MODELING AND ANALYSIS OF NON LINEAR CONICAL TANK PROCESS

J. Nancy Amala Geetha, G. Subramanian, V. Gokul
U.G. student, Department of Instrumentation and Control,
Saranathan College of Engineering, Trichy

Abstract- **This paper deals with the different tuning of PID (Proportional+Integral+Derivative) controller for a complex nonlinear process such that conical tank process. The conical process is such a difficult problem due to its nonlinear performance and continuously changing cross sectional area[3]. The difficulty faced in that process is overcome by different type of tuning techniques. To obtain a optimization process the these are the techniques used FOPDT, [2]tuning techniques and IMC controller.**

Index Terms- **FOPDT, PID CONTROLLER, TUNING TECHNIQUE**

I. INTRODUCTION

It is important to maintain the level of the tank in various fields. It mostly in process industries. The variation in the level by variable process parameters. It is adjusted and governs by PID controller and various tuning techniques [4]. By using this techniques the conical tank process to achieve optimization control. The PID controller offers the flexibility to achieve the ultimate limit to loop performance of industrial processes [1]. A PID controller has historically been considered to be the best controller.

PID controller is a control loop feedback mechanism widely used in process control systems. A PID controller calculates an error value as the difference between a measured process variable and desired set point. [1]The controller attempts to minimize the error by adjusting the process through use of a manipulated variable. A common characteristic of proportional control is an error between the set point and control point which is referred to droop(or)offset.[4]

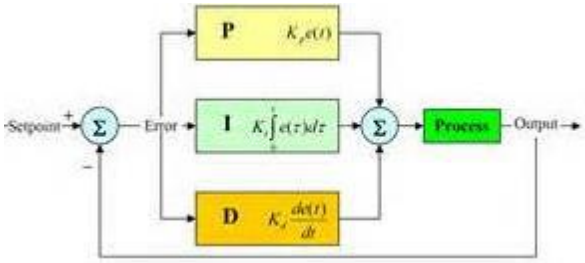


Fig.1 Basic process diagram

The general form of PID controller equation is,

$$G_c(s) = K_c(1 + \frac{1}{T_i s} + T_d s)$$

The offset is an undesired characteristic of proportional only and is easily eliminated by adding integral action. The integral adjusts controllers in accordance with both the size of the deviation from set point and the time it lasts [2].Derivative control is a prediction of future errors based on current rate of change. The sum of these actions is used to adjust the process via a control element such as the position of a control valve a damper or the power supplied to a heating element. Among the well-known methods are modified ZN method(MZN), damped oscillation method(DOSC),internal model control(IMC) and ISE,ITAE,IAE error performance approach.[5]

II. MATHEMATICAL MODELLING OF A CONICAL TANK

The nonlinear process of conical tank used in various process industries. These are concrete mixing industry, food processing industry, metallurgical industry or in various field. The process of developing the mathematical model by using consideration of process parameters is known mathematical modeling. Based on the input flow of tank and output flow rate through various cross

section area with respect to time. Based on two consideration the input flow is a manipulated variable. And level of conical tank is a control variable[3]. This can be achieved by controlling the input flow of the conical tank.

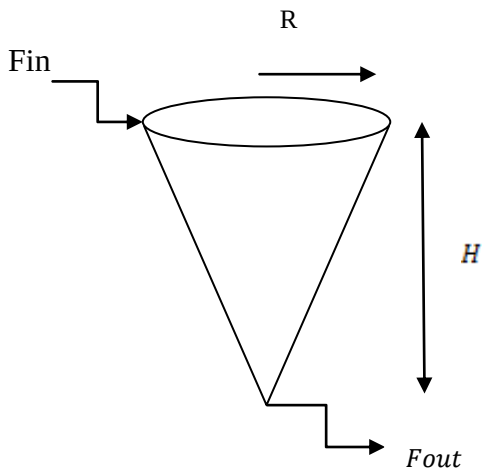


Fig2. Schematic diagram of conical tank

Process operating Parameters are,

Fin – Input flow rate of the tank

F out – Output flow rate of the tank

H - Total height of the conical tank.

R - Top radius of the conical tank

h - Nominal level of the tank

r - Radius at nominal level

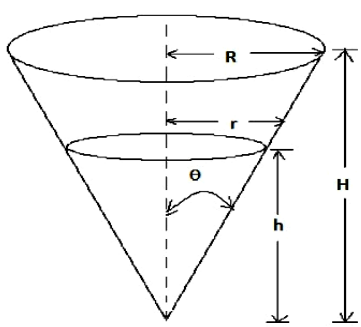


Fig3. Mathematical modeling of a conical tank

The area of the conical tank is given by

$$A = \pi r^2 \qquad (3.1)$$

$$tan\theta = \frac{r}{h} = \frac{R}{H} \quad (3.2) \qquad r = R * \frac{h}{H} \quad (3.3)$$

According to Law of conservation of mass,

Inflow rate-Outflow rate= Rate of Accumulation

$$F_{in} - F_{out} = A\frac{dh}{dt} \quad (3.4)$$

$$F_{out} = k\sqrt{h} \quad (3.5)$$

K is the discharge coefficient

On substituting (4.5) in (4.4), we get

$$F_{in} - k\sqrt{h} = A\frac{dh}{dt} \quad (3.6)$$

$$\frac{dh}{dt} = \frac{F_{in} - k\sqrt{h}}{A} \quad (3.7)$$

$\frac{dh}{dt}$ = Rate of Change of Height

Therefore, $$A = \frac{\pi * R^2 * h^2}{H^2} \quad (3.8)$$

Substituting the value of A in equation (8), we get

$$F_{in} - F_{out} = \frac{1}{3}\left[A\frac{dh}{dt} + \frac{h\left(2\pi R^2 h\frac{1}{H}\right) * dh}{dt}\right] \quad (3.9)$$

H(s)/ Fout (s) = k e-θs/τ s+1 ---------- (3.10)

Where, τ = 2A√(h)/b
K = 2 √(h)/b

Based on specification given by the transfer function is,

G(S) = 7.14 e-11.10s / (4.69S+1) ---- (3.11)

III. TUNING METHODS

For this paper we used 3 different types of tuning techniques they are,

- Damped oscillation method
- Modified ZN method
- Internal model control (Improve PI)

DAMPED OSCILLATION METHOD:

In many cases, plants are not allowed to undergo through sustained oscillations, as is the case for tuning using continuous cycling method. Damped oscillation method is preferred for these cases. Here, initially the closed loop system is operated initially with low gain proportional control mode with dead

time is zero. The gain is increased slowly till a decay ratio (p_2/p_1) of 1/4th is obtained in the step response in the output, as shown in Fig. 5. Under this condition, the period of damped oscillation, T_d is also noted. Let K_d be the proportional gain setting for obtaining 1/4th decay ratio. [1]

The optimum settings for a P-I-D controller are:(Table 1)

CONTROLLER	K_C	K_I	K_D
PID	1.1Gd	Pd/3.6	Pd/9

MODIFIED ZN METHOD:

In some of control loops the measure ofoscillation, provide by ¼ decay ratio and corresponding to large overshoots for setpoint changes are undesirable thereforemore conservative methods are oftenpreferable such as modified Z-N .These modified settings that are shown inTable 2 are some overshoot and no overshoot.[4]

The optimum controller settings are**:(Table 2)**

CONTROLLER	K_C	K_I	K_D
Some overshoot	0.33Kcu	Pu/2	Pu/3
No overshoot	0.2Kc	Pu/2	Pu/3

INTERNAL MODEL CONTROL:

The Internal Model Control (IMC) method was developed with robustness in mind. The Ziegler-Nichols open loop and Cohen-Coon methods give large controller gain and short integral time, which isn't conducive to chemical engineering applications. The IMC method relates to closed-loop control and doesn't have overshooting or oscillatory behavior. The IMC methods however are very complicated for systems with first order dead time. In this we chose the λ=87 for the optimum control.[4]

The optimum controller settings are**:(Table 3)**

CONTROLLER	K_C	K_I	K_D	Recommended λ/ d (λ> 0.2τalways)
Improve PI	(2τ + d)/ 2 λ	τ +□d/2	-	>1.7

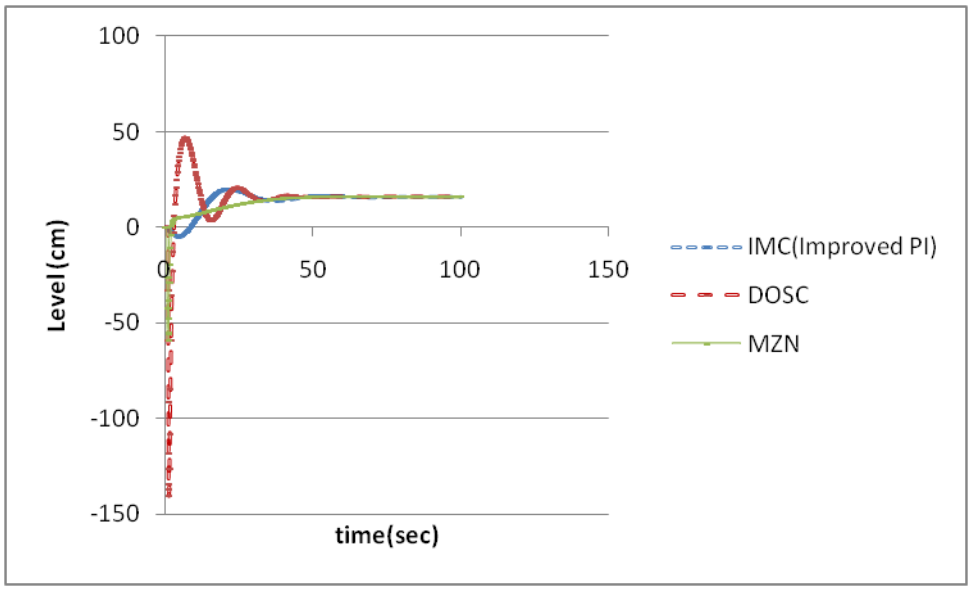
IV. PERFORMANCE CRITERIA FOR CONICAL TANK: (Table 4)

Techniques	Rise time	Settling time	Overshoot	Peak time
Damped oscillation method	0.441	26	195	8.77
Modified ZN method	31.7	33.6	1.71	3.69
Internal model control	5.87	45.3	23.5	1.24

V. ERROR PERFORMANCE CRITERIA:(Table 5)

Techniques	ISE	ITAE	IAE
Damped oscillation method	3.75	9.82	8.679
Modified ZN method	2.99	8.79	8.546
Internal model control	0.8387	1.147	7.629

VI. SIMULATION GRAPH:



VII. CONCLUSION

In this paper the PID controller by using three different type of tuning techniques are discussed. For better optimum control we chose the IMC (Improve PI) but it has over high over shoot than the modified ZN tuning method and it has settling time also high. So in my point of view for the nonlinear conical tank the best tuning method is modified ZN method it has low settling time and low overshoot as compare to IMC tuning method and damped oscillation method and then it also has low error criteria performance. So the Modified ZN method gives the better and optimum control.

REFERANCES

[1] Process Control (Principles and Applications) By SurekhaBhanot

[2] K. Ogata: ―Modern Control Engineering, Prentice-Hall India,Fourth Edition

[3] P. W .Mur rill, P. D. Schnelle, B. G. Liptak, J. Gerry, M. Ruel, F. G. Shin sky, Tuning PID Controller.

[4] Lee J., W. Cho; ”An Improved Technique for PID Controller Tuning from Closed Loop Tests”, AI Chef J, **36**, 1891(1990)

[5] Luyben W.L, M.L. Luyben; “Essentials of Process Control”, McGraw-Hill, 1997

[6] Erickson K.T., J.L. Hedrick; "Plant wide Process Control" John Wiley & Sons, 1999

[7] G. K. I. Mann, B. G. Hu, and R. G. Gosine, ―Time-domain baseddesign and analysis of new PID tuning rules, Proc. Inst. Elect. Eng.—Control Theory and Applications, vol. 148, no. 3, pp. 251–261, 2001.

[8] J. Nagrath, M. Gopal, ―Control System Engineering, New Age International Publications, 3rd Edition, 2002