Fuzzy-PID System Control for Tungsten Filament Heater of Thermal Vacuum Evaporation

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Fuzzy-PID System Control for Tungsten Filament Heater of Thermal Vacuum Evaporation

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Abstract: Vacuum coating is a solid material deposition technology that uses vacuum combustion using tungsten filaments. The quality of material deposition depends on the heat distributed by the tungsten filament to the material to be deposited. In this work, PID and Fuzzy-PID controller to control the heat of tungsten filament is simulated. The Tungsten model is represented with transfer function in s-domain. Optimization of Fuzzy-PID controller is done to obtain optimal heat of tungsten filament. Step and ramp responses of PID and PID-Fuzzy controlled system were investigated. The result shows that the Fuzzy-PID reach faster steady state compare to the PID system in the step response. The Fuzzy-PID also shows better performance in the ramp response.

1 INTRODUCTION

Thermal evaporator is widely used for material deposition (Khan et al., 2017). The challenge in designing thermal evaporator is optimizing the heat control so that uniform distribution of heat transfer can be obtained. Automatic heater control can be obtained by implementation of, Proportional Integral Differential control (Asraf, Dalila, Hakim, & Hon, 2017), Fuzzy (Kobersi, Finaev, Almasani, & Abdo, 2013) (Singhala, Shah, & Patel, 2014), Adaptive neuro fuzzy inference system ANFIS (Huang et al., 2018) (Atia & El-madany, 2016) (Premkumar & Manikandan, 2014), Genetic Algorithm and other robust control system. PID controller is widely used in many industrial applications for the effectiveness, simplicity and clear functionality. However, conventional PID is very sensitive with system uncertainties so that the performance can decrease with this problem. Optimization of PID parameter is currently still an interesting topic (Kumar & Kumar, 2017) (Jung, Leu, Do, Kim, & Choi, 2015). Many algorithms have been combined with PID such as fuzzy and genetic algorithm.

In order to obtain fast and stable PID, Fuzzy is implemented for optimizing PID parameter (Ochoa & Forero, 2018) (Liu, Pan, & Xue, 2015) (Lal, Barisal, & Tripathy, 2018) . The advantage of Fuzzy that can solve some uncertainty of the system is tried to be combined with the PID (Sahu, Pati, Mohanty, & Panda, 2015). Fuzzy PID is also has been also simulated in control system as in motor control (Choi, Yun, & Kim, 2013) (Jung et al., 2015)[Choi 2015] and heater control (Ochoa & Forero, 2018) (Atia & El-madany, 2016) .

Simulation of heater control using adaptive PID have been done in (Ochoa & Forero, 2018). The result shows that steady state is reached at arounf 30 s. Conventional structure of PID can be expanded with the new algorithm (Liu et al., 2015) (Kumar & Kumar, 2017). Some problem is still arise in this hibryd PID due to the system uncertainties in the experiment. Gradient descent algorithm was implemented in (Kumar & Kumar, 2017). However implementation in the experimental still need some improvement.

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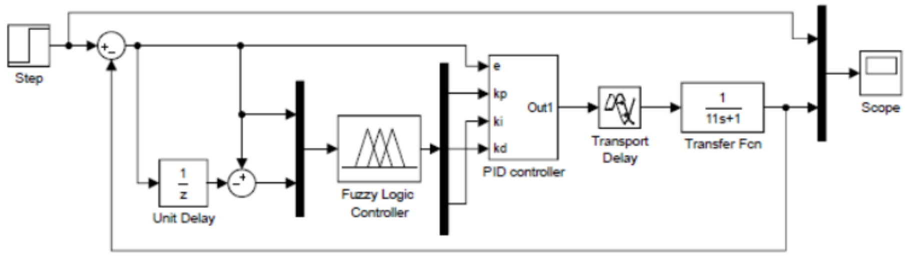

Figure 1: Fuzzy-PID control system.

In this work the Fuzzy PID is optimized for heating system which is like in (Ochoa & Forero, 2018). The difference is that the characteristic of the heater will be varied in order to test the adaptability of the control system. By testing the proposed control system for different characteristic of heaters, the parameter will be optimized for different behaviour of the system. The optimal parameter that works for different system will overcome the uncertaintes of the system in experiment. In order to increase the performance of the control system, The characteristic of the heater will also be confirm with the experiment. Some adjusment will be needed in order to overcome the system uncertanties which is omitted in simulation.

2 METHODS

The simulation model of system which is controlled using PID-Fuzzy is shown in the Figure 1. The system is controlled using PID controller. The parameter of PID is tuned using fuzzy logic controller. As an input of the fuzzy are the error and delayed error. The system is tested using step signal and also ramp signal to analyse the step and ramp response of the system. The detail model is explained in the following subsection:

2.1 Evaporator Model

As we know in the system theory, any plant can be modelled using transfer function. The transfer function is got from the Laplace transform of the differential equation of the system. The model of evaporator and heater which is used in this work is the same with the model in (Ochoa & Forero, 2018):

$$H(s) = \frac{K}{Ts+1} e^{-ds} \tag{1}$$

With K, T and transport delay d are 1, 11 and 1.8 then the equation 1 become:

$$H(s) = \frac{1}{11s+1} e^{-1.8s} \tag{2}$$

The value of K, T and d depends on the heater or evaporator that to be modelled.

2.2 PID Controller

PID controller is the most common controller in industry.

$$vt(t) = K_p e(t) + K_i \int e(t)dt + K_d \frac{de(t)}{dt} \tag{3}$$

The output of PID is driven by the error of reference compared to the output of the system as stated in equation 3. The PID parameters will influence the performance of the control system.

In MATLAB PID can simply applied with toolbox or can be applied with the following block diagram as shown in Figure 2.

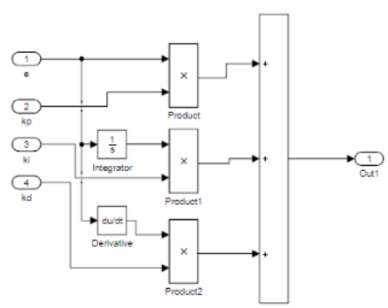

Figure 2: Block diagram of PID in Simulink.

2.3 Fuzzy Controller

Fuzzy inference system works based on set of rules which is called as membership function. The membership function set the relationship between input and output of the fuzzy controller (Vasičkaninová, Bakošová, Mészáros, & Oravec, 2015). Membership function in this works consists of two input which is error and derivative of error. The output will be Kp, Ki and Kd which are proportional, integral and differential constants. In (Liu et al., 2015) the output are PID parameters and additional parameter od integration order λ and derivative order μ∴. The membership function of input is shown in the Figure 3. The input is classified into negative big (NB), negative medium (NM), negative small (NS), zero (ZE), positive small (PS) positive medium (PM) and positive big (PB).

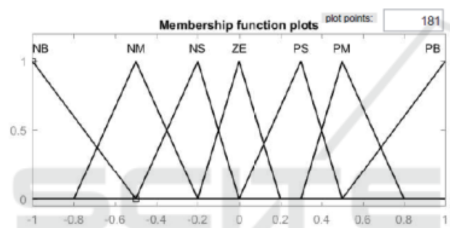

Figure 3: Membership function plot of input.

Membership function of output is shown in Figure 4. The output is classified as zero (ZE) medium small (MS), small (S), medium (M), big (B), medium big (MB) and very big (VB)

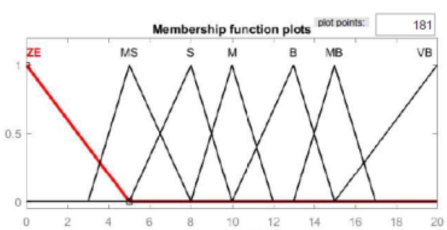

Figure 4: Membership function plot of input.

The relationship between input e and D_ and output Kp, Ki and Kd are presented in Figure 5, Figure 6, and Figure 7 respectively. The error and derivative or error decide the magnitude of theses PID Parameters as shown in the surface views.

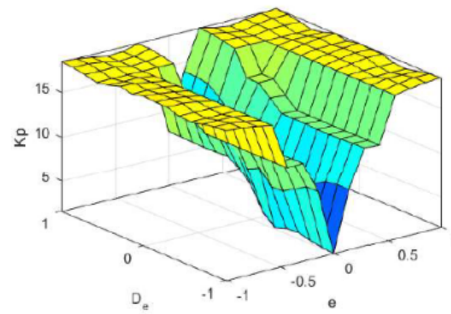

Figure 5: Surface view of input - output Kp.

The error and derivative of error as input of fuzzy will be processed with FIS to decide the output of the Fuzzy controller.

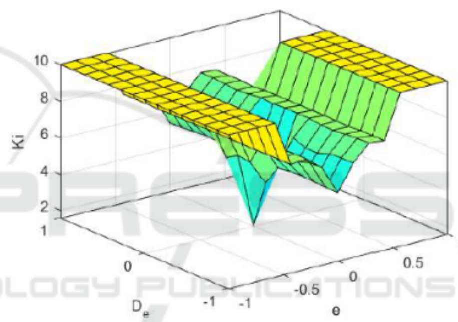

Figure 6: Surface view of input - output Ki.

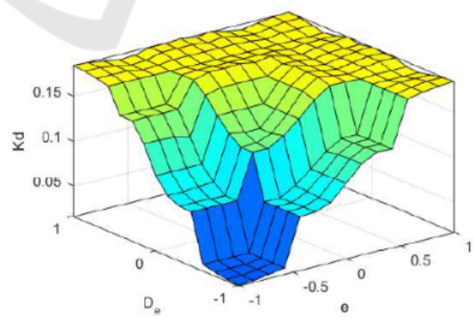

Figure 7: Surface view of input - output Kd.

The membership function might be optimized in order to get the fast response and stability of the control system.

3 RESULTS AND DISCUSSION

Step response is investigation of the response of the system with step input. This response is very important because usually, thermal evaporator is applied with the constant high temperature depends on the material. In the Figure 8, step response of the PID controlled system is presented:

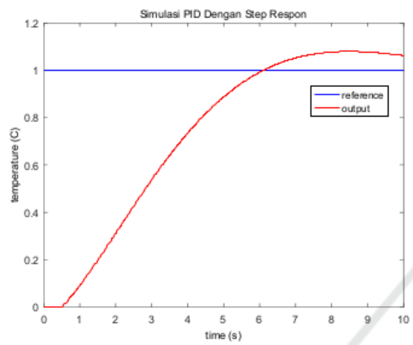

Figure 8: Step response of PID controlled system.

The system needs time to reach desired temperature. In the figure the step response show that the rise time is around 6 s and settling time more than 10 s respectively. It is faster compared to the result in (Ochoa & Forero, 2018) which is reached at around 20 s.

The response of the system with ramp signal input is presented in Figure 9. The ramp response is analysed to observe the behaviour of the system if the user wants to get the increased temperature of the thermal evaporator

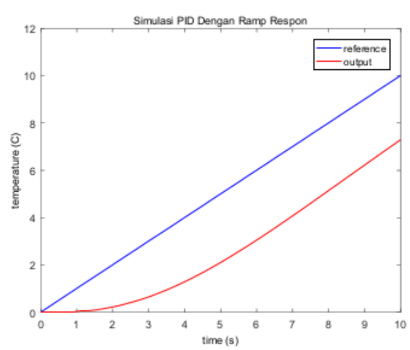

Figure 9: Ramp response of PID controlled system.

The result show that the output is not able to reach the increased desired temperature. This overshoot might be overcome by increasing the value of derivative constant.

Step response of Fuzzy-PID control system is presented in Figure 10.

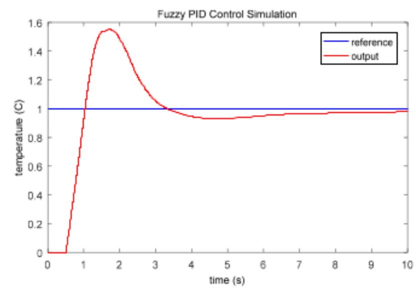

Figure 10: Ramp response of PID controlled system.

The figure shows that there is some overshoot before the system reach steady state. The rise time of the control system is approximately 0.6 s which is very fast compared to (Asraf et al., 2017) and (Ochoa & Forero, 2018). The settling time is around 7 s which are faster than conventional PID and the settling times in (Asraf et al., 2017) and (Ochoa & Forero, 2018). However the overshoot is bigger compare the result in (Ochoa & Forero, 2018).

The ramp response of Fuzzy-PID control system is shown in Figure 11.

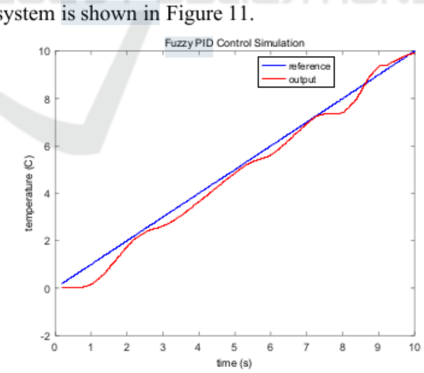

Figure 11: Ramp response of PID controlled system.

Comparing with PID control, the Fuzzy-PID can control the system with ramp signal as desired temperature. In the thermal evaporator, the increasing temperature to some constant value is important so that the high temperature value can be reached faster.

4 CONCLUSIONS

Simulation of control system for evaporator have been done. The result shows that PID-fuzzy reach faster rise and settling time on the step response compare to the PID control system. The ramp response show that the control system is able to adjust the output in-line with the desired temperature. The future work is finishing experimental setup which implement the simulation result and do experiment of deposition with the thermal evaporator.

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