Glycerin Bleaching Process Response Using Fuzzy PI+PID Controller

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Abstract— **This paper was aimed to develop and implement a Fuzzy PI+PID Controller for a glycerin bleaching process. In this study, the ideal PID control structure was tuned by using Integral of Time and Absolute Error (ITAE) method. The performance of the system was evaluated in terms of settling time (Ts), rise time (Tr) and percentage overshoot. Apart from that, the performance for different membership function was also compared. The results revealed that Fuzzy PI+PID controller method improve the glycerin bleaching process performance.**

Keywords: Glycerin bleaching process;Fuzzy Logic Controller (FLC);Tuning method; FOPDT model

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].

The task to maintain and control the temperature for a typical process is a very challenging task. It has been found out to be intrinsically difficult due to various factors such as producing slow dynamic response because of the process scale and the process thermal response [5]. In addition, the process will have lag or time delay before it reaches a steady uniform level which is stable. As in this paper, the time delay is 420s.

The PID controller is the most common used controllers in process control field. The selection of P, I and D values will determine whether the process is stable or unstable. However, the selection of the controller parameters is tedious and leads to poor performance of the system [5]. Fuzzy Logic Controller (FLC) is another controller that has been implemented in process control [6-8]. The combination of PID controller and fuzzy logic may contribute to the best performance for the glycerin bleaching process.

II. OBJECTIVE

The objective of this project is to develop and implement the Fuzzy PI+PID controller for glycerin bleaching process.

III. THEORY

A. PID Controller & 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.

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

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).

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

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

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

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).

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

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

B. Fuzzy Logic Controller

Fuzzy has been widely applied in many applications which related to the intelligent system such as intelligent traffic light, intelligent braking system and etc. Fuzzy logic controller usually contain of four major parts which are fuzzification, interface engine, rule base and defuzzification [6-8]. Figure 2 below show the general block diagram of fuzzy logic controller.

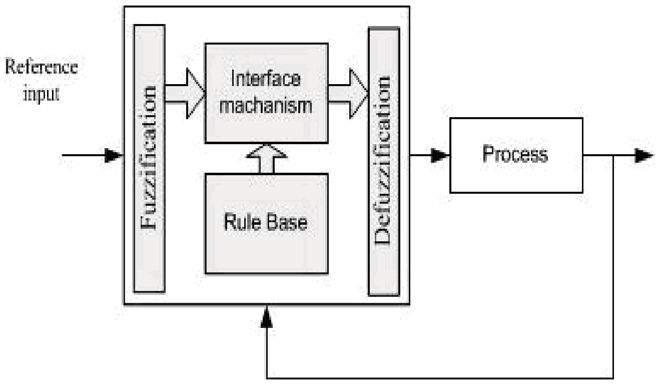

Figure 1: FLC general structure

Based on the structure in figure 1 above, fuzzification is a process of matching the input variable of the controller to a rule base linguistic form system. Interface mechanism consists of a set of linguistic control rules and employment rules to infer fuzzy control actions in response to fuzzified inputs.

Defuzzification is the process of converting the result reaches from the fuzzy set to the output controller value base on the universe of discourse output membership function. A fuzzy logic controller is normally built from the experience of the process control or operational engineer to determine the parameters and rules of the process. Membership function is the first step to determine the range of each process. For example, Low, Medium and High. Fuzzy rule will determine what will be the output when the two or more inputs for membership functions combine. In example, if the first input is Low and the second input is Medium, so the user will determine what will be the result for the output. Both membership functions and fuzzy rule related to each other in order to get the stable output response for the process.

IV. METHODOLOGY

Basically, the study is the continuation of the work done by [9-12]. 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 closed loop of the temperature control system for glycerin bleaching process is as shown in Fig. 2.

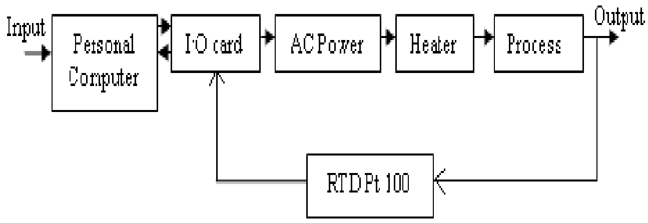

Figure 2: Block diagram of the temperature control system for glycerin bleaching process

The process model [10] as shown in Eqn. (6) was used for the study.

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

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

The application of Fuzzy PI+PID is a combination of three controllers which are proportional, integral and derivative controller. The block diagram of the Fuzzy PI+PID implementation to glycerin bleaching process is as shown in figure 3 below.

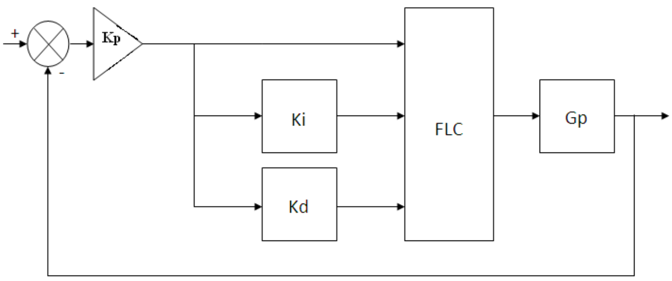

Figure 3: Fuzzy PI+PID block diagram

The inputs membership function to the Fuzzy PI+PID Controller are Error (E) and Change of Error (CE). In this study, membership functions of 3 and 5 were used and the performances of both results were evaluated.

V. RESULT AND DISCUSSION

In the result and discussion, the result for the ITAE tuning method which is without fuzzy, Fuzzy PI+PID for 3 membership functions and 5 membership functions were compared to determine which method is more suitable to use in the temperature control for glycerin bleaching process plant. All the experiments have been done by using LabView software.

Firstly for the ITAE tuning method, the value of *Kp, Ki* and *Kd* need to be calculate. The gains values were stated in table I below.

TABLE I
GAINS VALUES FOR ITAE METHOD

Gain		
Kp	Ki	Kd
1.2	0.0002	150

The formula for ITAE quite complicated but it results in a stable waveform for the output response. The output response shows in figure 4 below where it able to reach the stable position in short time and zero percentage overshoot.

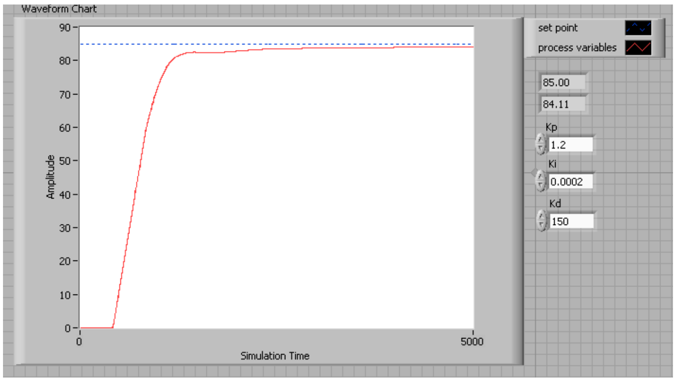

Figure 4: Output response for ITAE tuning method

As shown in the waveform above, it proved to be the best choice for the tuning method. However, if compare to the fuzzy method, this is where the research been done to determine the better choice to successfully produce the clean glycerin with proper temperature control. At first glance, fuzzy PI+PID looks really complicated to be done. The connection to build a correct block diagram was not easy and takes long time. Besides, the appropriate memberships need to be done by using “trial and error” method which it need to be implement in determining the fuzzy rule as well. *Kp* is the proportional of the controller while *Kd* is derivative and *Ki* is integral controller. The inputs and output for the three membership function showed in figure 5, 6 and 7 below. E is Error, CE is Change Of Error, and PID indicates the output for the process.

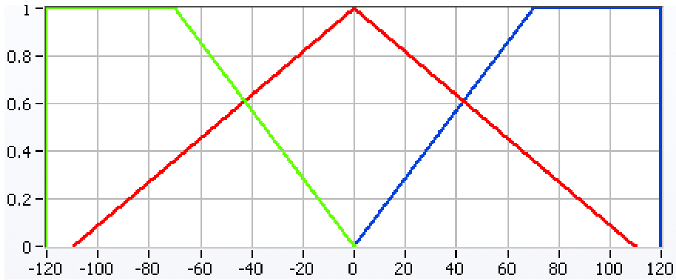
Figure 5: Input membership function for E

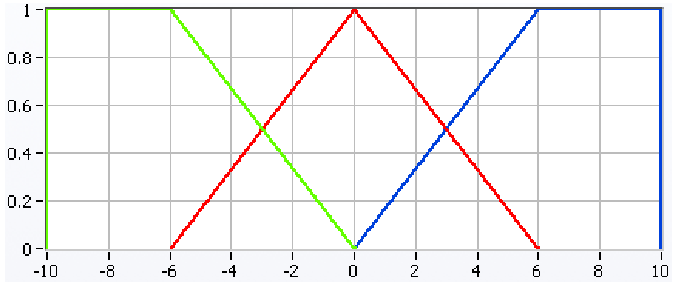
Figure 6: Input membership function for CE

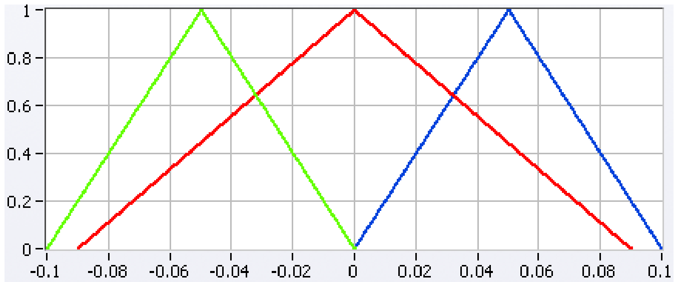
Figure 7: Output membership function for PID

The ranges of the membership were determined by using trial and error method to get the best output response. It is not like tuning method which the value fixed according to the formula given. Table II shows the fuzzy rule of the controller where NE is Negative, ZE is Zero and PO is positive. This indicates rule for each range based on the membership range where NE is for green color, ZE is for red color, and PO is for blue color.

TABLE II
FUZZY PI+PID CONTROL RULE FOR 3 MEMBERSHIP FUNCTIONS

E CE	NE	ZE	PO
NE	NE	ZE	ZE
ZE	NE	ZE	PO
PO	ZE	ZE	PO

The rule and the membership functions related to each other and it need to be decide based on the user according to their logic and multiple trials are needed to get the stable output waveform. As a result, figure 8 shows the more stable waveform if compare to the ITAE tuning method.

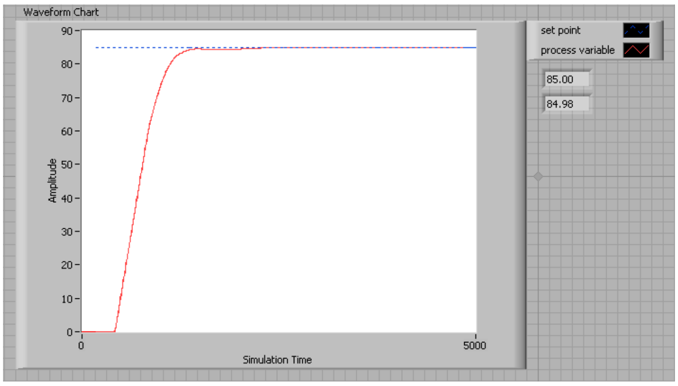

Figure 8: Output response for Fuzzy PI+PID method for 3 membership function

From the waveform above, it shows that the percentage overshoot is approximately to zero and higher rise time if compare to ITAE tuning method without fuzzy. Next, was to determine if more membership functions will results the better output response for the process. Figure 9, 10, and 11 show the inputs and output membership functions for this method.

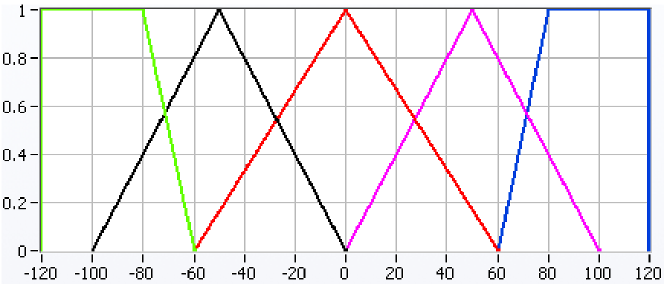

Figure 9: Input membership function for E

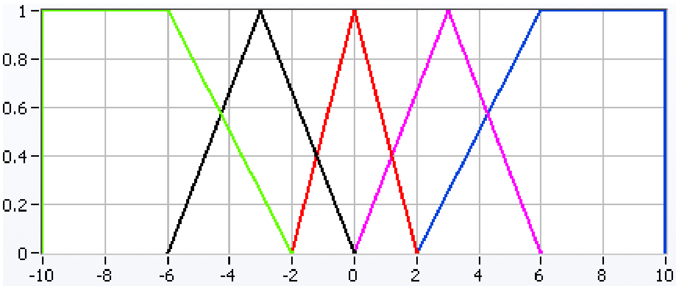

Figure 10: Input membership function for CE

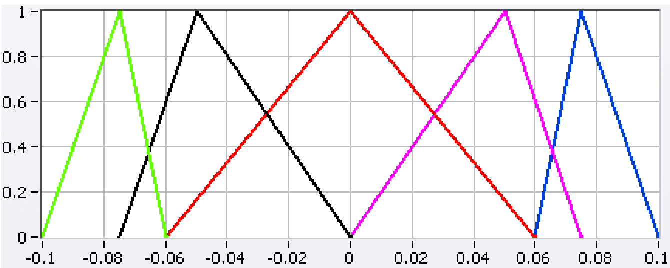

Figure 11: Output membership function for PID

Table III shows the fuzzy rule of the controller where NB is Negative Big, NS is Negative Small, ZE is Zero, PS is Positive Small and PB is Positive Big.

TABLE III
FUZZY PI+PID CONTROL RULE FOR 5 MEMBERSHIP FUNCTIONS

E CE	NB	NS	ZE	PS	PB
NB	NB	NS	NS	PS	PB
NS	NB	NS	ZE	ZE	PB
ZE	NB	NS	ZE	PS	PB
PS	NB	ZE	ZE	PS	PB
PB	NB	ZE	PS	PS	PB

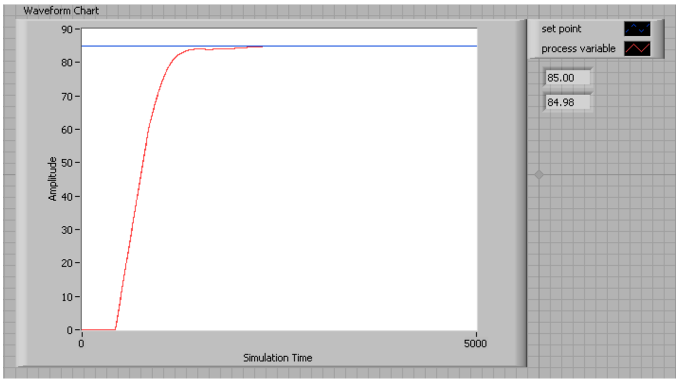

Figure 12: Output response for Fuzzy PI+PID method for 5 membership function

Based on figure 12, the result looks really quite similar with the result from figure 8. Table IV shows the accurate result of the percentage overshoot, rise time and settling time for all the method to clearly prove which method is the best for controlling the temperature of the glycerin bleaching process.

TABLE IV
RESULTS OF THE WAVEFORM

Type of Controller	Rise Time (s)	% Overshoot	Settling Time (s)
ITAE Tuning	2296.3	0	7100.7
Fuzzy PI+PID 3 Membership	2420.0	0	5452.1
Fuzzy PI+PID 5 Membership	2284.8	0	5288.2

VI. CONCLUSION

Fuzzy PI+PID for glycerin bleaching process were successfully simulated and analyzed. The results of the methods for both 3 and 5 membership functions were compared with a conventional controller, without fuzzy which is the ITAE tuning method. From the results, it was proven that by implement Fuzzy PI+PID, the result would be much better and stable. Although to find the output required a lot of times, but the output response varies, where the stability of the waveform can be increase until achieve the desired given setting. Unlike the tuning method, it was easy to just calculate the value for gains by using the given formula, but the output cannot be change and that will be the final result. So, Fuzzy PI+PID for 5 membership functions were proved to be the best choice for controlling the temperature for glycerin bleaching process control.

VII. ACKNOWLEDGMENT

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VIII. REFERENCES

[1] P.C. Wei, C.Y. May, and M.A. Ngan, "Degumming and Bleaching: Effect on Selected Constituents of Palm Oil," *Journal of Oil Palm Research*, vol. 16, No. 2, pp. 57-63, 2004.

[2] M. Rossi, M. Gianazza, C. Alamprese, and F. Stanga, "The Effect of Bleaching and Physical Refining on Color and Monir Components of Palm Oil," *JAOCS*, vol. 78, pp. 1051-1055, 2001.

[3] A.D. Rich, "Some Fundamental Aspects of Bleaching," *JAOCS*, vol. 47, pp. 564-566, 1970.

[4] G. Kaynak, M. Ersoz, and H. Kara, "Investigation of the Properties of Oil at the Bleaching Unit of an Oil Refinery," *Colloid and Interface Science*, vol. 280, pp. 131-138, 2004.

[5] C. Knospe, "PID Control," *IEEE Control Systems Magazine*, vol. 26, pp. 30-31, Feb 2006.

[6] I. S. Akkizidis, G. N. Roberts, P. Ridao, and J. Batlle,"Designing a Fuzzy-like PD controller for an underwater robot," Control Engineering Practice, vol. 11, pp. 471-480, 2003.

[7] Y. J. Chang, Y. M. Chen, C. A. Lee, Y. H. Wang, Y. C. Chen, and C. H. Wang, "Improving Temperature Control of Laser Module Using Fuzzy Logic Theory," in 20th IEEE SEMI-Therm Symposium, 2004.

[8] K. Y. Lee and U. C. Moon, "Temperature Control of Glass Melting Furnace With Fuzzy Logic and Conventional PI Control," in Proceedings of the American Control conference, Chicago, Illinois, 2000, pp. 2720-2724.

[9] N. Kamaruddin, Z. Janin, Z. Yusuf and M.N. Taib, "PID Controller Tuning for Glycerin Blecahing Process using Well-Known Tuning Formulas- A Simulation Study" IECON '09 35th Annual Conference of IEEE Industrial Electronics, pp.1682-1686, 2009.

[10] Yusuf, Z; Janin,Z.; Taib, M.N; ,"Fuzzy Logic Controller for Glycerin Bleaching Temperature Control", Signal Processing and Its Applications (CSPA), pp.1-5, 21-23, 2010 .

[11] Yusuf, Z; Janin,Z.; Taib, M.N; ," Application of Fuzzy PD Controller With Smith Predictor for Glycerin Bleaching Temperature Control", Intelligent And Advanced Systems (ICIAS), pp.1-5, 15-17, 2010 .

[12] Zakariah Yusuf, Zuriati Janin and Mohd Nasir Taib, "Application of Fuzzy Logic Controller for Glycerin Bleaching Process," IEEE Student Conference on Resarch and Development (SCOReD), pp. 438-441, 16-18 Nov. 2009.