Modelling And Characterization Of Internal Loop Air Lift Bioreactor Configurations Through Computational Fluid Dynamics

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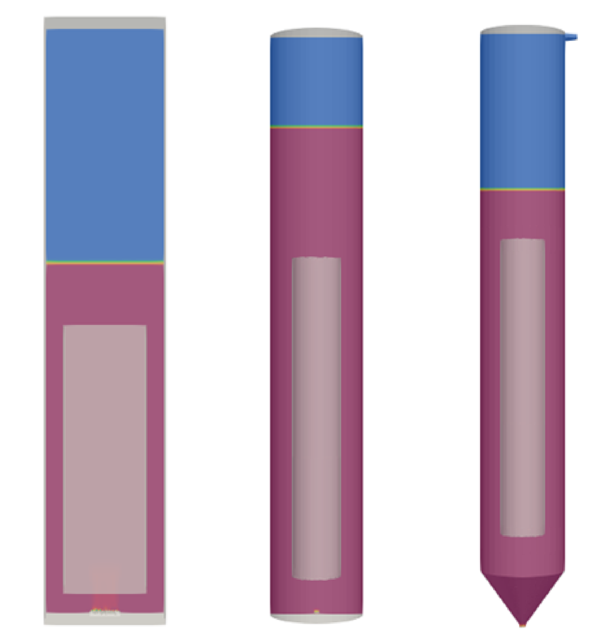
Background

Biorefineries offer potential pathways for producing organic chemicals, fuels, polymers, and electricity from biomass with complex processing technologies. Among these complex processing technologies, the design and analysis of bioreactors is crucial to the successful operation of biological processes. The improvement of mass transfer in and between phases through mixing is the key success factor in the design of bioreactors. The use of modelling and simulation has proven to be an effective tool for solving complex engineering problems whose analytical solutions cannot be obtained or are unavailable.

Introduction

In this study, computational fluid dynamics is utilized to characterize the flow of six different internal loop airlift bioreactor geometries with different interior configurations. Parameters such as phase turbulent kinetic energy and phase fraction are addressed. The variations of design parameters in the studied air-lift reactors will lead to optimal configurations that can lead to more efficient biorefinery concepts.



a) SSD01 b) CSD04 c) SDG04

Figure 1. Single draft tube geometries

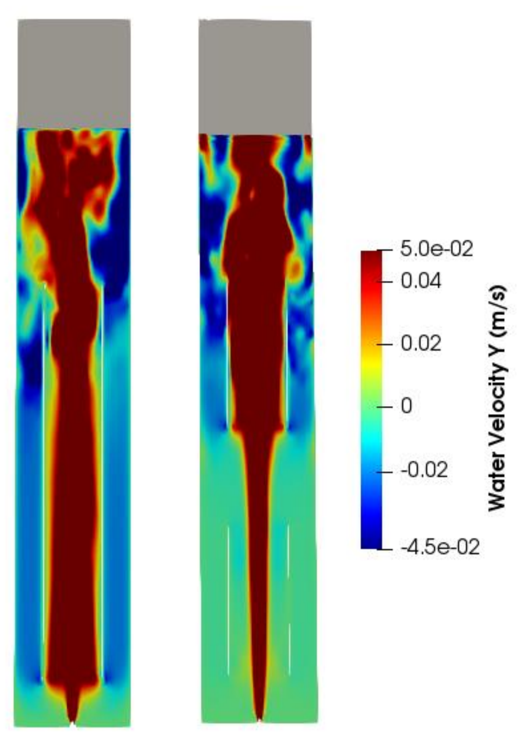


Figure 3. Axial water velocity on CSD04 and CDD04

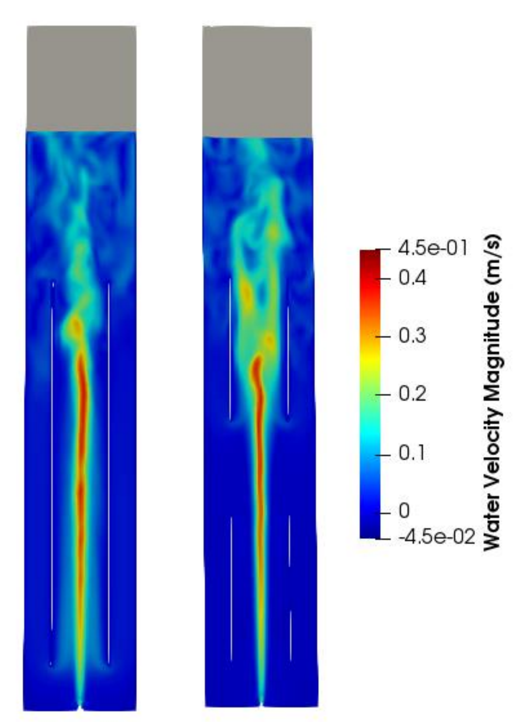
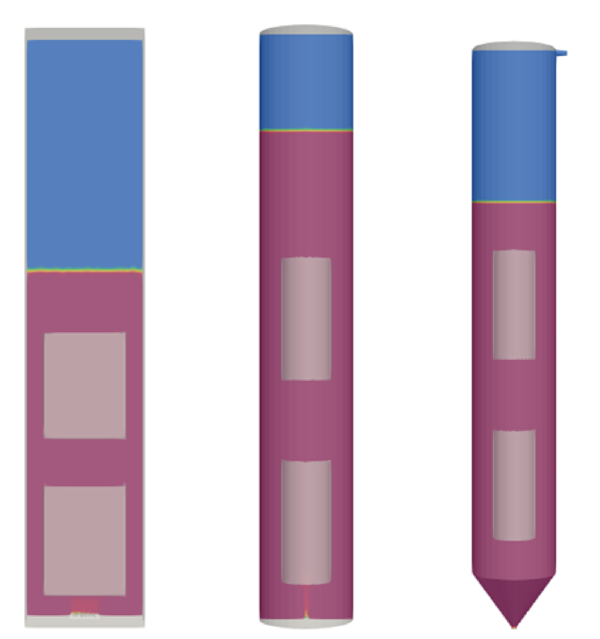


Figure 4. Water velocity magnitude on CSD04 and CDD04



a) SDD01 b) CDD04 c) DDG04

Figure 2. Double draft tube geometries

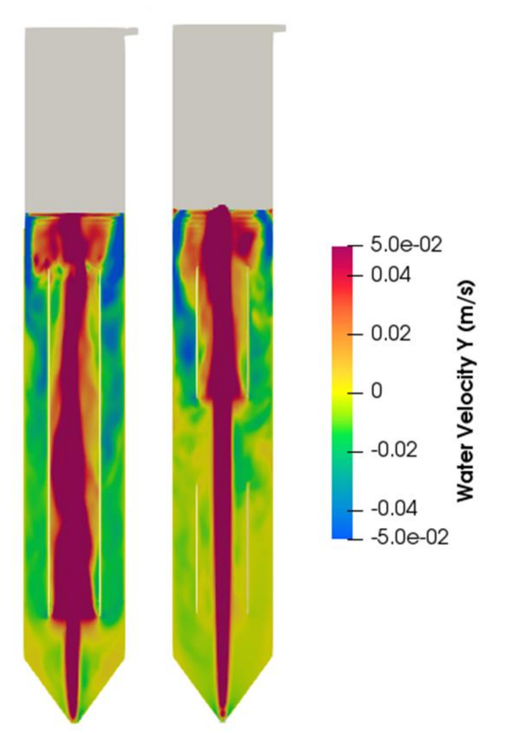


Figure 5. Axial water velocity on SDG04 and DDG04

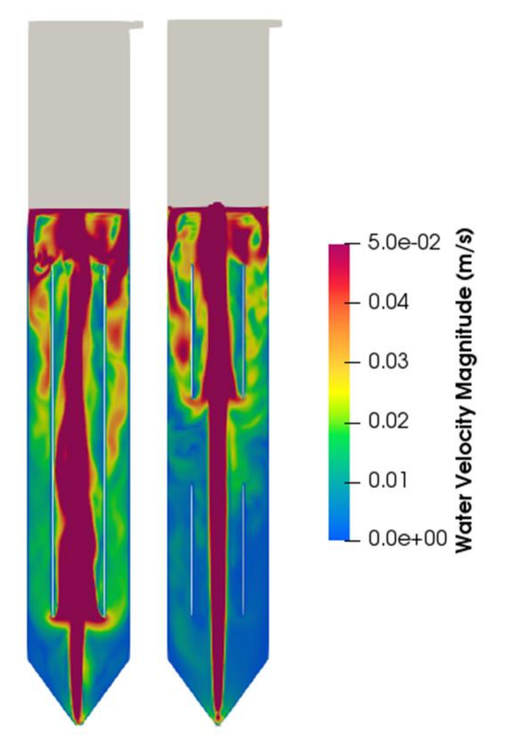


Figure 6. Water velocity magnitude on SDG04 and DDG04

Results

Figures 5 and 6 show the simulations at 60 seconds where in both geometries the downcomer velocity is present, while figure 3 is at 15 seconds of simulation and there is no downcomer velocity on the bottom draft tube of case CDD04. Figure 4 is focusing on showing the maximum upcomer velocity. On figure 8 the highest turbulent kinetic energy on the down comer is at the top. Figure 9 takes sampled values of the phase fraction in the upcomer.

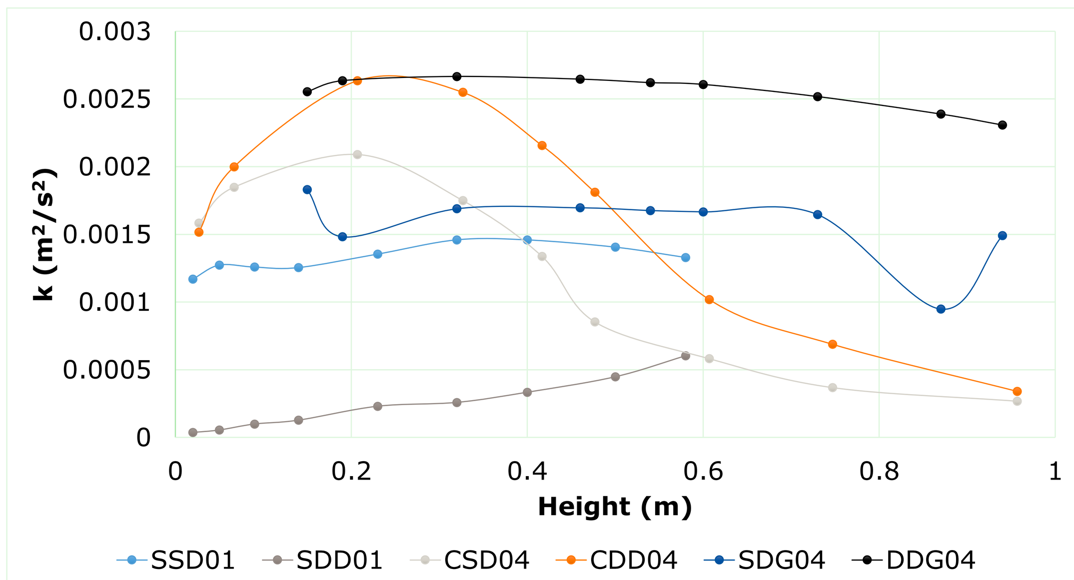


Figure 7. Plot comparing the turbulent kinetic energy in the upcomer

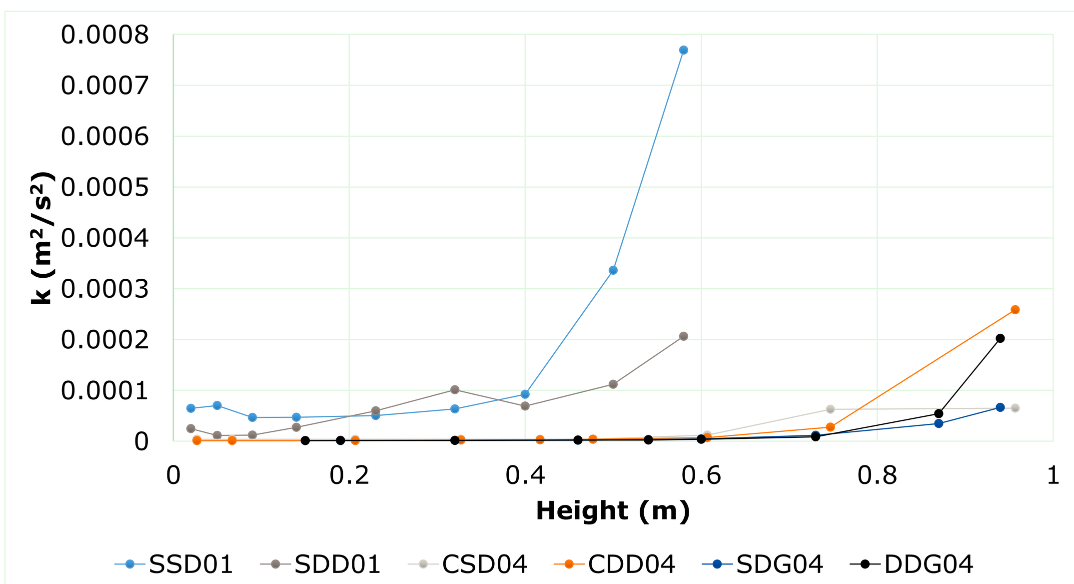
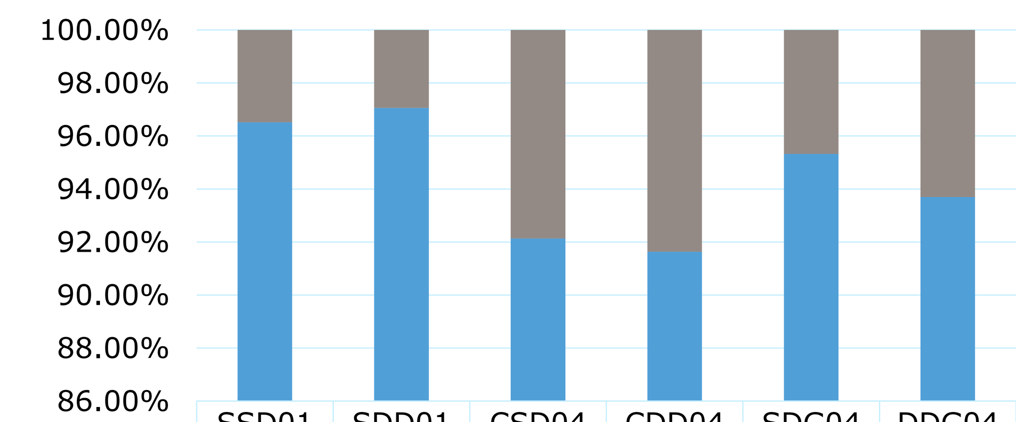


Figure 8. Plot comparing the turbulent kinetic energy in the downcomer



	SSD01	SDD01	CSD04	CDD04	SDG04	DDG04
Air	3.48%	2.94%	7.87%	8.36%	4.68%	6.30%
Water	96.52%	97.06%	92.13%	91.64%	95.32%	93.70%

Figure 9. Plot comparing the phase fraction in the upcomer when air phase is maximized

Materials and methods

Three different bioreactor geometries with two different internal configurations were simulated with the open-source software OpenFOAM version 9. The large eddy simulations method was used. The solver *multiphaseEulerFoam* which considers both phases as Eulerian was utilized for this simulations.

Figure 1 shows the single draft tube geometries. Figure 2 shows the double draft tube geometries. The red represents the fluid, in this case water, and the blue represent the gas, in this case air. Gas inlet velocities of 0.01 m/s and 0.04 m/s were utilized for the simulations.

Conclusions and future work

- Three different bioreactor geometries were simulated varying their internal configurations. Parameters like the distance between the top of the draft tube and the liquid's height, inlet type, gas inlet velocity and ratio bioreactor's diameter vs. draft tube diameter were varied.
- It has been found that splitting the draft tube enhances the mixing on the upper part of the bioreactor.
- The ratio of bioreactor diameter vs draft tube diameter affects the downcomer velocity.
- Simulations on a single bioreactor varying the distance between draft tubes, the number of draft tubes and the distance to the surface will be performed to evaluate their effect on the flow.

Acknowledgments

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 860477 – AgRefine – H2020-MSCA-ITN-2019.

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