Process Regime Classification and Modelling of a Sequencing Batch Reactor for Producing Polyhydroxybutyrate with Mixed Culture Using Neural Networks

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Abstract

This thesis presents a systematic methodology to enhance process control and optimisation for sequencing batch reactor (SBR) using both qualitative and quantitative tools to model process behaviour. The studied SBR is for producing Polyhydroxybutyrate (PHB), a biodegradable polymer with similar physical properties to polyethylene, by the means of Mixed Microbial Cultures (MMC). PHB production with MMC has gained attention as a method to decrease production cost by using bacteria that adapt well in complex substrates presented by inexpensive waste material. The process known as “feast and famine” or as “aerobic dynamic feeding” is a well-known strategy applied for bacterial production with MMC. The aim of this study is to provide a systematic scheme that enables generation of robust and reliable SBR recipes for production of PHB using MMC.

The batch process for PHB production with MMC has already been documented and mechanistic models were developed for process simulation. An analysing methodology to screen batch process behaviour is introduced in this study in direction of characterising operational pathway based on initial state of the batch. Application of this analytical procedure provides useful information about the operational pathways as well as a reliable tool to manipulate operational progression towards a particular phase regimen. In the course of developing the analytical tool, operational regimes are classified and labelled to provide qualitative representation of the batch processes.

Identification of the “feast” and “famine” phase operational regions opens a new window for empirical model development using process data. Since establishment of mechanistic relationships are complex and effort demanding, empirical modelling can be used as an advantageous alternative for building relationships between some process parameters of high interest. Bootstrap aggregated neural networks demonstrates high capability of target modelling when training data set is segregated into subsets of “feast” and “famine” phase data. These non-linear models predict PHB, biomass and feeding concentrations at different stages of a PHB batch operation, enabling generation of SBR recipes.

The SBR operation cycle for PHB production by MMC has a “feast” phase and a “famine” phase. While PHB formation occurs during the “feast” phase, a “famine” phase should be followed to cause a cell physiological adaptation to maintain PHB production capability of bacteria. The SBR recipe structure established in this study consists of six-stage cycles with implementation of the “phase manipulating tool” to assure occurrence of both “feast” and “famine” phases in each cycle. Operational reliability and robustness of the recipe is investigated along with load disturbance rejection by the means of the “phase manipulating tool”. At the end, Sequential Quadratic Programming (SQP) is used successfully as an optimisation algorithm to maximise PHB production under operational constrains.