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A Comparative Study on PID and IMC Controller in A Heat Exchanger

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ABSTRACT

The main objective of a heat exchanger system is to transfer heat from a hot fluid to a cooler fluid, so temperature control of outlet fluid is of prime importance. In this paper, firstly the reading from of the studied experimental data are taken and the controller for that is imparted and analyzed. Here both the PID controller and the internal model control is analyzed which is considered as one of the best advanced controller in the controlling a process in a most effective manner. The main aim of the proposed controllers is to analysisperformance of o the system and the rise time (t_r), peak time (t_p), settling time (t_s) is calculated.

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INTRODUCTION

Any plant automation system (technical as well as nontechnical ones) can't be designed and made operational without using methods of model building and simulation of the system to be automated (Despande, M.V.; Naim, A., Kheir). Depending on nature of plant and process certain basic knowledge of the subject (viz. physical sciences, engineering etc.) and prior information about the system is needed for modeling purpose. Rapid development of computer based control in the process industry (Coughanowr, D.R., 1991; Nagrath, I.J. and M. Gopal, 1999) has increased the importance of modeling and simulation of process. Based on available information and knowledge, of heat exchanger the transfer function are mathematically simulated for the control elements such as heat exchanger system (process), actuator, valve, sensor used in temperature control loop. By condensing steam the Process fluid is heated in the heat exchanger. It is implicit that, the process fluid at temperature T (L, t) is heated up to a certain desired outlet (t). The energy gained by the process fluid is the temperature provided by the latent heat of steam. There are many variables in the process that can change, causing the outlet (t) to deviate from its desired value. In such aθ(t) temperature situation some action must be taken to prevent deviation. By adjusting the control valve located in the steam line the process fluid temperature is maintained at the desired value .The proposed model for temperature control loop of heat exchanger .The sensor (S) measures the output temperature and sends its output signal to controller which is compared with its set point value. The controller produces the actuating signal which sends signal to pneumatic (I/P) converter that produces a pneumatic signal (3 – 15 psig) that regulates control valve (V) opening ,which in turn regulates the steam flow. The flow enters the heat exchanger and along with the help of other process inputs, θ (t) it produces an output temperature.

II Mathematical modeling:

In this section the heat exchanger system, actuator, valve, sensor are mathematically modeled using the available experimental data. The experimental process data's are summarized below. (Subhransu Padhee, YuvrajBhushanKhare, 2011).

Time constant = 30 sec

Heat Exchanger response to variation of process fluid flow gain=1°C/ (kg/sec)

Heat Exchanger response to variation of process fluid temperature gain=1°C/°C

Control valve capacity for steam = 1.6 kg/sec

Time constant of control valve = 3 sec

The range of temperature sensor = 50°C to 150°C

Time constant of temperature sensor = 10 sec

From the experimental data, transfer function and the gain are obtained as below.

Transfer function of process = $\frac{34}{30s+1}$

Transfer function of valve = $\frac{1.25}{3s+1}$

Gain of the Valve = 0.75

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Transfer function of the sensor = $\frac{0.08}{2s+1}$

III PID control of heat exchanger:

PID controller is the most used controller because it is simple to operate and very robust. The latest implemented PID controller is based on a direct digital design. These digital PID has many algorithms to develop their performance, for example anti wind-up, auto-tuning, adaptive, fuzzy fine-tuning and Neural Networks with the necessary operations remaining the same. Here Zeigler-Nicholas tuning rule is used for the PID tuning since it provide easy tuning formulae to find out the P, PI, PID control parameters (Kiam Heong Ang, 2009) For the PID Controller in the heat exchanger, the values of the tuning parameters obtained are K_p =5.16, T_i =7.12, T_d =1.78. Usually, initial design values of PI controller obtained by all means to be adjusted repeatedly through computer simulation until the closed loop system performs effectively until the desired the result is obtained. The performance terms such as Rise time Overshoot, Settling time and error; By tuning value of parameters *Kp*, *Ki* and *Kd* of the PID controller the steady state can be improved. The output of this is shown in the below graph at the end of the paper.

IV Internal Model Controller:

In many of the industrial application for control system none of the information such as Process model, Model uncertainty, Type of input, Performance objective are not available, with the result that the system usually performs in a less than optimal manner. The choice of a performance objective is subjective and often arbitrary. In the IMC method the integral square error is implied.

A block diagram of an IMC system is shown, in this diagram, G is the transfer function of the process and G_m is the model of the process .Here we relate the IMC Controller with the conventional PID Controller.

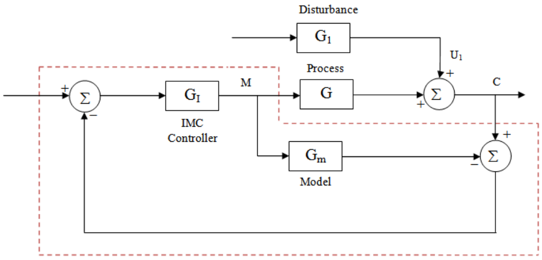

Fig. 1: General block diagram of internal model controller.

By using the following rules and considering the input one can design a IMC Controller:

Initially the process model is separated into two terms we determine a transfer function that has minimum phase characteristics .A system has non-minimum phase characteristics if its transfer function contain zeros in the right half plane or transport lags, or both. Otherwise a system has minimum phase characteristics. For step change in disturbance is determined by

$$G_I = \frac{1}{G_{m_m}} \qquad (1)$$

The result of applying the above equation will obtain a transfer function that is stable and does not require prediction; On the other hand it will have terms that cannot be implemented because they require pure differentiation

The IMC controller is obtained by multiplying it with the transfer function of the filter f(s) that can be represented as

$$f(s) = \frac{1}{(\lambda s+1)^n} \qquad (2)$$

Where λ is the filter parameter and n is an integer finally the equation of IMC can be obtained as

$$G_I = \frac{f}{G_{m_m}} \qquad (3)$$

The conventional transfer function G_c, use is formed with G_I and above equation is obtained and thereby process model, G_c turns out to be equivalent to a PID controller multiplied by a first-order transfer function thus

$$G_c = K_c\left(1+\tau_D s+\frac{1}{\tau_I s}\right)\left(\frac{1}{\tau_1 s+1}\right) \qquad (4)$$

Where,K_c ,τ_D,τ_I,$\tau_1$are the function of the process in the G_I and G

The experimental data are taken and are modeled accordingly as stated above and the following results have been obtained

$$G = G_{m_m} G_{m_a} \qquad (5)$$

$$G_{m_m} = \frac{42.5}{(3s+1)(30s+1)\,(90s^2+33s+1)}(-90s^2 - 33s + 1)$$

$$G_I = \frac{(3s+1)(30s+1)(90s^2+33s+1)}{42.5}\,\frac{1}{(\lambda s+1)^2}$$

In Practice λ is taken more than the time constant value, Here, the value of λ is taken as 1. Substituting the value to the above equation we get a transfer function of Internal Model Controller denoted as G_c

$$G_c = \frac{90s^2+33s+1}{(42.5s^2+85s+1)} \qquad (6)$$

V Problem Statement:

Here in this section we have developed a block diagram for the temperature control loop and have modeled for the heat exchanger system (process), actuator, valve, sensor using the experimental data available. For the individual systems transfer function model of are generated which in turn are combined to acquire the transfer function of the whole system. The transfer function model of the system is derived for the above experimental data.

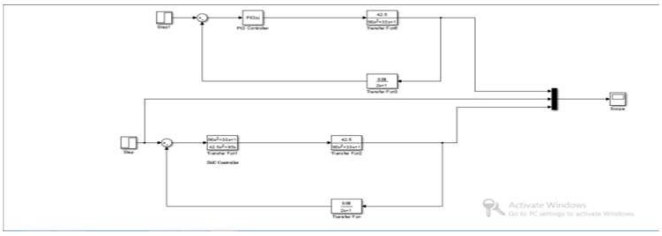

Fig. 1: Block Diagram of the System.

IV Result:

The closed loop modeling method described in this paper are analyzed for controller parameters (K_p, T_i, T_d) of PID and λ of IMC for heat exchanger. The various theoretical responses of the system are compared. The Rise time, peak time and settling time is calculated. The response of the PID and IMC are shown**.**

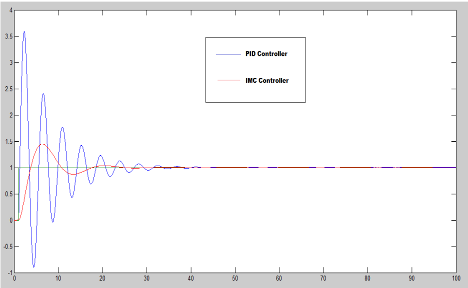

Fig. 2: Graphical response of the controllers.

V Response Of The Temperature Control System:

From the above the response it has been inferred that the neither the settling time nor the control accuracy is satisfied a sufficient amount when a conventional PID is used. The steady state error of the PID controller is greater than IMC. Thus shown that the IMC has better response than the conventional PID Controllers.

Table I: Comparison Of The System.

S.No	PARAMETER	PID	IMC
1	Rise Time	0.125	0.42
2	Peak over shoot	0.28	0.82
3	Settling Time	44.8	23.2
4	Peak Time	3.78	1.41

VI Conclusion:

This paper takes reading of heat exchanger system and evaluates different methods to control the outlet fluid temperature of different controllers are designed to control the outlet temperature of fluid and the performances of these controllers are calculated by one of the methods for performance evaluation is the time domain analysis of overshoot and settling time. So as future work FOPID controller tuned using genetic algorithm, artificial neural network, and fuzzy logic can be implemented for effective temperature control of the heat exchanger system.

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