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Experimental Validation of a Coupled Nonlinear Observer in a Hydrogen Production Dark Fermenter

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ABSTRACT

In order to optimize the production of hydrogen from glucose in a continuous dark fermenter, an existing and already experimentally validated strategy is to modify the organic loading rate (OLR) by manipulating the inflow rate, based on an output-feedback control algorithm that aims at maximizing the hydrogen productivity, obtained through on-line measurements of the biogas composition and flow rate. However, the validation was made with a known and constant inflow substrate concentration (Sin) and thus the OLR was proportional to the dilution rate. To realistically implement the controller, real time knowledge of this concentration is needed. Since it cannot be measured on-line, the coupling of a second-order sliding-mode observer and a linear robust Luenberger observer can be used to estimate the substrate at the reactor input. Although a validation of the proposed estimator has already been done using numerical simulations based on a mathematical model that was calibrated with past experimental data, a further experimental validation of the proposed estimator was still needed. This work presents these results, with data obtained for 10 combinations of hydraulic retention times (HRT) and inflow substrate concentrations according to a Latin hypercube experimental design, leading to different values of OLR. Upon changing the OLR, sufficient time was allowed for reaching steady state conditions, and then returned to a standard operating condition of HRT=8 h and Sin=15 g/L before testing a different condition. The collected data allowed testing the proposed nonlinear observer in open loop after the experimentation period and the results are encouraging, leading to good estimations of the inflow substrate concentration, but being sensitive to perturbations that lead to an erroneous estimation of the biomass concentration with the Luenberger observer. Nevertheless, the observer may be suitable to complement the output-feedback control strategy previously proposed.

Keywords: bio-hydrogen production; nonlinear observer; bioprocess control