Industrial Robots’ Application in Processing Production Line of Mechanical Parts

Guangjun Li*, Yingjun Luo
Beijing Vocational College Of Labour And Social Security, Beijing, China

*Corresponding author e-mail: liguang0519@163.com

Abstract. With the increasing improvement of intellectualization and automation, the advantages of applying the automation in the field of robotics are becoming outstanding. The robot is taking the place of labor, which greatly improves the production efficiency of enterprises. Taking the motor case processing production line as an example, this paper did research on groupware application of industrial robot technology, PLC technology, CC-LINK bus communication technology and CNC machine tool processing technology, designed the robot’s automatic loading and unloading device of the processing system and the automatic grading system for the finished product, which makes the robot and CNC machining become one and gains automatic and unmanned machining process of parts.

1. Introduction

With the rapid development of society and the improvement of science and technology, the production model of the industry has changed. The era of artificial intelligence is unstoppable, especially when the robots are being promoted and applied in a wider field. With the outstanding advantages of high accuracy, high work efficiency and the ability to bear great working strength, the industrial robots create better conditions for the improvement of production and quality in the whole industry. That the robots take the place of manual production is an important development trend in the future manufacturing industry and is the foundation for intelligent manufacturing. The arrangement of "Made in China 2025" promotes the implementation of the strategy of manufacturing power. And the high-class CNC machine tools and robots become one of the top ten fields for development.

This paper introduces the operation process of FANUC robot in the motor case processing production line and adopts FANUC robot to gain the automatic loading and unloading technology, to plan the robot’s reasonable movement trajectory, and to combine the industrial robot’s handling technology and CNC machine tool processing technology to realize the automatic load-upload workpieces, automatic gradation for finished products with high accuracy and efficiency.

2. Equipment layout of motor case in the automatic processing production line

The automatic processing production line of motor case consists of a loading conveying belt (with iRVision vision system), a uploading conveying belt (with iRVision vision system), a walking robot R1 (rail type), a fixed robot R2, two VM850 vertical machining centers, and one CLX360 CNC lathe, finished product basket, system control cabinet, etc..The equipment layout of the automatic processing production line is shown in Figure 1.
2.1. Analysis of CNC Machining Technology

The motor case parts are shown in Figure 2. The motor case is shown in Figure 3. As a part of batch production, the motor case is made of aluminum alloy ADC12. The workpiece processing content includes drilling, tapping, inner hole, step hole, and outer face. With the help of the groupware of robot and CNC machine tool processing technology, the workpiece is processed by automatic loading and uploading, which greatly improves the processing efficiency.
2.2. **FANUC robot**

FANUC robots provide the users with a development platform for an open and extensible robot control system. We can easily add visual detecting system and various sensors to the control system, or add various end tools to expand the functions of the robots, which can be integrated with the robot control system so as to gain the robot’s secondary developing function.

The automatic processing production line is equipped with two robots of FANUC Robot M-20iA handling system, and one of them with high repeatability is used as the walking robot R1, controlled by FANUC servo motor αiF12/3000, and driven by precise retarder, gear and gear rack. It can easily adapt to the arrangement of the machine on both sides of the rail. It is mainly used for the grabbing of blank workpieces, the loading of machine tools, the grabbing of workpieces between machining processes, the removing of finished products and the conveyance to conveyor belts. Another fixed robot R2 combines FANUC’s unique technology of intelligent robot (iRVision vision function) for uploading and grading the finished products in the basket.

2.3. **Design of robot hand**

According to the shape characteristics of the workpiece, the parts of pneumatic robot hand are designed which includes pneumatic, sensor and mechanical components. The pneumatic hand of the robot is shown in Figure 4.

![Figure 4. Pneumatic hand](image)

The feature of the fixture is that the bottom plate is connected to the end of the robot, and the two sets of cylinders control the two hands. The cylinder is equipped with a sensor to detect the release and clamping of the hands. The walking robot R1 is equipped with hands (refers to compound hands). One is for loading, while the other for taking apart the workpiece, as shown in Figure 5. Due to the demand of processing status, it must be equipped with a transfer table to make the workpiece flip. The workpiece flipping transfer table is shown in Figure 6.

![Figure 5. Compound hand clamping workpiece](image)

![Figure 6. Transfer table](image)

The uploading robot R2 is equipped with a single hand for grasping the finished product from the uploading conveying belt, and grading the basket, as shown in Figure 7.
3. Communication setting of Robot and PLC

In order to gain the on-site management and the general control, as well as improving the high-speed and reliability of signal transmission, the production line adopts Mitsubishi FX3U-64MT/ES-A PLC as the master station control, and configures with the CC-LINK function module, FX3U-16CCL-M. The robot is the slave station control. The master station and the slave station adopt CC-LINK bus technology, and the total control station adopts OMRON HMI monitoring configuration interface to realize monitoring, while PLC and robot adopt the I/O communication.

3.1. OMRON HMI Supervisory Control and Data Acquisition interface

The production line adopts OMRON NB10W-TW01B HMI to gain system monitoring. The functions of the master control screen include machine condition monitoring, robot starting condition monitoring, program switching, conveying belt monitoring, alarm information and so on. As shown in Figure 8.

![Master control screen of robot automatic processing workstation](image)

**Figure 8.** Master control screen of robot automatic processing workstation

The robot start condition screen refers to the condition that the robot should meet to start automatically. When the system does not enter the automatic state or the alarm information turns up, switch to the screen to confirm whether the robot start condition has been met at first. The screen of robot start condition is shown in Figure 9. There is no other monitoring described here.
3.2. CC-LINK bus communication between robot and PLC

CC-Link (Control & Communication Link) field bus, which has great functions in real-time, decentralized control, and intelligent machine communication, is a PLC-based field bus promoted by Japan Mitsubishi Electric Corporation. At the same time, it can link to various products of the field equipment manufacturers to provide users with the using environment of multi-manufacturers equipment. The network meets the requirements of users for open system architecture and reliability. Taking the general control station FX3U-64MT/ES-A PLC as the master station, the production line configures the CC-LINK function module FX3U-16CCL-M. The two robots become the slave stations of the remote equipment, and each slave station of the remote equipment takes up a station number. The connecting frame diagram is shown in Figure 10.

3.2.1. Side CC-LINK setting of robot as the slave station

Enter the [CC-LINK] setting screen on the robot’s TP operation panel and set as follows in Table 1.

| SETUP CC-LINK                  | JOINT 10% |
|--------------------------------|-----------|
| Remote device board: | 1/10      |
| 1 Error one shot:     | DISABLE   |
| 2 Station No:         | 1         |
| 3 Number of Stations: | 2         |
| 4 Baudrate:           | 156       |
| RWr(16)               |           |
| 5 Number of AOs:      | 4         |
| 6 Number of Registers:| 4         |
| 7 Reg start index:    | 2         |
| RWw(16)               |           |
| 8 Number of AIs:      | 4         |
| 9 Number of Registers:| 4         |
| 10 Reg start index:   | 6         |
| 11 Reg Date:          | Unsigned Int |

After setting the CC-LINK parameters, configure the CONFIG of the I/O Digital Out signal, set the SLOT number of the CC-LINK hardware card and the start bit of the signal. After the setting is done, the control cabinet needs restarting.
3.2.2. *Mitsubishi PLC Side CC-LINK setting as the master station*

The user enters the network parameter menu sets the CC-LINK parameters. The main content settings are shown in Table 2.

| Setting item          | Setting content | Setting item          | Setting content |
|-----------------------|-----------------|-----------------------|-----------------|
| Special block number  | 0               | Quantity of automatic | 1               |
| Type                  | Master station  | CPU downtime          | Stop            |
| Data connection type  | Master station  | Abnormal station      | Clear input data|
|                       | parameters start| setting of data       |                 |
|                       | automatically   | connection            |                 |
| Mode setting          | Remote network  | Setting during        | Refresh         |
|                       | (Ver.1 mode)    | CPU STOP              |                 |
| Total connections     | 2               | Connection block      | FX3U-16CCL-M    |
| Retry times           | 3               |                       |                 |

In addition, the CC-LINK station information is set as follows.

| Quantity of unit /Station No | Station type          | Extended cyclic setting | Quantity of station occupied | Quantity of remote site | Reserved/invalid station designated |
|------------------------------|-----------------------|-------------------------|-------------------------------|-------------------------|-------------------------------------|
| 1/1                          | Remote equipment station | 1x setting              | 2 stations occupied           | 64 points               | No setting                          |
| 2/3                          | Remote equipment station | 1x setting              | 2 stations occupied           | 64 points               | No setting                          |

In this way, the parameter setting of the PLC side CC-LINK is finished. The writing and reading operations of robot CC-LINK DI and DO signal should be programmed in the Ladder Logic Programming Language. The Ladder Logic Programming Language is shown in Figure 11 and Figure 12, and other PLC programs are not described one by one.

![Figure 11. CC-LINK DI signal PLC program](image1)

![Figure 12. CC-LINK DO signal PLC program](image2)

4. **Interface technology of robot, PLC and CNC machine tools**

To make sure the safety cooperation between the robot and the CNC machine tool, it is necessary to establish a safe and reliable communication connection among the robot, the PLC and the CNC machine tool. As for the hardware, the corresponding input and output points between the above three are linked with the shielding line. As for the software, the current state of the machine tool and the robot are collected through the robot’s specific software and PLC interface, and the control program which meets the logic of the loading and uploading are programmed. CNC machine tools and robot will gain the effective communication at last. It is important to deal with emergency stop signals, signals of CNC machine preparation completed, pneumatic signals of robotic hand, the releasing clamp signals of CNC machine tool fixture, and the signal of safety door.
The I/O signals of the CNC machine side and the FANUC robot are transmitted through the PLC. For example, the signal of the machine preparation completed is one of the required conditions to start the robot. As the input signal of the PLC, if this signal is valid, through the CC- The LINK, the PLC outputs a signal to the robot as an input signal to the robot. Similarly, the output signal of the robot side is used as the input signal of the PLC, while the corresponding output signal of the PLC is used as the input signal of the CNC machine tool, which means that the PLC acts as a transit signal among the above three. The interface signaling relationship of CNC machine tools, PLC, and FANUC robots is shown in Figure 13. The example of wiring between the CNC machine side and the PLC side I/O signal is shown in Figure 14 and Figure 15.

**Figure 13.** Interface transit relationship of CNC machine tool, PLC and robot

![Interface transit relationship of CNC machine tool, PLC and robot](image)

**Figure 14.** CNC machine side signal input PLC

![CNC machine side signal input PLC](image)

**Figure 15.** PLC side output to CNC machine tools

![PLC side output to CNC machine tools](image)

5. Conclusion

With the demand of industrial automation to reduce the labor intensity and unmanned production and to gain the high accuracy and efficiency of products machining, the machine tool manufacturers and users attach great importance to the robot’s automatic loading and uploading device, which acts as an assisting part of CNC machine tool. The fast and error-free communication between the robot control system and the machine control system, and the accuracy of the robot operation can strengthen the reliability of the system processing. This automatic processing production line integrates the advanced technologies like robot technology, PLC technology, sensor detecting technology, communication technology and numerical control technology, gains the technical combination of robot and CNC machine tool, simplifies the operation mode of CNC machine tools, and improves the operation safety of CNC machine tools. The workers’ labor intensity is reduced, the loading and
uploading of the workpieces and the automatic processing are connected tightly, which greatly improves the work efficiency and becomes applicable. The use of intelligent robots for high flexibility and automation with low cost will surely lead the intelligent manufacturing.

References
[1] Xiuyan Wang, Tingting Cheng, Research on Intelligent Grabbing of Industrial Robots Based on Monocular Vision, Machinery Design & Manufacture, 2011 05 135-136.
[2] Jiyun Cai, Applied Research of Industrial Robots in Automation Control, Science and Technology & Innovation, 2018 1 144-145.
[3] FANUC Robot series CC-LINK Interface(Slave) OPERATOR’S MANUAL.JAPAN:FANUC Co.,LTD.2012 10.
[4] Chujun Liang, Combination Application of Industrial Robot Loading and Uploading Technology and CNC Lathe Processing Technology, Equipment Manufacturing Technology, 2016 12 259-261.