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HUMIDITY PROCESS CONTROLLING USING FUZZY TYPE-1 AND TYPE-2 WITH PID CONTROLLER

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Abstract- This paper presents an approach to fuzzy type-2 proportional integral derivative (PID) controls for humidity process. Humidity affects product quality as well as human comfort. An experimental setup for humidifying process was developed and a suitable black box model is identified for the process. A fuzzy logic controller (FLC) is designed for this process with rule base based on internal model control proportional integral technique (IMCPI). FLC was simulated in the MATLAB environment for the humidifying process. The model was identified for a humidity process using process reaction curve and also validated with calculated data. Various control schemes that simulated in the MATLAB environment, tested for unit step input and the corresponding graph. By changing type of modeling, the step response of the system was analyzed. Simulation results show that fuzzy type-2 produces better results than the other techniques on this system. In this paper it is also proved that by fuzzy type-2 logic, the performance characteristics of the system will be improved.

Keywords: Fuzzy Type-1, Fuzzy Type-2, PID Controller, Humidity Process, Control System.

I. INTRODUCTION

Humid air plays key role in day to day activity. It is expressed in tens of relative humidity (RH) which is the ratio of actual amount water content in the air to that of the saturated air. The role of humidity is important in industrial sector and also to the human comfort. The need for humidity control is present in an ever growing number of applications and processes. From textile manufacturing to paper mills, from woodworking to lens manufacturing all have a requirement for an accurate and precise control over humidity levels within the process.

For industries such as textile, food processing, tobacco, pharmaceuticals and silicon wafer deposition, the RH level has to be maintained in order to get the desired product quality [1].To avoid damage of products, or to achieve proper process conditions, it is often important to keep the environment and the indoor climate within certain temperature and humidity limits. Low relative humidity may dry up the product, or high relative humidity may increase the water activity growing mould in the production process lines. Therefore, it is essential for the researchers and industrial units to study the effect of RH as well as to regulate the same.

Venkatesh and Sundaram [2] consolidated the importance of humidity for different process environment and various techniques for controlling the same available in the literature in their review article. Liau and Huang [3] conducted a study on opal photonic band gap crystal under RH controlled environment and they concluded that the crystal formation and stop band intensity was efficient under controlled RH. Enshen [4] studied that air humidity affects energy consumption of annual heating or cooling.

Lot of control techniques for humidity is available in literature. Guo and Zheng [5] proposed a control methodology for humidity and temperature in industrial workshop using intelligent techniques. Fuzzy based control is most suited for nonlinear processes [6-20]. Michels [9] proposed a fuzzy controller based on process model, which avoided the heuristic search for linguistic control rule. This work is addressing the identification of the model of a humidifying process of laboratory scale and comparing the effect of step responses of the process for fuzzy type-2 in compare fuzzy type-1 and PID controller.

II. EXPRIMENTAL UNITS

Venkatesh and Sundaram [2] examined the humidity process in an experimental unit. This experimental unit for the humidity process shown in Figure 1 consists of humidity chamber (HC) containing water in which primary air from the compressor is bubbled. The flow rate of the air into the chamber can be varied by manipulating the valve V1 and is metered using Rotameter R. The Rotameter is used for metering flow rate of the air. The exit humidified airflows through a coil of 3 m long and 1.25 cm diameter to provide time delay for the process.

The exit air humidity was measured using HIH-3610 series Honeywell RH sensor containing capacitive sensing element with laser trimmed thermostat polymer and on chip signal conditioning. It consumes less power and producing linear voltage with respect to RH. To identity the model using block box methodology, the primary airflow rate was adjusted using Rotameter and valve V1 to maintain 0.35 LPM (liters per minute). A step magnitude in air flow rate of 0.05 LPM was introduced in this process as in Equation (1). Figure 2 compares changes in experimental RH with that of calculated RH with respect to time. The model parameters were obtained as suggested by Bequette [10]. The identified model was validated with maximum error of ±1.5% using calculated response against experimental response.

$$G(s) = \frac{319.2}{720s+1} e^{-14.8s} \quad (1)$$

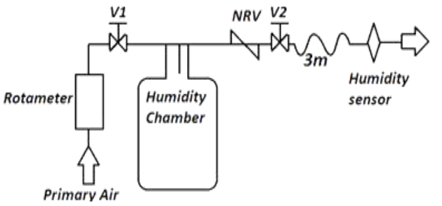

Figure 1. Experimental unit of humidity process

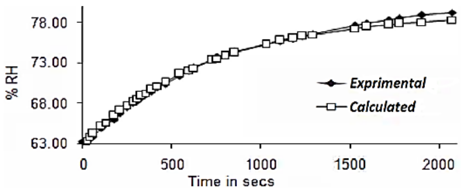

Figure 2. Process reaction curve

III. INTERNAL MODEL CONTROL BASED PI CONTROLLER

It is a model based control technique in which the inverse of the model is used to control the plant. If the model is perfectly matching with plant then the control action can be done efficiently. Normally there is a mismatch between plant and the model. Rivera, Morari and Skogestad [11] address this problem. The tuning rules are derived as follows [8].

$$K_c = \frac{\tau + \frac{\theta}{2}}{k\lambda} \quad (2)$$

$$\tau_1 = \tau + \frac{\theta}{2} \quad (3)$$

where, K_c is the proportional term, τ and θ are time constant and dead time respectively, k is the gain of the process, τ_1 is the integral time and λ is the tuning factor. The proportional term (K_c) is found to be 0.0425 and that of Integral term (τ_1) as 0.000635. The PI controller was tuned using the above settings.

IV. TYPE-1 FUZZY LOGIC SYSTEM

The fuzzy control is a new control method, it is mathematical basis, theoretical foundation and realization method has the very big difference with the traditional control method [13]. Fuzzy control is a computer numerical control method, which bases on fuzzy assembling, fuzzy language variable and fuzzy logic reasoning. It is a nonlinear intelligent control, which has satisfactory control effect. Fuzzy control is a control method using the basic ideas and fuzzy mathematics theory [13].

Because the controlling rules of fuzzy controller are obtained according to the control experience, the role of the fuzzy controller is imitating artificial control. While artificial control a production process, the general operators can only see the output variables of the rate of change or see the sum of output variable and output variable [12]. Later, you can control the operation process by experience. So in the normal fuzzy controllers, most of them select deviation of the e and its change Δe or e and $\int edt$ as its input variables while select the control as the output variables [12,18]. It determines the basic structure of the fuzzy controller as shown in Figure 3.

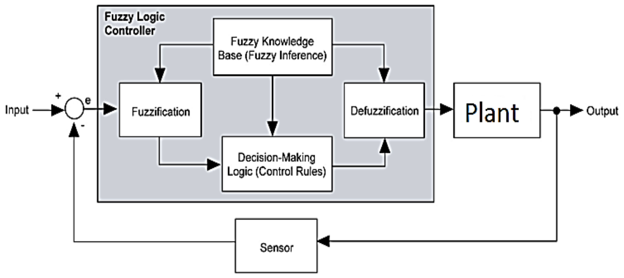

Figure 3. Basic structure of fuzzy controller

Figure 3 shows that the fuzzy controller can be divided into three parts: the fuzzy input interface, fuzzy inference fuzzy decision and fuzzy output interface [12, 17]. Fuzzy inference decision agencies can imitate human thinking characteristics, according to summarizing artificial control strategy of the rules of language to reason, and make the output value. Fuzzy decision can judge the fuzzy control value and change the fuzzy value into precise value for the controlled object [18]. Some advantages of fuzzy control are as follows.

- Fuzzy controller is a language controller, which is a nonlinear controller easy to control and master.
- Fuzzy controller does not rely on precise math model of controlled object. It can be used to control the system that model cannot recognize.
- Controller has strong anti-interference, and fast response, and it has strong robustness to the variation of parameters.
- Robust in nature.
- Can be modified easily.
- Multiple input and output sources can be used.
- Simpler than linear algebraic equation.
- Quick implementation.

V. TYPE-2 FUZZY LOGIC SYSTEM

Uncertainty is an inherent part of control used in real-world applications. The use of new methods for handling incomplete information and also to cope with large amounts of uncertainties is of fundamental importance. The general framework of fuzzy reasoning allows handling of much of this uncertainty. Fuzzy logic systems employ classical fuzzy sets to represent uncertainty by numbers in the range [0 1].

When something is uncertain, such as a measurement, it is difficult to determine its exact value, and of course, classical fuzzy sets make more sense than using crisp sets.

However, it is not reasonable to use accurate Membership Functions (MF) for highly uncertain cases and therefore other Fuzzy Sets (FSs) may be able to better handle such uncertainties. The so-called type-2 Fuzzy sets are known to serve as better alternative in such cases [19]. The concept of type-2 fuzzy set was initially proposed as an extension of classical (type-1) fuzzy sets.

Type-2 fuzzy sets are very useful in circumstances where it is difficult to determine an exact membership function for a fuzzy set hence they are very effective for dealing with uncertainties [20]. Figure 4 shows the structure of a type-2 FLS. It is very similar to the structure of a type-1 FLS. For a type-1 FLS, the output-processing block only contains the defuzzifier. We assume that the reader is familiar with type-1 FLS's, so that here we focus only on similarities and differences between two FLS's.

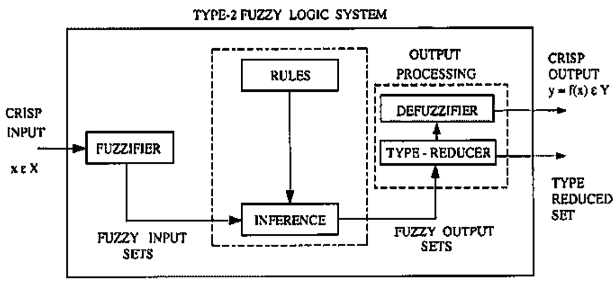

Figure 4. Basic structure of fuzzy type-2 controller

VI. DESIGN OF FUZZY TYPE-1 PI CONTROLLER

Our fuzzy type-1control system has two inputs and one output. The input variables are error (*e*) and error deviation (*de*). We used fuzzy type-1 toolbox to do our settings of fuzzy type-1 controller as Figure 5. The fuzzy type-1 rule base table obtained as Table 1.

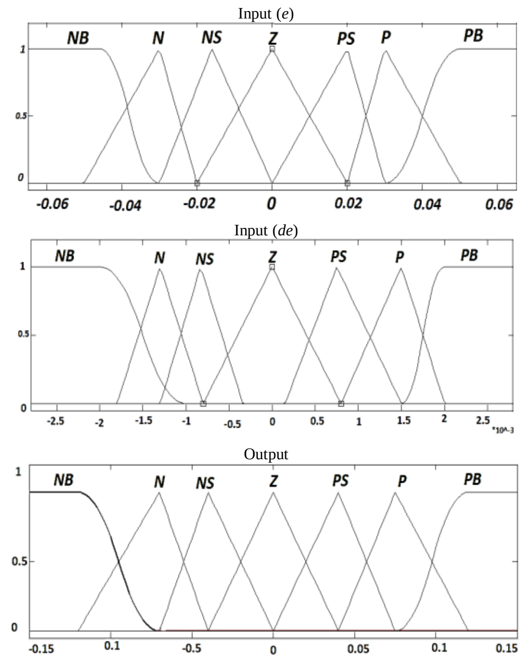

Figure 5. Inputs and output variables membership function for fuzzy type-1

Table 1. Fuzzy type-1 rules

e\de	NB	N	NS	Z	PS	P	PB
NB	NB	NB	N	Z	P	PB	PB
N	NB	N	N	Z	P	P	PB
NS	N	N	NS	Z	PS	P	P
Z	N	NS	NS	Z	PS	PS	P
PS	N	N	NS	Z	PS	P	P
P	NB	N	N	Z	P	P	PS
PB	NB	NB	N	Z	P	PB	PB

VII. DESIGN OF FUZZY TYPE-2 PI CONTROLLER

Similar to what was done in fuzzy type-1, fuzzy type-2 is designed. Similar to fuzzy type-1, the fuzzy type-2 control system has two inputs and one output. The input variables are error (*e*) and error deviation (*de*). We used fuzzy type-2 toolbox to do our settings of fuzzy type-2 controller as follows:

A. Fuzzification

In this paper, Gaussian distributed membership functions were considered and divided into seven regions. We quantize into the seven subsets, these subsets are {NB, N, NS, Z, PS, P, PB} that represent Negative Big, Negative, Negative Small, Zero, Positive Small, Positive, Positive Big. Gaussian-shape of membership function is chosen. The fuzzified inputs and output have been shown in Figure 6.

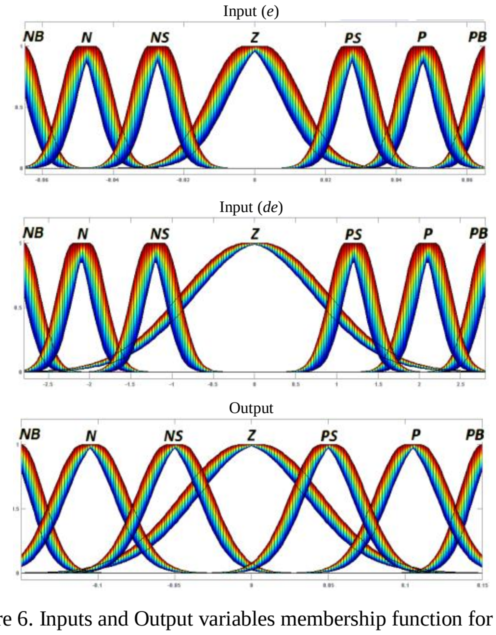

Figure 6. Inputs and Output variables membership function for fuzzy type-2

Table 2. Fuzzy type-2 rules

e\de	NB	N	NS	Z	PS	P	PB
NB	NB	NB	N	N	N	NS	NS
N	NB	N	N	N	N	NS	NS
NS	NB	N	N	N	N	N	NS
Z	NS	Z	Z	Z	Z	Z	PS
PS	PS	P	P	P	P	P	PB
P	PS	PS	P	P	P	P	PB
PB	PS	PS	P	P	P	PB	PB

B. Fuzzy Inference Rule

The fuzzy type-2 rule base table obtained as Table 2. Based on above fuzzy control rules, Mamdani algorithms of fuzzy reasoning were chosen here.

VIII. SIMULATION RESULTS

Under the environment of MATLAB/Simulink software, use module and control box supplied by MATLAB software to establish the simulation model of humidity Process. The model was identified for a humidity process using process reaction curve and also validated with calculated data. Various control schemes were simulated in the MATLAB environment and also tested for unit step input and the corresponding graph is shown in Figure 7. The time domain specification such as maximum peak and settling time (T_s), performance indices such as integral absolute error (IAE), integral squared error (ISE), integral time absolute error (ITAE) and integral squared absolute error (ISAE) were shown in Table 3.

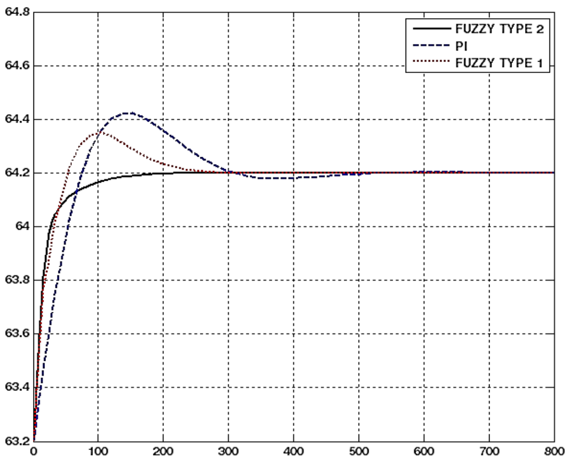

Figure 7. Process reaction curve for unit step input

Table 3. Specifications and performance of the controllers

	PI	Fuzzy Type 1	Fuzzy Type 2
Peak	64.43	64.35	---
TS	288	220	123
IAE	64	32.9	20.7
ISE	24.88	9.95	8.84
ITAE	6900	1525	454
ISEA	1140	172	96.3

IX. CONCLUSIONS

A humidity process in laboratory scale was developed and identified. FLC controller based on PID was simulated in MATLAB environment for the identified model. It was concluded from Table 3 that the fuzzy type-2 best controller performance can be achieved and Better time domain specifications can be arrived.

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