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Design of Automatic Production Line Training System Based on PLC

Na LIANG, Jiang XIAO

Beijing Forestry University, 487 mailbox, Beijing Forestry University, No. 35 Qinghua East Road, Haidian District, Beijing, 100083, China

[1] Tel.: 15210074161, [2] 13910766308

E-mail: lcmz1616@163.com, xiaojiang56@126.com

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Abstract: Automatic production line training system is used to simulate the actual process of industrial production. According to the actual needs of teaching instrument market at present, for the purpose of students or staff training, the author designs a practical automatic production line simulation training system. Using Siemens S7-200 PLC as the control core, setting sensors, buttons and lights, power supply module, motors, pneumatic components, mechanical structures for the integration, dividing into feeding, processing, assembly, sorting, robot units, and achieving interconnection between the unit controllers via PROFIBUS. It is used to simulate the various manufacturing aspects of workpieces from raw materials to finished products in the actual industrial production lines. The system covers mechanical principles, pneumatic control technology, sensors, electrical control technology, programmable logic controller and other related knowledge points, supports professional experimental courses of automation, mechanotronics and so on. A series of practical ideas are adopted in the subject. The entire system is fully open, students can have a comprehensive view of the internal wiring situation; freely detachable, can operate under single-station or overall system; supporting secondary development, can be re-build according to the innovation requirements. *Copyright © 2013 IFSA.*

Keywords: Automatic production line, PLC, Training system.

1. Introduction

Automatic production line training system is used to simulate the actual process of industrial production. It is used in training room of colleges and universities, to cultivate students' cognition, operation, then using and developing abilities. In order to cater to the educational philosophy and teaching need of today's colleges and universities, the training system is a comprehensive experimental teaching system which is connecting theoretical teaching with practical training. Through the demonstration experiments, assembly debugging and programming, students can stimulate learning interests, exercise practical abilities and thinking skills, consolidate expertise, improve professionalism and guide students to adapt to the demand for jobs in the future.

1.1. Research Status

Before the 1920s, the production line and semi-automatic production line appeared in the automotive industry; 1920s, Henry Ford founded the automotive industry assembly line; later, combination automatic line gradually emerged; the development of automatic control and computer technology,

prompted the completion of the automation workshops and factories [1]. Today, automatic production line is developing toward the direction of adjustable varieties, higher flexibility, faster and lower cost. With the automatic production line developing by leaps and bounds, the development of automatic production line simulation device has been greatly improved [2]. At present, many ordinances manufacturers have achieved the rapid development of automatic production line simulation ordinances. Most of today's automatic production simulators have achieved demonstration, debugging operations, programming and other basic functions, but there is considerable room for improvement [3]. Developing a removable, secondary developing, working sub-station or run-online training system is a far-reaching issue.

1.2. Issues to be Addressed

The system uses Siemens S7-200 PLC as the control core, setting sensors, buttons and lights, power supply module, motors, pneumatic components, mechanical structures for the integration, dividing into feeding, processing, assembly, sorting, robot units, can operate under single-station or overall system. It is used to simulate the actual process of industrial production. The entire system is fully open, freely detachable, supporting secondary development, can be re-build according to the innovation requirements.

2. The Overall System

Automatic production line training system consists of five units: feeding unit, processing unit, assembly unit, sorting unit and robot unit. The units are all installed in the aluminum alloy rail training table, the overall system block diagram is shown as Fig. 1.

Each unit of the system is an independent mechatronic system. Feeding, processing, assembly, sorting units basically depend on pneumatic actuator, robot unit takes the position controlling mode driven by the stepper motor. In terms of on-line operation, each unit is undertaken by a PLC, and achieving interconnection between the unit controllers via PROFIBUS. The entire system can simulate supplying, processing, assembly, sorting, transporting and other process of actual industrial production line.

Button and indicator modules including start, stop, reset, function buttons, manual / automatic, single / overall knob, the alarm indicator and emergency stop button. Start and stop buttons are used to control the start and stop operation of the unit; reset button can reset all the action element to initial position; function button is set for secondary development; spinning manual / automatic, single / online knob at the same time can select single-station or overall system situation.

Each unit of the system needs to be powered separately. The power supply module includes air switch and one-channel switching power, one-channel switching power can convert 220 VAC to 24 VDC and supply to each unit.

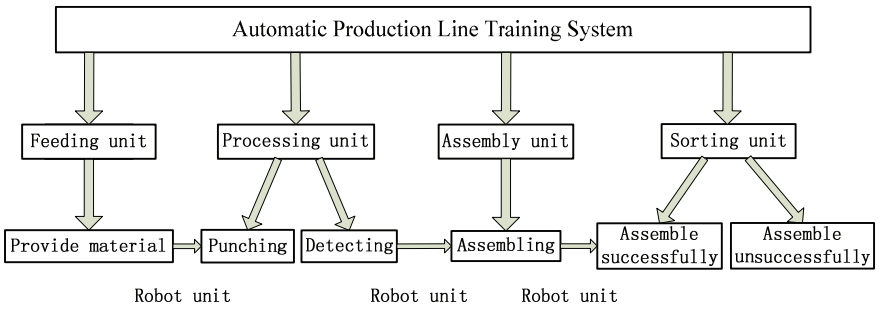

Fig. 1. The overall system block diagram.

3. Feeding Unit

The feeding unit is the first unit which plays a feeding role of supplying raw materials to the next unit. It can launch the material in the silo to the transfer stage automatically, so that the robot will crawl and transport it to other units. The configuration diagram of feeding unit is shown in Fig.2.

Feeding unit selects fiber optic sensor and amplifier, photoelectric sensor. Fiber optic sensor is mounted on the bottom side of the silo to detect the material; photoelectric sensor is used to detect whether the material is reaching.

Material transporting conveyor belt is driven by motor, the driving wheel is φ90 × 36 mm (wheel diameter × wheel thickness), the driven wheel is 40 × 36 mm (wheel diameter × wheel thickness). Micro-AC gear motor and the gearbox can regulate the actual speed between 9-135 rpm [4]. Lower speed can not only provide a greater torque, but also make the material smoothly fall on the conveyor belt, and obtained the similar speed with the conveyor belt within a shorter time and a smaller displacement, thus ensure the stability.

Choosing SMC mini pen-type cylinder, the cylinder push block pushes the material in the hopper to the material transfer stage. Connect SMC one-way

solenoid valve to the pen-type cylinder. One-way solenoid valve is a single electronic control components, it will control one-way cylinder, and return to its original position when lost power. Each pneumatic circuit consists of cylinder, one-way throttle valve, two-five way valve, manual valve, pneumatic FRL, pressure gauge, gas supply, muffler and other components. When the two-five way valve coil is energized, the cylinder piston driven stem extending and pushing the material; when the two-five way valve coil is de-energized, the valve stem move back to the initial position [5].

The flowchart of feeding unit is shown as Fig. 3.

4. Processing Unit

This unit has four workstations. Robot grabs the workpiece to the first workstation. When the workpiece is detected, the dial rotates, moving workpiece to the stamping punch workstation, then moving it to the stamping detection workstation to detect whether it is qualified, and then sending it to the fourth workstation, waiting for the robot to send it to the next unit. The configuration diagram of feeding unit is shown in Fig. 4.

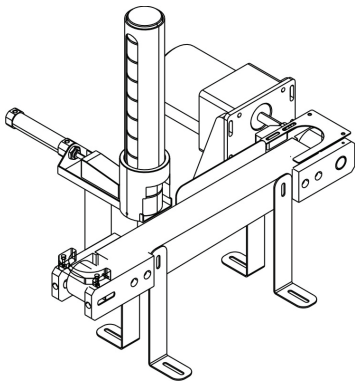

Fig. 2. The configuration diagram of feeding unit.

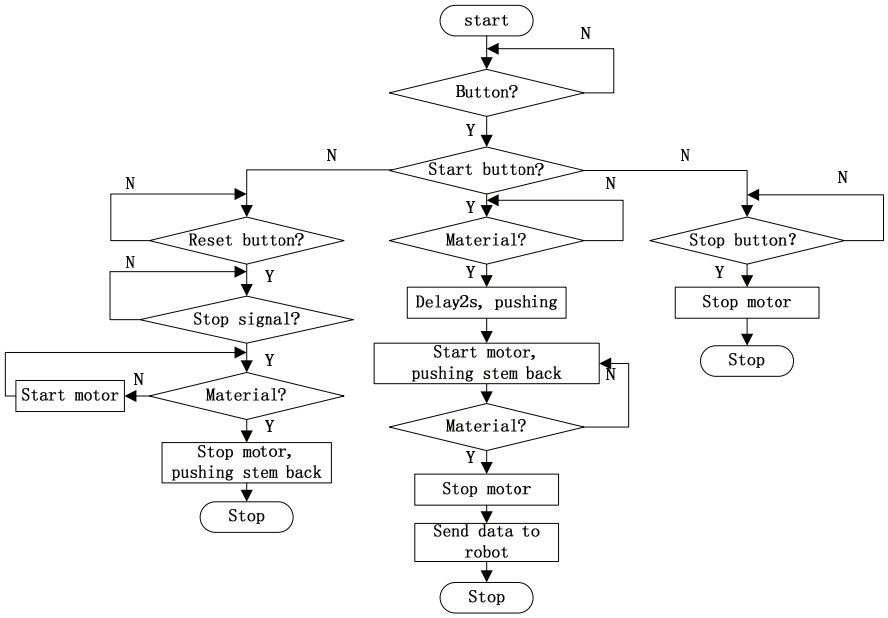

Fig. 3. The flowchart of feeding unit.

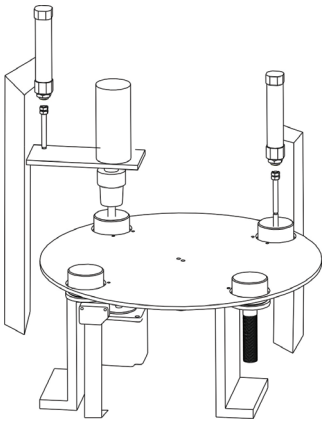

Fig. 4. The configuration diagram of processing unit.

Processing unit selects photoelectric sensor, proximity switch and two micro-switches. The photoelectric sensor is installed below the first workstation, using to detect whether the aluminum material is sent here; proximity switch is mounted on the bottom of the second workstation to detect whether the workpiece is arriving accurately; the two micro-switches are fixed on the first and fourth workstation of the robot run rails, using to judge the current running position of robot.

The dial controlling motor is hybrid stepping motor, which is installed on the bottom of the turntable and driving turntable rotating. Thin cylinder drives a DC gear deceleration motor rotating downward, to simulate the drilling movement.

SMC thin cylinder drives stamping punch motor move along the Y-axis direction; SMC mini pen cylinder simulates stamping detection operation. When the two-five way valve coil, which connected to thin cylinder is energized, stem drives drilling motor to punch; when the valve coil is de-energized, the valve stem moves back to the initial position [6]. Mini pen cylinder acts similarly.

Processing unit works as follows: The robot transports the workpiece to the first work station of the turntable, photoelectric sensor detects the presence of the metal parts, motor drives turntable rotating ninety degrees to the second workstation, DC gear motor moves along the Y-axis negative direction to simulation the operation of the stamping, and then the dial rotates to simulate punch detecting, finally the dial rotates to the fourth station, the proximity switch detects the metal workpiece and then sends the information to PLC, robot will send workpiece to the next unit.

5. Assembly Unit

The function of assembly unit is to embed the metal pin into the workpiece, and complete the assembly process. This unit focuses on pneumatic controlling, is the main unit of pneumatic control training. The configuration diagram of assembly unit is shown in Fig. 5.

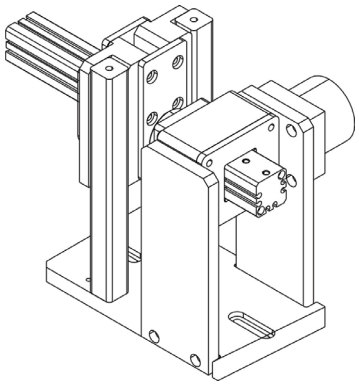

Fig. 5. The configuration diagram of assembly unit.

The unit contains a rotating cylinder and two square cylinders, selecting SMC swing cylinder to control the rotation of the assembly slot. Pushing cylinder is SMC thin cylinder, using for pushing out the metal pin. Ejecting cylinder is SMC standard cylinder, using to top out the assembly slot. The joint action of pushing and ejecting cylinder makes the workpiece complete the assembly process quickly and accurately [7]. Rotating cylinder and ejector cylinder connect to the two-way solenoid valve. The two-way solenoid valve is a double electronic controlling components, it can control two-stroke movement.

When the left coil of solenoid valve which is corresponding to rotating cylinder is energized, the left intake path and the right exhaust path switch on at the same time, rotating cylinder swings clockwise, and drives assembly platform to rotate 90 degrees, when the left coil is de-energized, rotating cylinder stops turning and keeps the original state; when the right coil is energized, the right intake path and the left exhaust path switch on at the same time, rotating cylinder swings counterclockwise, and drives assembly platform to rotate negative 90 degrees, assembly station returns to the initial position, when the right coil is de-energized, the bilateral gas path close at the same time, rotating cylinder stops.

When the left coil of solenoid valve which is corresponding to standard cylinder is energized, the ejector cylinder piston drives stem out and tops out the assembly slot, when the left coil is de-energized, the bilateral gas path close at the same time and keep the original state; when the right coil is energized, the ejector cylinder piston drives stem back to the original state, when the right coil is de-energized, the ejector cylinder piston stops.

When the coil of solenoid valve which is corresponding to the thin cylinder is energized, the pushing cylinder piston drives the stem out, pushes metal pin out to the hole of the workpiece; when the coil is de-energized, the stem of pushing cylinder returns.

The pneumatic picture of assembly unit is shown as Fig. 6.

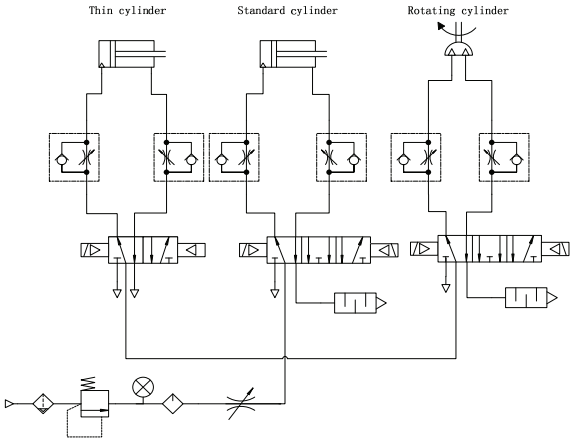

Fig. 6. The pneumatic picture of assembly unit.

The assembly unit works as follows: workpiece is placed on the assembly platform, rotating cylinder rotates ninety degrees, the ejecting cylinder tops out the assembly platform, then the pushing cylinder pushes the metal pin out to workpiece, completing assembly process. The ejecting cylinder returns, rotating assembly platform goes back to the initial position, robot sends the workpiece to the next unit.

6. Sorting Unit

This unit includes a fiber-optic sensor and its amplifier, proximity switch and beam photoelectric

switch. Fiber-optic sensor is installed on the sorting table to detecting the material. Proximity switch is suspended on the sorting platform, the distance between the metal pin that assemble successfully and the proximity switch is 4 mm, while the distance between the workpiece and the proximity switch is above 5 mm. Due to the detection range of the proximity switch is 3-5 mm [8], when workpiece arrives within the detection range of the sensor, proximity switch can detect its presence or not, that is whether the workpiece has been successfully assembled; beam photoelectric switches are installed in the middle of the trough to detect whether sorting operation is successful or not, then control the motor to stop.

DC reduction gear motor can drive conveyor belt to transport the material to sorting detection point.

Selecting small no-shaft-rotating pen cylinder to regulate the extending of baffle at the successfully assembled trough. In order to reduce the impact of the baffle caused by the movement of the workpiece, to make workpiece change direction when encountering baffle, this requires the contact surface between baffle and workpiece is arc, which requires the cylinder that controlling the damper must be no-shaft-rotating kind [9]. When the solenoid valve coil is energized, the cylinder piston drives the stem out, pushes baffle out; when the solenoid valve coil is de-energized, the stem of cylinder returns.

Sorting unit works as follows: fiber optic sensor detects the sorting materials, then controls motor to drive the transmission belt. Proximity switch detects the material when it reaches the centre of the belt, if it can detect the presence of the metal pin, indicating that the workpiece has been successfully assembled, cylinder pushes the baffle out, intercepts the workpiece, lets it slide into assembled slot; if proximity switch can not detect metal pin, indicating that the workpiece has not been successfully assembled, cylinder remain intact, lets it slide into no-assembled slot; when the workpiece slide into the slot, beam photoelectric switches detect the workpiece, baffle returns back, motor stops, sends completing signal to the robot unit, accepts the next workpiece sorting task.

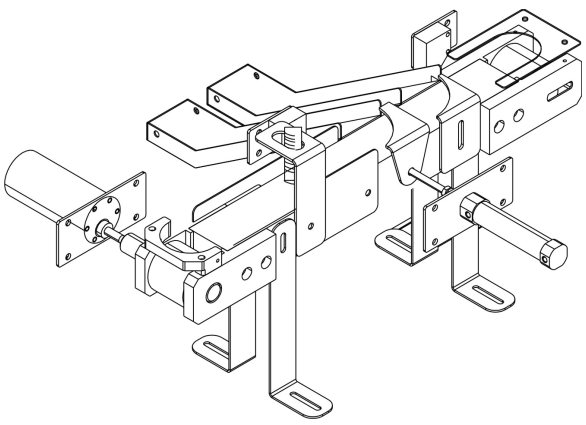

Fig. 7. The configuration diagram of sorting unit.

7. Robot Unit

The robot unit is the driving unit of the entire system, plays an important role of linking the remaining four units to complete the handling function among the other units. In this unit, the coordinates setting of robot's moving direction is shown as Fig. 8.

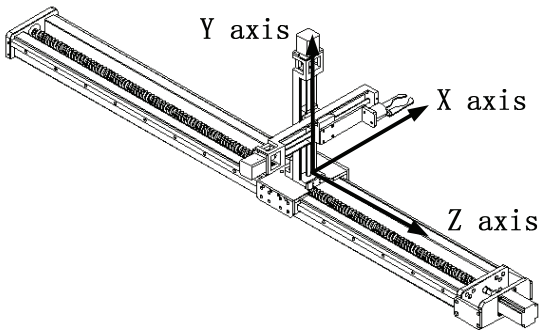

Fig. 8. The coordinate diagram of robot moving direction.

The robot unit has four micro-switches, the X and Y-axis rails each has a micro switch respectively, indicating the robot's moving limit position in X, Y direction; Z-axis rail has two micro switches, corresponding to the dwell position of the robot at the assembly unit and the sorting unit respectively.

X-axis selects 1500 mm thread screw and EG series linear guide; due to Y-axis and Z-axis having a shorter stroke (300 mm) and a smaller load, selects straight-line modules to realize the moving of gripper in this two-axis direction [10].

This unit has three stepper motors, which are used to control the movement of the manipulator in the three directions -X, Y and Z. Using two-claws sliding rail gripper to grip the workpiece. The towline can avoid the winding knot problems caused by the robot's movement [11]. When the solenoid valve coil is energized, the gripper clamps, grabs the workpiece; when the coil is de-energized, the gripper releases, puts down the workpiece. Fig. 9 is the electrical diagram of robot unit.

This unit works as follows: the robot can move along the X, Y, Z axis direction, rely on pulses and micro switches to locate accurately, indicate its duration position by micro switches, transport the workpiece to the corresponding position according to the needs and complete crawling and placing function.

8. Network Control and Overall System Running

8.1. Network Control

The system is running with the STEP7 programming software. In the network settings, the robot is driving unit, the other four are driven units.

Setting the communicate parameters in the system block, that is all the units are communicating with the robot unit. The transmission baud rate is set to 9600 bps with PPI communication protocol [12].

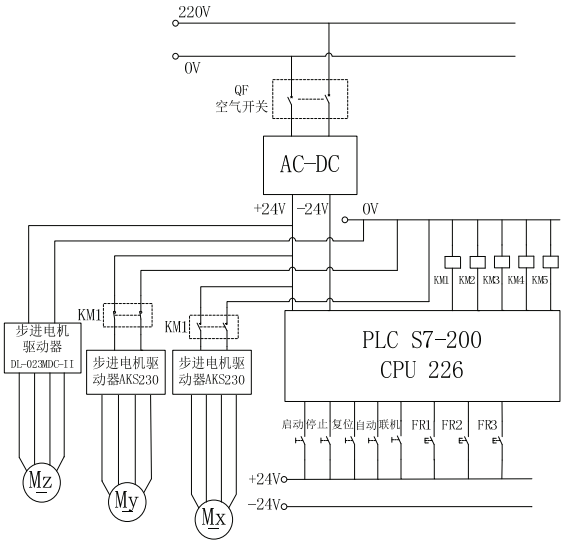

Fig. 9. The electrical diagram of robot unit.

In the PPI network, the robot unit must specify the driving property with the Port0 controlling byte SMB30 in the first scan cycle. After setting, the robot program will generate NET_EXE subroutine [13].

In the processing and robot program that selecting stepper or servo motor, the STEP7 wizard will generate the PTO (Pulse Train Output) subroutine automatically [14].

8.2. The Overall System Running

When the overall system is running, the running diagram is shown as Fig. 10. The thick line is PLC-PROFIBUS bus cable, it is used to connect PLC via Port 0, to realize communication of the whole system [15]. After programming and debugging, we can download the program to PLC via serial programming cable, in order to achieve the running purpose of the overall system without computer.

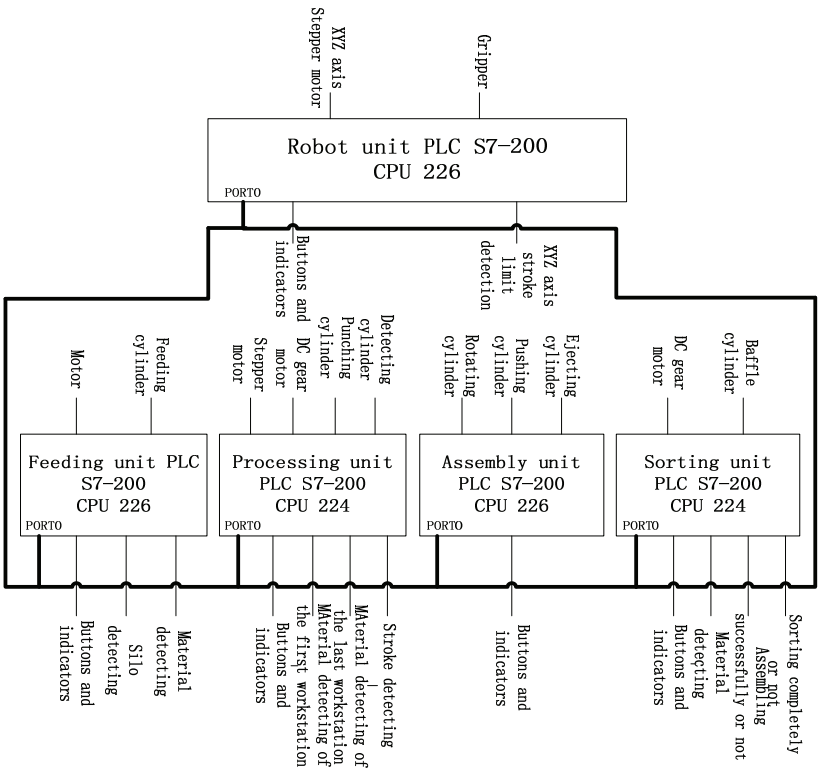

Fig. 10. The overall system running diagram.

9. Results and Discussion

The automatic production line training system can be applied in the training room of colleges and universities as the following three aspects: automatic production line simulation demonstration; according to the hardware design, compiling to achieve the overall function; reassembling the system according to the requirements and programming with the reserved bits properly, innovating more practical functions.

Compared with the other training systems at the teaching instrument market at present, the system has the following obvious advantages:

The System is fully open, especially the controlling cabinet, students can have a comprehensive view of the internal wiring, it is easy to apperceive and understand for students.

The system is freely detachable, it can operate under single-station or overall system. We can choose the type and quantity of the workstations according to the training requirements.

The controlling system has reserved some controlling bits, they can be used for developing and innovating.

10. Conclusions

The automatic production line training system covers electrical control technology, pneumatic control technology, sensors, mechanical principles and other related knowledge points. The entire system is fully open, freely detachable, can operate under single-station or overall system, can be re-build according to the innovation requirements. Experiments show that the system has simple hardware structure and reasonable programming, runs reliably and stably. It fits today's education philosophy of closely integration between theory and practice, has important and long-term significance of high-quality talents cultivation, the seamless connection of universities and enterprises.

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