Hochschule
Augsburg University of
Applied Sciences

Fakultät für
Maschinenbau

External Review Report on Doctoral Thesis

SIMULATIONS OF PHOTOBIOREACTORS FROM HYDRODYNAMICS AND MASS TRANSFER POINT OF VIEW

Institute: Institute of Process Engineering
Branch: Design and Process Engineering
Doctoral student: Ing. Miroslav Rebej

Summary evaluation of the dissertation:

The thesis treats the mathematical modeling of a microalgae cultivation vessel based on multiphase flow simulation of the photobioreactor process by integrating the principles of mass transfer in the reactor's hydrodynamics. The author provides a detailed literature review that introduces in the numerical modelling of multiphase flows and its application in the field of photobioreactors. Challenges in numerical modelling of flow mechanism in photobioreactors are pointed out, results for different model approaches are presented and discussed.

The numerical work is companioned by laboratory experiments. Validation data were gained from two reactor types, that where built up and operated for a couple of different operating conditions.

The work provides in overall a systematical approach, a clear structure, a focused analysis and consistent conclusions. The topic of the thesis is discerning, the amount of work (simulation and experimental part) comprehensive. The scientific requirement of a doctoral thesis is fulfilled.

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Opponent's statement in accordance with the current requirements of the study and examination regulations:

a) Modelling of photobioreactors is with regard to the complex coupling of physical, chemical and biological phenomena an ambitious topic. The dissertation converts the topic with current methods of numerical simulation respectively experimental measurement techniques.

b) The dissertation followed the derivation of a mathematical model for a microalgae photobioreactor based on multiphase flow analyses. The target is achieved, modelling results are presented, discussed, analyzed and verified with experimental data.

c) Problem solving procedure and results of the dissertation with an indication of the specific contribution of the doctoral student:

Both the numerical part and the experimental part of the work show a systematic and structured approach. In the numerical part, the hydrodynamic model in the CFD simulations is first compared with experimental data for different operating states of the photobioreactor before integrating the mass transfer model to predict the dissolved CO_2 concentration. Finally, a radiation model is included to analyze the light intensity of the reactor process. This structure seems sensible and logical.

d) Importance for the practice or development of the field:

The dissertation provides a valuable contribution to the fundamental understanding of processes in photobioreactors that are decisive for the further development of algae cultivation. Microalgae technology has great potential in pharmaceutical products, agriculture and as a CO_2 filter for climate protection. In addition, the dissertation deepens the understanding of the processes in multiphase flows in general.

e) Formal arrangement of the dissertation and its language level:

The doctoral thesis has a sensible structure, a factual language and clear wording, graphic representations (tables, data analyses and other illustrations) are comprehensible and complement the text in an appropriate way. A relative representation of the simulation and measurement variables with regard to influencing variables (e. g. velocities, volumes, shear stresses, etc.) might have been useful for analysis purpose. The description of the numerical model set-up (net structure and quality, domain structure, boundary conditions at walls or phase boundaries, material sizes, etc.) could have been done in a bit more detail.

f) Whether the student proved/did not prove creative abilities in the given area of research and whether the work meets/does not meet the requirements for standard dissertations in the given field:

The PhD student dealt in his thesis with the challenging study of two-phase flows in photobioreactors and worked on them with current scientific methods both simulatively and experimentally. The results obtained deepen the understanding of reaction processes, thus the doctoral thesis fulfils the standard requirements in the regarded research field.
However, the fundamental analysis and discussion of the physical effects as well as the plausibility check of the obtained results (e. g. by sensitivity studies and systematic variation of model sizes on the numerical side) could have been carried out a little more intensively.

Based on the above points, I recommend the dissertation for defense and at the same time I recommend that after its successful defense, Mr. Ing. Miroslav Rebej awarded the academic title of Ph.D.

Discussion questions:

1) The data analyses were largely carried out in two dimensions. Can influences in the state and process variables in the third spatial direction be neglected?
2) For the description of turbulence modulation of the two-phase flow, the standard k-ε-Model was used. In the literature there are adaptations of the model by additional source terms or load-dependent modelling of the turbulent viscosity in particular for two-phase flow modelling. Have these approaches been considered in the simulations?

Augsburg, 03.11.22

Prof. Dr.-Ing. A. Jördening
External Reviewer