CFD Modelling and Validation of Mixing in a Model Single-Use-Technology Bioreactor

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Single-use-technologies (SUT) are a category of disposable bioprocessing components which have increased in popularity in the biopharmaceutical industry in recent years [1]. Stirred single use bioreactors use a polymeric bag supported by a rigid metal frame. The bag is disposed of and replaced after use, removing the need for energy-intensive and time consuming cleaning and sterilisation in place, as well as improving the flexibility of the production facility [2]. They are currently applied mainly to the production of vaccines by mammalian cell cultures [3] due to the low shear and oxygen requirements when compared to industrial fermentation processes.

This work is part of a PhD project which aims to produce a validated CFD model of multiphase gas-liquid mixing in a cubic SUT bioreactor. This geometry is preferred due to the high bag integrity and simplicity over existing cylindrical SUT bioreactors. A magnetically-driven floor mounted impeller is also included in order to further simplify the geometry and allow for the close stacking of multiple bags. Multiphase modelling in a 1 m^3 vessel has been performed using the commercial software ANSYS CFX at a range of stirrer speeds and gas flow-rates in an attempt to optimise conditions in the reactor for oxygen mass transfer. Turbulence is modelled using the k-ε model, with impeller motion modelled using the multiple reference frame method. Five different models for the mass transfer coefficient, k_L, which are suitable for calculation from CFD derived parameters such as turbulent eddy dissipation and superficial gas velocity, are compared. An optimum stirrer speed of 400 RPM was identified, above which the mass transfer - characterised by k_La values - is not improved despite the additional power input. A proposed 200 L variation of this cubic design was also investigated, showing significantly improved gas mass transfer.

Validation of the models is performed in a separate lab-scale cubic glass tank, with point velocity measurements taken using two-dimensional Laser Doppler Anemometry (LDA). These measurements are combined to create profiles within the vessel which are compared to a CFD model of the same geometry. Three impeller types are used for the validation experiments; a six-bladed Rushton impeller, a four-bladed radial impeller and a four-bladed axial impeller. Validation experiments are currently performed in single-phase, however the process will be expanded to cover multiphase gas-liquid systems including both liquid-phase velocity and bubble size distribution measurements. A good agreement is observed between the modelled and experimental profiles in-line with the impeller, in particular the swirling flow patterns characterised by the tangential velocity.

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