Design and Research of Electric Handling Device for An Aerospace Product

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Abstract. In the assembly process of aerospace products, manual loading and unloading, handling, overturning and other operations are often repeated. These operations have the problems of low efficiency, high labor intensity and low safety. In order to solve these problems, this paper designs a kind of electric transport turnover device according to the modular idea. In addition, the flexible design of the design is considered, which can be applied to the handling of various products with different structures. The reliability test of the device is carried out, and the results show that the device can meet the reliability requirements of the cabin level aerospace product in the process of handling and overturning.

1. Introduction
With the increase of the total assembly tasks of aerospace products, the frequency of repeated manual handling, loading and unloading and overturning in the process of assembly, testing, painting and testing of a certain aerospace product also increases. There are safety risks such as product drop and collision in these operations, which not only limits the improvement of production efficiency, but also brings greater labor intensity to the operators on the production line.

Through investigation and research, it is found that the electric handling device is powered by the attached rechargeable battery, and the product can be lifted and flipped through the panel control, and the electric handling device can be moved at any time to adapt to different directions and positions. Compared with the automatic equipment on the production line, it has the characteristics of small size, convenient operation, flexible structure, safe and efficient operation\textsuperscript{[1,3]}. At present, it has been widely used in modern assembly industry, machining center, automobile assembly and other industries. But
the utilization rate of electric handling device is relatively low, mainly because the reliability cannot be guaranteed.

In this paper, aiming at the problems of low efficiency, high labor intensity and low safety in the assembly process of aerospace products, a set of special electric handling device of cabin level aerospace products is developed by using modular design idea, and the reliability test is carried out. The result show that the device can meet the reliability requirements in the assembly process.

2. Overall Design

2.1 Design Requirement

In the assembly process of aerospace products, it is necessary to carry out product handling, loading and unloading, overturning and other operations, which requires the device to realize the overall movement of the product, and the product can move up and down the device, flip and other functions. The specific requirements and relevant parameters are shown in Table 1.

| S/N | Designation                      | Parameter              | Remark                      |
|-----|----------------------------------|------------------------|-----------------------------|
| 1   | Weigh of grab                    | ≥200kg                 |                             |
| 2   | Product diameter                 | ≤400mm                 |                             |
| 3   | Displacement of up and down movement | 1200mm          |                             |
| 4   | Rotating angle                   | 180°                   | Clockwise/Anticlockwise     |
| 5   | Moving speed                     | Man-machine synchronization |                              |
| 6   | Work environment                 | Room temperature       |                             |
| 7   | Speed of up and down movement    | 0.1~0.5m/s             | Adjustable                  |
| 8   | Speed of turnover                | 0.3~0.6r/s             | Adjustable                  |

On the basis of meeting the above functions, safety and reliability are the key points in the development process of the device. The main considerations are as follows: (1) Due to the particularity of aerospace products, the battery should have explosion-proof function. (2) Some parts of aerospace products have sensitive components, which should be avoided when grasp. (3) Measures should be taken to prevent the products from falling during the process of rising, descending and rotating. (4) The devices should be provided with anti-misoperation measures and overload protection functions.

2.2 Scheme Design

According to the design requirements, the scheme design of the electric handling device mainly includes safety module design, control module design, grab module design, lifting module design, rotation module design and device structure design. The design route is shown in Figure 1.
3. Module design of electric handling device

3.1 Design of grabbing module
Because the surface of the product is covered with convex structure, sensitive elements and other parts, the surface of the product should be prevent from being damaged by the grabbing mechanism. At the same time, in order to ensure the reliability of product handing, the grabbing module should have reliable grasping force. However, the grasping force should not be too large to avoid deformation of the cabin. To make sure that the operator knows whether the grabbing mechanism has completed the clamping action, the clamping force control system is introduced and the clamping force is determined by computer test. When operating the device, the operator can judge the product has been clamped by observing the status indicator light on the control cabinet from red to green.

According to the structural characteristics of the product, the grabbing module adopts "motor drive and manipulator" structure, its structure in shown in Figure 2, includes: drive motor, manipulator, mounting plate, ball screw, clamping mechanism and so on. The clamping mechanism is hoop type with soft contact material with large friction coefficient, ensure the safety of the product and its surface sensitive components, and provide enough friction force to prevent the product from slipping during the overturning process.

According to the characteristics of the product, the clamping force is determined to be 800N by calculation.

![Figure 2 Grabbing module structure](image)

3.2 Design of lifting and rotating module
In order to ensure the stable and safe descending process of products, it adopts the form of synchronous belt wheel transmission; One-way rolling bearing is installed in the lifting module, so that the lifting module can only rotate freely in the rising direction, so as to eliminate the risk of falling and improve the safety of the product in the rising process. Up and down is provided by the motor.

3.3 Design of the control module
PLC is used to control the operation of each part of the device\(^{[4]}\), which consists of three parts: PLC1, PLC2 and PLC3. PLC1 is the lifting control system of the device, that connected to the input and output; PLC2 is the overturning control system of the device, that connected to the input and output ; PLC3 is the clamping control system of the device, that connected to the input and output and pressure sensor.

3.4 Design of the safety module
3.4.1 Clamping security. In order to effectively avoid misoperation, the device uses two hands to control the remote controller and double buttons to complete the clamping and releasing actions; in addition, limit switch is set to realize automatic locking after power failure. High damping rubber protective layer is installed at the contact part between clamping mechanism and product, the vertical
tightening force is increased while avoiding mechanical clamping injury of aerospace products. The clamping force control system is introduced to ensure the same clamping force each time through the pressure sensor, status display lamp and PLC control system.

3.4.2 Design of misoperation. In order to prevent product damage due to misoperation, the operating handle is designed to "avoid misoperation". The up-down and turning action of the operating handle is controlled by the single key of the remote control terminal, when holding aerospace products, two hands are required to control until the indicator light changes from red to green. When releasing the product, two hands are required to control until the clamping mechanism disengages from the product.

3.4.3 Overload design. Built in overload sensor, if the load is greater than 5%-10% of the capacity of the equipment or the load is unstable, overload sensor makes lifting function invalid. Through modular design, the final 3D model of the device is shown in Figure3.

![Figure 3 Three dimensional structure model](image)

4. Reliability analysis of clamping
In order to verify the safety and reliability of the device in the process of use, simulation are carried out according to the worst conditions during the use of the device\(^{[5,6]}\). The simulation parameters are shown in Table 2.

| S/N | Designation       | Parameter    |
|-----|-------------------|--------------|
| 1   | Clamping force    | 800N         |
| 2   | Poisson's ration  | 0.33         |
| 3   | Elastic modulus   | 45000MPa     |
| 4   | Allowable stress  | 220Mpa       |

Add boundary conditions to the model in the simulation software, as shown in Figure 4.

![Figure 4 Boundary conditions](image)

The analysis result is shown in Figure 5.
5. Reliability verification test of device

According to the above simulation results, the reliability verification test of the device is carried out. Three stress concentration positions on the product are selected, and three strain gauges are posted on each position. The deformation of the product is measured when the device is clamping the product during the test. The measurement results are shown in Table 3.

| S/N | Number of strain gauge | strain / μm | strain / μm |
|-----|------------------------|-------------|-------------|
| 1   | 0                      | -1          | -1          |
| 2   | -64                    | -65         |             |
| 3   | -101                   | -103        |             |
| 4   | -32                    | -35         |             |
| 5   | -54                    | -56         |             |
| 6   | -75                    | -77         |             |
| 7   | -3                     | -5          |             |
| 8   | -23                    | -24         |             |
| 9   | -21                    | -23         |             |
| 10  | -88                    | -91         |             |
| 11  | -81                    | -84         |             |
| 12  | -16                    | -20         |             |
| 13  | 37                     | 37          |             |
| 14  | 9                      | 8           |             |
| 15  | 98                     | 99          |             |
| 16  | 24                     | 24          |             |
| 17  | 31                     | 30          |             |
| 18  | 280                    | 282         |             |
| 19  | 0                      | -1          |             |
| 20  | -23                    | -25         |             |
| 21  | -16                    | -17         |             |
| 22  | 43                     | 43          |             |
The generalized Hooke's law is shown in formula 1:

\[ \sigma = E \times \varepsilon \]  \hspace{1cm} (1)

Table 3 shows that the maximum strain is 282\( \mu \)m. Combined with the generalized Hooke's law, the maximum stress can be calculated to be 12.69MPa, which is close to the simulation results. The results verify the reliability of the simulation, and show the feasibility of the design scheme of the electric handling device.

6. Conclusions
In this paper, according to the requirements of handling and overturning in the assembly process of aerospace product, the design and research of electric handling device are carried out. The conclusions of this work are summarized as follows:

(1) Design an electric handling device including safety module, control module, grab module, lifting module, rotation module and device structure.

(2) The simulation results show that the maximum stress is 19.438MPa and the maximum deformation is 0.1071mm, which meets the requirements of safety and reliability.

(3) The reliability verification test is carried out, and the test results are consistent with the simulation results.

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