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Design and Control of Automatic Production Line for Chemical Food Additives

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With the people's living standards improving greatly, the demand for chemical food additives (CFA) has been continuously increasing. But in the backward CFA production system, there is lack of transparency for the processing information, making it difficult to gain the consumers' trust. For this, this paper designs a complete set of automatic production lines for CFA to control and manage the whole process, and also designs the Internet of Things (IoT)-based electronic tag system. The research results show that the system can make distributed control of various dispersed input and output points in the CFA production process; the design of electronic tags can make it clear for the people about the information of raw materials entering factory, production and processing information, inventory information, and ex-factory information; the entire design system works well and can greatly improve the management efficiency of CFA manufacturers. This research lays a technical foundation for the technical upgrading of CFA production lines.

1. Introduction

Chemical food additives (CFA) are substances that are added to foods for a certain purpose in the processing, manufacturing, packaging, storage, and transportation of foods because of the needs in sensory or process technology (Ju et al., 2017). However, due to the scientific and professional nature of CFA, many consumers do not understand it, and even fear about it (Gonzalez et al., 2014). CFAs help to improve the nutritional value of foods, prevent food spoilage, promote food stability and storage, facilitate food adaptation and automation, and meet the needs of different groups of people (Kastner et al., 2014). The food industry is concerned with the health of all people, and every country attaches great importance to it. The competition of CFA is inseparable from its high standardization, intensification, mechanization and informationization. The modern food processing industry is developing in the direction of technicalization and clustering (Oliveira et al., 2015, Valente et al., 2012; Rajendra Pawar et al., 2018).
The development of CFA automatic processing equipment and automatic production lines can drive the development of the food processing industry, manufacturing and commerce (Horcas et al., 2016). At present, China's total output of CFA ranks first in the world, but the proportion of total production by automatic production lines is below one-third. Therefore, China's CFA enterprises have a very broad space for development (Mul'chin et al., 2010). The future CFA processing industry will develop in a diversified, standardized, graded, low-cost and green environmental protection direction (Oda et al., 2017). The automatic control system is mainly composed of four systems: analog instrument control, centralized digital control, distributed control and fieldbus control, including computer hardware, communication network, transmission equipment and instrumentation (Pinzi et al., 2009). In view of the current CFA production, the integrity of processing information cannot be guaranteed, making it difficult to gain the trust of consumers (Mousavi & Siervo, 2017). Therefore, taking CFA as the research object, this paper focuses on the key technologies of automatic production line management and control integration system, and based on the electronic tag system technology, develops the management information and CFA information management system by combining the characteristics of CFA processing information.

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2. Management and control-integrated system design of automatic production line system

2.1 System overall design

The entire CFA automatic production line is based on a control system and targets the management system. The entire system must have high reliability and self-diagnosis in the event of failure (Chen et al., 2016). The main control technologies of the control system include production process control, process data acquisition and processing, equipment status data acquisition and processing, alarm and emergency handling, key process parameter monitoring and information integration services. The main technical functions of the management system include raw material entering information management, processing information collection, ex-factory information management and inventory information management. The CFA automatic production line control system designed in this paper adopts the combination of distributed control system and field bus control system, mainly including production line operation control and monitoring, process data management, product information identification, product information management and traceability, etc.; the operation of entire production line includes two parts: monitoring and remote services, namely process monitoring and enterprise level monitoring.

2.2 Key technologies of design and control for automatic production line system

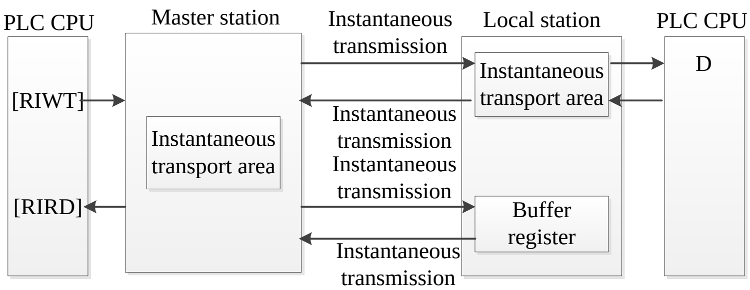
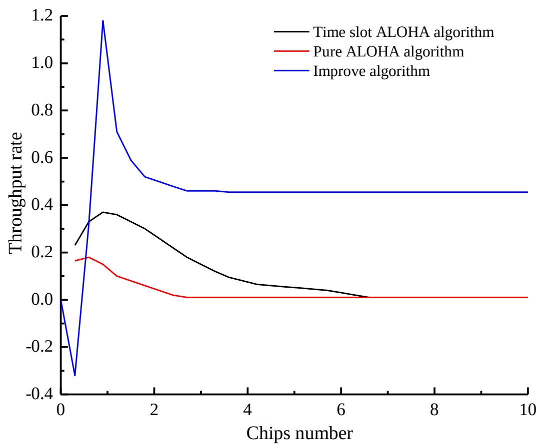


Figure 1: CC-LINK local station equipment station instantaneous communication process



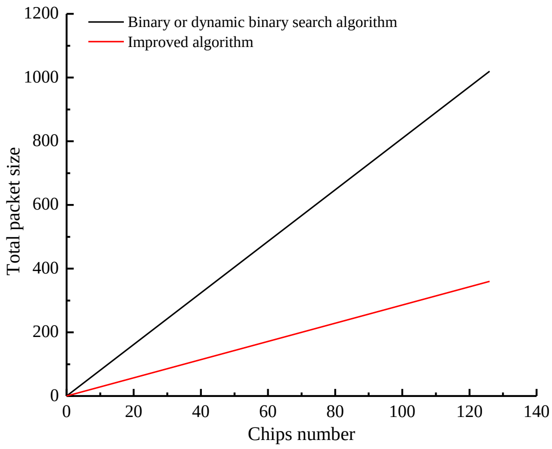


Figure 2: Throughput graph of three algorithms   *Fig.3 Packet graph of two algorithms*

The key technologies for the design and control of CFA automatic production lines include the PLC communication technology, the anti-collision technology of electronic tags, and the information network technology of EPC system. Fig.1 shows the instantaneous communication process of the CC-LINK local equipment station, indicating that the instantaneous transmission and communication will not affect the cyclic transmission of the system, and ensure high-speed and reliable communication. Radio frequency identification (RFID) is a non-contact electronic tag identification technology. In this section, an improved RFID tag-based anti-collision algorithm was used. Fig 2 lists the comparison between this algorithm and the other two common algorithms on system throughput. It can be clearly seen that the improved algorithm requires the number of tags to be more than one, and within the effective recognition range, the throughput of the improved algorithm is greater than the slotted ALOHA algorithm and the pure ALOHA algorithm. Fig.3 shows the data packet diagram of the improved RFID tag-based anti-collision algorithm and binary or dynamic binary search algorithm, which indicates that the data packets of both algorithms increase linearly with the increase of the number of chips, and the total packets of the improved anti-collision algorithm is lower than the other two algorithms.

3. Software and hardware system design of chemical food additive automatic production line control system

3.1 Hardware design of control system

The reliability and stability of the automatic production line system is the main principle of the design. The design core is the PLC control technology. The hardware design of the control system must ensure the stability and safe operation of the system, and also meet the control requirements of the controlled system. The selection of the hardware system includes programmable controller, touch screen, inverter, control system hardware configuration and network configuration. Fig.4 shows the hardware structure of the control system. The network of the hardware system consists of CC-LINK, and the control core PLC is connected to the inverter, other devices and the intermediate controller through the bus. After completing the system hardware configuration, the setting of station type, station number, and baud rate are performed.

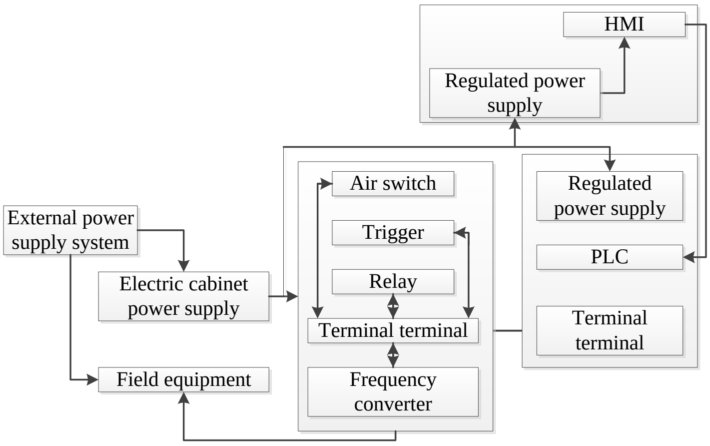


Figure 4: Control system hardware structure diagram

3.2 Software design of control system

The software design of the CFA automatic production line control system includes two parts: PLC program design and process monitoring configuration software design. The synchronous control system adopts master-slave control system. Fig.5 is a schematic diagram of three-line linkage control, in which the three lines are controlled by the inverter, and the automatic operation of the system can be realized through the PLC program. Fig. 6 shows the synchronous control scheme of the motor; through the closed-loop control mode, the synchronous operation of multiple motors is realized. Fig.7 shows the automatic production line control system. The entire automatic production line control system includes data acquisition, data processing, data display, alarm processing, management and maintenance; its main control interface consists of status display area and control area, to directly control the start and stop of the system.

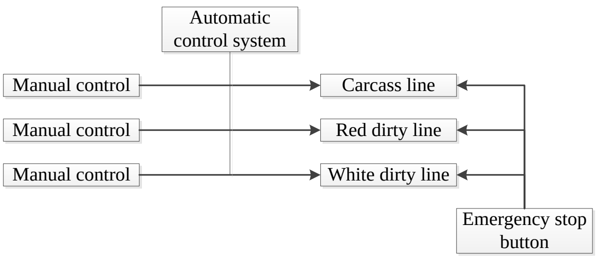


Figure 5: Three-line linkage control diagram

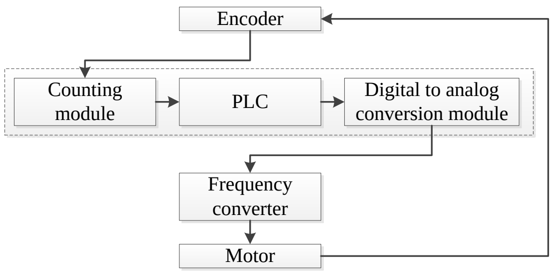


Figure 6: Motor synchronous control scheme

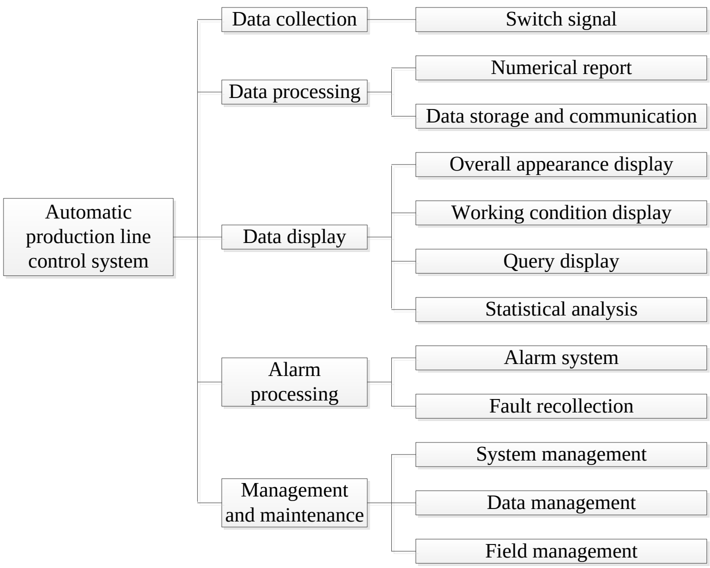


Figure 7: Automatic production line control system

4. Management system design of automatic production line for chemical food additives

4.1 Design of electronic product code system based on Internet of Things

According to the enterprise plan, the entire automatic production line system for CFA requires real-time collection, recording and management of information to ensure production and processing in line with strict procedures. According to different CFA production processes, automatic production lines often contain multiple-branch processing stations, and the processing at different stations will have a great impact on the final CFA. In order to reduce the system use and maintenance costs, this paper sets the electronic tag to be recyclable, and the tags on the production line represent all the information for the batch of food additives, including raw material entering information, production processing information, inventory information and ex-factory information etc.

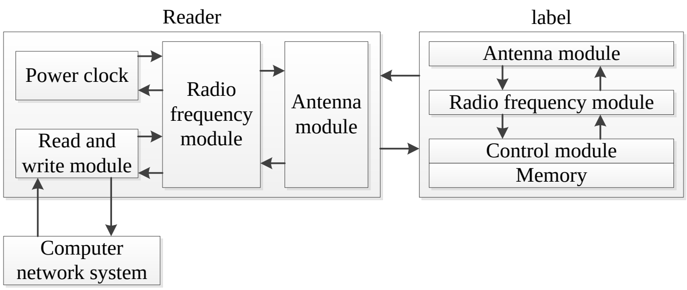


Figure 8: Radio frequency identification system

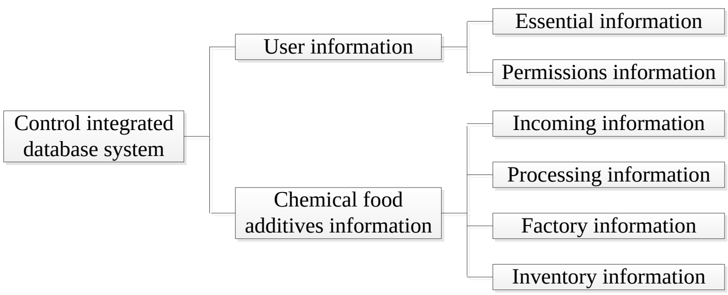


Figure 9: System database structure diagram

The electronic product codes used in the whole system are scientific, comprehensive, compatible and international, and the electronic code for each batch is unique. RFID technology can use the non-contact identification of electronic codes to achieve two-way communication, thus endowing chemical food additives a unique identification code and realizing automatic identification of products. Fig. 8 shows the RFID system consisting of two parts: the tag and reader. Fig.9 is a structure diagram of system database; the entire database information includes user information and CFA information, the specific user information data sheet, production information data sheet, and inventory information data sheet (Tables 1-3).

Table 1: User information data sheet

Field name	Data type	Field size	Space
User number	Char	20	Not allow
User name	Varchar	30	—
User password	Varchar	30	—
User rights	Varchar	25	—
User sex	Varchar	5	—

Table 2: Production information data sheet

Field name	Data type	Field size	Space
EPC coding	Char	60	Not allow
Production time	Char	20	Not allow
Production manager	Varchar	30	—
Storage time	Char	20	Not allow

Table 3: Inventory information data sheet

Field name	Data type	Field size	Space
EPC coding	Char	60	Not allow
Storage time	Char	20	Not allow
Inventory location	Varchar	30	—
Quality guarantee period	Char	20	Not allow
Warehouse temperature and humidity	Varchar	20	—
Warehouse manager	Varchar	30	—

4.2 System debugging and operation

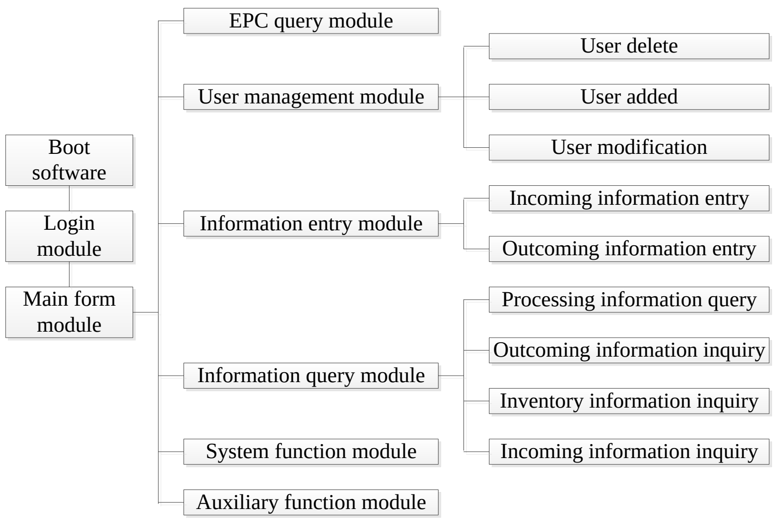


Figure 10: Client software overall structure

In the entire automatic production line control system, the client-side is the hub of human-computer interaction. Fig.10 shows the overall structure of the client software. The main form module is the main module of the entire client, including the electronic code query module, the user management module, and the information entry module, information query module, system function module and auxiliary function module. In this paper, for the designed automatic production line system for CFA, the installation, commissioning and trial operation of the system equipment were carried out, and the electrical system installation and wiring, control system software and management system components were debugged. The results show that the automatic production line system meets the processing requirements for CFA and operates in good condition.

5. Conclusions

Taking the chemical food additives as research objects, this paper focuses on the key technologies of automatic production line design and control system, and also debugs the system. The specific conclusions are as follows:

(1) The key technologies for the design and control of CFA automatic production lines include the PLC communication technology, the anti-collision technology of electronic tags and the information network technology of EPC system.

(2) The entire automatic production line control system includes data acquisition, data processing, data display, alarm processing, management and maintenance. Its main control interface consists of two parts: the status display area and the control area, which directly controls the start and stop of the system.

(3) The electronic tag on the production line represents all the information of the same batch of food additives, including raw material entering information, production and processing information, inventory information and ex-factory information. The operation and debugging results of the system show that the automatic production line system meets the processing requirements of CFA, and the production line is in good working condition.

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