

# Development of Monitoring Control and Fuzzy Control Test of Finned-Tube Heat-Exchanger Test-Board<sup>1</sup>

Yongpan Chen	Jili Zhang	Bin Zhang	Fusheng Gao
Doctoral Candidate	Ph.D. Professor	Associate Professor	Professor

School of Municipal & Environmental Eng, Harbin Institute of Technology  
Harbin P. R. China, 150090  
cyp257@126.com

**Abstract:** In order to satisfy the testing requirement of finned-tube heat-exchanger test-board, this paper designs an exclusive auto-monitor and control subsystem, studies the fuzzy control means for the supply air temperature of the heat-exchanger, and accomplishes the fuzzy control performance test. According to the experimental results, this auto-monitor and control subsystem could not only reduce the testing time for thermodynamic performances of finned-tube heat-exchanger, but also actualize easily the stable control of the supply air temperature of the heat-exchanger.

**Key words:** finned-tube heat-exchanger; test-board; auto-monitor and control; fuzzy control

## 1. INTRODUCTION

Monitoring control system of finned-tube heat-exchanger test-board is a pivotal instrument to research the thermal performances, the development of which is very important to improve the automatization and reliability, raise the precision of measure, avoid artificial error and shorten entire test process. Experts have studied the heat transfer and resistance of the finned-tube heat-exchanger since 1960's. Fusheng Gao built the first test board at harbin institute of technology in 1965<sup>[1]</sup>. W.L.Bryan constructed the temperature and humidity air tunnel to research the heat-mass exchange performances in 1982<sup>[2]</sup>. Zhiguo Tang built a finned-tube heat-exchanger test board to study the heat transfer in 2002<sup>[3]</sup>. The fore test boards depend on artificial

regulation and have to span a long test process. According to the working condition, this paper instructs the method to determine the precision of apparatuses, designs an exclusive auto-monitor and fuzzy control subsystem, and accomplishes the fuzzy control test of supply air dry temperature in order to validate the precision and the transition control time.

## 2. BASIC STRUCTURE AND INSTRUMENTS DETERMINE

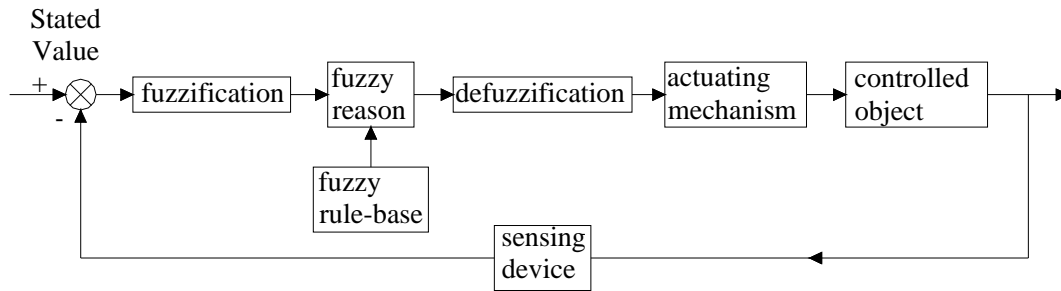
Fig.1 provides the structure of the Finned-Tube Heat-exchanger Test-Board. This Board contains four parts, such as air pretreating section (shown as component 1 and 2 in Fig.1), air measuring section (shown as component 3 in Fig.1), testing section (shown as component 6 in Fig.1), and water pretreating section. In testing section, the in-air dry temperature is restricted within 18~28°C, the in-air wet temperature is restricted within 16~20°C, in-water temperature is restricted within 5~10°C, in-air velocity is restricted within 1~4m/s. By regulating the heater and humidifier of the air pretreating section, the air performances in front of the testing section could be controlled. By measuring the air dry temperature, air wet temperature, and the air volume, the heat transfer in air side for finned-tube heat-exchanger could be obtained. By measuring the change of water temperature and water velocity, some performances could be educed such as the heat transfer in water side, water resistance.

According to the standards<sup>[4]</sup>, we can choose the instruments as following:

1) The top error of temperatures in front of the test- sample is less than or equal to 0.6 °C, and the

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**Fig.2 The principle diagram of computer control system**

Then, the signal is transformed into 4~20mA standard signal by special amplifier.

The pressure resistances of orifice meter and heat-exchanger are measured by SST digital capacitance pressure or pressure difference transmitting instrument. This instrument has eminent capacity of noise proof and zero stabilization, and temperature auto-compensation.

The pressure differences are recorded by PCI1713 analog input card with pressure difference transmitting instrument in this finned-tube heat-exchanger test-board. This card holds 12 bits A/D resolution factor, 32 single-ended analog input channels, or 16 double-ended analog input channels. There is an isolation protection of 3600V<sub>DC</sub> between the inputs and PCI1713. Users can set the all inputs independently to different ranges: 0 to ±10V, 0 to ±5V, 0 to 10V.

3.2 Controlling Subsystem

The principle of controlling in-air temperature of the finned-tube heat-exchanger is shown as Fig.2. By Using ADAM4018 module to measure the air temperature where the thermocouple is placed,

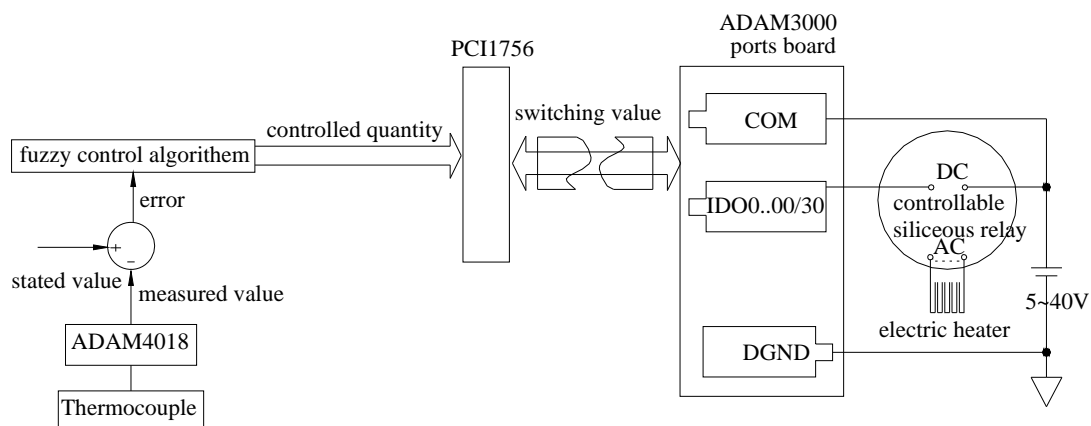
program can calculate the error and error variance ratio according to the target value. These variants are fuzzificated, fuzzy reason, and defuzzificated. At last, the program can gain the precise controlled quantity which is outputted to controllable siliceous relay to control the time of heating.

The controlled quantity is outputted by PCI1756 digital I/O card with controllable siliceous relay, as shown Fig.3. This card holds 12 bits A/D resolution factor, 32 isolated digital output channels. There is an isolation protection of 2000V<sub>DC</sub> between the outputs and PCI1756. The PCI1756 can either retain the last digital output settings and values, or return to its default configuration based on the jumper setting. This practical function eliminates danger caused by mishandling during unexpected system resets.

4. SOFTWARE ARCHITECTURE OF THE TEST-BOARD

4.1 Design Idea of Monitoring and Control System

Because this software is applied to finned-tube heat-exchanger for real time measuring and control. Besides measuring, control, and data process, it needs



**Fig.3 The Schematic configuration of control system**

to consider some other factors, such as safety and stability of system, manipulative facility, and extend compatibility of itself.

#### 1) Safety and stability of software

The longer finned-tube heating exchanger test-board runs, the more important safety and stability of software is. By programming and testing software, we can find there may be two kinds of possible mistakes in running process: one kind is foreseeable mistakes and other kind is unforeseen mistakes. Further more foreseeable mistakes are composed of computer running mistakes and man-made mistakes. The computer running mistakes have many kinds, for example, equipment input or output port mistake, the memory overflow, 0 as the denominator, the negative number' extract and so on, especially the latter two kinds frequently appear in the software testing stage. For this kind's mistake, the program will process directly without any cue. For unforeseen mistakes we add general error processing code to prevent suddenly breakdown. Therefore, we can effectively guarantee safety and long time running of this software without any error.

#### 2) Manipulative facility

This program is designed for general users. Considering manipulators aren't computer professional, the surface is very simple and there are corresponding cues for each operation. This program is equipped necessary and detailed help document, so that manipulators could master how to operate it after studying software manuals and training simply.

#### 3) Extension and compatibility

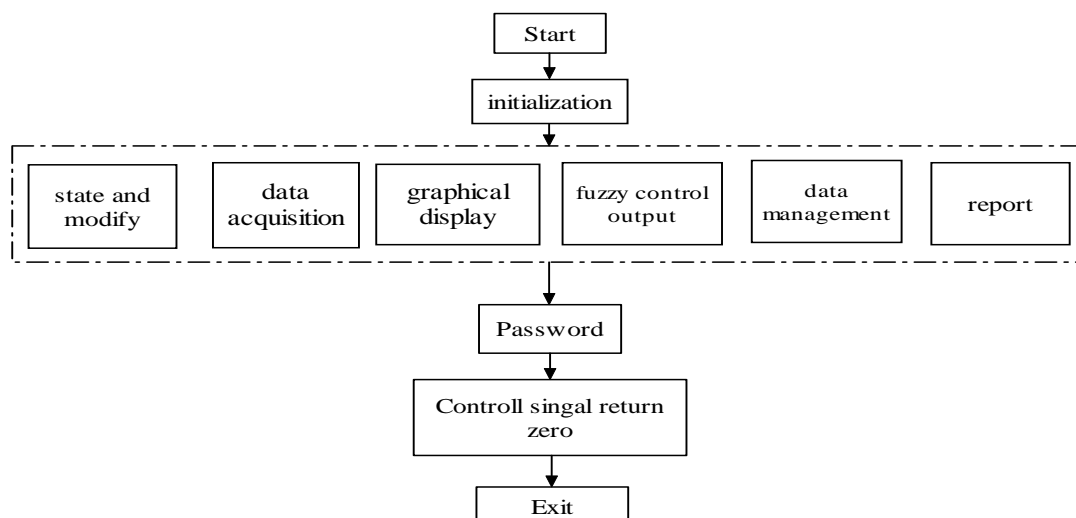
The ideological system of modular programming runs through the course of designing. Single function is designed into general module, general subprogram, or dynamic-link-libraries. All the parameters can be modified or stated. Although programming is more difficult, versatility of this software is raised effectively. For example, there are six points using curve fit in creating reports. We write the algorithm routine into dynamic-link-libraries, to increase the utilization ratio of codes and reduce software size, and to serve for other software conveniently. The data in this program can be exported into general Excel document for convenient analysis process.

### 4.2 Design of Master Program for Monitoring and Control

We adopt modular programming in the process, and there are several modules: state and modify module, data acquisition module, graphical display module, fuzzy control output module, data management module, and report module. Each module is stand-alone program. The structure of the main program is shown as Fig.4.

In order to control the in-water temperature and in-air dry temperature, we adopt FFSI (function fuzzy subclass illation) <sup>[5]</sup> as the core of fuzzy control. This integrated system can measure parameter automatically, query historic data, export data into general Excel for farther analysis, and create report for different working station.

This program creates reports for different



**Fig.4 The software structure diagram**

working station, which contain corresponding curve diagram and curve fit equation. The dominance of this test-board from other homogeneous in our country is automatic measuring and control without manual work.

### 5. SUPPLY AIR TEMPERATURE FUZZY CONTROL TEST

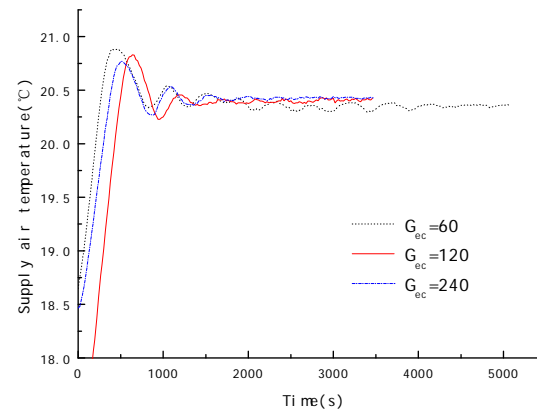
We define the actual spans of error and error difference as basic spans. In order to realize fuzzycation in fuzzy control process, we must transform input variables into corresponding fuzzy span from basic span by multiplying a suitable factor. So we define  $G_e$  as quantization factor of error, and  $G_{ec}$  as quantization factor of error difference.

It is important to choose suitable quantization factor  $G_e$  and  $G_{ec}$  for designing fuzzy controller besides an excellent fuzzy rule base. Then in the condition of fixed fuzzy rule base, we control the supply air temperature by rejiggering quantization factor  $G_e$  and  $G_{ec}$ . The results are shown as Fig.5, 6 and Table 1. The results indicate that the values of  $G_e$  and  $G_{ec}$  affect the performances of fuzzy controller greatly. We should select suitable quantization factor for different actual object.

In Fig.5, we can see that big  $G_{ec}$  value will cause the low rise speed and long transition time; small  $G_{ec}$  value will cause high rise speed and big overshoot even oscillation shown as  $G_{ec}=60$ . Big  $G_{ec}$  shortens the basic span of error difference, so the transition time become longer, overshoot become small and system lags in response. By contraries, small  $G_{ec}$  enlarges the basic span of error difference.

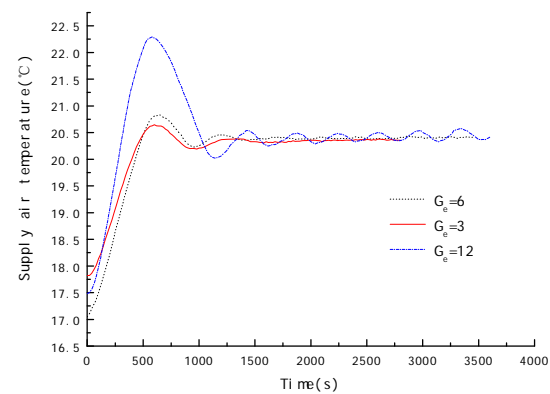
greatly.

### 6. CONCLUSIONS



**Fig.5 Supply air control temperature at  $G_e=6$**

In Fig.6, we can see that big  $G_e$  value will cause small inertia, high rise speed, big overshoot even oscillation; small  $G_e$  value will cause retardation.



**Fig.6 Supply air control temperature at  $G_{ec}=120$**

Big  $G_e$  shortens the basic span of error, so the control of error augments and dead zone is shorten.  $G_e$  affects the performances of fuzzy controller

By changing quantization factor  $G_e$  and  $G_{ec}$  in the test, we could find that this change is actually the basic span change of error and error difference which

**Tab. 1 Results of test**

		Target value(°C)	Stabel value(°C)	Warp (°C)	Transition time(s)	Peak value(°C)	Overshoot (%)
$G_e=6$	$G_{ec}=60$	20.50	20.38	0.12	3612	20.88	2.45
	$G_{ec}=120$	20.50	20.41	0.09	1460	20.83	2.06
	$G_{ec}=240$	20.50	20.40	0.10	1637	20.77	1.81
$G_{ec}=120$	$G_e=3$	20.50	20.37	0.13	1713	20.65	1.37
	$G_e=6$	20.50	20.41	0.09	1460	20.83	2.06
	$G_e=12$	20.50	20.47	0.03	none	22.28	8.84

reflects the actual value span. If the basic span is enlarged, while the actual span is narrow, then the response speed is low. By contraries, if the basic span is shortening, while the actual span is broad, then the overshoot will be serious. All these could affects the performances of fuzzy controller greatly.

If the test-board completely depends on manual work to measure and adjust, it needs 3 hours at least from beginning control to stable work. However if we use hardware and software system of this test-board, we merely need 24 minutes to complete the same process, so we can say this test-board not only shortens greatly experiment debugging time but also improves work efficiency.

## REFERENCES

- [1] Fusheng Gao. The performance analyses and verification of an air conditioner. Selected works of Fusheng Gao on air conditioning[M]. Harbin: Harbin Institute of Technology Press, 1993:20-28.(In Chinese)
- [2] P. M. Chung. Frost Formation and heat transfer on a Cylinder Surface in Humid Air Cross Flow[J]. Heating Piping and Air Condition, 1982, 30:9-10.
- [3] Zhiguo Tang. Research and analyses on convection heat-exchange coefficient of finned heat-exchanger[D]. Tongji University. 2002.(In Chinese)
- [4] GB10223-88. Assembly of air conditioner standards[M]. Standards Press of China, 1997:530-543.(In Chinese)
- [5] Jili Zhang. Fuzzy-neural network control and its applications in building thermal process[D]. Harbin: Harbin University of Civil Engineering and Architecture. 1998.(In Chinese)