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Designing a Fuzzy Controller for the Controlling Temperature of Slab

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Abstract
The problem of heating is a common problem in the industry. Slab is a common type of billet in metal heating problems. This paper presents a solution for modeling slab using transfer function model. A fuzzy controller is also designed to control the heating process of the slab. The fuzzy controller has been designed based on the parameters of the slab, heater, and converter. Through simulation of the control system, it is shown that the controller is capable of controlling the temperature of the slab to reach the set temperature or to satisfy the technological requirements.

Keywords: Heating Problem, Slab, Transfer Function Model, Fuzzy Controller, Heating Furnace

1. Introduction

In the problem of heating slab, the necessary requirement is to control the temperature of the heating furnace according to the temperature requirements of the slab, thus ensuring the technological requirements set forth with the slab. In order to be able to design the temperature control of the slab according to the indirect method of measuring the temperature of the slab, we need to build a mathematical model of the slab (which is the mathematical model of the heat transfer process in the slab). The model can be built by two methods that are numerical method [1-3] and transfer function model method [4-6]. Numerical methods such as the method of dissociation of variables [1]; model method [2]; The finite element method [3] often has high complexity, so it is not suitable for the design of real control systems. The method of modeling slab as transfer function [3-7] is very suitable for controller design. In the previous article, we have modeled 3-layer slab by transfer function. Therefore, we use that transfer function model to design a fuzzy controller to control the slab temperature.

2. Main Contents

Consider the model of 1-side heating furnace [3-7] as follows

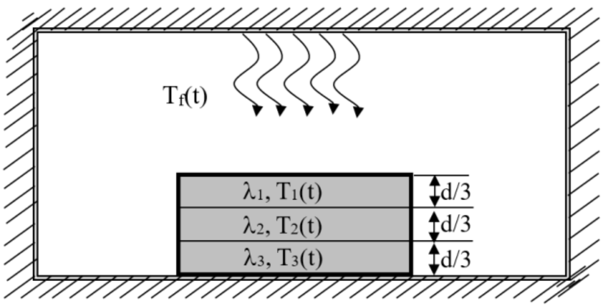

Fig 1: Heat transfer model of furnace

According to [3-7], we have the layer-by-layer transfer function of the slab as:

$$W_3(s) = \frac{1}{25.7s + 1}$$

$$W_2(s) = \frac{25.7s + 1}{660.49s^2 + 77.1s + 1}$$

$$W_1(s) = \frac{660.49s^2 + 77.1s + 1}{141622.26s^3 + 22106.76s^2 + 720.2s + 1}$$

To control the temperature of the slab, we use the P-D fuzzy control system structure as follows:

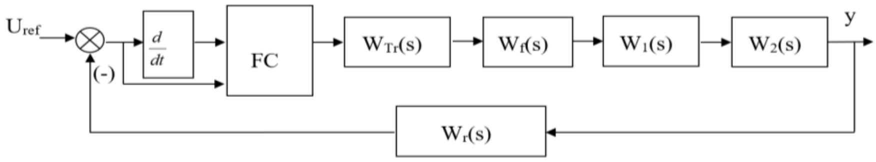

Fig 2: Structure of slab temperature control system

Where W_{tr} is the transfer function of the Tiristor converter; W_f is the transfer function of the resistance furnace; W_r is the transfer function of the proportional link
According to [3-7] we have

$$W_{Tr}(s) = \frac{22}{0.0033 + 1};$$
$$W_f(s) = \frac{5.e^{-30s}}{500s + 1};$$
$$W_r(s) = 0.01.$$

The results of fuzzy controller design are as follows: Language variables and value sets: Temperature deviation ET= [-40C, +10000C], definition of 7 fuzzy sets: ET = {much negative, medium negative, little negative, zero, little positive, medium positive, high positive} or ET = {NB, NM, NS, ZE, PS, PM, PB}. DET temperature rise rate = [-2, +2], defined with 7 fuzzy sets DET = {NB, NM, NS, ZE, PS, PM, PB}. The output of the fuzzy controller OUT is the percentage of the excitation power for the furnace (%P). Variable OUT with 7 singleton fuzzy sets: %P = {V1, V2, V3, V4, V5, V6, V7}. We choose the form of the membership function of the variables as a triangle, build a max-min composition rule with 49 rules. Choose defuzzification by equal partitioning method (Bisector).

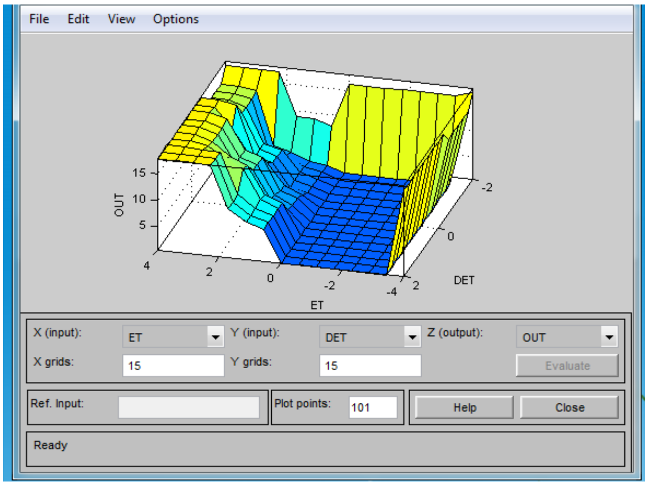

Fig 3: Surface of composition law

The control model of the plate in Matlab - Simulink is as follows

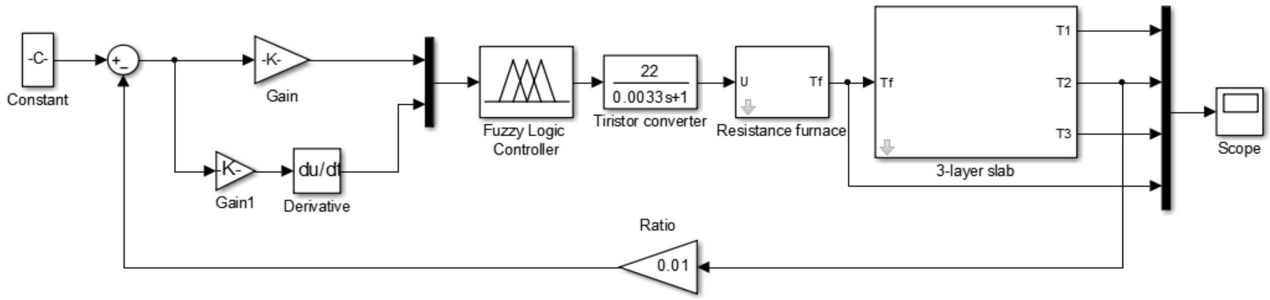

Fig 4: Simulik diagram of slab temperature control system using fuzzy controller PD

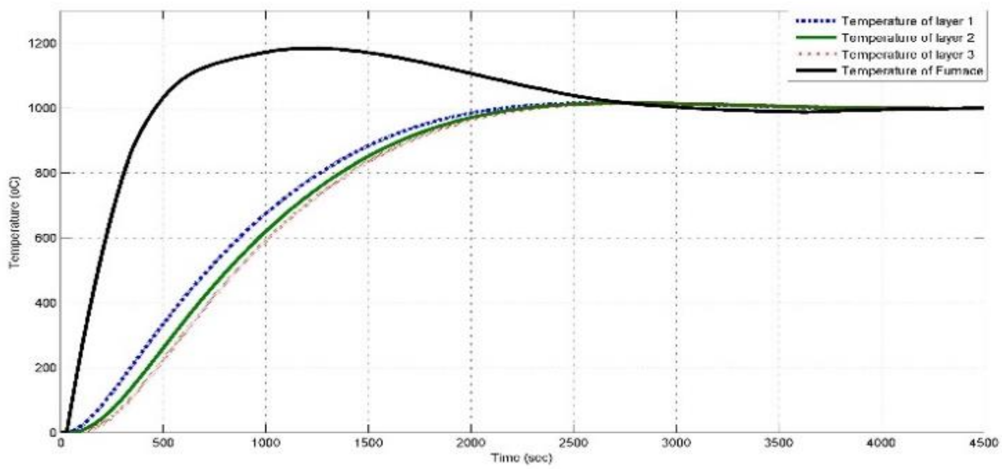

Fig 5: Simulation results of the temperature control system 3-layer slab

With this system we perform temperature control of the 2nd layer of the slab. The simulation results are as follows

Comment: Based on simulation results of slab control system using PD dynamic opening controller, we see:

+ Transition time 4000s; Overcorrected amount 1.6%; The number of oscillations is 1 time; Static deviation $S_t\% = 0\%$.

+ After 2800s, the temperature of the three layers of slab is nearly equal. After 4300s, the temperature of 3 layers of slab almost coincides with the temperature of the furnace.

Thus, using the dynamic fuzzy controller PD, we can control the slab temperature to reach the desired temperature (set temperature) with zero static error, the amount of over-adjustment is very small (1.6% compared to the allowable level is from 10-30%).

3. Conclusion

Based on the transfer function model of the slab, the authors have designed a fuzzy controller to control the temperature of the slab. The simulation results show that the fuzzy controller can control the temperature field in the slab to satisfy the technological requirements. The simulation results have shown the correctness of the proposed algorithm and opened up its applicability in practice. In the next studies, we will conduct experiments on real systems to verify the correctness of the research in practice.

4. Acknowledgement

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