Controller Tuning of Pilot Plant Heat Exchanger in Pulp Mill using Computer Simulation Techniques

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Control schemes and simulation studies have already gained wide acceptance and applications, in Chemical Process Industries. Having established the merit of computer control of chemical processes, the objective of this paper is, addressed as to get the Supervisors in Pulp Mill exposed to controller tuning using computer simulation techniques. The system adopted for the work is 1-1 Shell and Tube Heat Exchanger System. The choice of the system is accounted on the fact that it is the common and one of the most important process engineering operation systems in Pulp mill. Finally, in this paper, a strategy for modeling and tuning the controller settings with minimum real time operation is proposed.

INTRODUCTION

Control schemes and simulation studies have already gained wide acceptance and applications in Chemical Process.Industries. Preferential application of control schemes is due to their ability to correct the dynamic disturbances quickly and effectively. Simulation studies are rather useful in tuning the controller to an optimum working condition. Control Schemes and Simulation Studies have, of late, ceased to be luxuries. They are better understood as necessary optimization strategies. Now, having established the merit of computer control of chemical processes, the objective of this paper is addressed as to get the Supervisors in Pulp Mill exposed to controller tuning using computer simulation techniques. The system adopted for the work is 1-1 Shell and Tube Heat Exchanger System. The choice of the system is accounted on the fact that it is the common and one of the most important process engineering operation systems in Pulp mill. Finally, in this paper, a strategy for modeling and tuning the controller settings with minimum real time operation is proposed.

EXPERIMENTAL EQUIPMENT

The feed (inlet) to the heat exchanger is supplied from a

HEAT EXCHANGER SPECIFICATIONS

(Type: Shell and Tube)

Flow	Counter current
Shell side fluid	Hot water
Tube side fluid	Cold water
No. of tubes	3
Tube material	Copper
Shell material	Galvanized iron
Insulating material	Plaster of paris
Pitch	Triangular pitch
Tube diameter (id)	16E-3 m
Tube diameter (od)	20E-3 m
Tube length	1.2912 m
Shell diameter	88.9E-3 m
Baffle spacing	45.45E-3m from both ends
H.T Area & Coefficient	0.5031 m^2 & 59.73 $W/m^2\,°C$

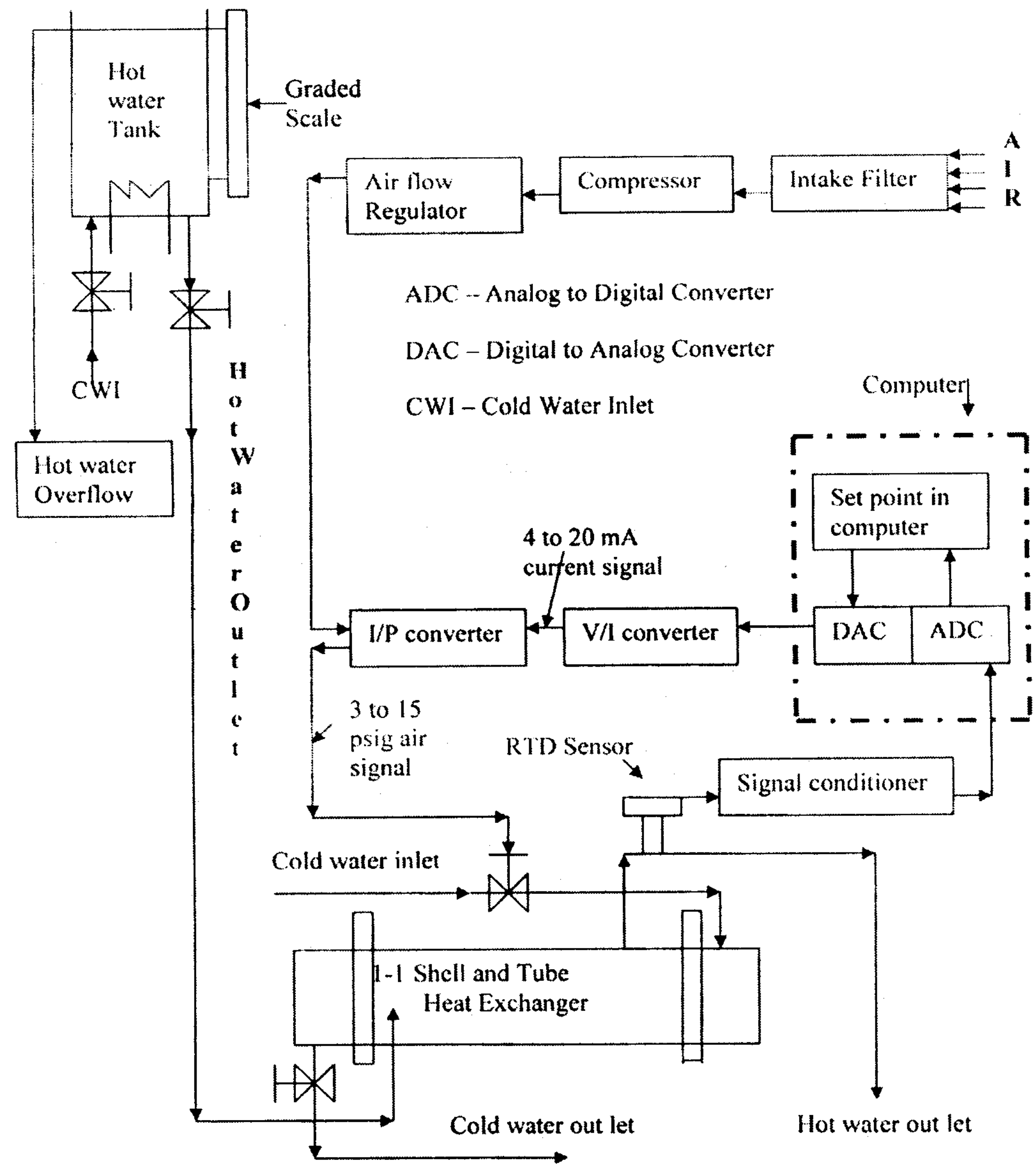

Fig. 1 : Functional Diagram 1-1 Shell and Tube Heat Exchange Control System

tank fitted with heating coil. . The temperature of the inlet feed can be read from the temperature indicator. Hot water flows through the shell side and the cold water passes through the tube side. Due to temperature difference, heat exchange takes place. The outlet temperature is measured with an AD 590 temperature sensor. The functional diagram of 1-1 shell and tube heat exchanger control system is shown in Fig. 1.

The Scheme of Work

- Development of a black-box model (process identification).
- Determination of controller settings using Synthesis technique.
- MATLAB Simulink Tools for simulation studies.
- Results, discussion and conclusion.

THEORY

Process Identification (Modeling and Simulation)

The dynamics of the process is essentially described as

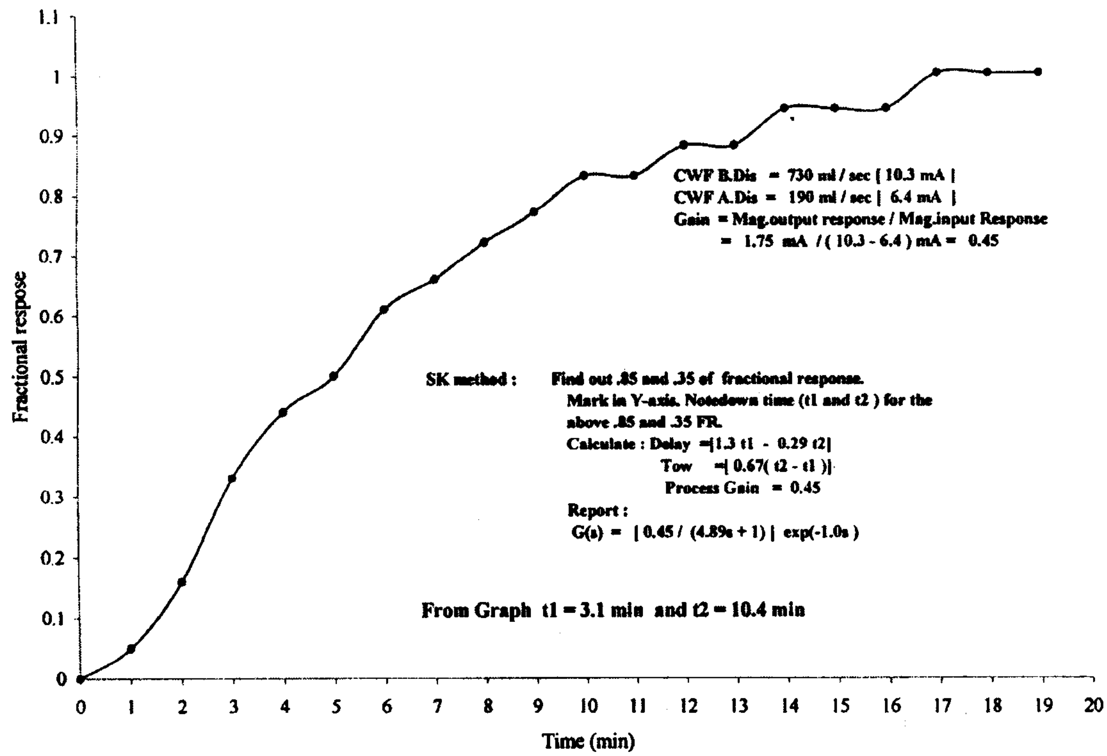

Fig. 2 : Pulp Mill : Heat Exchanger System Model Identification

Table 1

τc	Kc	τ_I
0.5	7.24	4.89
1.0	5.43	4.89
2.5	3.10	4.89
3.5	2.41	4.89
4.5	1.97	4.89

τ c : Tunable parameter

Kc : Controller Gain

τ_I : Integral Time

Table 2

Kc	S.T.	D. R	R.T	O.S	IAE
7.24	9.37	nil	2.34	0.16	2.128
5.43	7.81	nil	3.59	0.40	2.477
3.10	16.25	nil	nil	nil	3.613
2.41	21.25	nil	nil	nil	4.03

S.T -> Setting Time D. R -> Decay Ratio

R. T -> Rise Time O. S -> Over Shoot

IAE -> Integral Absolute Error

a mathematical model. Studying the time-dependent behavior of the process variables based on fundamental quantum balances may develop a conventional model. The model thus obtained is highly theoretical and is not much likely to describe the complete dynamic behavior of the process that is vulnerable to disturbances. The theoretical credibility of the process model is to be asserted by a semi-realistic background of the identification process. Therefore, a black-box model is developed using a direct method of process identification.

Using the MATLAB Simulink Tool, a marching solution for the framed mathematical model is obtained. The simulation results are plotted and the response curves are studied for various values of the tuning parameter obtained by synthesis method. Finally, the best tune for

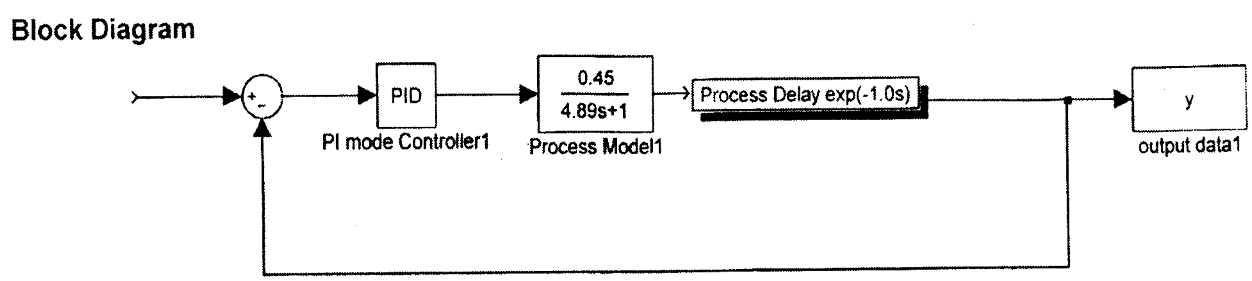

Fig. 3

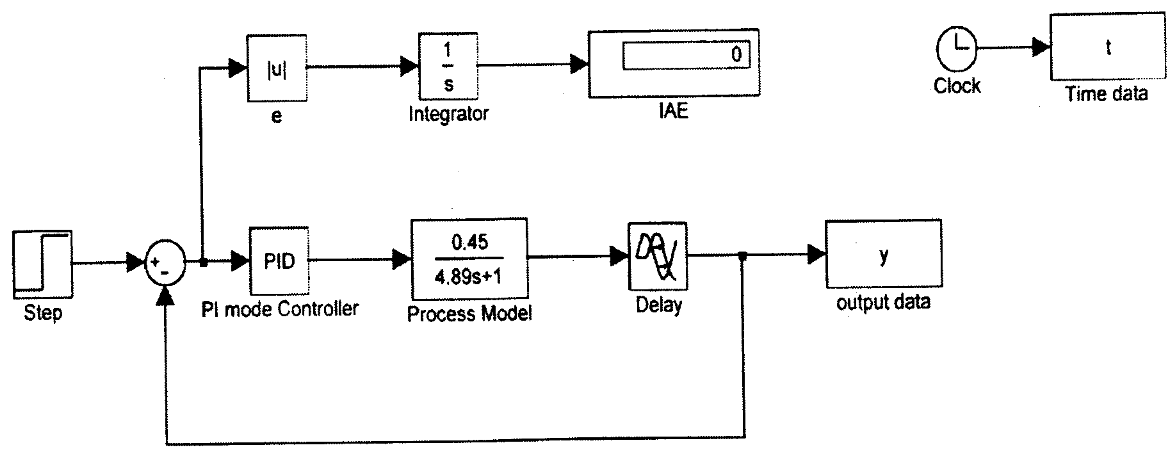

Fig. 4 : Design of PI controller for Pilot Heat Exchanger in Pulp Mill : Based on Systhesis Method

the controller settings is identified.

NOTE

- Controllable Variable -Outlet temperature of hot water .
- Manipulated Variable -Inflow of cold water.

PREREQUISITES

- Identification of order of process from the time domain step change test response curve.
- Transfer functions of process, controller (PI) and transfer Lag.
- Controller parameters for PI mode
- MATLAB Programming
- Working with MATLAB Simulink Tool.

METHOD AND MATERIALS

The heat exchanger is 1-1 shell and tube heat exchanger with counter current flow. Hot fluid is flowing in shell side and cold fluid is flowing in tube side. The exchanger

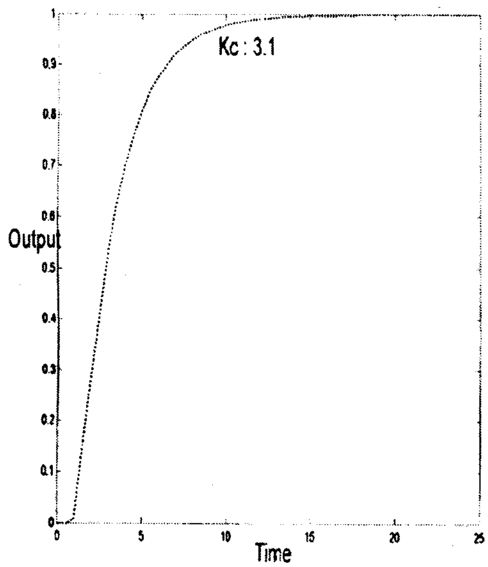

Fig.5c

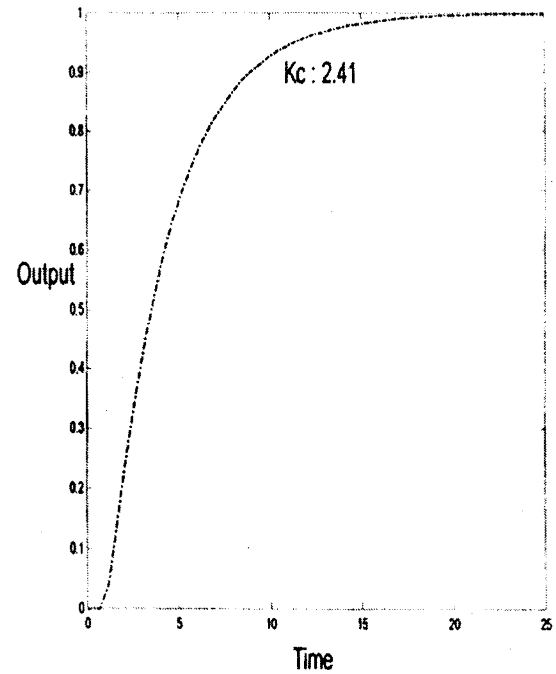

Fig.5d

is perfectly insulated in the outer side. The hot water flow rate is fixed and the cold water flow rate is fixed initially at 730 mils. After reaching a steady state condition in the system, a step magnitude of 540 ml/s in the cold water flow rate is given. The hot water outlet temperature varies and this variation in temperature in volts (RTD sensor output) is recorded against time until a new steady state is attained. This recorded data is converted into fractional response and is plotted against time to obtain process reaction curve.[Ref. Fig [2). The reaction curve resembles to the first order with time delay pattern. From this reaction curve the model parameters (D, Time Delay, K_p,Process Gain, $\tau P'$ Process time

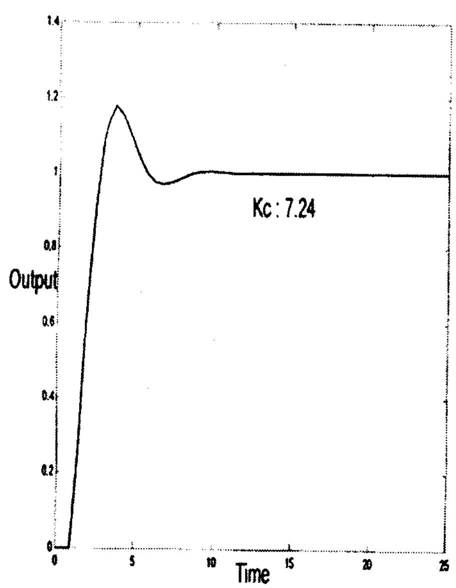

Fig.5a

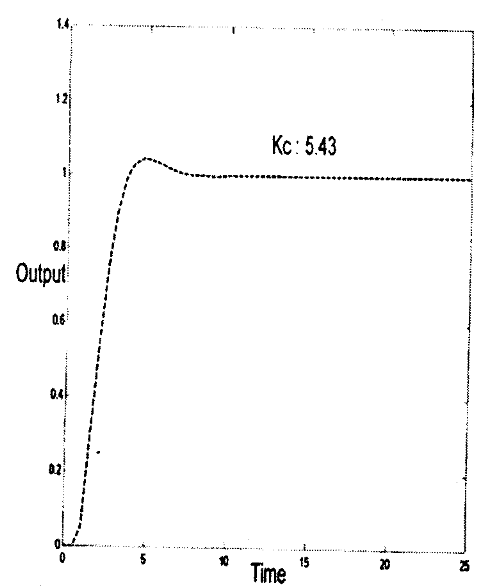

Fig.5b

constant) are obtained by Sundaresan and Krishnasamy (SK) method[1].

The block diagram of this control system is shown in Fig.3. By using synthesis method[2], the controller .settings (Kc, gain of the controller, τ_I, integral time) are obtained from the model parameters. Simulation is carried out with this values in the platform of Simulink tools in MATLAB[4] and the generated out put data are recorded in graphical format. Fig.4 and Fig.5 show the simulink diagram and the response curves for various values of controller settings. The response curves are analysed in terms of offset, settling time, rise time, decay ratio and IAE[3] (Integral Absolute Error) (Ref. Table [2]]. Based on the desirability of the above quantities the best controller settings are identified. (ie) the optimum values of the controller tuning parameters are recorded.

RESULTS AND DISCUSSION

From Fig.2, model parameters (D, K_p, 'τ_p) and Model representation in Transfer function are .determined by SK method as follows.

By drawing a horizontal line in Y axis in Fig 2 at 0.35 and 0.85, the time required to reach 0.35 and 0.85 of fractional response are noted from X axis. (T1 = 3.1 min and T2 = 10.4 min).

From this values the dead time and time constant of the process are obtained as follows.

Delay =[1.3 tl - 0.29 t2] = 1 min

Tow = [0.67(t2 -t1)] = 4.89 min

The process gain is calculated as follows.

CWF B.Dis = 730 ml / sec or in terms of mA [10.3 mA]
CWF A.Dis = 190 ml / sec in terms of mA [6.4 mA]
Process Gain = Kp = Mag.output response / Mag.input Response = 1.75 mA1 (10.3-6.4)mA= 0.45

where CWF B.Dis stands for cold water flow rate before disturbance and CWF A.D is stands for cold water flow rate after disturbance. Here mag.output response is the difference between the temperature of hot water (in terms of mA) before and after disturbance .

The Transfer function Model of the Process is

$$G(s) = (0.45 / 4.89s + 1) \exp^{(-1.0s)}$$

Using this model parameters values, the controller settings by synthesis method are determined. Table[l] shows various controller settings . Table[2] shows the performance of the various controller settings. It is observed that the values of Kc = 5.43 and τ_I = 4.89 makes the system stable and well suited for the controller settings.

CONCLUSION

In this paper, PI controller settings required for controlling the liquor temperature in heat exchanger is simulated using simulink tools in the plat form MATLAB. This methodology can be straight away adopted for real time operations of heat exchanger in digester in pulp mills.

The experimental methods carried out in the laboratory using this technique confirm the applicability of this method. Though hot water and cold water are used in this study, it can be extended to any industrial fluids. The respective process parameters only will vary but the methodology will be the same.

Note: For practice of Supervisor in pulp mill using simulation techniques, the hot water in this study may be replaced by cooking liquor in the digester.

Also the cold water may be replaced by the steam flow.

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