Development of Monitoring Control and Fuzzy Control Test of Finned-Tube Heat-Exchanger Test-Board[1]

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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[1]. W.L.Bryan constructed the temperature and humidity air tunnel to research the heat-mass exchange performances in 1982[2]. Zhiguo Tang built a finned- tube heat-exchanger test board to study the heat transfer in 2002[3]. 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 INSTRUME-NTS 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℃, the in-air wet temperature is restricted within 16~20℃, in-water temperature is restricted within 5~10℃, 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[4], 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 ℃, and the

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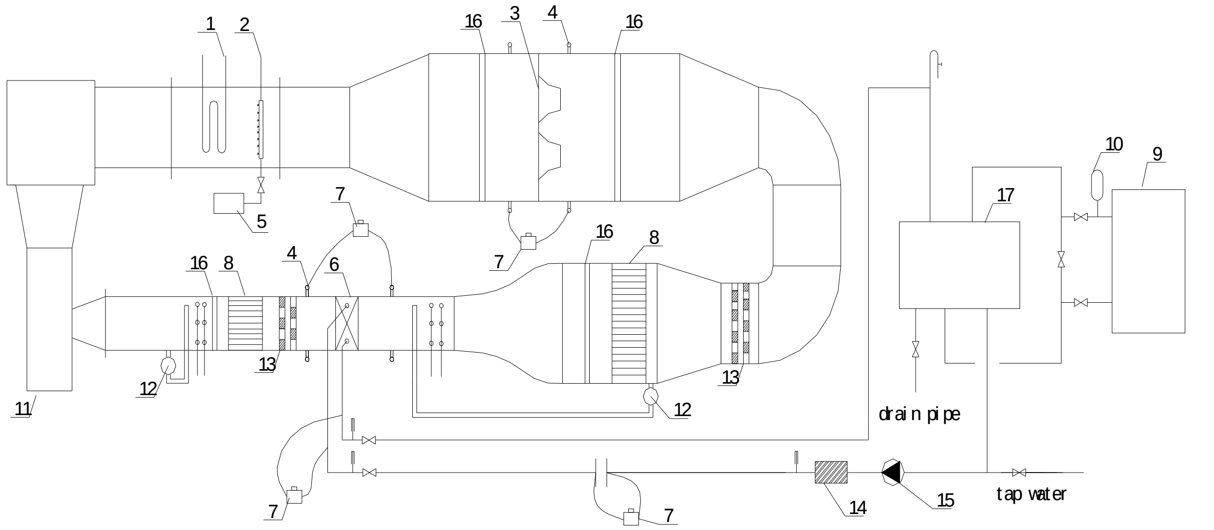

Fig.1 The structure of finned-tube heat-exchanger test-board

1-heater 2-humidifier 3-muzzle 4-pressure hoop 5-boiler 6-sample 7- pressure difference transmitter 8-rectifying unit 9-heat pump 10-constant pressure container 11-fan 12-sampling fan 13-air admixture 14-micro-adjustment for water temperature 15-recycle pump 16-rectifying mesh 17-water container

top error of velocities is not more than 20 percent of the minimum air velocities.

2) The precision of the air dry temperature and wet temperature must exceed ±0.1℃ in the test of Finned-tube heat-exchanger. These precisions must greater than ±0.2℃ in heating experiment. The minimum value about precision of other temperatures is ±0.5℃.

3) The accuracy of the micro manometer, which is used to measuring the air pressure, is limited in one percent of the measured value. When the air pressure is less than 100Pa, the resolution factor is 1Pa. We must assure that the minimum scale spacing of the manometer for measuring water resistance is less than 133Pa, and the accuracy of the manometer for measuring water pressure is greater than or equal to one percent of the measured value, and the minimum scale spacing of the manometer for measuring the atmosphere is less than or equal to 100Pa.

4) The accuracy of the instrument for measuring air flux is limited in one percent of the measured value.

5) The accuracy of the flow meter to measure water flux is less than one percent of the measured value.

3. HARDWARE ARCHITECTURE OF THE TEST-BOARD

The hardware architecture for computer monitoring and control is composed of measuring subsystem and controlling subsystem.

3.1 Measuring Subsystem

The temperature is measured by intelligent acquisition module ADAM 4018 with thermocouples in this finned-tube heat-exchanger test-board. This module, which is suited to industrial monitoring and control especially, holds 16 bits A/D resolution factor, 6 difference analog input channels, and 2 single-ended analog input channels. We could set the input range of each channel in the program. There is an isolation protection of $3600V_{DC}$ between the inputs and ADAM 4018. This is ideal for industrial applications where high-voltage protection is required. Users can set the eight inputs independently to different ranges: 0 to ±15mV, 0 to ±50mV, 0 to ±100mV, 0 to ±500mV, 0 to ±1V, 0 to ±2.5V. In this test-board, we adopt the range of 0 to ±15mV, and ±20mA, with a 125Ω electric resistance. The module delivers temperature values into the host computer through RS485 BUS, when it is queried. We just use one intelligent acquisition module ADAM 4018, and realize communication with the host computer by adding in RS485/RS232 transducer.

The pressure resistance of nozzle is measured by KY-800 pressure difference transmitting instrument.

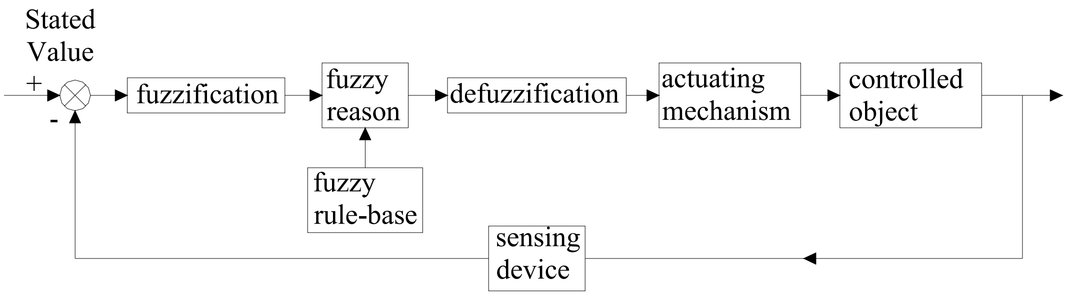

Fig.2 The principle diagram of computer control system

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 $3600V_{DC}$ 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 $2000V_{DC}$ 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. SOFWARE 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

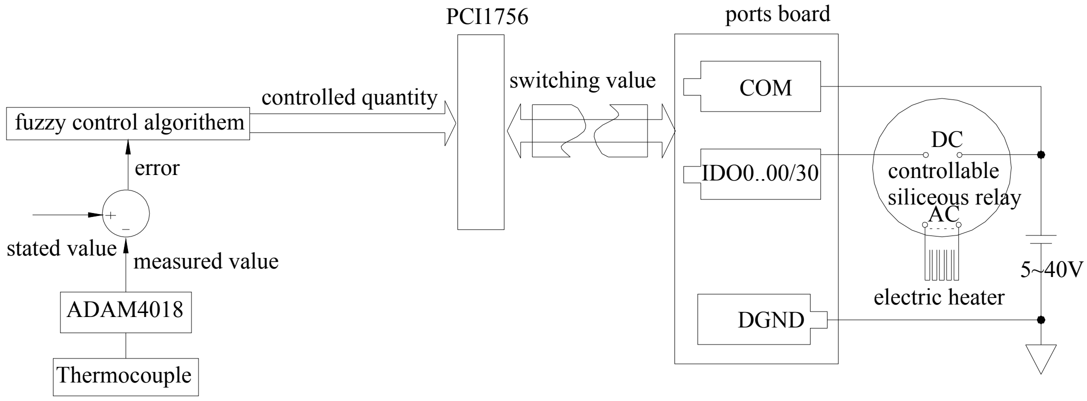

Fig.3 The Schematic configuration of control system

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 r 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) [5] 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

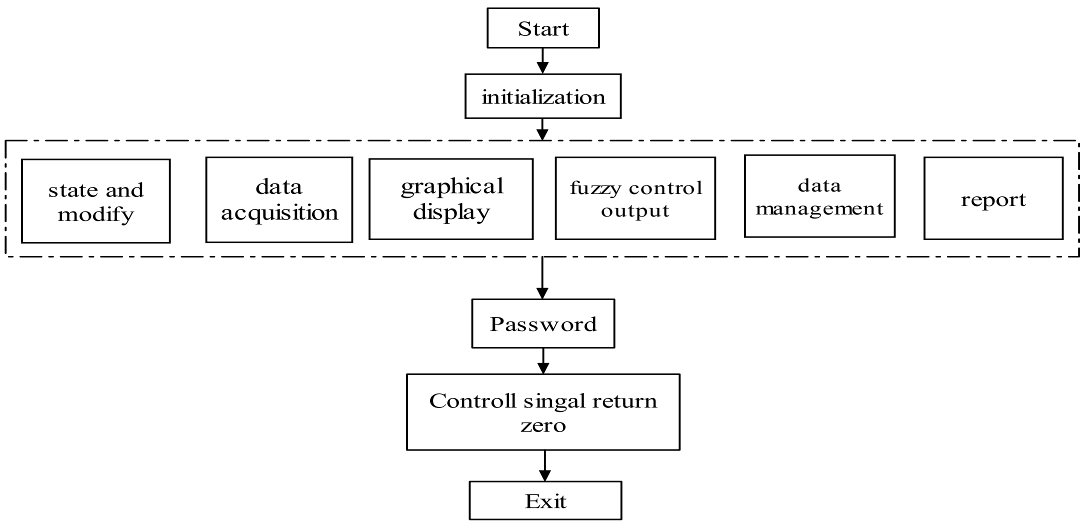

Fig.4 The software structure diagram

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 THEMPERATURE 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.

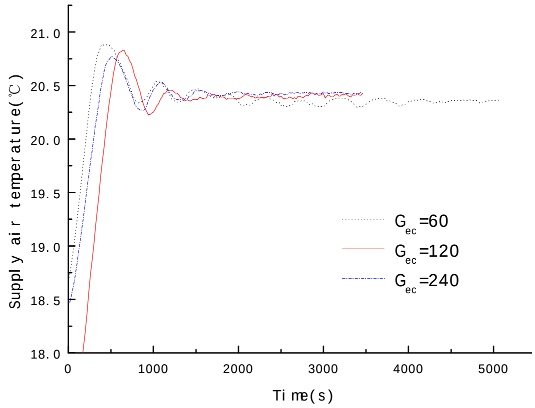

Fig.5 Supply air control temperature at Ge=6

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.

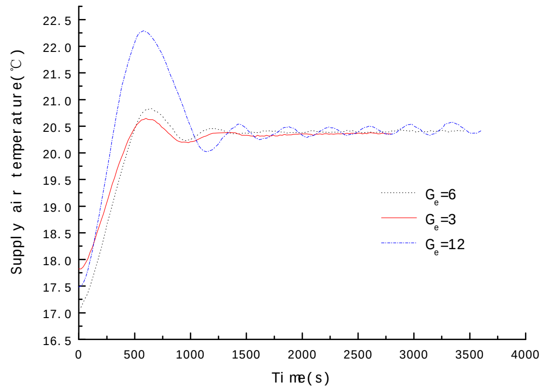

Fig.6 Supply air control temperature at G_{ec}=120

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 greatly.

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

6. CONCLUSIONS

Tab. 1 Results of test

		Target value(□)	Stabel value(□)	Warp (□)	Transition time(s)	Peak value(□)	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.

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