Review of the doctoral thesis

Author: Ing. Ondřej Pártl

Title: Mathematical Modelling of Non-Isothermal Compositional Compressible fluid Flow in Porous Medium and above Its Surface

Title in Czech: Matematické modelování neizotermického proudění směsi stlačitelných tekutin v porézním prostředí a nad jeho povrchem

Supervisor: prof. Dr. Ing. Michal Beneš

Field / programme: Mathematical Engineering / Application of Natural Sciences

School: Czech Technical University in Prague, Faculty of Nuclear Sciences and Physical Engineering, Department of Mathematics

General overview

The thesis develops mathematical models and numerical schemes for multi-component fluid flow in and outside of a porous medium. It is divided into an Introduction and four main chapters. There is no concluding chapter and each of the chapters or sections contains its own conclusion. The summary of the main results and the outlooks for the future are presented in the Introduction. The thesis also contains a list of symbols, three appendices and a list of bibliography.
The structure conforms to the typical structure of a doctoral thesis and of scientific texts in general. The division into chapters is logical. The existing state-of-the-art is presented with adequate citation of work by previous authors. Specifying a chapter could help the curious reader when following the references to books for definitions.
The presentation is clear, the equations, figures and tables are properly annotated and referenced in the text. The list of symbols provided is of great help when interpreting the numerous equations. The thesis shows a good command of the English language by the author and I was not able to find any mistakes.

The topicality of the thesis

The area of the research is very topical. The topic of very complex multi-component fluid flow and especially coupling of the outer and the porous media flow is a very active area of research with industrial applications and also geophysical applications (soil physics in the vadose zone, air pollution from waste rack dumps, etc.). The articles from which the thesis stems were published in prestigious international peer-reviewed journals.

The methods, results and the novelty

The main results of the thesis are mathematical models of the non-isothermal flow of gas with multiple components within and outside of a porous medium, including the interface coupling conditions, a series of numerical schemes for their solution and en extensive set of numerical tests. In each case, the existing models and schemes are properly cited and the novel aspect is clearly distinguished. The approaches selected, namely the equations from which the mathematical model was developed and the finite element and the control volume method are appropriate for the task.

Fulfilment of the aims of the thesis

The seven research goals of the thesis were laid out in the Introduction in section 1.5 and the achieved results are summarized in section 1.6. All research goals were fulfilled successfully.

Comments and questions

I have only a small number of remarks and comments. None of them can significantly affect the overall evaluation of the thesis.

1. Do the assumptions about the nature of the porous medium (sect. 2.1.2) allow for pores that are not interconnected with other pores?

2. A sufficient amount of existing literature is introduced in section 2.2.1 but in section 2.2.2 it is not clearly distinguish which parts come from this literature and which are new. In the same section, is the tilde over v intended in eq. 2.66?

3. Do the numerical scheme (especially the coupling condition) and the software implementation allow the boundary between the porous medium and the free flow area to have an arbitrary angle or to be curved?

4. Were the experiments by P. Schulte used in section 4.1.3 published or were the results received as a private communication?

5. In pictures 4.10 and 4.11 it is hard to see the positions of points in the 3D space. Some vertical guiding lines or connections of the points in the grid would help. The difference in the orientation of the two graphs may add to the confusion.

6. In test in section 4.2.1, I would expect for the free-flow in such dimensions and velocity to develop a boundary layer near the porous medium. Was there any boundary layer developing in the numerical solution and if not, how is it suppressed?

7. Was the solution of the momentum equation with a drag force inside of the porous medium, instead of the Darcy equation, considered (possibly unifying the mathematical model inside and outside)? Would that be feasible with the present approach?

Conclusion

The thesis is a very good contribution to the area of porous media flows. It fulfils all requirements for a doctoral thesis and I recommend it to be accepted for the defence.

In Prague 4.11. 2019

Mgr. Vladimír Fuka, PhD.
Katedra fyziky atmosféry
MFF UK