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Predictive Adaptive Control of an Activated Sludge Wastewater Treatment Process

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Abstract

This paper presents an application regarding a model based predictive adaptive controller used to improve the effluent quality of a conventional activated sludge wastewater treatment process. The adaptive control scheme consists of two modules: a robust parameter estimator and a predictive controller. The controller design is based on the process model obtained by recursive estimation. The performances of the adaptive control algorithm are investigated and compared to the non-adaptive one. Both the set point tracking and the regulatory performances have been tested. The results show that this control strategy will help overcome the challenge for maintaining the discharged water quality to meet the regulations.

Keywords: wastewater treatment, predictive control, adaptive control, parameter estimation

1. Introduction

Wastewater treatment plants (WWTPs) are key infrastructures for ensuring a proper protection of our environment. The biological treatment is an important part of any WWTP and the activated sludge process is the most common biotreatment process used to treat sewage and industrial wastewaters. Conventional activated sludge systems are focused on the removal of carbonaceous organic matter. These biological processes are nonlinear and complex, representing a challenge from the control point of view due to the enhanced environmental regulations related to the effluent quality and the large variations in the influent flow rates and concentrations [1].

An overview of the activated sludge wastewater treatment process mathematical modeling is presented in [2]. A variety of control strategies for WWTP were proposed in the available literature: conventional PID control, fuzzy control, predictive and optimal control [3,4], all of them presenting good performances in a certain operating point. The control strategy proposed in this paper takes into consideration the controller adaptation to the process parameter changes caused by high variations in the influent flow rate or concentration. The purpose of this paper is to investigate the performance of an adaptive control algorithm (AGPC) based on the Generalized Predictive Control (GPC) method [5]. The performances of the AGPC algorithm are investigated on an activated sludge wastewater treatment process. Therefore, the activated sludge process was first modeled and the model was calibrated and validated based on a combination of laboratory tests and plant operating measured data, available from Romanofir WWTP.

2. Process Description and Modeling

The model of the process was developed based on data obtained from an operational WWTP. The biological treatment process of this WWTP is a conventional activated sludge system with two *components*: a *bioreactor* operating under aerobic conditions and a *settler* (Fig. 1). A widely used model to describe the dynamics of biological treatment processes is

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the Activated Sludge Model Nr.1 (ASM1) [6]. Since this model is complex, containing a large number of state variables and parameters, it is necessary to simplify it into a simpler model, more suited for control purposes. Considering only two material components, a soluble substrate and a particulate biomass component, the mathematical model of the biological treatment process for the removal of organic matter will be composed of a set of four non-linear differential equations, three equations for the aerated bioreactor and one for the settler. The process model and the sensitivity analysis are described in greater detail in [7].

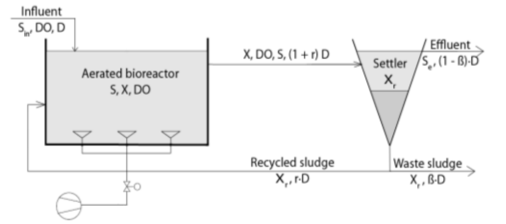

Fig. 1 Biological treatment process schematic

3. Adaptive Control Algorithm

The adaptive control scheme consists on two modules: a robust parameter estimator and a model based predictive controller. The controller design is based on Certainty Equivalence Principle, the estimates of the process model parameters are used instead of the unknown true values in the control law design. The controller design is based on the process model obtained by recursive estimation.

3.1. Controller Design

The GPC design procedure is well described in the literature [5]. The key idea is to minimize the following cost function:

$$J = \sum_{j=N_1}^{N_2}[y(t+j) - y_r(t+j)]^2 + \sum_{j=1}^{N_u}[\rho(j)[\Delta u(t+j-1)]^2 \quad (1)$$

where: Δ is the differencing operator 1-q^{-1}, y_r is the future reference sequence and N1 - the minimum costing horizon, N2 - the maximum costing horizon, Nu - the control horizon and $\rho(j)$ - the control-weighting sequence are the controller design parameters.

3.2. Parameter Estimation

To estimate the parameters of the plant model, a version of the Standard Recursive Least Square Algorithm (RLSA) was used. The use of the basic identification scheme may lead to unstable adaptive process control. For practical implementations of adaptive control strategies, this scheme must be modified in order to provide a robust parameter estimator. The parameter estimation algorithm includes data normalization, a dead zone, a forgetting factor and data prefiltering [8].

4. Simulation Results

The simulations were carried out in the MATLAB environment and the closed loop controllers performances for the concentration of organic matter (S_S), considered as controlled process output, were investigated. The aeration flow (W) was considered the manipulated input. The nonlinear model of the biological treatment process was used to simulate the process dynamics. To obtain the transfer function from W to S_S the model was linearized around the nominal operating point (the influent organic matter concentration S_{Sin}=765mg/l). The second operating point was considered for a lower influent organic matter load, S_{Sin}=300 mg/l. Performances for effluent organic matter concentration S_{Sef} which is more relevant were determined and plotted.

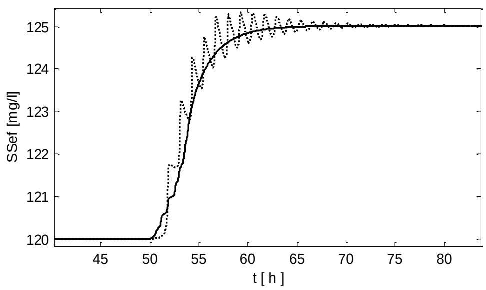

Fig. 2 Setpoint tracking performances. AGPC-continuous line, GPC-dotted line

In Fig. 2 setpoint tracking performances of the adaptive predictive controller (AGPC) and predictive controller (GPC) for the second operating point can be compared. Performances are appreciably improved in the AGPC case (continuous line) because the estimator will correct the model parameter values and will adapt the controller to this situation.

Fig. 3 presents the regulatory performances during simulation tests when the disturbances are applied on the influent organic matter concentration SSin. The SS setpoint is fixed such as the regulations for the organic matter concentration in discharged water are met most of the time (SS effluent (CCO-Cr) <125 mg/l). Also in this case AGPC has slightly improved performances.

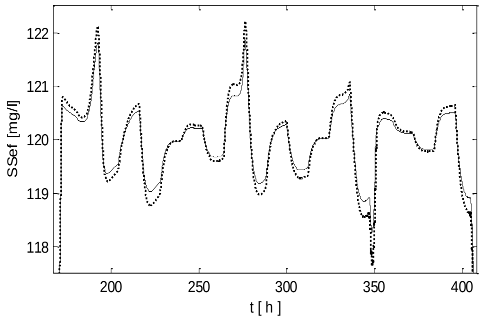

Fig. 3 Regulatory performances. AGPC-continuous line, GPC - dotted line

5. Conclusions

In this paper, the performances of an adaptive model based predictive control strategies for the organic matter concentration in the effluent of the biological treatment process of a WWTP have been evaluated. Simulation studies were based on the non-linear model, obtained from mass balance equations and they have indicated that the proposed control method performs well and can be easily used. Both the setpoint tracking and the regulatory performances have been investigated. The regulations for the organic matter concentration in discharged water are satisfied in a high percentage.

Acknowledgement

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