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Control of Level in Chemical Industry for a Nonlinear Conical Tank process.

Marshiana D[1]*, and P Thirusakthimurugan[2].

[1]Research Scholar, Sathyabama University, Chennai, Tamilnadu, India.
[2]Department of EIE, Pondicherry Engineering College, Pondicherry, India.

ABSTRACT

In all the major Chemical industry the most important problem is the control of level for a nonlinear system depending on the viscosity and flow of various chemical components. The nonlinear system considered for the study is a conical tank which provides an easy flow of chemical components due to its shape. The system identification of this nonlinear process is done using mathematical modeling and it is approximated to a first order system. By applying a closed loop PI control technique the level is maintained. Simulation is done by the MATLAB software
Keywords: Chemical industry, Mathematical Modeling, PI control, MATLAB software.

***Corresponding author**

INTRODUCTION

The control of the level provides a major role in the chemical industry. The raw material for many chemical products includes pharmaceuticals, solvents, fertilizers, pesticides and plastics[1]. To avoid the rusting and maintaining the flow of the process evenly can be done by using a conical tank system. Due to its shape the raw materials can be disposed easily and quickly. It assures optimal stirring and mixing of ingredients. It provides a fast and hygienic cleaning. The majority of the pollution incident occurs due to spillage, overfilling of tanks, poor practices and poor treatment facilities.

In the highly industrialized countries, control of level improve process safety and efficiently utilize resources. In the developing countries, the main aim is the production [2] of products should be rapid for applying process automation. The furthermost requirement for process automation is used in many industries like the chemical industry, petrochemical industry, Pharmaceutical industry and power generating industry[3,4]. The importance of automation technology continues to increase in the process industries.

The control of fluid level in tanks is a essential issues in process industries. The conical tank shows its nonlinearity because of its shape. Design a controller for a nonlinear process is difficult and excessively hard to implement it. The principle assignment of the controller configuration is to accomplish the preferred working conditions and to design the controller to attain its optimum execution performance.

A non-linear process, the conical tank level process whose parameters vary with respect to the process variable is considered. The desired level is maintained and controlled at a fixed outlet flow rate. The time constant and gain are the important variables which vary as a function of level in the chosen process. V.R.Ravi et al.[5] proposes that there is a need to control a Level because if the level is too high may upset reaction equilibrium of the whole process which may cause damage to equipment, or result in spillage of expensive or hazardous material from the process. If the level is too low, it may have bad consequences for the sequential operation carried out by the process. Hence, control of liquid level is an important and common chore in process industries. Nonlinear models are used where accuracy over a wider range of operation is required where they can be directly incorporated into control algorithms. Anandanatarajan.R et al. [6] have done work in nonlinear conical tank system which finds wide application in process industry. S.Nithya et al [7,8,9] proposes that the nonlinearity is because of its change in shape. Their shape assures optimal rousing and mixing of ingredients and provides a fast and hygienic cleaning.

MATHEMATICAL MODELING

Assumptions are made for determing the mathematical model of the conical tank system. They are (i) level as the control variable (ii) inflow to the tank as the manipulated variable .This is achieved by controlling the input flow into the tank.The Figure 1 shows the schematic diagram of the conical tank system.

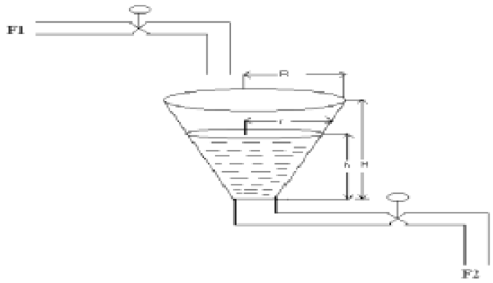


Figure 1: Schematic diagram of the Conical Tank system.

Operating Parameters are

F_1 –Tank Inflow rate
F_2 –Tank Outflow rate
H - Height of the conical tank.
R - Top radius of the conical tank
h - Nominal level of the tank
r - Radius at nominal level

Mass balance Equation is given by

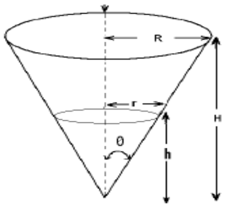
$$F_1 - F_2 = A_1\frac{dh}{dt} \quad (1)$$

$$F_2 = b\sqrt{h} \quad (2)$$

Where $b=a\sqrt{(2g)}$

Where a- area of the tank at the outlet position
g- acceleration due to gravity

By substituting the equation and considering the cross sectional area of the tank at any level h



$$\tan\theta = r/h = R/H$$

$$A = \pi r^2 \quad (3)$$

$$A = \pi R^2 h^2/H^2$$

Where $r = R^2h^2/H^2$

Transfer function (TF) is given by taking the partial differentiation of the linearised equation and its corresponding Laplace transform [10].

$$\frac{h(s)}{F1(s)} = \frac{k}{\tau s+1}$$

Where

$$\tau = \frac{2A\sqrt{h}}{b}$$

$$K = \frac{2\sqrt{h}}{b}$$

The figure 2 shows he experimental setup of conical tank system

Controller techniques

PID controller is a combination of P,I,D controllers. This type of controller is incorporated because of the drawbacks of using the controllers P, I, D alone. Every controller is designed with the purpose of calculating the time domain performance specifications such as rise time, settling time and error values. The block diagram of the closed loop system is shown below:

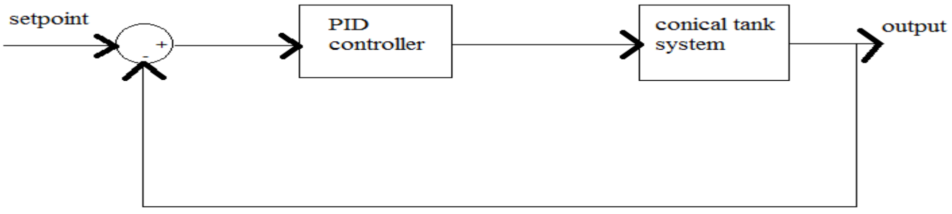


Figure 2: Block diagram of a system with feedback(closed loop system)

Feedback controller is usedin this process whose output(control variable) depends on the setpoint and process variable. To calculate the value of error, the following formula is used:

$$e(t) = S.P - P.V$$

The calculated error value can be minimised by optimising the parameters. The controller tuning parameters k_p, k_i, k_d have to be adjusted so that the conical tank system is stable and gives the best performance.

The setpoint provided by the operator is given to the summer which also takes in feedback signal from the output. This error signal is applied to the PID controller which predominantly consists of P, I, D controls which are adjusted to obtain the desired output. The combination of these three signals is then given to the process i.e conical tank process(non-linear system). The output is observed and the corresponding feedback is applied.

Ziegler Nichols Method

The open loop response of the given transfer function is determined so as to calculate the tuning parameters. Ziegler Nichols tuning method is used to tune the parameters at an optimum level. This method can also eliminate the integral and derivative values of the controller i.e sustained oscillation method.The controller design is based on the plant step response.The process dynamics can be conveniently characterized by the normalised dead time and defined as,

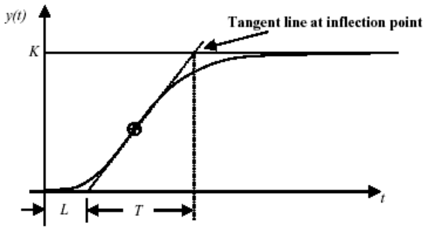


Figure 3: Reference curve for Z-N method

The above graph is used as a reference to calculate the values of L and T. A graph is plotted (amplitude vs time) and the values such as L and T were calculated and tabulated. The values to be found out are proportional gain(k_p), integral time(Γ_i) and derivative time(Γ_d) are shown in the table

Cohen-Coon Method

The cohen coon method is said to be offline method for tuning of process it is because that the step change can be given to the input once it is at steady state. The output is calculated depending on the time constant ,its time delay and its response can be evaluated to control the initial parameters.

IMC Method

The internal model control philosophy relies on the principle “the control can be achieved only if the control system encapsulates, either simplicity or explicity, some representation of to be controlled the process”.

Methods	K_p	T_i
CC	$\frac{1}{k}\frac{\tau}{t_d}\left(1+\frac{t_d}{3\tau}\right)$	$t_d\left(\frac{30+3\frac{t_d}{\tau}}{9+20\frac{t_d}{\tau}}\right)$
ZN	$\frac{1.2T}{L}$	0.5L
IMC	$\frac{\tau}{K\tau_c}$	τ

Table 1: Formulas for calculating the PI controller for Various technique

Methods	K_p	τ_i
CC	117.060	10.471
ZN	114.857	7.3206
IMC	0.0989	5.055

Table 1: PI controller values for Various technique

RESULTS AND DISCUSSION

The Simulation is carried out using MATLAB software for a nominal value of 50% of its total tank level to validate the performance. Servo and regulatory response is determined for the setpoint of 25cm using the various controller techniques where the ZN provides a better controller output having better performance criteria. The graphs provides the output at level of 25cm.

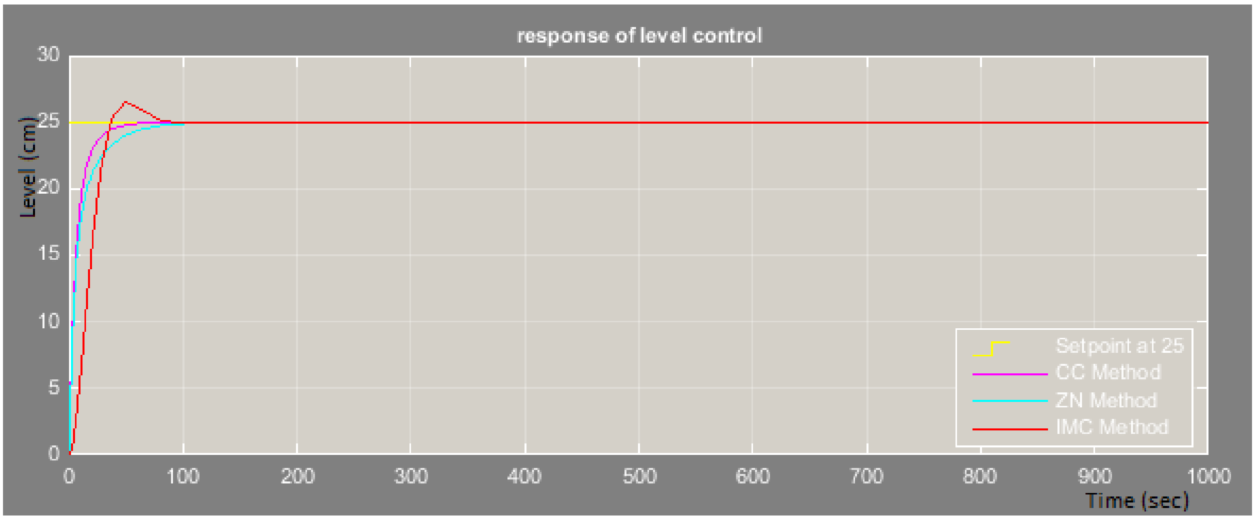


Figure 4: Level control for the process for a setpoint of 25 cm

Figure 5: Level control for the process for a setpoint of 25 cm having the input change

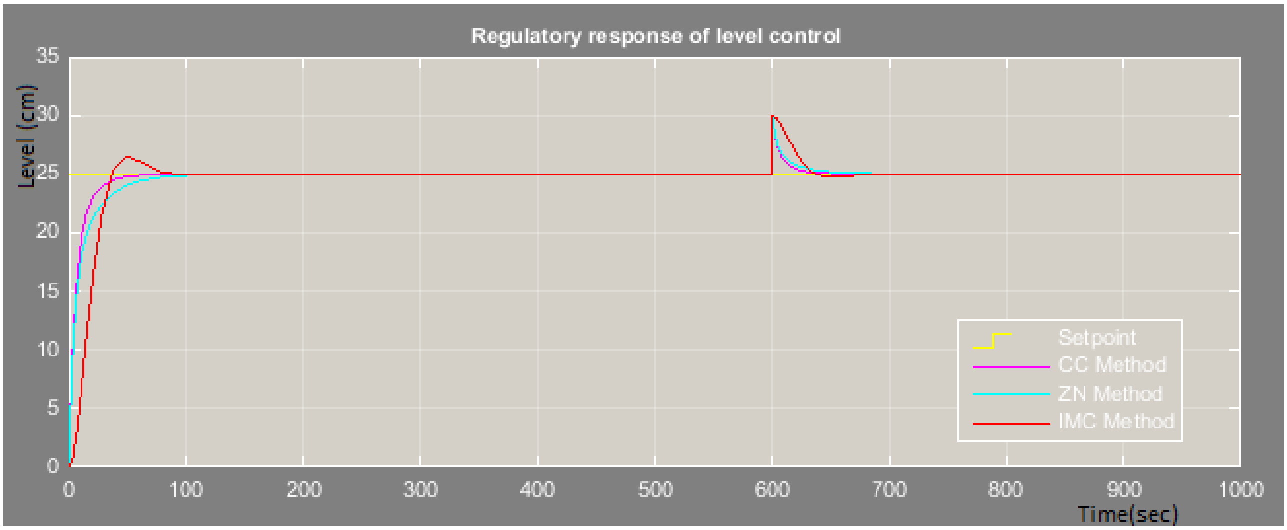


Figure 6: Level control for the process for a setpoint of 25 cm having the Load disturbances

Figure 7: Level control for the process for a setpoint of 25 cm having the setpoint tracking and Load disturbances

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