TEMPERATURE CONTROL USING PID GAIN SCHEDULING METHOD FOR GLYCERIN BLEACHING PROCESS

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***Abstract*— The aim of the study is to design and implement the temperature control using gain scheduling method for glycerin bleaching process. The controller has tuned using ITAE method and several operating condition of controller correspond to the process gain a developed. The performance of the system was evaluated in term of percentage overshoot; rise time and settling time by comparing the response obtain before and after gain scheduling implementation. The result revealed that the implementation of gain scheduling can improve the performance of glycerin bleaching process.**

Keywords: PID controller; Glycerin Bleaching Process; Gain Scheduling Controller.

I. INTRODUCTION

Color is a major characteristic in preparation of hardened products from pure glycerin like margarine base stocks. Color pigments presence in the crude glycerin contributes the undesirable color effects to the quality of the finished product [1-2]. The glycerin bleaching process [3] is important for producing a light colored pure glycerin of acceptable quality.

Mechanically the glycerin bleaching process is carried out by adding the adsorbent to the reactor tank containing contaminated crude glycerin, stirring the mixture to achieve good contact of adsorbent with the glycerin and maintaining the temperature for a sufficient time before drawing off the bleached glycerin.

The performance for glycerin bleaching process using adsorption method significantly depend on the properties of the crude glycerin to be bleached, dosage and type of absorbents used and the bleaching operating temperature [4].

Amongst, the operating temperature was the most parameter affecting the quality of finished bleached glycerin. This is due to the application of heat to the glycerin will creates more color formation which will decrease the nutrition values as the temperature increase [1-4].
In this case, good temperature control system for glycerin bleaching process is needed to avoid negatively impacting the bleached glycerin. It is known that the temperature control produce a slow response and the best candidate to control this type of response is PID controller.

In the field of process control system, it is well known that the PID controller have proved their usefulness in providing satisfactory control [5-8]. The PID controller is a combination of proportional, integral and derivative control. It offers rapid proportional response to error, while having an automatic reset from the integral part to eliminate steady state error. The derivative section will stabilize the controller and allows it to respond rapidly to changes in error. This combination will improve the process performance and enhance the process controllability.

However the PID controller can perform poorly, and even becomes unstable if improper values of the P, I and D are used [6-7]. The optimum PID parameters will determine an optimum response of glycerin bleaching process.

II. OBJECTIVE

The objective of this study is to design the temperature control using gain scheduling method that will determine an optimum response of glycerin bleaching process.

III. THEORY

A. PID Controller and Tuning

The ideal PID algorithm is as shown in Eqn. (1) where u is the control signal, e is error, K_p is the proportional gain, T_i is the integral time, and T_d is the derivative time.

$$u(t) = Kp(e(t) + \frac{1}{Ti}\int_0^t e(t)d(t) + Td\frac{de(t)}{d(t)}) \quad \dots (1)$$

Several tuning rules had been derived for PID controller. One of the methods was the ITAE tuning rule. In this tuning method, the controller gains can be calculated using Eqn. (2), Eqn. (3) and Eqn. (4).

$$K_p = \frac{0.965}{k}\left(\frac{L}{T}\right)^{-0.855} \quad \dots (2)$$

$$T_i = \frac{T}{0.796 + (-0.147)\left(\frac{L}{T}\right)} \quad \dots (3)$$

$$T_d = 0.308T\left(\frac{L}{T}\right)^{0.9292} \quad \dots (4)$$

The term L and T in the formulae represent the time delay and process time constant of the process respectively. The Glycerin bleaching process is best represented using first order plus dead time (FOPDT) model as shown in Eqn. (5).

$$Gp(s) = \frac{ke^{-Ls}}{Ts+1} \quad \dots (5)$$

The ITAE tuning [9] is a method of adjusting the PID parameters with the objective of minimizing the integral of time absolute error performance index.

B. *PID Gain Scheduling*

Gain scheduling is a method to find auxiliary variables that correlate well with the changes in process dynamics. Then the controller parameters are determined at a number of operating conditions based on the scheduling variables that have been deformed.

The scheduling variables can be the control signal, the process variable (PV) or an external signal. The general block diagram for gain scheduling implementation is as shown in Fig. 3.

IV. Methodology

Basically, the study is the continuation of the work done by [13]. The study is based upon a glycerin heat bleaching process plant, installed at Distributed Control System Laboratory (DCS) in Universiti Teknologi Mara (UiTM), Malaysia.

The simplified diagram of the physical arrangement of the reactor tank shown in Fig. 1.The closed loop block diagram of the temperature control system for glycerin bleaching process is as shown in Fig. 2.

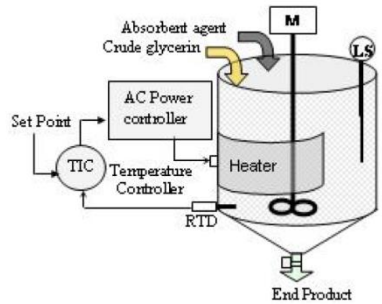

Fig. 1: Simplified diagram of reactor tank

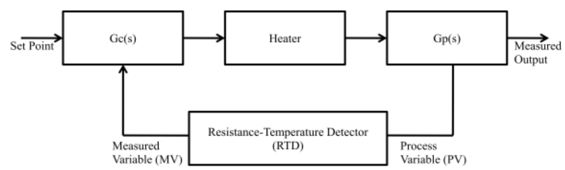

Fig. 2: Closed-loop temperature control block diagram

The process model [13] as shown in Eqn. (6) was used for the study.

$$Gp(s) = \frac{4.8e^{-420s}}{3397s+1} \quad \dots (6)$$

The integral time absolute error (ITAE) tuning method was used to tune the controller parameters and the response was observed.

The application of gain scheduling to the system is as shown in Fig. 3. Several operating conditions of the controller called scheduling variables correspond to the glycerin process gain were developed.

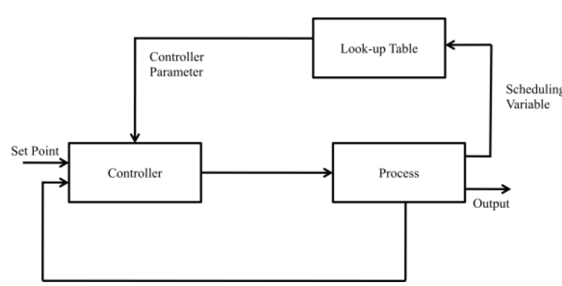

Fig. 3: Block diagram of the system with gain scheduling

The performance of the system was evaluated in terms of percent overshoot, rise time and settling time by comparing the response obtained when using gain scheduling in the loop and without gain scheduling applied in the loop.

In order to evaluate the robustness of the system, the system was tested with the set point change.

V. Results and Discussions

A. Control without Gain Scheduling

The PID parameters are found as Kp= 1.2, Ti = 4367 sec and Td =150 sec. The response for the process with process gain, $k = 4.8$ and when it change to $k = 7$ is observed and shown in Fig. 4.

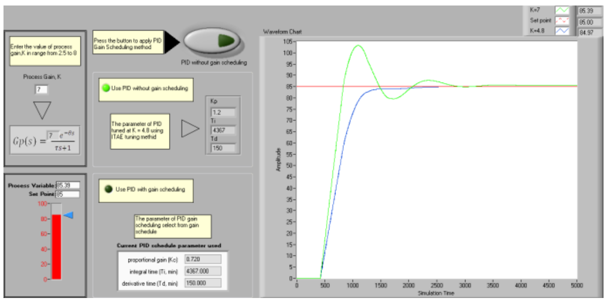

Fig. 4: Process response without gain scheduling at $k = 4.8$ (blue) and $k = 7$ (green)

Fig. 4 shows that the response for $k = 4.8$ is stable and follows the desired temperature. However, when the process gain increase to $k = 7$, it is observed that the response having high percent overshoot and starts oscillate.

Table I shows the percent overshoot, settling time and rise time for a process without gain scheduling method. In term of overshoot for process gain, $k = 7$, the high percent overshoot with 20.9 % compared to process gain, $k = 4.8$.

TABLE I

DYNAMIC PERFORMANCE WITHOUT GAIN SCHEDULING METHOD

Process Gain, k	Percent Overshoot	Settling Time	Rise Time
4.8	0%	7100.7s	2296.3s
7.0	20.9%	10018.5s	1316.3s

B. Control with Gain Scheduling

The proportional control parameter, Kp that correspond to the different process gain are as shown in Table II with constant Ti = 4367 sec and Td = 150 sec.

TABLE II

PARAMETER LOOKUP TABLE FOR DIFFERENT PROCESS GAIN

Process Gain, k	Kp
2.8	2.04
3.2	1.8
3.7	1.56
4.8	1.2
5.7	1.02
6.9	0.84
8	0.72

The response when implement the gain scheduling method to the process is as shown in Fig. 5.

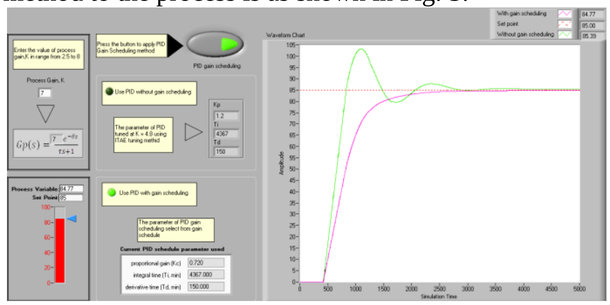

Fig. 5: Process response comparison

It is observed that the dynamic process performance improved when the gain scheduling method implemented to the process as shown in Table III. In term of percent overshoot with using gain scheduling give zero overshoot. It also has high rise time with 3120.5s and slows in settling time with 7964.3s.

TABLE III

DYNAMIC PERFORMANCE COMPARISON

Process Gain, k=7	Percent Overshoot	Settling Time	Rise Time
Without gain scheduling	20.9%	10018.5s	1316.3s
With gain scheduling	0%	7964.3s	3120.5s

The speed of the response is improved by providing the integral term to the process. Table IV shows the look-up table for PID controller with constant Td= 150.

TABLE IV

PARAMETER LOOKUP TABLE FOR DIFFERENT PROCESS GAIN

Process gain, k	Kp	Ti
2.8	2.04	4294
3.2	1.8	4290
3.7	1.56	4287
4.8	1.2	4242
5.7	1.02	4284
6.9	0.84	4271
8	0.72	4283

The response is as shown in Fig. 6 and the dynamic process performance is tabulated in Table V. Proportional plus integral improve the performance of proportional control with 7864.6s for settling time and 3116.2s for rise time.

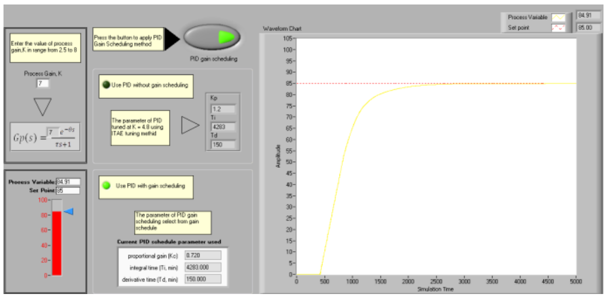

Fig. 6: Process response using scheduled Kp and Ti

TABLE V

DYNAMIC PERFORMANCE COMPARISON

Gain Scheduling Method	Percent Overshoot	Settling Time	Rise Time
Proportional only	0%	7964.3s	3120.5s
Proportional and Integral	0%	7864.6s	3116.2s

In order to test the robustness of the system, the set point change test has been conducted and the response is as follow in Fig. 7. It is observed that the response is smoothly tracking the set point and the result is satisfactorily.

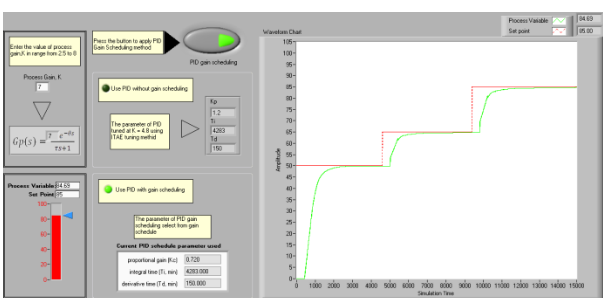

Fig. 7: Set point change using PI with gain scheduling

VI. CONCLUSION

The temperature control system for glycerin bleaching process is successfully designed and the optimum response for the process is obtained.

The implementation of gain scheduling to the temperature control system for glycerin bleaching process improve the dynamic performance of the system in terms of settling time, rise time and percent overshoot.

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