Publication of Little Lion Scientific R&D, Islamabad PAKISTAN
Journal of Theoretical and Applied Information Technology
31st July 2011. Vol. 29 No.2

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

MODEL DEVELOPMENT FOR OXYGENATION OF BONE WASH EFFLUENT

[1]J.SUMATHI, [2]S.SUNDARAM

[1]Assistant Professor, Department of EIE, SEEE, SASTRA University, Tamil Nadu, India-613401
[2]Professor, Department of EIE, SEEE, SASTRA University, Tamil Nadu, India-613401

ABSTRACT

Effluent from bone wash industry diluted with different quantity of water was oxygenated at 3 different speeds ranging from 135 to 155 rpm in a 1.5 litre Tokyo Rikakikai bioreactor at 298K. The data was subjected to regression analysis and fitted to a first order plus dead time model with an error of less than 5 percent. The model parameters were used to design controller settings by Z-N (PID), Skogestad, Smith predictor and IMC methods. A closed loop analysis using the above controller settings indicate that IMC is better suited for the process based on rise time, settling time and overshoot. Closed loop performance based on ISE, IAE and ITAE also suggested a similar conclusion.

Keywords*:* *Bone Wash effluent, Modeling, Z-N (PID), Skogestad, Smith Predictor and IMC.*

1. INTRODUCTION

Liquid effluents from various industries such as distillery, textile and paper slaughter houses pose serious health hazard to humanity. In the slaughter houses the bones are washed with water and pumped to effluent treatment plants. In the treatment of liquid effluents one of the primary steps is aeration to remove odour. Under aeration results in improper treatment while over aeration is a waste of power. Optimum aeration and design of suitable controller to maintain air flow is vital for effluent operator of the effluent treatment plant. Dissolved oxygen is an important parameter to be monitored. Development of model aeration for various industrial effluents will help in the design of model based controllers. Brown and Laboureur [1] investigated aerobic sludges and successfully stabilized dye metabolites. Chachuat [2] studied activated sludge with reference to optimal control. Vives [3] used a laboratory scale sequencing batch reactor to analyze aerobic reaction and also developed control software for the process. Debabrata Mazumder *et al* [4] used a shaft type hybrid reactor to analyse sludges. Kayyuh-ju etal [5] studied dissolved oxygen in wastewater treatment. Bahadır [6] focused on electrochemical treatment of paint industry effluent. Oliveira [7] designed an adaptive controller which is precise, stable and robust to disturbances and to inaccuracies like variability in raw materials typical in fermentation processes. The controller is simple, easy to implement, and could possibly improve productivity in processes for which oxygen transfer capacity is limiting production. Traor´e [8] have proposed a method for Fuzzy control of dissolved oxygen in a batch reactor pilot plant. fuzzy logic proved to be a robust and effective DO control tool, easy to integrate in a global monitoring system for cost management. Sanchez Rojas [9] summarizes and discusses effluent analysis, focusing on the methods and techniques.

Giriraj *et al.* [10] applied Skogestad modification of IMC rule and with non-traditional tuning method based on Genetic Algorithm. Marshall *et al* [11] have proposed a method for calculating ISE analytically which is based on Parsevals theorem and contour integration. Chen, Seborg [12] and Skogestad [13] used IAE and total variation of manipulated variable as one of the performance metrics for the performance analysis of PI and PID controller based on direct synthesis and disturbance rejection. In the past two decades there has been a great advance in the theory for the design of robust uncertainty tolerant multivariable feed back control systems [14].

Literature does not report quantitatively the effect of dilution and the duration of aeration on dissolved oxygen. No attempt has been made to generate suitable model for the aeration process. This work studies experimentally the effect of effluent to water ratio on dissolved oxygen and also the impact

Publication of Little Lion Scientific R&D, Islamabad PAKISTAN
Journal of Theoretical and Applied Information Technology
31st July 2011. Vol. 29 No.2

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

of stirring on the stability of the process. Based on the data various models were analyzed and the best suited model identified. This model has been used in simulation studies for designing controllers based on various performance criteria such as rise time, settling time, overshoot, ISE, IAE and ITAE.

2. EXPERIMENTAL SETUP PROCEDURE

A Tokyo Rikakikai 1.5 litre fermentor with provisions for setting of airflow, temperature and speed of stirrer is shown in Figure (1).

Fresh effluent from bone wash industry was diluted with distilled water to obtain various effluent concentrations ranging from 0 to 100 percent in steps of 10 percent. One litre of effluent of known concentration was charged into the fermentor.

The dissolved oxygen was monitored using an online Lutron, (India) dissolved oxygen probe with a digital indicator and interfaced to a personal computer. Purified air was suddenly metered through a Gallenkamp rotameter at a rate of 1 lpm into the effluent in the fermentor. The dissolved oxygen was monitored and recorded for ten different concentrations and three speeds (135, 145, and 155rpm).

Figure 1 Experimental setup - Batch Process

3. RESULT & DISCUSSION

Ten concentrations of water and effluent ranging from 0 to 100 percent effluent at three different speeds were studied. However results for two concentrations of effluent 10 and 60 percent effluent and three speeds are presented and discussed below since the general pattern for other concentrations are similar. Figure 2 presents the experimental and calculated data for two concentrations (60 and 10 percent) and three speeds. The data was fitted by regression analysis to a first order plus dead time model given by equation (1).

$$DO(t) = DO(0) + KA\,[1-\exp-(t-\tau_d)/\tau] \text{ ------(1)}$$

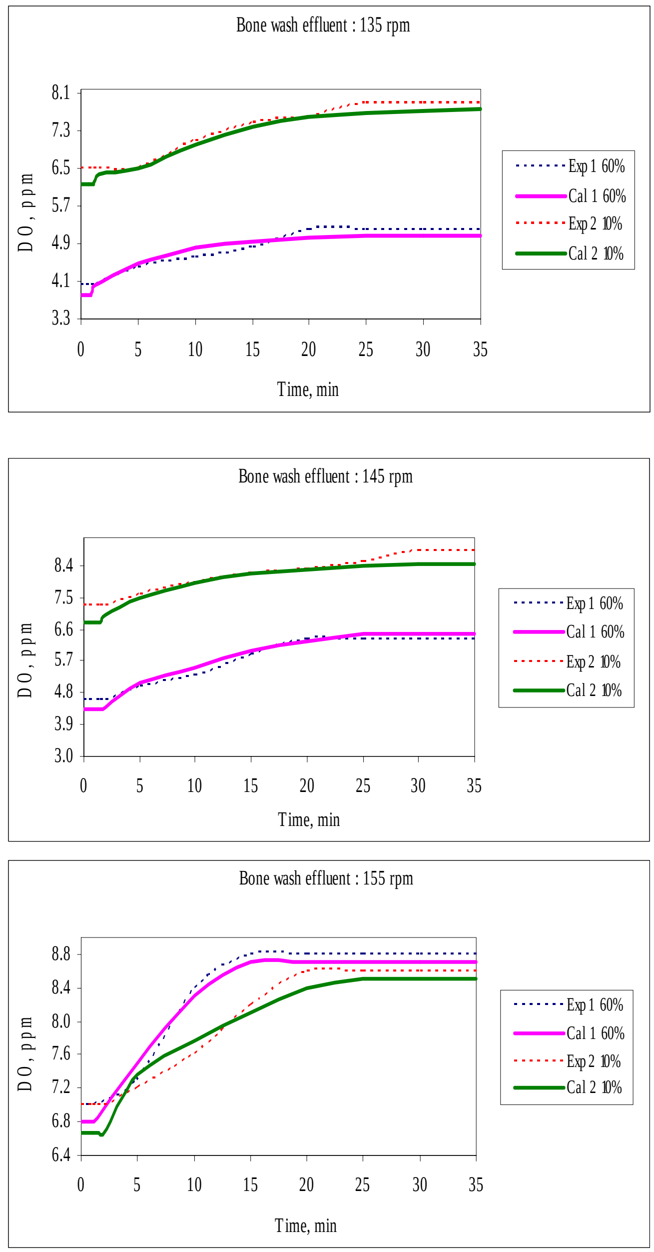

Figure 2: Experimental and calculated values for 60% and 10% concentration of Bone wash effluent for speeds of 135,145,155 rpm.

Table1 gives model parameters K, τ, τ_d for two concentrations and three speeds. The values of DO

Publication of Little Lion Scientific R&D, Islamabad PAKISTAN
Journal of Theoretical and Applied Information Technology
31st July 2011. Vol. 29 No.2

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

calculated using model parameters agreed with experimental data with an error of less than 5 percent as seen from figure 2. Based on model parameters a closed loop simulation was carried out using MATLAB (15). Various tuning methods such as Z-N, Skogestad, Smith predictor and IMC (16) were studied for selecting controller parameters.

Table 1: Model parameters for 2 concentrations and 3 speeds.

Speed, rpm	Percentage concentration of effluent	K	τ	τ_d
135	60	3.7	6.8	1.20
	10	1.4	7.0	1.58
145	60	4.2	10.0	0.32
	10	1.3	9.2	1.22
155	60	1.6	18.0	1.10
	10	1.2	10.0	2.05

4. CONCLUSION

Figures 3 to 6 gives the closed loop response simulated using MATLAB for two concentrations at 145 rpm for servo and regulator problem. Tables 2 and 3 compare the performance of various controllers based on rise time, settling time, peak overshoot, ISE, IAE and ITAE analysis for both servo and regulator problem. Similar results were obtained for the other two speeds and concentrations.

It can be concluded as seen from tables 2 and 3 that for bone wash industry effluent the controller design based on IMC is far superior to other methods with the lowest rise time, settling time peak overshoot, ISE, IAE and ITAE. Further work on other effluents such as Textile, Paper and Distillery are in progress.

5. FUTURE WORK

Other industrial effluents such as textile, distillery, paper and paint can be subjected to similar studies and generalised model and control criteria established work in this area is in progress in the laboratory.

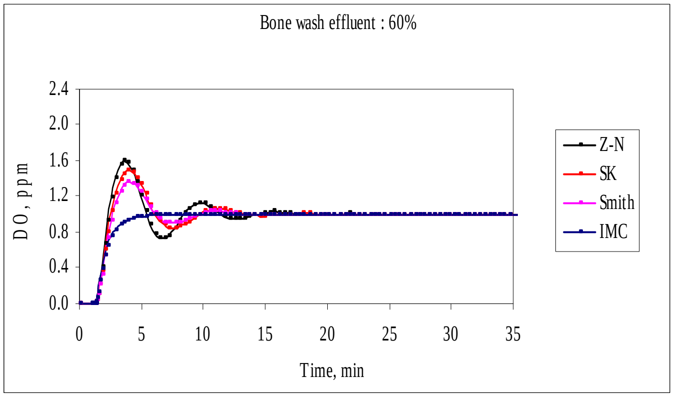

Figure 3: Servo response for 145 rpm, 60% Bone wash effluent.

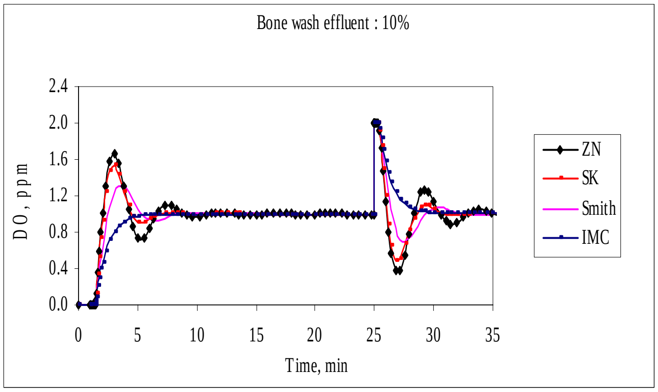

Figure 4: Servo response for 145 rpm, 10% Bone wash effluent.

Figure 5: Regulator response for 145 rpm, 60% Bone wash effluent.

Publication of Little Lion Scientific R&D, Islamabad PAKISTAN
Journal of Theoretical and Applied Information Technology
31st July 2011. Vol. 29 No.2

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

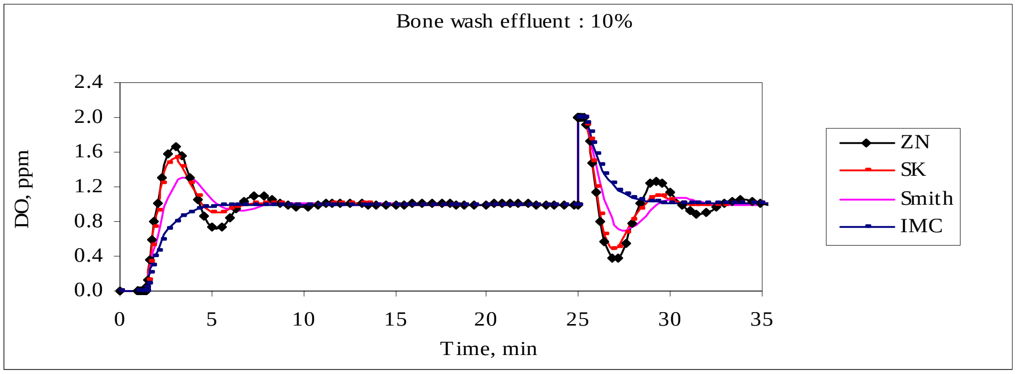

Figure 6: Regulator response for 145 rpm, 10% Bone wash effluent.

Table 2: Performance analysis of controllers for Servo problem.

Speed, rpm	Rise time (t_r), seconds				Settling time (t_s), seconds				Percentage overshoot			
	Z-N	SK	Sm	**IMC**	Z-N	SK	Sm	**IMC**	Z-N	SK	Sm	**IMC**
135	2.50	3.01	3.90	--	23.9	9.29	14.90	**6.32**	50.0	36.90	22.00	**-1.97**
145	1.10	1.68	1.57	--	14.1	6.52	7.26	**4.29**	56.1	4.60	2.70	**-0.58**
155	1.70	2.80	2.80	--	15.7	13.10	10.6	**4.98**	53.1	48.40	20.10	**-1.08**

Speed, rpm	ISE				IAE				ITAE			
	Z-N	SK	Sm	**IMC**	Z-N	SK	Sm	**IMC**	Z-N	SK	Sm	**IMC**
135	25.4	15.30	8.77	**8.72**	34.10	24.93	17.3	**14.8**	70.3	51.2	49.4	**45.7**
145	19.1	11.88	18.70	**7.30**	38.35	20.30	27.7	**12.5**	44.3	29.7	29.3	**25.4**
155	27.8	14.40	10.80	**10.00**	39.40	16.41	19.4	**16.4**	57.2	41.6	47.2	**40.2**

Table 3: Performance analysis of controllers for Regulator problem.

Speed, rpm	Rise time (t_r), seconds				Settling time (t_s), seconds				Percentage Overshoot			
	Z-N	SK	Sm	**IMC**	Z-N	SK	Sm	**IMC**	Z-N	SK	Sm	**IMC**
135	28.0	2.92	3.40	--	17.9	8.80	12.72	**3.10**	62.9	37.2	28.8	**1.13**
145	32.7	1.88	1.99	--	16.2	6.86	7.83	**3.16**	69.7	44.7	32.0	**0.06**
155	18.5	3.32	3.47	--	23.7	12.10	9.30	**3.54**	80.9	42.3	23.2	**0.75**

Publication of Little Lion Scientific R&D, Islamabad PAKISTAN
Journal of Theoretical and Applied Information Technology
31st July 2011. Vol. 29 No.2

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Speed, rpm	ISE				IAE				ITAE			
	Z-N	SK	Sm	**IMC**	Z-N	SK	Sm	**IMC**	Z-N	SK	Sm	**IMC**
135	21.4	14.1	61.8	**12.4**	22.8	16.3	63.7	**15.6**	51.6	23.5	31.5	**23.3**
145	11.6	14.6	62.6	**10.5**	21.2	16.8	64.6	**14.2**	46.7	22.1	21.9	**12.3**
155	20.7	16.4	64.5	**14.4**	22.1	20.0	65.9	**16.1**	65.6	33.0	29.3	**22.4**

Nomenclature

A - Step change in air rate, lpm
K - Steady state gain
DO - Dissolved Oxygen, ppm
DO (0) - initial value of DO, ppm
DO (t) - value of DO at any time, ppm
IMC - Internal Model Control
Sm - Smith predictor
SK - Skogestad
Z-N - Ziegler-Nichols
PI - Proportional-Integral
PID - Proportional-Integral- Derivative
ISE - Integral of the square of the error
IAE - Integral of the absolute value of error
ITAE - Integral of time-weighted absolute error
τ - time constant, min
τ_d - delay time, min

ACKNOWLEDGEMENT:

Authors wish to thank Rengarajan Amirtharajan, Assistant Professor III, Department of ECE, School of Electrical & Electronics Engineering, SASTRA University for his time and support.

REFRENCES:

[1] D.Brown and P.Laboureur, "The aerobic biodegradability of primary aromatic amines". *Chemosphere*, Vol. 12, No. 3, 1983, pp. 405-414.

[2] B.Chachuat, N. Roche and M.A. Latifi, "Optimal aeration control of industrial alternating activated sludge plants", *Biochemical engineering journal*, Vol 23 (3), 2005, pp. 277-289.

[3] M.T.Vives, M. D. Balaguer, S. García, R. García, J. Colprim., "Dyeing wastewater treatment in a sequencing batch reactor system", *Journal of Environmental Science and Health*, Part A, Vol. 38, No. 10, 2003, pp. 2089 - 2099.

[4] Debabrata Mazumder, Somnath Mukherjee, Pradip K. Ray, "Treatment of distillery an aerobic effluent in a hybrid biological reactor", *International Journal of Environment and Pollution*, Vol. 32 No. 1, 2008, pp. 43 - 56.

[5] Kay Yuh-Ju Ko, Bayliss, C. McInnis and Graham C. Goodwin, "Adaptive control and identification of the dissolved oxygen process", *Automatica*, Vol. 18, No. 6, 1982, pp. 727- 730.

[6] TK.Bahadr Korbahti, Nahit Aktas and Abdurrahman Tanyolac, "Optimization of electrochemical treatment of industrial paint wastewater with response surface methodology", *Journal of Hazardous Materials*, Vol. 148, No. 1, 2007, pp 83-90.

[7] R. Oliveira, R. Simutis, S. Feyo de Azevedo, "Design of a stable adaptive Controller for driving aerobic fermentation processes near maximum oxygen transfer capacity" Journal of

Publication of Little Lion Scientific R&D, Islamabad PAKISTAN
Journal of Theoretical and Applied Information Technology
31st July 2011. Vol. 29 No.2

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Process Control, Vol 14, 2004, pp. 617–626.

[8] Traor´e, S. Grieu , S. Puig b, L. Corominas, F.Thiery, M. Polit , J.Colprim, "Fuzzy control of dissolved oxygen in sequencing batch reactor pilot plant", *Biochemical Engineering Journal*, Vol. 32, 2006, pp. 239–243.

[9] F.Sanchez Rojas Æ C. Bosch Ojeda., "Effluent analysis in analytical chemistry, "*An Overview Anal Bioanal Chem*, Vol. 382, 2005, pp. 78–991.

[10] S.M. Giriraj Kumar,R. Jain, N.Anantharaman,V.Dharmalingam and K.M.M. Sheriffa Begum, "Genetic algorithm based PID controller tuning for a model Bioreactor" *Indian. Institute of Chemical Engineers*, Vol. 50, No. 3, 2008, pp. 214 - 226.

[11] J.E.Marshall, H.Gorecki, A.Korytowski and K.Walton, "Time delay systems: Stability and performance criteria with applications", Ellis Horwood. 1992.

[12] D.Chen and D.E.Seborg., "PI/PID controller design with transient performance specifications", *IEEE Transactions on Education*, Vol. 45, No. 4. 2002, pp. 364 - 370.

[13] S.Skogestad, "Probably the best simple PID tuning rules in the world", *AIChE, Annual Meeting*, Reno, Nevada, November 2001, pp. 276.

[14] J.C.Doyle and G.Stein, "Multivariable feedback design concepts for a classical modern synthesis" *IEEE Trans. On Automat, Cont. conf.*, Vol. 26, 1981, pp. 4-16.

[15] Rudra Pratap, "Getting Started With MATLAB", Oxford University Press. 2002

[16] Dale E.Seborg, Thomas.F.Edgar, Dunca A.Mellichamp, "Process Dynamic and Control", *WILEY, Second Edition*. 2004.

.

AUTHOR PROFILES:

Dr S.Sundaram received the Ph.D. Degree in Chemical engineering from Indian Institute of Science, Bangalore in 1969. Currently he is a Visiting Professor at SASTRA University, Thanjavur. His research interest includes Chemical Engineering, Instrumentation and Biomedical Engineering.

J.Sumathi received the Degree in Biomedical Signal Processing and Instrumentation Engineering from SASTRA University, Thanjavur. She is a research student of Dr.S.Sundaram. Currently, she is an Assistant professor in Department of Electronics and Instrumentation Engineering in SASTRA University. Her area of interest includes Process Control and Biomedical Engineering.