Internal Model Control for Outlet Temperature Control of Falling Film Evaporator

Aravind R. Varma and Dr. Mary Thomas

Abstract--- Internal model controllers are useful in chemical processes where accurate model is not available. Internal model controllers need controller transfer function which can be calculated by determining inverse of process transfer function. Outlet temperature is one of the control variables of the falling film evaporator which can be controlled by manipulating shell side pressure. By using internal model control settling time can be reduced when compared to PI or PID control.

Keywords--- Internal Model Control, Falling Film Evaporator, Settling Time, Temperature Control

I. INTRODUCTION

Chemical processes usually introduce high non-linearity and the parameters of these processes are time variant in nature. The dead time introduced by these processes is considerable. If a reasonably accurate dynamic model of process is available controller can be designed based on this model.

A wide variety of methods are used to design PID controllers based on process models. Analytical expression for controller parameters can be derived from process model. Internal model control was developed by Morrari and co-workers.

A process model and controller output is used to determine the actual response. The error in both responses is the input to the internal model. Modeling errors and unknown disturbances are not accounted for this model.

Aravind R. Varma, Dept. of Chemical Engineering, Govt. Engineering College, Thrissur, India. E-mail:aravindrvarma001@gmail.com
Dr. Mary Thomas, Head of the Department, Dept. of Chemical Engineering, Govt. Engineering College, Thrissur, India

IMC Design parameters are developed based on Morrari's calculation.IMC controller is based on inverse of the process rather than entire process.IMC methods are used to develop equivalent controllers when modeling errors and known disturbances are present.

II. PROCESS MODEL

Concentrating weak liquors are done using 3 effect evaporator system. This method is useful in concentrating liquors in food industry, pharmaceutical and in chemical industry.

Falling film evaporators are used in concentrating caustic soda which is the process under consideration. 30-32 per cent concentrated NaOH is converted to concentrated NaOH (98% conc) after 3 stages.

Most of the industrial processes utilizes the level of liquid in separator as the process variable and liquid level is controlled by manipulating the outlet flow. The main disturbance variable affecting the process is feed flow rate. The response of the level controller to the disturbance variable is slow and takes 20-30 minutes to reach steady state. By implementing temperature control the detection of effect due to disturbance variable is rapid and reduces the settling time to 188 seconds. MV used is shell side pressure

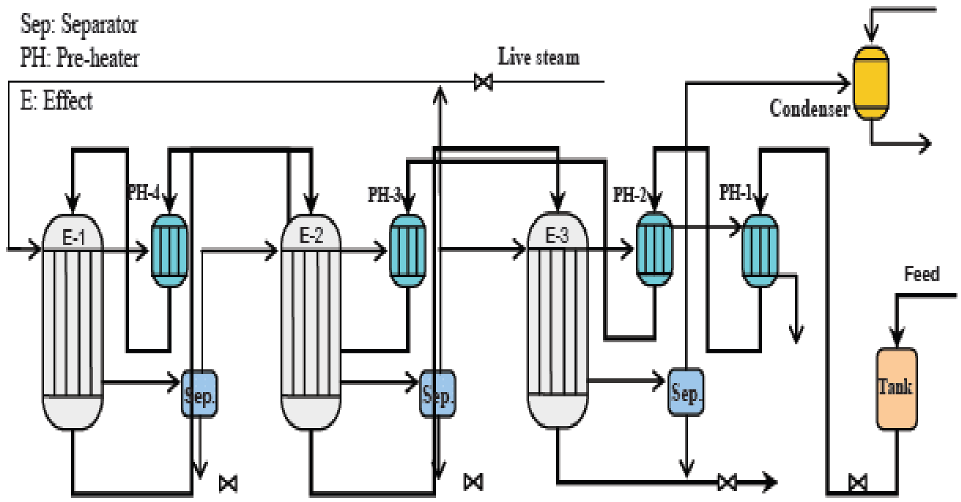

Fig. 1: Triple Effect Evaporator System for Concentrating NaOH

III. TRANSFER FUNCTION

The transfer function of the process was obtained using time domain data for MV and PV obtained after conducting experiment.

For Evaporator-1

$Y(s)/U(s) = 3.261\,s+0.2184/(s^2+1.533s+0.009588)$

Y(s) =L(outlet temperature of NaOH)

U(s)=L(shell side pressure)

For Evaporator-2

$Y(s)/U(s)= 224.8\,s+10.81/(s^2+10.79s+0.5597)$

Y(s) =L (outlet temperature of NaOH)

U(s) =L (shell side pressure)

System identification tool in Matlab is used for estimating transfer function.

IV. IMC BASED PI CONTROL

IMC Control parameters are determined based on Morrari's rules. For a second order system with a zero of the form TF= $(Bs+1)/(T^2s^2+2\delta Ts+1)$, tuning parameters of a PI Controller is given below. When IMC controller is designed $G_p(s)$ for Evaporator 1 and Evaporator 2 are given above.

Transfer function of the process model is given by $G_p(s)$. The transfer function is given by

For Evaporator-1

$Y(s)/U(s) = 8.442s+0.7736/(s^2+2.048s+0.02678)$

Y(s) = L (outlet temperature of NaOH)

U(s) = L(shell side pressure)

For Evaporator-2

$Y(s)/U(s)= 19.05s+2.686/(s^2+1.241s+0.1539)$

Y(s) =L (outlet temperature of NaOH)

U(s) =L (shell side pressure)

System identification tool in Matlab is used for estimating transfer function.

Q is calculated by the relation $(1/\ (G_m(s)\ \lambda))$.Where lambda is the tuning parameter for the controller. Tuning parameter for two evaporators are 4 and 12 respectively for better response. When equivalent PID Controller is designed the relation $G_c=Q/(1-QG_m)$is used.

Table 1: Tuning Data for PI Controllers

Process	Controller	K_p	K_I	K_D
Evaporator 1	PID	1	0.025	0.0000001
Evaporator 2	PID	0.07414	0.02	0.002

Table 2: Tuning Data for IMC Based PI Controllers

Process	Controller	K_p	K_I	K_D
Evaporator 1	IMC based PID	9.34	0.25	4.5
Evaporator 2	IMC based PID	0.5415	0.07	0.44

V. Result& Analysis

IMC Controller gives a better response in terms of rise time and settling time than conventional PID.

Table 3: Result for PID Control

Process	Controller	Settling Time	Overshoot
EV1	PID	210s	3%
EV2	PI	59s	0

Table 4: Result for IMC Based PID Control

Process	Controller	Settling Time	Overshoot
EV1	IMC based PID	48s	1%
EV2	IMC based PID	18s	0

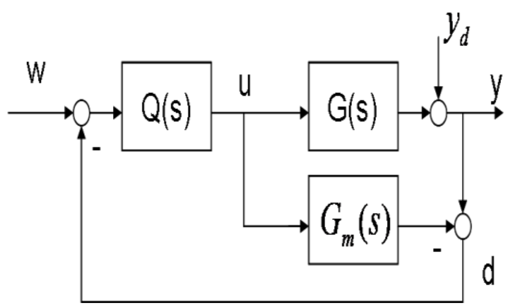

Fig. 2: Schematic Diagram of IMC Control

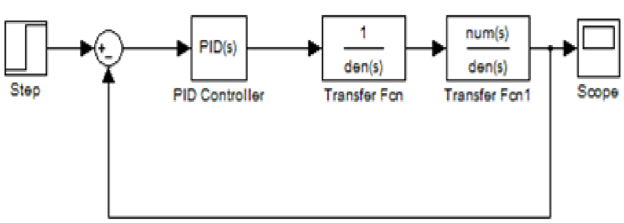

Fig. 3: Block Diagram of IMC Based PID Control of Evaporator 2

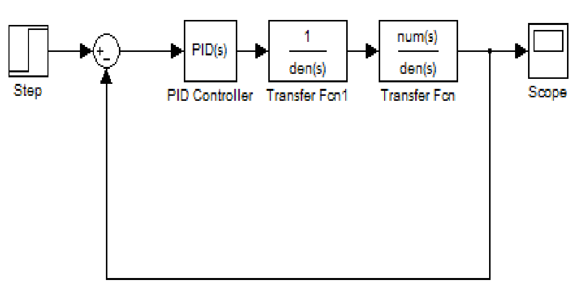

Fig .4: Block Diagram of IMC based PID Control of Evaporator 1

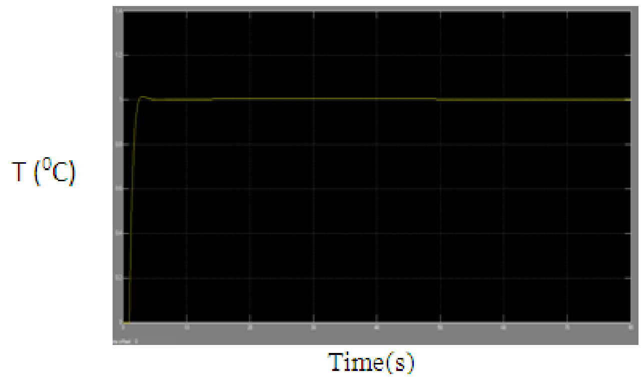

Fig. 5: Response of IMC based PID Control for Evaporator1

VI. Conclusion

IMC based PID controller gives a better response than PI or PID control for Evaporator-1 and Evaporator-2. The overshoot introduced is reduced in the case of evaporator 1.

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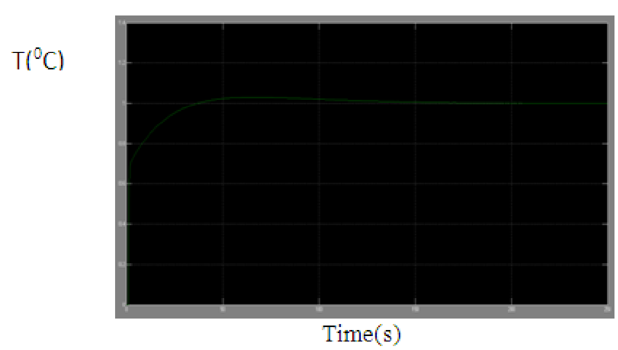

Fig. 6: Response of PID Control for Evaporator 1

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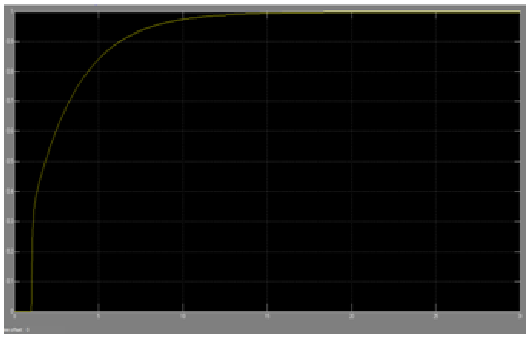
T(^{0}C)

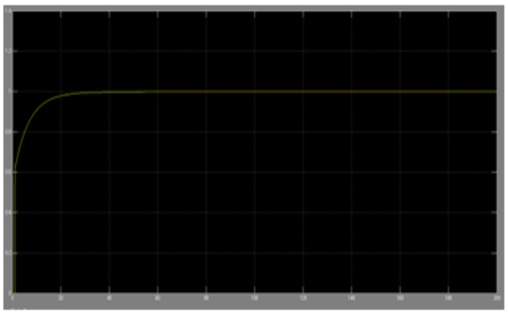


Time(s)

Fig .7: Response of IMC based PID Control for

Evaporator 2

T(^{0}C)



Time(s)

Fig. 8: Response of PID Control for Evaporator2