ČESKÉ VYSOKÉ UČENÍ TECHNICKÉ V PRAZE

fakulta jaderná a fyzikálně inženýrská

Prof.Dr.Ing. Michal BENEŠ
katedra matematiky
fakulta jaderná a fyzikálně inženýrská
ČESKÉ VYSOKÉ UČENÍ TECHNICKÉ V PRAZE
Trojanova 13
120 00 PRAHA 2

Tel.: *(420-2)-2435 8540*
Fax: *(420-2)-2491 8643*
E-mail: *michal.benes@ fjfi.cvut.cz*

Scientific board
FJFI ČVUT Praha

Ref: Zak/18

Prague, September 27 2018

Supervisor's report

PhD student: Ing. Alexandr Žák

Thesis: "Mathematical Models of Phase Transitions in Porous Media"

The submitted thesis has been prepared within the framework of the research carried out in the Department of Mathematics, Faculty of Nuclear Sciences and Physical Engineering, Czech Technical University in Prague (FNSPE CTU) in collaboration with the Colorado School of Mines, Golden. The author deals with the solid - liquid phase transitions in porous media. The purpose of the thesis was to develop mathematical models of solidification in porous media at macroscopic and microscopic scale and to open new horizons of research related to soil thawing and freezing in the context of environmental as well as material science.

First part of the thesis explains details of motivation for the research which comes from the environmental and material science. As the description of phase transitions in porous media require knowledge from several domains of physics, next chapter is devoted to summarizing thermodynamics of multiphase systems, mechanics of porous media and conservation laws of governing quantities.

The subsequent chapter focuses on developing mathematical models of phase transitions in porous media. First, the coordinate framework is established based on Eulerian and Lagrangean systems. Then, corresponding conservation laws are formulated using a general balance law. Then, the model at macroscale is suggested which couples the energy balance with the poromechanics of saturated medium without flow. This model contains an experimentally suggested

term controlling the latent heat release and reflecting pore structure. Part of this model is analyzed mathematically.

Next, a model of phase transition at microscale is derived, which assumes a symmetric two-dimensional structure of the medium. The pore symmetry is used to estimate the phase interface curvature at each point of the pore in advance, which simplifies the model itself. Finally, a model of phase transition at microscale in a general pore geometry is suggested. Here, the phase interface is described by means of the phase-field method.

The computational chapter contains results of numerical solution of the above mentioned three models by means of the finite-element method. The author implemented equations of the models into the environment of a selected finite-element package. The weak formulation of the models is summarized in the text. The author additionally performed auxiliary computations testing the coupling of key quantities across the phase interface. From the computations, we see their quantitative as well as qualitative behavior and mutual comparison. At the laboratory scale, the author used his models to verify the conditions of particular experimental setups prepared by collaborating research teams.

The submitted thesis presents the achievements of the author in the mathematical modeling of phase transitions in porous media. I emphasize the author's original contribution in designing all three models considered in the thesis. The author so far published 3 articles directly related to the topic (1 in the Scopus indexed and 2 in the impacted journals). He several times presented his results in the international conferences (of them, the Interpore conferences are the most important) and draw attention to the given topic.

The PhD study of the candidate made part of the cooperation between the CTU in Prague and the Colorado School of Mines, Golden, where he is a frequent visitor. His work contributed to the design of experiments carried within the common project at the Faculty of Civil Engineering, CTU. He actively participated in the educational process in the Department of Mathematics, supervised students, and has been guiding exercises in basic courses. He also held the English taught course in variational methods and finite elements for the Japanese exchange students.

During the work on the topic, the candidate proved very high ability to independently master and develop problems of interdisciplinary

and multi-physics character. Through his work, the topic of phase changes accompanied by structural changes has become integral part of the research activities within the collaborative work of CTU FNSPE and Colorado School of Mines Golden. Respecting the above mentioned facts, I have all reasons to recommend the candidate to the committee for the defence of the degree Doctor of Philosophy. As the thesis opens new directions of the research of high importance and some parts of it are still worth of publishing, I suggest to postpone publishing the thesis for 3 years from the defense date in agreement with Sec. 47b) of the Act 111/1998 coll. on Higher Education and on Changes in and Amendments to some other Acts.

prof.Dr.Ing. Michal Beneš

(supervisor)