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COMPARISON OF PID CONTROLLER TUNING TECHNIQUES FOR TEMPERATURE PROCESS

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Abstract: Temperature measurement in today's industrial environments encompasses a wide variety of needs and applications. This paper gives an approach of tuning various controllers in a temperature process. The analysis has been done for tuning methods such as Closed ZN (Zeigler-Nicholas), Modified ZN with and without overshoots, IMC (Internal Model Control). A comparison between the performance criteria and between the time domain specifications has been carried out. The experimental results are compared and the method with better performance has been identified.

Keywords: IMC, IMC-PID, Flow, MATLAB, PID, SISO

I. INTRODUCTION

Control of temperature is an important and common task in all process industries. Tuning is adjustment of control parameters to the optimum values for the desired control response. Stability is a basic requirement. However, different systems have different behaviour, different applications have different requirements, and requirements may conflict with one another.

Proportional Integral Derivative (PID) controllers are widely used in these process industries due to the fact of their simplicity, easily applicable and robustness. The PID controller offers higher flexibility to achieve desired response. PID controller has all the necessary dynamics, fast reaction on change of the controller input (D mode), increase in control signal to lead error towards zero (I mode) and suitable action inside control error area to eliminate oscillations (P mode).

In PID controller the gain and time constant of the process can change recurrently by changing the tuning parameter. Both open loop and closed loop are used for tuning, in which both open loop and closed loop are determined by ZN tuning rule. In PID controller the error are calculated between process variable and set point. The error can be minimized by tuning the controller parameters. .The transfer function of a temperature process has been determined using process reaction curve in which the parameters such as dead time, gain, time constant are calculated. With the help of these parameters the values of Proportional Gain, Integral time and Derivative Time has been determined. Different tuning methods such as Closed ZN, Modified ZN, and IMC-PID are performed. IMC provides a much easier framework for design of robust control system. The Best Controller for the process has been determined and characteristics are studied.

II. EXPERIMENTAL SETUP

The setup contains a heating tank system, solid switch relay. The temperature sensor used here is RTD Pt 100. A Rotameter is connected to the heating tank to measure the flow of the liquid. Heating control is provided by proportional power controller. The process signal is converted into output signal of 4-20mA with the help of transmitter. A part of output is fedback into the controller. The process parameters are controlled through computer by manipulating heat input to the process.

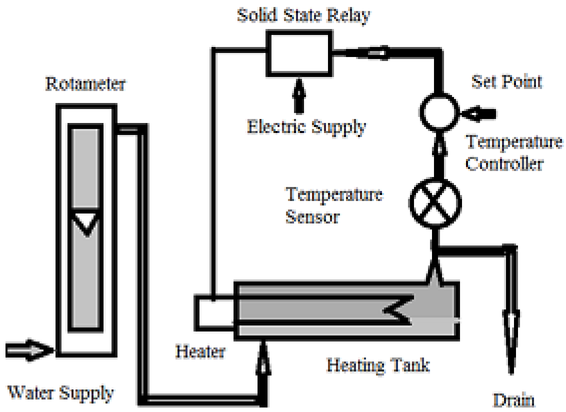
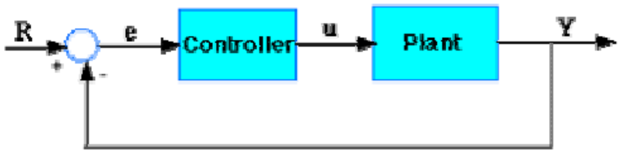


Fig 1. Experimental setup for heating tank

III. MODELING OF THE TEMPERATURE PROCESS:

The schematic diagram for the closed loop system is shown in the fig



Plant is the system to be controlled, Controller provides the excitation for the plant, in which R is the input of the plant, error is determined by calculating the value of e, y is the desired output of the plant, and U is the output of the controller. The overall design of the plant is controller in this closed loop system.

The transfer function of the process is determined by open loop response. In which the gain, dead time and time constant are determined by process reaction curve method. The general format of transfer function is

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$$G(s) = \frac{Ke^{-t_d s}}{\tau s + 1}$$

K-proportional gain, t_d-dead time, τ-time constant
The transfer function obtained from the process is

$$G(s) = \frac{10}{(32s + 1)} e^{-s}$$

IV. CONTROLLER TUNING

A. *Closed ZN method*

This method was introduced by John G. Ziegler and Nathaniel B. Nichols in the 1940s. The Ziegler-Nichols' closed loop method is based on experiments executed on an established control loop (a real system or a simulated system).The Z-N method is more robust because it does not require a specific process mode. This is a trial and error method based on sustained oscillations.

TABLE 1
CLOSED ZN METHOD TUNING FORMULA

CONTROLLER	k_p	τ_i	τ_d
with overshoot	$0.33K_u$	$P_u/2$	$P_u/3$
without overshoot	$0.2/K_u$	$P_u/2$	$P_u/3$

B. *Modified Ziegler-Nichols Methods*

For some control loops the measure of Oscillation, provide by ¼ decay ratio and the corresponding large overshoots for set point changes are undesirable therefore more conservative methods are often preferable.

TABLE 2
MODIFIED ZN METHOD TUNING FORMULA

CONTROLLER	K_c	τ_i	τ_d
P	$0.5K_u$		
PI	$0.45K_u$	$P_u/1.2$	
PID	$0.6K_u$	$P_u/2$	$P_u/8$

C. *Internal Model Control (IMC)*

Morari and his co-workers have developed an important new control system strategy that is called Internal Model Control or IMC. The Internal Model Control philosophy relies on the Internal Model Principle, which states that control can be achieved only if the control system encapsulates, either implicitly or explicitly, some representation of the process to be controlled.

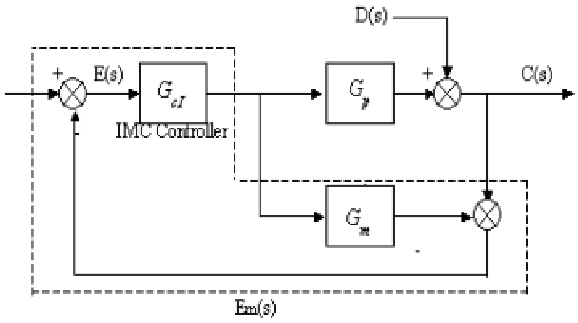
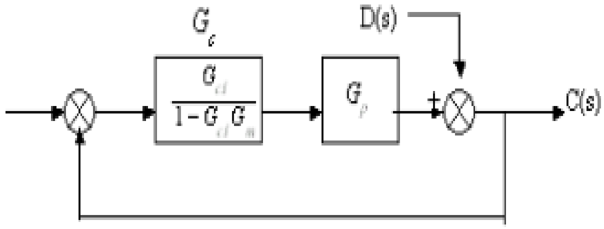


Fig 2. Internal model control basic structure

In this diagram G_p is the transfer function of the process and G_m is the transfer function of the process model. Also G_{cI} is the IMC controller transfer function.
The equivalent feedback control system for IMC structure



V. COMPARISON AND RESULT

The time domain specifications of the above mentioned tuning methods are tabulated and compared. The time domain specification includes the peak time, rise time, settling time and peak overshoot and performance indices like ISE,ITAE,IAE,and MSE.

TABLE 3 IMC METHOD TUNING FORMULA

CONTROLLER	K.Kc	τ_I	τ_D	τ_F	RECOMMENDED λ/d(λ>0.2τ always)
PID	$\frac{2\tau + d}{2(\lambda + d)}$	$\tau + \frac{d}{2}$	$\frac{\lambda d}{2\tau + d}$	$\frac{\lambda d}{2(\lambda + d)}$	>0.25
PI	$\frac{\tau}{\lambda}$	τ	-	-	>1.7
IMPROVED PI	$\frac{2\tau + d}{2\lambda}$	$\tau + \frac{d}{2}$	-	-	>1.7

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TABLE 4
COMPARISON OF TIME DOMAIN SPECIFICATIONS

TUNING METHODS	RISE TIME (T_r)	PEAK TIME (T_p)	SETTLING TIME (T_s)	PEAK OVERSHOOT
CLOSED ZN METHOD	2.08	3.2	14.75	60%
MODIFIED ZN (WITH OVERSHOOT)	3.01	5.35	25.5	35%
MODIFIED ZN (WITHOUT OVERSHOOT)	3.78	6.6	34	40%
IMC	12.2	-	15	-

TABLE 5
COMPARISON OF PERFORMANCE INDICES

TUNING METHODS	ISE	ITAE	MSE	IAE
CLOSED ZN METHOD	18.5723	9.0662e+100	3.7384e+198	9.0662e+100
MODIFIED ZN(WITH SOME OVERSHOOT)	1.8730e+201	3.7363e+100	8.4466e+202	1.3500e+103
MODIFIED ZN (WITHOUT OVERSHOOT)	23.1763	1.3500e+103	8.4466e+202	1.3500e+103
IMC	5.1513e+206	1.2842e+104	7.7072e+204	1.2842e+104

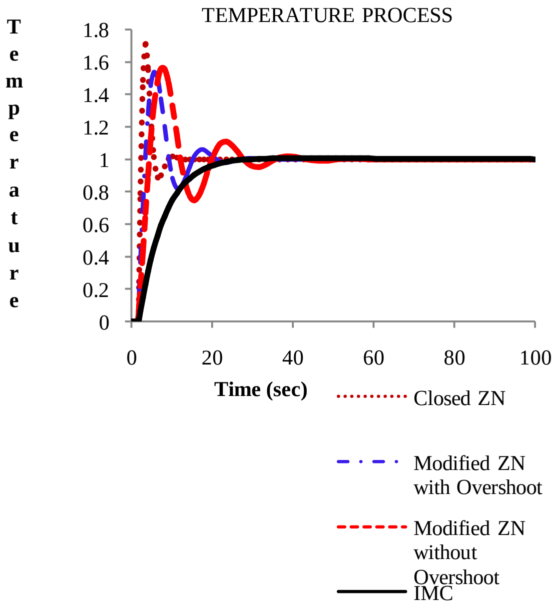

Fig 3.Simulated Results for the Temperature Process

From the time domain specifications and the graph it is seen that the method with minimum settling time and zero peak overshoot is the INTERNAL MODEL CONTROL method (IMC). Due to these factors the IMC method is considered as the method with better performance than other methods.

VI. CONCLUSION

The closed-loop responses for Ziegler-Nichols tuning for ideal PID controller has offset. The responses are quite oscillatory. This is one of the major disadvantages to the Z-N tuning method. If the process conditions change, then the control system may become unstable. In order to overcome these disadvantages IMC control is implemented. The main advantage to IMC is that is provides a transparent framework for control system design and tuning. Thus, IMC is able to compensate for disturbances and model uncertainty. The results provided prove that IMC method is better than rest of the mentioned methods.

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