CONTINUOUS SEMI-SOLID STATE BIOREACTOR OPTIMIZATION THROUGH MODELING THE INTERNAL MULTIPHASE FLOW

Paulo Seleghim Júnior
São Carlos School of Engineering / University of São Paulo (USP)
FAPESP Process 2010/00442-5 | Term: May 2010 to Apr 2012

The increase in the use of biofuels raised new challenges to engineering problems. In this context, the optimization of chemical reactors, particularly bioreactors and photobioreactors, is crucial to improve the production of biofuels in a sustainable manner. This research work reports the development of an optimization method and its application to the design of a continuous flow bioreactor envisaged to be used in industrial fermentation processes. Mass and momentum conservation equations are simulated via CFD and specific a posteriori performance parameters, determined from the flow solution, are fed into a multiobjective evolutionary algorithm to obtain corrections to the parameters of the geometrical configuration of the reactor. This heuristics is iterated to obtain an optimized configuration vis-à-vis the flow aspects portrayed by the performance parameters, such as the shear stress and the residence time variations. An open source computer package (PyCFD-O) was developed to perform CFD simulations and the optimization processes automatically. First, it calls the preprocessor to generate the computational geometry and the mesh. Then it performs the simulation susing OpenFOAM, calculates the output parameters and iterates the procedure. ThePyCFD-O package has proved reliable and robust in attest case, a ~1m^3 continuous fermentation reactor. The multiobjective optimization procedure actually corresponds to search for the Pareto frontier in the solution space characterized by its geometric parameters and the associated performance parameters (dispersion of residence times and shear stresses). Optimal design configurations were obtained representing the best tradeoff between antagonistic objectives, i.e. the so-called non-dominant solutions.

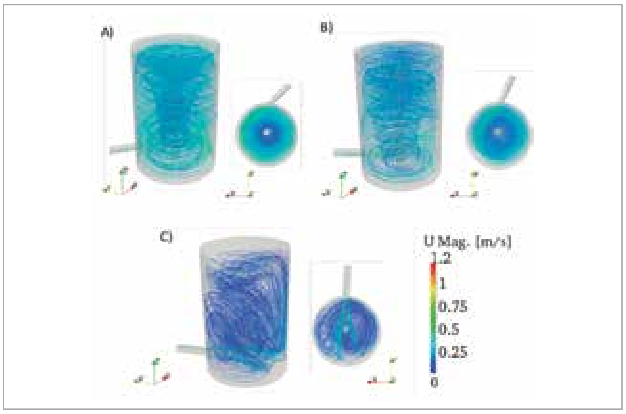

Figure 1. Example of the optimized geometries with streamlines for 3 individuals belonging to the non-dominated front: A) $\alpha = 43.5°$, $H_{out} = 1.15$ m; B) $\alpha = 62.7°$, $H_{out} = 1.28$ m; C) $\alpha = 87.3°$, $H_{out} = 1.28$ m

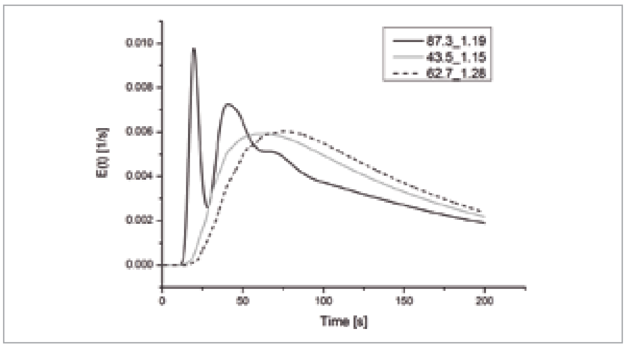

Figure 2. Example of reduction of the RTD dispersion during the optimization procedure

SUMMARY OF RESULTS TO DATE AND PERSPECTIVES

Test cases were simulated using PyCFD-O package. The characteristic Pareto frontier associated with the problem was determined and the corresponding optimal configurations were identified. Performance was, thus, optimized with respect to minimum residence time distribution (RTD) and shear stress (SST). Results concerning the photobioreactor lead to the development of a new photobioreactor configuration which prevents performance degradation, permitting to upscale the geometry to thousands of cubic meters and more. This development resulted in two utility patents submitted to INPI, Brazil.

- Open source code (PyCFD-O) for optimal bioreactor design through CFD simulation and evolutionary multiobjective algorithms, as depicted below.

- Test case 1: optimization of a 1m3 continuous fermenter; optimal injection angle (α) and output pipe height (H_{out}) with respect to the residence time distribution and shear stress.

- Test case 2: optimization of a 1m3 airlift photobioreactor; optimal internal recirculation plate positioning with respect to the residence time distribution and shear stress.

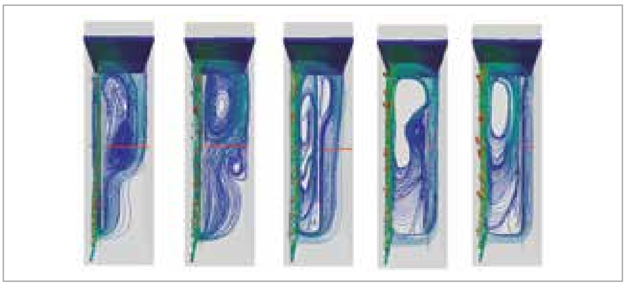

Figure 3. Influence of the horizontal position of the recirculation plate on the stream lines

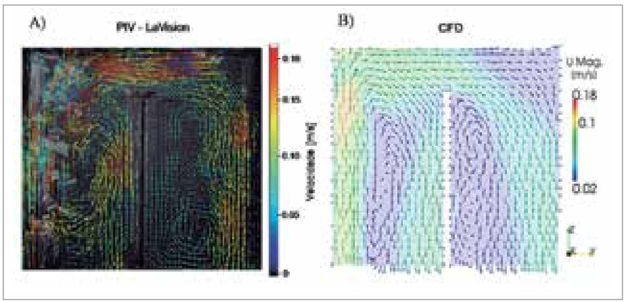

Figure 4. Detail of the flow field around the top of the recirculation plate for an optimal configuration

MAIN PUBLICATIONS

Monteiro PAS, Polikarpov I, Seleghim PJ. 2014. Sistema de injeção de gases para reatores de agitação pneumática. Patente: Privilégio de Inovação. Número do registro: BR 10 2014 018637 9. Instituto Nacional da Propriedade Industrial, Brasil

Monteiro PAS, Polikarpov I, Seleghim PJ. 2013. Arranjo de módulos de cultivo em malha hexagonal para um fotobiorreator escalonável de cultivo industrial de microalgas a altas concentrações. Patente: Privilégio de Inovação. Número do registro: BR 10 2013 020387 4. Instituto Nacional da Propriedade Industrial, Brasil.

Ansoni JL, Brandi AC, Seleghim PJ. 2014. Resolution of an inverse thermal problem using parallel processing on shared-memory multiprocessor architectures. *Inverse Problems in Science & Engineering.* **23**: 1-25.

Ansoni JL, Brandi AC, Seleghim PJ. 2013. Convection coefficient estimation by the truncated singular value decomposition method applied to the associated inverse thermal problem. *Heat Transfer Engineering.* **35**: i.9, 803-811.

Ansoni JL, Seleghim PJ. 2015. Optimal industrial reactor design: development of a multiobjective optimization method based on a posteriori performance parameters calculated from CFD flow solutions. *Advances in Engineering Software*, 2015. (*accepted*).

Paulo Seleghim Júnior

Escola de Engenharia de São Carlos
Universidade de São Paulo (USP)
Departamento de Engenharia Mecânica
Av. Trabalhador Sãocarlense, 400
CEP 13566-590 – São Carlos, SP – Brasil

+55-16-3372-9416
seleghim@sc.usp.br