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Design of Model based controller for Two Conical Tank Interacting Level systems

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Abstract: *This paper presents the modelling and control of Two Tank Conical Interacting systems which is highly a non linear process. A Model based controller is designed for the process at different operating regions and its performance is studied with and without disturbance. The aim is to control the liquid level of tank. Piecewise linearization technique is applied for linearising the non linear system output. An Internal Model control is designed for each region. The controller will be simulated using MATLAB SIMULINK software.*

Keywords: *Conical Tank Interacting Level systems, IMC Controller, Mathematical Modelling, MATLAB software, Non linear process.*

I. Introduction

The control of liquid level is mandatory in all process industries. Most of the process industries need the usage of conical tanks as its structure contributes to better drainage of solid mixtures, slurries and viscous liquids. Food processing industries, Concrete Mixing industries, Hydrometallurgical industries and waste water treatment industries are some examples which makes effective usage of conical tanks.

To achieve a satisfactory performance using conical tanks, its controller design becomes a challenging task because of its non-linearity. A very important task of a controller is to maintain the process at desired set point and to achieve optimum performance even in the presence of disturbances. Many Industries use Proportional Integral Controller (PI) and Proportional Integral Derivative controller (PID) because of its simple structure and easy tuning.

An alternative to this controller is the usage of Internal Model controller (IMC) which gives satisfactory performance for Conical Tank Interacting Level systems [1]. In this paper an Internal Model Controller is designed and implemented to Conical Interacting systems [2]. This controller uses the model of the process to run in parallel with the actual process [3]. The IMC design procedure is exactly same as the open loop control design procedure. Unlike the open loop control the IMC structure compensates for disturbances and model uncertainty.

Paper is organized as follows. Section II describes the Mathematical modelling of Two Tank Conical Interacting Systems and its operating parameters. Piecewise linearization is carried out around four operating regions.The implementation of IMC controller is discussed in Section III. Section IV presents experimental results showing four different simulations for four regions. Finally Section V presents Conclusion.

II. Mathematical Modelling Of Two Tank Conical Interacting System

The two tank conical interacting system consists of two identical conical tanks (Tank 1 and Tank 2), two identical pumps that deliver the liquid flows F_{in1} and F_{in2} to Tank 1 and Tank 2 through the two control valves C_{V1} and C_{V2} respectively. These two tanks are interconnected at the bottom through a manually controlled valve, MV_{12} with a valve coefficient β_{12}. F_{out1} and $F_{out\,2}$ are the two output flows from Tank 1 and Tank 2 through manual control values M_{V1} andM_{V2} with valve coefficients β_1 and β_2 respectively. The non linear equations describing the open loop dynamics of the Two Tank Conical Interacting Systems is derived using the Mass balance equation and Energy balance equation principle [4].

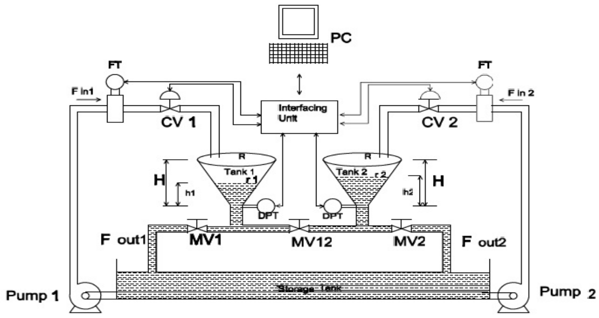


Fig. 1 Schematic diagram of two tanks Conical Interacting System

The Mathematical model of two tank conical interacting system is given by equations 1 and 2. [5]:

$$\frac{dh_1}{dt} = \left[\frac{F_{in1} - h_1 \dfrac{dA(h_1)}{dt} - \beta_1\sqrt{h_1} - sign(h_1 - h_2)\beta_{12}\sqrt{|h_1 - h_2|}}{\dfrac{1}{3}\pi R^2 \dfrac{h_1^2}{H^2}} \right] \quad (1)$$

$$\frac{dh_2}{dt} = \left[\frac{F_{in2} - \beta_2\sqrt{h_2} + sign(h_1 - h_2)\beta_{12}\sqrt{|h_1 - h_2|} - h_2 d\dfrac{A(h_2)}{dt}}{\dfrac{1}{3}\pi R^2 \dfrac{h_2^2}{H^2}} \right] \quad (2)$$

Where

$A(h_1)$ = Area of Tank 1 at $h_1(cm^2)$
$A(h_2)$ = Area of Tank 2 at $h_2(cm^2)$
h_1= Liquid level in Tank 1 (cm)
h_2= Liquid level in Tank 2 (cm)

TABLE I
Operating Parameters Of Two Tank Conical Interacting System

Parameter	Description	Value
R	Top radius of conical tank	19.25cm
H	Maximum height of Tank1&Tank2	73cm
F_{in1} & F_{in2}	Maximum inflow to Tank1&Tank2	$252cm^3/sec$
β_1	Valve coefficient of MV_1	$35\ cm^2/sec$
β_{12}	Valve coefficient of MV_{12}	$78.28\ cm^2/sec$
β_2	Valve coefficient of MV_2	$19.69\ cm^2/secs$

The open loop responses of h_1 and h_2 are shown in fig.2 as shown below.

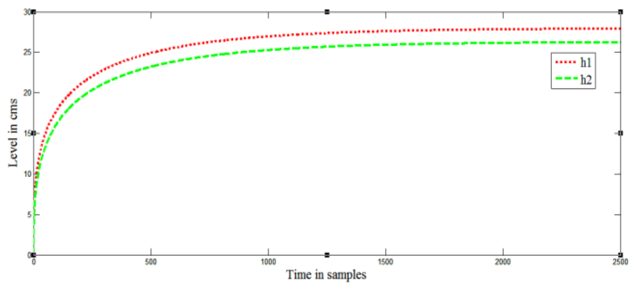


Fig. 2 Open loop response of h_1 and h_2

The process considered here has non linear characteristics and can be represented as piecewise linearized regions around four operating regions[6]. Transfer function for every region is obtained by substituting the values of time constant and gain using Process reaction curve method as shown in Table III.[7].

TABLE III Model Parameters Of Two Tank Conical Interacting System

Region	Inflow (cm^3/s)	Height h_2 (cms)	Steady State Gain	Time constant (secs)	Transfer Function model
I	0-66	1.374	0.0208	0.002	$\frac{0.0208}{0.002s+1}$
II	66-120	4.19	0.0349	0.03	$\frac{0.0349}{0.03s+1}$
III	120-186	8.447	0.0454	0.146	$\frac{0.0454}{0.146s+1}$
IV	186-252	12.56	0.0498	0.338	$\frac{0.0498}{0.338s+1}$

III. Implementation Of Internal Model Controller (IMC)

A more comprehensive model based design method, Internal Model Control was developed by Morari and co-workers. The IMC method is based on the simplified block diagram as shown in Fig. 3[8].

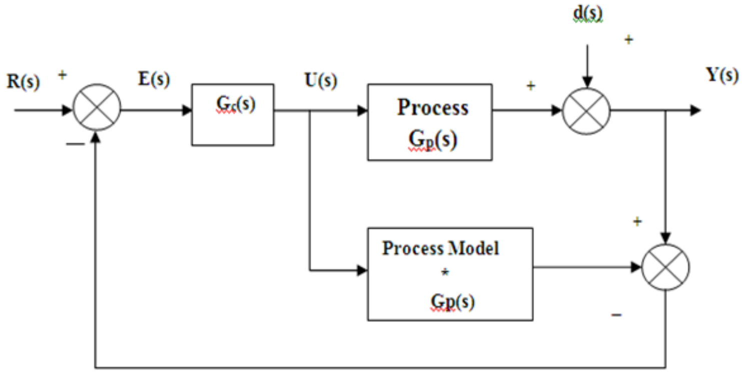


Fig. 3 Internal Model Control (IMC)

Internal Model Control is designed in two steps.

Step 1: The process model is factored as :

$$\tilde{G} = \tilde{G}_{+} \tilde{G}_{-} \quad (3)$$

Where $\tilde{G}_{+}$ contains any time delays and right half plane zeros.In addition $\tilde{G}_{+}$ is required to have a steady state gain equal to one in order to ensure that the two factors in equation 3 are unique.

Step 2: The controller is specified as:

$$Gc^{*} = (1/\tilde{G}_{-})\, f \quad (4)$$

Where f is a low pass filter with a steady state gain of one.

Thus the Internal Model Controller is designed as inverse of the Process model which is in series with the low pass filter.

Fig.4 represents the MATLAB simulink diagram of Internal Model controller for region 1.

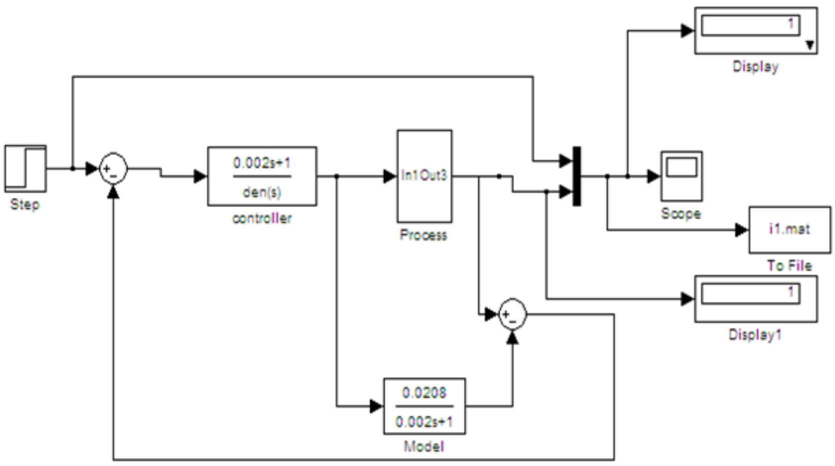
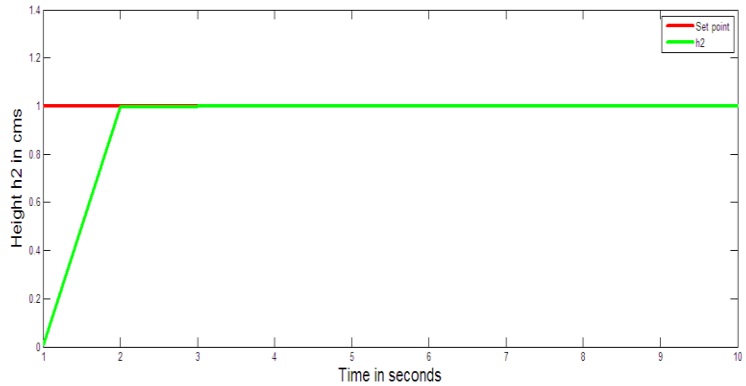


Fig. 4 Simulink diagram for region 1 using Internal Model Control (IMC)

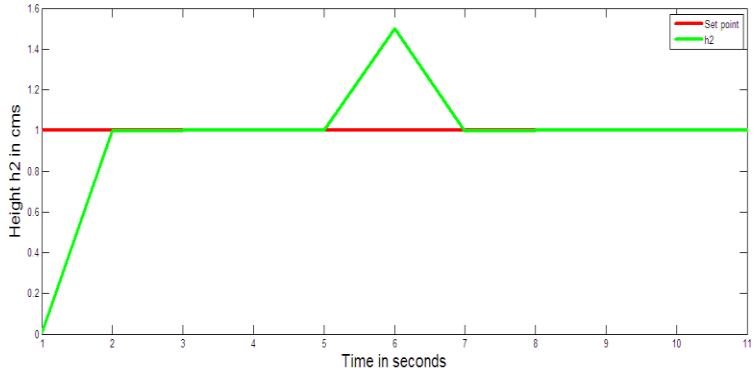
Similarly the Process is simulated for different regions and the responses obtained with and without disturbances are discussed in section IV.

IV. SIMULATION RESULTS

The simulation is carried out using MATLAB software for all the four regions of Two Tank conical Interacting systems. Both servo and regulatory responses are obtained for all the regions. The performance of IMC controller for all the four regions are shown in Fig. 5(a&b),6(a&b),7(a&b) and 8(a&b)with and without disturbance. Also set point tracking of servo response is obtained.



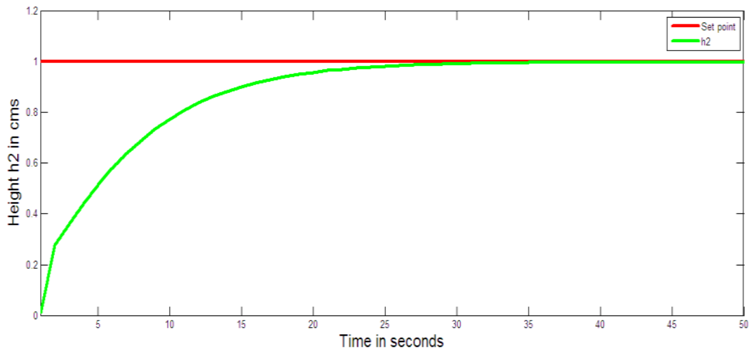
(a)



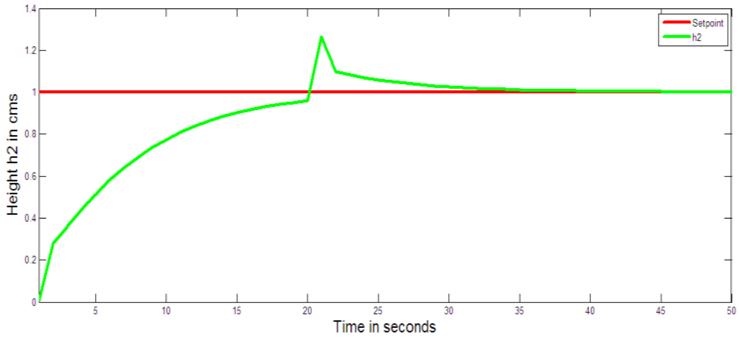
(b)

Fig. 5 Controller response for region 1 (a) Without disturbance (b) With disturbance

Fig.5. shows the IMC controller response for region 1 (0-66 cm^3/s).The response clearly indicates how the IMC controller effectively works so as to reach the desired set point even in the presence of disturbance as shown in fig 5(a&b).



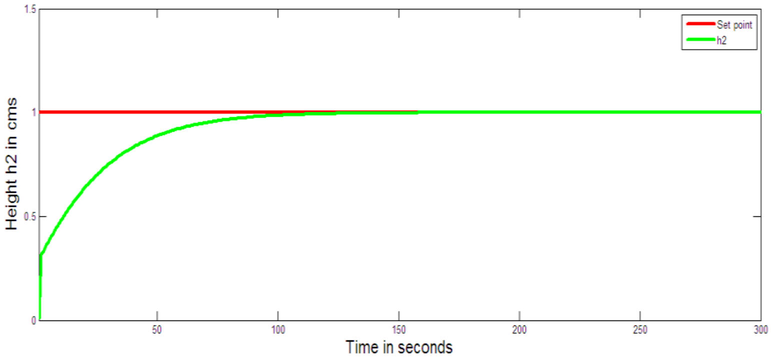
(a)



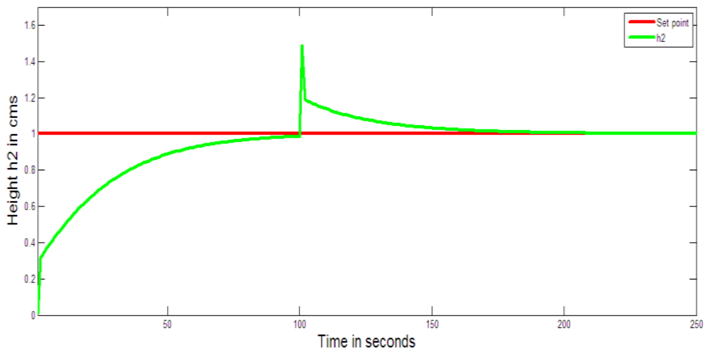
(b)

Fig. 6 Controller response for region 2 (a) Without disturbance (b) With disturbance

Fig.6. shows the IMC controller response for region 2 (66-120 cm^3/s).The response clearly indicates how the IMC controller effectively works so as to reach the desired set point even in the presence of disturbance as shown in fig 6(a&b).



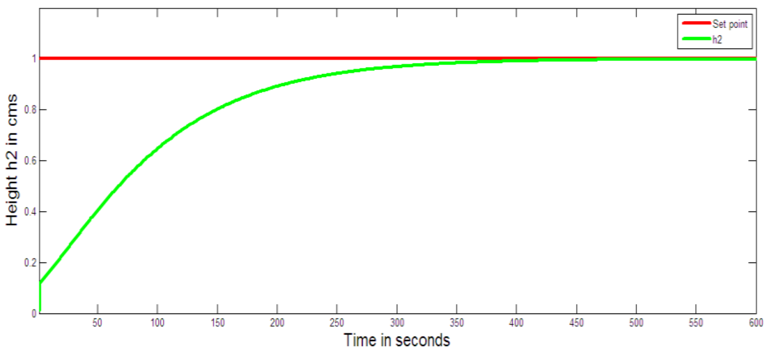
(a)



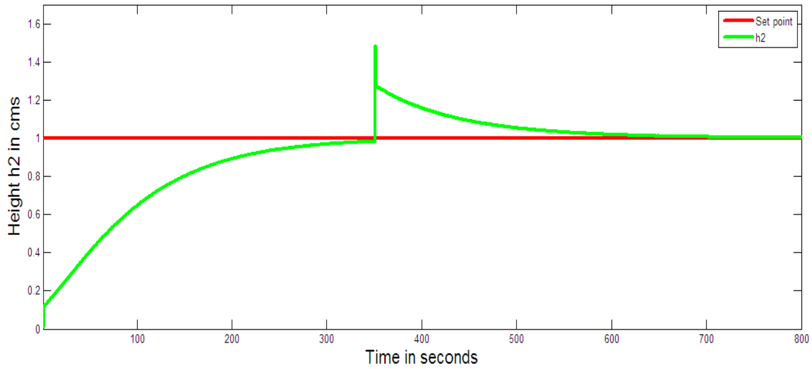
(b)

Fig. 7 Controller response for region 3 (a) Without disturbance (b) With disturbance

Fig.7. shows the IMC controller response for region 3 (120-186 cm^3/s).The response clearly indicates how the IMC controller effectively works so as to reach the desired set point even in the presence of disturbance as shown in fig 7(a&b).



(a)



(b)

Fig. 8 Controller response for region 4 (a) Without disturbance (b) With disturbance

Fig.8. shows the IMC controller response for region 4 (186-252 cm^3/s).The response clearly indicates how the IMC controller effectively works so as to reach the desired set point even in the presence of disturbance as shown in fig 8(a&b).

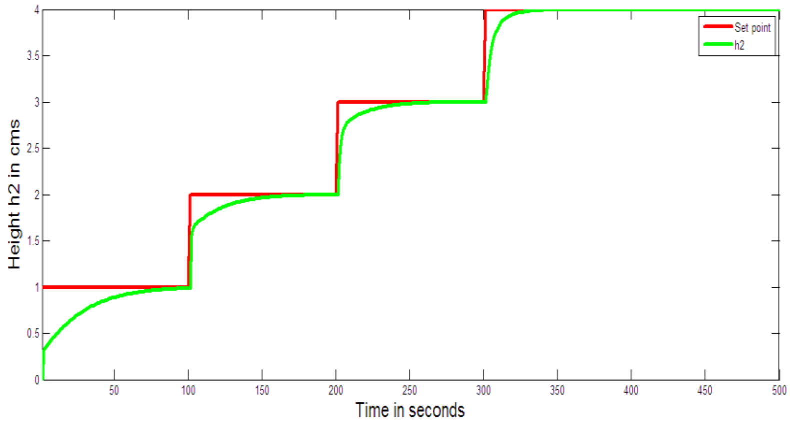


Fig. 9 Set point tracking

Fig.9. shows the set point tracking response using IMC controller.

V. CONCLUSION

Design of Internal Model based controller has given good and acceptable performance without oscillation as well as fast settling response. Besides, it also shows good result for disturbance rejection with fast settling response. The Model based controller is designed in such a way that the system is robust and physically realizable. This concludes that the Internal model control is applicable for nonlinear interacting conical tank systems.

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BIOGRAPHY

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