

Design and Implementation of Connector Automation Workstation Based on Industrial Robots

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Abstract: Addressing the issues of low production efficiency and difficulty in defect control in the segmented production of PA6 in-mold injection molded connectors, this paper designs an automated workstation that integrates cutting and feeding, robotic transfer, injection molding, and pressure-resistant sorting. Taking bimetallic insert connectors as the processing object, four major functional units are divided to complete the structural design of the cutting and feeding equipment unit, six-axis robotic handling unit, vertical injection molding machine docking module, and pressure-resistant detection and sorting unit, establishing a closed-loop automated process flow. The equipment adopts PLC linkage control, and the modular structure adapts to connectors of multiple specifications, reducing labor costs and having significant promotional and application value for the intelligent production of similar small-part injection molded products.

Keywords: In-mold injection molding, connector, automatic tooling, six-axis robot, Pressure test.

1. Introduction

Automotive electronic connectors are the basic components for electric energy and signal transmission in complete vehicles. The industry widely adopts the in-mold injection molding process with embedded metal terminals made of PA6 engineering plastic. The assembly accuracy of terminals and the voltage withstand and insulation performance of finished products directly affect the stability of the vehicle's electrical system. Currently, most small and medium-sized connector manufacturing enterprises in China adopt a segmented and discrete production model, where the stations for terminal cutting, insert loading, injection molding, and finished product voltage withstand testing are independent of each other. Material transfer between processes relies on manual labor, which presents many drawbacks in mass production. Manual cutting of terminal strips results in poor positioning consistency, easily leading to defects such as missing terminals, misalignment, and deformation; manual placement of inserts involves high labor intensity, and prolonged operations are prone to missed terminal assembly, resulting in batch injection molding scraps, and quality hazards cannot be eliminated in advance in the front-end processes. At the same time, the physical separation of injection molding and voltage withstand testing stations leads to appearance defects such as plastic scratches and terminal bending in finished product turnover. Offline testing cannot provide real-time feedback on abnormalities in cutting and feeding processes, which is not conducive to continuous process optimization [1-3].

Currently, most automation equipment on the market are

single-function dedicated machines that can only independently complete terminal cutting or finished product pressure testing. There is a lack of integrated workstations that cover the entire process flow, and process connection still relies on manual labor, resulting in insufficient automation integration. With the acceleration of the intelligent and automated transformation in the automotive parts industry, enterprises urgently need a closed-loop automation equipment that integrates cutting, feeding, injection molding handling, and online pressure sorting [4-6].

This article combines the mass production requirements of a dual-insert connector, integrates hydraulic punching, circular conveyor, six-axis flexible handling, and online pressure sorting technology, designs an integrated intelligent workstation, completes the modular layout of the entire machine, designs the core actuator structure, plans the closed-loop automated production sequence and online defect detection system, effectively solves the problems of high labor costs, lagging defect control, and low space utilization in traditional segmented production, and has important promotion and application value for the intelligent production of similar small-part injection molded products.

2. Product Structure and Production Process Requirements

The research object of this article is the in-mold injection molded connector made of PA6 material, as shown in Figure 1. The product includes two sets of metal insert structures, which must meet the electrical voltage withstand and insulation performance requirements after injection molding.



1-Metal part a



2-Metal part b



3-Finished injection-molded connector

Figure 1. Connector

The core process steps for product production are as follows: (1) Cutting and separating two types of terminal inserts from the metal strip; (2) Precisely loading the inserts into the lock block fixture; (3) Online detection of missing pins and defects; (4) Orderly placement of the fixture matrix; (5) The robot sends the fixture into the vertical injection molding machine to complete in-mold injection molding; (6) The injection-molded finished products are taken out and transferred to the pressure test station; (7) The finished products undergo pressure performance testing, and are automatically sorted and discharged according to whether they are qualified or defective.

3. Overall Layout Design of Integrated Tooling

Based on the product production process, an integrated tooling overall layout design based on industrial robots is carried out. The entire tooling system consists of four major functional units, as shown in Figure 2. The four units are the cutting and feeding equipment, the Fanuc six-axis robot handling unit, the vertical injection molding machine, and the pressure testing and sorting equipment. The entire workstation relies on an endless conveyor line and a six-axis robot to achieve seamless material flow. The robot movement area is equipped with aluminum profile safety fences to meet industrial equipment safety standards.

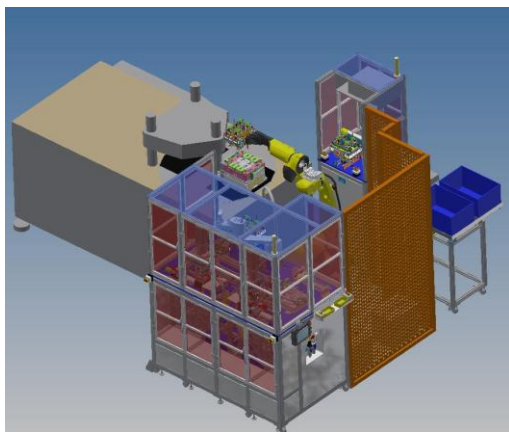


Figure 2. Overall layout design of integrated tooling

4. Structure and Mechanism Design of Each Functional Unit

4.1. Design of the Cutting and Feeding Equipment Unit

The cutting and feeding unit is a crucial part at the start of the production line, handling things like terminal punching, loading inserts, checking for shortages, arranging the fixture matrix, and returning carriers—all the upfront tasks. Inside, it

has a circular assembly line, a four-axis robot, needle mechanisms, needle refilling mechanisms, and a matrix carrying platform. You can see the overall setup of the cutting and feeding equipment in Figure 3.

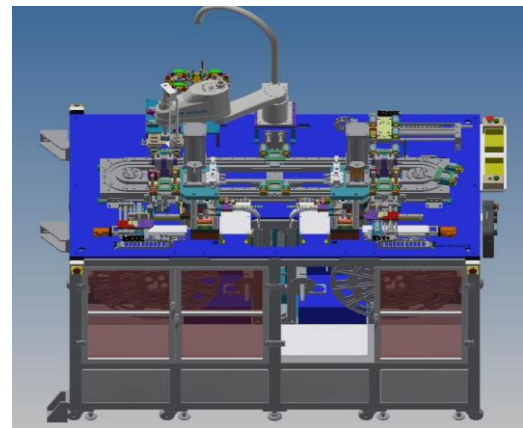


Figure 3. Cutting and feeding equipment

4.2. Design of Six-Axis Robot Handling Unit

The core equipment of the handling unit is a Fanuc six-axis industrial robot, as shown in Figure 4. Serving as the material transfer hub for the entire production line, it connects the cutting and feeding unit, vertical injection molding machine, and pressure testing unit, enabling flexible material handling across processes. The robot's end is equipped with a customized composite gripper head that integrates a material presence/absence detection sensor. Before grasping the matrix fixture, it automatically detects the presence of the lock block insert to prevent empty fixtures from being fed into the injection mold, which can cause material shortage defects.

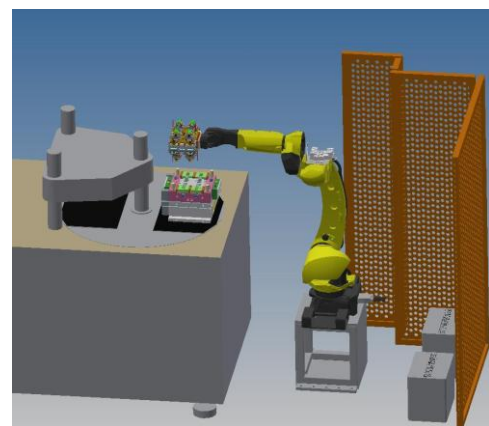


Figure 4. Design of a six-axis robotic handling unit

4.3. Design of Docking Module for Vertical Injection Molding Machine

The vertical injection molding machine is the core equipment for product molding, equipped with dedicated

injection molds. The mold cavity and locking block dimensions are precisely matched to ensure the positioning accuracy of metal inserts during in-mold injection. The injection molding process is controlled in conjunction with the entire tooling and electronic control system. After the robot completes material feeding, it sends a start signal to the injection molding machine. Upon completion of molding, the mold opening signal is sent back to the robot, automatically triggering the material retrieval action, achieving fully automated linkage between injection molding and handling sequences.

4.4. Design of Voltage Withstand Testing and Sorting Unit

The pressure test unit is responsible for the electrical insulation performance testing and automatic sorting of injection molded products, addressing the issue of low efficiency in traditional offline testing. As shown in Figure 5, its structure comprises a pressure test base, a dual-sided pressure test mechanism, a discharge and transfer module, and a finished product storage rack. When the pressure test base is at the material pickup position, the robot discharges the material and transfers it to the testing position where the pressure test mechanism holds the material for testing. After testing, the material is discharged separately through the discharge and transfer module. Non-conforming products are placed in a waste box, while conforming products are discharged onto the production line.

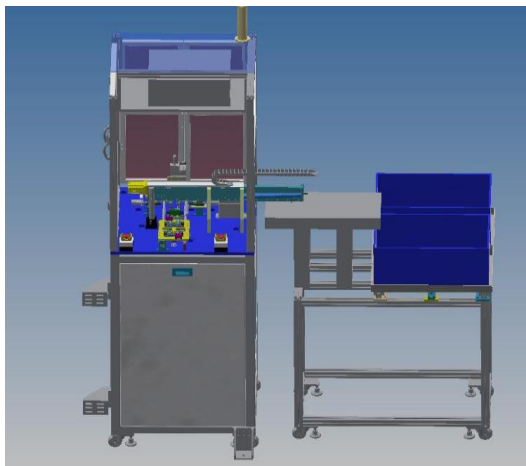


Figure 5. Pressure-resistant Testing and Sorting Unit

5. Design of Complete Machine Tooling Action Process

The entire integrated tooling adopts a closed-loop automated timing process, with interlocking signals for each process. The complete production steps are as follows:

- (1) The material strips of Insert 1 and Insert 2 are fed into two sets of cutting molds, respectively, and the hydraulic cylinder descends to punch the mold, completing the cutting and separation of the terminals;
- (2) The pin-clamping and discharging mechanism sequentially loads the cut metal inserts into the empty lock block carriers of the circular assembly line;
- (3) The lock block carrier flows along the circular assembly line, with the press needle mechanism shaping the terminals, and the counting mechanism detecting the number of lock block terminals;
- (4) The qualified lock blocks are transferred to the four-axis

robotic workstation, where the four-axis gripper claws grab the lock blocks and neatly arrange them onto the injection molding fixture matrix platform;

- (5) The Fanuc six-axis robot grasps the entire set of fixtures on the matrix platform, and the chuck sensor detects the presence or absence of inserts. After confirming that there is no missing material, it is transferred to the mold cavity of the vertical injection molding machine;

- (6) The robot exits the safety area, the injection molding machine performs in-mold injection, and after cooling and molding, the mold is opened;

- (7) The six-axis robot grasps the fixture carrying the injection molded product and transfers it to the material pickup seat of the pressure testing equipment;

- (8) The discharge and transfer module transfers the finished product to the pressure test station, where dual-sided probes press the terminals to complete the high-voltage insulation test;

- (9) After the inspection is completed, the system automatically sorts the products: defective products are placed into the waste box, while qualified products are sent to the assembly line and delivered to the material storage box;

- (10) The empty lock block carrier is returned to the cutting and feeding starting station by the circular assembly line, and the cycle of loading inserts is repeated to complete the closed-loop process.

The entire process only requires operator intervention when the material tape is depleted, needles are replenished due to shortage, the finished product material box is full, or defective waste materials are cleared, significantly reducing the frequency of manual intervention.

6. Complete Machine System Control and Technical Parameters

The entire equipment adopts a unified linkage PLC program, with interlocking action sequences for each process. In the event of faults such as material shortage, material jamming, or poor pressure resistance, the equipment automatically stops and sounds an audible and visual alarm. The human-machine interface provides visual prompts for fault locations, allowing maintenance personnel to quickly locate and handle the issue, reducing equipment downtime and improving the overall utilization rate of the production line. The online pressure resistance full inspection mode can be integrated with the factory's MES system to automatically collect data such as production takt time, number of defective products, and frequency of faults.

The intelligent production line for connectors based on robots is shown in Figure 6. Its technical parameters include the following four aspects: (1) Overall dimensions of the complete machine: length×width×height = 5200 mm×4000 mm×2500 mm, with a reference height of 1350 mm for the workbench, which can be adjusted slightly according to the height of the vertical injection molding machine; (2) Electrical power supply: main circuit AC220 V, 50 Hz, with equipment sensors, cylinders, and robotic actuators uniformly powered by DC24 V; (3) Pneumatic system: cylinders and hydraulic auxiliary mechanisms operate at a working pressure of 0.5~0.7 MPa, and can operate stably by connecting to the centralized air source in the workshop; (4) Manpower allocation: the standard configuration for the entire line includes one operator, who is responsible for material tape replenishment, equipment monitoring, defective product

cleanup, and finished product handling.



Figure 6. Intelligent Connector Production Line Based on Robots

7. Summary

This article designs an intelligent production line for in-mold injection molded connectors, integrating functions such as cutting and feeding, injection molding, and pressure testing. It completes the structural design of key mechanisms for four major functional units and plans a closed-loop fully automated production process, achieving integrated automation of the entire process from insert cutting, injection molding, to finished product electrical testing. The modular structural design possesses good product adaptability and flexibility, and has significant promotional and application value for the intelligent production of similar small injection molded products.

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