure 3. Simulation and measurement of moisture profiles in case of drying of a cylinder of wood (diameter 25 mm) by a step in relative humidity from 85% to 35%.

The connecting of all models, shown in figure 4, finalizes the complete model

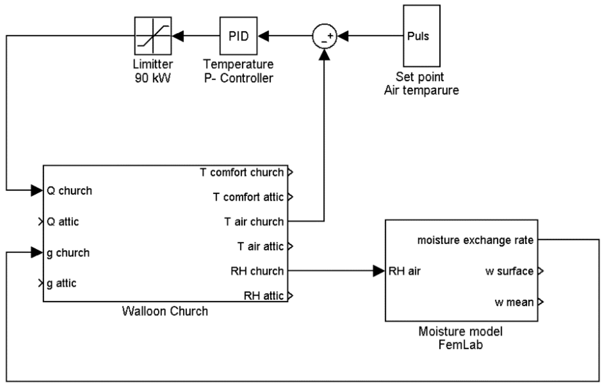

Figure 4. The complete model in SimuLink

Step 4: Evaluation

(*D*) If the final model is ready, the simulation results should be evaluated and if necessary the modeling parameters and/or the models themselves should be modified.

(*R*) The model shown in figure 4 is used to study the moisture content near the surface and the drying rate (defined as the rate of change of moisture content near the surface) for two cases: a) no heating and b) full heating capacity, i.e. no limitations in air temperature or relative humidity changing rate. Figure 5 shows the simulated indoor air temperature, relative humidity and moisture content of the wood near the surface for the two cases. The simulation period is one month. The church is heated four times a month.

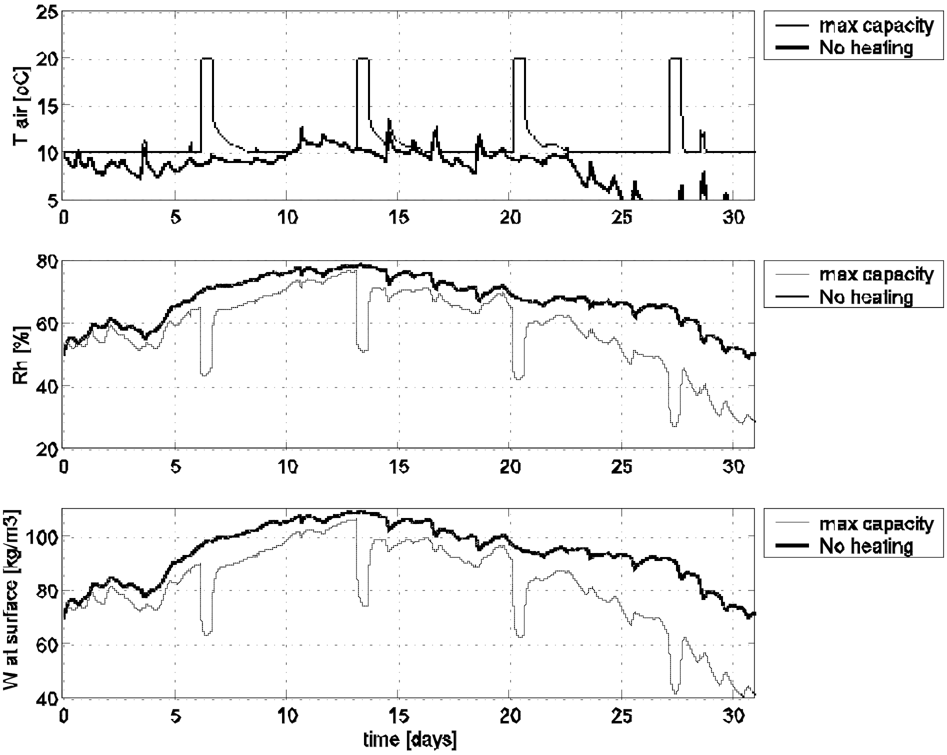

Figure 5. The simulated indoor air temperature, the relative humidity and the moisture content of the wood near the surface. The simulation period is December 2000.

From figure 5 the difference in peak drying rate for the two cases, no heating and full heating capacity, is very clear: The peak drying rate in the case of full heating is of order 100 times bigger than in the case of no heating. These peaks can cause drying induced stresses and have to be minimized to prevent possible damaging of the wood.
In (van Schijndel et al. 2003b) two more advanced control strategies were simulated. The first type is a limited indoor air temperature changing rate. The second type is a limited indoor air relative humidity changing rate. Recommendations from international literature suggest that a changing rate of 2 ^{o}C/hour will preserve the interior of churches The study shows that a limitation of indoor air temperature changing rate of 2 ^{o}C/hour can reduce the peak drying rates by a factor 20. A limitation of the relative humidity changing rate of 2 %/hour can reduce the peak drying rates by a factor 50. The latter has the disadvantage that the heating time is not constant. The 2 ^{o}C/hour control strategy was implemented in the real church. Evaluation after a year showed that the operation strategy functioned satisfactory.

4. DISCUSSION

The case study shows that in order to evaluate peak drying rates in monumental objects (i.e. church organs) for several control strategies of the heating systems, it is essential to use an similar integrated HAM model as presented in this paper. Furthermore, the provided guideline and the application of it in the form of a case study, might improve the accessibility of the HAMLab models for design.
So far the use of the website is very limited due to the absence of a library of buildings with English descriptions. These essential features will be added in near future.

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