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Model analysis and controller design for aeration of textile industry effluent

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Presentation Outline

- Abstract
- Literature survey
- Experimental setup and procedure
- Modeling
- Controller design
- Result Analysis
- Summary

Abstract

- Disposal and control of effluents has been a serious challenge to researchers.
- Aeration being the primary step in effluent treatment, effluents from textile industry was aerated in a fermentor at 300K till saturation.
- The data was fitted to a FOPDT model with an error of less than 5 percent.
- The model was used to design closed loop controllers based on various performance criteria for both regulator and servo problems.
- The results indicate that IMC controller is superior to a PID controller based on genetic algorithm.

Literature Survey

Topic	Author
Textile industry effluents – Its health effects	Venceslau M.C., Toms and Simon J.J
Characterization and reuse of textile effluent treatment plant waste sludge in clay bricks	R.Baskar, K.M. Meera Sheriffa Begum, S.Sundaram
The Aerobic Biodegradability of Primary Aromatic Amines	Brown D. and P. Laboureur
A sensitive dissolved oxygen sensor based on a charge-transfer complex modified electrode	TU Yifeng
On-line Monitoring of Anaerobic- Aerobic Biotreatment of a Simulated Textile effluent for Selection of Control Parameters	S.R.R. Esteves, S.J.Wilcox, C.O'Neill, F.R.Hawkes, D.L.Hawkes
Genetic Algorithm Based PID Controller Tuning for a Model Bioreactor	S.M. Giriraj Kumar, R. Jain, N. Anantharaman, V. Dharmalingam and K. M.M. Sheriffa Begum

Experiment setup

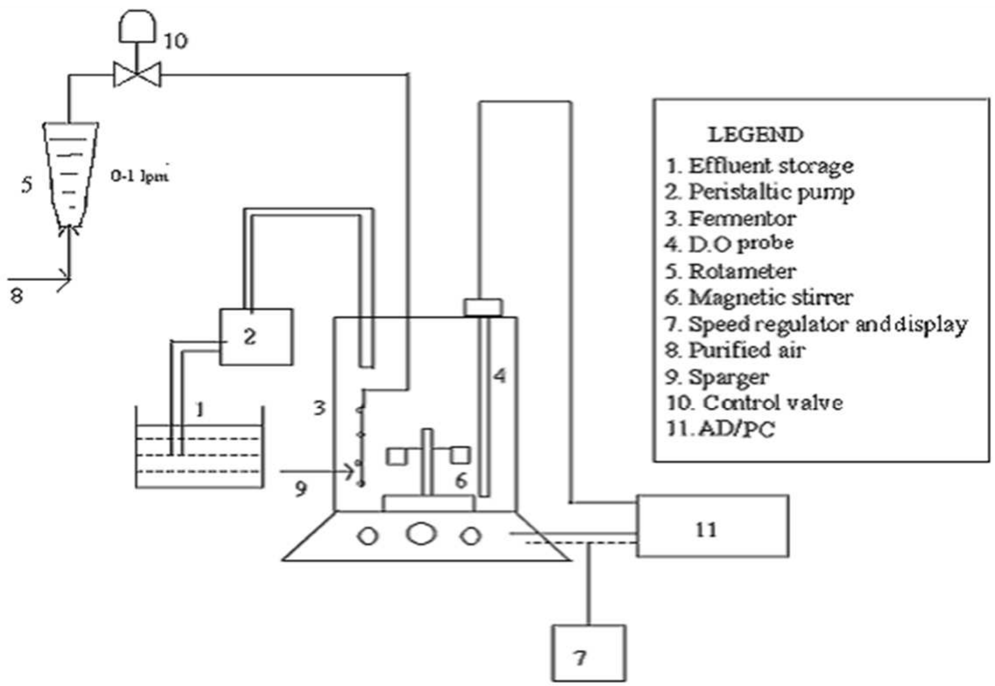


Fig.1: Experimental setup for process model.

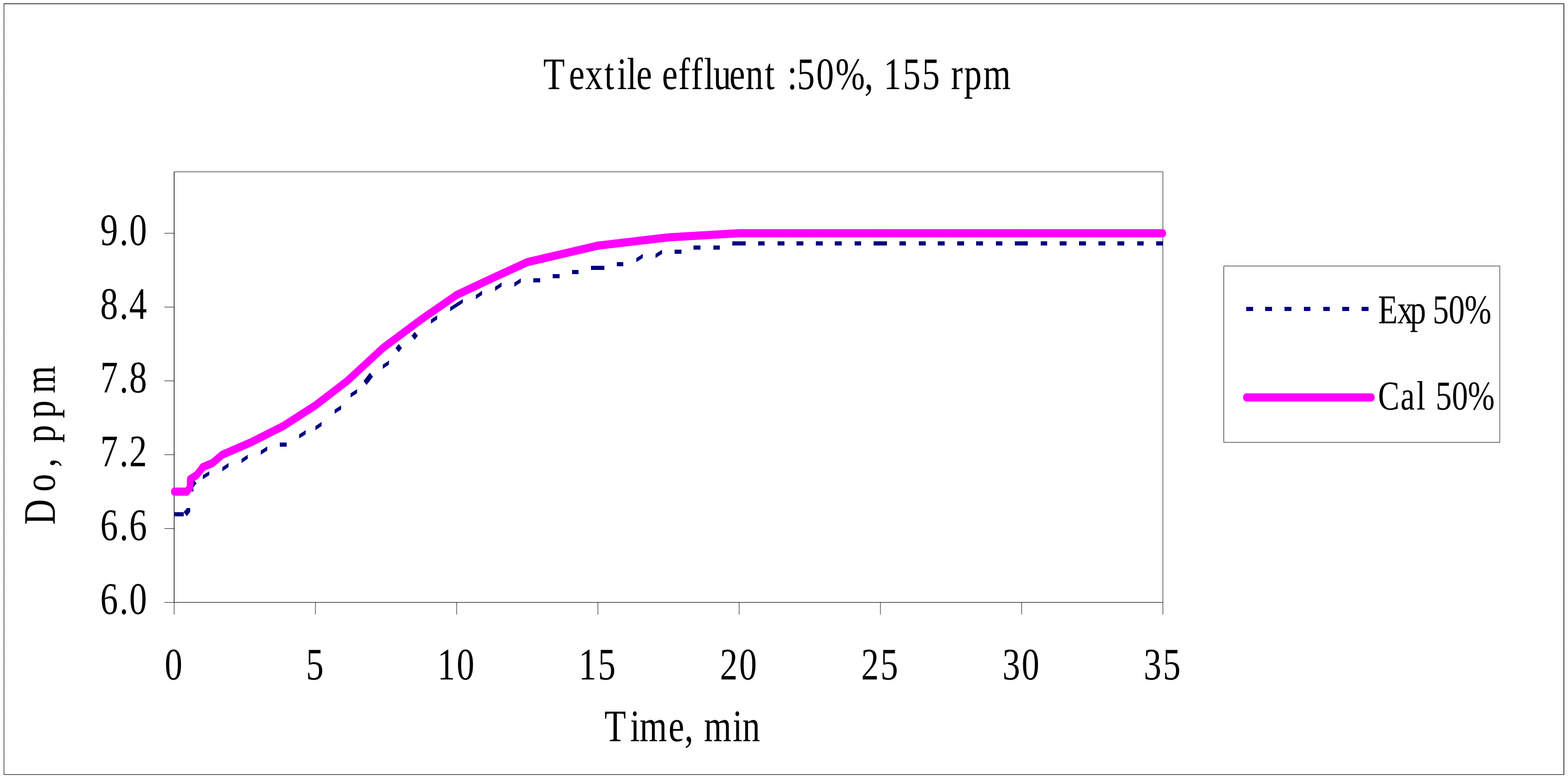
Procedure

- The 1.5 liter fermentor has provisions for adjustment of air flow, temperature and speed of stirrer.
- Fresh effluent was diluted with water to obtain various concentrations ranging from 0 to 100 percent in steps of 10 percent.
- One liter of fresh effluent of known concentration was charged into the fermentor from storage tank using a peristaltic pump.
- The dissolved oxygen was monitored using a PC.

Procedure

- At time t = 0, purified air was suddenly metered through a rotameter at a rate of 1 lpm.
- The dissolved oxygen was monitored and recorded for ten concentrations and three speeds (135, 145, and 155 rpm) with time till saturation.
- The data for 50% concentration and 155 rpm is given as representative sample.
- Similar graphs were obtained for other concentrations and speeds.

Experimental and calculated values of DO for textile effluent



Modeling

- The experimental data was fitted by regression analysis to a first order plus dead time model given by equation.

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

where, DO (t) is dissolved oxygen, ppm at any time t

DO (0) is dissolved oxygen, ppm at time t = 0

A - Step input in air rate, lpm

τ - Process time constant, min

τ_d - Delay time, min

K_p - Process gain, DO/lpm

Modeling

- Similar values where obtained for other concentrations and speeds subject to diurnal variations.
- The values of DO calculated using model parameters agreed with experimental data with an error of less than 1 percent.

Model parameters for 50% concentration and 155 rpm

Effluent	K_p	τ_d (min)	τ (min)
Textile	1.2	1.3	9.7

Experimental and calculated values of DO for 50% textile effluent

Time (min)	0	1.4	5	10	15	20	25	30	35
DO(Exp)	6.6	6.6	6.9	7.5	8.0	8.4	8.4	8.4	8.4
DO(Cal)	6.15	6.60	6.80	7.80	7.90	8.50	8.60	8.70	8.80

Controller design

- Genetic Algorithm (GA) based Proportional Integral Derivative (PID) controller.
- Transfer function for PID controller is given by

$$G_c = K_c(1 + \frac{1}{\tau_i s} + \tau_d s)$$

$$K_p = K_c$$

$$K_i = K_c / \tau_i \, ;$$

$$K_d = K_c \tau_d$$

- Internal Model Controller (IMC).

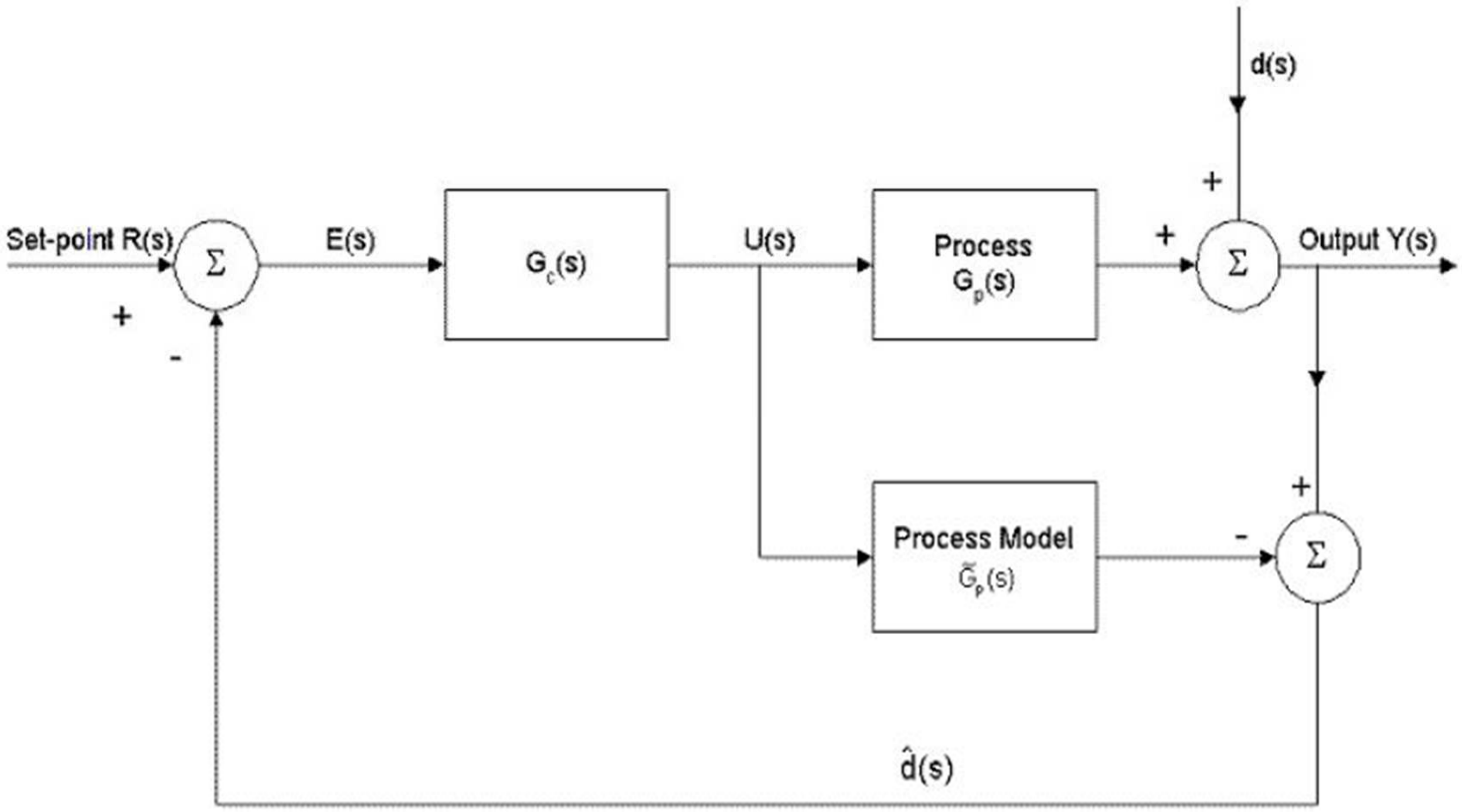
Genetic Algorithm

- It is a method for solving both constrained and unconstrained optimization problems that is based on natural selection, the process that drives biological evolution.
- The genetic algorithm repeatedly modifies a population of individual solutions.
- Genetic Algorithm rules are selection rules, crossover rules & mutation rules.

GA based PID Controller Design

- Objective Function : minimizing ITAE.
- Tuning Parameters: K_p, K_i, K_d
- Constraints: The gain values of the controller should be 0 to K_u.

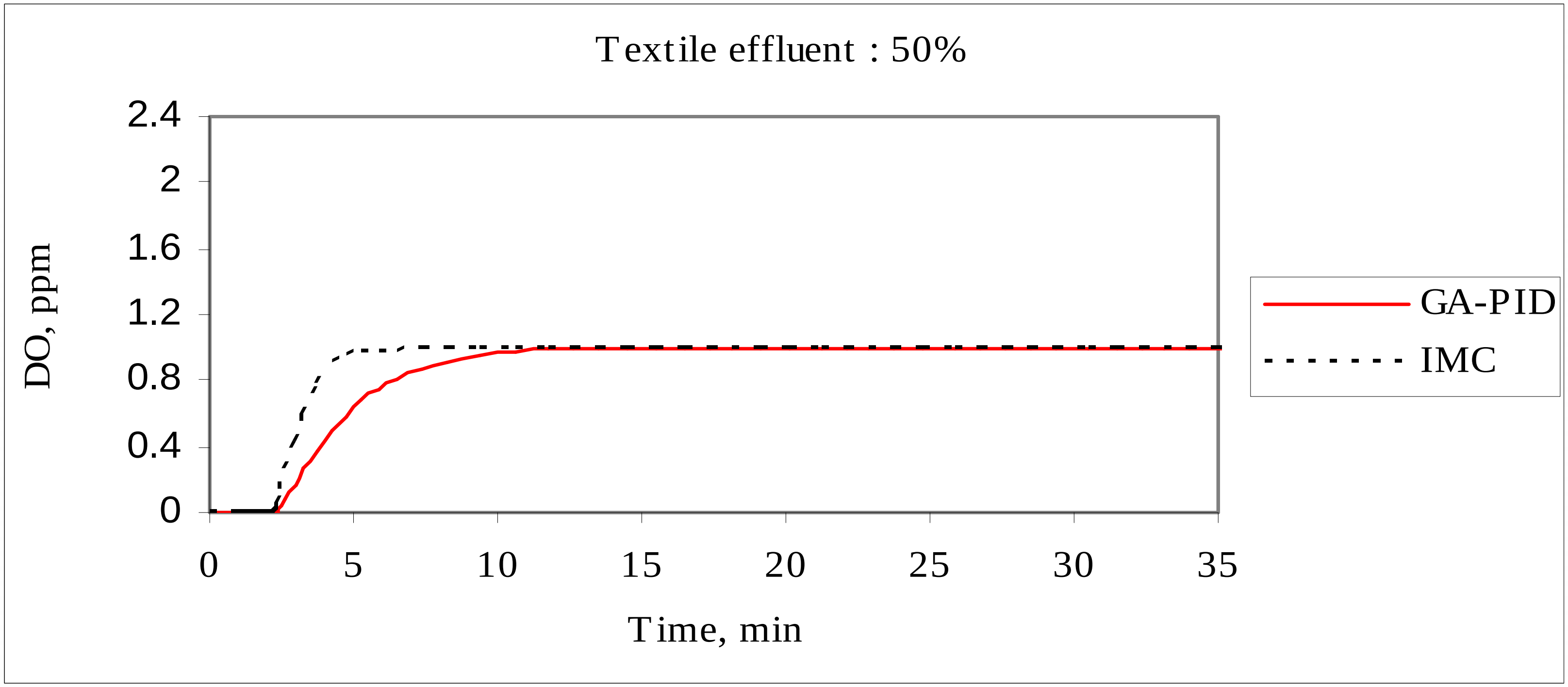
Internal Model Controller (IMC)



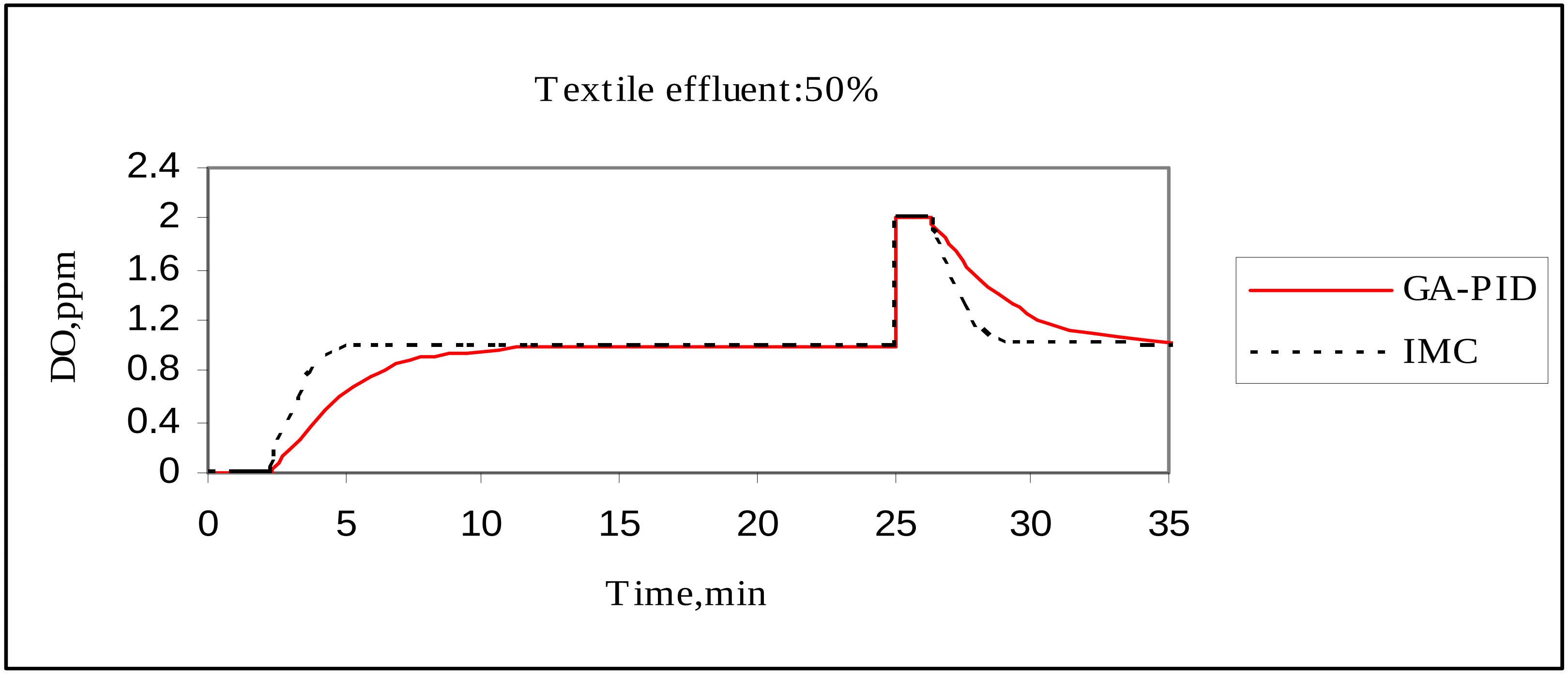
Result Analysis

- Based on model parameters a closed loop simulation was carried out using MATLAB.
- Various tuning methods such as Genetic Algorithm and IMC were studied for selecting controller parameters.
- Comparison of controllers performance is done based on rise time, settling time, percentage overshoot, ISE, IAE and ITAE for both servo and regulator problem.

Servo response for IMC and GA-PID



Regulatory response for IMC and GA-PID



Experimental and calculated values of DO for 50% textile effluent based on IMC & GA-PID

Response	Tuning method	Rise time, sec	Settling time, sec	Percentage overshoot	ISE	IAE	ITAE
Servo	IMC	10.0	4.0	0.00	15.66	17.31	11.49
	GA-PID	15.0	8.0	0.00	15.88	18.23	14.36
Regulatory	IMC	15.0	4.0	0.00	10.93	22.29	3.12
	GA-PID	19.0	7.5	0.00	11.27	23.05	3.56

Summary

- Aeration of textile industry effluent process is modeled and the data are fitted to FOPDT.
- The model was used to design closed loop controllers based on various performance criteria for both regulator and servo problems.
- The results indicate that IMC is slightly better than GA based PID for this process.
- Similar results were obtained for other concentrations and speeds.
- Experimental validation of the controller settings was carried out for 50% concentration and 155 rpm. It confirmed that IMC was better than GA-PID.