1 INTRODUCTION

A reliable model of microalgae growth is of paramount importance for photobioreactor (PBR) design, control and eventually PBR performance optimization. Nevertheless, even having an adequate lumped parameter model (LPM) of microalgae growth, another serious difficulty resides in the description of microorganism growth in a distributed parameter system (as PBR) where relevant variables, e.g., the irradiance and flow field, are distributed heterogeneously. Further, we propose a reliable methodology for PBR modeling and design which is based on integration of the CFD code ANSYS Fluent with a photosynthetic reaction kinetics. In order to validate our approach, a laboratory Couette-Taylor bioreactor, see Fig. 1, is used in a simple case study.

2 MODEL DEVELOPMENT

2.1 Governing equations of algal growth – LPM

The photosynthetic microorganisms growth is usually modeled as the steady-state light response curve (so-called P–I curve), which represents the microbial kinetics (either of Monod or Haldane type). However, in order to describe some dynamic phenomena, e.g., the flashing light enhancement (Davis, 1953), a dynamic model is needed. The phenomenological three-state model of photosynthetic factory proposed by Eilers & Peeters (1993) and further developed by Rehák et al. (2008) was chosen because it correctly describes the principal physiological mechanisms: photosynthetic light-dark reactions and photoinhibition, see Fig. 2 below.

2.2 DPM of algal growth – Eulerian (PDE based) approach

Systems with distributed parameters are described either using a Lagrangian approach, i.e., trajectories of individual microalgae within a PBR are determined and consequently the resulting irradiance history (in form of a distribution) is used as the stochastic input for an ODE (LPM), or Eulerian approach, i.e., by means of partial differential equations (PDE). Here, we describe a PBR as following Convection-Reaction-Diffusion (Dispersion) System, when for the reaction term the PSF model was used, see Cˇelikovsky ´ et al. (2010): Singular Perturbation Based Solution to Optimal Microalgae Growth Problem and its Infinite Time Horizon Analysis. IEEE Transactions on Automatic Control, vol.55, 3, pp. 767-772.

3 CONCLUSION

We proposed a model of microalgae growth consisting of three interconnected parts: (i) Convection-Reaction-Dispersion PDE, (ii) fluid-dynamic model (a CFD code), and (iii) model of irradiance distribution.

The validation of our just proposed distributed parameter model of microalgae growth (1) was made on our laboratory CTBR, see Fig. 1. CTBR performance was simulated in different flow regimes, resulting in so-called flashing light enhancement, cf. Fig. 3 in Papáček et al. (2017).

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References


