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ZIEGLER-NICHOLS CONTROLLER WITH ONLINE IDENTIFICATION VERSUS PID CONTROLLER COMPARISON

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Abstract: *Nonlinear system control is generally difficult; the same problem is with chemical reactors, which belong into this category. It is necessary to know as much information about controlled system as possible, and on this basis a suitable controller can be then proposed. The possibilities of identification and subsequent controller design are studied in this paper. Authors are dealing especially with exothermic semi-batch processes, where the temperature control is necessary.*
Key words: *temperature control, online identification, exponential forgetting, semi-batch reactor*

1. INTRODUCTION

Batch and semi-batch reactors are widely used in chemical, biotechnical, and pharmaceutical industries. To obtain the desired product quality during the production period an accurate temperature control is required. The temperature profile in batch and semi-batch reactors usually follows three stages (Bouhenchir et al, 2006): (i) heating of the reaction mixture up to the desired reaction temperature, (ii) maintenance of the system at this temperature and (iii) cooling stage in order to minimize the formation of by-products. Any controller used to control the reactor must be able to take into account the above listed stages. Other difficulties arise because of the nonlinearities of the reactors. The important requirement of the optimal control is an accurate process model. It is necessary to know as much information as possible about this model. For this purpose, online identification can be used to identify the model parameters at the same time when the data are being collected. This can lead to an improvement of nonlinear system control.

Neural network was applied to similar system (Wu et al, 2010) to accommodate the online identification of a nonlinear system. The authors found this strategy effective in identification and control of a class of time-varying-delayed nonlinear dynamic systems. Neural networks are often presented as a suitable method to reach exact results in batch processes. The other approach was used in the next study (Cho et al, 2008), where the authors applied a dual-mode (DM) control improved by iterative learning technique. Simulations showed that the proposed method can enhance the conventional DM control with small efforts. For rapid and suitable reference-trajectory tracking a self-adaptive predictive functional control algorithm by Škrjanc was recommended (Škrjanc, 2008). This approach was successful in a reactor with switching between cold and hot water in the inlet.

This paper presents results of experiments obtained by simulations of the batch process using Ziegler-Nichols controller for the second order process with filtration of D-component (ZN2FD). These results are compared with author's previous work (Novosad, 2007). The paper is organised as follows. In section 2, the semi-batch reactor and the ZN2FD controller with online identification methods are described; section 3 presents the reader with simulation results and section 4 concludes the current work and suggests new areas for investigation.

2. METHOD SECTION

As can be found in the previous work (Macků 2003) the described batch process is used for chromium sludge with sulphuric acid processing. Process itself is strongly exothermic, so that the temperature control is necessary. The change of the chromium sludge input flow rate serves as a manipulated variable.

2.1 Ziegler-Nichols controller for second order processes with filtration of D-component using Tustin approximation (ZN2FD)

In this work, ZNFD with an online identification method – last squares method (LSM) - was applied to calculate the optimal reactor feeding to optimize the whole process. Control law follows:

$$u_k = q_0 e_k + q_1 e_{k-1} + q_2 e_{k-2} - p_1 u_{k-1} - p_2 u_{k-2} \tag{1}$$

where e_k is the control error ($e_k = w_k - y_k$) and the controller parameters are calculated using the following equations:

$$q_o = K_P \frac{1 + 2(c_f + d_d) + \frac{c_i}{2}(1 + 2c_f)}{1 + 2c_f} \tag{2}$$

$$q_1 = K_P \frac{\frac{c_i}{2} - 4(c_f + c_d)}{1 + 2c_f} \tag{3}$$

$$q_2 = K_P \frac{c_f(2 - c_i) + 2c_d + \frac{c_i}{2} - 1}{1 + 2c_f} \tag{4}$$

where K_P is a proportional gain; parameters c_i and c_d contain integrative and derivative part of controller; c_j contains an adjustable time constant of the filter.

Detailed description can be found in (Bobál & Chalupa, 2003).

3. RESULTS SECTION

An identification of suitable models which accurately describe a batch reactor process is essential to successful optimization and control. In this study, on a semi-batch reactor by means of a simulation, Ziegler-Nichols controller for second order processes with filtration of D-component (ZN2FD) was tested and the effect of various parameters changes on a quality of the process control was monitored.

3.1 PID controller without online identification

In the previous work (Novosad, 2007), the same semi-batch reactor was controlled by a PID controller without online identification. ZN2FD controller used in this paper gives a better performance of temperature profile without oscillating and overshoots (Fig. 1).

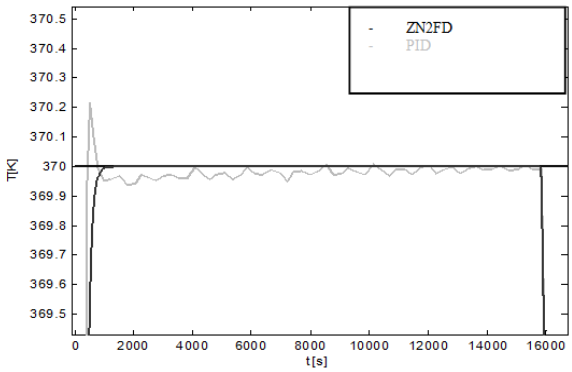

Fig. 1. Comparison of the temperature profiles between ZN2FD and PID controllers

On the other hand, the feeding profile (Fig. 2) at the beginning of the process is better in the PID controller case. ZN2FD controller gives some rapid changes of feeding, which are not very suitable. However, this is valid only at the beginning of the process control.

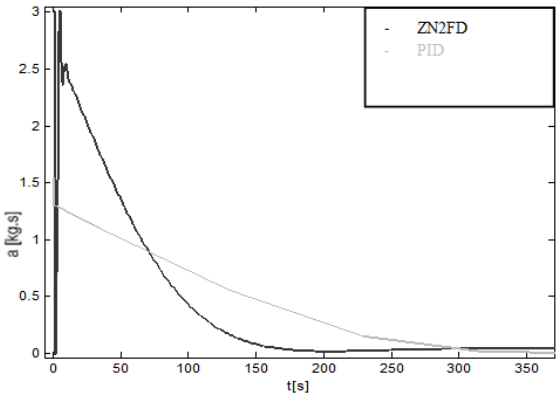

Fig. 2. Comparison of the feeding profiles between ZN2FD and PID controllers at the beginning of the process

In the whole period, ZN2FD controller holds feed rate without oscillations in contrast to PID controller (Fig. 3). These oscillations may be caused by missing online identification.

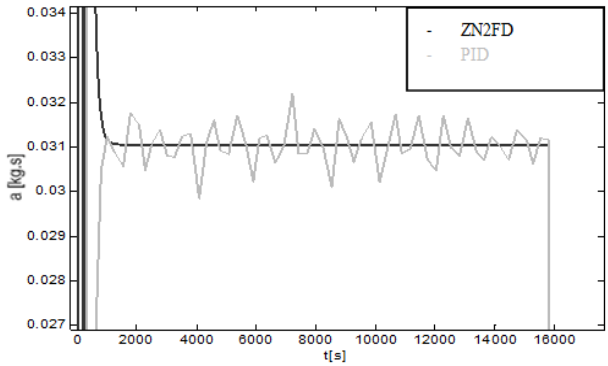

Fig. 3. Comparison of the feeding profiles between ZN2FD and PID controllers

4. DISCUSSION SECTION

In this study, the ZN2FD controller for the temperature control in a semi-batch reactor was demonstrated by simulation means. Also, a controller using the online identification strategy was implemented in our process. Two methods of identification were tested, Least Square Method (LSM) and LSM with exponential forgetting. However, there wasn't any visible improvement for simulations using the on-line identification with exponential forgetting. It may be caused by forgotten values from the beginning of the control process. Therefore, it can be reported that simulation software needs all values from the previous steps for good performance in our case of the semi-batch reactor.

The implemented control strategy was compared also with PID control used in the same process in the previous work (Novosad, 2007). Based on the presented results, it can be concluded that the proposed ZN2FD controller can effectively overcome problems with oscillating around the desired value. In comparison with a PID controller from the previous study, ZNFD showed better quality of the process control.

Some other methods, which could possibly improve this process, will be studied in the future work. Other approaches will be applied to the batch process to find out other possible improvements.

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