Modeling, Parameter Identification, State and Input Reconstruction for a Fixed-bed Biofilter (C. Renotte, P. Bogaerts, I. Queinnec, P. Saucez and A. Vande Wouwer)

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This paper considers a pilot-scale fixed-bed biofilter used for nitrate removal in municipal wastewater treatment. The biofilter is a continuous bioreactor in which microorganisms (i.e. the biomass) grow from the consumption of two substrates, i.e. nitrate and nitrite. Process dynamics is described by a set of mass balance partial differential equations (PDEs), which allow the evolution of the several component concentrations along the bioreactor axis to be reproduced. These model PDEs can be solved numerically using a conventional method of lines approach. In order to analyze the dynamic behavior of the biofilter, fluid samples can be taken on-line at 8 different locations along the reactor axis, providing concentration measurements for nitrate, nitrite and organic substrate. Based on a set of experimental data collected over a relatively long period of time, several alternative model formulations, corresponding to different macroscopic reaction schemes, reaction kinetics and assumptions on the evolution of the active biomass along the reactor bed, are considered. Particularly, very long (several days up to several weeks) transient phases are observed after changes in the feed flow rate, which can be explained through the introduction of a biomass desactivation reaction. The model equations contain a set of unknown parameters, e.g. pseudo-stoichiometric coefficients and kinetic parameters, which are inferred from experimental data by minimizing a least-squares criterion measuring the deviation between the logarithms of the measured and simulated outputs (this particular form of the criterion corresponds to the assumption of a constant relative error). This task is performed using a Levenberg-Marquardt algorithm. Positivity constraints are imposed on the parameter estimates through a logarithmic transformation. In addition to the model parameters, some operating conditions, e.g. inlet nitrate concentrations and fluid flow rates, are uncertain and have to be estimated from the measurement data as well. The relatively good model agreement demonstrates the validity of the proposed assumptions on the macroscopic reaction scheme and reaction kinetics. Finally, the model is used to design a state observer which allows component concentration profiles to be reconstructed on-line from a few pointwise measurements. In addition, the estimation of the composition of the wastewater fed to the biofilter is considered, a problem of great significance in the early detection of pollution. The design technique used to solve this Unknown Input Observation problem involves the reduction of the model PDEs and a

state transformation. An unknown-input-free system is then obtained, to which conventional state estimation methods directly apply.