Systematic Research on Auto Assembly and Disassembly of Small Engine in Aircraft

LI Wenqiang1*, SUN Xiangkun1, LI Chaoshi2, LI He3

1. School of Mechanical Engineering, Shenyang Aerospace University, Shenyang 110136, China.
2. Shenyang Aviation Industry Group Co., Ltd. Shenyang 110000, China.
3. Shenyang Aircraft Corporation. Shenyang 110850, China.
lwqss@163.com, sun577786547@163.com
saiglicaoshi@hotmail.com, saclihe@163.com

Abstract. The engine is one of the key core components in aircraft, in order to enhance automation and efficiency in the process of installation and disassembly for current small engine, using automatic control technology, a set of automatic disassembly and assembly system for aircraft engines is developed to replace the traditional mechanical installation vehicle. Corresponding for small engine to study the automatic disassembly system, the system uses laser sensors to locate the engine disassembly and assembly. Servo motors are used to drive the walking mechanism, lifting mechanism, and fine-tuning mechanism to realize multi-degree-of-freedom adjustment during engine disassembly and assembly. And the digital video is used to monitor the gap collision. Finally, the paper realizes the automatic high-precision disassembly and assembly of small engines. Through verification, the efficiency of the disassembly and assembly system has increased by more than 70%, the work efficiency has been greatly improved.

1. Introduction
As the core of the aircraft power system, aircraft engines have the characteristics of large volume and weight, complex structure, dense surface pipes, small installation gaps and so on. Aircraft engines are often installed and disassembled during aircraft manufacturing, assembly and maintenance, and we need a dedicated engine disassembly vehicle to disassemble and assemble it[1-2]. At present, most aircraft engine use mechanical and hydraulic methods to disassemble and assemble[3-4], and there are a series of problems during this process such as complicated attitude adjustment, long disassembly and assembly cycle, difficult docking, poor installation accuracy, low efficiency and low degree of automation. Some universities and their institutes have carried out related researches on automatic engine installation systems. However, it is difficult to apply digital engine installation technology in practice at present, and efficient and automated aircraft engine disassembly and assembly systems and its devices are the development trend of aircraft engine disassembly and assembly. Combining the characteristics of the disassembly and assembly process of small engines, based on the research of the existing domestic and foreign aircraft engine disassembly and assembly process and equipment technology, a scheme of automatic engine disassembly and assembly system is proposed, which can
change the traditional mode of aircraft engine disassembly and assembly, shortening the assembly cycle, improving the degree of automation and working efficiency, and promoting the rapid development of aviation manufacturing technology.

2. Aircraft engine disassembly and assembly work process
The disassembly and assembly process of aircraft engines is divided into engine installation and disassembly. The engine installation process is as follows: the engine is placed on the disassembly and assembly vehicle, the disassembly and assembly vehicle is adjusted by reciprocating movement, and then the engine is positioned by the positioning mechanism, which makes the axis of the loading vehicle parallel to the engine installation compartment. When it reaches the position of the aircraft engine installation compartment, the lifting mechanism of the launching disassembly vehicle is operated to raise the engine. After reaching the designated position, the fine-tuning mechanism begins to adjust the multiple complex posture of the engine which is ready to install, such as lateral, longitudinal, vertical, pitch, roll and yaw, and then it is fixed with positioning pins. Finally, the aircraft engine is installed in the engine installation cabin, the lifting mechanism is lowered to make the engine disassembling vehicle leave, and the installation process of the engine is completed. The disassembly process is the opposite of the installation process. It also uses the engine disassembly vehicle to disassemble the engine to complete the entire disassembly and assembly work of the aircraft engine.

3. Mechanical system design
Combining the appearance structure and disassembly process characteristics of the small aircraft engine, the mechanical structure of the disassembly and assembly system is designed. The system is mainly composed of the walking mechanism, the lifting mechanism, the fine-tuning mechanism, the positioning device and the disassembly mechanism. The basic mechanical structure of the disassembly and assembly system is shown in Figure 1.

![Figure 1 Basic structure diagram of disassembly device](image)

1. positioning device 2. fine-tuning mechanism 3. lifting mechanism 4. disassembly mechanism 5. walking mechanism

The walking mechanism consists of traction bars, a chassis, Mecanum wheels, which can reach the designated position. The chassis of the disassembly device is equipped with 4 Mecanum wheels to ensure that the walking mechanism has good maneuverability. The lifting mechanism realizes the overall raising or lowering of the fine-tuning mechanism through the screw elevator. The lifting mechanism can maintain the stability of the fine-tuning mechanism through the motor during the working time, and realize the power-off self-locking protection function through the linear screw. The fine-tuning mechanism meets the six-degree-of-freedom fine-tuning through six screw elevators, and servo control are used to realize the adjustment of multiple degrees of freedom: up and down, left and right, forward and backward, pitch, roll and horizontal rotation, and it also has three-level protection functions, such as Motor self-locking, limit switch, linear screw. The positioning device uses a laser target plate to position and it keeps the disassembly and assembly device moving along the engine axis,
adjusts the disassembly and assembly device to reach the lower cover of the engine compartment, and lifts the engine to a position parallel to the engine axis in the engine compartment. The disassembly and assembly mechanism is mainly composed of front and rear support points, connection interfaces, laser rangefinders, pressure sensors, screw jacks and other components, which are used to fix the aircraft frame and install or disassemble the engine. Through the organic combination of the above mechanisms, the overall mechanical structure of the disassembly and assembly system is formed.

4. Control system design
The system needs to adjust multiple degrees of freedom for the walking mechanism, lifting mechanism, and fine-tuning mechanism. The control and detection objects include 11 servo motors, multiple proximity switches, laser rangefinders, pressure sensors, etc., taking the stability and reliability of the system into consideration, it adopts PLC and CAN bus-based control system solutions[4], supplemented by photoelectric detection, logic processing, servo positioning and other technologies to realize a control system integrating sensing, detection and control.

4.1. Hardware structure
The principle of the hardware selection is to ensure that the control system is stable, reliable and long-life operation, the actuator has a fast response, and the hardware should have a friendly HMI. The hardware block diagram is shown in Figure 2. It is mainly composed of PLC, touch screen, communication module, digital video monitoring system, servo controller, motor, detection switch and power supply. Through the real-time detection of sensors, the PLC controls the position and speed of all motors through the bus network, thus realizing the effective adjustment of the engine disassembly and assembly device, and it’s also supplemented by the effective observation of digital video to ensure the efficient disassembly of the engine installed.

Figure. 2 Block diagram of the hardware structure
The programmable logic controller adopts the Delta DVP20SX2 PLC[6-7], which uses the PLC as the core processing unit of the system, collects input signals, performs logic analysis and processing, and controls the corresponding execution devices to achieve the requirements of system control. The touch screen adopts Delta's 10-inch touch screen. The system's parameter presets, walking mechanism, lifting mechanism and fine-tuning mechanism can be controlled and operated through the touch screen. Meanwhile, the operating status of the system can be displayed and alarmed in real time.

The system includes a total of 11 servo motors, including walking motors, lifting motors, horizontal fine-tuning motors, longitudinal fine-tuning motors, and vertical fine-tuning motors, which carry out multi-axis motion control. The system is equipped with a CAN bus communication module to connect with the servo controller. The control commands are issued though PLC, the communication module is used to send the signal to each servo controller, and the Mecanum wheel is driven to run by the driving of the walking servo controller to realize the forward, backward, moving left, moving right, and
rotating of the walking mechanism.

The disassembly and assembly device is equipped with two sets of laser ranging modules, through which the relative position is positioned. During operation, the laser rangefinder emits a red laser beam, which is projected on the laser target, forming a red dot. When measuring the relative distance, the system will send the measurement data to the PLC at the same time. The data will be fed back to the operation interface for employees to view and the effective distance is 200mm to 2000mm. The system is also equipped with a pressure sensor. In the process of engine disassembly and assembly, the force will be measured in real time. When the displayed pressure reaches the preset pressure value, the system will issue an alarm to ensure the safety of the engine and the disassembly and assembly equipment. Two pressure sensors are installed at the lugs of the engine disassembly and assembly device to detect the support pressure in real time and send the signal to the PLC for dynamic display. When the displayed pressure reaches the preset pressure value, the system will issue an alarm to ensure that the engine has been pre-allocated to prevent damage to the engine thrust pin when the engine is disassembling and assembling.

The system is equipped with multiple detection switches, including detection switches for the lifting mechanism, the horizontal, longitudinal, vertical fine-tuning of the fine-tuning mechanism which are installed in their initial position and end position, and the detection switches for their specify point locations to ensure the stability of the system signal detection.

In order to avoid the collision between the engine outline and the aircraft structure frame, a video monitoring system is adopted, and a miniature CCD video unit is also equipped for video monitoring of the installation process of the aircraft. All the above preparations are to realize reliable, safe and fast installation of the engine.

4.2. Software design

The control system software adopts a modular structure design, including PLC program and human-machine interface. The PLC program is developed by Delta WPLSoft programming software. It mainly includes data acquisition module, walking control module, lifting control module, fine-tuning control module, and multi-axis operation module, calculation processing module and alarm management module, etc., these module can complete the functions of data collection, walking mechanism operation, lifting mechanism operation, fine-tuning mechanism operation, calculation processing and fault alarm, etc., which can meet the overall requirements of automatic installation and disassembly of the engine.

![Figure. 3 Chassis adjustment and its mechanism adjustment interface diagram](image)

The touch screen has a good HMI, and the system is developed by Delta software. It is mainly composed of four parts, which are chassis adjustment, mechanism adjustment, alarm information and administrator setting interface. The chassis adjustment interface is responsible for realizing the three speeds switching, ten directions control and precise positioning functions. The mechanism adjustment interface is responsible for realizing the engine lifting, translation, and six-degree-of-freedom fine-tuning positioning functions during the engine installation process; The alarm information interface is responsible for realizing the functions of displaying faults and fault resetting when a fault alarm occurs during the working process; The administrator interface is set to realize multi-level
authority management for operators, maintenance personnel and management personnel. The touch screen chassis adjustment and mechanism adjustment interface are shown in Figure 3. The chassis adjustment interface has three speed selection modes, namely low-speed, medium-speed, and high-speed mode. The ten buttons of front, rear, left, right, left front, left rear, right front, right rear, left rotation, and right rotation to control the movement of the chassis can meet the requirements of direction control. At the same time, the real-time measurement data of the two laser ranging systems are displayed in the distance 1 and distance 2 display boxes on the chassis adjustment interface, which is convenient for operator to monitor. The left half of the mechanism adjustment interface is for the adjustment of the lifting mechanism, the movement speed of the lifting mechanism can be select, which are low-speed and high-speed modes, and the speed of low-speed mode is 3mm/s and the speed of high-speed mode is 20mm/s; The middle part can fine-tune the six degrees of freedom of the engine, through the effective control operation of the touch screen, the overall movement posture of the engine can be adjusted.

5. Experimental verification of the precision of disassembly and assembly fine-tuning mechanism

5.1. Positioning accuracy of fine-tuning mechanism
In the experiment, the Hexagon laser tracker is used to measure the longitudinal, vertical, and lateral movement accuracy of the fine-tuning mechanism. During the measurement, the fine-tuning mechanism starts to move from the longitudinal, vertical, and lateral zero points to the end of the positive and negative strokes to the prescribed displacements of 5mm, 2mm, and 2mm, and uses the laser tracker to measure the actual movement displacement. The horizontal, longitudinal, vertical measurement lengths are 90mm, 550mm, and 25 mm respectively. Then the laser tracker will be used to measure the longitudinal, vertical, and lateral movement five times repeatedly. The maximum standard deviation is used as the repeat positioning accuracy, and the running accuracy is obtained. The positioning accuracy is shown in Table 1. The measurement results indicate that the longitudinal, vertical and horizontal motion positioning accuracy and repeat motion accuracy meet the design requirements of the system, ensuring the system's fine-tuning motion accuracy.

| Precision               | Longitudinal | Vertical | Horizontal |
|-------------------------|--------------|----------|------------|
| Positioning accuracy    | ±0.5mm       | ±0.5mm   | ±0.5mm     |
| Repeat positioning accuracy | ±0.2mm       | ±0.2mm   | ±0.2mm     |

5.2. Comparison of disassembly and assembly efficiency
The developed automatic disassembly and assembly system can be used to conduct disassembly and assembly experiments on small engines, the engine alignment cycle can be reduced from 2 hours/unit to 0.4 hours/unit, the engine installation or disassembly cycle can be reduced from 4 hours/unit to 0.8 hours/unit. Compared to unused automatic disassembly and assembly system, the engine alignment cycle is shortened by 80%, and the engine installation and disassembly cycle is shortened by 70%, thereby the efficiency of engine disassembly and assembly is improved and the work intensity is reduced.

6. Conclusion
A set of automatic disassembly and assembly system for small aircraft engines has been developed to realize the automatic high-precision disassembly and assembly. Through the research of the automatic engine disassembly and assembly system, the previous engine disassembly and assembly mode is changed, which provides technical and equipment support for the realization of the multi-variety, high quality, high efficiency and low-cost rapid development of aircraft, and the system can also be extended to aerospace, weapons, ships and other fields. The automation control scheme uses CAN bus
technology combined with PLC control to realize the motion control of 11 servo motors, and a HMI has been developed with perfect functions and convenient operation. The laser tracker is used to measure the accuracy of the horizontal, longitudinal, vertical directions of the fine-tuning mechanism of the disassembly and assembly system. The result shows that the motion positioning accuracy is ±0.5mm, and the repeat positioning accuracy is ±0.2mm, which meets the accuracy requirements of complex posture adjustment. And compared with the traditional way of engine disassembly and assembly, this system shortens the engine alignment cycle by 80%, and the engine installation and disassembly cycle is shortened by 70%, which meets the requirements of the system.

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