Available online at www.sciencedirect.com

SciVerse ScienceDirect

Procedia Engineering 15 (2011) 639 – 643

Procedia Engineering

www.elsevier.com/locate/procedia

Advanced in Control Engineering and Information Science

Application of Fuzzy Theory in Temperature Control System of Thermoforming Machine

Chunhua Dua,Shaoke Chenb,Xiaoming Lianga,b,a*

*ChunhuaDu,Shantou University ,Shantou City,Guangdong Province,Ch*ina,515063*
Shaoke Chen, Shantou University ,Shantou City,Guangdong Province,China,515063
Xiaoming Liang, Shantou University ,Shantou City,Guangdong Province,China,515063

Abstract

In order to apply Fuzzy PID control theory in thermoforming machine, people must make discourse analysis for the temperature control system of the thermoforming. Before finishing the Fuzzy PID control of thermoforming machine, they also need to apply fuzzy controlling table in control system. The coming of fuzzy controlling table attribute the success to the use of fuzzy mathematics in automation. The selection of membership function 、 the formula of fuzzy rule 、 the process of fuzzy inference are based upon the use of fuzzy mathematics. the process of fuzzy inference can be simulated by the simulink module of MATLAB.

Key words: Fuzzy PID; Thermoforming machine; Fuzzy mathematics; MATLAB;

1. Overview

In the process of plastic forming, temperature control have a great influence on quality of plastic forming. If the temperature of plastic sheet is inaccurate, there will be much more flaws in plastic product. For example, when the temperature of plastic forming, the plastic sheet can't be formed. At present, the most temperature control of heater band in heating furnace of thermoforming machine highly dependent on workers. This design can direct control the temperature of heater band according to the temperature of plastic sheet. It puts fuzzy self-adaptive PID control theory to use in temperature control.

2. Introduction of Fuzzy Self-adaptive PID Control Theory

The Fuzzy Self-adaptive PID Control Theory[1] is using the radical principle of fuzzy mathematics and methed, base on the control condition and control rule from the temperature control system of the

* Corresponding author. Tel.: 15875489433
E-mail address: duchunhua555@163.com

doi:10.1016/j.proeng.2011.08.119

thermoforming machine and acture response of machine, then begin fuzzy inference and get the best parameters of fuzzy self-adaptive PID control of the temperature control system. The operational principle of fuzzy self-adaptive PID control is showed as figure 1.

Base on the figure of fuzzy self-adaptive PID control theory, fuzzy self-adaptive PID control is to search for relationships of the three parameters of fuzzy self-adaptive PID control and temperature head e and the rate of change of temperature head de/dt. In process of control, temperature control system detect the temperature head e and the rate of change of temperature head de/dt though temperature sensor, then modify the three parameters of fuzzy self-adaptive PID control in time. So that the three parameters can meet the demands of the different temperature head e and the rate of change of temperature head de/dt.

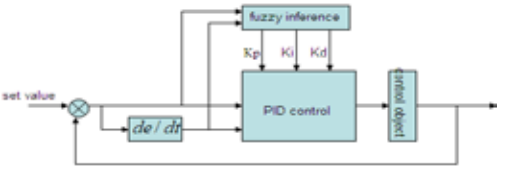


Figure 1 the figure of fuzzy self-adaptive PID control theory

3. Setting parameters of fuzzy self-adaptive PID control

The fuzzy self-adaptive PID control of the temperature system in thermoforming machine puts fuzzy mathematics theory to use in PID control, and builds the fuzzy control rule table for fuzzy self-adaptive PID control by using computational reasoning. The process of building fuzzy control rule table mainly depended on the experience andtechnological knowledge of the designers. In this design, it is necessary to build 3 fuzzy control rule tables for the three parameters(Kp、Ki、Kd) of fuzzy self-adaptive PID control. The concrete constructing method as follow:

3.1. Divide input and output space

Divide input and output space of control system is define couples of fuzzy sets in discourse domain of fuzzy rules. For a control system, the more fuzzy sets in discourse domain of fuzzy rules, the more spaces will be divided in discourse domain, and more exquisite the control system may become. Then the precision of control system will be improved. But the precision of control system can't be impoved in direct ratio to the spaces which be divided in discourse domain. Otherwise the control system needn't much high precision. Amount of computation for control system will be added ripidly. Then the speed of control system will be decreased. Consequently, when use fuzzy self-adaptive PID control in the control system of thermoforming machine, it is good enough to divide five spaces in discourse domain. The division of fuzzy discourse domain as follow:

Description of division in discourse domain of temperature head:{negative big、 negative small、zero 、 positive big、 positive small}viz namely {NB、NS、ZO、PS、PB}

Description of division in discourse domain of the rate of change of temperature head:{ negative big、 negative small、 zero、 positive big、 positive small } viz namely {NB、NS、ZO、PS、PB}

Description of division in discourse domain of output space:{ negative big、 negative small、 zero 、 positive big、 positive small } viz namely {NB、NS、ZO、PS、PB}

3.2. Build fuzzy control rule

It is the first step to build 3 fuzzy control rule tables for fuzzy self-adaptive PID control in the control system of thermoforming machine. They are fuzzy control rule tables for Kp、Ki、Kd of fuzzy self-adaptive PID control as table 1 show.

Table 1 Fuzzy rule table of Kp、Ki、Kd

EC / E	NB	NS	ZO	PS	PB
NB	PB	PB	PS	PS	ZO
NS	PB	PS	PS	ZO	NS
ZO	PS	PS	ZO	NS	NS
PS	PS	ZO	NS	NB	NB
PB	ZO	NS	NB	NB	NB

EC / E	NB	NS	ZO	PS	PB
NB	NB	NB	NS	ZO	ZO
NS	NB	NS	NS	ZO	PS
ZO	NS	NS	ZO	PS	PS
PS	NS	ZO	PS	PS	PB
PB	ZO	PS	PS	PB	PB

EC / E	NB	NS	ZO	PS	PB
NB	PS	NB	NB	NB	PS
NS	ZO	NS	NS	NS	ZO
ZO	ZO	NS	NS	NS	ZO
PS	ZO	ZO	ZO	ZO	ZO
PB	PB	PS	PS	PS	PB

3.3. Evaluation for fuzzy variable

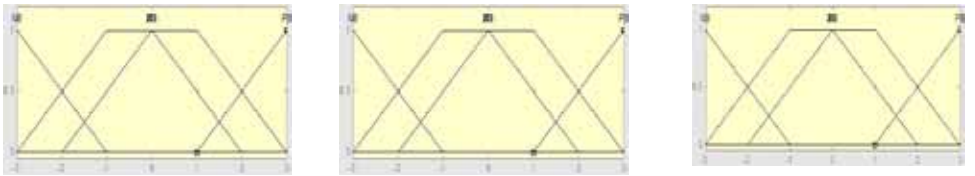
In process of control, thermoforming machine use fuzzy self-adaptive PID control in temperature control system when the temperature head in the range of -30℃～30℃.Therefore,changing discourse domain must be done before thermoforming machine use fuzzy self-adaptive PID control. The range of temperature head which is [-30， 30] can be converted to [-3， 3] though transfer functions as y=T/10+0.5.Then fuzzy variable is evaluate in the range of [-3，3]. Concrete method of evaluation for fuzzy variable as follows:

The membership functions of fuzzy terms should be defined before evaluating fuzzy variable. When define the membership functions of fuzzy terms, the sigmacompleteness of fuzzy control rules must be contented..In order to satisfy the demand of control system, suitable membership functions should be defined according to many factors.

(1) shape of membership functions[2] The more quickly curves of embership functions in discourse domain vary,the more precipitous shapes of membership functions become. And then the resolution ratio and sensitivity of control system are greater. But the fuzzy control rules and time of calculating in control system may add. On the contrary, the more slowly curves of embership functions in discourse domain vary, the smaller sensitivity of control system is. And system can't give right output when input is small. Thermoforming machine need small resolution ratio, so embership functions can be defined as lines whose slope was 1.

(2) spreading of embership functions in discourse domain[2] Spreading of embership functions in discourse domain must be equitable. Fuzzy sets can spread all discourse domain. In order to keep a point is not be spreaded by two or more embership functions, embership functions of removed fuzzy sets should be non-intersect. When the adjadjacent embership functions overlap, one point must correspond only one of the biggest degree of memberships of embership functions. Self-adaptive faculty of control system for characteristic parameter enhance when overlapping coefficient become big. But sensitivity of control system decrease.

In order to keep high sensitivity and good processing property, overlapping coefficient should be between 0.2 to 0.6. According to all of above and the characteristics of thermoforming machine, embership functions can be defined as follow. Show as figure 2.



(a) (b) (c)

Figure 2 (a) embership functions of input e,(b) embership functions of input ec, (c) embership functions of output u

3.4. Compile fuzzy conditional statement

According to fuzzy control rule table of fuzzy self-adaptive PID control of thermoforming machine's temperature control system, fuzzy conditional statement is compiled as follows:

①if E=NB or NS and EC=NB then u=PB

②if E=NB and EC=NS then u=PB

3.5. Fuzzy inference

Fuzzy relation can be ascertain as formula (1) show base on the first fuzzy conditional statement.

$$R= \lfloor (NB_E+NS_E) \times PBu \rfloor . \lfloor NB_{EC}+PB_U \rfloor \quad (1)$$

If real error amount is e and t rate of error amount is ec, formula (2) can be reasoned out base on

$$u=e \circ R. \quad u_1=e \circ \lfloor (NB_E+NS_E) \times PB_U \rfloor .ec \circ \lfloor NB_{EC}+PB_U \rfloor \quad (2)$$

If embership functions value of e and ec is define 1 for their quantitative grade and others are 0, formula (2) can be reduced as follow:

$$u_1=min\{max[\mu_{NB}(i); \mu_{NS}(i)]; \mu_{NB}(j); \mu_{NBu}(x)\}$$

Other controlled variables are calculated with the method as above.

$$u=u1+u_2+\cdots \quad (3)$$

According to (3),then choose a decision method to calculate precise controlled variable. Building three fuzzy control rule tables as table 2 on the basis of different i and j. Then the three parameters of fuzzy self-adaptive PID control can be got though transition function.

3 Simulation of fuzzy self-adaptive PID control

Simulating fuzzy self-adaptive PID control can be done by using simulink module and fuzzy module of MATLAB. Open simulink module of MATLAB, simulink model is built as figure 3 show.

Design fuzzy inference model at FIS editor. Open FIS editor and build interface of fuzzy inference which have two inputs and three outputs as figure 4.

Table 2 fuzzy control rule table of parameters

e \ ec	-3	-2	-1	0	1	2	3
-3	3	2	2	1	1	0	0
-2	2	2	1	1	0	-1	-1
-1	3	2	1	1	0	-1	-1
0	1	1	1	0	-1	-1	-1
1	1	1	0	-1	-1	-2	-3
2	0	-1	-1	-2	-2	-2	-3
3	0	-1	-1	-3	-3	-3	-3

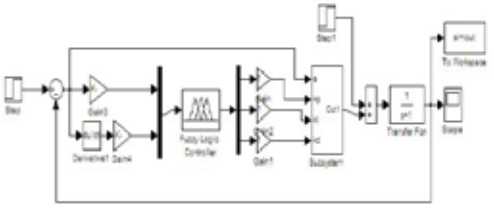


Figure 3 simulink model of fuzzy self-adaptive PID control

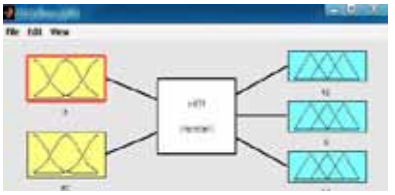


Figure 4 FIS inference with two inputs and three outputs

4. Summary

Different fuzzy control rule tables for different control systems can be built though the method above. It can be judged by the result of MATLAB simulink that fuzzy rules and embership functions is suitable for fuzzy self-adaptive PID control system or not. This fuzzy rule table can satisify for the thermoforming machine. Other thermoforming machines need different fuzzy rule tables.

Acknowledgement

The authors wish to thank the Technology Innovation Fund for Technology-based Small and Medium-sized Enterprises，the Science &Technology Ministry, the Ministry of Finance， P. R. China for providing a grant (No:3131116214403131),the science and technology plan projects of Guangdong Province, P. R. China for providing a grant (No:2010CY064), the Co-operation of Industry-University-Research Institute, Guangdong Province & Ministry of Education, P. R. China for providing a grant (No: 2009B090300175) .

Reference

[1]S.G.Liu,J.M.Wei,Z.C.Zhu. Fuzzy Control Techniques[M].Beijing:China Textile & Apparel Press,2001.

[2]Y.R.Huang,L.G.Qu. Parameter Adjusting And Realizing Of PID Controller[M]. Beijing: Science Press,2010.

[3]X.M.Shi,Z.Q.Hao.Fuzzy Control And MATLAB Simulink[M].Beijing: Tsinghua University Press;Beijing Jiaotong University Press,2008.

[4]B.P.Hou,P.Lu,L.K.Fu.The Design of Self-self-adaptive Fuzzy PID Controller and its Computer Simulation Base on MATLAB[J].Automation Engineering Tianjin University of Light Industry,4(2001)：32-35.

[5]X.Y.Zhang,X.Q.Wu,P.Y.Zhang.Design of Electric Boiler Temperature Control System Based on Fuzzy Seif-tuning PID[J].Information Technology,11(2010):107-110.

[6]Y.X.Yang,D.L.Cui,A.J.Zhou.Seif-self-adaptive Fuzzy PID Controller and Realizing the Control System in Simulink Environment[J].Ship Electronic Engineering,4(2010) :127-130.