Wheel Hub Automatic Production System Based on Industrial Robots

Bin Zhang¹,²,³*, Zongxue Lu¹, Qiang Wang³, Shiyi Cui³, Guangxin Jia³, Jun Yang¹,²

¹School of Automation, Southeast University, 210096, P. R. China
²Key Laboratory of Measurement and Control of Complex Systems of Engineering, Ministry of Education, Nanjing, 210096, P. R. China
³Lianyungang JARI Automation CO., LTD., Lianyungang 222006, China

Corresponding author's e-mail: 230209099@seu.edu.cn

Abstract. In this thesis, a control system for a wheel hub machining line based on a Fanuc robot, which includes adopting Siemens 300PLC as the main control unit, performing wheel circumferential positioning and center correction based on vision technology, and controlling the machine tool to perform real-time tool compensation based on the measured data, is researched and designed to achieve fully automatic unmanned wheel processing.

1. Introduction

In recent years, the complexity of industrial robot systems has become higher and higher, and the transition from automation to intelligence has become a trend for robot applications. In view of the current status of the wheel processing industry, this article adopts the Fanuc robot instead of manual production. A set of production line system for automotive wheel automatic processing based on vision technology, laser ranging, tool compensation and other technologies is designed to realize the automation and intelligence of the entire machining production line.

2. System architecture and process flow

2.1. System architecture

Wheel Hub Automatic Production System consists of FANUC 210F robot, logistics docking and conveying platform, the vertical carOP10, the sleeping carOP20, the machining centerOP30, cleaning and blowing device, run out detection device, vision positioning system, online tool compensation system, detection platform, etc. The logistics docking and conveying platform includes loading platform, unloading platform, and waste platform. The vision positioning system mainly includes the circumferential coarse positioning of the loading platform and the fine positioning of the wheel center correction. The function of the run out detection device is to detect whether the robot puts the hub into the machine tool or not. The online tool compensation system mainly implements automatic tool compensation for OP10 and OP20 based on the laser detection results and manual tool compensation on the remote interface based on the absolute or relative deviation. The overall system layout is shown in Figure 1.
2.2. System process flow

The robot uses a two-handed claw design, claw 1 is used to put the hub, and claw 2 is used to take the hub. First, the wheel hub is sent to the loading platform by the blank logistics line, and then it is centered, jacked up, and servo-rotated. In the third step, the wheel hub is judged by the visual positioning system for circumferential positioning. When the characteristic position is found, the servo is stopped and the wheel is grabbed and placed on the vertical car OP10 by the robot. After the wheel hub is processed by OP10, OP20, OP30 three machine tools, the finished product is placed on the unloading platform by the robot and finally enters the finished product logistics line. The whole process flow is shown in Figure 2, whose cycle is about 150s.
3. Design of master control system

3.1. Hardware design
The main control cabinet uses Siemens CPU313C-2DP as the main controller, and WEINVIEW MT8102iE as the on-site human-machine interface. The main control PLC and robot control cabinet use Profinet-DP communication to realize data transmission between them. The PLC is equipped with a CP343-1 Ethernet module to realize data exchange with vision positioning system and online tool compensation system, a CP340 serial communication module to obtain the hub inner diameter data from the detection device based on laser ranging technology, and three SM323 DI16 / DO16 module to exchange signals with three machines. The entire control system is shown in Figure 3.

3.2. Software programming
The software part mainly includes Siemens 300 PLC program and HMI program.
Siemens 300 PLC program is programmed in a modular programming manner in the Siemens Step7 environment. OB1 is the main loop program, which runs one by one in each cycle of the program and is divided into unconditional call modules and conditional call modules. The unconditional calling module will be called in each cycle, mainly including robot-related signals, machine tool process docking signals, loading, unloading, waste conveyor signals and some functional blocks of the touch screen interface. The condition call module is mainly a module which is actively triggered under specific conditions, mainly including program blocks for fault monitoring, emergency processing, judging run out detection, and communication with robots, visual positioning system, machine tools and the detection platform. In addition, the program also includes an initialization organization block OB100, three PLC diagnostic organization blocks, and a cyclic interrupt block. The PLC software function block diagram is shown in Figure 4.

Figure 4 Control software structure diagram

The touch screen program is mainly divided into four interfaces: robot, parameter setting, status monitoring and alarm query, as shown in Figure 5. The robot interface mainly displays robot signals and other equipment preparation information under automatic operation conditions. The parameter setting interface includes setting information of all peripheral devices. The status detection interface includes monitoring of all input and output signal points of the PLC. The alarm query interface can view alarm information for all devices. In addition, real-time and historical inside diameter and height information can be viewed, and the tool compensation value of the machine can be modified in the tool compensation monitoring interface.
4. Vision and tool function applications

4.1. Visual applications
This project uses Basler’s industrial camera, aca1300-60gm as the coarse positioning in the circumferential direction, aca2500-14gm as the precise positioning of the center hole of the wheel hub, and a linear blue light source is selected. The software is based on Python for programming, which uses the python packaged interface provided by Basler to quickly develop applications and test Basler cameras. This method is used to improve the efficiency of project integration and reduce project development costs. The vision system interface is shown in Figure 6.
4.2. Realization of tool compensation

The tool compensation function in this project is mainly used in the field control layer. The tool management system of the technology department can be implemented in the upper computer, which uniformly manages the tools, monitoring data, fixtures, etc. to provide production resource information for various links such as process, scheduling, production preparation, etc., while achieving corresponding inventory and process management to reduce quality problems caused by human operations.

In addition to the production equipment of the on-site workshop, the tool management system includes the upper computer tool management software of the process management department. The robot is responsible for conveying the wheel loading, unloading, and processed wheels to the monitoring device. The monitoring device transmits the monitoring data to the main control PLC through the serial port, and then to the tool management system. The tool management system performs a reasonable analysis based on the detection results and transmits the tool compensation data to the machine tool. In addition, the system can be extended with DNC distributed numerical control system, MDA data acquisition and analysis management system, and large-screen visual management system in the workshop. Tool application field application interface and host computer management software interface are shown in Figures 8.
Using machine vision on-line detection technology, the on-line detection data, including the diameter size of the shaft center hole, the length size of each installation position and the diameter size. Read the current value of tool offset, and determine the current thermal deformation according to the database. A comprehensive error prediction model is formed by synthesizing the above factors, so as to calculate a real tool wear compensation. To achieve the purpose of automatic detection of automatic step size. The new tool compensation value of the feed axis of the machine tool is:

$$U_2 = U_0 - (L_0 - L_a) - \Delta u$$

where:

- $U_0$ —Initial tool compensation value of machine tool
- $L_0$ —Dimension value required by machining theory
- $L_a$ —Actual dimension value of on-line inspection

$\Delta u$ —Temperature change may lead to dimension change value (mainly reflected in the use of cold machine, when the temperature rises rapidly, it needs to consider the temperature change, when the machine reaches the thermal stability processing, reduce the temperature compensation effect)

5. Robot programming

The Fanuc robot program is mainly programmed by the teach pendant to find the robot teaching points and make some logical judgments. According to the wheel processing technology flow, the robot calls subroutines at different stations in the main program RSR0001. Most of the robot movement instructions use J and L. The priority is to use J instructions to make the robot's movements more stretched and coherent, while generally L linear instructions are used to ensure that the robot's trajectory is straight and avoid the machine tool fixture collision for relatively small internal space of the machine tool. The robot action flow is shown in Figure 9.

The robot will judge the signal waiting before each process action. If the waiting timeout, it will make a pause alarm, and after manual confirmation, it can automatically return to the origin. Finally, the program ends.
6. Concluding remarks
This article mainly designed a set of wheel hub automatic production line, adopting Fanuc industrial robot, taking Siemens 300PLC as the main control unit, integrating vision technology, online tool compensation technology, online monitoring and other technologies to achieve unmanned wheel processing production line. At present, the system has been operating steadily in a wheel factory in Guangdong, but during the operation, there are still some problems that need to be improved, such as the interference of natural light in the vision system, and the rules of the tool compensation process.

Acknowledgements
This work was financially supported by Special Fund for Transformation of Scientific and Technological Achievements of Jiangsu Province(BA2019092).

References
[1] Wang Haixia, Li Zhihong, Wu Qingfeng. Application and Development of Industrial Robots in Manufacturing [J]. Mechanical & Electrical Engineering Technology, 2015.10
[2] Wu Zhedong, Hu Hangfang. Application analysis of machine vision in industrial robot grabbing technology [J]. Technology and Economic Guide, 2019, 27(05):97.
[3] Xu Bofan, Zhao Hua, Xue Wenkai, etc. Research of FANUC Robot Grasping System Based on Visual Guidance [J]. Modular Machine Tool & Automatic Manufacturing Technology, 2018.07.
[4] Wuhuimin, Li Xiaomei. Application Discussion of Tool Compensation in Numerical Control Milling [J]. Henan Science and Technology, 2018(28): 43-46.

[5] Wang Weilong. Research and Implementation of Intelligent Tool Management System [J]. China Computer & Communication, 2019(04): 115-117+120.

[6] Ma Xiaofan, Yao Bin, Chen Binqiang, etc. Development of intelligent manufacturing tool management system and tool remaining life monitoring function [J]. Aeronautical Manufacturing Technology, 2018, 61(18): 68-73.