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Hygric property determination based on dynamic measurement techniques and metaheuristic strategies

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Abstract

To speed up the hygric characterization of building materials dynamic measurements can be applied; the data-processing of their experimental output can however be challenging. This paper presents the applicability of a metaheuristic, in the current study the Grey Wolf Optimizer, for the estimation of the vapour transport properties based on a fictitious dynamic sorption experiment. A profile likelihood analysis is applied to check the identifiability of the parameters and to define the likelihood-based confidence intervals. For the estimation, two approaches are followed: (1) the estimation of physical parameters and (2) the estimation of non-physical parameters in a parametric function. Both approaches result in a close agreement with the target values. Though, not all parameters in the parametric function are practically identifiable and correlation is detected. Furthermore, the definition of the search space for the parameters in the parametric function may require some knowledge on the typical course of such a function.

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Keywords: Hygric properties, dynamic experiments, metaheuristics, Grey Wolf Optimizer, identifiability, parametric function

1. Introduction

The moisture storage and transport characteristics of building materials are crucial input parameters in building simulation models. The characterization of those properties is however time consuming. Dynamic measurements could speed up the characterization process; the data-processing of the experimental output is however much more challenging. This study shows the applicability of dynamic measurements in combination with a metaheuristic strategy to characterise the vapour transport properties of building materials. Metaheuristic strategies are stochastic inverse

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methods that explore the search space in order to find near-optimal solutions (in this case the material properties) of an optimization problem (in this case defined by an objective function that indicates the difference between experimental and modelled output). In general, metaheuristics result in a higher computational cost compared to gradient-based techniques; though, their higher flexibility and stochastic sampling strategy might be beneficial in many optimization problems, especially when dealing with non-linear problems.

In the current study, a metaheuristic, called Grey Wolf Optimizer (GWO), is tested on a numerical benchmark, i.e. a dynamic moisture sorption experiment (Section 3). A profile likelihood analysis is applied to define the identifiability and the confidence intervals of the different parameters. The estimation of physical parameters as well as non-physical parameters in a parametric function is performed. Section 2 first reiterates the general principles of parameter estimation together with the global working mechanism of the Grey Wolf Optimizer, and adds the background on identifiability and the profile likelihood approach. In Section 4 the main findings are discussed and the main conclusions are drawn.

2. Methodology

2.1. General principle

To estimate the material properties based on dynamic measurements, the workflow shown in Fig. 1 is followed. In a first step, a hygric experiment (Part A) is performed. Next, the experimental boundary conditions of this experiment are imposed to a hygric model incorporated in a parameter estimation model (Part B). Note that this input is the observed input, which may – due to e.g. sensor inaccuracies – differ from the actual experimental boundary conditions. In the parameter estimation model, the output obtained based on the hygric model is compared to the measured output. Also this output may be subject to measurement noise. The comparison between both outputs is made based on an objective function. The metaheuristic algorithm analyses different candidate solutions. Next, the achieved information is used to suggest other candidate solutions that maximize the likelihood (or minimize the residuals between measured and simulated output) described by the objective function. In the current study, this optimization is performed based on the Grey Wolf Optimizer (GWO).

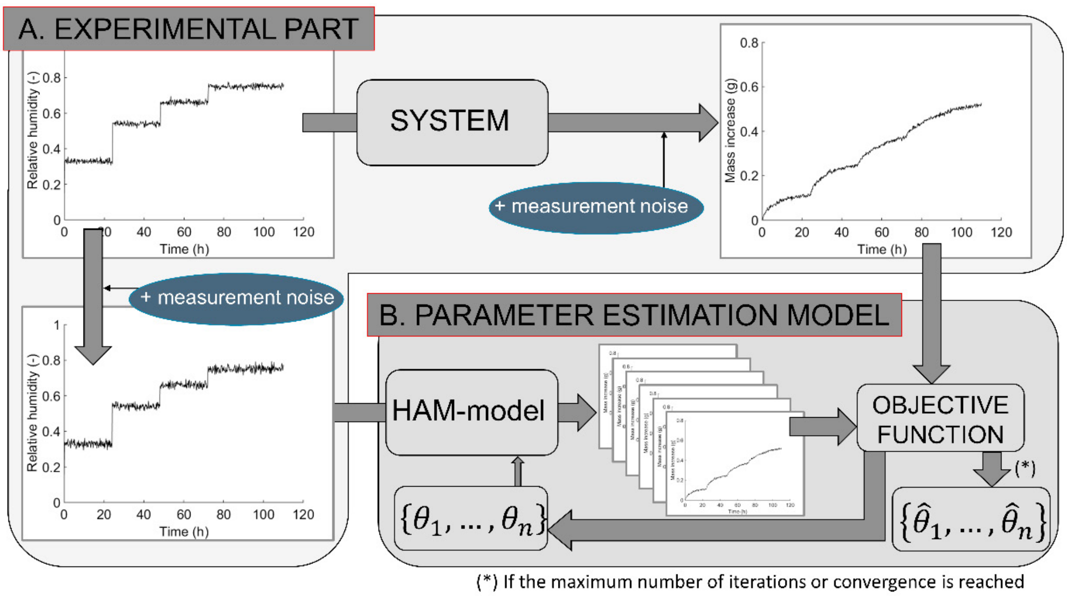

Fig. 1. schematic overview of the parameter estimation workflow.