Construction of Intelligent Chassis Assembly Line based on Machine Vision and Industrial Robot

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Abstract. The intelligent chassis assembly line integrates digital production control system, automatic loading and unloading system of heavy-duty robot, machine vision hole centering system, professional high-precision docking platform, robot automatic screw tightening system and quality control system. It realizes the automatic, intelligent and unmanned assembly process of the rear axle assembly of the intelligent agricultural machine chassis with the middle motor, the middle motor bracket, the front motor and the front motor bracket. The production line has been successfully put into use, creating the first intelligent assembly of intelligent agricultural machinery chassis in China.

Keywords: Chassis Assembly; Robot; Machine Vision; Quality Traceability; Docking Platform.

1. Introduction

Since the 13th five-year plan, the endogenous demand of China's manufacturing industry in terms of improving quality, efficiency and core competitiveness has continued to grow, the intelligent manufacturing system is flourishing with each passing day, the supply capacity of intelligent manufacturing is constantly enhanced, and the overall development trend is good. Following the development trend of intelligent manufacturing, it is urgent to design and manufacture the first automatic and intelligent chassis assembly line of intelligent agricultural machinery in China. While solving the actual production problems, it is also necessary to explore the intelligent manufacturing system of intelligent agricultural machinery.

In order to realize the automation of chassis assembly of intelligent agricultural machinery and the traceability of product production process, and improve the consistency of products, an automatic assembly line based on machine vision positioning is designed. First, the multi degree of freedom high-precision adjustment platform and docking platform are designed to realize the accurate adjustment and hole alignment of the rear axle assembly and assembly parts; Secondly, the heavy-duty robot and customized fixture are used to load and unload the assembly parts in turn, and the accurate reference alignment of the two assembly parts is realized with the high-precision positioning of machine vision and distance sensor; Finally, the self-adjusting docking platform is used to complete the docking of the assembled parts, and the automatic screw tightening equipment is used to fix the two parts with bolts.

2. Introduction to Assembled Products

The main components of the chassis of the intelligent agricultural machine are the rear axle assembly, the middle motor, the middle motor bracket, the front motor, the front motor bracket and the front axle assembly. In this automatic production link, the automatic assembly of the rear axle assembly, the middle motor, the middle motor bracket, the front motor, the front motor bracket and other components is realized. The overall weight of the assembled product is about 2570kg and the overall dimension is 2900mm × 2800mm × 660mm. Its structure is shown in Fig 1.

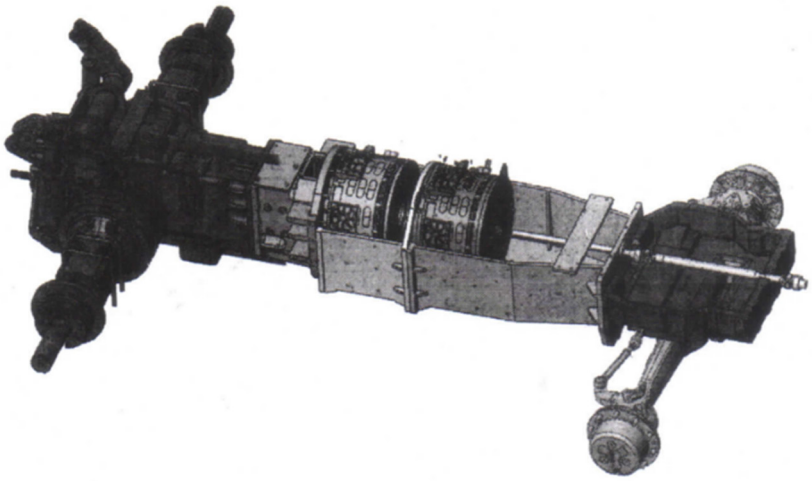


Fig 1. Schematic diagram of chassis product components

1) Rear axle assembly
Overall dimension: 1700mm × 2800mm × 1000mm, component weight is about 1400Kg;
2) Middle motor
Overall dimension: 360mm × 520mm × 520mm, component weight is about 300Kg;
3) Middle motor bracket
Overall dimension: 490mm×690mm×460mm, component weight is about 270Kg;
4) Front motor
Overall dimension:360mm×520mm×520mm, component weight is about 300kg;
5) Front motor bracket
Overall dimension:1010mm×690mm×460mm, component weight is about 300kg;
In the last step of the automatic assembly process, the two assembly parts are locked with screws. Now the types and quantities of screws used are counted, and the statistical results are shown in Fig.2

Middle motor	Output axial end face	M10×40	20mm	8
Middle motor bracket	Axial end face	M12×50	20mm	17
	Side of motor base	M12×40	20mm	16
Front motor	Output axial end face	M10×40	20mm	8
Front motor bracket	Axial end face	M12×50	23mm	12
	Output axial end face	M12×40	20mm	16

Fig 2. Screw statistics

3. Assembly Line Objectives

1) Strong compatibility, realizing automatic assembly of various chassis models.
2) High automation, automatic in feeding, testing, centering, assembly, locking and other aspects.
3) The operation is simple. In order to improve the work efficiency of the on-site workers, the assembly process is designed as brief as possible to reduce the information input process of the workers.
4) Complete informatization, realize information management of work plan, assembly operation and quality inspection, and realize visual management of equipment status and process data.

4. Difficulty Analysis

The design of the intelligent assembly line needs to solve the following difficulties:

1) A reasonable precision platform is designed for the assembly part to realize the accurate adjustment of multiple degrees of freedom of the assembly part. At the same time, the load should also meet the overall weight after assembly, that is, 2570kg.

2) The loading process of the assembled parts is completed by the heavy-duty robot. The design of the fixture in the loading process needs to consider the rapid clamping and the protection of the parts to avoid the damage to the parts as much as possible.

3) After the assembly parts are loaded, how to quickly position the loaded parts, design a pallet with strong versatility and accurate positioning, and reduce the weight of the pallet as much as possible to facilitate loading by robots.

4) During the assembly process, the two parts are adjusted quickly and accurately to achieve the purpose of accurate engagement of the assembly parts.

5) In the process of automatic production, the loading and unloading of parts and the tightening of screws are all automatic means. Four robots are used, and the working space cannot have the participation of workers. It is necessary to solve the product quality problems in the assembly process and improve the personal safety of workers.

5. Overall Design

5.1 Overall Layout

The intelligent assembly line of intelligent agricultural machinery should not only solve the above difficulties, but also meet the intelligent demand of modern industrial production, from the release of production tasks, material distribution, to automatic assembly and transfer, and finally the information upload after product assembly.

The overall layout of the intelligent chassis assembly line is designed in the form of multi station and assembly line operation. Its main components are the rear axle and adjustment platform, guide rail, screw tightening robot, automatic screw feeder, loading and unloading robot, high-precision docking platform, station terminal, machine vision, station monitoring, etc. Its layout is shown in Fig. 3. The overall layout of the assembly line is clear and definite, with complete functions and comprehensive consideration of personnel safety protection.

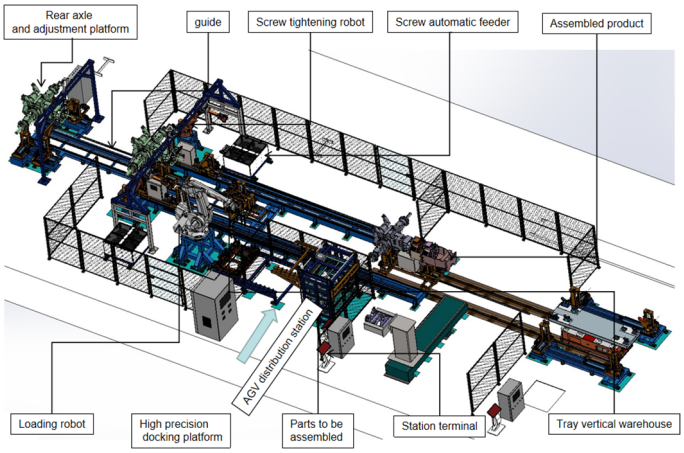


Fig 3. Overall layout

5.2 Workflow

According to the actual chassis assembly process, the work flow of this intelligent assembly line is as follows:

1) A production order is issued through the workshop production control system. The production order will be directly issued to the operation terminal of each station. The worker can log in to the system with personal permission to view the task order. The task order contains product model, quantity, process requirements and other data.

2) After the worker completes the preparation, the workshop logistics system will be triggered, and the AGV will be called according to the Mo to distribute the corresponding materials.

3) The material distribution is complete, including the middle motor to be assembled, the middle motor bracket, the front motor, the front motor bracket, the fastening screw, etc. the operator places the material on the tooling tray for the first step of positioning.

4) After the rear axle components are loaded, they are transported to the automatic assembly station through the high-precision multi degree of freedom adjustment platform and guide rail.

5) The state information of the assembly joint surface within the system coordinate is detected by the laser distance measuring device.

6) Adjust the platform to adjust the rear axle attitude according to the detection results, so that the joint surface meets the requirements of automatic assembly tolerance in the system coordinate system.

7) The heavy-duty robot uses the end clamp to clamp the feeding tray and the assembly parts above the tray and place them on the high-precision docking platform.

8) Machine vision and distance measuring sensors identify the state of the joint surface of the assembled parts, and use the docking platform to adjust its state to match the state of the joint surface of the rear axle.

9) Machine vision identifies the through holes on the joint surface of the rear axle assembly and the threaded holes on the joint surface of the assembly parts, so that the center lines of the corresponding through holes and threaded holes are on a straight line.

10) The docking platform moves along the guide rail to make the assembly surfaces of the two parts contact.

11) The screw automatic feeder conveys the corresponding screws. The screw tightening robot clamps the screws and locks the assembly parts with the end screw tightening mechanism;

12) After the locking process is completed, the station quality management system identifies the assembly effect and uploads the results to the production control system to realize product quality traceability and assembly process informatization.

13) After the assembly is confirmed, the transfer vehicle of the next station will transfer it to the next station.

6. Key Technologies

6.1 Adjustment Platform and Docking Platform

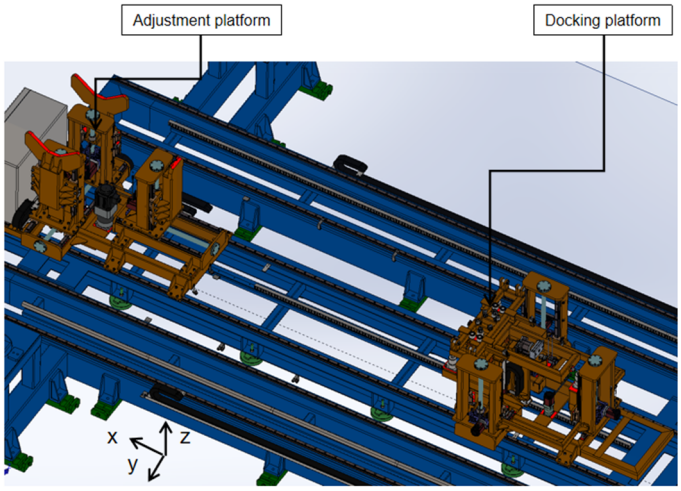


Fig 4. Schematic diagram of adjustment platform and docking platform

In the assembly line, the adjustment platform and the docking platform are designed with the main components such as motor, reducer, trapezoidal lead screw and guide rail, and the adjustment platform and docking platform are installed on the high-precision guide rail, as shown in Fig. 4.

The rear axle assembly is placed on the adjustment platform and supported by three points. The movement in the X direction is realized by gear rack transmission. The movement in the Z direction is realized by the simultaneous upward or downward movement of the three support points, and the rotation of the components in the Y direction is realized by the upward and downward movement of the front support points; The assembly parts and their pallets are placed on the docking platform, and the movement principle is similar to that of the adjustment platform.

The function of the adjustment platform is to slightly adjust the posture of the rear axle assembly. The power is provided by the output shaft of the motor and reducer assembly. Due to the heavy load, it is necessary to verify whether the power meets the actual demand. The verification process is as follows:

Known condition: weight of rear axle assembly distributed at each support point $W = 467\text{kg}$, gravitational acceleration $g = 9.8m/s^2$, friction coefficient $\mu = 0.21$, trapezoidal lead screw $R = 5\text{mm}$, lead angle $d = 4°40' = 4.67°$, motor assembly output torque $T = 50\,N \cdot \text{m} = 5000\text{N} \cdot \text{cm}$, screw efficiency: $\eta = (1 - \mu \times \tan(d))/(1 + \mu / \tan(d)) = 0.275$.

Verification conclusion: Ascending thrust

$$F = (2\pi \times \eta \times T)/R = (2\pi \times 0.275 \times 5000)/0.5 = 17270N.$$

The selected motor components and trapezoidal lead screw specifications are verified to be suitable for the rising power demand of the station.

6.2 Feeding and Precise Positioning of Assembly Parts

With the continuous improvement of manufacturing automation. There are more and more applications and demands for industrial robots to carry, sort, stack, spray and other operations. It is an inevitable trend of industrial development to replace human beings with robots for repetitive and high load work [1].The industrial robot with rated load of 450kg is used in the assembly line. The assembly parts refer to the middle motor, the middle motor bracket, the front motor, the front motor bracket, etc. according to the design of the assembly line, they are connected and locked with the rear axle assembly in sequence. The steps are as follows.

1) The AGV in the workshop distributes the assembly materials to the upper material station;

2) The operator places the assembled parts on the tooling pallet respectively;

3) The robot clamp clamps the crossbeam on both sides of the tooling tray to carry out the feeding process, and places it on the docking platform;



Fig 5. Positioning mode of pallet

4) Machine vision simultaneously detects the mating mounting surfaces of the rear axle assembly and assembly parts to ensure that the two mounting surfaces are parallel and the screw holes are aligned with the through holes;

5) The docking platform moves along the X direction, and at the same time, the vibration equipment of the docking platform is opened to solve the impact caused by the pin docking difficulty;

During the operation of the assembly line, the middle motor and the tooling tray are placed on the docking platform, as shown in Fig.5.

6.3 Visual Inspection and Screw Hole Alignment

Before the docking of the two parts to be assembled on the assembly line, the joint surface and hole position shall be inspected to meet the requirements of automatic assembly. The requirements are as follows:

1) The parallelism of the joint surface of two parts is within 0.2mm.

2) The concentricity of corresponding screw holes and through holes shall be within 0.2mm.

The assembly line is realized by combining machine vision and distance measuring sensor. The distance measuring sensor is used to measure the joint surface and the machine vision is used to detect the position of the corresponding hole. As shown in Fig. 6.



Fig 6. Machine vision inspection and positioning

Machine vision uses double cameras to detect the hole positions of two parts at the same time, find the hole contour, and then find the center of the hole. The two-dimensional histogram oblique division method for locating the edge area is to set four straight lines parallel to the main diagonal line of the two-dimensional histogram on the plane. The projection of the two-dimensional histogram on the plane is divided into five areas by these four straight lines. The area belonging to the edge is fuzzed, and the membership function is shown in the following formula.

$$P_{\mathrm{mn}} = F\left(X_{mn}\right) = \left(1 + \frac{X_{\max} - X_{mn}}{\alpha}\right)^{-\beta}$$

In the formula: X_{mn} is the gray value of the (m,n)-th pixel of the image; α and β are fuzzy factors; $X_{\max}$ is the maximum gray scale of the image; P_{mn} is the blur value of the (m,n)-th pixel of the image[2]

After the blurring processing, the edge region is enhanced. After the local blurring and enhancement processing, the image edge is detected, and the sequential morphological transformation

is used to achieve the sub image. The information entropy and weight coefficient of the sub images are calculated, and the final edge of the hole corresponding to the joint surface is obtained after weighting the sub images. The detection process is shown in Fig. 7. The data of the detection result is fed back on the operating system interface in real time, as shown in Fig.8.

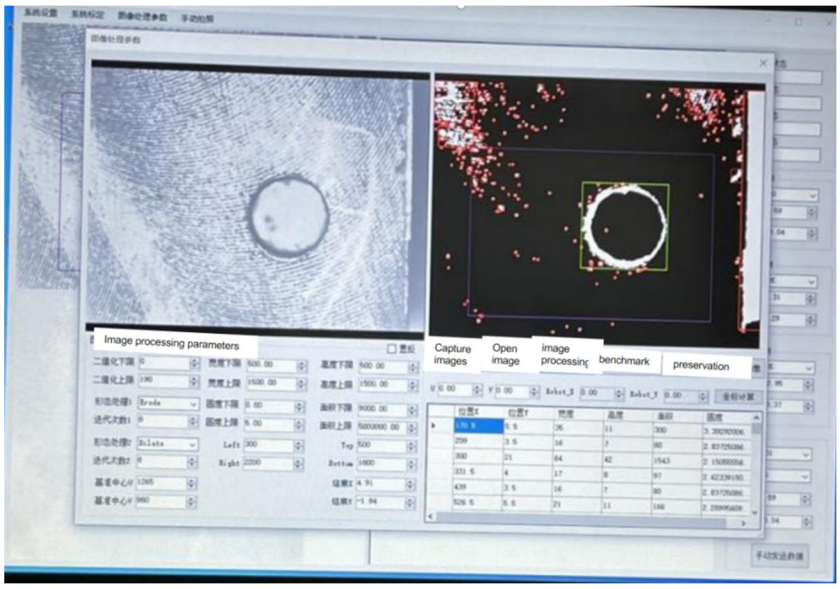


Fig 7. Machine vision inspection process and result display

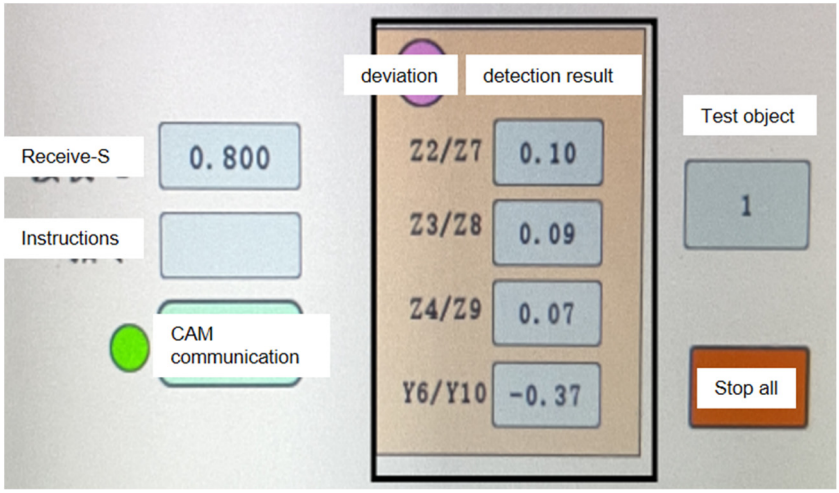


Fig 8. The detection results are fed back to the operating system in real time

6.4 Product Quality Management

Product quality traceability relates to the final product quality and production safety. It is an important part of digital production and an important link of modern industrial production process. Product quality traceability has the following functions: for any nonconforming product found at any time, it can not only be responsible to the person, but also can effectively analyze the quality problems and formulate corresponding measures to solve them [3].

In this assembly line, from the production task release, the distribution and loading of assembly parts, the supervision of the assembly process, to the product verification after assembly, each link is set with steps such as process detection, matching verification and result verification. Each station is equipped with high-definition camera equipment to realize the requirements of visualization and digitization of the production process. The interface of automatic assembly station quality management system is shown in Fig.9.

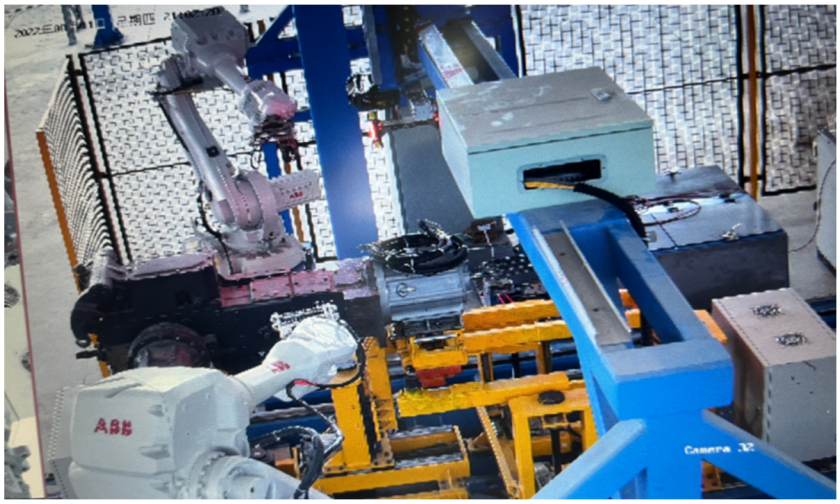


Fig 9. Product quality management system

6.5 Control System Design

The intelligent assembly line control system is the core of the equipment execution layer in the automatic control system. It interfaces with the workshop production control system and accepts the action instructions of materials; Downward control of various execution equipment to realize the driving, conveying, material positioning, detection and assembly of the underlying equipment; Complete the process control and information transmission of material transportation. In addition, it also provides rich and vivid human-machine interface, safety protection measures and various operation modes to assist staff in equipment operation and maintenance. It is an important part of the automation system. The control system adopts Siemens PLC products, communicates with the upper computer through industrial Ethernet, and IO is collected by Siemens IO module. Motor control is adopted for electric drive. Servo motor control is adopted for equipment requiring stable transportation or precise positioning. The human-machine interface is a combination of touch screen and button. The human-machine interaction interface of the control system is shown in Fig.10.



Fig 10. Control interface

7. Summary

The first intelligent chassis assembly line of intelligent agricultural machinery in China has been successfully put into use. The success of the above scheme has been verified through actual production, and the feedback is good. The intelligent assembly line is summarized as follows.

1) Efficiency: at present, the assembly line is in use. It takes 32-35 minutes to complete the assembly of the whole line. Compared with the current manual assembly, the working time is greatly shortened and the working efficiency is improved.

2) Consistency: the products produced by this assembly line can ensure a high degree of consistency, and the consistency of assembly relationship and screw tightening can be improved qualitatively.

3) Traceability: in the whole production process, the source can be traced from the scanning of assembly parts, the statistics of screw tightening torque, and whether the assembly is in place.

4) Professional: pin matching is involved in the assembly of the middle motor housing and the front motor housing. The matching tolerance of this link is high. Therefore, a high-precision docking platform is independently designed to enable it to carry out the assembly work smoothly and quickly.

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