2026

BRICS SKILLS COMPETITION

(BRICS+ FUTURE SKILLS & TECH CHALLENGE)

Industrial Robot Digital Twin Technology Application

BRICS-FS-40

Test Project

(Offline_International Final)

June, 2026

Content

Module A Virtual debugging of industrial robot system

A-1 Simulation environment construction

(1) Scene building

Use PQFactory software to open the CHL-DS18.robx file and open the display interface as shown in Figure 1-1. According to the installation steps, assemble each unit of the workstation into Figure 1-2.

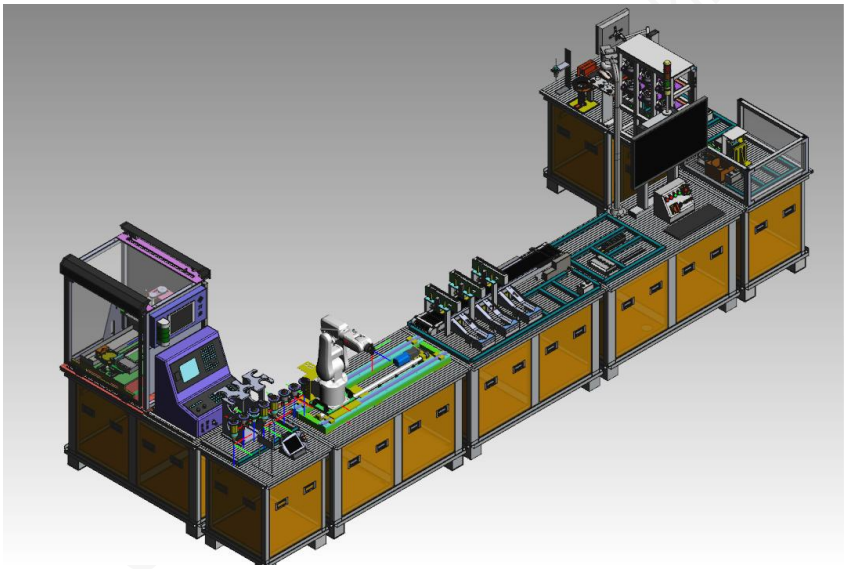

Figure A-1 PQFactory file

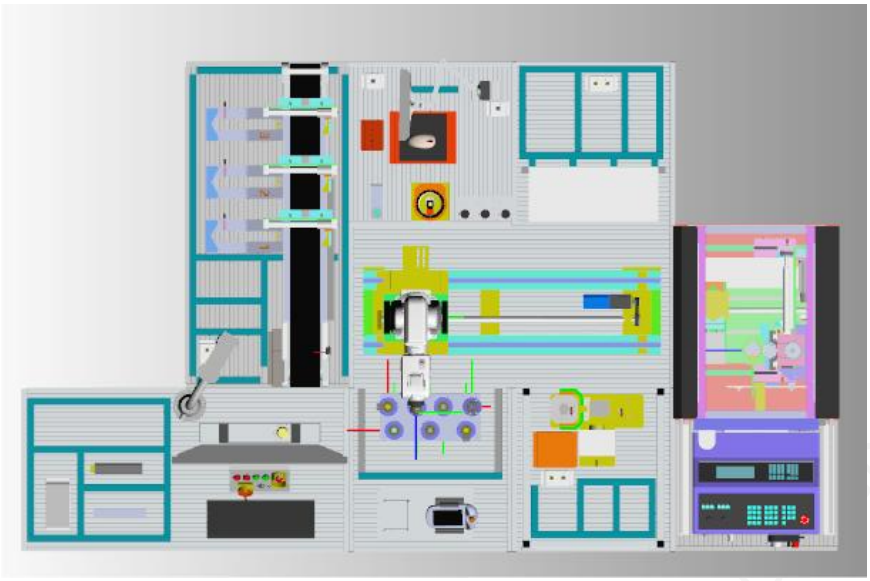

Figure A-2 Top view after assembly

requirement of assembling ：

1. With the "execution unit" as the benchmark and each processing unit as the basic unit, the assembly of all working units is carried out;

2. During assembly, the side surfaces of the tabletop panels of each processing unit should be attached together; the table planes of each processing unit should be kept in the same plane state (as shown in Figure 1-3).

3. The quick-change tool on the tool unit is installed and placed in the appropriate position on the tool rack according to the requirements.

(2) Definition of workstation model

1、In the virtual simulation system, photoelectric sensors are defined for storage unit 3 and 6 stations to enable them to have sensor detection functions, which can detect the corresponding parts of products on the corresponding stations and associate corresponding variables.

2、In the virtual simulation system, the red and green indicator light color status of storage unit 3 and 6 stations is defined, requiring the green color to be displayed when

there is material in the storage position and red color to be displayed when there is no material in the storage position, and corresponding variables are associated.

In the virtual simulation system, define the state machines for the three cylinders at the No.3 sorting unit crossing. Under the 'Scenario' model, locate the assemblies 'Sorting-Horizontal Barrier 3', 'Sorting-Upper Pusher 3', and 'Sorting-Lower Pusher 3', and define them as state machines named 'Sorting-Horizontal Barrier 3 State Machine', 'Sorting-Upper Pusher 3 State Machine', and 'Sorting-Lower Pusher 3 State Machine'. For 'Sorting-Horizontal Barrier 3', set the state machine to move in a 'translation' direction, with a minimum movement range of '0mm' and a maximum of '52mm', consistent with the actual cylinder movement direction. Set two states: state 1 is the lifting state, with a movement time of 0s and a joint value of 0mm; state 2 is the lowering state, with a movement time of 1s and a joint value of 52mm. For 'Sorting-Upper Pusher 3', set the state machine to move in a 'translation' direction, with a minimum movement range of '0mm' and a maximum of '110mm', consistent with the actual cylinder movement direction. Set three states: state 1 is the return state, with a movement time of 0s and a joint value of 0mm; state 2 is the extension state, with a movement time of 1s and a joint value of 16mm; state 3 is the push-out state, with a movement time of 3s and a joint value of 110mm. The sorting-down push plate 3 is set to move in a 'translation' direction, with a minimum movement range of 0mm and a maximum of 147mm, consistent with the actual cylinder movement direction. It has three states: State 1 is the return position, with a movement time of 0s and a joint value of 0mm; State 2 is the extended position, with a movement time of 2s and a joint value of 131mm; State 3 is the extended-out position, with a movement time of 3s and a joint value of 147mm.

4. In the virtual simulation system, define the state machine for the front door of the processing unit. Under the 'Scene' model, locate the assembly 'Processing-Left Sliding Door,' rename its components, and define it as a state machine named 'Processing-Left Sliding Door State Machine.' Set the state machine's movement mode to' Translation, 'with a minimum movement of 0mm and a maximum of 550mm. The direction of movement should match the actual cylinder movement. Define two states: State 1 is the closing state, with a movement time of 0s and a joint value of 0mm; State 2 is the opening state, with a movement time of 1s and a joint value of 550mm. After defining the state machine, use' Processing-Left Sliding Door State Machine 'to grasp the' Processing-Left Sliding Door-Sensor Shield.'

5. Define variables for the status machine, indicator light, sensor and guide rail of the virtual simulation workstation. The variable address player is defined by himself.

6. Set the snapshot of the virtual simulation workstation correctly. The snapshot is the initial state of the workstation.

A-2 Manual debugging of integrated system

Complete the address matching of PQFactory and communication setting, so that it can realize external signal communication with PLC control box. Through PLC programming, manual control of virtual scene is realized. The requirements are as follows:

1、Move the switch button 1 to extend and retract the telescopic cylinder at the storage unit station 3;

2、Move the switch button 2 to extend and retract the telescopic cylinder at storage

unit station 6;

3、Move the switch button 3 to open and close the safety door on the left side of the processing unit;

4、Press the "start" button of the training box, and the green light of storage unit station 3 and station 6 is on;

5、Press the "stop" button on the training box, and the red light of storage unit station 3 and station 6 is on.

Note: The PLC address of the PLC control box is shown in Table A-1 below.

Table A-1 IO table

order number	address	function annotation	order number	address	function annotation
1	Q0.0	Activate the indicator light	1	I0.0	start button
2	Q0.1	Reset indicator light	2	I0.1	stop button
3	Q0.2	Turn off the stop light	3	I0.2	reset button
4	Q0.3	buzzer	4	I0.3	scram button
5	-	-	5	I0.4	Turn on switch 1
6	-	-	6	I0.5	Move switch 2
-	-	-	7	I0.6	Move switch 3
-	-	-	8	I0.7	Move switch 4
-	-	-	9	I1.0	Diffuse reflection photovoltaics1.
-	-	-	10	I1.1	Diffuse reflection photovoltaics2.
-	-	-	11	I1.2	Slot photoelectric
-	-	-	12	I1.3	proximity switch
-	-	-	13	I1.4	safety protection device

A-3 Virtual debugging of integrated systems

(1) HMI interface programming design

1. Design the HMI monitoring interface, which can monitor the opening and closing

status of the safety door on the left side of the machine tool; monitor whether the hub of storage unit 3 and 6 is in a state; monitor the current track position of the industrial robot.

2. Design the HMI automatic process interface. In the HMI interface, you can select the assembly vehicle number (optionally 3 or 6), choose the process branch, and enter the left branch (hub sorting) or the right branch (hub return to warehouse). Add an "automatic start" button in the HMI interface.

(2) Virtual debugging process and debugging

Based on the process flow shown in Figure A-3, develop a PLC program and an industrial robot simulation program for virtual simulation, ultimately achieving virtual debugging and running the entire process flow. Using the initial feature and status information provided in Table A-2, adjust the positions of the hub and logo on the workstation to complete the virtual debugging of the production process for one hub part.

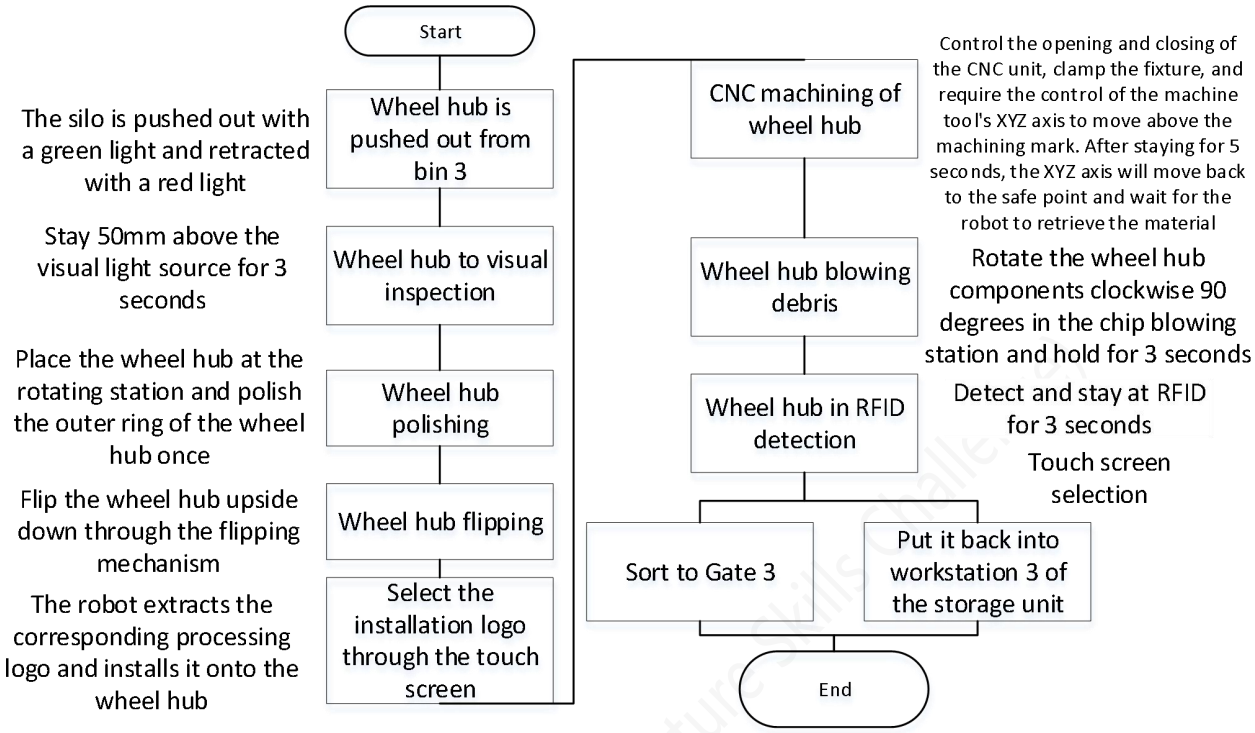

Figure A-3 Process flow chart

Table A-2 Initial state of the virtual debugging process hub

The hub is placed in its initial position	Whether to install the car logo	Rim placement direction
Bin 3	not have	Face down

ModuleB Industrial robot system integration application

B-1 Hardware construction and electrical wiring

(1) Hardware construction

According to the system layout scheme verified by virtual simulation, adjust the

relative positions of each unit and complete the hardware assembly and fixation of the application platform.

ask ：

The position of each unit is adjusted according to the layout design. Requirements: the foot support of each unit is raised, and each unit is fixed by connecting plate.

Adjust the bottom cabinet door panels of each unit. Requirements: The platform bottom cabinet is internally connected and there is no door panel blocking, all the outer sides are installed with door panels, and the extra door panels are placed in the U-shaped bracket.

(2) Electrical and network connections

According to the system layout scheme design and control system scheme design, complete the circuit, gas line and communication line connection of each unit, and complete the cable connection of the industrial robot trainer.

ask ：

(1) The power cable is installed by the quick connector plug of the bottom plate of the unit cabinet and laid through the lower wire trough of the cabinet; the air source and communication cable is installed by the equipment end and laid through the upper wire trough of the cabinet.

(2) The part of the power cable between units that is not placed in the trough shall not be bent, and shall be neatly placed on the bottom plate of the base cabinet.

(3) After the total power line of the application platform is connected, it is covered with the temporary trough provided by the station.

(4) The gas source cable must enter the trough on the tabletop part, and the part that does not enter the trough is fixed on the tabletop or column with a fixing buckle and a

tie band. The cutting length should be appropriate, and there should be no bending, winding or deformation, and no leakage of gas allowed.

(5) The communication cable must enter the trough on the tabletop part. The part that does not enter the trough is fixed on the tabletop or column with fixing clips and strapping tapes. There should be no bending, winding or deformation.

(6) When connecting the cable of the industrial robot teaching device, pay attention to the interface direction and the use method of the tightening nut. Do not turn the quick connector before it is fully inserted.

B-2 Robot and peripheral system unit debugging

(1) Integration and debugging of CNC unit

1. Install the signal table of CNC unit, write the PLC program inside the CNC to realize:

(1) In manual mode and MDA mode, the CNC front door is opened by pressing button 1. After the front door is opened, the indicator light 1 above button 1 is lit.

(2) In manual mode and MDA mode, the CNC gripper is released by pressing button 4. After the release is in place, the indicator light 4 above button 4 lights up.

(3) In manual mode and MDA mode, the CNC front door is closed by pressing button 7. After the front door is closed, the indicator light 7 above button 7 is lit.

(4) In manual mode and MDA mode, the CNC vise is clamped by pressing button 10. After clamping, the indicator light 10 above button 10 is lit.

Figure B-1 Button and indicator light definition

2. Tool installation and tool alignment

Use the tools and tools provided on site to complete the tool installation of the CNC unit. Set the machine tool mechanical zero point correctly, and carry out the tool operation.

3、 numerical control machining

According to the machining drawing shown in Figure B-2 and the machining process table shown in Table B-1, write or call the machining program to complete the machining of the workpiece:

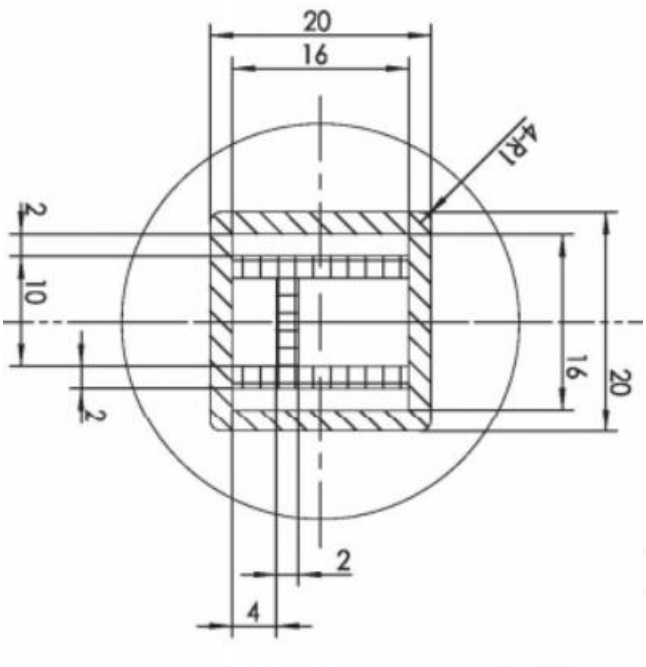

Figure B-2, processing drawings

Table B-1 Processing process table

step	Blade diameter (mm)	main shaft speed (r/min)	feed rate (mm/min)	cutting depth (mm)
1	Φ2	8000	500	0.5

ask ：

(1) Processing shall be carried out within the scope of product parts;

(2) CNC machining parts shall be programmed and debugged by the operator, and the corresponding machining program shall be verified under the MDA mode of the machine tool;

(3) After CNC machining, the characteristics of the product parts can be clearly seen, and other requirements are not made;

(4) The spindle position is at the origin of the machine coordinate system at the beginning and end of machining.

(2) Visual unit integration application

1. Visual calibration

Write the visual calibration program and complete the parameter calibration of the vision system. Use the calibration board tool provided on site, and complete the vision calibration by writing the industrial robot and vision program.

2. Visual inspection

Initially, one hub is placed on the front of storage unit station 4. Random length scratch stickers (fixed position) are attached to visual inspection area 3 and color label stickers (fixed position) are attached to visual inspection area 4.

Through the industrial robot to grasp the hub parts and place them in the visual camera field of vision of the visual unit, PLC and WINCC programs are written to achieve the following functions:

(1) Grasp the hub on storage unit workstation 4, and perform a scratch detection on the visual inspection area 3 of the hub's back, ensuring the correct measurement of the scratch length. Also, detect the label color in visual inspection area 4, ensuring the correct color identification. The length and color information should be accurately displayed on the WINCC interface. After the inspection is complete, return the hub to storage workstation 4. The scratch length value is a visual data obtained after the visual controller has been calibrated, and the error between this value and the actual length must not exceed ±0.5 mm (WINCC displays the length data with two decimal places).

(3) Joint debugging of robot system and peripheral equipment

According to the flow chart shown in Figure B-4, press the green "self-reset" button on the control panel to start the process. The green light of the three-color lamp

flashes at a frequency of 1Hz. When the process is over, the green light of the three-color lamp goes out and the red light stays on.

During the process demonstration, the industrial robot should be in automatic mode and the process is not allowed to interrupt. The specific programming requirements are as follows:

1. Robot programming and debugging

(1) Safety posture setting of industrial robot

For the operation and programming of industrial robots, determine the safe posture of the industrial robot body under which the industrial robot body will not collide with the surrounding equipment. When the seventh axis of the robot unit is running, the industrial robot body must maintain this posture and cannot move at the same time.

(2) Parameter configuration of the seventh axis of the robot unit

① For the PLC programming of the robot unit, the control parameters for the servo motor are set to match the actual specifications, enabling the PLC to control the motion of the seventh axis. The servo motor encoder has a resolution of 131,072 pulses per revolution (17 lines), the electronic gear ratio of the servo motor driver is set to 900:1, the reducer has a reduction ratio of 3:1, the synchronous belt has a reduction ratio of 1.5:1, and the ball screw pitch is 5mm.

Requirement: The seventh axis movement speed shall not exceed 50 mm/s.

② According to the internal wiring diagram of the robot unit provided, the PLC inside the robot unit is programmed to realize the functions of return to the origin, positioning motion and constant speed motion of the seventh axis. The origin sensor is located on the zero scale side.

(3) Pick up and return the quick change tool

For the operation and programming of industrial robots, the industrial robot can pick up and put back the required tools, and the action process is coherent without collision. The position of the tool rack for quick tool change can be adjusted according to the use requirements. Note: The industrial robot shall not release the tool in the air so that it falls on the tool rack.

(4) Use of quick change tools

For industrial robot operation and programming, the industrial robot can complete the action control of the tools used, such as clamping/unclamping of gripper tools, suction/unreleasing of suction cup tools, rotating of electric tools, and realize the picking up, releasing and processing of products.

2. Robot and CNC machine tool joint debugging

The requirements for writing industrial robot and PLC program are as follows:

(1) The industrial robot will take a hub from the grinding station, the safety door of the CNC unit is opened, and the industrial robot will put the hub on the fixture of the CNC unit;

(2) The industrial robot exits the CNC unit, the safety door of the CNC unit is closed, and the fixture of the CNC unit clamps the hub;

(3) The CNC machine tool will process the graphics on the specified drawing B-2 and the processing technology table in Table B-1. The operator must manually flip the workpiece between its front and back sides using the grinding unit to ensure that the CNC machining area on the front side of the workpiece is processed. After processing, the CNC spindle will return to its original position at the machine tool.

(4) Industrial robots pick up parts from the fixtures of CNC units.

3. Robot and vision system joint debugging

Write a robot and vision program with the following requirements:

(1) The industrial robot picks up the hub parts and performs visual detection of product features in the back area;

(2) Detect the length of scratches in visual area 3. If the length of scratches is less than or equal to 22mm, enter the left branch of the process;

(3) Detect the length of scratches in visual area 3. If the length of scratches is greater than 22mm, enter the right branch of the process.

4. Robot and other peripheral devices are connected and adjusted

(1) Storage unit

According to the design results of the control system scheme and the internal wiring diagram provided for the storage unit, the three-dimensional storage unit process is formulated to achieve the following functions:

① The position pallet is pushed out and retracted by external signals.

② The sensor of each position can sense whether the current product parts are stored in the position.

③ The position indicator light will be lit according to the storage status of parts in the position. When there is no part stored in the position, the red light will be lit; when there are parts stored in the position, the green light will be lit.

(2) Sorting unit

According to the design results of the control system scheme and the internal wiring diagram of the sorting unit provided, the process of the sorting unit is formulated to achieve the following functions:

① Start the conveyor belt according to the external instruction, and lower the blocking cylinder of the designated sorting mechanism. When the product parts move

to the designated sorting mechanism, the conveyor belt stops.

② When the product parts trigger the sensor at the starting end of the conveyor belt, the corresponding gate sorting cylinder is lowered according to the external instruction.

③ When the product parts move to the designated sorting mechanism, the sorting mechanism pushes the cylinder to push the product parts into the sorting passage, and then through the positioning cylinder of the passage, the product parts are positioned at the V-shaped slot, and then retracted after 3s.

(3) Polishing unit

Based on the control system scheme design results and the internal wiring diagram of the polishing unit provided, the process of the polishing unit is formulated to achieve the following functions:

① When the industrial robot is ready to place the hub parts to the grinding station or prepare to take the hub away from the grinding station, the clamping cylinder of the grinding station is released and the flipping fixture is on the side of the rotating station;

② When the industrial robot is ready to place the hub parts to the rotary station or ready to take the hub away from the rotary station, the clamping cylinder of the rotary station is released, and the flipping fixture is on the side of the grinding station;

③ The flipping tool can flip and accurately position the hub parts between the grinding station and the rotating station;

④ When the hub is in the rotating station, the corresponding clamping cylinder clamps. Grinding process 1: grinding in area 3 and area 4. Just contact the end face grinding tool with the surface of the hub and start grinding, keep grinding for 3S and

then close grinding.

⑤ When the hub is in the rotating station, the corresponding clamping cylinder is clamped. Grinding process 2: Use the end face grinding tool to complete the grinding of two circular outer rings on the back of the hub, as shown in Figure B-3.

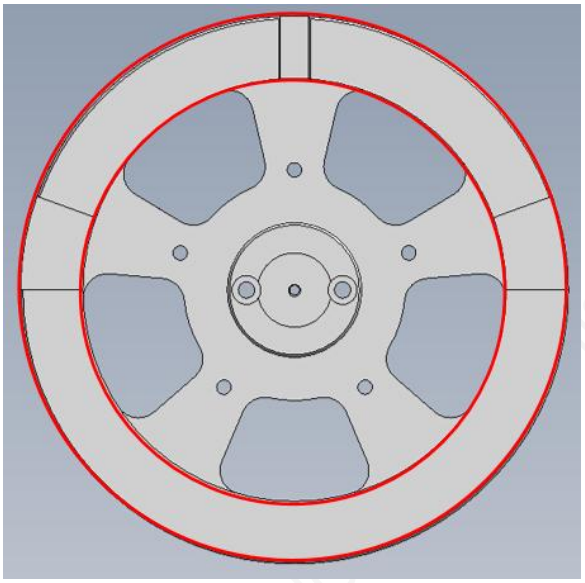

Figure B-3 Grinding profile of grinding process 2

(4) Assembly module

Assembly module process requirements:

① The industrial robot uses a single suction cup tool to suck up the car logo from the car logo library;

② Place the logo on the hub without the logo, and press it with a suction cup tool.

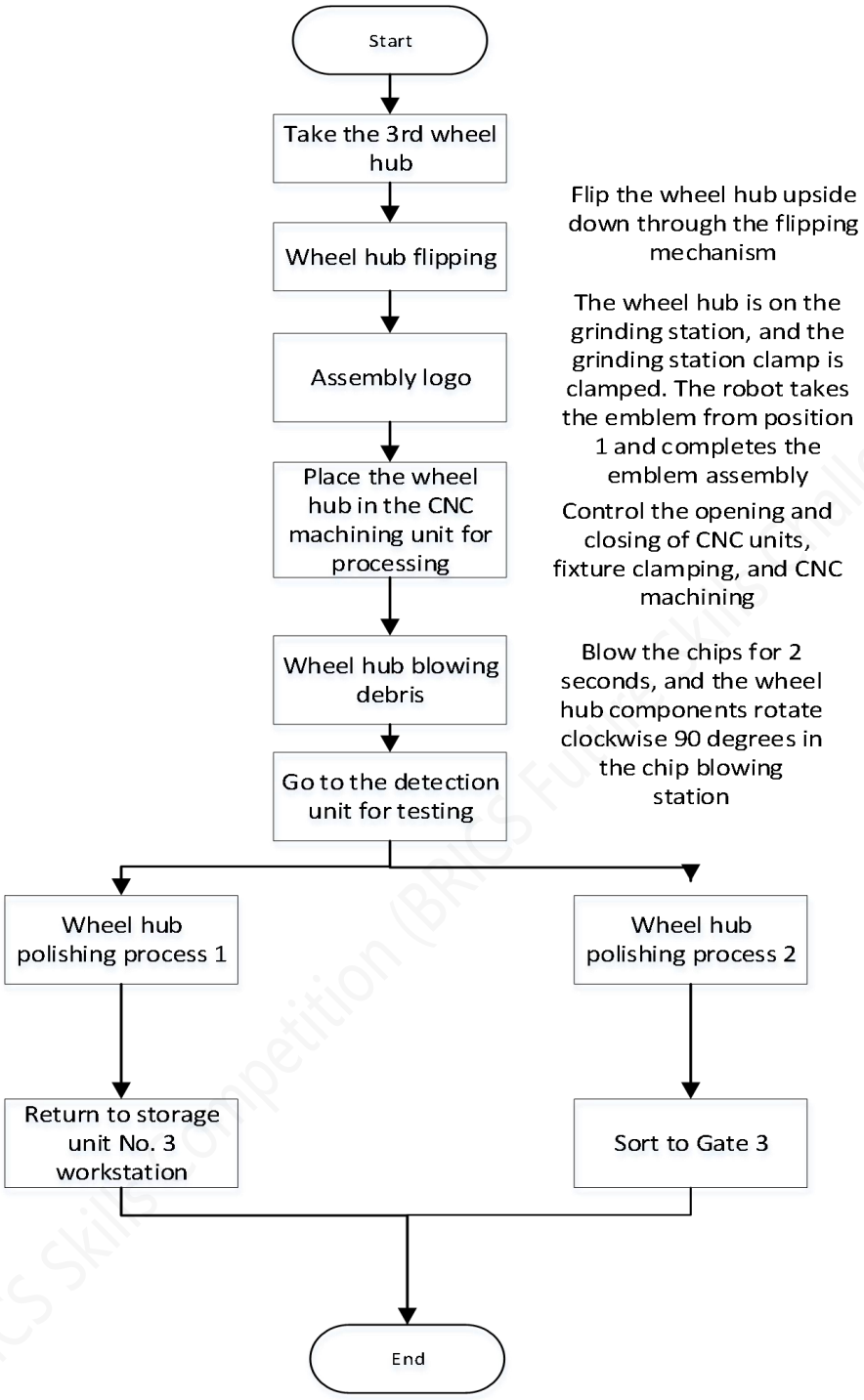

Figure B-4 Robot and peripheral system joint debugging flow chart

B-3 Industrial robot system integration and commissioning

(1) MES system application configuration

1、MES system gateway configuration

(1) Use the gateway configuration software to configure the gateway and establish a communication channel to meet the data interaction with the PLC of the device.

(2) Refer to "PLC_MES Collection Point Table Information" in "D:\Reference materials", and add the data that needs to be monitored and written to the collection point of the gateway and the collection point table of PLC.

(3) Establish MQTT channel, load the collected data, and upload the data to MES.

(4) Save the project and download it to the gateway

(5) Open the gateway monitoring software to monitor the collection status of required data.

2、Develop business processes for MES system

(1) Definition of system management center

① The player opens the browser and logs in to the MES system according to the account and password provided on site.

② Under the system management center, a new production supervisor role is created, and the system role attribute is set as no (role name: supervisor, role code: S0001);

③ Authorize the process configuration tool module, all menus under the process dispatching center and production execution center for the newly created production supervisor role and save them;

④ Under the system management center, a new customized organization is created (organization name: production manufacturing application, organization code: J0001, organization type: provincial company);

⑤ Under the system management center, a new production supervisor account is

created and the production supervisor role is assigned. The initial login password of the new account is: 123456; (Login account: supervisor1, user nickname: ABC

(2) Design of order approval model

① Under the process configuration tool, a new process classification (process name: LC1 and classification code: L0001) is added;

② Under the process configuration tool, create a process model for 'Production Order Approval.' The process should have at least two nodes: the first node is where the process initiator submits the order, and the last node is where the production supervisor approves the order. After completing the model design, publish it to the process category. (Model name: Model1, Model key: orderRecord)

(3) Approval of order business association

Under the process configuration tool, associate the 'Production Order Approval' process with business operations. Add a new 'Production Order' form, ensuring the form Key is set to 'orderRecord'. Select 'Process Title Generation Script' as the process script for the process title. For both the PC and mobile form addresses, select 'Process Form Address (PC, Mobile)' as the process script. In the other process options, uncheck the 'Skip Same Processor' option, then save the changes.

(4) Approval of order event binding

For the newly added 'Production Order' form, bind process events. Add three events in sequence: [Update Business Table Status (Review, Return)] with the event type set to [Task Creation] and the event script as [Process Event 1-Update Business Table Status (Review, Return)]. Next, add [Update Business Table Status (Process Completion)] with the event type set to [Process Completion] and the event script as [Process Event 2-Update Business Table Status (Process Completion)]. Finally, add

[Update Business Table Status (Process Termination)] with the event type set to [Activity Cancellation] and the event script as [Process Event 3-Update Business Table Status (Process Termination)].

(5) Production data definition

① Under the production data center, add new equipment, "production equipment number" SC0001, and select predefined process as "production process";

② Under the production data center, add a new equipment group with the group number: BZ0001 and the group name: Group 1. Then add "Equipment Management" and select the equipment added in step 1 to join the group;

③ Under the production data center, find the "processing unit" code named [DS18], click and select it, and click Add in the workgroup management list on the right to add the group added in step 2 to the "processing unit".

(6) Enter the order

Under the process work center, enter the BOM information as "hub finished product", fill in the "required quantity", and submit for approval.

3. Data acquisition and visualization

(1) Process assignment

① After connecting the WIFI provided by the tablet, log in to the MES system on the tablet with the account of the production supervisor to complete the production order approval process.

② Order calculation is carried out in the process dispatching center.

③ In the process work center, the production plan of the processing unit type [equipment operation unit] is issued;

④ In the process work center, select the task data, click the equipment operation

work in the upper right corner, and assign the operation task to the production equipment created in "Production Equipment Definition";

⑤ Log in to the MES system with the provided account on the computer, execute the production order task under the production execution center, and start the corresponding process of physical equipment.

(2) Production data monitoring

After the system starts running, log in to the MES system of the tablet with the account of the production supervisor, and monitor the operation status information of the current equipment in the production execution center.

Table B-2 Monitoring information

order number	cell	Parameter items
1	Execution unit	The target motion position of the translation slide table
2	Warehouse unit	Whether the wheel parts are stored in each position
3	Numerical control unit	The tool number currently in use
4		The machining unit spindle has X/Y/Z mechanical coordinates
5		main shaft speed
6	Sorting unit	Whether there are hub parts at each sorting crossing

（2）Comprehensive debugging of robot system

1. Comprehensive debugging involves one product part, which is ordered and executed by MES. If MES order execution cannot be realized, the comprehensive debugging of the system shall not score.

(1) The system detects the storage information of parts in the storage unit. The robot picks up the appropriate tool to take out the parts from the no.1 workstation

of the storage unit, with the front of the hub facing up and the car logo installed.

(2) Scan the RFID electronic tag on the back to retrieve the preset process information (this information is manually entered by the referee before scoring). The process is executed in the order of the preset information. For example, "A1B3C2C3E2" (the meaning of the RFID electronic tag information is detailed in Table B-3). During the operation, if the hub needs to be flipped, the contestant should use the flipping mechanism of the grinding unit to flip it.

(3) According to the process information, complete CNC machining, grinding, testing, sorting, storage and other tasks according to the process, and display the current process information on the WINCC interface. For example, when executing A1 process, WINCC displays "current A1 process is being executed".

Table B-3 Information meaning of RFID electronic tag

order number	Process number content	meaning
1	A1	Numerical control machining of letter "A", size is customized
2	A2	Numerical control machining letter "B", size is customized
3	B1	Polish area 1 and area 2
4	B2	Polish area 3 and Area 4
5	B3	Draw the trajectory shown in Figure B-3
6	B4	Blow chips on the hub
7	C1	The current real-time date and time stamp data is written into the front RFID chip of the hub and displayed on the WINCC interface. The data should not be overwritten throughout the whole process (for example, if it is May 20,2025, then write: 2025-5-20)
8	C2	Write the current day of the week timestamp data to the front RFID chip of the hub and display it on the WINCC interface. The data must not be overwritten throughout the process (e.g., Mon for Monday, Tue for Tuesday, Wed for Wednesday, Thur for Thursday,

		Fri for Friday, Sat for Saturday, and Sun for Sunday)
9	C3	Write the current time stamp data to the front RFID chip of the hub and display it on the WINCC interface. The data should not be overwritten throughout the process (for example, if 9:28 is written, then 09h28m is written)
10	D1	Put the hub back in position 1
11	E1	Put the hub into the sorting unit and sort it to the No.1 crossing
12	E2	Put the hub into the sorting unit and sort it to the second crossing
13	E3	Put the hub into the sorting unit and sort it to the No.3 crossing

（3）Digital twin application of industrial robots

1、The communication program for the industrial robot is written, requiring the use of an interrupt program, which is triggered by a timing interrupt to send the joint angles of the industrial robot to the digital twin software. The sending format is "RA:0,0,0,0,0,90#" (the middle 6 values are the actual 6 joint angles of the robot)

2、Open the digital twin model, select ABB robot, "Connection Settings";

3、After the virtual debugging is started, verify the synchronization of the real industrial robot gripping claw tool process with the virtual one