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Fuzzy control of dissolved oxygen in a sequencing batch reactor pilot plant

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Abstract

The present work is part of a global development of reliable real-time control and supervision tools applied to wastewater pollution removal processes. In these processes, oxygen is a key substrate in animal cell metabolism and its consumption is thus a parameter of great interest for the monitoring. In this paper, are presented and discussed the results of the dissolved oxygen (DO) control in a SBR pilot plant based on a predefined 8 h step-feed cycle. As first approach, the application of classical methods (on/off and PID) was considered. Due to the non-linear character of the process, the PID parameter adjusting was very difficult and the obtained results showed a beating phenomenon around the setpoint. This phenomenon was more and less amplified according to the step of the cycle and the water pollution level. The second approach to achieve more stable DO control was based on a fuzzy logic strategy, taking into account the step and the difference between the measured DO and the setpoint. In this case, control action performances were highly improved. It is also shown that, using the fuzzy controller, the pH profile made it possible to clearly detect the ammonia valley during the aerobic phases. Thus, fuzzy logic proved to be a robust and effective DO control tool, easy to integrate in a global monitoring system for cost managing.

Keywords: SBR pilot plant; Efficient and robust control; Fuzzy logic; Wastewater treatment plant; Dissolved oxygen

1. Introduction

One of the major evolutions in the conception field of automated systems concerns the taking into account, from the first phases, of their reliability. The reliability characterizes the system performances and returns the aptitude to correctly fulfil a fixed mission. It is related to the capability to resist to material, software or human failures, and to possible environmental aggressions. The reliability is partly obtained by design choices related to the system technological field: materials, dimensioning or manufacture [1]. Another part results of techniques concerned with information sciences and technologies: the reliability depends on an applicative architecture, which, in addition of the system nominal functions, includes failures detection, localization and diagnosis functions. This architecture allows to detect operating mode changes, in particular related to environmental behaviour changes. It also rests on forecast functions, failures or aggressions accompaniment and command or objectives reconfiguration. All the above-mentioned functions ensure desired reactivity characteristics.

In the particular case of sequencing batch reactors (SBR) technology, the instrumentation, the control and the automation are key factors when the process must be operated to achieve restricted discharge levels [2]. The dissolved oxygen (DO) is nowadays, one of the most important parameter to control because of its impact on the biological processes and the energy saving related to aeration [3].

Various works are dedicated to the DO control in bioprocesses [4,5]. The results obtained generally depend on the process complexity and also, on the control techniques used. The classical methods (on/off and PID) have largely been used but, due to the non-linear character of the bioprocesses and the lack of available models, the controllers were developed for specific operating and environmental conditions.

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Now, research interests are more and more directed towards using artificial intelligence techniques [6]. In this field, the control action offers the possibility of integrating expert knowledge and the technologic specificities of the process [7].

The work presented in this paper is part of a real-time control system study based on on-line calculated oxygen uptake rate (OUR), oxidation–reduction potential and pH profile to optimize the cycle length of the SBR for organic matter and ammonia removal [3,8,9] in which the DO had a high influence. First of all, DO control was necessary in order to avoid final aerobic phases at high levels of DO. Due to the repeated anoxic–aerobic pairs, the beginning of anoxic phases at high DO levels concluded with time and carbon source reduction suitable for denitrification purposes [9]. For this reason, three kinds of DO control strategies were applied and compared: (i) a simple on/off control, (ii) PID control and (iii) a fuzzy logic-based DO control.

The aim of this paper is to compare the obtained results using different types of DO control (on/off; PID and fuzzy logic control) in the SBR pilot plant installed in Celrà-wastewater treatment plant (WWTP) treating urban wastewater.

2. Materials and methods

This section presents the SBR pilot plant installed in Celrà-water treatment site and its biological specificities. The dissolved oxygen parameter is then described before the presentation of the different control strategies.

2.1. The SBR pilot plant

The SBR pilot plant set up in Celrà-wastewater treatment plant treats about 700 L of mixture of urban and industrial wastewater per day. The treatment is mainly based on organic matter and nitrogen removal. The SBR technology operates from a sequence of fill and draw cycles. These systems include a biological nutrient removal process. A fixed cycle of these characteristics, to achieve complete nitrification and denitrification (Fig. 1), was defined by previous lab-scale studies [10]. This 8 h cycle, with six feeding steps and the alternation of aerobic and anoxic phases was also successfully applied in another SBR pilot plant treating the Cassà wastewater.

A step-feed strategy for nitrogen removal means that the influent filling phases must be carried out under anoxic conditions in order to increase the denitrification efficiencies. It is important to take into account the alternation of aerobic and anoxic phases to permit a complete nitrogen removal. Fig. 2 shows the SBR pilot plant scheme. It is composed of a stainless-steel square reactor (1000 L capacity) treating the influent wastewater. The monitoring and control system is based on probes from Endress-Hauser®, cards and interfaces, developed over Labwindows®, from National Instruments®. The plant is equipped with DO-temperature (OXIMAX-W COS 41), pH (CPF 81) and ORP (CPF 82) probes. The

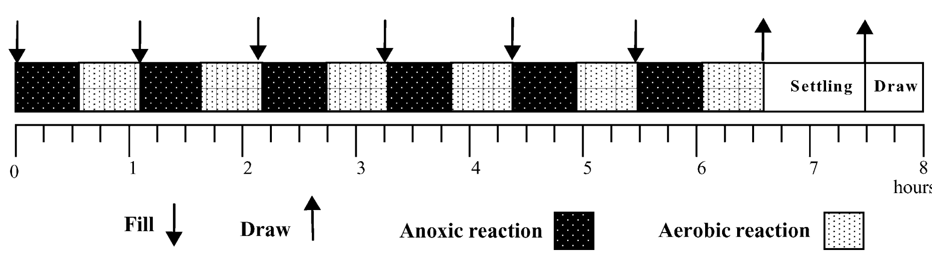

Fig. 1. Operational periods of the SBR pilot plant with filling strategy. Eight hours cycle with six feeding steps and the alternation or aerobic and anoxic phases.

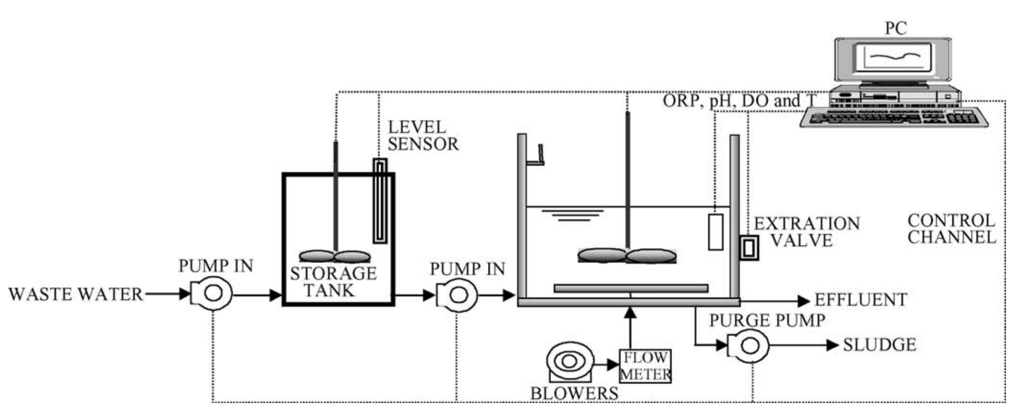

Fig. 2. Schematic overview of the SBR pilot plant installed in Celrà-wastewater treatment site.