Research on Air-Conditioning Control Strategy of Textile Mill Based on Bidirectional Fuzzy Dynamic Decoupling Compensation

Yannian Wang¹, Kai Du², Yunhui Wu³, Hengkun Tang⁴

¹,²,³,⁴College of Electronics and Information, Xi’an Polytechnic University, Xi’an, Shaanxi, 710048, China

²Corresponding author’s e-mail: 664661571@qq.com

Abstract. This paper introduces the main problems in the air conditioning system of China’s textile mills. Due to the coupled line problem of temperature and humidity affecting each other in the temperature and humidity regulation system, it is difficult to adjust the air conditioning system in the textile mill, and it is also more difficult to adjust the air conditioning system in the textile mill because of the influence of region, season, human activities and so on. In view of this situation, the air conditioning control system of textile mill based on TMS320F28335 was designed by dynamic decoupling control method. The reasonable adjustment and control of the equipment of the air conditioning system can achieve the stable control of the temperature and humidity of the workshop of the textile mill and reduce the energy consumption of the air conditioning control system. The practice shows that the system has good dynamic performance, high control precision and remarkable energy saving effect, and has a broad application prospect in air conditioning control in textile enterprises.

1. Introduction

In the textile mill, the air temperature and humidity of the workshop are the key factors affecting the quality of textile products. In the current textile production environment of our country, the temperature range of its production workshop is 33~35°C, and the humidity range is 55~58%, if it cannot meet this requirement, it will seriously affect the quality of the products produced. The traditional air conditioning control mode of textile mill still adopts the method of manual control, not according to the actual situation of the environment parameters inside and outside the workshop to choose the optimal adjustment mode, but based on experience to adjust, so the adjustment accuracy is not high, the adjustment time is longer. This paper designs the air conditioning control system of the textile mill based on TMS320F28335, which automatically controls the air conditioning system of the textile mill by adding the control mode of dynamic fuzzy decoupling compensator after the temperature and humidity regulation algorithm. According to the change of the environment inside and outside the workshop, the control quantity of the executive equipment is adjusted in time to ensure the stability of the temperature and humidity of the workshop, which meets the requirements of the stable adjustment of temperature, humidity and the reduction of energy consumption in the workshop of the textile mill.

2. System structure

The structure of the air conditioning control system is shown in Figure 1. In the control system, the main chip is a microprocessor TMS320F28335 developed by TI. Temperature and humidity sensors collect the temperature and humidity in the workshop and outside the workshop, and values of temperature and
humidity are sent to the main processor through the signal processing circuit. The main processor performs algorithm operations on temperature and humidity values, and then the main processor outputs the control signal to the wind valve actuator and the inverter. The wind valve actuators control louver. The inverters control fans and the circulating pump. The touch man-machine interface displays the operation status of each part of the system and sets the temperature and humidity required by the production workshop, as well as the display of alarm information.

3. System control method
In the process of textile production, the requirements of the environmental parameters such as temperature and humidity of the workshop are strict, and the data of the external environment of the workshop should be taken into account in the process of adjusting the air conditioning system of the textile mill, while the distribution of the textile mill in our country has the characteristics of wide area, different environmental parameters of the same season and different areas, and the diversification of the external environment of the workshop has certain influence on the adjustment of the air conditioning equipment of the textile mill. The process index of the air conditioning control system of the textile mill is the temperature and humidity of the production workshop. The adjusting equipment is the adjustable physical quantity such as the louver opening degree and the fan speed, and the coupling relationship between temperature and humidity makes the adjustment of the air conditioning control system more difficult. In this system, through two-way dynamic fuzzy decoupling compensation, temperature and humidity are close to the target value, and the smaller the coupling between temperature and humidity is. The coupling effect between temperature and humidity is negligible with the long-term operation of the system equipment.

3.1 Air conditioning System control strategy
Air conditioning control system regulation rules are shown in Figure 2.
When adjusting the temperature, it will lead to the change of the humidity; when adjusting the humidity, it will lead to the change of the temperature; through the change of the temperature and humidity, establish the respective Dynamic Fuzzy decoupling compensator for compensating coupling amount regulation to achieve the decoupling of temperature and humidity.

\( F_1(t) \) is the main regulation algorithm of temperature, the main regulation equipment of workshop temperature is the supply fan. The algorithm formula is shown in formula 1:

\[
F_1(t) = F_1(t-1) + K_1 {F_1(t)} \left( \frac{T_{\text{max}} - T_{\text{min}}}{2} \right)
\]

\( F_1(t) \): Supply fan control derived from temperature control algorithm value.

\( F_1(t-1) \): The output value of the supply fan at the previous moment.

\( K_1 \): The correction coefficient of the output value of the supply fan, the value range is 0~1 and the default value is 0.5.

\( T_{\text{max}} \) and \( T_{\text{min}} \) are the adjustable maximum and minimum values of the supply fan respectively.

\( T \): Real-time measurement of workshop temperature.

\( F(t) \) is the main regulation algorithm of humidity, the main regulation equipment of humidity in the production workshop is circulating pump and fresh air louver. The algorithm of circulating water pumps is shown in formula 2:

\[
F_2(t) = F_2(t-1) + K_2 {F_2(t)} \left( \frac{H_{\text{max}} - H_{\text{min}}}{2} \right)
\]

\( F_2(t) \): Control value of circulating pump derived from humidity control algorithm.

\( F_2(t-1) \): Output value of circulating pump at the previous moment.

\( K_2 \): The correction coefficient of the output value of the circulating pump ranges from 0 to 1 and the default value is 0.5.

\( F_{\text{max}} \) and \( F_{\text{min}} \) are the adjustable maximum and minimum values of the circulating pump respectively.

\( H_{\text{max}} \) and \( H_{\text{min}} \) are the maximum and minimum values of the range of humidity required by the workshop.

\( H \): Real-time measurement of workshop humidity.

The fresh air louver adjustment algorithm is shown in formula 3:

\[
F_3(t) = F_3(t-1) + K_3 {F_3(t)} \left( \frac{E_{\text{max}} - E_{\text{min}}}{2} \right)
\]

\( F_3(t) \): Fresh air louver control values derived from humidity control algorithm.

\( F_3(t-1) \): Output value of fresh air louver at previous moment.

\( K_3 \): The correction coefficient of the output value of the fresh air louver ranges from 0 to 1 and the default value is 0.5.
\[ F_{3\text{max}} \text{ and } F_{3\text{min}} \text{ are the adjustable maximum and minimum values of the fresh air louver respectively.} \]

\[ E_{\text{max}} \text{ and } E_{\text{min}} \text{ are the maximum enthalpy value and the minimum enthalpy value of the apparatus dew point. The maximum and minimum enthalpy value of the apparatus dew point are calculated according to the maximum temperature and humidity set by the workshop and the minimum temperature and humidity.} \]

\[ F(t) \text{ according to formula 4 and 5.} \]

Increase humidity in workshop:

\[ F(t) = \begin{cases} F_3(t), \text{workshop humidity } < \text{target humidity} \\ F_2(t), \quad F_3(t) = F_3(t)_{\text{max}} \\ F_3(t), \quad F_2(t) = F_2(t)_{\text{max}} \end{cases} \quad (4) \]

Reduce the humidity in the workshop:

\[ F(t) = \begin{cases} F_2(t), \text{workshop humidity } > \text{target humidity} \\ F_3(t), \quad F_2(t) = F_2(t)_{\text{max}} \\ F_3(t), \quad F_3(t) = F_3(t)_{\text{min}} \end{cases} \quad (5) \]

The maximum and minimum values of temperature and humidity in the production workshop are set through the touch screen.

The process exhaust fan is the main cooling device of the textile equipment, when the outdoor temperature is high in summer, the process exhaust air louver is generally closed, and the process exhaust fan expels the heat of the textile equipment to the outdoor; when the outdoor temperature is low in winter, the opening degree of the process exhaust air louver is controlled by the algorithm of the process exhaust air louver. The process exhaust fan can send the heat from the textile equipment to the air conditioning room for the secondary return air regulation, which can greatly reduce the unnecessary waste of energy.

The control value of the ground exhaust fan is calculated from the control value of the supply fan. The adjustment formula is shown in formula 6.

\[ P_d + P_g \leq P_s \quad (6) \]

\[ P_d \text{ is the maximum power value of the ground exhaust fan. } P_g \text{ is the maximum power value of the process exhaust fan. } P_s \text{ is the maximum power value of the supply fan.} \]

According to the operating power of the equipment, we can know the control frequency of the equipment when running. The process exhaust fan operates with the maximum power, so there is a difference value \( \Delta e \) between the blower and the ground suction fan. \( \Delta e \) is modified on the touch screen.

The adjustment formula of the ground suction window is shown in formula 7.

\[ F(t)_g = F_{3\text{max}} - F_3(t) \quad (7) \]

\( F(t)_g \) is the output of the ground exhaust air louver.

### 3.2 Design of dynamic fuzzy decoupling compensator

In this paper, the temperature dynamic fuzzy decoupling compensator and humidity dynamic fuzzy decoupling compensator are added after the adjustment algorithm of temperature and humidity respectively.

Dynamic fuzzy decoupling compensator 1 is the decoupling compensation for humidity regulation, and output \( U_1 \) is the increment of the actuator adjustment corresponding to the humidity deviation; In the process of current adjustment, it can be obtained temperature to humidity the coupling result humidity Deviation \( \Delta t_1 \), deviation change rate \( \Delta t_1 \) as well as the increment of the current time of each executive body \( \beta_1 \). Humidity Relationship between Variation Rate and Deviation Value As shown in formula 8:

\[ \Delta t_1 = \frac{\Delta(t_1-1) - \Delta t_1}{T} \quad (8) \]

\( \Delta t_1 \): For the measured Humidity reduces demand Humidity.
\( \Delta(t_1 - 1) \): For the last hour Humidity Deviations.
\[ \Delta t_2 = \Delta(t_2 - 1) \]

\[ \Delta t_2 \] is the measured temperature minus the required temperature.

\[ \Delta(t_2 - 1) \] is the deviation of temperature at the previous moment.

Based on the current adjustment, select \( \Delta t_1, \Delta t c_1, \Delta t c_2 \) and \( \Delta t c_3 \) of the first seven adjustments, and the quantization fields of the outputs \( U_1 \) and \( U_2 \) are set to \{PB, PM, PS, ZO, NS, NM, NB\}. Dynamic fuzzy decoupling control rules for humidity and temperature regulation of air conditioning systems in textile mill are shown in table 1 and table 2:

| Table 1. Humidity dynamics fuzzy decoupling rule control table. |
|---------------------------------|
| \( U_1 \) | NB | NM | NS | ZO | PS | PM | PB |
| NB | NB | NM | NS | ZO | PM | PM | PB |
| NM | NM | NM | NS | ZO | PS | PM | PB |
| NS | NS | NM | NS | ZO | PS | PS | PM |
| ZO | NM | NS | NS | ZO | PS | PS | PM |
| PS | NM | NS | NS | ZO | PS | PS | PM |
| PM | NB | NM | NS | ZO | PS | PM | PB |
| PB | NB | NM | NM | ZO | PM | PM | PB |

| Table 2. Temperature dynamic fuzzy decoupling rule control table. |
|---------------------------------|
| \( U_2 \) | NB | NM | NS | ZO | PS | PM | PB |
| NB | NB | NM | NM | ZO | PS | PM | PB |
| NM | NM | NM | NS | ZO | PS | PM | PB |
| NS | NS | NM | NS | ZO | PS | PS | PM |
| ZO | NB | NM | NS | ZO | PS | PM | PB |
| PS | NM | NS | NS | ZO | PS | PS | PM |
| PM | NB | NM | NM | ZO | PM | PM | PB |
| PB | NB | NM | NM | ZO | PM | PB | PB |

The increment \( \beta \) of the first 7 humidity adjustments and the increment \( \theta \) of the temperature adjustment are ranked as \( \beta_1 \) to \( \beta_7 \) and \( \theta_1 \) to \( \theta_7 \) from small to large, and the output \( U_1 \) and \( U_2 \) domains are respectively formula 10 and formula 11.

\[ U_1 = \{ \beta_1, \beta_2, \beta_3, \beta_4, \beta_5, \beta_6, \beta_7 \} \]

\[ U_2 = \{ \theta_1, \theta_2, \theta_3, \theta_4, \theta_5, \theta_6, \theta_7 \} \]

According to the regulation rules of the air conditioning control system, the final control output of actuator 1 and actuator 2 is:

\[ Y_1 = F_1(t) + U_2 \]

\[ Y_2 = F_2(t) + U_1 \]

The decoupling compensation control rules of the fuzzy compensator are updated after each adjustment. Both the output \( U_1 \) and the output \( U_2 \) are based on the first 7 coupling quantities of the current regulation, and each adjustment is constantly close to the optimal control output.
4. Data analysis

The traditional control mode and the dynamic decoupling control mode are shown in figure 3 and 4. In figure 3, under the dynamic decoupling control mode, the adjustment error of the temperature in the workshop of the textile mill is ±0.3℃, and the adjustment error of the humidity is ±5%. With the operation of the system, the regulation time is reduced twice than the traditional regulation time. The change curve of temperature and humidity gradually tends to be gentle to meet the requirements of temperature and humidity in the workshop production line. By applying the dynamic decoupling control mode of the system, the error of temperature and humidity is reduced and the adjustment time is shortened, and its adjustment effect is obviously better than that of the traditional control mode.

![Temperature Contrast](image)

Figure 3-a. Temperature contrast.

![Humidity Contrast](image)

Figure 3-b. Humidity contrast.

From figure 4, it can be seen that after applying the air conditioning control mode of this system, the electricity consumption is obviously reduced, and the total energy consumption is reduced by 13.8%. By applying the dynamic regulation algorithm, the effect of reducing the electric energy is better than that of the traditional control mode.
5. Conclusion
In this paper, the air conditioning control system of textile mill based on TMS320F28335 is designed, and the decoupling algorithm of bidirectional dynamic fuzzy decoupling compensator is applied in the system to realize the rapid regulation of temperature and humidity of production workshop demand. By constantly dynamically updating the optimal fuzzy decoupling rules, the control accuracy of temperature and humidity in the textile workshop is improved, and the energy consumption of the air conditioning regulation system is reduced. At the same time, it has the characteristics of reliability and easy operation, which meets the requirements of the textile enterprises on the air conditioning control system.

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