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WELCOME SPEECH FROM THE RECTOR

Assalamualaikum Wa Rahmatullahi Wa Barakatuh,

In the Name of Allah, the Most Beneficent, the Most Merciful

May the peace, the mercy, and the blessings of Allah be upon you.

Distinguished Participants, Ladies and Gentlemen,

On behalf of Syiah Kuala University, I would like to welcome all of you to the The 6th Annual International Conference Syiah Kuala University in conjunction with The 12th International Conference on Mathematics, Statistics and Their Application (ICMSA), 2016.

I sincerely hope this conference is inspiring and also the one to be anticipated in the next years to come. The organizing committee is committed to make this conference a success with its ready applications not only to the university but also to the government. No matter how much we can accomplish by ourselves, whether it be research or development, it is never sufficient in this world of knowledge. Therefore, the focal drive of this conference is to exchange ideas, and by participating in this exchange, it is hoped that all parties who may benefit from the conference can apply it in managing activities in their areas. It is pleasing to note that the agenda of this conference covers a wide range of interesting topics related to life sciences, sciences and engineering, social sciences, and special topics on mathematics and statistics sciences.

Last but not the least, my deepest gratitude goes to the Organizing Committee, institutions, and companies who have directly and indirectly supported the well-running of this seminar. The committee has organized a vibrant scientific program and is working hard to present highly respected and internationally notorious speakers to lead it. Although we try our finest to be professional, on behalf of the Rector of Syiah Kuala University, please accept our sincere apologies should there be inconveniences that occur before, during, or after the event.

I wish you a very productive conference with exciting and encouraging discussions and exchange of knowledge so that together we can anticipate a future of groundbreaking sciences, technologies and education. May God bless us all with good health to make this event a successful and enjoyable one!

Thank you.

Prof. Dr. Ir. Samsul Rizal, M.Eng

Rector of Syiah Kuala University

MESSAGE FROM THE CHAIRMAN

Assalamualaikum Wr. Wb.

Honorable Guests, Presenters, and Participants,

As the Chairperson of the Organizing Committee, I take the privilege to warmly welcome our distinguished speakers and delegates who have come from all over Indonesia and overseas to our conference today. We are indeed honored to have you here with us.

The Annual International Conference (AIC) conference is a forum of information distribution, scientific discussion of literature, research, innovative and sustainable technology, industry product, etc. The AIC activity has been carried out regularly by Unsyiah since 2011. This year, the university will host The 6th Annual International Conference (AIC) in conjunction with The 12th International Conference on Mathematics, Statistics and Their Application (ICMSA). Furthermore, in this year The AIC program will also deliver an Innovation Expo and Industrial Forum event.

With many research activities that are conducted today on the global extent, it is important to share them to promote integrity in research at an international level. Accordingly, about 150 papers will be presented in this event, including those in the fields of Sciences and Engineering, Life Sciences, Social Sciences, and ICMSA topics. Therefore, to all participants, I would like to thank you for your valuable contributions to this conference.

I am also happy to inform that the committee is fortunate to have five keynote and invited speakers from Australia, Canada, Thailand, Malaysia and Indonesia, who have supported us from the very beginning with their capabilities to try and personally come and meet you all here at the conference.

At this juncture, I would like to take the opportunity to thank everyone who has made this event happen. It is a great pleasure for me to be a part of the organizing committee to coordinate such a remarkable conference. It does not only function as a platform to bring us who are academicians, researchers, students and others in sharing our research and experiences, but it also bridge us to further share ideas, concerns and constructive examples that we gain from this conference to build our society.

Finally, I hope that all participants will have memorable moments through this conference. The weather in Banda Aceh at the moment is at its best, so we hope that you enjoy your stay in Banda Aceh.

Thank you.

Sincerely,

Chairman of Committee

Dr. Syaifullah Muhammad, M. Eng

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PI Control of a Continuous Bio-Reactor

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Abstract

A bio-reactor is a vessel in which chemical process is carried out which involves organisms or biochemically active substances derived from such organisms. On the basis of mode of operation, a bio-reactor may be classified as batch, fed batch or continuous (e.g. a continuous stirred-tank reactor model). An example of a continuous bio-reactor is the chemostat. This paper investigates a PI (Proportional Integral) control of a continuous bio-reactor which is tuned by direct synthesis method. Process performance for servo problem were presented in this paper.

Key words: Proportional Integral control, simulation, bioreactor, direct synthesis method.

Introduction

The use of a control system for monitoring and controlling a biological process is shown in Figure 1 (Dochain, 2008). The central element of this scheme is the process. On this process, a number of measurements were carried out, either in the liquid or gas medium. On the basis of the knowledge available about the process and the control objectives, control algorithm can be developed.

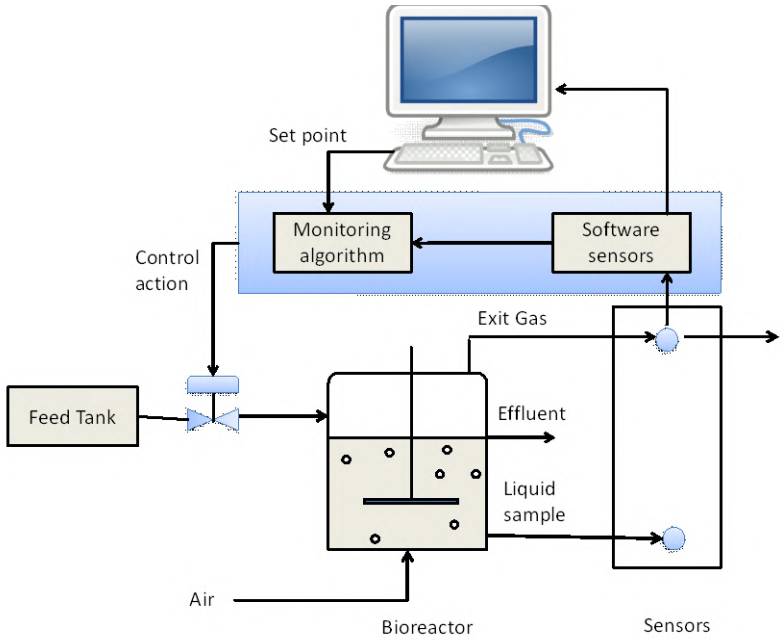

Figure 1. Schematic representation of bioprocess control system

In industrial bioprocess, the main objective is usually to maximise microbial growth or microbial production of some compound produced by microorganisms (Johnsson, et.al., 2015). Therefore, it is necessary to maintain a suitable environment for microorganisms at all times.

Dynamic study of the biological process, as in any processing industry, is important. Modeling biochemical processes is also a delicate exercise. It is different from physical process where there are laws that have been known for centuries. The majority of the models in biology depend on empirical laws.

Riggs and Karim (2006) presented the dynamic model of the bio-reactor system. Based on the differential equation provided, Agustriyanto (2015) obtained the Laplace transfer functions of the

bioreactor which were first order. These transfer function models are very useful for design of the automatic control of the bio-reactor system.

PI (Proportional Integral) or PID (Proportional Integral Derivative) controllers have been the most extensively used process control technique in the process industries for many decades because of their simplicity, robustness, and wide ranges of applicability. The direct synthesis approach is a popular design method for PI/PID controllers because explicit tuning formulas can be analytically derived by using process models.

The aim of this research is to implement PI (Proportional Integral) control algorithm to the bio-reactor system and to determine controller settings based on simple direct synthesis method (Seborg, 2010). Performance of the controller for servo problem will be presented.

Methods

The Bio-Reactor System

The bio-reactor system studied here (Riggs and Karim, 2006) is shown in Figure 2. A mechanistic model for this process is presented in the following:

$$\frac{dx}{dt} = -\frac{F_V}{V}x + \mu_{\max}x \tag{1}$$

$$\frac{dS}{dt} = \frac{F_V}{V}S_F - \frac{F_V}{V}S - \frac{1}{Y_{xS}}\mu_{\max}x \tag{2}$$

$$\frac{dP}{dt} = -\frac{F_V}{V}P + \frac{1}{Y_{xP}}\mu_{\max}x \tag{3}$$

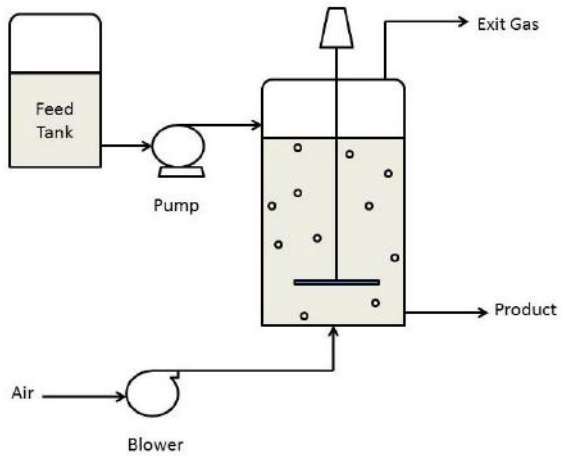

Figure 2. Continuous bio-reactor system

The Monod kinetics is assumed for cell growth and that most of the substrate is consumed by the cells. The process parameters and variables for this model is given in Table 1.

Feed contains sugar as a substrate (S) from corn or other grains (such as wheat, rice, barley etc) and nutritional salts to support for cell (x) growth. The cells (x) consume the substrate (S) and produce the product (P) and CO_2. An air blower provides oxygen to the cells. The exit gas is primarily composed of N_2 from the air, the unconsumed O_2, and CO_2 produced by the cells from the consumption of sugar. The cell concentration is measured by a turbidity meter, the substrate concentration is measured by an on-line HPLC analyzer. In industrial bio-process, filters are usually used for all streams entering and leaving the reactor to maintain sterile conditions although they are not shown in the Figure.

Table 1. Process parameters and steady state values

Symbol	Parameters and Variables	Values and units
F_v	Feed rate to the reactor	1000 L/h
K_s	Monod's saturation constant	0.1 g/L
P	Product concentration in the reactor	1.25 g/L
S	Substrate concentration in the ractor	25 g/L
S_F	Substrate concentration in the feed to the reactor	50 g/L
t	Time	h
V	Volume of the reactor	5000 L
x	Cell concentration in the reactor	0.25 g/L
Y_{xP}	Yield factor	0.2 g-cells/g-product
Y_{xS}	Yield coefficient	0.01 g-cells/g-substrate
μ_{max}	Maximum specific growth rate	0.2/h

Open Loop Transfer Function

The open loop transfer function for Bio-Reactor System (Figure 3) has been found (Agustriyanto, 2015) by solving those model equations (i.e Eq.(1) to (3)) subject to the parameters and steady state values given in Table 1 using Differential Equation Editor (DEE) in Matlab. The results were then identified using System Identification Toolbox.The method were also explained in Agustriyanto and Fatmawati (2013) and Agustriyanto (2014).

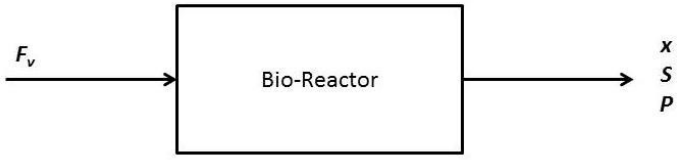

Figure 3. Open loop bio-reactor system

The results are as follows, where bar sign show that the variable are in devation form.

$$\begin{bmatrix} \bar{x} \\ \bar{S} \\ \bar{P} \end{bmatrix} = \begin{bmatrix} \dfrac{-0.005}{100s+1} \\ \dfrac{0.54813}{96.663s+1} \\ \dfrac{-0.025}{100s+1} \end{bmatrix} \left[\bar{F}_v\right] \qquad (4)$$

Control of Bio-Reactor System

The product (P) was selected as controlled variable and feed rate to the reactor (F_V) as manipulated variable. The closed loop system for Bio-reactor is shown in Figure 4. It is assumed that the transfer function for sensor and final control element (control valve) are 1, therefore they can be neglected in the figure.

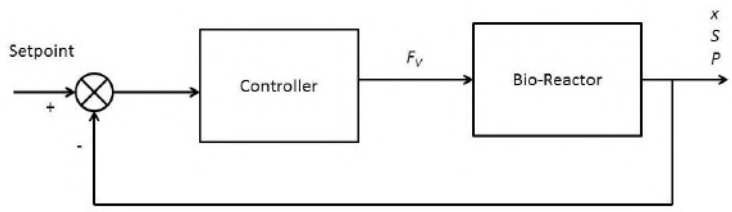

Figure 4. Closed loop of the bio-reactor system

PI (Proportional Integral) mode was selected for the controller and as the transfer function of the system are first oder, then direct synthesis method of tuning (Seborg, 2010) can be applied.

Direct Synthesis Tuning Menthod

Direct synthesis method for a first order process: $G_p(s) = \frac{K_p}{\tau_p s + 1}$ are as follows:

Let $G_p(s) =$ transfer function of the process

$G_c(s) =$ transfer function of the controller

If all the dynamics of the other elements in the closed loop system were neglected, the following overall transfer functions was obtained:

$$\frac{cv}{SP} = \frac{G_c.G_p}{1 + G_c.G_p} \quad (5)$$

Where *cv* = controlled variable

SP = Setpoint

The above equation can be re-arrangged to get the equation for feedback control law as follows:

$$G_c = \frac{1}{G_p}\left[\frac{\frac{cv}{SP}}{1 - \frac{cv}{SP}}\right] \quad (6)$$

In other words, controller consists of the inverse of the process model and the specification of the characteristic response of closed loop. $\frac{cv}{SP}$. The process model can be obtained from plant identification, while characteristic response of the closed loop ($\frac{cv}{SP}$) must be specified. A form of simple specification are as follows:

$$\frac{cv}{SP} = \frac{1}{\lambda s + 1} \quad (7)$$

Where: λ is the closed loop time constant specified by the user.

Substituting the above expression into the control law:

$$G_c = \frac{1}{G_p}\left[\frac{\frac{cv}{SP}}{1 - \frac{cv}{SP}}\right] = \frac{1}{G_p}\left[\frac{1}{\lambda s}\right] = \frac{\tau_p s + 1}{K_{p.}\lambda s} = \frac{\tau_p}{K_p \lambda}\left[1 + \frac{1}{\tau_p s}\right] \quad (8)$$

Based on the description of the process, then we can get ideal form of the PI controller:

$$k_c = \frac{\tau_p}{K_p.\lambda} \quad (9)$$

$$\tau_I = \tau_p \quad (10)$$

This direct synthesis method can be used for servo problem of first order process only. Chen and Seborg (2002) also presented PI controller design based on disturbance rejection. For other process which are not first order, direct synthesis method are also available (Rao et.al., 2008; Anil and Sree, 2015).

Results and Discussion

A closed loop system of a Bio-Reactor were simulated by using Simulink. Table 2 shows controller parameter obtained by Direct Synthesis method. Here, the value of $\lambda = 5$ was chosen, while *Kc* and τ_I were calculated using Eq.(9) and (10).

Table 2. Controller parameters

Loop	Kc	τ_I	λ
(P-Fv)	-800	100	5

As can be seen in Figure 5, product concentration follow the changes in set point. The performance is quite good. The performance for this servo problem (trajectory tracking) can be increased if we use smaller value of λ.

Figure 6 shows the dynamic of two other variables (cell and substrate concentration) which were not controlled. When the set point changed from 1.25 to 1.3 g/L, it will affect cell and substrate concentrations. In the new steady state values, cell concentration become 0.26 g/L while substrate concentration become 24 g/L from the initial values of 0.25 and 25 g/L respectively.

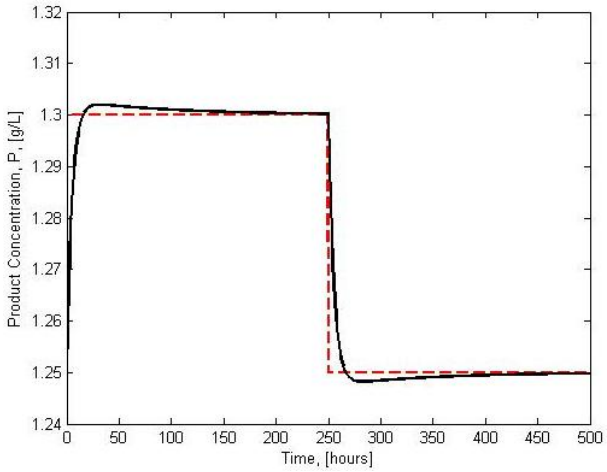

Figure 5. Plot of product concentration (P) vs time (h) and its set point (--)

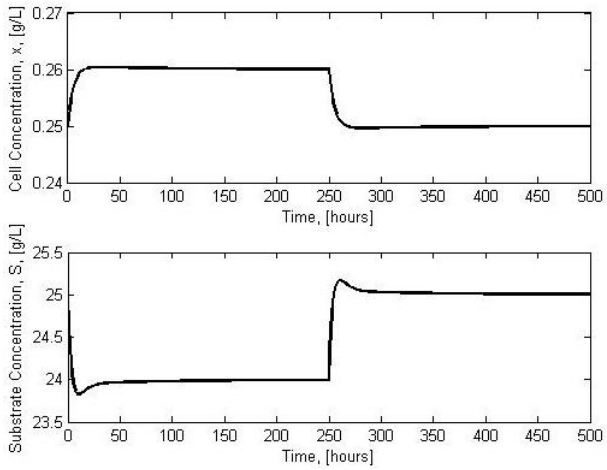

Figure 6. Plot of cell (x) and substrate concentration (S) vs time

Conclusions

Closed loop simulation results for servo problem of a continuous bio-reactor system have been presented. The direct synthesis tuning method was used in this simulation and gives good performance for set point changes as shown in Figure 5. The set point changes also affect cell and substrate concentration as presented in Figure 6.

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