Comparison of Industrial Agitation for Batch Reacting Vessel Mixing in Bioethanol Fermentation

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Abstract

Bioethanol production is an increasingly important venture within the biofuels industry, where the primary product is used nowadays as an additive to petrol or diesel in order to comply with governmental environmental policy and energy demands. This forms part of a global attempt to reduce fossil fuel consumption and produce sustainable energy. Thus significant efforts must be directed towards optimizing the bioethanol fermentation process. In yeast fermentation production of ethanol, a key parameter in the process is that of batch mixing, which enables reaction to occur within the fermenter but also is optimized to ensure yeast cells are not victim to shear damage, ensuring that reaction occurs to its kinetic optimal point. In industrial bioethanol reacting vessels several agitators are used, however comparison of different agitation is largely achieved on a trial and error basis. Agitation tends to be kept low to create a bio-friendly environment; however this is not efficient from a process point of view. Producing a 3D simulation of these fermentations using two widely used agitators allows for better insight into the vessel mixing to be gained, and for comparison to be made with the specific reaction process in question.

COMSOL Multiphysics simulations of the batch vessels were generated, with calculated inputs close to industrial practice, and with two different types of commonly used industrial agitators - the Rushton turbine and the Marine propeller. Simulation was completed by making use of the coupling of several physics modules; CFD - turbulent fluid flow; the mixing module - fluid flow with rotating machinery; and CAD import. Wall distance physics were also implemented, and eddys turbulence dissipation of energy was assessed throughout the vessels during agitation. The mixing within the two vessels were compared and contrasted in terms of agitation power consumption, effective mixing, critical stirring speeds for cell suspension, shearing damage, and were optimized by factoring in estimated capital and operating costs. Mixing was seen to be similar with both agitators, where the key difference between the two lay in power consumption being much larger for the Rushton turbine, and therefore an accompanying larger operating cost implication. Power consumption, however, was found to be similar at low agitation velocities, at which critical stirring speed is achieved and is sufficient for operation. Shear damage was found to not occur within this velocity range (0.36-1.31 s-1). The Marine propeller was deemed a more suitable choice for bioethanol fermentation in light of the different optimizations achieved using the simulated parameters. COMSOL Multiphysics ® was found to be a useful simulation tool in enabling these comparisons to be achieved, and in successfully allowing for the mimicking of an industrial operating environment.

Figures used in the abstract

Figure 1: Bioethanol fermenter with Rushton turbine agitation.

Figure 2

Figure 3

Figure 4