Lucerne University of
Applied Sciences and Arts

HOCHSCHULE
LUZERN

Technik & Architektur
FH Zentralschweiz

MSE | MASTER OF SCIENCE IN ENGINEERING

Master-Thesis Engineering, Fachgebiet Energy and Environment

One-Dimensional Modelling of Heat and Mass Transfer with Variable Material Properties

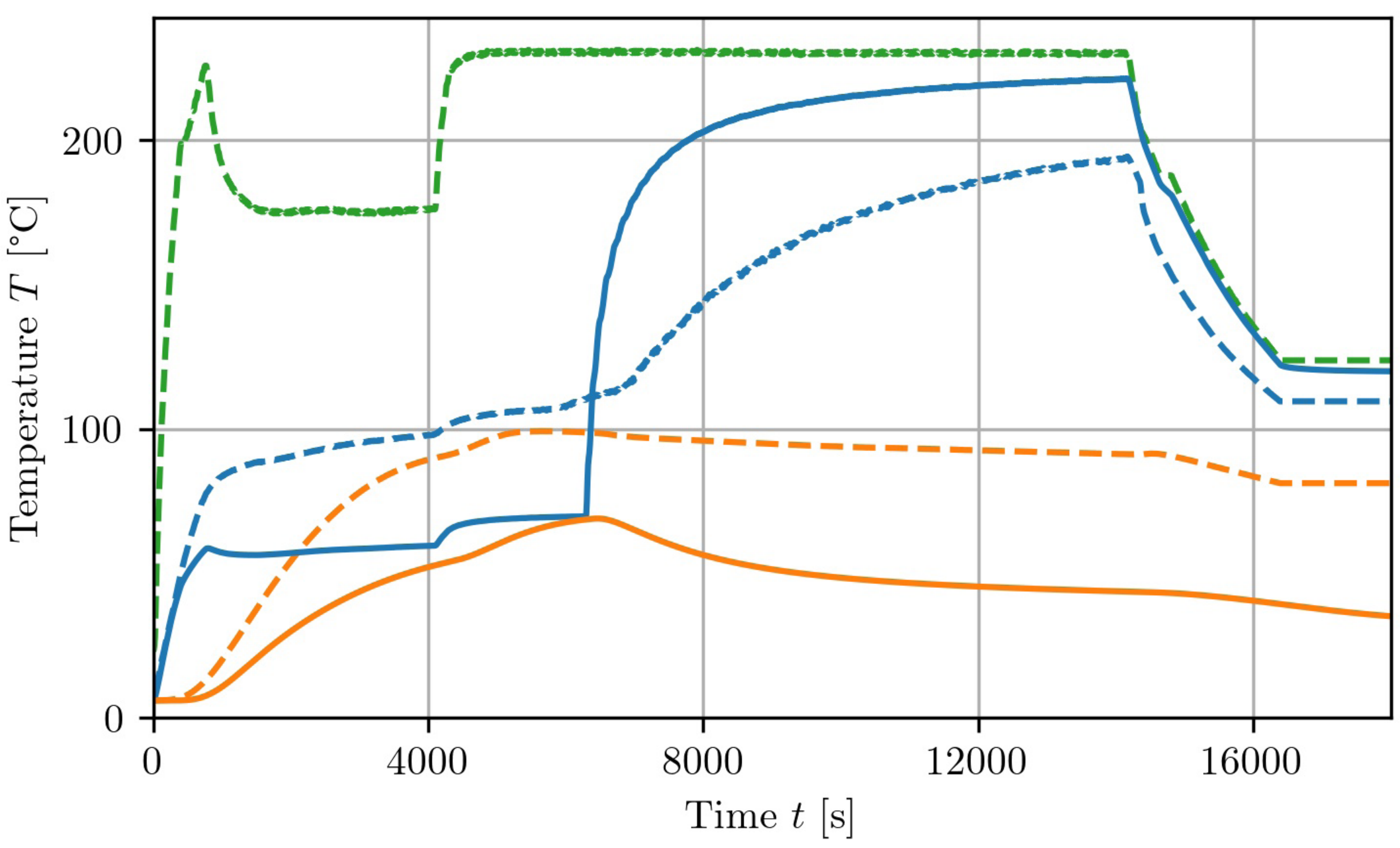

Figure 1: Comparison between experimentally determined and simulated temperatures of the rigid porous media. Oven temperature (- - -), measured (- - -) and simulated (——) surface temperature, measured (- - -) and simulated (——) centre temperature.

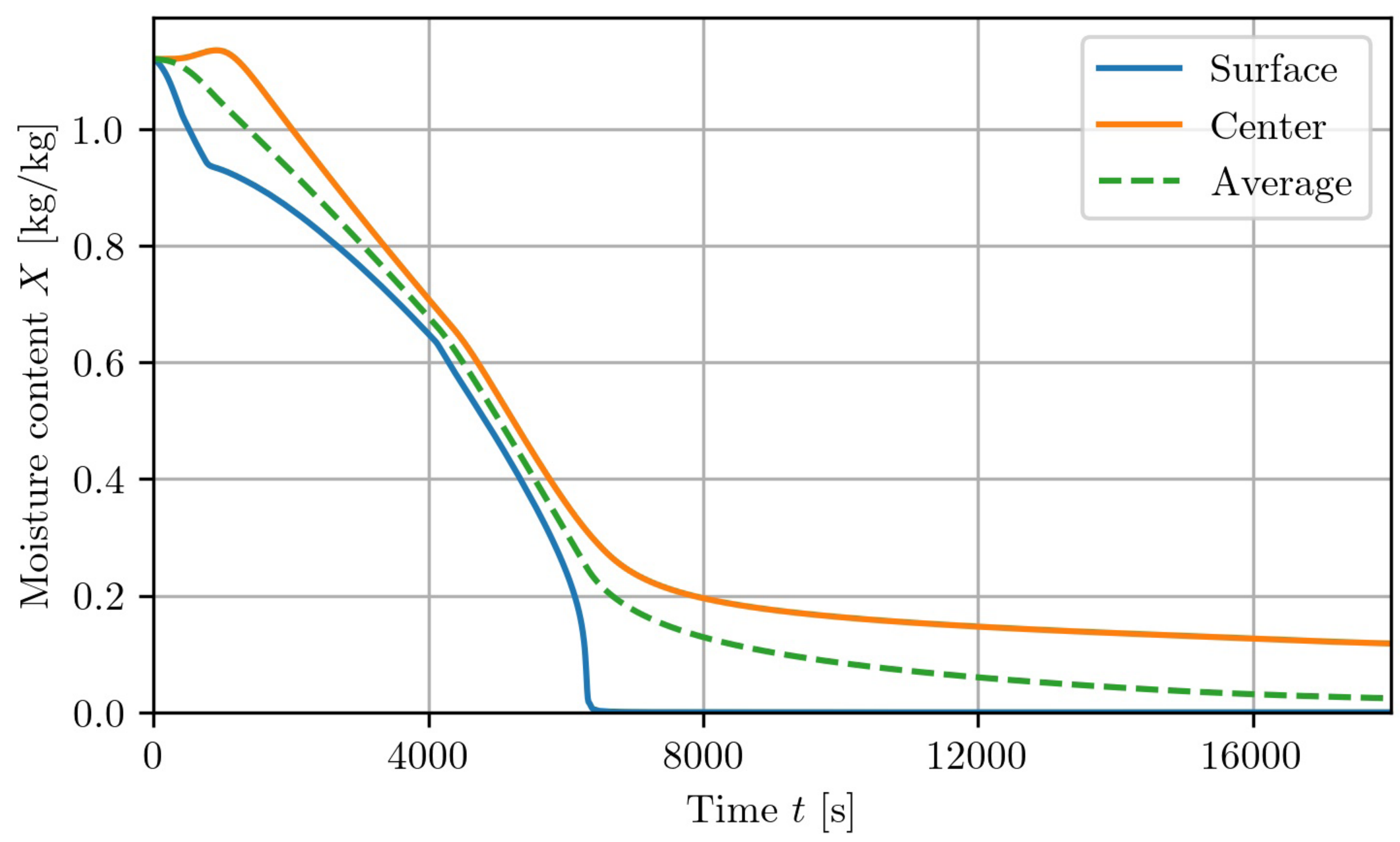

Figure 2: Simulated temporal development of the moisture content X of the rigid porous media.

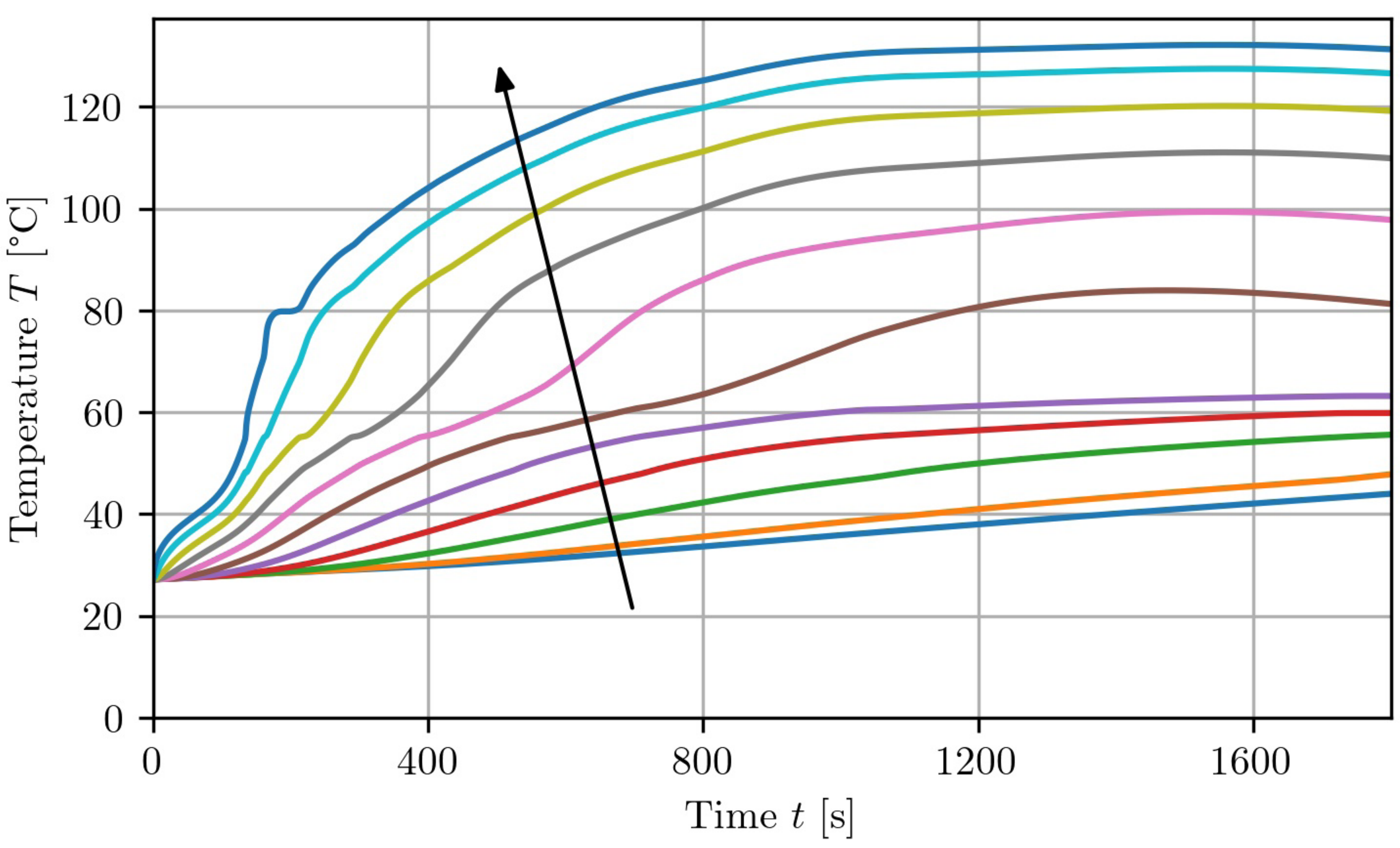

Figure 3: Temporal development of the temperature T in the different cells of the deformable porous media. The arrow points from the first cell (bottom) to the last cell (top).

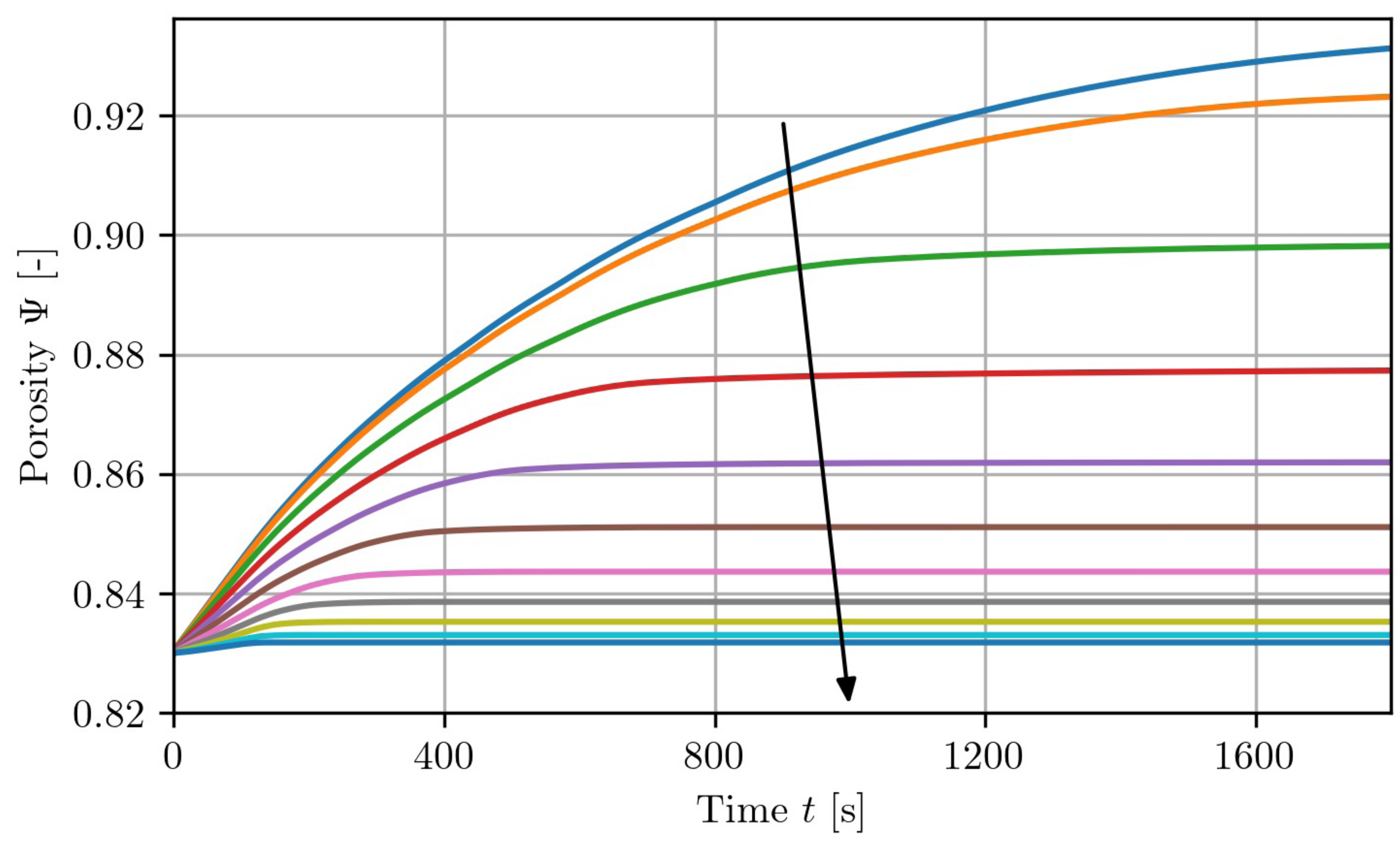

Figure 4: Temporal development of the porosity Ψ in the different cells of the deformable porous media. The arrow points from the first cell (bottom) to the last cell (top).

Problem Statement

Simulation models describing the baking process are nowadays usually based on mathematical models supported by empirical correlations. Thus, these models can only be used in the already known area where the correlations are valid. A physical modelling of all relevant process phenomena in the baking oven and especially of the baking product avoids this limitation, but is extremely demanding and computationally intensive.

The goal of this master thesis is to develop a 1-D model (1-D in space and time) for a baking product, which represents the baking process based on physical modelling. The model should be as universal as possible, i.e. different material compositions, crust formation (multi-layer model), phase changes and volume changes should be taken into account.

Approach

A one-dimensional model for deformable porous media, respective baking products, has been developed. In a first step, a model for rigid porous media was developed, which then served as the basis for the deformable porous media. Among other things, this model includes a CO_2 production term which, in combination with a viscoelastic solid, causes deformations in the medium. The obtained models were then discretized using the finite volume method and implemented in Modelica®. Afterwards, the model for the rigid porous media has been validated with a brick. The model for deformable porous media could not be fully implemented, so only preliminary results were presented.

Results

The validation of the rigid porous media, with a brick, has shown that the temperature profiles (Figure 1) can be reproduced qualitatively. At the beginning however, the model reacts too strongly to the temperature reduction of the oven air. The simulated moisture content (Figure 2) decreases in the first section rapidly. In the second section, however, it decreases slowly.

For the deformable porous media, no validation could be carried out, only preliminary results for bread were presented. Figure 3 shows that it is not possible to distinguish between two sections, as was the case with the brick. However, it could still be shown that the CO_2 generation leads to an increased porosity (Figure 4) and thus to an increase in volume.

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