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Design of Intelligent Laminator Feeding System Based on Visual Guidance

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Abstract: The intelligent transformation of photovoltaic packaging equipment has become an industry necessity. In this paper, the laminated intelligent energy loading system is designed based on machine vision recognition to meet the requirements of new double glass component laminating process. Through reasonable layout analysis and structural design, according to the characteristics of module plate type and lamination process, the visual automatic feeding mechanical system is designed to realize the intelligent picking, handling and feeding of photovoltaic modules. The double glass module transmission system with process fixture frame is innovatively designed to assist visual identification and calibration, improve the positioning accuracy of the vision system and the overall operation accuracy of the component feeding system, and improve the intelligent level of the photovoltaic modules laminating machine.

Keywords: Feeding manipulator, Intelligent feeding system, Fixture, Conveyor belt made of heat-resistant fabric, Packaging of photovoltaic modules.

1. Introduction

Photovoltaic module laminating equipment is in the industrial transformation period from automation to intelligent and digital upgrading. According to the action plan for intelligent photovoltaic development of our country, the photovoltaic industry in the future should achieve technological breakthroughs in intelligent manufacturing technology and equipment, and continue to enhance the position of photovoltaic industry of our country in the global value chain. Therefore, the intelligent transformation of photovoltaic packaging equipment has become an inevitable industry [1,2].

With the development of solar cell technology and photovoltaic module packaging process, new requirements are put forward for the function and laminating process of the laminator. Photovoltaic module laminating machine has a five level structure of feeding, laminating, curing, cooling and discharging, and module feeding is an important process in the production line. Traditional photovoltaic modules are packaged by TPT backplane and glass. In its laminating process, the requirements for the placement accuracy of modules on the feeding table are relatively low. Therefore, generally, straight or field shaped laminated feeding is adopted by manual placement. However, with the development of module technology and the continuous expansion of photovoltaic product application scenarios, the traditional module packaging process is no longer suitable for the packaging of new modules. New battery modules, such as double glass modules and BIPV photovoltaic tiles, are prone to quality problems such as breakage, many bubbles at the corners, etc. in the process of applying the traditional lamination process, with large quality risks and low production efficiency. In this paper, according to the structural characteristics and packaging process requirements of double glass components, a vision guided laminator feeding system is designed. The intelligent manipulator cooperates with the transmission platform to achieve the precise positioning and intelligent feeding of components, accurately identify the fixture frame on the high-temperature cloth transmission belt, and obtain the component position and orientation information. The structure is relatively simple and practical.

2. Laminator Visual Feeding System

The vision guided laminating machine feeding system completes the handling, transmission and standard placement of photovoltaic modules through the feeding manipulator, laying the foundation for the subsequent vacuum pressing process, improving the production efficiency and output quality of the modules, with continuous movement track, fast response and high accuracy, and can coordinate and cooperate in a timely manner according to the production rhythm.

As shown in Figure 1, the visual feeding system of the photovoltaic module laminator mainly includes the transmission system, manipulator grabbing device, visual identification system and control system. The transmission system is a high-temperature cloth transmission mechanism driven by the thimble, and the upper surface is designed with equal spacing as a process fixture for visual identification. After the double glass assembly is assembled, it is transmitted to the lower part of the grasping manipulator by the roller. The manipulator grabbing device completes the grabbing operation of the double glass component under the action of the control system and transports it to the designated fixture along the X direction. After that, the high-temperature cloth conveying mechanism is jacked up by the thimble, and the double glass component is placed in the fixture frame by the grasping manipulator [4].

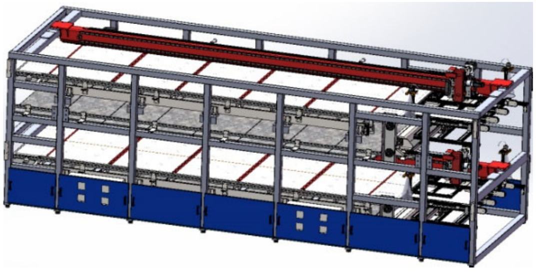


Figure 1. Visual feeding system

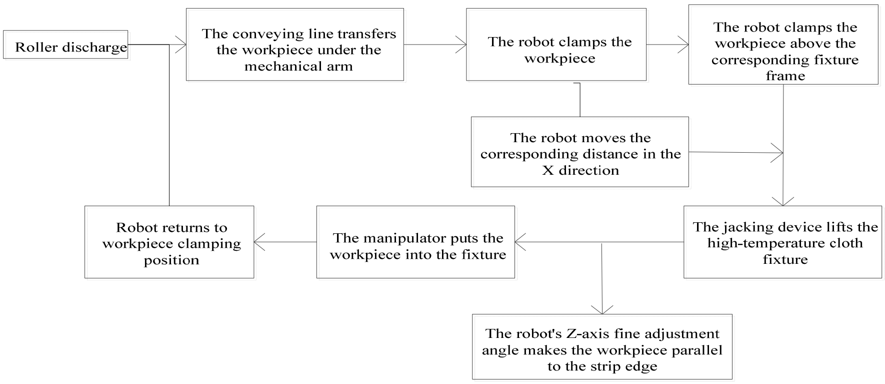


Figure 2. Working flow chart of feeding system

3. Design and Analysis of Loading Manipulator

3.1. Structure Design of Loading Manipulator

As the double glass component does not need to be flipped during loading, the loading manipulator only needs 4 degrees of freedom, namely, X, Y, Z three mutually perpendicular motion axes and one rotation axis around Z, so as to realize the movement of X axis, Y axis and Z axis and the rotation of Z axis, and complete the grasping, transferring and placing functions required during the assembly loading process. The double glass component loading manipulator is connected with the cabinet of the laminator loading system. The overall structure of the manipulator is shown in Figure 3. To ensure the manipulator has good stiffness and reliability, it is necessary to design and determine the size of each manipulator, the installation position of the drive motor and the actuating claw.

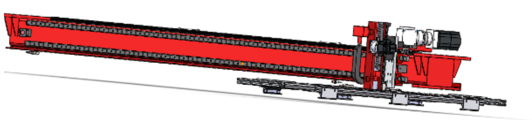


Figure 3. Overall structure of feeding system

3.2. Kinematics analysis of feeding manipulator

(1) Motion equation analysis of feeding manipulator

In this paper, D-H representation is used to analyze the kinematics of the feeding manipulator of the laminator. By studying the relationship between the displacement, speed and acceleration of each part of the feeding manipulator, the optimal motion path of the end effector of the manipulator is predicted. When creating the model, the base coordinate axis Z0 is in the direction of the first joint axis, and the two axes *X*n and *Z*n are vertical. According to the standard D-H, the coordinate system of the feeding manipulator of the laminating machine in this paper is established, and the DH parameter table of the manipulator shown in Table 1 is obtained.

Table 1. DH parameter table of manipulator

Joint	θ_i	d_i	a_i	α_i	Range of motion
1	0	d_1	0	90	0~6
2	90	d_2	0	-90	0~0.3
3	0	d_3	0	0	0~0.3
4	θ_4	1	0	0	-30~30

Therefore, the motion equation can be obtained according to DH parameters of the feeding manipulator:

$$ {}^0_4T = {}^0_1T\,{}^1_2T\,{}^2_3T\,{}^3_4T = \begin{bmatrix} n & o & a & p \\ 0 & 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} 0 & 0 & -1 & -d_3-1 \\ 0 & -1 & 0 & d_2 \\ 0 & 0 & 0 & d_1 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (1) $$

Where, n - normal vector, $n = o \times a$; o - azimuth vector; a - approach vector; p -position vector.

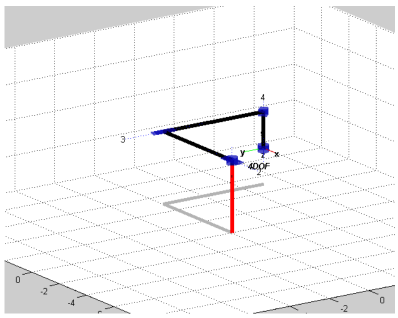


Figure 4. Motion model of the laminator feeding manipulator

(2) Workspace analysis of loading manipulator

In order to realize the feeding operation and movement track of the component feeding manipulator, it is necessary to reserve enough working space for the manipulator during the design, installation, operation and maintenance of the feeding system of the laminator. The workspace of the manipulator refers to the collection of the position points that the end effector can reach when carrying out the operation of grasping, transferring and placing. In this paper, Monte Carlo method is used to realize the visualization process of the manipulator workspace of the loading manipulator. According to the collective concept, the working space of the loading manipulator can be expressed as:

$$W = \left\{ \begin{matrix} p_x(q_1,\cdots,q_6) \\ p_y(q_1,\cdots,q_6) \\ p_z(q_1,\cdots,q_6) \end{matrix} \middle| q_i^{\min} \le q_i \le q_i^{\max}, i = 1,2,\cdots 6 \right\} \quad (2)$$

Where, p_x, p_y, p_z - end position coordinate of loading manipulator; q_i - Joint variables; $q_{\max}$ and $q_{\min}$ - upper and lower limits of joint range.

The space simulation results of the manipulator are shown in Figure 5 and Figure 6. It can be seen from the space point cloud that the working space of the loading manipulator is compact and there is no cavity phenomenon.

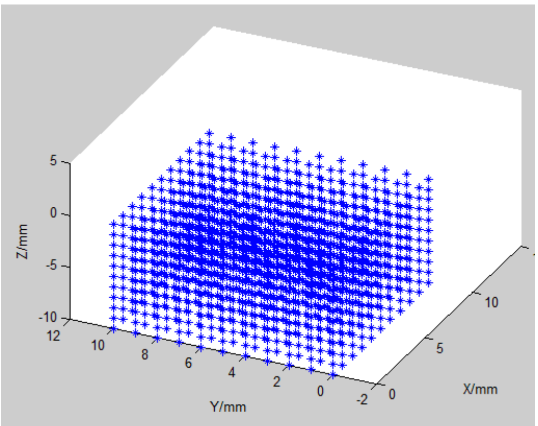


Figure 5. Feeding manipulator working space

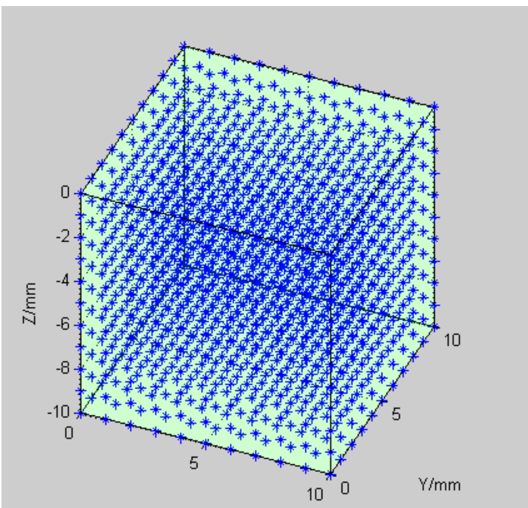


Figure 6. Feeding manipulator envelope space

4. Transmission System Design

Considering the characteristics of the double glass module and the requirements of the laminating process, a high temperature cloth transmission system is developed to facilitate the identification of the visual system. The high temperature cloth is supported by the transmission platform, which together with the transmission platform forms the transmission system, driving the double glass module to complete the feeding process.

4.1. High temperature cloth transmission platform

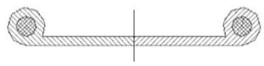
Considering the requirements of vacuum laminating process and feeding and transmission of double glass modules, the transmission platform is designed with preheating function, and multiple aluminum heating plates are set on the rack to form. The high-temperature cloth is laid on the transmission platform. In order to reduce the friction between the high-temperature cloth and the transmission platform, the lower layer of high-temperature cloth is set below the high-temperature cloth and above the transmission platform, which helps to extend the service life of the aluminum heating plate. This "preheating and transmission" double-layer transmission platform design can reduce the temperature change gradient of the module, effectively avoid the deformation, bubble, warpage and other phenomena due to uneven heating when the module enters the high temperature laminating chamber at low temperature, and improve the laminating quality of the module.

4.2. Technology fixture

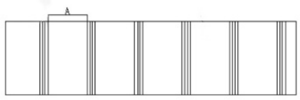
Compared with the traditional TPT module, the double glass module is fragile and has poor ductility. In this paper, a Teflon cloth processing fixture is added on the flexible high-temperature cloth transmission platform to reduce the fragment rate of the module and improve the efficiency and accuracy of visual system identification.

The fixture structure is shown in Figure 7. The laminated process fixture is composed of ribbon Teflon cloth evenly and equidistant distributed on the high-temperature cloth transmission belt. Two adjacent parallel fixtures form a group. The high-temperature cloth transmission platform is divided into several equidistant process fixture frames in turn. The space size of each process fixture frame matches the size of the double glass component [5]. The color of the fixture is different from that of the high-temperature cloth. When working, the visual identification system uses the process fixture frame as the visual identification base point to judge the position of the components, and the control system drives the loading manipulator to place the components in the fixture frame to complete the component loading process.

The process fixture on the high-temperature cloth has the functions of defining the component position, buffering the laminating pressure, and identifying the base point with the position information, which can effectively prevent the battery module from misplacement during the transmission and loading. The height of the fixture is related to the thickness of the battery module. The height of the fixture is required to be slightly less than the thickness of the module during design, so as to protect the module and buffer the pressure during the lamination of the battery module. Generally, the thickness of double glass component is 6 mm, so the height of process fixture is generally set between 5-6 mm.



a. Cross section of fixture



b. Fixture distributed on high-temperature cloth

Figure 7. Structure diagram of fixture

5. Conclusion

In this paper, aiming at the module loading problem in actual production, the characteristics of double glass modules and their laminating process requirements, a set of intelligent laminating machine feeding system for double glass photovoltaic modules is designed based on the visual identification system, including visual feeding system and module transmission system. Through the determination of the degree of freedom of the loading manipulator, the calculation of the motion model parameters, and the design of the transmission and drive scheme of the manipulator, a mechanical gripper for loading double glass components is developed to complete the functions of grasping, transferring and placing the components. Combined with the 3D model to realize simulation and analysis, the model simulation of the manipulator and the analysis of the manipulator workspace are established. The visual identification system obtains the component position signal by identifying the process fixture on the high-temperature cloth conveyor belt, and the control system drives the manipulator to realize the standard placement of the components.

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