XVI Congreso Nacional de Biotecnología y Bioingeniería
21 al 26 de Junio de 2015 Guadalajara, Jalisco, México.
Guadalajara

A NONLINEAR OBSERVER DESIGN FOR FERMENTATION SYSTEM FOR ETHANOL PRODCUTION BY *SACCHAROMYCES CEREVISIAE*

[1]Omar S. Castillo-Baltazar ,[1]Carlos H. Herrera-Méndez, [2]Ricardo Aguilar-López [1]Jesús R. Rodríguez-Núñez, [1]Vicente Peña-Caballero,

[1]Departamento de Ingeniería Agroindustrial, División de Ciencias de la Salud e Ingenierías. Campus Celaya-Salvatierra, Universidad de Guanajuato, Ave. Ing. Barros Sierra No.201, Es,q. Ave. Baja California. Ejido Santa María del Refugio, 38140. [2]CINVESTAV-IPN, Departamento de Biotecnología y Bioingeniería, Instituto Politécnico Nacional 2508, San Pedro Zacatenco, 07360, México, DF.

Palabras clave: observer design, S. cerevisiae, ethanol

Introduction. At present production of alcoholic beverages by *Saccharomyces cerevisiae* through a continuous fermentation process is gaining importance. However, it is not always possible to monitor process variables, either by lack of the sensor on the market or its high cost. An alternative is to design observers for unmeasured variables using information available measurable variables in the process. In this paper the design of a state observer for a biological process of alcohol production by *S. cerevisiae* is presented. The observer proposed contains a proportional type contribution and a sliding term for the measurement o error, which provides robustness of the estimation against noisy model uncertainties[1].

Methods. *Model*. In this work we use the model for *S. cerevisiae* proposed by Díaz-Montaño *et al*[2,3] :

$$\frac{dx_1}{dt} = \left(\left(\frac{dx_1}{dt}\right)_{growth} - D\right)x_1$$

$$\frac{dx_2}{dt} = -\left(Y_{xs} + Y_{ps}\right)\left(\frac{dx_1}{dt}\right)_{growth} x_1 - m_s x_1 + \left(x_{2,0} - x_2\right.$$ (1)

$$\frac{dx_3}{dt} = \alpha\left(\frac{dx_1}{dt}\right)_{growth} x_1 - x_3 D$$

Where $x_1, x_2$and $x_3$are biomass, substrate and product concentrations in g/L, here the kinetic rate, $\left(\frac{dx_1}{dt}\right)_{growth}$, is:

$$\left(\frac{dx_1}{dt}\right)_{growth} = \mu(x_2, x_3) = \mu_{max}\frac{x_2\left(1 - x_3 k_p\right)}{k_s + x_2 + x_2^2 k_i} \qquad (2)$$

And kinetic parameters and operating variables, the reader is referred to the work of Díaz-Montaño, et al., 2009).

Observer design methodology. The system for biological process for ethanol production in Ec. (1) can be represented in matrix for as follows:

$$\frac{d\boldsymbol{x}}{dt} = \boldsymbol{f}(\boldsymbol{x}, \boldsymbol{u}, \boldsymbol{y}) \qquad (3)$$

$$\boldsymbol{y} = \boldsymbol{h}(\boldsymbol{x}) = \boldsymbol{C}\boldsymbol{x}$$

Where $\boldsymbol{x} = [x_1\ x_2\ x_3]^T \in \mathbb{R}_+^3$ is the corresponding state vector, $\boldsymbol{y} = [0\ 1\ 0\,]\boldsymbol{x} \in \mathbb{R}_+^1$ is the measured system output.

Observer design. The general structure of observer for ethanol system in Ec. (1) is:

$$\frac{d\hat{\boldsymbol{x}}}{dt} = \boldsymbol{f}(\hat{\boldsymbol{x}}, \boldsymbol{u}, \boldsymbol{y}) + \boldsymbol{\Theta}(\boldsymbol{\varepsilon}) \qquad (4)$$

Where $\boldsymbol{\varepsilon} = \boldsymbol{x} - \hat{\boldsymbol{x}}$ is the error

In Ec. (4) $\boldsymbol{\Theta}(\boldsymbol{\varepsilon}) = \pm\boldsymbol{K}\boldsymbol{\varepsilon} \pm \boldsymbol{G}\boldsymbol{\Phi}(sign(\boldsymbol{\varepsilon}))$

In this work $\boldsymbol{\Phi}(sign(\boldsymbol{\varepsilon}))$ has the following structure:

$$\boldsymbol{\Phi}(sign(\boldsymbol{\varepsilon})) = \boldsymbol{G}sign(\,\boldsymbol{\varepsilon})exp((\boldsymbol{\varepsilon})) \qquad (5)$$

Here for the Ec. (5) note that term in Ec. (6) is bounded

$$\|\boldsymbol{G}\boldsymbol{G}sign(\,\boldsymbol{\varepsilon})exp((\boldsymbol{\varepsilon}))\| \leq 1 \qquad (6)$$

Considering Ecs. (3)-(4) and error dynamic

$$\frac{d\boldsymbol{\varepsilon}}{dt} = \frac{d\boldsymbol{x}}{dt} - \frac{d\hat{\boldsymbol{x}}}{dt} \qquad (7)$$

is easy show that Ec. (7) can be expressed as:

$$\|\boldsymbol{\varepsilon}\| \leq \frac{\boldsymbol{g}}{(\boldsymbol{L} - \boldsymbol{k})}\left(1 - \exp(\boldsymbol{L} - \boldsymbol{k})\,t\right) + \boldsymbol{\varepsilon_0}\exp(\boldsymbol{L} - \boldsymbol{k})\,t \qquad (8)$$

and for t → ∞

$$\|\boldsymbol{\varepsilon}\| \leq \frac{\boldsymbol{g}}{(\boldsymbol{L} - \boldsymbol{k})} \text{ or } \|\boldsymbol{\varepsilon}\| \leq \frac{\boldsymbol{g}}{\boldsymbol{L}} \qquad (9)$$

Results. The proposed observer provides a good state estimation (**Fig. 1**), can be seen that the estimation error of the sliding mode observer is larger than that of the proposed observer.

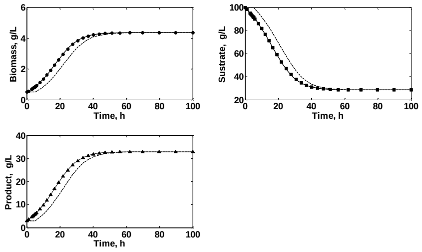

Fig.1 Results of biomass (●), substrate (■) and product (▲) (ethanol) estimations actual values, sliding mode observer, and (– –) proposed observer (▬). This scenario present the case where $\boldsymbol{y} = [0\ 1\ 0\,] = x_2$"Substrate concentration" whit $D = 0.08\frac{1}{h}$

Conclusions. Proposed observer present acceptable performance compared to a sliding mode observer

References.

1. P.A. Lopez-Perez *et al*, Fuel. 2012, http://dx.doi.org/10.1016/j.fuel.2012.11.0203.
2. D. Díaz-Montaño *et al*, AMCA. 2009.
3. M. Arellano-Plaza *et al*, JCBPS. 2007,1, 1-6.