The Design of Flow Proportional Control Valve Test Equipment

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Abstract. The basic working principle of the flow proportional control valve of a certain type of airplane is introduced in this article. The configuration, function and characteristics of flow proportional control valve test equipment are mainly introduced, and the automatic control system of which was designed by use of panel computer, PLC and frequency converter. Finally, the reliability and the practicability are validated by amounts of atopic experiments.

1. Introduction
The flow proportional control valve (referred to as proportional valve) is an important accessory of a new type of aircraft fuel system. It is mainly used to control the front group fuel tank and the airfoil fuel tank deliver to the supply tank according to the set sequence and proportion to ensure that the center of gravity of the aircraft moves within the specified range. In the routine maintenance of the aircraft, the accessory often needs fault diagnosis or replacement, and all of them need to perform specific performance tests. It can be used after being in compliance with the technical specifications. Due to the lack of proportional valve test equipment, the repair work of the aircraft is obstructed, which affects the performance rate of the aircraft. We designed and developed a new flow proportional valve test device for aircraft. The test and evaluation showed that the test device has the capacity for all types of performance testing of the proportional valve, and fully meets the design requirements.

2. Basic operation principle of flow proportional valve
The proportional valve is a combined fuel transfer valve, which is mainly composed of valve body, front group solenoid valve, airfoil solenoid valve, downstream float assembly, upstream, upper l float assembly, and the components are connected through a control pipeline or an electric cable. The flow proportional valve is installed on the fuel pipe, the two inlets are respectively connected to the front group fuel tank and the airfoil fuel tank supply pipe, one outlet is connected to the supply fuel pipe leading to the fuel supply tank. The basic working principle is as follows.

2.1. Regular fuel delivery
The proportional valve controls the opening and closing of the proportional valve by sensing the fuel level change in the fuel tank by the fuel float assembly. When the fuel level drops below the control fuel level of the fuel float assembly, the fuel float can open the pressure relief hole of the control tube to relieve the pressure of the flat diaphragm membrane of the valve body. At this time, under the regular
working condition of the system pump source, the flat valve opened under the action of fuel pressure, the fuel in the corresponding fuel tank is delivered to the fuel supply tank; when the fuel level in the fuel supply tank rises above the closed fuel level of the fuel float, the fuel float closes the pressure release hole of the control tube, and the flat valve of the valve body When the membrane cavity is built, the flat valve is closed under the action of fuel pressure, the fuel circuit is cut off, and the fuel pipeline stops supplying fuel to the fuel supply tank.

2.2. Proportional fuel delivery
The two orifices of the proportioner are factory-set with a proportional rotation axis with an area ratio of (1:2). The proportioner controls the fuel pressure of the two orifices to be approximately equal, thereby controlling the front tank and the airfoil tank to deliver fuel at a set flow ratio (1:2).

2.3. Fuel delivery sequence control
The proportional valve controls the fuel delivery sequence by the fuel level of the upper and lower floating slide valves in the fuel supply tank. When the fuel level of the fuel supply tank is higher than the upper floating slide valve control fuel level of the valve, the front group of the valve and the inlet end of the airfoil are closed, and the fuel is stopped; when the fuel level of the fuel tank is higher than the lower floating of the valve When the valve is lower than the upper floating slide control fuel level, the front group is opened, airfoil is closed, the front group fuel tank is delivered, and the airfoil tank is not fueled; when the fuel tank fuel level is lower than the lower floating valve of the valve When the fuel level is controlled, the front group of the valve and the inlet end of the airfoil are all open, and the fuel in the front group and the airfoil tank are merged together through the corresponding valves, and are controlled to be supplied to the fuel tank according to the set flow ratio.

3. Proportional valve test device composition and function
There are four test technical standards for flow proportional valves: fuel delivery sequence, flow ratio and proportional error, fuel differential pressure, and fuel delivery opening and closing time test. The integrated test system is mainly composed of a fuel test system and a PLC control system.

3.1. Fuel Test System
According to the technical standard of the proportional valve, the principle of the fuel test system of the proportional valve is shown in Figure 1. The shutter body 9 and the front group electromagnetic shutter 32, the airfoil electromagnetic shutter 19, the lower fuel float assembly 31 and the fueling float assembly 34 constitute a combined proportional valve. The fuel system consists of five parts.

![Figure 1. The principle of the fuel test system](image-url)
3.1.1. **Front group fuel subsystem.** The main function is to supply a pressurized fuel source of nominal flow to the front port of the proportional valve. Mainly composed of fuel suction filter 1, fuel pump 3, safety valve 4, precision fuel filter 5, turbine flow transmitter 6, pressure transmitter 7 (pressure gauge 8). When the sub-system is working, the fuel pump 3 is driven by the motor to suck fuel from the large fuel tank 38, and the fuel is pressurized by the fuel pump and sent to the front end of the proportional valve. When the front group fuel tank is separately transported, it passes directly through the proportional valve flap body, and is output from the outlet, flows through the pressure transmitter 10 (pressure gauge 11), and returns to the large fuel tank. When the fuel is connected in parallel with the airfoil fuel sub-system, after the proportional valve main body 9 meets, the fuel is supplied to the fuel supply tank in proportion. The change of the output flow rate is controlled by the front group frequency converter to control the rise and fall of the motor speed of the fuel pump 3, so that the output flow rate meets the test requirements.

3.1.2. **Airfoil fuel subsystem.** The main function is to supply a pressurized fuel source of nominal flow to the airfoil port of the proportional valve. It is mainly composed of fuel suction filter 21, fuel pump 23, safety valve 24, precision fuel filter 25, turbine flow transmitter 26, pressure transmitter 27 (pressure gauge 28) and the like. When the sub-system is in operation, the fuel pump 23 operates to draw fuel from the large fuel tank 38, and the fuel is pressurized by the fuel pump and sent to the inlet end of the proportional valve. When the airfoil fuel tank is separately transported, it passes through the proportional valve body and then outputs from the outlet, flows through the pressure transmitter 10 (pressure gauge 11), and returns to the large fuel tank. When the fuel is connected in parallel with the former group fuel sub-system, after the proportional valve shutter body 9 meets, the fuel is supplied to the fuel tank in proportion. The change of the output flow is controlled by the airfoil frequency converter to control the rise and fall of the motor speed of the fuel pump 23, so that the output flow rate meets the test requirements.

3.1.3. **Combined fuel subsystem.** The main function is to provide the corresponding rated flow of pressurized fuel source to the front group port and the airfoil port of the proportional valve at the same time, cooperate with the automatic control system to complete the front group flow, airfoil flow, front group/airfoil flow ratio and proportional error, annex differential pressure, valve opening and closing time test. Among them, the value of the accessory differential pressure is subtracted from the lower value of the two inlet pressure transmitters 7 and 27, minus the value of the outlet pressure transmitter.

3.1.4. **Float control subsystem.** The main function is to complete the regular fuel delivery and the control of the fuel delivery in sequence. The upper floating slide valve 34, the electric contact pressure gauge 33 and the control tube pressure relief electromagnetic valve 32 which are opened and closed before the front proportional valve are controlled; the lower floating slide valve 31, the electric contact pressure gauge 30, and the control tube pressure relief electromagnetic valve 29 composition. The fuel inlet and the fuel discharge of the float tank are respectively controlled by the fuel inlet solenoid valve 36 and the fuel discharge solenoid valve 37. When the fuel inlet solenoid valve 36 is energized to open, the fuel from the outlet of the proportional valve shutter body enters the float tank, and the float is floated. The fuel surface in the fuel tank rises; when the fuel discharge solenoid valve 37 is energized to open, the fuel in the float fuel tank flows back to the fuel collecting tank 16, and the fuel surface of the float fuel tank drops.

3.1.5. **Return to the fuel system.** The main function is to pump the fuel in the fuel tank back to the large fuel tank. It is composed of the fuel collecting tank 13, the fuel collecting tank 16, the liquid level transmitter 17, and the fuel returning pump 19, and the fuel collected in the fuel collecting tank 16 is pumped back to the large fuel tank 38. The liquid level transmitter 17 can collect the pressure of the bottom surface in the fuel tank in real time, and convert it into the liquid level by the PLC. When the liquid level reaches the upper limit height of the top surface of the fuel tank, the fuel return pump is
automatically turned on; when the fuel level drops to the lower limit of the fuel tank, the return pump is automatically controlled by the PLC to stop working.

3.2. automatic control system
The flow proportional valve test device is composed of a tablet computer, a PLC and a frequency converter, and constitutes an automatic measurement and control system. The working state of the proportional valve is controlled and adjusted, and the flow rate and flow rate error of each branch, the differential pressure of the accessory, and the opening and closing of the valve can be completed. Automatic testing of time.

3.2.1. Hardware part. The block diagram of the system is shown in Figure 2. The system is mainly composed of tablet, printer, PLC, inverter, input and output module, pressure transmitter, turbine flow and transmitter, liquid level transmitter and solenoid valve.

![Figure 2. The hardware part diagram of the system](image)

The upper computer uses an industrial tablet. The programmable controller and the industrial tablet calculator are applied to the control system, and the advanced sensors and actuators are used to form the hardware foundation of the control system, and the programmable logic is used to realize the process logic control. The industrial tablet computer is used as the upper computer to complete the functions of data collection, display, storage, query printing and the like.

3.2.2. Software part. The host computer program is designed with Delphi 2010, communicates with the programmable controller through RS232 interface, displays various status information in the whole test process. The touch screen software system adopts WinCE operating system and MCGS embedded version configuration software, which is convenient. Complete various complex operation interface design, save, query, print various data, make reports and trend curves, realize complex process control; PLC programming program uses Mitsubishi Gx Developer software.

The system is equipped with both manual and automatic control methods. The manual control refers to separately operating the actuators through the control panel switches and buttons. This method can be used for system commissioning and maintenance and as a supplement to automatic control. Automatic control is an efficient working procedure, generally used for regular working processes, and is controlled by PLC.

4. Technical characteristics

4.1. Adjustment of two-way fuel flow
It is determined by the performance index of the proportional valve that the pump source is pumped by a dual pumping system and should be of low pressure and large flow type. The front group and airfoil motor power is 11KW, the fuel pump model is IHGB65-200(1)A type, and the rated flow rate is 47000L/h. The return pump motor power is 0.75KW, the fuel pump model is IHGB40-100(1)A type, and the rated flow rate is 11000L/h. In order to ensure the safety of the system and the tested parts, the relief valve opening pressure is 0.6MP. In order to make both flow rates meet the test requirements, the
test system controls the speed of the respective fuel pump motors through the front group and the airfoil inverter to adjust the dual fuel flow to achieve the rated state. Since the inverters are all selected from international famous brands, the sensitivity and accuracy exceed the design specifications. The test system collects the signals of the flow sensor and the pressure sensor in real time by the PLC, and calculates the flow ratio, flow ratio error and pressure loss (whichever is less than the two inlet pressures, and the inlet pressure minus the outlet pressure is the pressure loss).

4.2. Detection of fuel delivery sequence
The detection of the fuel delivery sequence is mainly done by the float test control section (see Figure 1). The working principle is: keep the front group and the airfoil are the rated state of the fuel delivery, the liquid level of the float test tank starts to rise, and when the lower floating slide valve 31 controls the fuel level a, the proportional valve front group. The inlets are all open to the fuel supply tank; when the test tank liquid level rises to or above the control fuel level a of the lower floating slide valve 31 and is lower than the upper floating slide control fuel level b, the front group remains open. Airfoil should be closed; when the liquid level of the small tank rises above the upper floating slide valve to control the fuel level, airfoil remains closed and the front group should also be closed.

4.3. Detection of opening and closing time
Closing time: When the proportional valve is working in the rated state, the small fuel tank inlet solenoid valve 36 is opened, and when the liquid level of the small fuel tank rises to a certain position (a or b), the fuel float floats to close the pressure relief pipe, and the pressure inside the control pipe is established. The electric contact pressure gauge sends a pressure-building signal, starting from the start of the rise of the control pipe pressure, and ending of the main pipe to 10% of the rated value, and the closing time is calculated by the PLC.

Opening time: The proportional valve is in the closed state. When the small fuel tank discharge solenoid valve 37 is opened, the fuel float is lowered with the liquid level of the small fuel tank. When it reaches a certain position (a or b), the fuel float opens the pressure relief pipe, and the control pipe begins to vent. The pressure and electric contact pressure gauges generate a sluice pressure signal, which is the starting point when the control pipe pressure drops, and the end time is reached when the main pipe flow rate rises to 80% of the rated value, and the opening time is calculated by the PLC.

4.4. Test Interface
Clicking the proportional valve test button in the touch screen selection interface, the function test interface will appear on the touch screen, as shown in Figure 3.

The middle part shows the instantaneous values of the pipeline fuel transfer test system and accessories. From left to right, the front group inlet pressure, airfoil inlet pressure, accessory outlet pressure, front group flow, and airfoil flow, respectively.

The lower part is the stable data collected after the system reaches the test conditions. The lower left side is the main performance measured value of the proportional valve, which is the front group flow rate, airfoil flow rate, the front group/airfoil flow ratio, the accessory differential pressure, etc. Green, failed to be red. The lower right side is the system status, which are the front group and airfoil frequency conversion status.

The bottom left side of the interface is the test system control status display. When the working status is on, the character is black. When the failed status is off, the character is red. The bottom right side of the interface is distributed with four operation buttons, from left to right. Start test, stop test, parameter settings, and return button. When the “Start Test” button is clicked, the system performs an automatic test; when the “Stop Test” button is clicked, the system stops the automatic test. When you need to change the system parameters, you can click the “Parameter Setting” button, enter the modified value, and click the ENT key to modify the setting value.
5. Conclusion
The test device shows that the combination of tablet, PLC and inverter technology enables the control and test automation of the proportional valve. The PLC-controlled proportional valve automatic control system improves the automation of the test and improves the reliability of the system. The test device is not only fully functional, comprehensive, compact and safe, but also has the advantages of flexible control and convenient operation, and fully meets the design requirements. It can complete the full performance test of the proportional valve of a certain type of aircraft flow.

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