Posudek práce

předložené na Matematicko-fyzikální fakultě
Univerzity Karlovy

☐ posudek vedoucího ☑ posudek oponenta
☐ bakalářské práce ☑ diplomové práce

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Název práce: Modelling of advection-diffusion processes in liver tissue
Studijní program a obor: Fyzika, Matematické a počítačové modelování ve fyzice
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Jméno a tituly oponenta: RNDr. Ondřej Souček, Ph.D.
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Odborná úroveň práce:
☑ vynikající ☐ velmi dobrá ☐ průměrná ☐ podprůměrná ☐ nevyhovující

Věcné chyby:
☑ téměř žádné ☐ vzhledem k rozsahu přiměřený počet ☐ méně podstatné četné ☐ závažné

Výsledky:
☐ originální ☑ původní i převzaté ☐ netriviální kompilace ☐ citované z literatury ☐ opsané

Rozsah práce:
☐ veliký ☑ standardní ☐ dostatečný ☐ nedostatečný

Grafická, jazyková a formální úroveň:
☑ vynikající ☐ velmi dobrá ☐ průměrná ☐ podprůměrná ☐ nevyhovující

Tiskové chyby:
☑ téměř žádné ☐ vzhledem k rozsahu a tématu přiměřený počet ☐ četné

Celková úroveň práce:
☑ vynikající ☐ velmi dobrá ☐ průměrná ☐ podprůměrná ☐ nevyhovující

Slovní vyjádření, komentáře a připomínky oponenta:

The presented thesis deals with the goal of modeling transport phenomena for chemical compounds within the liver tissue. Specifically, it focuses on the process of tracer transport within a three-compartment system consisting of the blood vessel, hepatocytes and the bile system. Each of the three systems possesses a distinct complexity and the three systems interact with each other through two types of active interfaces: the blood-hepatocyte and the hepatocyte-bile interface.

The thesis consists of four chapters. The first chapter provides a summary of the physiological context and presents the motivation behind the selection of the studied subsystem. Moving on to the second chapter, which forms the core of the modeling part, an analysis of the compartments within the studied subsystem is presented. This chapter is quite involved and includes a model reduction analysis for the class I mixture formulation of 3D multicomponent flow within the blood system, as well as of the interaction between the blood vessel and the hepatocyte walls, considering processes such as active transport and facilitated diffusion. The resulting form of the reduced advection-reaction-diffusion equations shows some variations compared to the standard literature. The author thoroughly discusses the origin of these differences and their relationship to the more conventional setting found in the literature. This approach is also applied to the bile-hepatocyte system, while the transfer across the hepatocyte is modeled in a simplified, pure-reaction-type manner. At this stage, it is important to acknowledge the author's deep understanding of the biochemical background of the problem, which enabled him to successfully execute and provide insightful comments on each step of the presented model reduction.

The third chapter is devoted to several proof-of-concept numerical simulations of the reduced compartment system, considering a prescribed fluorescent tracer input into the blood system. The primary objective here is to evaluate the influence of key model parameters in determining the dominant tracer transport regime. The numerical implementation was developed "from scratch"in Python, without relying on existing numerical libraries, with the intention of enabling the seamless integration of the methodology into larger code frameworks. Lastly, in the concluding chapter, potential generalizations of the derived reduced model system are examined, along with the prospects of its application within a broader multi-scale, multi-component model of liver tissue.

The presented thesis demonstrates the author's ability to address a complex biophysical problem, identify the primary physical phenomena involved, and develop a meaningful initial 1D-0D-1D approximation that allows for testing basic assumptions against experimental data. Given the high complexity of the problem, certain sections of the exposition may be somewhat concise. Specifically, the description of the numerical implementation could have been more detailed, and a slightly improved explanation of the double perfusion model used to describe the mean flow in the bile and blood systems would be appreciated.

Apart from those minor points, I cannot help but appreciate the author's courage in delving into a highly complex and interdisciplinary problem. I congratulate them on successfully simplifying it to a form that allows for meaningful application of numerical techniques in studying the problem. In my opinion, the thesis fully meets all the necessary requirements, and I highly recommend acknowledging it as a diploma thesis.

Případné otázky při obhajobě a náměty do diskuze:

1. Could you kindly provide a few additional details regarding the double perfusion model introduced in section 2.4.1? This model pertains to the flow of blood and bile and was employed to determine the average velocities of both substances. Additionally, could you briefly explain the origin or basic concept behind the system 2.27?

2. Could you comment briefly on the stability and accuracy of your numerical implementation? What are the main difficulties you have encountered and what do you consider to be a potential bottleneck regarding generalizations to higher dimensions?

3. What will be, in your opinion, the next step in the development of the more general model?

Práci:
☑ doporučuji
☐ nedoporučuji
uznat jako diplomovou.

Navrhuji hodnocení stupněm:
☑ výborně ☐ velmi dobře ☐ dobře ☐ neprospěl

Místo, datum a podpis oponenta: Ondřej Souček

Praha, 31. května 2023