Design of Management and Control System of Aero-engine Nozzle Processing Line

Kai Chang[1,2,*], DeChao Zheng[1,2], Jian Yin[1,2] and Guangchao Tan[1,2]

[1] Intelligent Detection and Equipment Department, Shenyang Institute of Automation Chinese Academy of Sciences, Shenyang 110016, China.
[2]Institutes for Robotics and Intelligent Manufacturing, Chinese Academy of Sciences, Shenyang 110016, China.

[*]E-mail: changkai@sia.cn

Abstract. This paper introduces a kind of management and control system of machining production line for aero-engine nozzle. The main logistics is based on the logic control of PLC, which can dispatch a robot to realize the automatic transfer of the parts between workstations, automatic feeding and unloading of processing and testing equipment. Workstations are equipped with RFID to detect the identification of each nozzle. The system can reconstruct the process route according to the nozzle type, associate processing and test data of the nozzle with their identification number to establish the processing file. It realizes data exchanges between management and control systems by OPC interface, achieves centralized monitoring and control of the equipment of the whole line and improves the informatization level of workshop.

1. Introduction

At present, China's aviation manufacturing equipment is developing at a high speed. In most aeronautical parts processing factories, although multi-axis high-precision CNC equipment is introduced, the flow of semi-processed products between devices are still carried manually. It is inefficient and inconvenient to adjust the processing parts between processes, resulting in the accumulation of semi-finished products which occupies a large amount of space. Therefore, the demand for establishing automatic mechanical processing logistics transmission line is increasing day by day.

Because of the particularity of aviation products, the production process based on small and medium batches need to deal with a variety of processing objects. So, the production information changes frequently. It is very important to grasp the information of parts for the production management and control system.

Based on the nozzle processing project of an aero-engine company, this paper introduces a management and control system for a flexible machining production line, which can realize the automation of feeding and unloading, centralized control and monitoring of processing process and the establishment of parts processing files.

2. The layout of machining production line and design goal of management and control system

2.1. The layout of machining production line

The layout of machining production line for an kind of aero-engine nozzle is shown in figure 1. The processing flow is: putting the blank into the upper rotating silo manually → automatic marking → processing in turning-milling compound center → milling center → cleaning and drying → measuring in CMM → putting finished product to the lower rotating silo automatically. In order to maintain production rhythm of turning-milling and milling process cycle, two milling centers are arranged in machining production Line. The robot which can clamp the nozzle automatically with ground track realizes the automation of main logistics.

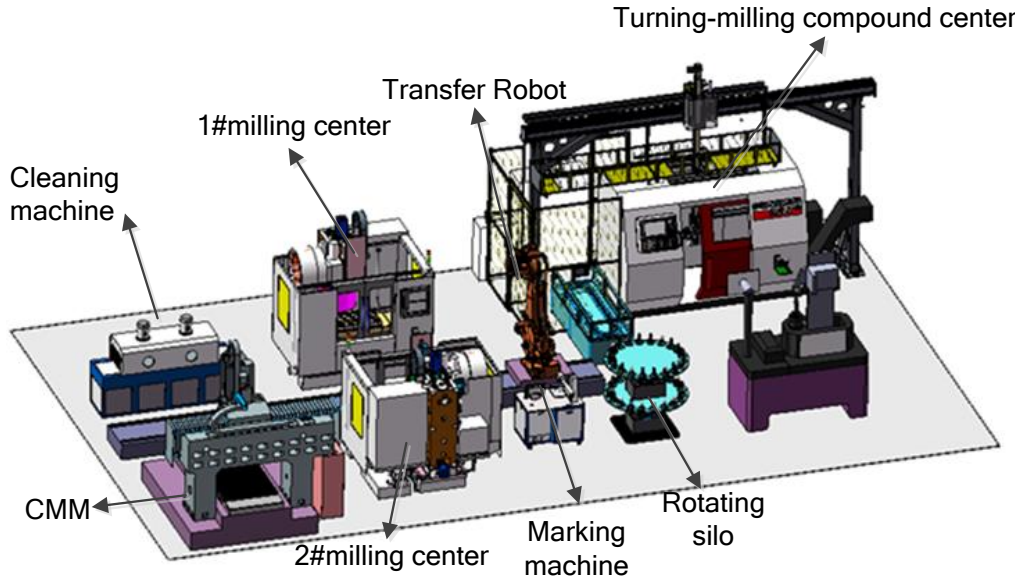

Figure 1. The layout of machining production line.

2.2. The design goal of management and control system

Based on the layout above, we need to establish a reliable system of management and control which can support the operation of a flexible machining production line. According to the technical agreement, it needs following 4 functions：

- The control system can dispatch the robot to realize the automatic transfer between all workstations of machining production line.
- The control system can identify the code of parts at each station which can be uploaded to the management system.
- The management system can realize real-time acquisition of production status data, reconstruct the process route according to the identification of parts and centralized display the status of all equipment.
- The management system can establish the process files of nozzle parts. The processing and testing key data of each production can be traced through unique identification code.

3. Design and implementation of management and control System

3.1. Hardware design of control System

The core of the main logistics control system is PLC 315-2PN/DP. Through field bus PROFIBUS and RS232 serial communication interface, it can interact with 6-DOF robot, three CNC machines (840D SL CNC system), cleaning machine, marking machine and CMM. It can dispatch robot to realize material placement for a station equipment, and then notify the equipment to start. When the equipment completes a work cycle, the completion signal of processing or testing will be fed back to main logistics control system, and then it will dispatch the robot to grab the parts to the next workstation to complete the full automation operation of the whole logistics.

In order to automatically collect the key data of each workstation which will be correlated with the code of nozzle number, RFID read-write head are configured in marking machine, CNC machine, cleaning machine and CMM workstations. The RFID carrier tag is embedded in the accompanying tooling of each nozzle component. Each RFID read-write head has PROFIBUS bus interface which can be connected to the main control PLC for read-write programming. When the robot grabs the blank parts to the marking machine station (1 # workstation), the management system transmits the information of flow number to the main control PLC and marking machine. After the marking process, the control system will notify the robot to grab the blank to the RFID read-write head of this workstation and write the code information into the RFID carrier embedded in accompanying tooling to achieve the unification of nozzle identification number and storage object of RFID carrier. When the nozzle parts arrive at a workstation, control system will read nozzle code stored in RFID carrier tag through the read-write head of this workstation and upload it to management system [1]. According to nozzle type, management system can switch processing, cleaning or measuring program to achieve flexible production. It can also bind the processing or measuring data information of the workstation to the nozzle number and complete the establishment of product processing files. Thus, the control system network established is shown in figure 2.

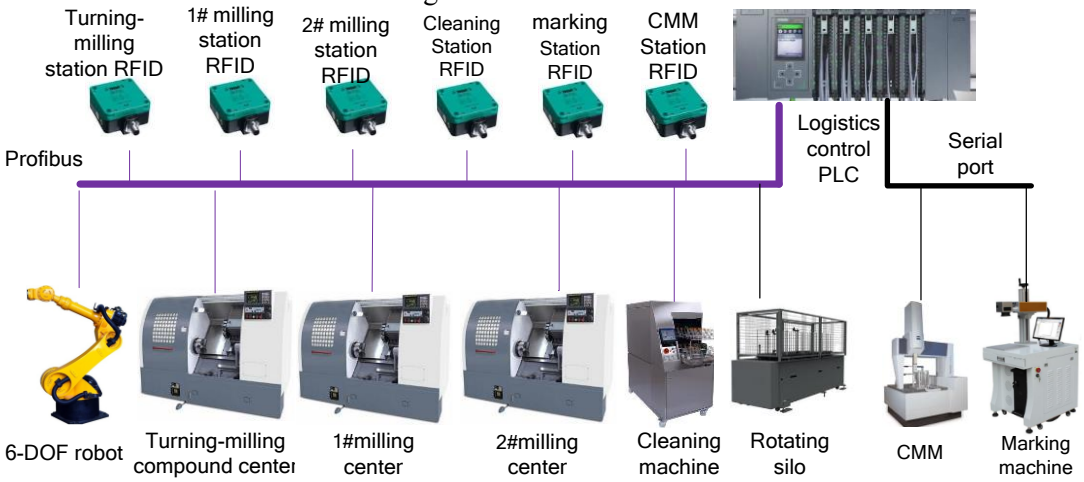

Figure 2. Hardware network diagram of control system.

3.2. Hardware design of management system

The management system is based on the IPC in the central control room. It uses industrial Ethernet to connect production units, electronic Kanban and other terminals together. Through OPC technology, the data interface between the production units and information Layer is opened, that realizes the interaction of production information [2]. The overall network structure of the management system is shown in figure 3.

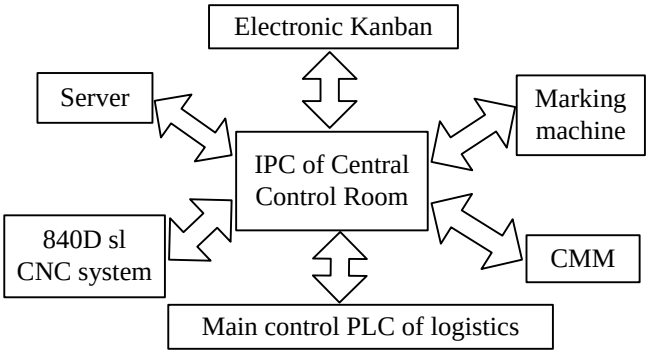

Figure 3. The network structure of the management system.

Managers can set production plan information in the IPC software interface of the centralized control room. After the production plan is formed, the system transmits the coding information of the nozzle to the marking machine, which engraves the unique coding identification for each nozzle component in the production process. The IPC platform of centralized control room can interact with each CNC machine and logistics main control PLC through OPC interface. So the management system can grasp the real-time status information of each equipment and realize Andon management by electronic Kanban [3]. The system can store the number of nozzles, the processing and testing data in the database of the server. By inputting the processing time or the number of the relevant batches of nozzles into the IPC software interface, the production information record of a certain nozzle can called out to be viewed.

3.3. Software design of control system

The realization of the control system mainly includes two parts: the logic control program of the main control PLC, the feeding and unloading motion control program of 6-DOF robot with seventh axis. Robot motion control program is mainly composed of the feeding and unloading motion instruction set and robot state self-checking module [4].

The main control PLC program is mainly composed of robot operation scheduling module, equipment status module, equipment communication module and RFID read-write module. Robot operation scheduling module can dispatch the robot to grab nozzle parts, finish automatic feeding and unloading cooperated with all devices and complete the main logistics operation according to the process flow. The equipment status module is responsible for collecting the production status signals of running, waiting, abnormal alarm and overtime alarm which will be uploaded to the management system used in production process monitoring and Andon management. The equipment communication module can receive the ready and running status word signals of the equipment and transmit the start or stop control word signals to the equipment through PROFIBUS bus and serial port to realize automatic feeding and uploading with the cooperation of each equipment and 6-DOF robot, automatic start of processing or testing program. The RFID read-write module can read the number of nozzle parts which are being processed or tested at a certain workstation and notify the management system to switch the processing, testing or cleaning procedures according to the nozzle type. When the processing or testing of a workstation is completed, the relevant process data are saved in the database with the nozzle number. Figure 4 is a basic flow chart for a workstation.

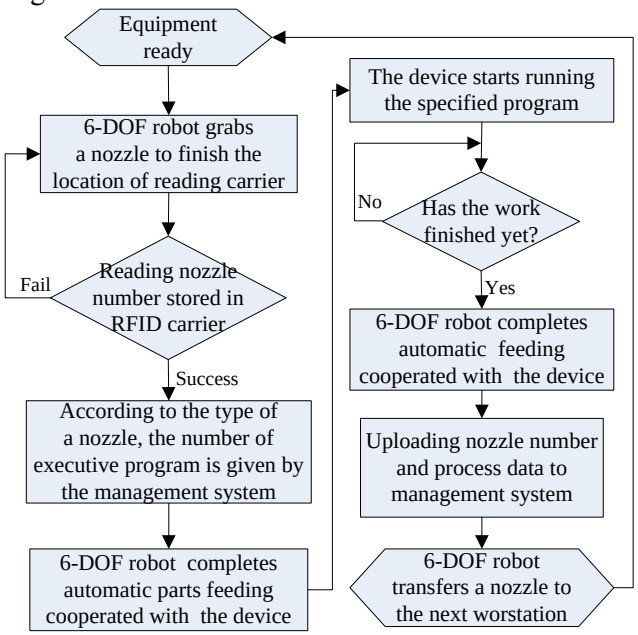

Figure 4. Basic flow chart of a workstation program.

3.4. Software design of management system

The overall implementation of management system is based on C/S architecture. It uses C# language to write the client program of management system and SQL Server 2014 database to store nozzle number information with related process data sets. The software is designed with modular structure, mainly including four functional modules: data acquisition, equipment status monitoring, Andon management and quality data traceability. The data acquisition module provides data support for the implementation of other modules by means of collecting status information of processing equipment and testing equipment, processing quality data and main logistics status etc. through the OPC interface. Equipment status monitoring module can display the running status information of each processing or testing equipment on the IPC client and electronic Kanban terminals. The operation of the whole line is unattended except the feeding and unloading for the rotating silo. Therefore, the management system uses Andon management module to realize the horn call and the display electronic Kanban of emergency, which will prompt managers to remove failures and resume production as soon as possible. The quality data traceability module can uniquely correlate the production quality data collected with the nozzle number to form the production process files. In figure5, the picture shows the main interface of IPC client in centralized control room programmed. In figure6, the picture shows the milling center monitoring interface of IPC in centralized control room programmed.

Figure 5. Main interface of IPC.

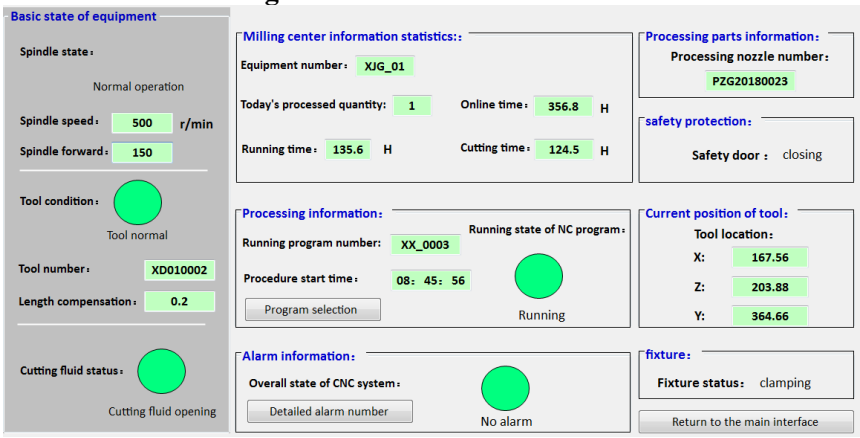

Figure 6. Milling center monitoring interface of IPC**.**

4. Debugging

For the robot, we start to debug in the virtual environment by offline simulation software to test the transfer time and optimize the track of the robot. It will reduce the downtime caused by the adjustment in the field [5].

For the debugging of the management system, we set up OPC server on IPC, test database function of storing and reading data and separately call each functional module to test operation result by the IPC client and adjust accordingly.

5. Conclusion

This paper describes a design method of the management and control system of machining production line for aero-engine nozzle. The system has realized the integration of control and management in the production process of aero-engine nozzle and improved the level of automation and informatization for the process of machining. Now, the system has been put into use in the processing of some aero-engine nozzles. Compared with the initial situation, the whole production line reduce staffing by 6 people; production efficiency has increased by 30%; the area of material caching between devices has decreased by 12 ㎡. It creates good economic benefits for enterprises. At present, the second phase project, the upgrade and reform for management system, has been started. It will increase some functions such as equipment running status report, SPC analysis, cutting tool management and so on. It will take a firm step to improve production measures, increase equipment utilization, promote product quality and realize digital management of the whole production line.

Acknowledgments

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References

[1] Hongtao Zhao, Hui Ma and Jingchun Yi 2009 *Techniques of Automation and Application* (Harbin: China Automation Society) vol 28 pp 52-54
[2] Jiang Han, Zhipeng Li and Daoyang Yu 2008 *Manufacturing Automation* (Beijing: Beijing Press and Publishing Board) vol.8 pp19-22, 53
[3] Chenggang Lu, Shuhong Chen and Ping Chen 2009 *Chinese Journal of Scientific Instrument* (Beijing: China Instrument and Instrument Society) vol 10 pp 56-59
[4] Kai Chang, Dechao Zheng and Hongfei Bai 2015 *Manufacturing Automation* (Beijing: Beijing Press and Publishing Board) vol.11 pp 58-60
[5] Wei Li, Naiguang lu and Mingli Dong 2018 *Robot* (Shenyang: China National Book Import and Export Corporation) vol 3 pp 301-308