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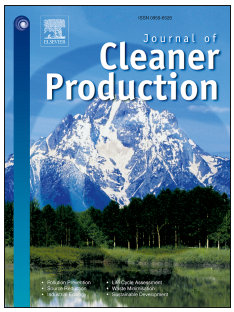

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Performance and Robustness Evaluation of Nonlinear Autoregressive with Exogenous Input Model Predictive Control in Controlling Industrial Fermentation Process

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Abstract

Malaysia holds a variety of energy resources; oil, natural gas, coal and renewable energies such as biomass, solar and hydro. In spite of these abundant resources, the nation still reliant on fossil fuel for industrial and transportation sector even though fossil fuel is depleting worldwide. In this regard, renewable energy resources are becoming attractive for sustainable energy development in Malaysia. Bioethanol is one of a potential biofuel with a high octane number and has replaced lead as an octane enhancer in petrol. In bioethanol fermentation, the process possesses complex dynamics caused by the microorganisms involved in the process as well as the variation in the biomass composition with the operating conditions. In this work, a nonlinear model known as the Nonlinear Autoregressive with Exogenous input model was developed and embedded in the Model Predictive Control strategy to control the fermentation process. Then, the performance of the Nonlinear Autoregressive with Exogenous input Model Predictive Control was evaluated and compared with linear Model Predictive Control and Proportional Integral Derivative controller for set point tracking and disturbance rejections. The robustness tests have also been carried out using the linear and nonlinear Model Predictive Controls proposed. In the robustness test, the nonlinear Model Predictive Controller successfully settled back to the original product concentration and fermenter temperature set points with settling time three hours. Meanwhile the linear Model Predictive Controller only settled at 95.8 % of the product concentration set point and 97.1 % of the fermenter temperature set point with settling time more than five hours. From the results, Nonlinear Autoregressive with Exogenous input Model Predictive Control has shown better performance and more robust as compared to linear Model Predictive Control and Proportional Integral Derivative controller.

Keywords: Bioethanol, Fermentation, Model Predictive Control, System Identification, NARX Model

1. Introduction

Ethanol has shown a high potential as an attractive alternative to petroleum-based fossil fuels (Li and Chan-Halbrendt, 2009) which is predicted to cease within less than 60 years (Liew et.al, 2014). It has received great interest among researchers due to its high prospective as a transportation fuel. Moreover, ethanol is environmental friendly and produce clean combustion. Ethanol which is produced by fermentation from crops is known as bioethanol and has been commercially implemented in Brazil and United States (Chng, et.al, 2016). To cater the great demand of bioethanol (Shapouri and Gallagher, 2005), it is normally produced in the industrial continuous bioethanol fermentation process (Wang and Lin, 2010). This production of bioethanol of course, has to apply the principle of minimizing negative environmental impacts and even improving the environment as proposed by Yong et al. (2015). A significant issue in bioethanol production that needs special attention is the nonlinear dynamic behaviour of the microorganism involved in the fermentation process, and it is very challenging to be controlled by conventional controller (Proll and Karim, 1994). To overcome the inadequacy of the conventional controller in controlling this process, the study of advanced control strategies has gained much interest in the recent years.

The last 10 to 15 years show significant amount of efforts has been carried out by technology suppliers in improving the usability of their advanced controller products such as Model Predictive Control (MPC) (Darby and Nikolaou, 2012). Beginning in 1996, the MPC has gained a lot of attention to control the fermentation process. Overall, the results of the proposed MPC by these researchers exhibit desirable control characteristics such as good in tracking set point, have small overshoot response and good in disturbance rejection. MPC refers to a control algorithm that explicitly incorporates a process model to predict the future response of the controlled plant and take appropriate action through optimization. Quarterman et al. (2014) have implemented the model-based control in fermentations process for enhancing bioethanol production and maintaining acceptable overall growth rate in oxygen-limited conditions. While in the model development, researchers have mainly focused on Nonlinear Autoregressive with Exogenous input (NARX) model such as in the works of Efe et al. (2007),

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