Design of Grain Dryers’ Control System

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Abstract: TMS320F28335 which is a TI high-performance TMS320C28x series 32-bit floating point DSP processor is used as the core of the controller, and the hardware is designed, which includes temperature collection, temperature and humidity collection, moisture detection and motor control. The development environment of the system CCS, and then for the characteristics of grain dryer control system, the control system software modular design, the use of fuzzy control method to achieve food grain motor control, and MATLAB simulation analysis, Fuzzy control is used to control the feasibility of the grain moisture.

1. Significance and background
In this essay, grain dryers’ control system demands a good human-computer interface and a fast handling capability. The primary performances of grain dryers are: precision, which means moisture content of grains, which have completed drying, should try best to reach optimization value set beforehand; stability, which means in the process of controlling, the system must be stable, making sure the homogeneity of water of grain after drying; response speed, which means to every disturbance, such as the difference of grain moisture content entering the dryer, the controller should quickly make adjustment to make sure the stability of the system; adaptability, control system can normally work under a wider range of process conditions [1]. Besides, in the process of grain dryers’ control, it should also reach the level of adjusting the humiture of drying medium, the temperature of grains, the temperature of exhaust gas, grain moisture content, the testing of material position and ultralimit alarming, as well as realize automatic adjustment to the temperature of dry medium and the speed of drying (the revolving speed of displace motors).

The basic aim of grain dryers’ control system is to make the water of grain after drying within its safety range. The control aim of the system developed in this essay is as followed:

1) To control the water of grain after drying by adjusting draining crop speed, with inlet grain moisture content within 14%-16% and water of grain after drying within 10-12%;
2) To make sure grain temperature in the drying process by changing the temperature of hot wind...
in the drying period;
(3) To control the process of drying work to realize the humiture of drying medium, the
temperature of grains, the water temperature of modulation section, grain moisture content and
the testing of material position and ultralimit alarming.

2. The general planning of system hardware
From the overall function of grain dryers’ control system and the control objectives, there are
several requirements about the system’s controller.
(1) The performance of the control system’s microprocessor must have a higher requirement. For
example, in order to realize the accuracy of processing data, such as temperature, grain moisture
content, etc. in real time, it must have the ability to process data quickly.
(2) The control system’s microprocessor must have multi-input and multi-output interfaces;
(3) The control system’s microprocessor must also have a larger and programmable storage unit
and internal memory unit so as to reach the capacity of storing different types of data;
(4) The control system’s microprocessor must have communication ports and multiple interrupt
response methods, such as: external response, timer interrupt response, etc.
Based on above four points about the requirements to grain dryers’ controller, the article
primarily selects DSP as the controller of grain dryers. The general planning of the designed
control system is showed in figure 1.

![Figure 1. The overall control system block diagram](image)

There are mainly two major parts, data collection and CMOD, of which data collection includes
moisture detector and all kinds of sensors. Sensors mainly include temperature sensor, temperature
and humidity sensor and material level sensor. CMOD mainly controls inlet grain elevator, drain grain
motor, water and hot blast heater and other units. The distribution of all sensors in grain dryers’
control system and the layout of its partial actuators are presented in figure 2.
2.1 Hardware Selection
The selection of hardware is shown in the below table 1[2].

| Controller Selection      | DSP(TMS320F28335) |
|---------------------------|-------------------|
| Temperature Sensor        | DS18B20           |
| Temperature and humidity sensor | SHT11            |
| Grain moisture detection  | PT-2703           |
| Level signal acquisition  | HJ-SE Series Rotary Level Sensors |

Among them, DS18B20 sensor separately tests the temperature of inlet grain, the grain temperature of drying chamber, the temperature in the cooling section and temperature of hot water.

SHT11 temperature and humidity sensor is used to test the humidity of hot wind and tail gas. The measuring instrument PT-2703 for grain moisture content is used to test the moisture content of grains at the inlet grain entrance and outlet grain entrance.

HJ-SE series damped rotation type level sensor is used to test the height of grains in grain dryers’ provision section so as to fix when the elevator starts to transport grains, keep the weight of grains inside the grain dryers stable and the safety of equipment.

2.2 Electric Machine Control Module
The drying and control process of grain dryers needs a lot of electrical motors, including the feeding motor of water and hot blast heater, draught fan, water pump, drain grain motor, bucket elevator, etc. In the control process, controlling the feeding motor of water and hot blast heater and drain grain motor is very important, which can only make sure the temperature of hot water and hot wind as well as the moisture content of outlet grains during the process of drying. Hence, in this essay, the introduction focuses on the controlling of the feeding motor of water and hot blast heater and drain
Water and hot blast heater adopts the screw conveyor to transport fuel. During the drying process, mainly rely on the screw conveyor to adjust the water and hot blast heater and control the temperature of hot wind and hot water. Adjust the motor speed of draining crop mechanism to reach the purpose of controlling the grain moisture content. Therefore, the motors of screw conveyor and draining crop mechanism adopt servo motors to drive. Compared with other controllers, one of DSP’s advantages is to control the motor more easily, which is one of the most important reasons to select DSP as controller. This article adopts PWM to regulate the speed and control the transportation motor of hot blast stove[3].

Figure 3 shows the control principle of the transportation motor. DSP, as the core of control system, contains A/D conversion module inside and samples phase current to complete the corresponding current regulation. The speed regulator adopts PID control algorithm. Control the duty ratio of modulating signals according to its control output so as to control motor speed.

![Figure 3. Motor control schematic](image)

### 3. The software design of grain dryers’ control system

Under the development of CCS3.3, write the control program first and then download the written program into the TMS320F28335[4].

#### 3.1 Software’s general design

The software development of grain dryers’ control system adopts modular scheme, which mainly includes data collection, action executing, human-computer interface, alarm and other modules. During the control process of grain drying, mainly use the system’s main program to separately adjust different subroutines to complete the functions the control system needs. The flow chart of the system’s main program is shown in figure 4.
When the grain dryers’ control system starts to work, which means DSP is being charged, firstly, invoke the system’s initializer to initialize every module, such as DSP’s initialization, timer and interrupt initialization, etc. When the drying process begins, collect the temperature of drying segment and cooling section inside the drying tower through DS18B20 and the temperature of inlet grain machine. SHT11 adopts humiture of hot blast air, which transfers the digital signals to DSP and compares with set value. DSP processes the adopted information to control the motor speed of hot blaster heater’s inlet material machine. If the temperature of hot blast air and hot water surpasses the range, it will sound an alert. When moisture detector detects the moisture value does not match the set value, the upper computer will send out related control demands to adjust the frequency of drain grain motor and control its rotate speed.

3.2 Temperature Sample Module
DSP can control DS18B20 through a port of a line, whose specific progress is to perform reset first, and then all kinds of ROM instructions, memory reference instruction, etc. Its storage command operation table is shown as table 2, which mainly includes the command of reading serial number (33H), searching ROM commands (FOH), matching ROM (55H), skipping ROM (CCH) commands, as well as alarming and searching commands.
Table 2. Stores the command table

| The name of the instruction | Instruction code | Function Description |
|-----------------------------|------------------|----------------------|
| Read ROM                    | 33H              | Read the ROM serial number in the DS18B20 |
| Search ROM                  | F0H              | Search device encoding |
| Matches the ROM             | 55H              | Finds the device based on the encoded value |
| Skip ROM                    | CCH              | Skip reading the encoded value operation |
| Alarm search                | ECH              | Alarm device search |

3.3 Temperature and humidity gathering module
DSP may adopt the communication mode of two-wire system to transport related data with SHT11. Before the commencement of communication, DSP firstly send start-up sequence. It means when the clock signal SCK is of high level, turn the DATA from the high level to low level and in the next time when SCK is of high level again, turn the DATA into high level. Then, invoke writing time slot to publish temperature or humidity command and delay a while to wait for the completion of measurement. During the process, SHT11 will pull the data cable into low level. When the measurement is finished, DSP will invoke reading time slots to read the measurement data of temperature and humidity and store them in the fixed units. F28335 will compare measured value with set value, producing start and stop of different equipment and alarm signals. The command of SHT11 is shown in figure 3.

Table 3. SHT11 Command Table

| The name of the instruction                  | Instruction code |
|---------------------------------------------|------------------|
| Temperature Measurement                     | 03H              |
| Humidity measurement                        | 05H              |
| Read the status register                    | 00111            |
| Write status register                       | 00110            |
| Soft reset                                  | 11110            |

4. Fuzzy control of the drain grain motor speed
Fuzzification is to change the certain value in the discussion domain into the fuzzy sets of quantificational field. In the actual control process, the two major factors-systematic deviation and deviation variation rate play the main role. Commonly take the two amounts as the input quantities to control the system and perform adjustment. Output often chooses the amount which needs controlling. Hence, the article selects water sampling value of grain after drying and deviation value E of target
water content, the variation rate of deviation value EC, the rotate speed of drain grain motor U as linguistic variances.

In the fuzzy control of grain dryer, if set the expected value of moisture content of grain after drying as F1 and grain moisture content of drain grain entrance measured by moist content detector as F2. Then the deviation E and the change rate of deviation value EC respectively are:

\[ E(t) = F1 - F2 \]

\[ EC(t) = E(t) - E(t - 1) \]

Select the 7-grade quantization level of three linguistic variances, which means \{-6, -5, -4, -3, -2, -1, 0, 1, 2, 3, 4, 5, 6\}. The universe of discourse of deviation E is \([-3, +3]\), the universe of the change rate of deviation value EC is \([-2, +2]\) and the universe of U-output speed of drain grain motor is \([-200, +200]\). Then quantification factor Ke, Kec and scale factor Ku are respectively:

\[ K_e = \frac{6}{3} = 2 \], \[ K_{ec} = \frac{6}{2} = 3 \], \[ K_u = \frac{200}{6} \].

In the end, build up simulation model as is showed in figure 5.

![Simulation Model](image)

**Figure 5.** Fuzzy control simulation model

Simulation results are showed in figure 6. The time constant curve 1 corresponds to be 210 and the time constant curve 2 corresponds to is 300. It can be seen that the two situations can realize non-overshoot control. Besides, fuzzy control does not have clear influence on parameters variation, reduces the interference to control system by various interference factors in the process of control and applies fuzzy control onto the control of drain grain motor to make the rotate speed change steadily and fast.
Conclusion
Through the analysis of functional requirements of grain dryers’ control system, the essay fixes the general control planning of the system. Adopt F28335 as the core controller and design the hardware, which mainly includes temperature data collection, temperature and humidity gathering, moisture detection, motor’s control, etc. Ensure that adopt DS18B20 temperature sensor in the control system to measure the temperature in every part and SHT11 temperature and humidity sensor to test hot blast air. Use the PWM module of F28335 to perform frequency control on the feeding motor of water and hot blast heater and grain dryer’s drain motor. In the end, it introduces to systematically develop environment CCS, and then performs modularized design for software of control system. Meanwhile, adopt the method of fuzzy control to realize the drain grain motor’s control, design corresponding rules and use MATLAB to perform simulated analysis, which determines the possibility that use fuzzy control to command the outlet grain moisture.

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