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System Identification and Controller Design for Shell and Tube Heat Exchanger

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ABSTRACT

Heat exchanger are widely used in many process industries which transfer heat from one medium to another medium which alter the temperature distribution of two fluids. This paper involves a mathematical modelling for Shell and tube heat exchanger using MATLAB. The mathematical modelling can be done by using system identification procedure. Transfer function of a model is obtained from the system identification. The model is simulated using SIMULINK and the PID parameters are obtained by using Cohen coon method. Response of Heat Exchanger is observed using PI and PID controller . The results shown in the graphical form.

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INTRODUCTION

Heat exchangers are extensively used in process industry. A most common type of heat exchanger used in industries is Shell and Tube Heat Exchanger. This heat exchanger fids application in oil refineries and other huge chemical processes and is suitable for higher-pressure applications (Mercere, G., *et al*., 2009). As its name imply, this type of heat exchanger consists of a shell with a bundle of tubes inside it where one fluid runs through the tubes, and another fluid flows over the tubes to transfer heat between the two fluids. It has larger ratio of heat transfer surface to volume than double-pipe heat exchangers, and it is easy to produce in a large range of size and arrangement (Subhransu Padhee, 2014).

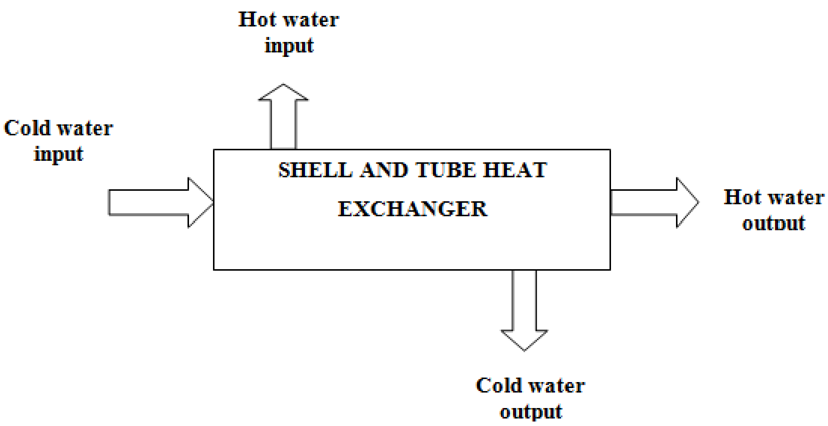

Fig. 1: Block diagram of shell and tube heat exchanger

Controller is a device introduced in the system which modify the error signal and produce control action .Controllers are used in many process as it improve steady state accuracy by decreasing the steady state errors and increasing the stability of the system. They also help in reducing the offsets produced in the system. Controllers controls Maximum overshoot of the system and also help in reducing the noise signals produced in the system. PID is the most commonly used controller which find its applications in various areas of automatic control. Though there are several high end

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controllers better than existing PID, the simplicity and path record of PID controller makes it an noticeable choice for most of the control problems.

II. Transfer Function Estimation:

Data from shell and tube heat exchanger is collected. These data is used for estimating the transfer function .The transfer function of heat exchanger is found by system identification toolbox using MATLAB (Tatang Mulyana, *et al*., 2011). System identification is an experimental method to build model from input and output data. The model should be able to describe the behaviour of the process around an operating point. The model is constructed with the help of the system identification toolbox in MATLAB. Transfer function is ratio of output to input. It is given by $G(S)=K/(1+T_{p1}s)$.Transfer function of the heat exchanger obtained from system identification toolbox is G(S)= 3.959/(S+4.546).

III. PI Controller:

PI controller is mostly used to remove the steady state error resulting from Proportional controller. This controller finds its uses where speed of the system is not concern. Proportional controller has no ability to anticipate the future errors in the system. It cannot decrease the rise time and eliminate the oscillations, so proportional plus integral controller is preferred (Smriti Rao, K., Ravi Mishra,). PI Controller is a device which consists of two terms that produce an output signal .One term is proportional to input signal and other term is proportional to the integral of input signal. PI controller is simple, low cost and easy to design. Integral action eliminate offset, increases the loop gain and makes system less sensitive to parameter variations.

P(proportional) = $K_P e(t)$

I(integral) = $K_i \int_0^t e(t)d(t)$

PI controller output, $U(t)= K_P\ e(t) + K_i \int_0^t e(t)d(t)$

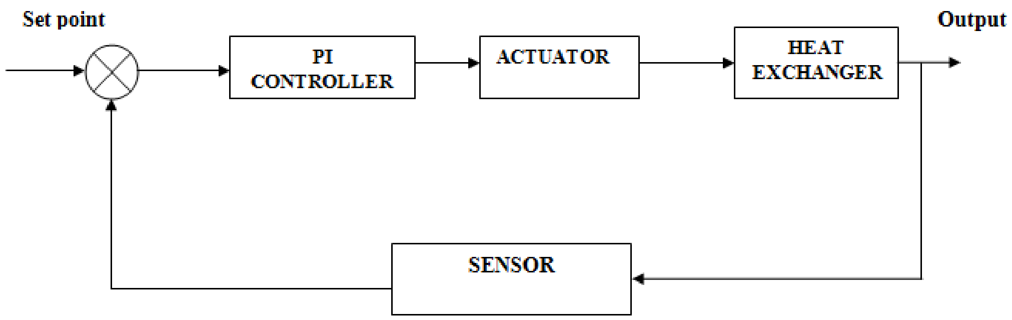

Fig. 2: Block diagram of PI controller

PI controller is tuned using Cohen Coon Method. The control parameters obtained by using this tuning method are shown below

Table I: PI Controller parameters

PI controller	K_P	K_i
	0.3159	0.3233

Transfer function of PI controller is $K_P+\frac{K_i}{S}$ where K_P and K_i are proportional and integral gain.

IV. PID controller:

PID controllers are widely used in many industries because of it combine the advantages of proportional, derivative and integral control action. The reason PID controllers are so popular is that using PID gives the designer a huge number of options for changing the dynamics of the system (Liu, G.P. and S. Daley, 2001). It makes the system less sensitive to parameter variations(P mode),reduces the steady state error without manual reset(I mode) and improves stability of the system and The Derivative term provide faster response of the system (D mode) (Kyoung, K.A., *et al*., 2007). The proportional plus integral plus derivative controller(PID) consist of three terms, that produce an output signal .One term is proportional to input signal and other term is proportional to the integral of input signal and third one proportional to derivative of input signal.

P(proportional) = $K_P e(t)$

I(integral) = $K_i \int_0^t e(t)d(t)$

D(derivative) = $K_d \frac{d(e)}{d(t)}$

PID controller output, $U(t)= K_P\, e(t) + K_i \int_0^t e(t)d(t) + K_d \frac{d(e)}{d(t)}$

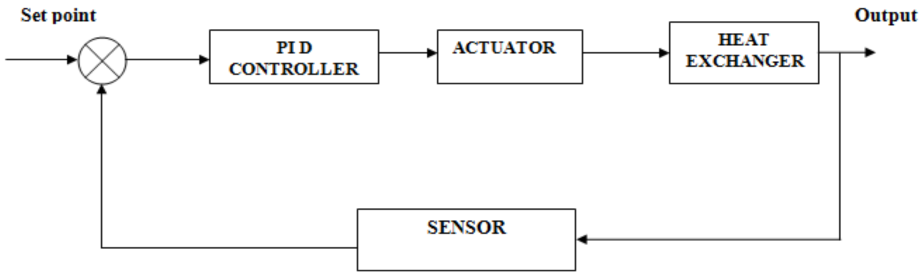

Fig. 3: Block diagram of PID controller

Transfer function of PI controller is $K_P+\frac{K_i}{s}+K_D s$ where K_P, K_i and K_D denotes the coefficients for the proportional, integral, and derivative terms, respectively. P denotes the present values of the error, I denote the past values of the error and D relates the predicted future values of the error, based on its current rate of change. The PID controller is tuned using Cohen Coon Method. The control parameters obtained by using this tuning method are shown below

Table II: PID Controller parameters

PID controller	K_P	K_i	K_d
	0.4972	1.362	0.2258

V. Simulation results:

PI controller tends to increase the oscillation in the process response. It tends to make the system unstable because it responds slowly towards the produced error. PI has advantage such as no offset, it is not used in many industries because complexity, costlier and produce slow response, oscillations and overshoot. PI controller will not predict the error in near future. This problem can be solved by using derivative mode which has ability to predict the error in near future. Thus the drawback of PI controller are overcome by PID controller.PID shows a smaller maximum overshoot than the PI controller and has no steady state error due to the I action (KiamHeongAng, *et al*., 2009). From the table III we can observe that settling time, rise time and maximum overshoot of PI and PID controller.PID results in lesser settling time, rise time and maximum overshoot than PI controller. PID requires no offset, faster and produce less oscillations and low overshoot than PI controller. PI and PID controller response are observed in simulation results which are shown in below figure.4

Table III: Comparison Of Different Parameters In Controllers

CONTROLLER	Rise Time	Maximum Overshoot	Settling Time	IAE
PID	11.25	11.4	10	55.77
PI	11.45	11.58	10.05	64.36

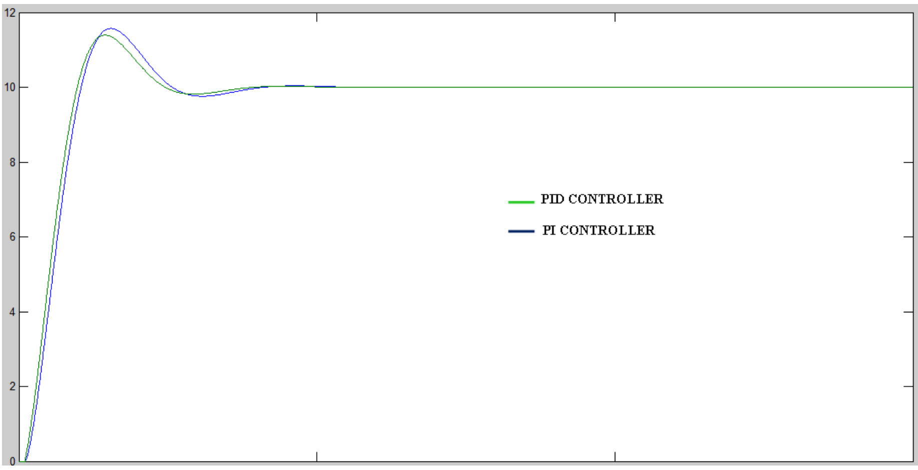

Fig. 4: Controller Response Of PI and PID controller

Conclusion:

Thus the transfer function of the heat exchanger is obtained and controller response of heat exchanger using PI and PID was observed. Simulation results show that PID performs well than PI controller. PI results in slow response, instability and does not predict error in near future where as PID overcome these drawback of PI controller since it combines the advantage of P,I and D controller.

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