American Journal of Engineering Research (AJER)
e-ISSN : 2320-0847 p-ISSN : 2320-0936
Volume-03, Issue-07, pp-54-59
www.ajer.org

Research Paper Open Access

Performance Evaluation of Fuzzy Logic Controller with Conventional PI (Designed at Higher Dilution Rate) Controller for continues Bioreactor.

Ballekallu Chinna Eeranna, G.Prabhaker Reddy[2]
[1]*Dept. of Petroleum Engineering, Lords Institute of engineering and Technology, Hyderabad, India,Phone: 91-9866400329,*

***Abstract:* -** In this paper, a fuzzy logic controller for unstable continuous Bioreactor is proposed. The essential idea is the controller's gain tuning based on the error pattern (difference of controlled variable and its set point) and fuzzy rules. The performance of the proposed controller is compared with conventional PI (designed at higher dilution rate). Simulation results show that when the gain of nonlinear process has a big change, proposed controller has better performances than PI.

***Keywords:* -** *Fuzzy logic control, Bioreactor, Input Multiplicities, productivity.*

I. INTRODUCTION

Input multiplicity occurs when two or more sets of input variables provide the same output conditions. Biological processes can exhibit complex nonlinear behavior such as multiplicity. A number of published papers have reported input and output multiplicity found in various Biological processes.

In recent years the industrial application of advanced control techniques for the process industries has become more demanding, mainly due to the increasing complexity of the processes themselves as well as to enhanced requirements in terms of product quality and robustness properties of systems under feedback control. In this work, the design and evaluation of , unlike model based nonlinear controller, the lesser computationally involved fuzzy logic controller of for bioreactor is presented to overcome the control problems associated with conventional PI controller due to input multiplicities.

II. PROCESS DESCRIPTION

We consider here an isothermal continuous bio reactor, which can be described by the following unstructured model equations for simulation studies to evaluate the proposed controller (Henson,M.A.and. Seborg,D.E. (1982)) :

Cell Balance:

$$\frac{dX}{dt} = -DX + \mu X$$

Substrate Balance:

$$\frac{dS}{dt} = D(S_f - S) - \mu \frac{X}{Y}$$

Product Balance:

$$\frac{dP}{dt} = -DP + (\alpha\mu + \beta)X$$

At t = 0, $X = X_s$, $S = S_s$, $P = P_s$

The specific growth rate model is assumed to exhibit both substrate and product inhibition:

$$\mu=\mu_m\{[1-(P/P_m)]S\}/(K_m+S+S^2/K_i)$$

Where α, Pm,Km and Ki are respectively the maximum specific growth rate, product saturation constant, substrate saturation constant and substrate inhibition constant. The nominal values of the parameters and the operating conditions used in the present study are given as: α=2.2 g/g, b=0.2 g/g, mm =0.48 h^{-1}, Pm= 50 g/l, Km=1.2 g/l, Ki=22 g/l , Sf=20 g/l and Y=0.4 g/g (Chidambaram,M and Reddy, G.P. (1995)).
If the biomass and substrate are of negligible value when compared to that of the product, the productivity Q can be defined as the amount of product cells produced per unit time:

$$Q=DP$$

The steady state solution of Eqs. (1) to (5) are obtained in order to calculate D for a given value of Q as:

$$b_1D^4+(b_2-h_1)D^3+(b_3-h_2)D^2-h_3D-h_4=0$$

$$h1=\alpha^2/Sf$$
$$h2=\alpha\{2S_f\beta-Q\,[1/Y+(S_f\alpha/Pm)]\}$$
$$h3=(\alpha/Pm\,Y)\,Q^2-Q\,[(2\alpha\beta S_f/Pm)+(\beta/Y)]+S_f\beta^2$$
$$h4=(\beta/Pm)[(Q^2/Y)-\beta S_fQ]\qquad \text{with}$$
$$b1=\alpha^2a/\mu_m\,;\quad b2=(2\alpha\beta/\mu_m)\,a-(\alpha Q/\mu_m)\,b\,;$$
$$b3=(\beta^2/\mu_m)a-(Q\beta/\mu_m)\,b+(Q^2/\mu_m)\,c\qquad \text{and}$$
$$a=(S_f^2/K_I)+S_f+Km\,;\qquad b=[1+2(S_f/K_I)]/Y;$$
$$c=1/(Y^2K)$$

The numerical solution of Eq. (7) gives three positive real roots and one negative root. Of three positive roots, the lowest value of the root gives negative value of S from the steady state solution of the model equations. Hence for the operating condition chosen in this work, only two positive realistic values for D are obtained.The steady state values of X,S,P and hence Q are calculated for the operating conditions. Fig. 1 shows the steady-state response of Q versus D and for a given value of Q there are two values of D due to input multiplicities.

Also, it exhibits the maximum productivity value of 3.7 (g/lh) i.e., Q at the peak. In the present work, it is proposed to study the fuzzy logic controller performance near the optimum value as any controller cannot designed at optimum with slope value is zero. The value of Q near the optimum is 3.5 (g/l h) is selected and it is obtained with either D = 0.22 1/h or D=0.13 1/h. At the lower value of D, the steady state gain is positive, here at the larger value of D the gain is negative

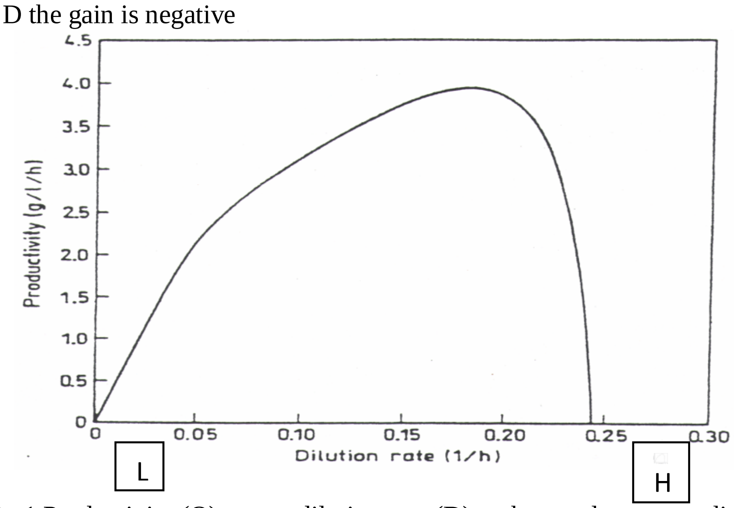


Fig.1 Productivity (Q) verses dilution rate (D) at the steadystate condition.
L- Lower dilution rate and H=Higher dilution rate

III. DESIGN OF A FUZZY LOGIC CONTROLLER

In the fuzzification step, the productivity and productivity rate are selected as input variables to the fuzzy controller. Universes of discourse of these input variables are divided into three fuzzy sets and they are linguistically called as HIGH, LOW and OK as shown in the Figs. 2 & 3. The Gaussian membership functions with the appropriate ranges have been used for these fuzzy sets. The lower and higher values of the dilution rate (D) have been selected as Fuzzy output variables.

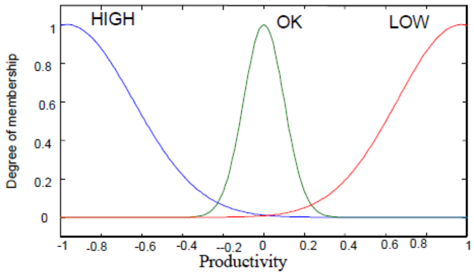


Fig. 2 Fuzzy sets of Productivity

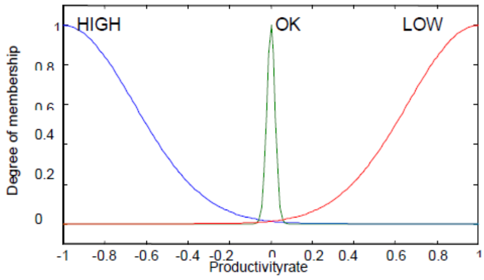


Fig. 3 Fuzzy sets of Productivity rate

Similar to the input variables the universe of discourse of the output variables is divided into three fuzzy sets with linguistic names INCREASE, DECREASE, and NORMAL as shown in the Figs.4 &.5.

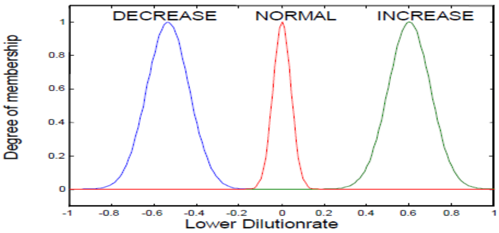


Fig.4 Fuzzy sets of lower dilution rate

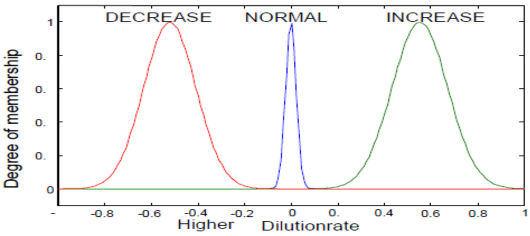


Fig.5 Fuzzy sets of higher dilution rate

In the rule base, the rules have been considered to generate the control action at lower and higher values of dilution rate (D). The rule base takes into account the opposite behavior at both the input values. i.e. process gain is positive at lower input value and it is negative at higher input value.

The six rules are:

(1) If(productivity is HIGH)then (lower_Dilutionrate isDECREASE)(higher_Dilutionrate is INCREASE)

(2) If (productivity is LOW) then (lower_Dilutionrate is INCREASE)(higher_Dilutionrate is DECREASE)

(3) If (productivity is OK) then (lower_Dilutionrate is NORMAL)(higher_Dilutionrate is NORMAL)

(4) If (productivity is OK) and (productivityrate is HIGH) then (lower_Dilutionrate is DECREASE)(higher_Dilutionrate is INCREASE)

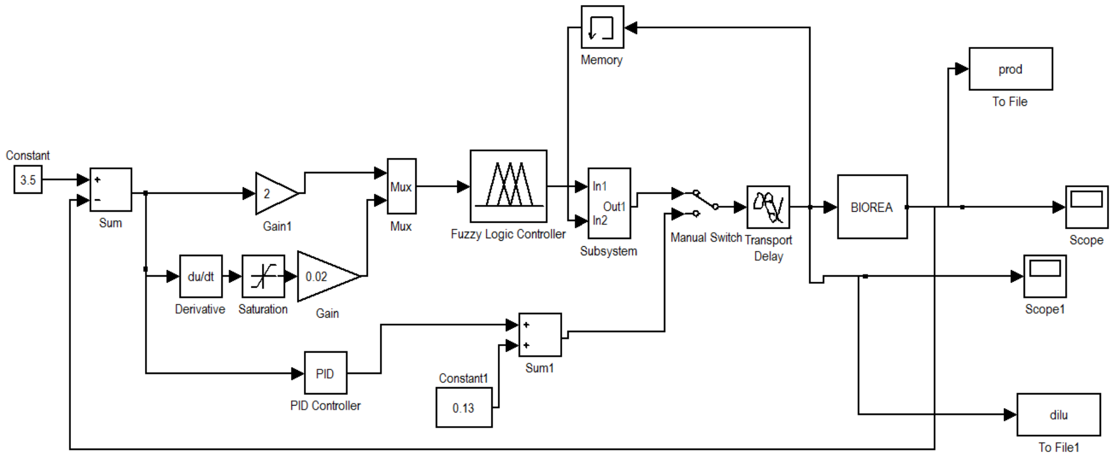
(5) If (productivity is OK) and (productivityrate is LOW) then (lower_Dilutionrate is INCREASE)(higher_Dilutionrate is DECREASE)

(6) If (productivity is OK) and (productivityrate is OK) then (lower_Dilutionrate is NORMAL)(higher_Dilutionrate is NORMAL)

The centroid method has been used to obtain the crisp value in the dilution rate. The fuzzy controller always provides two crisp values i.e. one is at lower value (D = 0.13 h^{-1}) and the other is at higher value (D= 0.22 h^{-1}) in dilution rates for control action and the value, which is nearer to the operating value between these two, is to be selected for the implementation.

IV. RESULTS AND DISCUSSION

The performance of proposed fuzzy logic controller and conventional PI controller to the Continuous bioreactor with input multiplicities in dilution rate is evaluated using the closed loop block diagrams as shown in Figs 6 & 7. These block diagram are developed using MATLAB version 6.1 and its associated SIMULINK and FUZZY LOGIC tool boxes. The scaling factors (gains):Gain=3,Gain1=0.02 Gain2=0.0046, Gain3=0.00032 for the fuzzy logic controller have obtained by trial and error method from simulation studies. The parameters of conventional PI
controller used in the simulation studies are, Kc=-0.005, τI =9.35 h (Chidambaram,M and Reddy, G.P. (1995)).



. 6. Block diagram for fuzzy logic controller & conventional PI controller

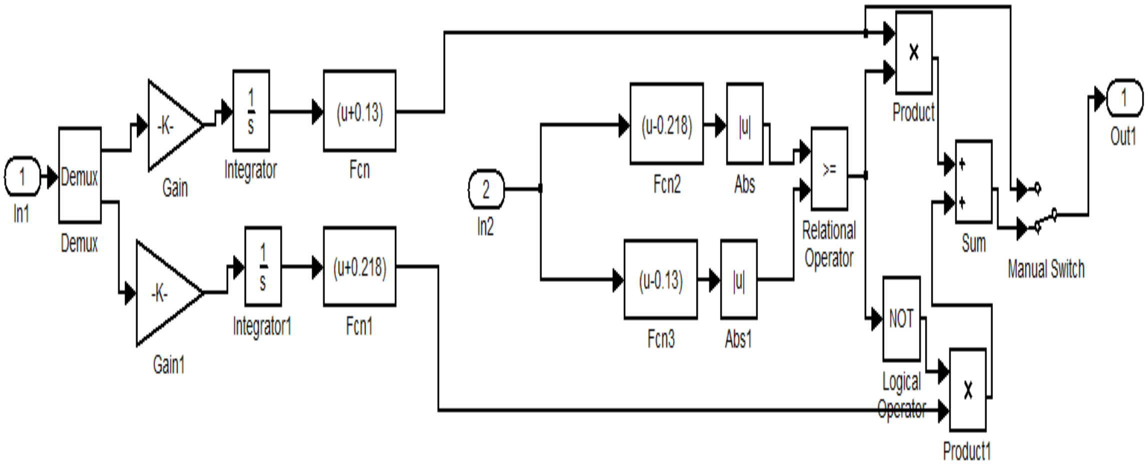


Fig. 7. Block diagram for subsystem of fuzzy logic controller shown in Fig. 6

4.1 At higher input Dilution rate (D=0.218 hr^{-1})

Servo problem: The closed loop responses at two operating points for set point change of ±10%, have been obtained and are presented in Figures from 8 and 9. In these Figures, the response of PI is compared with fuzzy logic controller. For +10% changes in set point, here the PI gives stable response and offset 0.05%, whereas the fuzzy logic controller reaches the set point in 40 hrs of time. These results show that fuzzy controller performance has been faster and offset free response than that of PI controller. Similar kind of faster responses are obtained for -10%. The performances of Fuzzy logic control remain superior at two operating points.

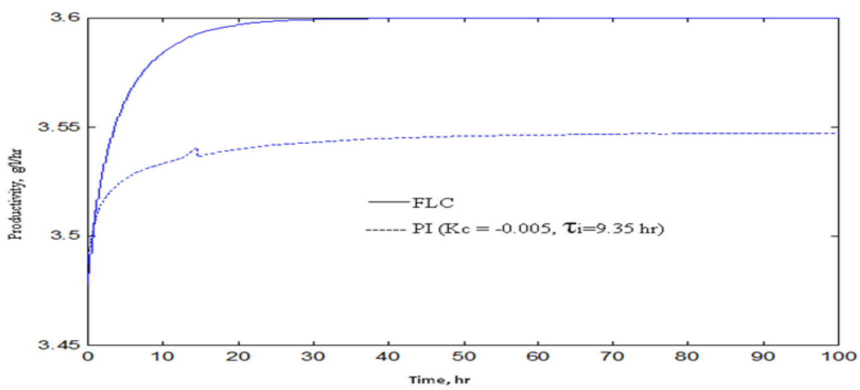


Fig 8 Closed loop response of productivity for step change in set point from 3.5 to 3.6 (+10%) at higher input

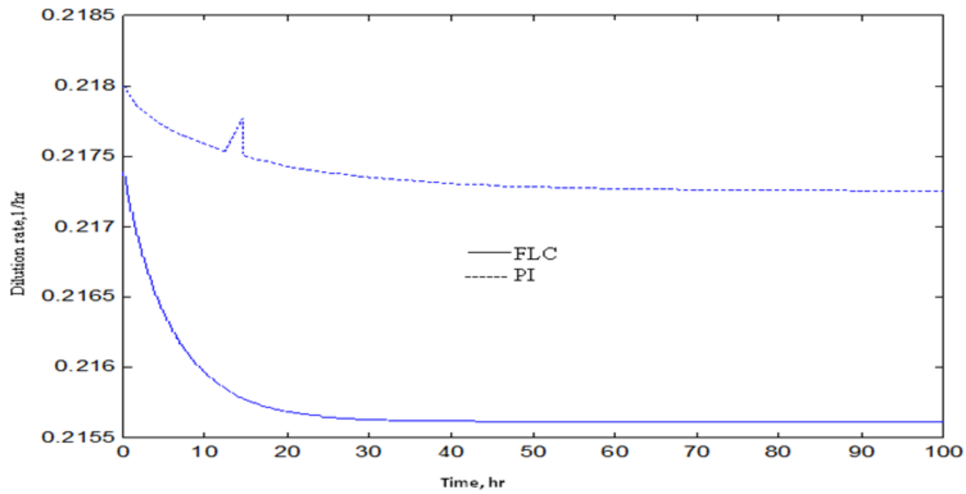


Fig 9. Control action in Dilution rate vs. time as shown in Fig 8

Regulatory problem:
Regulatory response in productivity of fuzzy logic and conventional PI is shown in Fig. 10 for a step change in substrate feed concentration (S_f) from 20 to 24(+20%) g/l. This result shows that the fuzzy logic controller faster than that of the linear PI.

Proposed fuzzy logic controller reaches set point with in 30 hrs, where as PI reaches after 50 hrs. Proposed fuzzy logic controller has maximum deviation of less than 2% where as PI controller has a lager deviation of about 6 %. Fuzzy logic controller has lower settling time than the PI controller. The corresponding control actions in terms of dilution rate are smooth and they are shown in fig.11.

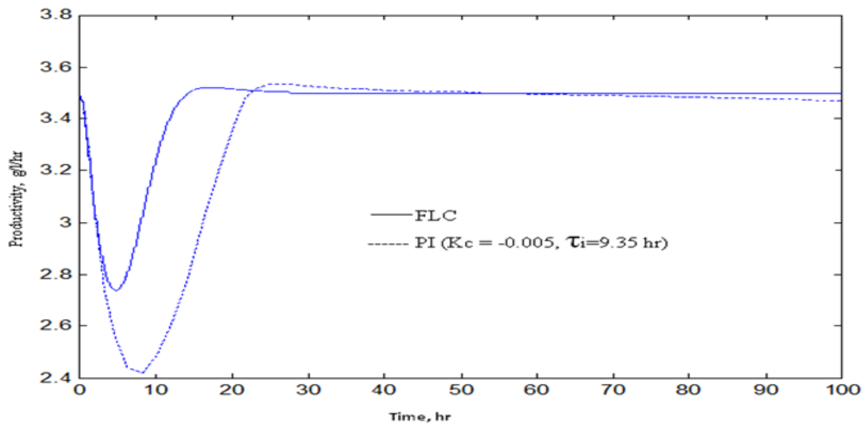


Fig 10. Closed loop response of productivity for a change in Sf from 20 to 24 (+20%) at higher input

.

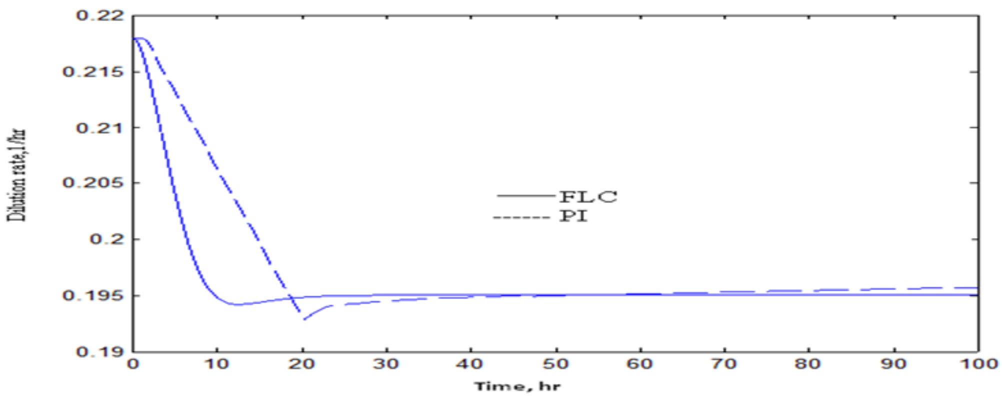


Fig 11 Control action in Dilution rate vs. time as shown in Fig 10

V. CONCLUSIONS

For a continuous bioreactor with input multiplicities in dilution rate, the performance of present fuzzy logic controller productivity is found to much superior to that of the conventional PI controller at higher dilution rate. where as the linear PI controller (designed at higher dilution rate) will give unstable responses and results in wash out condition. Thus, the present fuzzy logic controller is superior to linear PI controller productivity and can overcome the control problems due to the input multiplicities

REFERENCES

[1] Koppel, L.B.(1983) Input multiplicities in process control, Chemical Engineering Education, pp58-63, & 89-92. Mamdani,E.H., Assilian, S.(1975) An experiment in linguistic synthesis with a fuzzy logic controller International, Journal of Man-Machine Studies.7pp1-13.

[2] Srinivas,M and Chidambaram, M(1995) Fuzzy logic control of an unstable bioreactor, Bioprocess Engineering. 12 135-139

[3] Henson,M.A.and. Seborg,D.E. (1982) Nonlinear control strategies for continuous fementer " Chemical engineering Science,47pp821-835.

[4] Srinivas,M and Chidambaram, M(1995) Fuzzy logic control of an unstable bioreactor, Bioprocess Engineering. 12135-139.

[5] Mamdani,E.H., Assilian, S.(1975) An experiment in linguistic synthesis with a fuzzy logic controller

[6] International Journal of Man-Machine Studies.7pp1-13. Michio Suzeno (1985) An introduction survey to Fuzzy control, Information Sciences, 36 pp59-83.

[7] Reddy, G.P. and Chidambaram, M (1995) Nonlinear control of bioreactors with input multiplicities in dilution rate, Bioprocess Engineering. 12pp 151-155.