Intelligent Fuzzy-PID Hybrid Control for Temperature of NH3 in Atomization Furnace

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Abstract: *This paper presents a systematic ap-proach for the design and implementation of temperature controller us-ing* ***Intelligent Fuzzy-PID Hybrid Controller for Temperature control in Process Industry****. The proposed approach employs PID based intelligent fuzzy-controller for determination of the optimal results than PID con-troller parameters for a previously identified process plant. Results indicate that the proposed algorithm significantly improves the performance of the chemical plant. It is anticipated that designing of PID based fuzzy controller using proposed intelligent techniques would dramatically improves the speed of response of the system, Rise time and settling time would be reduced in magnitude in the intelligent scheme as compared with conventional PID controller. ..*

Keywords*:* *Process plants, Steam temperature control, Industrial system, Multiobjective control; Optimal-tuning; PID control Fuzzy logic control, genetic algorithms, nonlin-ear control, optimal control, PIDcontrol*

Introduction

Well-known proportional-integral-derivative PID controller is the most widely used in industrial application because of its simple structure. On the other hand conventional PID controllers with fixed gains do not yield reasonable performance over a wide range of operating conditions and systems (time-delayed systems, nonlinear systems, etc.). Control techniques which based on fuzzy logic and modified PID controllers are alternatives to conventional control method. Fuzzy logic control (FLC) technique has found many successful industrial applications and demonstrated sig-nificant performance improvements.Fig.1.shows fuzzy control system.

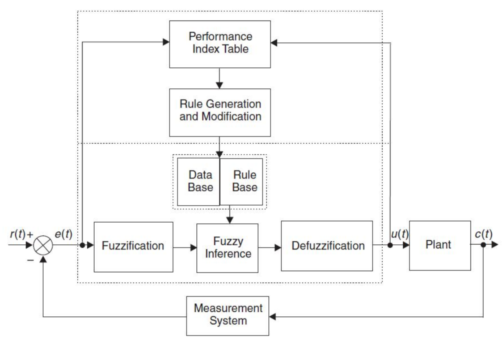


Fig. 1 FUZZY CONTROL SYSTEM

Palm has analytically demonstrated the equivalence between the fuzzy controller and sliding-mode controllers.

Fuzzy PID controller used in this paper is based on two input FLC structure with coupled rules. FLC has two inputs and one output. These are error (e), error change (de) and control signal, respectively. Linguistic variables which imply inputs and output have been classified as: NB, NM, NS, ZE, PS, PM, PB. Inputs and output are all normalized in the interval of [-1, 1]. The linguistic labels used to describe the Fuzzy sets were 'Negative Big' (NB), 'Negative Medium' (NM), 'Negative Small' (NS), 'Zero' (ZE), 'Positive Small'

(PS), 'Positive Medium' (PM), 'Positive Big' (PB). It is possible to assign the set of decision rules as shown in Table I. The fuzzy rules are extracted from fundamental knowledge and human experience about the process. These rules contain the input/the output relationships that define the control strategy. Each control input has seven fuzzy sets so that there are at most 49 fuzzy rules.

TABLE-I

Example of Decision Table

de/e	NB	NM	NS	Z	PS	PM	PB
NB	NB	NB	NB	NM	NM	NS	ZE
NM	NB	NB	NM	NS	NS	ZE	PS
NS	NB	NM	NS	NS	ZE	PS	PM
Z	NM	NS	NS	ZE	PS	PS	PM
PS	NM	NS	ZE	PS	PS	PM	PB
PM	NS	ZE	PS	PS	PM	PB	PB
PB	ZE	PS	PM	PM	PB	PB	PB

Temperature of melted amonia in atomization furnace is controlled only by adjusting the valve of fuel gas, so the objective can be treat as a SISO system. The error of the temperature of melted ammonia in atomization furnace 'e' and the change of that 'de' are confirmed as two inputs of the fuzzy controller. The output of Fuzzy-PID hybrid controller denoted by 'u' is a combination of the output of fuzzy controller and the output of PID controller, symbolized as u_1 and u_2 respectively, involving a weighting calculation for bumpless switch between the two controllers The valve of gas fuel is adjusted in the proportion of *u.* The weighting coefficient 'α' as a function of *e* can decide which controller operating mainly according to *e.* The fuzzy controller works mostly if *e* is larger than set point, or else the PID controller becomes the main controller with a bumpless switch.

In the proposed work the main objective of the investigator is to compare the performances of conventional PID controllers and the intelligent fuzzy logic controller. For this comparison, two parameters needs to be evaluated i.e. Overshoot and settling time. This paper suggests a fuzzy logic based controller which acts with the help of artificial intelligence techniques. There are many artificial intelligence techniques and fuzzy logic is one of them.

SIMULATION RESULTS

Gas Tank Temperature Controller

Gas synthesis is the process of mixing NH3 at high pressure and high temperature. Here temperature is 380^{o}C and pressure is 200kg/m^2. From this process we get 18% of ammonia.

Temperature controller is used to control the temperature of process in gas tank. In this the set temperature is 380^{o}C and PID temperature controller reaches set temperature in six hours and fifteen minutes. Fuzzy model was developed using error, change in error and fuzzy output to improve the settling time.

Table 1 Fuzzy system, for oil tank temperature controller

(a) Membership functions of Error input.

Membership function for Error			
Linguistic variable	Initial value	Peak value	Final value
Very Small (VS)	-20	50	100
Small (S)	70	140	210
Medium (M)	180	260	340
High (H)	260	325	390

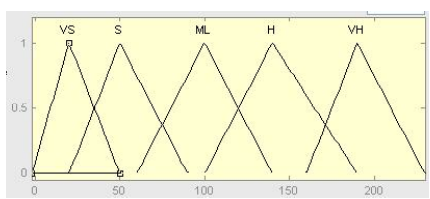
(b) Membership functions of Change in Error input.

Membership function for Change in Error			
Linguistic variable	**Initial value**	**Peak value**	**Final value**
Very Small (VS)	-40	-30	-20
Small (SM)	-30	-20	-10
Medium (MD)	-20	-10	0
Large (L)	-10	0	10

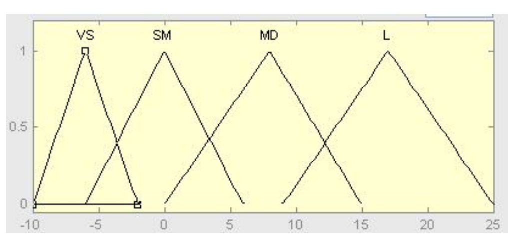
(c) Membership functions of Fuzzy output.

Membership function for Fuzzy Output			
Linguistic variable	**Initial value**	**Peak value**	**Final value**
Very Small (VS)	-20	80	140
Small (S)	100	180	260
Medium (M)	200	280	360
Large (L)	340	380	420
Very Large (VL)			

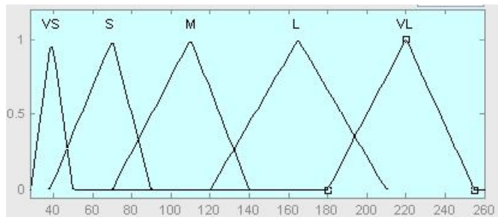
To develop Fuzzy controller, firstly error signal(e) is calculated by subtracting output of PID temperature controller from set temperature then change in error(“e) was calculated by subtracting previous error from current error. Considering error and change in error as input and fuzzified output as output function membership functions are created for each input and output. Membership functions for these quantities are defined as in above Table 1. The membership functions are shown in schematic form in Fig. 2.



(a) Membership functions of Error input.



(b) Membership functions of Change in Error input.



(c) Membership functions of Fuzzy output.

Fig.2. Fuzzy system, for oil tank temperature controller

A rule base was developed for the fuzzy model using simple IF-THEN rules.

The rule base is summarized as in Table 2

Fuzzy output (Fz)	**Change in Error (?e)**			
Error(e)	N	SM	M	L
VS	L	-	L	L
S	-	M	-	-
M	N	SM	-	-
H	N	-	M	-

On the basis of this rule base a fuzzified output is calculated. This Fuzzy model is simulated in MATLAB fuzzy logic toolbox GUI, and results are obtained. Then results are plotted along with the actual temperature and set temperature obtained from the process, are plotted in Fig.2

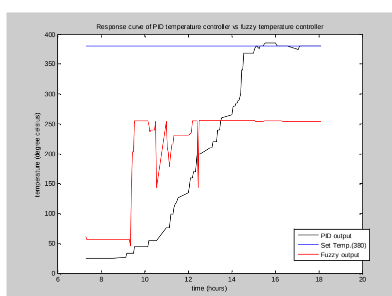


Fig.2. Response curve of PID temperature controller Vs Fuzzy temperature controller in oil tank temperature controller

Red graph shows the fuzzy output of fuzzy model of gas tank temperature controller.black line represent the output of PID temperature controller and blue line represent the set temperature.Fuzzy output has some oscillations in rising time and also has very large steady state error. To improve this fuzzy response the membership functions of all the input and output are increased.

The rule base is also revised as shown in Table 3. By using this rule base, oscillations in fuzzy response decreases and steady state error was also reduced than the last fuzzy model.

Table 3 Improved Rule base

fuzzy output (Fz)	Change in Error (?e)					
Error (e)	N	NS	SM	M	L	VL
VS	EL	EL	EL	EL	-	-
S	-	VL	VL	VL	-	-
M	-	L	L	L	-	-
H	-	ML	L	L	-	-
VH	S	M	M	ML	ML	-
EH	VS	VS	S	M	M	M

The MATLAB simulation results are plotted along with the actual temperature and set temperature obtained from the process, are plotted in Fig.4.

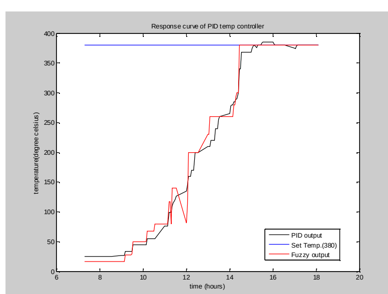


Fig.4 Improved Response curve of PID temperature controller Vs Fuzzy temperature controller in oil tank temperature controller

The rule base is revised as shown in table . By using this rule base, oscillations in fuzzy response decreases and steady state error were also reduced than the last fuzzy model. To achieve future improvements, the range of membership functions has been changed, and rule base is also changed.

and rule base is shown in Table 4.

Table 4 Improved Rule base

Fuzzy output (Fz)	Change in Error (?e)					
Error (e)	N	NS	SM	M	L	VL
VS	EL	EL	EL	EL	-	-
S	-	EL	EL	EL	-	-
M	-	VL	VL	VL	-	-
H	-	ML	L	L	-	-
VH	-	M	M	ML	ML	-
EH	VS	VS	S	M	M	M

The MATLAB simulation results are plotted along with the actual temperature and set temperature obtained from the process, are plotted in Fig.5.

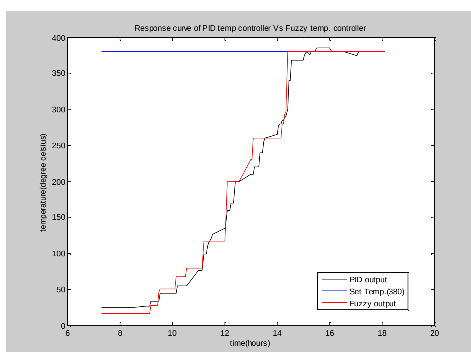


Fig.5. Improved response curve of PID temperature controller Vs Fuzzy temperature controller in oil tank temperature controller

Here the steady state error and settling time both have been improved. Steady state error is decreased to zero and settling time is reduced by 2 hours and 30 minutes. For Further improvements, rules have been revised the steady state error and settling time both have been improved. Fuzzy output and rule base have been revised. Revised Fuzzy output and rule base are shown in Table 5.

Table 5. Improved Rule base

Fuzzy output (Fz)	Change in Error (?e)					
Error (e)	N	NS	SM	M	L	VL
VS	EL	EL	EL	EL	-	-
S	-	EL	EL	EL	-	-
M	-	VL	VL	VL	-	-
H	-	L	VL	VL	-	-
VH	-	ML	ML	L	L	-
EH	VS	S	VS	M	M	-

The MATLAB simulation results are plotted along with the actual temperature and set temperature obtained from the process, are plotted in Fig.6.

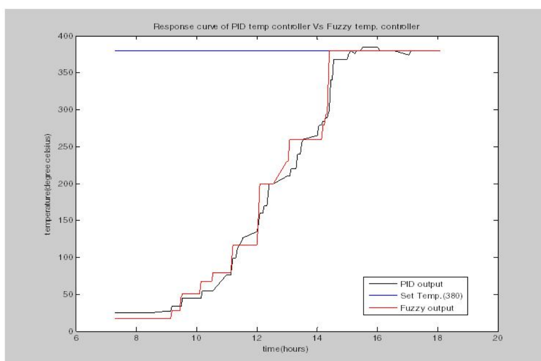


Fig.6. Improved response curve of PID temperature controller Vs Fuzzy temperature controller in oil tank temperature controller

Here fuzzy output response contains lesser oscillations. Settling time is also reduced by 15 minutes from last fuzzy model. Total settling time is reduced by 2 hours and 40 minutes. Improved error input, fuzzy output and rule base are shown in Table 6.

Comparing first fuzzy model in Fig. 3 and last fuzzy model in Fig 6 developed for oil tank temperature controller, an analysis is made that by increasing the number of membership functions from 5 to 7 for error input. and from 4 to 6 membership functions for change in error input, from 5 to 9 membership functions of fuzzy output, a response curve has been obtained that has a settling time of 1hour 55 minutes, and oscillations in response curve are all most removed. This fuzzy model reduces the settling time by 3 hours and 15 minutes.

Conclusions

Aiming at characteristic of agro plants and control requirement, a Fuzzy-PID hybrid controller with advantages of both fuzzy controller and PID controller integrated is presented in this paper. The available field application shows Fuzzy-PID hybrid controller can not only restrain the large fluctuation to temperature effectively, but also has excellent static performance. Fuzzy-PID hybrid controller has decisive effect on keeping stable temperature of agro and provides powerful support for smooth production process. Owing to improving production and super quality product by application of Fuzzy-PID hybrid controller, considerable economy benefit is brought to the enterprise.

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