Energy Configuration Design and Configuration Scheme of Actuator for Large Aircraft Flight Control System

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Abstract: The energy configuration of the actuator of the flight control system directly affects whether the aircraft is stable and safe to fly. On the one hand, the safety of flight control system is closely related to the energy configuration of actuator, and it needs to be carefully configured to meet the requirements of safety index of flight control system; on the other hand, the development of electric drive actuator technology is increasingly mature and the reliability is continuously improved, which can effectively reduce the weight of aircraft; therefore, it is important to study the energy configuration design of flight control system actuator. Firstly, this paper studies the configuration design of aircraft control system in foreign countries, summarizes the design idea and development trend; secondly, designs the hydraulic configuration requirements of flight control system actuators and power supply system configuration requirements, and improves the flight control safety and reliability through the hybrid configuration of multiple energy sources; finally, a large aircraft flight control system actuator energy configuration scheme is provided to promote the design and development of flight control system.

Keywords: Flight control system, actuator, energy configuration, large aircraft, safety.

Flight control system is one of the key systems affecting aircraft safety. It is very important to design high safety and high reliability flight control system [1]. The actuator of flight control system is the key equipment for receiving the command of flight control system, driving the rudder surface motion and completing the attitude change of aircraft. Therefore, it is of great significance to carry out the energy configuration design of the actuator of flight control system [2].

Since the flight control system employs only electro-hydraulic servo actuators, traditional large aircraft flight control systems typically rely on a single hydraulic power source. Consequently, a hydraulic system failure significantly impacts the flight control system, rendering the control surfaces inoperable and directly compromising flight safety. Additionally, the hydraulic power piping must comply with regional safety and rotor burst requirements, further increasing aircraft weight.

Currently, the technology of electric drive actuators is advancing rapidly, with options such as electro-hydraulic actuators (EHA) and electro-backup hydraulic actuators (EBHA), offering more configuration combinations for flight control system actuators. To align with the trend of aircraft moving toward multi-electric and all-electric systems, it is necessary to promptly conduct scientific research and flight tests to verify the reliability of electric drive actuators.

Considering all the above, this paper proposes a multi-energy redundancy hybrid configuration for the actuator energy design of the flight control system, addressing the impact of single-energy failure on the system, improving the architecture of the flight control system, and effectively enhancing its safety and reliability.

1. CONFIGURATION OF ACTUATOR FOR AIRCRAFT FLIGHT CONTROL SYSTEM ABROAD

1.1. B787

Three sets of hydraulic systems are servo-controlled by REU, and hydraulic servo actuators are used for the main rudder surface, and electric actuators (EMA) are used for some spoilers and electric motors are used for horizontal stabilizers.

The B787 aircraft has 3 hydraulic systems, and some rudder surfaces are equipped with electrical control as backups. The energy configuration is shown in Figure **1**.

If three sets of hydraulic systems fail (this condition is extreme and the probability is very low), the unit can use the main pitching flat door, the standby pitching with the flat door and the driver disk, and the electric moving horizontal stabilization surface and two pairs of spoilers for pitching and rolling control.

If the flight control signal is completely lost, the pilot can use the spare pitching flat door and driver disc to control the pitch and roll of the aircraft directly through the electrical control horizontal stabilizer and spoiler pair.

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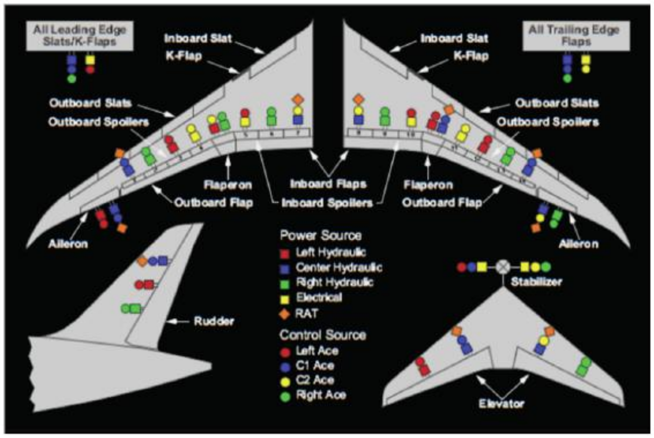

Figure 1: Energy Configuration of Actuator.

1.2. A380

The energy system of 2E+2H is adopted. The auxiliary wing and lifter are equipped with an electric hydrostatic actuator (EHA), some spoilers and rudders are equipped with electric backup hydraulic actuators (EBHA), and the horizontal stabilizer and slot wings are equipped with electric motor drive mode.

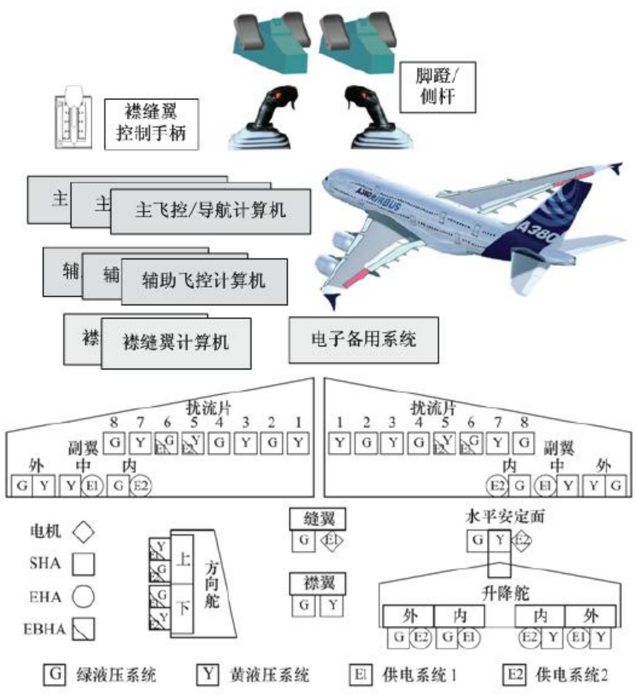

Figure 2: Hydraulic energy configuration diagram of flight control system.

1.3. A400M

The control surface is controlled by electrical signals. In addition to traditional electro-hydraulic actuators, the electric hydrostatic actuator (EHA) is provided as backup in the elevator, auxiliary wing and rudder channel.

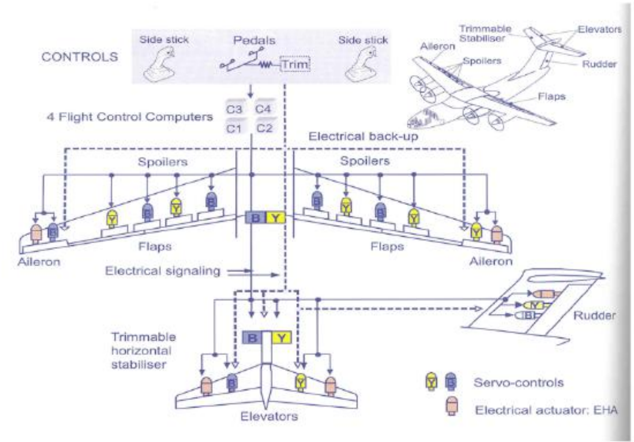

Figure 3: Hydraulic energy configuration diagram of flight control system.

1.4. A350

The energy system of 2H+2E is adopted. Some auxiliary wings, elevators and rudders are equipped with electrostatic actuators (EHA, 5 pieces), and some No. 3 and No. 12 spoilers are equipped with electric backup hydraulic actuators (EBHA), and 2 electric motors (E1+E3) are provided on the horizontal stabilizer.

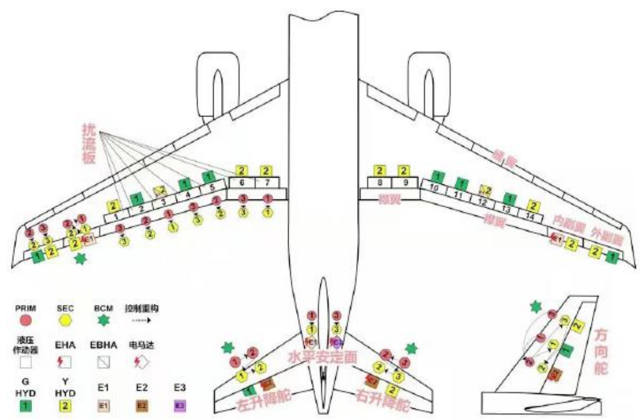

Figure 4: Hydraulic energy configuration diagram of flight control system.

1.5. Summary

a) The flight control system has been developed from hydraulic energy only to the combination of hydraulic and power supply energy, and the energy configuration scheme of the actuator is diversified [3];

b) With the development of actuator technology, electrostatic actuators (EHA) and electric backup hydraulic actuators (EBHA) and other types have emerged. When the actuator energy is configured, there is more selectivity [4].

2. ENERGY CONFIGURATION DESIGN OF ACTUATOR OF FLIGHT CONTROL SYSTEM

a) Energy Design of Air Control System Configuration Actuator

1) Meet the safety requirements: the energy demand for single rudder surface of the flight control system shall meet the requirements of functional hazard analysis, and the layout area of hydraulic pipeline and power supply cable shall meet the safety requirements;

2) Emergency energy shall be configured on the minimum steering rudder surface of the aircraft to meet the minimum flight safety requirements when the flight control system is operated;

3) Reduce weight, the same hydraulic pressure, the same power supply will be arranged near.

b) Configure hydraulic system design

1) All control surfaces of the aircraft shall have sufficient flow and pressure in each flight mission profile to meet the requirements of aircraft take-off, cruise and landing control;

2) Equalize the flow of each set of hydraulic system;

3) Prevent special risks such as bird impact, rotor blasting, etc.

c) Design of Configuration Power Supply System

1) Electric drive actuator of flight control system has enough power in each flight mission profile to meet the needs of normal operation;

2) Equalize the power of each power supply system.

3. ENERGY CONFIGURATION SCHEME OF ACTUATOR OF FLIGHT CONTROL SYSTEM

According to the energy configuration design of the actuator of the flight control system, a large aircraft flight control system actuator energy configuration scheme is proposed. The configuration scheme accords with the safety requirements of a certain aircraft to the flight control system. The configuration scheme highlights the configuration scheme, which provides favorable support for the development of flight control system, which has certain engineering significance.

3.1. Overview of a Large Aircraft

Flight control system control surface: auxiliary wing (two on the left and right), lifter (1 on the left and right), rudder (1 piece), horizontal stabilizer (1 piece), ground spoiler (2 pieces each), multifunctional spoiler (4 pieces each on the left and right), slit wing (1 on the left and right respectively) and flaps (1 on the left and right respectively).

Aircraft minimum steering rudder surface: auxiliary wing, lift rudder, rudder.

The hydraulic system is equipped with 4 sets of independent hydraulic energy system, and No. 1 hydraulic system is equipped with a ram air turbine (RAT) as emergency pump to realize the maneuverability of the aircraft when all engines fail.

The power supply system consists of an emergency power supply system consisting of two sets of storage batteries and emergency generators to provide power supply for critical and important loads under emergency conditions.

3.2. Energy Configuration Scheme of Actuator

The energy allocation principle of each control surface is as follows:

1) The hydraulic system of each control surface is configured by the shaft symmetry method. Hydraulic pressure No. 1 and No. 3 are dedicated to the flight control system, and the rudder surface shall be configured as much as possible to share the flow;

2) Meet safety requirements: at least 2 sets of hydraulic system shall be provided for each main steering surface (failure rate of single hydraulic system 1E-04 (per flight hour));

3) No.1 hydraulic pressure shall be equipped with RAT as emergency pump, and the flight control minimum steering rudder surface (auxiliary wing, elevator and rudder) shall be equipped with No. 1 hydraulic pressure;

4) Hydraulic system and power supply system are all symmetrically designed systems. In order to avoid common mode failure of No.1 and No.4 systems, No.2 system and No.3 system, use No.1 and No.3 systems to control the same main rudder plane, and No.2 and No.4 systems

control the combination of the same main rudder plane;

Meet regional safety requirements:

1) Auxiliary wing and elevator: No.1 and No.3 hydraulic pressure are arranged at rear edge, No.2 and No.4 hydraulic pressure are arranged at leading edge;

2) Directional rudder: No.1 and No.3 hydraulic pressure shall be arranged on the rear beam, and No.2 and No.4 hydraulic pressure shall be arranged on the front beam;

3) Horizontal stabilization surface: No.2 and No.4 hydraulic pressure shall be arranged on the rear beam;

4) Flap wings: No.1 and No.3 hydraulic arrangement flaps; No.2 and No.4 hydraulic arrangement seam wings.

6) Ground spoiler: No.2 and No.4 DC power supply with high voltage (270V);

7) Internal multifunctional spoiler: No.1 and No.3 high voltage (270V) DC power supply;

8) Outboard multifunctional spoiler: evenly configure No. 1 and No. 3 hydraulic pressure.

See Figure **5** for energy configuration diagram of actuator of flight control system.

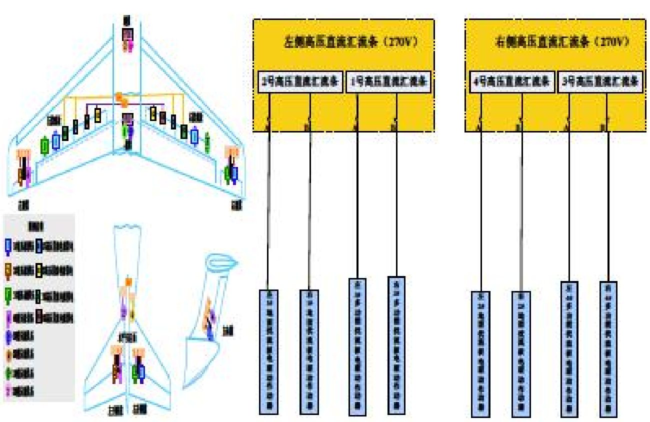

Figure 5: Energy Configuration Diagram of Actuator of Flight Control System.

3.3. Configuration Scheme Highlights

a) A set of hydraulic system failure flight control system rudder surface.

When any set of hydraulic system fails, all main control surfaces of the aircraft can work normally, ensuring that the flight quality of the aircraft is not affected.

b) Two sets of hydraulic system failure flight control system rudder surface

When any two hydraulic systems fail, flight quality can be degraded.

c) Three sets of hydraulic system failure flight control system rudder surface

The power supply system supplies power to two pairs of ground spoilers, multi-functional spoilers (No.3 left, No.4 left, No.3 right, No.4 right) and horizontal stable surface electric drive actuators, so that the aircraft has certain handling capability.

d) Power Supply System Failure Flight Control System Rudder Surface

1) The four-way power supply system is equipped with equal number of rudder surfaces and equal power;

2) The failure of three-way and below power supply system has little influence on the rudder surface of flight control system;

3) The four-way power supply system fails, and the flight control system loses two pairs of ground spoilers and multi-functional spoilers (No.3 left, No.4 left, No.3 right and No.4 right) to make the aircraft have sufficient handling capability.

4. CONCLUSION

In this paper, by studying the configuration design of the actuator of aircraft control system abroad, this paper summarizes the design idea and development trend; focuses on designing the hydraulic configuration and power supply system configuration of flight control system actuator. The configuration of multiple energy sources fundamentally solves the influence of single energy failure on the flight control system; provides a large aircraft flight control system actuator energy configuration scheme, and explains the configuration scheme highlights, which lays a solid foundation for the flight control system scheme, which has certain engineering significance.

The energy configuration design of flight control system actuators for large aircraft is achieved through a combined arrangement of power and hydraulic sources, as well as electrically driven actuators and electro-hydraulic servo actuators. This approach facilitates the advancement of the power system, enhances energy efficiency, reduces reliance on a single hydraulic system, alleviates the weight of hydraulic pipelines, and improves the architecture of the flight control system, thereby increasing its safety and reliability.

REFERENCES

[1] Rulin Z. Modern Aircraft Flight Control System Project [M]. Shanghai: Shanghai Jiaotong University Press 2015.

[2] Sentang W. Flight Control System [M]. Beijing: Beijing Aerospace University Press, 2005.

[3] Siyu T. Research on Characteristics and Control Technology of Electric Motor in Multi-electric Aircraft [C]/The Third China Aeronautical Science and Technology Conference 2017; 223-228.

[4] Qing Z. Comprehensive Performance Analysis and Research of Non-similar Hybrid Actuator for Multi-electric Aircraft [J]. Design and Research of Civil Aircraft 2021; 3.

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