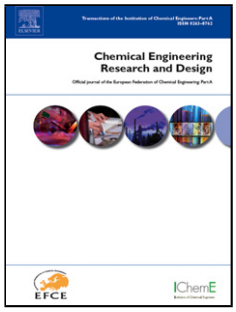

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Hydrodynamic characterisation of dual-impeller submerged membrane bioreactor relevant to single-use bioreactor options

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Abstract

The flow characteristics e.g. velocity and velocity gradients in a conventional stirred sMBR with in-line tubular membrane module for integrated production and recovery of value-added material, are studied. Considering a hybrid vessel, the flow characteristics are conflicting parameters, viz. high shear is required for membrane walls and low shear required for microbial cells. Attempt is made to find a range of parameters that are balanced against known critical values. The task is resolved by numerical solution of a theoretical model of dual flat-blade impeller Biostat® 5 L (T=0.16 m, D=6.6 cm) equipped with tubular membrane module (L=23 cm, d=12 mm) operating in non-Newtonian biofluid (flow index range, $0.34<n<0.78$). CFD for gas-liquid cross-flow (e.g. Eu-Eu model) at $Re \sim 10^3$-2.10^4 and mesh 10^6 cells is employed. In a study aimed at sMBR bulk and near-wall flow properties, the effect of gas flow at various tip velocity (1-2.5 m/s), sparging intensity (8-16 m/s) and rheology on shear is revealed. In a range of specific input power 10^2-5.10^3 W/m^3, the bulk shear rate varied in the range 20-60 s^{-1} and mean wall shear varied between 600 s^{-1} and 3000 s^{-1}. Wall shear stress non-uniformity in the range 1-30 N/m^2 is registered. The gas phase is found to reduce wall shear, but to increase shear uniformity. In view of preserving cells' viability, zonal shear rates of the vessel bulk and sparger openings were determined. Relating the data to similar results in single-use vessels, a correlation reported previously for bulk average shear rate $\dot{\gamma}$ versus input power [$\dot{\gamma}=C(P/V_R)^{1/3}$] is confirmed.

A range of balanced bulk and wall shear relevant to hybrid operation is determined. In view of the reported scalability of the conventional MBR design and reusable bioreactors, the data could be used for extrapolation.

Keywords: mixing, sMBR, tubular membrane, shear, fouling, cell viability

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Abbreviations: CFD, computational fluid dynamics; EPS, extracellular polymeric substances, e.g. exopolysaccharides; MRF, multiple reference frames; RT, Rushton turbine; SUF, single-use fermenter; sMBR, submerged membrane bioreactor; rpm, revolutions per minute; vvm, vol/vol/min;

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