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Model Based Tuning of Controller for an Aerobic System

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Abstract: An aerobic system with varying downstream transportation lag was subjected to step response analysis to evaluate a suitable model using a dissolved oxygen sensor. The experimental data fitted a first order plus dead time model (FOPDT) with a maximum error of five percent. The model parameters were used to estimate various controller settings adopting methods such as Skogestad, Z-N, Smith predictor & IMC using MATLAB. A comparison of closed loop response using the estimated controller parameters suggested that IMC controller is best suited for this process. *Copyright © 2008 IFSA.*

Keywords: Aerobic process, Transportation lag, Modeling, PID, Smith Predictor, IMC

1. Introduction

In biochemical processes phytoplankton and macroalgae present in water produce oxygen by photosynthesis, while bacteria and other organisms such as zooplankton, algae & fish consume oxygen by respiration. The results of these two mechanisms determine the concentration of dissolved oxygen, which indicates the growth of biomass. The difference between the physical concentration of oxygen in the water (or the theoretical concentration if there are no living organisms) and the actual concentration of oxygen is called the biological demand in oxygen. Dissolved Oxygen is an important parameter which has to be controlled in food processing and fish farming industries.

The selection of the controller for a particular process is essentially an optimization problem in which the designer of the control system attempts to satisfy certain criteria for optimality, the result of which is often referred to as good control. Good control will also reduce energy use by keeping the process

variables at the set points. A typical criterion for good control is that the response of the system to a step change in set point should have a minimum overshoot, minimum rise time and settling time.

In earlier works model parameters have been used for controller design for conductivity [1, 2, 3, 4, 5] and humidity process [6]. This study focuses on biochemical process where Dissolved Oxygen(DO) is one of the controlled parameters.

2. Experimental Setup

Fig. 1 shows the setup with varying transportation lag of 1, 3 and 5 meters. Air and process liquid (water) are fed to the process through a pre calibrated Gallenkamp rotameter. The dissolved oxygen probe and accessories supplied by M/s DEEP VISION, Chennai, is fitted online in the exit and is interfaced to a PC -P4 processor. L_1 , L_2 , and L_3 are the delay of 1, 3 and 5 meters and can be realized by operating valves V_1 , V_2 , V_3 , V_4 , V_5 and V_6 as shown in Fig. 1. Valves V_7 , V_8 and V_9 is to maintain different levels in the tank.

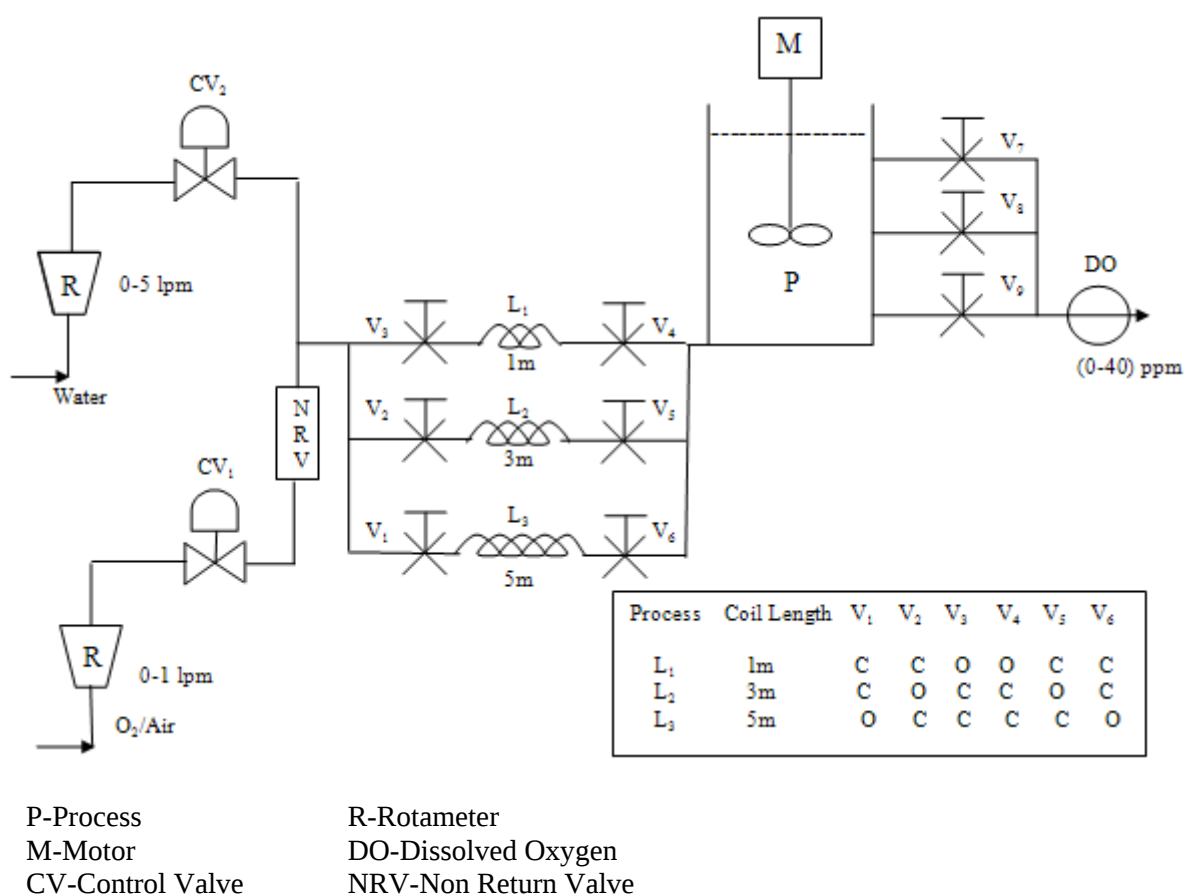
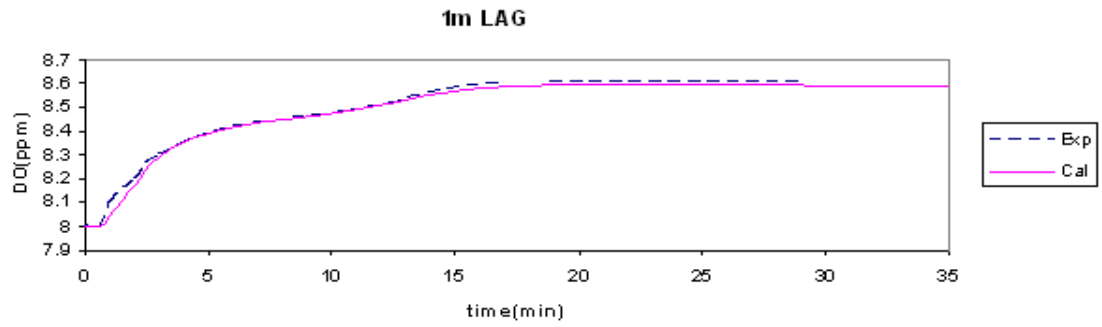


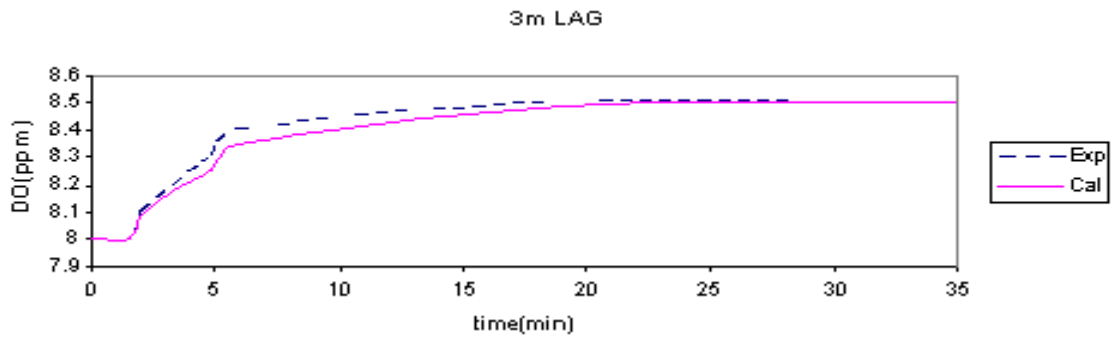
Fig. 1. Experimental set up for Process Model.

3. Experimental Procedure

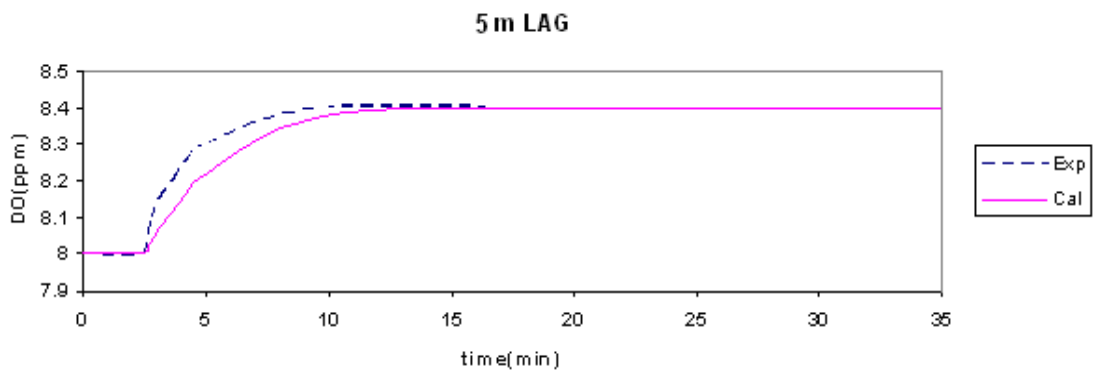
Water is initially allowed at the rate of 1.5 lpm and various transportation lag are monitored through valves V_1 to V_6 . Air is suddenly injected at rate of 0.8 lpm and exit DO is recorded. The results for the 3 lag pipes are shown in Fig. 2.



(a) Model 1.



(b) Model 2.



(c) Model 3.

Fig. 2. Experimental and calculated values using first order plus dead time (FOPDT) models for three different transportation lag.

4. Process Identification

The results shown in Fig. 2 are fitted to a first order plus dead time model given by equation (1):

$$\frac{D.O}{q_{air}} = G_p = \frac{k_p e^{-T_d s}}{\tau s + 1} \quad (1)$$

DO - Output Dissolved Oxygen, in ppm

q_{air} - Air inlet, in lpm.

The values of DO calculated from equation (1) for 3 different lags shown in Fig. 2 agree with experimental data with an error of less than 5 percent.

5. Controller Tuning

The model parameters were used to simulate closed loop response using MATLAB. Four different tuning methods, Z-N (PID), Skogested, IMC and Smith predictor were analyzed and their closed loop response is shown in Fig. 3. The details of these methods are discussed in detail elsewhere [3, 7, 8, 9, 10].

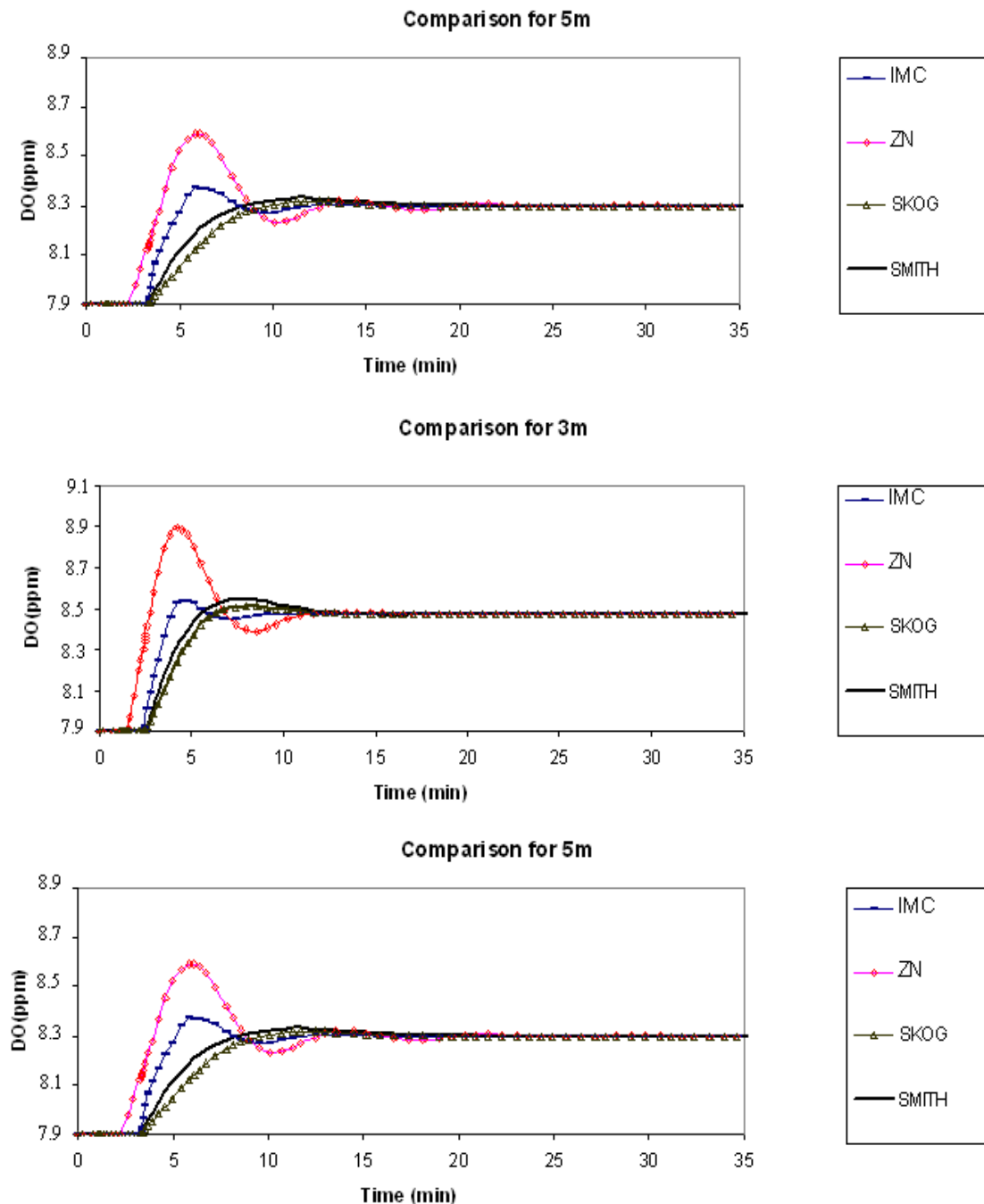


Fig. 3. Responses of Skogestad, Z-N (PID), Smith Predictor, IMC for the processes of pipe length of 1 m, 3 m, 5 m.

Table 1. Performance Comparison of Controllers.

Tuning methods	Process pipe length (m)	Rise time tr (min)	Settling time ts (min)	Overshoot (%)
Z-N(PID)	1	2	19.1	90
	3	2.685	30	50.5
	5	4.13	32	40
SKOGESTAD	1	2.77	33	16
	3	6.6	15	6
	5	10	28.5	4
SMITH PREDICTOR	1	2.573	9.9	9.5
	3	5.2	22.5	6
	5	8.51	23	3
IMC	1	13.13	13.13	0
	3	3.95	12.9	7.5
	5	5.15	22	6

6. Result

The response of Z-N (PID), Skogestad, Smith predictor and IMC controllers for set point changes for three processes are compared in terms of rise time, settling time and overshoot and are shown in figure 3. The performances of various controllers are given in Table 1.

7. Conclusion

It is observed, from Table 1 that the Skogestad has the smallest rise time, fastest response. The Z-N has high overshoot and a larger settling time. The Smith predictor has less overshoot, but a large settling time than the IMC controller. The IMC controller has the least settling time, rise time and minimal overshoot. The present study concludes that the IMC is the best suited for the processes studied.

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Guide for Contributors

Aims and Scope

Sensors & Transducers Journal (ISSN 1726-5479) provides an advanced forum for the science and technology of physical, chemical sensors and biosensors. It publishes state-of-the-art reviews, regular research and application specific papers, short notes, letters to Editor and sensors related books reviews as well as academic, practical and commercial information of interest to its readership. Because it is an open access, peer review international journal, papers rapidly published in *Sensors & Transducers Journal* will receive a very high publicity. The journal is published monthly as twelve issues per annual by International Frequency Association (IFSA). In addition, some special sponsored and conference issues published annually.

Topics Covered

Contributions are invited on all aspects of research, development and application of the science and technology of sensors, transducers and sensor instrumentations. Topics include, but are not restricted to:

- Physical, chemical and biosensors;
- Digital, frequency, period, duty-cycle, time interval, PWM, pulse number output sensors and transducers;
- Theory, principles, effects, design, standardization and modeling;
- Smart sensors and systems;
- Sensor instrumentation;
- Virtual instruments;
- Sensors interfaces, buses and networks;
- Signal processing;
- Frequency (period, duty-cycle)-to-digital converters, ADC;
- Technologies and materials;
- Nanosensors;
- Microsystems;
- Applications.

Submission of papers

Articles should be written in English. Authors are invited to submit by e-mail editor@sensorsportal.com 6-14 pages article (including abstract, illustrations (color or grayscale), photos and references) in both: MS Word (doc) and Acrobat (pdf) formats. Detailed preparation instructions, paper example and template of manuscript are available from the journal's webpage: <http://www.sensorsportal.com/HTML/DIGEST/Submission.htm> Authors must follow the instructions strictly when submitting their manuscripts.

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Smart Sensors Systems Design

A five-day advanced engineering course
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General Information

This course is suitable for engineers who design different digital and intelligent sensors, data acquisition, and measurement systems. It is also useful for researchers, graduate and post graduate students. Course will be taught in English.

Course Description

An advanced engineering course describes modern developments and trends in the field of smart sensor systems and digital sensors design.

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Deadline for Registration:

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