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DEVELOPMENT OF CONTROL SYSTEM FOR FOOD PROCESSING TESTING MACHINE

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ABSTRACT

Computer control system has been widely applied in food industry with the development of computer industry. This thesis introduces a kind of control system that uses the upper and lower computer structures taking tablet machine as the upper computer and single chip microcomputer (SCM) as the lower computer. This study mainly includes contents of overall system design, hardware and software design and design of upper computer application software. It first makes an introduction on the overall design of the system including working process of food processing testing machine, hardware and software design of testing machine control system as well as overall control scheme design of the testing machine; moreover, provides detailed information on hardware design of lower computer of testing machine control system, puts forward development direction conforming to practical application and discusses temperature control module and on-off input and output module; finally researches the software design of upper computer of testing machine, realizes real-time record and monitoring of field data and works out machine running, record query, alarm and other dynamic operation pictures. This system is able to manage food processing production in a modern way to improve the efficiency of production; and meanwhile, control the precision and achieve significant economic benefits. It also has excellent reference and guiding effects on other automatic food processing industries.

1. Introduction

Food has been always important strategic supplies in every historical stage of each country. An increasing number of new technologies and methods were used in food industry, and a variety of comprehensively used technologies drove the development of food industry as scientific and technological revolution in the 20th century had a profound impact on the food processing industry. For example, Voicu et al. (2008) conducted researches on new apricot hybridization. Jun et al. (2004) explored processing industries of apple and Goff (2013) discussed mechanical processing modes of yoghourt, cheese, ice cream and other dairy products.

Food processing industry combining agriculture and industry with the tertiary industry is inseparably interconnected with agriculture and helps each other forward (Rehber and Rehber, 2000). Food processing industry in developed countries as an important growth point of national economy has turned into a significant manufacturing sector and export

sector for earning foreign exchanges (Viaene and Gellynck, 1999). Developed countries develop food industry early and considerably due to early and high industrialization and urbanization plus fast science and technology development. Food processing industry with a great variety of goods and high degree of mechanization and automaticity guarantees the production efficiency of processing enterprises, at the same time, ensures the stability, integrity, reliability and standardization of product quality. Japan possesses advanced food processing technology, exquisite manufacturing and high degree of automation (Ijiri et al., 2007); food processing industry in France has a very strong development momentum for nearly 30 years and its industrial output grows rapidly (Gopinath and Munisamy, 2005); food production in Germany is featured by complete and diverse variety (Martínez, 2010). America as a great corn production, processing and consumption country has large corn yield, which brings huge economic benefits for the United States (Davis et al., 2000).

Food processing automation in China starts late and has relatively low technical level although it develops rapidly, and its technological content remains to be further improved. Besides, complete sets of food equipment matching food industry are also relatively lagging. Featured by small scale, backward equipment, weak foundation, low technical content, serious disconnection of automatic control system with process design and mechanical manufacturing, poor stability and kitting of products and low precision and degree of automation, most of the enterprises related to food industry still depend on importing a large number of foreign packaging machineries and components, which is not suitable for the rapid development requirements of China's food industry. Therefore, improving the automation level of food processing industry has been of a very considerable practical significance with the popularization and application of microcomputer. Based on current situation of China's food processing industry above, this study describes the technical indicators of food processing testing machine as well as functions of control system in detail.

2. Materials and methods

2.1.Working process of food processing testing machine

Working process is shown in Figure 1.

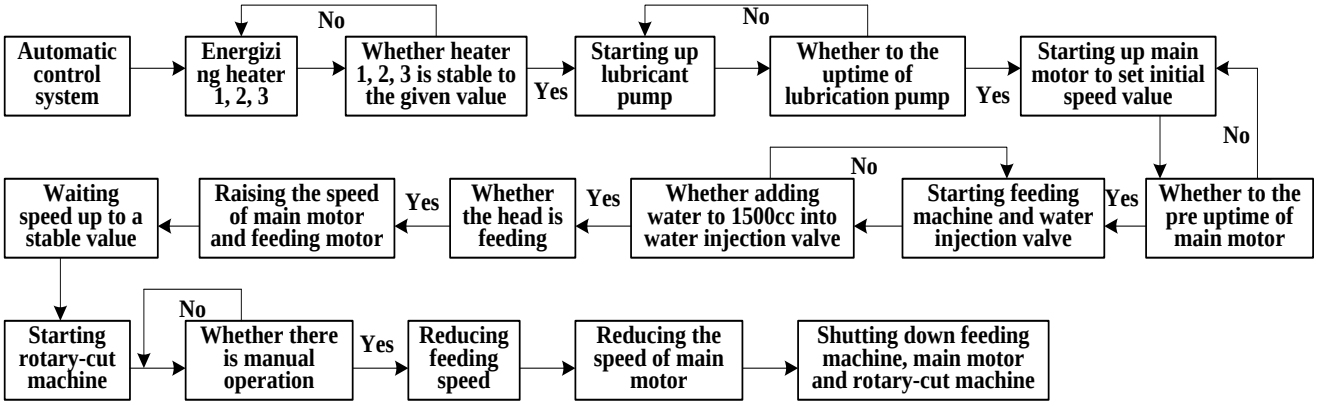

Figure 1. Working process

2.2. Overall design of hardware in testing machine control system

The upper computer uses PPC-1501 panel industrial personal computer (IPC) as man-machine interaction device.

Frequency control device uses a frequency converter series applied in controlling the speed of three-phase current motor, i.e., MICROMASTER420 variable voltage and variable frequency (VVVF) (Siemens).

Sensor adopts temperature sensor (PT100) and pressure sensor (30MPa and 0.2MPa).

2.3. Overall control scheme design of food processing testing machine system

(1) Distributed control system (DCS) and RS-485 computer bus are used.

(2) PPC-1501 panel IPC is taken as host computer.

(3) Based on the design of single chip microcomputer (SCM), input and output modules exchange information with host computer by RS-485 computer bus, so as to collect temperature, pressure and cooling parameters, receive orders from the host computer and output controlled variable.

(4) VVVF device from Siemens as frequency control device receives speed governing order and outputs a given rotational speed by communicating with RS-485 computer bus and host computer.

(5) Application software does a secondary development based on Kingview 6.51 (Wellin Tech) and realizes the given control requirements, development contents include control algorithm and field-bus communication.

3. Results and discussions

3.1. Hardware design of lower computer of testing machine control system

(1) Design of temperature control module

① Scheme constitution

Featured by high precision and excellent stability, thermal resistance is capable of transmitting, displaying and recording temperature output after appropriate data processing (Doyle and Mazzotta, 2000). PT100 thermal resistance sensor is taken as a temperature measurement device, and SCM system consisting of AT89C52 control center controls external heating device and realizes the accurate control of temperature by various control algorithms. Principle of the system is in Figure 2.

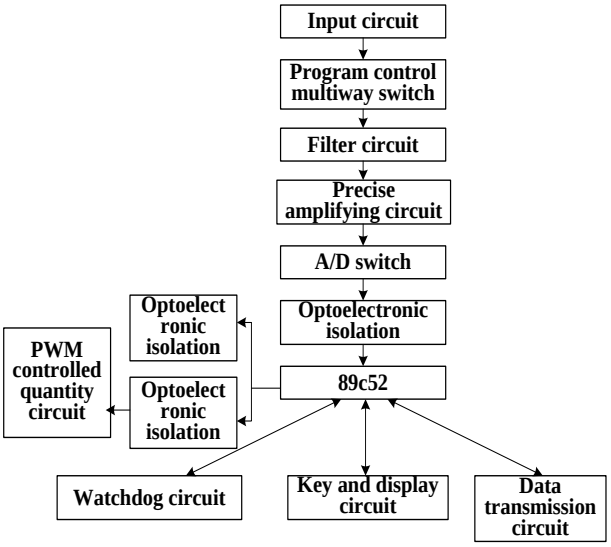

Figure 2. Principle of the system

② Design of input channel

A. PT100 wiring circuit

Resistance of thermal resistance is positively associated with temperature. The following formula describes the characteristics of PT100, and it can be obviously seen that temperature has a non-linear relationship with electrical resistance.

$$R_1 = R_0 \times (1 + A \times t + B \times t^2 + C \times (t - 100) \times t^3) \quad (1)$$

Of them, $A=3.9082\times10^{-3}1/°C$, $B=-5.802\times10^{-7}1/°C^2$, $C=-4.2735\times10^{-12}1/°C^4$, and R_0 is the resistance at 0°C.

B. Design of program control multiway switch

An 8 channel analog is used in measuring, and two differential motion four channel analog switch CD4O52 was applied in selecting each channel (Chen et al., 2004).

C. Filter circuit

To inhibit interference noise, a primary hardware filter circuit is added before the signal amplification and the structure is symmetrized to make sure line balance.

D. Precision differential amplifier circuit

Precision differential amplifier circuit has plenty of advantages, such as slow input, signal amplification, strong common-mode rejection ability as well as single-ended output (Prokopenko et al., 2008). Hence, this thesis uses three pieces of operational amplifier OP07 with low offset voltage and current plus low drift to constitute a two-level precision differential amplifier circuit.

E. A/D switching circuit

Differential amplifier, V/F switch and optoelectronic isolation are used in converting analog input into frequency signal for processing, and V/F switch is realized by applying LM331. In addition, LM331 adopting temperature-compensation circuit is able to improve the conversion accuracy in the whole operating temperature range.

③ Design of control circuit

AT89C52 SCM (ATMEL Corporation) is taken as the control center of analog quantity module (ShengXue, 2009; Hongli *et al.,* 2008), mainly functioned by collecting analog quantity, controlling the output according to different control algorithms; transmitting collected analog state to upper computer by serial port of network communication; receiving data and orders sent from upper computer and controlling the electronic luminescent display (ELD) status.

A. Upper computer

Eight T89C52 SCM (ATMEL Corporation) is taken as the control center of analog quantity module, mainly functioned by collecting analog quantity, controlling the output according to different control algorithms; transmitting collected analog state to upper computer by serial port of network communication; in the meanwhile, receiving data and orders sent from upper computer and controlling the display state of light emitting diode (LED).

B. Watchdog circuit

25045 watchdog circuit resets automatically when the system enters into an endless loop or system voltage decreases to below minimum operating voltage due to break down (Hirose et al., 2004). 40% serial bit in the 25045 is used in expanding PROM storage control parameters, alarm parameters and other control information and data, and exports those information automatically when backroll after power-on reset.

④ Design of output channel

There are mainly two kinds of output quantities in this module; one is to control working condition of external device, and the other one is an alerting signal. Output signal sends drive circuit to control controlled objects by optoelectronic isolation and Schmidt level switch. Seven Darlington circuits UNL2003 are used in driving. Thyristor outputs a string of complete sine wave by adjusting power and zero-crossing trigger technology in the control cycle, and then the breakover time of thyristor in the control cycle is changed by altering the number of sine wave to control the power.

⑤ Design of key and display circuit

Keyboard and display as components realizing man-machine interaction can not only interfere with the state of equipment and data input, also report operating condition and processing results to people (Horacek, 2008).

A. Keys

To save interface line, matrix keyboard interface made up of row line and column line is designed, and keys are located in the intersection of row and column. Five 1/0 ports can form a keyboard with 6 keys in this module.

B. Display circuit

Display adopts serial-in parallel-out shift registers 74HC164 consisted of 9 LED Nixie tube and its static drive circuit to control digital display. Display segment code is loaded serially by SCM and instructed by 74HC164 drive LED during working.

⑥ Design of communication interface

RS-485 serial interface bus is used for data acquisition and network control, sending end driver transmits transistor-transistor logic (TTL) level signal into differential signal and outputs it, and then reverts differential signal to TTL signal in the receiver. Communication distance can reach 1200m when transmitting speed is 100KBIT/S. Serial port of light 89C52 is connected to RS-485 bus via optocoupler 6N136 and RS-485 bus driver SN75176, and finally exchanges data with personal computer (PC) through 4852/232 module.

⑦ Design of power circuit

Multiple stabilized voltage supply is applied in supplying power for each part of the circuit to improve the ability of resisting disturbance of system, and meanwhile, realize the application of optoelectronic isolation technology in isolating input and output channel. 12V power supply is designed for operational amplifier, analogue switch and temperature sensor; 5VI for the connection part of central processing unit (CPU) and optocoupler; 5V2 for the connection part of optocoupler and input and output channel. Each power supply is made up of 7800 series three terminal regulator, and adjustable three-terminal voltage regulator LM317 can be used for forming 1.75V power supply, in order to power ELD Nixie tube.

(2) On-off input and output module

①Scheme constitution

Based on SCM and shifting register, this study designs an inexpensive and highly efficient intelligent multi-channel on-off input and output module (Tan *et al.*, 2003). Microprocessor uses 89C52 (Atmel Corporation) to expand on-off switch quantity condition input in the parallel port (Cristea and Danchiv, 2010), deserializer chip 74HC164 outputs all required control signal and controls 32-channel output. Hardware mainly includes SCM, input and output channel circuit, data communication circuit, and detailed process is shown in Figure 3.

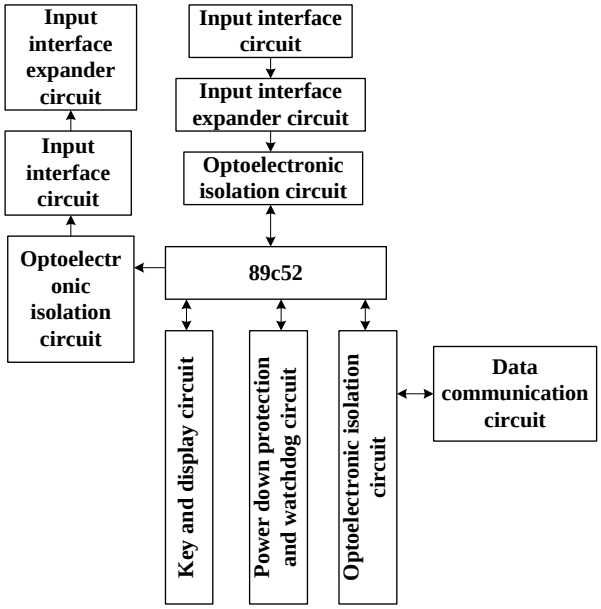

Figure 3. Process of on-off input and output

②Design of input channel

A. Design of input interface circuit

The selection of R1 needs to consider resistance and power consumption, and its volume should not be oversize (Huber and Jovanovic, 2000). The relationship between power consumption p, resistance R1 and alternating voltage effective value U that may be joined up wrongly is displayed in Figure 4.

$$P = \frac{1}{R}\left(\frac{V_{cc}}{2} + 0.45U\right)^2 \quad (2)$$

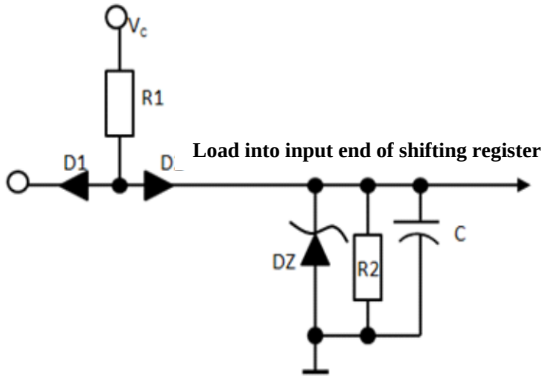

Figure 4: Signal conditioning of input channel and circuit protection

B. Design of input interface expander circuit

Four pieces of 8 bits parallel input serial output shift register 74HC165 is applied in expanding channel 32-channel switch input, and P0.0 port of SCM controls S/L of 74165 in a working way of parallel input or serial output.

③Design of control unit

AT89C52 SCM as the control center is able to collect switching value on time, process calculation, output control law, and transmit collected switch condition to upper computer by serial port of network communication, also receive data and orders from upper computer and display switch condition as well as confirm and report accident.

Watchdog circuit is similar to temperature control module, especially design of communication interface and power circuit. Here, it is not explained in detail.

3.2 Design of upper computer software of food processing testing machine

(1) Design of upper computer control software

① Input of control parameters and display of controlled variable

One advantage of this module lies in forming a visual man-machine interface combined with strong graphic function of computer. Some control parameters of lower computer are capable of making lower computer hardware produce corresponding actions by clicking and inputting screen of upper computer, and meanwhile, controlled variable can be displayed on the screen of upper computer in the graphic form.

② Realization of proportion integration differentiation (PID) control algorithm

As to the temperature control experiment, upper computer software adopts visual basic (VB) to realize time optimal PID control and transmits controlled quantity, i.e., breakover time of thyristor to lower computer by serial port, and then, lower computer transmits the obtained temperature value to upper computer as input of control system.

③ Communication with lower computer

Every communication of CP asks SCM 8 channel input instructions and 8 channel output control parameters and other command groups (Díaz et al., 2002). Figures 5 and 6 show the communication process of control host computer and SCM.

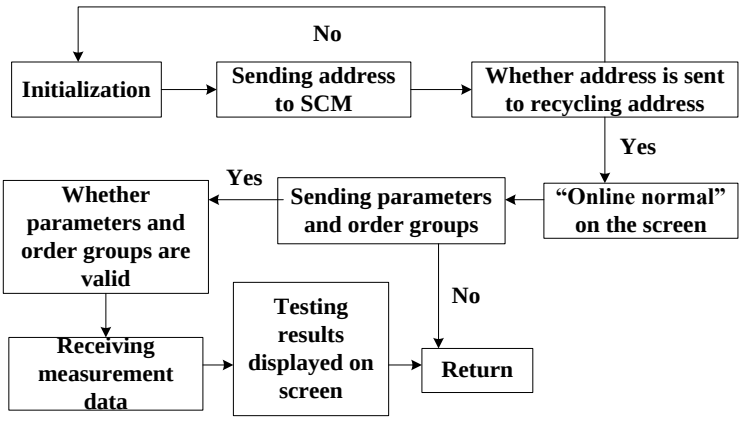

Figure 5. Process of PC communicating with SCM

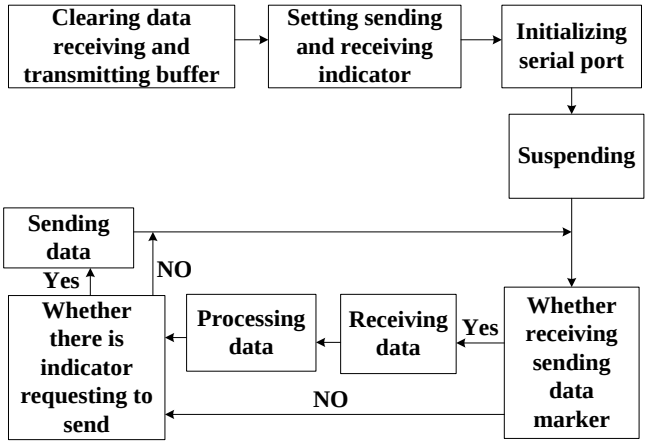

Figure 6. Process of SCM communicating with PC

(2) Design of upper computer monitoring pictures

Graphical interface is aimed to simulate actual process and corresponding device with abstract pictures. Database construction refers to establish a concrete database to reflect attribute of industrial control object, for instance, pressure and temperature inside charging barrel of food processing testing machine. Monitoring picture system of testing machine is composed of several monitoring pictures, including parameter setting and operating picture, running condition picture, temperature history curve and real-time curve picture, alarming window picture. Its system framework is in Figure 7.

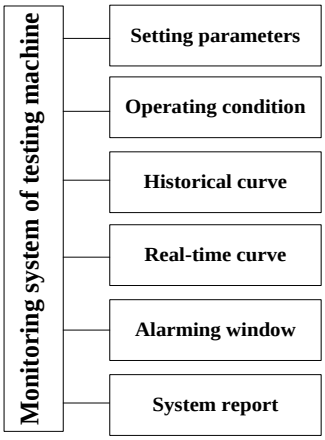

Figure 7. Framework of monitoring system

4.Conclusions

Based on current condition and development tendency of domestic food processing testing machine, this study proposes and designs a control system for food processing testing machine that meets the domestic market demand. This control system integrating data acquisition, real-time control and display in one not only reduces the cost of system, also makes full use of computer resources and speeds up the development. At the same time, this thesis carries out a thorough and extensive research on theoretical analysis, control strategy and industrial control software development according to the characteristics of food processing testing machine.

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