The Review and Development of the Landing Gear Emergency Release System

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Abstract. Landing gear emergency release system is a common design of modern aircraft. In this paper, the typical landing gear emergency release system is analyzed, and the advantages and disadvantages of various emergency release forms are compared. This paper analyzed the research status of here and there electric emergency release technology, and made a preliminary study on the key technologies of electrical actuation. The development direction of the landing gear emergency release system is proposed.

1 Introduction

Landing gear system is one of the important systems that affect the safety of aircraft[1-2]. The retraction system is an important part of the landing gear system, also is a department with high failure probability. In order to improve the safety of landing, China's civil aviation regulations CCAR25.729 (c)[3] stipulate that under the condition of normal appearing in any reasonably likely failure or a single hydraulic source or equivalent energy with landing gear retraction system, the aircraft should have at least one landing gear emergency release method.

2 Landing gear emergency release system present situation analysis

The working principle of landing gear emergency release is making the upper locks of the landing gear and the landing gear doors of unlocked through certain way, so two chambers of the actuating cylinder bypass to relief pressure, then relying on the landing gear its own gravity and aerodynamic loading free down and be locked. Typical emergency release unlocked methods include: mechanical emergency release, electric explosion emergency release, electrical hydraulic actuation emergency release, electric mechanical actuation emergency release and so on. In addition, military aircraft or UAV also uses air as emergency energy or explosive blasting to unlock[4], the application of which is certain limited.

2.1. Mechanical emergency release

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Mechanical emergency system is applied commonly in civil aircraft. A typical mechanical emergency system uses cable to transmit, unlock by mechanism, release pressure by bypass valve. As shown in Fig. 1[5], linkage parts of the system include the landing gear doors upper lock, the gear upper lock and bypass valve parts, and the system is independent with normal retraction system using hydraulic actuation. The pilot pulls the emergency release handle, the system operates the landing gear components with the following sequence: (1) the bypass valve and cut off normal pressure supply and normal loop and loop bypass to the return line; (2) landing gear and landing gear door upper lock locked.

The advantages of mechanical emergency system is safe and reliable, so it is widely used in large civil aircraft. Such as Airbus A320 (Fig. 2), the Boeing B373, and China's regional aircraft employ the mechanical cable emergency system.

The disadvantages of mechanical emergency release system are:

- Mechanical structure is complex, take up more structural space.
- A large number of the pulley mechanism and the transmission rod are designed in the systems, so the assembly requirements between the key components are higher.
- The maintenance work is big and difficult. Because of the change of external load, and the change of environment temperature of the plane, body structure and aircraft control system generate different relative deformation, so to cause the cable loosening and elastic mechanism clearance, or to lead to tight and additional steel friction mechanism. At the same time, due to wear, crushing, corrosion and broken wire etc. often happen during cable use, the pulley part due to wear can also lead to the rotation is not flexible. All of these are difficult for normal maintenance work.

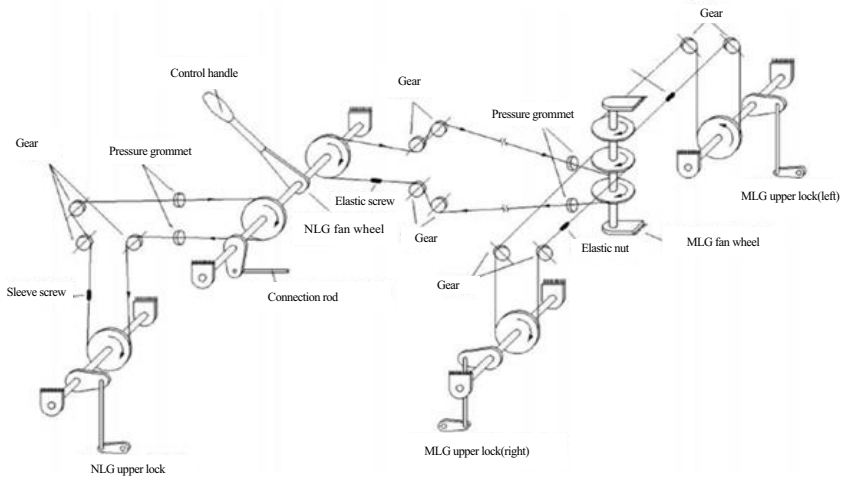

Figure 1. Schematic diagram of mechanical emergency release system

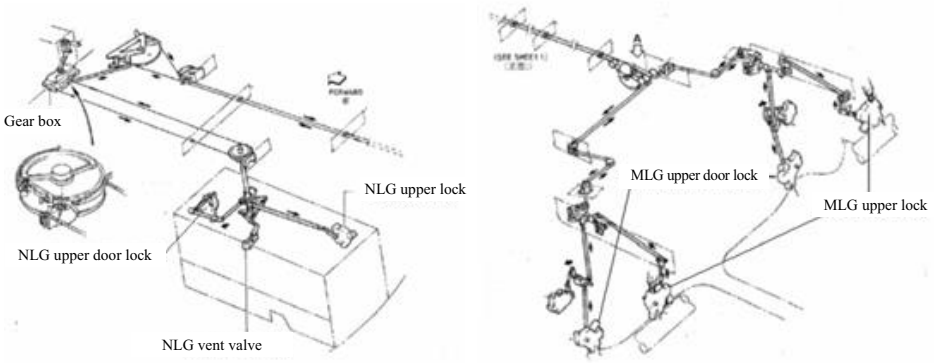

Figure 2. Emergency release system of A320 diagram

2.2. Electric explosion emergency release

The principle of electric explosion emergency unlocking is, when the hydraulic system failure, the electrical explosion impact air flow, the air flow instead of hydraulic pressure to push the piston rod drives the unlocking actuating device, shown as Fig.3.

Electrical explosion emergency unlocking method abandons the complex structure of the electric emergency drive or mechanical cable device, without increasing the complexity of the motor drive system. Electric explosion with the compact structure, light weight, simple and easy to implement, is applied for UAV and small aircraft.

Electrical explosion emergency unlocking carries out the problems of redesigned lock mechanism which is relatively complex, regular maintenance and replacement because of the electric explosion belongs to consumables, and difficult to meet the requirements of the airworthiness.

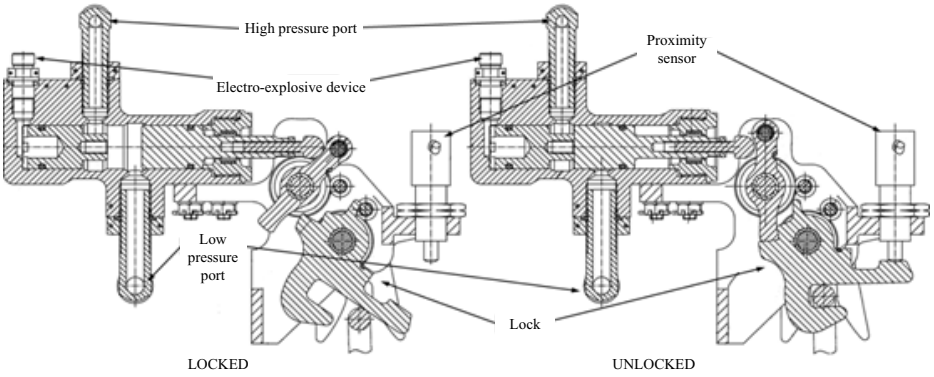

Figure 3. Working principle of the mechanism lock of electric explosion emergency release

2.3. Electrical hydraulic actuation emergency release

Electrical hydraulic actuation is known as Electro hydraulic Actuator(EHA), the system includes DSP controller, power drive unit, motor, servo pump and other components. As an electrical actuator technology, EHA is also used in a large number of modern aircraft technology (Fig. 4), such as A380 turning and braking systems and B787 landing gear emergency release system. For emergency landing gear and the door put itself, electro hydrostatic actuator can be used as an alternate energy emergency unlocking, and without the addition of actuator (use original hydraulic actuating cylinder), but need to have the valve block system corresponding to the original hydraulic pipeline to isolate.

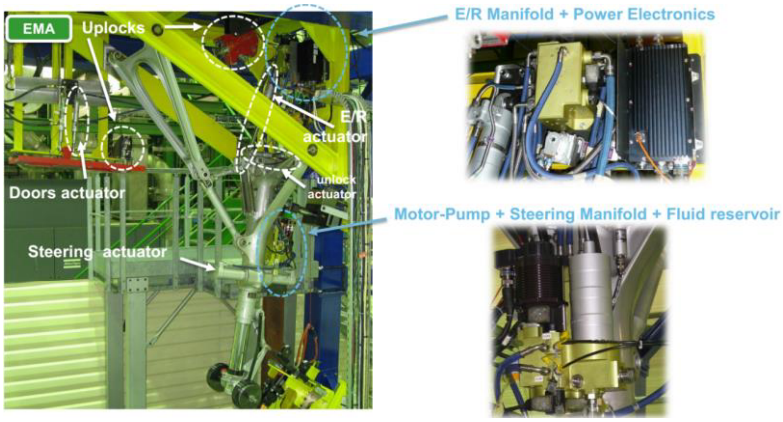

Figure 4. The application of EHA in the nose landing gear of a certain type of aircraft

The advantages of electrical hydraulic actuation emergency release are showed as follow: the actuating cylinder of the lock mechanism is small, so the electric hydraulic actuator can easily meet the requirements without large flow hydraulic pressure, at the same time, the system changes to the lock mechanism is small, no need to add additional operating device, telex control system to facilitate the realization of the monitoring of components, so it is easy to detect, good maintainability, the system is simple and reliable, and the fault tolerance capability is high.

The disadvantages of electrical hydraulic actuation emergency release are also obvious: a complete set of EHA and a separate electric power system will increase the weight of the system itself, larger system changes, need to increase a set of power system and to coordinate with the original hydraulic system to switch working mode, for the original to hydraulic actuating system, adding a set of EHA costs quite highly.

2.4. Electric mechanical actuation emergency release

Electric mechanical actuation is also known as electro Mechanical Actuator EMA[6-8]. The system includes emergency release controller, electro - hydraulic upper lock, electric lock device and so on. In this emergency release method, controlling the hydraulic valve block component in the bypass mode to release pressure, unlocking the upper locks of various components, and transmitting the locked and unlocked signals of upper and lower locks are all operated in the emergency release controller. The electric unlocking device is an independent driving device (shown in Fig.5), which is based on the original hydraulic actuating unlocking device. The device is generally composed of a motor and a worm wheel, working principle is shown in Fig.6. The electric mechanical actuation emergency release system is the development trend, the newly developed A380 landing gear emergency release system is the use of the electric actuator.

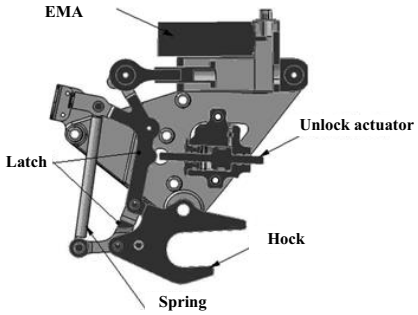

Figure 5. Lock mechanism of electric mechanical actuation emergency release

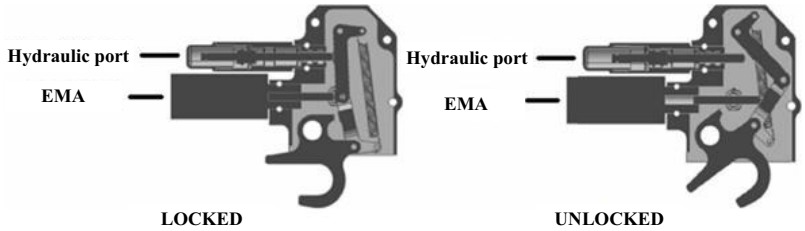

Figure 6. Working principle of lock mechanism

The advantages of electric mechanical actuation emergency release are: compared with the mechanical emergency release system, the weight is obviously reduced, and the volume is small and easy to be arranged, FBW system facilitates the realization of the monitoring of components, so it is easy to detect, good maintainability.

The disadvantages of electric mechanical actuation emergency release are: larger system changes, need to increase a set of power system and the need to coordinate with the original hydraulic system to switch working mode; with the increase of the reliability of electronic components, and the redundancy design will increase the safety and reliability of the system, but still need to work on the full power of the emergency response system for reliability risk assessment; the lock mechanism needs to be redesigned, which is more complicated.

2.5. Comparison

Comparison of the four forms of emergency release is shown in Tab. 1.

Table 1. Comparison of the four forms of emergency release

form	Scope of application	advantage	disadvantage
mechanical emergency release	Widely used in large civil aircraft A320, B737	Safe and reliable	(1) the structure is complex, occupying more structural space; (2) the assembly requirements of key structural parts are higher; (3) the maintenance work is high and difficult.
electric explosion emergency release	Suitable for unmanned aerial vehicles and small aircraft	(1) compact structure, light weight, easy to decorate; (2) the system is simple and easy to implement.	(1) the lock mechanism needs to be redesigned and more complex; (2) electrical explosion type belongs to consumables, need regular maintenance and replacement; (3) reliability needs to be tested and verified.
electrical hydraulic actuation emergency release	wide, such as B787, especially for the situation that the lock mechanism can not be changed	(1) the system has little change to the lock mechanism, no need to add additional operating device; (2) easy detection, good maintainability; (3) simple and reliable, and the fault tolerance capability is high.	(1) the EHA and a separate electric drive system will increase the weight of the system itself; (2) the system changes greatly, need to increase a set of electric drive system and need to coordinate with the original hydraulic system in order to change the working mode; (3) for the original hydraulic drive actuating system, by adding a set of EHA cost quite highly.
electric mechanical actuation emergency release	Widely applicable to all types of models, such as A380	(1) the weight is obviously reduced, and the volume is small and easy to be arranged; (2) FBW system to facilitate the realization of the monitoring of	(1) the system changes greatly, need to increase a set of electric drive system and need to coordinate with the original hydraulic system in order to change the working mode; (2) the reliability risk assessment of all electric

		components, so it is easy to detect, good maintainability;	driven emergency release system; (3) the lock mechanism needs to be redesigned and more complex;

3 Research on the status of electric mechanical actuation emergency release

In 1990s, the U.S. Air Force leaded "more electric aircraft (MEA) " project, , including the army, Navy, and NASA more than and 50 companies to participate in the program, aims to replace the complex actuation system, high maintenance, mixed hydraulic and pneumatic machinery and electric propulsion system with non power consumption power, in order to improve the reliability of aircraft power system to reduce the dependence on ground support equipment, thereby reducing the cost of launching weapons.In the MEA project, more electric aircraft technology has been fully developed in the United States, and is widely and fully tested, and many techniques have been applied in practical application, has made a lot of research.In 1999, Collins set up the model of the landing gear all electric brake system, based on the simulation of the braking system based on MATLAB/Simulink, and some of the key structural strength of the brake was analyzed. In 2000, NASA made EMA technology successfully applied to F18 aileron drive improvement on the original hydraulic actuating device by the electric actuator to replace, designed the electric actuator control system, and the success of the test results showed that the electric actuator performance and hydraulic actuator performance is very close. In 2009, AbdElhafez etc. Compared the difference between the MEA and the traditional hydraulic aircraft, as well as the advantages of MEA. In 2010, Skorupka etc. applied the all electric technology to UAV landing gear retraction, turning and brake system, and the design of the electric actuator control system successfully tested.

In China, the development of all electric technology is slow, but in recent years, many scholars have done a lot of research. In 2009, Sun Jiyong designed a small aircraft electric actuator control system, realized the multi-point coordinated control and multi task coordination control, in order to improve the reliability and stability of the system, used CPU redundancy technology on the control board and driver board were made redundant design. In 2011, Wang Tao etc. designed a landing gear controller of double - double redundant structure, which is in the board setting center ruling redundancy, between boards setting non center ruling redundancy, then combined the two kinds of redundancy. Otherwise, it used a non similar redundancy design and hardware error detection, greatly improved the stability of landing gear controller. In 2012, Li Lin etc. designed a ball-screw type double redundancy electric actuating cylinder, which is mainly composed of a main actuating device (DC servo motor), emergency actuation device (pneumatic motor, pneumatic clutch), a mechanical device (locking mechanism, a piston cylinder, a piston rod and connecting parts etc.), transmission device (reducer, synchronous belt, ball screw), detection device (switch) and other components. They also designed a set of electric actuator systems with feedback (including emergency release), and verified the systems. In 2012, Bao Qunmin and others proposed a double-redundancy controller design for a small aircraft landing gear electric control demand. The controller used DSP as the control core, achieved the four quadrant operation of the motor control, and the system had the function of over-current protection.

4 Key techniques of EMA

4.1. EMA controller

EMA emergency release system is controlled by independent controller. Firstly ensure that the landing gear system valve assembly in bypass mode for pressure relief, the emergency release controller controls each gear upper lock unlocked, the landing gear release free by gravity and locked down, at

the same time, independent assessment about controller downlock signals are transmitted to EICAS (the engine indication and crew alerting system).

When the emergency release clearance is placed in the emergency position, the following actions will be carried out in sequence:

(1) the landing gear to put down the discrete signal command sent to the emergency release controller;

(2) landing gear system control valve assembly emergency discharging controller after receiving the instruction, the high and low pressure pipe, hydraulic pressure relief loop control system;

(3) emergency release controller sends commands to drive the corresponding motor, unlock the front, the main landing gear PC Lock, the landing gear will be under the action of gravity and aerodynamic force to put down;

(4) the emergency release controller independently assess the landing gear under the lock signal, and the evaluation results will be transmitted to the EICAS system and display.

4.2. The locked rotor protection

In the locked rotor protection, there are three kinds of common blocking protection. Using relay realizes the overload protection or the low voltage circuit breaker with the relay realize the over-current protection. When the motor current switch starts after a long time and can not be reduced, thermal overload protection relay act, and power supply main circuit contactor disconnect the motor. This method is only suitable for the long time the motor overload caused by the operation of the high temperature protection. Using speed relay realizes the protection. It makes the motor tripping by controlling contactor coil with time relay and the speed switch contact with logic and relations. This kind of traditional blocking protection has certain limitations, and not suitable for low speed operation, shift and angle of operation of motor, stepping motor and servo motor blocking protection. Using PLC realizes blocking protection. By detecting the external signal of photoelectric sensor (displacement or velocity signals) and PLC internal timer, counter device, preparation of blocking protection control program, can realize the operation of the motor stall protection of low-speed operation, shift and angle.

5 Conclusion

This paper introduce four typical emergency release unlocked methods, such as mechanical emergency release, electric explosion emergency release, electrical hydraulic actuation emergency release and electric mechanical actuation emergency release. Compare the four methods from Scope of application, advantage and disadvantage. Analysis the status of EMA emergency release. For the design of EMA emergency release, give some proposals.

Even though the cost will be increased, the EMA landing gear emergency release system is already the development direction. The operation is very convenient, just press the button or switch; because of electric cable replace mechanical cable, layout of the system in the fuselage and cockpit becomes very flexible and convenient, and the weight of the entire system is significantly reduced. In the future, it will gradually replace the mechanical landing gear emergency system.

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