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LAMBDA TUNING TECHNIQUE BASED CONTROLLER DESIGN FOR AN INDUSTRIAL BLENDING PROCESS

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ABSTRACT

In the present paper, controller design is performed using lambda tuning method and controller performance is compared for various values of desired closed loop time constant. A blending system, which can be represented as a first order plus dead time model, is selected from literature survey for this analysis.

The performance is calculated in terms of rise time, settling time, over shoot (%), peak, gain margin, phase margin and closed loop stability. The PID tuning parameters are calculated for performance evaluation. Comparison is performed to select the best value of desired closed loop response time which gives best performance for the selected process model.

1. INTRODUCTION

A simple blending system process is used to introduce some important issues in control system design [1].

Many processes in industry are modeled as FOPDT model. This type of process has time delay as its inherent property. Time delay may be because of many reasons, especially due to far sensor location. This type of process is complex in nature and requires special attention. Lambda tuning technique, although invented long time back is still used in industrial practice. This requires immediate attention to compare the existing controller tuning technique for its set-point tracking and disturbance rejection capability and find the best value of lambda the process selected for investigation.

A simple blending process is used to introduce some important issues in control system. Blending operations are commonly used in many industries to ensure that final products meet customer specification. A continuous, stirred-tank blending system is shown in Fig. 1. The control object is to blend the inlet stream that the has desired composition. Stream 1 is a mixture of a two chemical species, A and B .that its mass flow rate $w1$ is constant, but the mass fraction of A .$x1$, varies with time. Stream 2 consists of pure A and thus $x2 = 1$. The mass fraction of A in the exit stream is denoted by x and the desired value (set point) by Xsp. Thus for this control problem, the controlled variable is x, the manipulated variable is $w2$, and the disturbance variable is $x1$ [9].

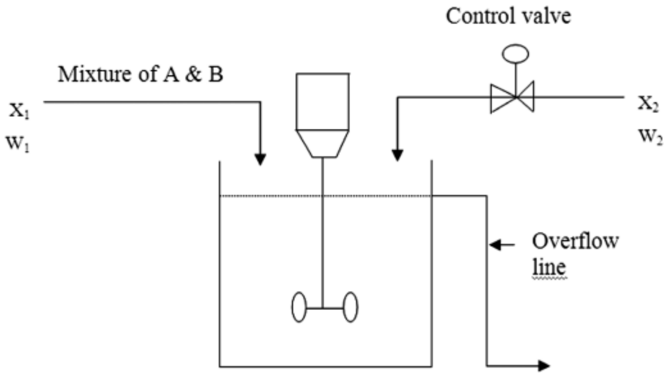

Figure 1: Stirred Tank Blending System

1.1. An Overview of PID Tuning

Proportional-Integral-Derivative (PID) controller has been used successfully for regulating processes in industry for more than 60 years. Although many tuning techniques, online or offline, model based or using analytical approach exist but still the new tuning techniques are being developed and compared for its performance evaluation with the existing tuning technique.

PID controllers are particularly suited for pure first or second order processes, while industrial plant often present characteristics such as high order, time delays, nonlinearities and so on. In this context, the tuning of the parameter is a crucial issue and the many tuning techniques are used such as internal model control, Ziegler Nichols close loop method, Cohen Coon method, direct synthesis method, Fuzzy logic method, and soft tuning methods [1].

The control system performs poor and even it becomes unstable, if improper values of the controller tuning constants are used. So it becomes necessary to tune the controller parameters to achieve good control performance with the proper choice of tuning constants. The tuning method can be used to adjust the controller parameter.

1.2. Lambda Tuning

"Lambda Tuning" refers to all tuning methods where the control loop speed of response is a selectable tuning parameter; the closed loop time constant is referred to as "Lambda". It is based on the same IMC theory is model-based and uses a model inverse and pole-zero cancellation to achieve the desired closed loop performance [15].

Lambda Tuning is used widely in the pulp and paper industry. Where it was realized early-on that a strong connection exists between paper uniformity and manufacturing efficiency on the one hand, and control loop interactions with upstream hydraulics on the other. Paper is as solid product that can be judged (see and feel), therefore it captures all upstream variability in its final product. Lambda Tuning offered a new way of coordinating the tuning of the paper mill loops to gain improved process stability along with a uniform product. By contrast, the Lambda Tuning technique is not well known outside the pulp and paper industry at this time [7].

As stated above, one should first eliminate any bad acting field devices prior to beginning Lambda Tuning. Once the field devices have been checked and corrected as required, a bump test with the controller in manual is performed to understand open loop dynamics of the process. The testing should be performed over a range of typical operating parameters. The collected data should be fitted to a simple dynamic model [13].

Poorly operating control loops cause loss in productivity in almost every industry worldwide. Therefore performance monitoring has been an active area of research for the past decades. In this work, a newly developed fault detection method is applied to the monitoring of λ-tuned control loops. The λ-tuning method has, due to its simple use, become very popular in the pulp and paper industry and is now spreading to other industries [7].

Lambda Tuning for an Integrating Process is slightly different in that the user needs to determine the arrest time for a disturbance; the arrest time or Lambda is the time to stop the rise or fall of the process variable (PV) due to a step change in load. The technical aspects of Lambda Tuning are described in detail elsewhere [8].

1.3. Methodology

Blending operation is commonly used in many industries to ensure that final products meet customer specification. The transfer function is given as [1]:

$$G(s) = 1.54 \exp(-1.075s) / 5.93s + 1$$

Using Pade's approximation, the modified transfer function may be written as :

$$G(s) = 1.54*(1 -.535s)/ (5.93s + 1)(1 +.535s)$$

For finding the controller tuning parameters using lambda tuning method, equating

$$1.54/(5.93s+1)(1-.5355) = 1/K_{cu}(1+1/T_I s + T_d s)*1/\lambda s;$$

is the tuning parameter.

Comparing above equation, we get

$$K_{cu}/T_I s = 1/\lambda s$$

$$K_{cu}/T_I = 1/\lambda$$

Therefore,we get

$$T_I = 5.395 ; \quad T_d = .580$$

and $K_{cu} = T_I/\lambda$

For
$\lambda = 1;\ Kcu\ (1) = 5.395/1 = 5.395$
$\lambda = 2;\ Kcu\ (2) = 5.395/2 = 2.6975$
$\lambda = 3;\ Kcu\ (3) = 5.395/3 = 1.79$
$\lambda = 4;\ Kcu\ (4) = 5.395/4 = 1.3487$
$\lambda = 7;\ Kcu\ (7) = 5.395/7 = .7707$
$\lambda = 12;\ Kcu\ (12) = 5.395/12 = .449$
$\lambda = 16;\ Kcu\ (16) = 5.395/16\ Kcu\ (16) = .337$
$\lambda = 17;\ Kcu\ (17) = 5.395/17\ Kcu\ (17) = .317$

The PID controller transfer function is calculated now for these values of lambda,

For $\lambda = 17$, $= Kcu\ [1 + 1/T_I s + T_D s]$
$= .317\ [1 + 1/5.395\ S - .58075]$
$= .317 + .0587/s - 1.8547s$
$P = .317\ I = .0587\quad D = -1.8547$

Similarly, for

For $\lambda = 12$,
$P = .449$
$I = .083302$
$D = -.2607$

For $\lambda = 7$
$P = .7707$
$I = .1428$
$D = -.4475$

1.4. Result Analysis

Simulation is performed to analyze the stability, set point tracking and disturbance capabilities. The controller parameters are determined and the controller is inserted in the feedback loop along with FOPDT process model.

Controller design using different values of lambda for lambda Tuning method is attempted as shown in Figs. 2, 3 and 4.

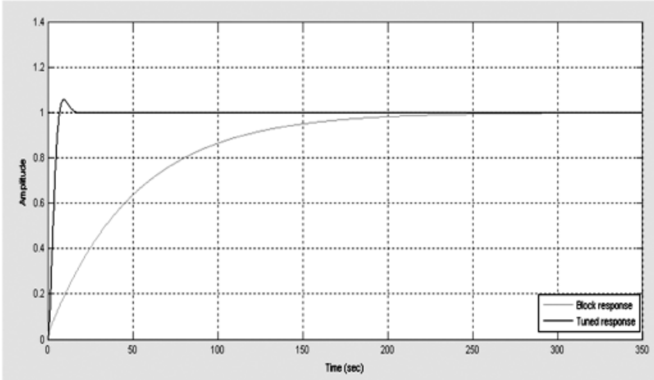

Figure 2: PID Controller Response for Lambda Tuning Method

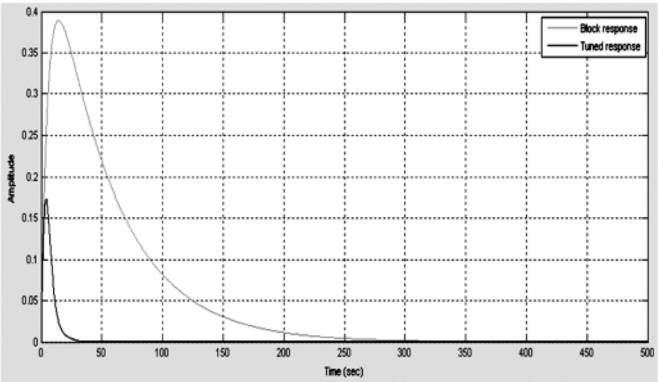

Figure 3: PID Controller Step Rejection for Lambda Tuning Method

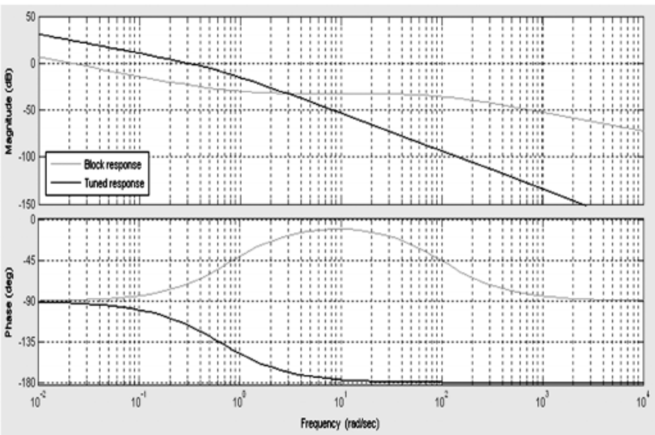

Figure 4: PID Controller Open Loop Bode Plot for Lambda Tuning Method

The Table 1 show that the PID controller for Lambda tuning. The PID controller block parameter has calculated. Now the applied. *P* Block controller parameter is .2673 and *I* block controller parameter is .0381.Now the derivative parameter is –.26403.

Table 1
PID Controller Tuned and Blocks Parameter for Lambda Tuning

Controller parameter	*Tuned*	*Block*
P	2.6835	.2673
I	.64514	.0381
D	–4.2086	.26403
N	6.3762	100

The performance parameter rise time, settling time, overshoot (%), peak are 112, 198, 0, 999 respectively. The performance indices for different λ values are given in Table 3. Large value of λ give more sluggish control. So Small values of λ is eatter as comparison to high values of for PID controller of Lambda tuning.

Table 2
PID Controller Performance for Lambda Tuning Method

PERFORMANCE	*TUNED*	*BLOCK*
Rise Time (sec)	4.54	112
Settling time (sec)	13.6	198
Overshoot (%)	5.72	0
Peak	1.06	.999
Gain margin	Infinity	Infinity
Phase margin	63.9	.0201
Closed loop stability	stable	stable

Table 3
Comparison PID Controller Different Lambda Tuning Values

Performance Parameter	*λ = 16*	*λ = 12*	*λ = 07*	*Automatic tuned*
Rise time(sec)	112	49.7	28	4.54
Settling time (sec)	198	88.9	49.8	13.6
Overshoot (%)	0	0	0	5.72
Peak	.999	.999	.999	1.06
Gain margin (db)	Infinity	32.9	28.1	Infinity
Phase margin(deg)	.0201	90.1	87.7	63.9
Closed loop stability	Stable	Stable	Stable	Stable

Hence, small values of Lambda produce faster responses, while large value of lambda gives more sluggish control, while designing controllers based on lambda tuning method for a FOPDT model.

References

[1] Dan Chen and Dale E. Seborg, "PI/PID Controller Design Based on Direct Synthesis and Disturbance Rejection", *Ind. Eng. Chen. Res* 2004, **41,** pp. 4807-4822.

[2] Morari M. and Zafiriou E., Robust Process Control, Prentice Hall, 1989.

[3] Guillermo J. Silva Stabilization of Time Delay System Proceeding of the American Control Conference Chicago, Ilinods. Dec 2004.

[4] Ziegler J.G. and Nichols N.B., "Optimum Settings for Automatic Controllers", Trans. ASME, pp. 759-768, 1942.

[5] Oglesby M. J., "Achieving Benefits Using Traditional Control Technologies", *Trans. Inst*. MC, No. 1, 1996.

[6] Dahlin E.B., "Designing and Tuning Digital Controllers", *Instr and Cont Syst*, **41** (6), pp. 77,

[7] Chien I-Lung and Fruehauf P.S., "Consider IMC Tuning to Improve ControllerPerformance", Hydrocarbon Processing, Oct. 1990.

[8] William S. Levine, W.S (Editor), "CRC Control Handbook", *CRC Press and IEEE Press*, 1996.

[9] William S. Levine, W.S (Editor), CRC Control Handbook, Chapter 72, "Control of the Pulp and Paper Making Process". CRC Press and IEEE Press, 1996. Chapter 72 - Bialkowski W.

[10] Gregory K. McMillan (Editor in Chief), Process/ Industrial Controls and Instrumentation Handbook, 5The Edition. McGraw-Hill, 1999. Isbn 0-07-012582-1. Section 10.17.

[11] Sell N, editor, Bialkowski W.L. and Thomasson F.Y. Contributors, Process Control Fundamentals for the Pulp & Paper Industry, TAPPI Textbook,TAPPI Press, 1995.

[12] J.Astrom and T.H.agglund (1995), "PID Controllers: Theory, Design and Tuning". *Instrument Society of America*, 2nd Edition.

[13] Jukka Lieslehto, "PID Controller Tuning Using Evolutionary Programming", *American Control Conference*, VA June 25-27, 2001.

[14] Ziegler, J. G.; Nichols, N. B., "Optimum Settings for Automatic Controllers". Trans. ASME 1942, 64, 759.

[15] Rovira, A. A.; Murrill, P. W., Smith, C. L., "Tuning Controllers for Setpoint Changes". *Instrum. Control Syst.* 1969, **42** (12), 67.