Fault Analysis of Abnormal Opening of the Main Landing Gear Door of Civil Aircraft

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Abstract. The main landing gear door is an important component of the landing gear system. The system is in a state of failure and will not play the role of extending and retracting when the door extension/retraction fault. This article analyzes the main landing gear door extension/retraction principle and fault cause of civil aircraft, deeply studies the control process and logic of the Uplock, and improves the understanding of the landing gear door extension/retraction system.

1. Introduction
During the take-off and landing phases, the safety of the aircraft mainly depends on the effective work of the landing gear[1]. In the landing gear (LG) extension and retraction system, usually there are multiple driving forces coordinated in the system[2], due to the large number of kinematic mechanisms. When the aircraft takes off and lands, the LG door and the LG move according to a certain sequence of movements to realize the opening, extending, and retracting of the LG. Due to the coordinated action of multiple mechanisms, when controlling the extension/retraction of the LG door, a possible phenomenon is that the LG door Uplock cannot be locked and the door cannot be closed[3]. This article analyzes the cause of abnormal opening fault of the main landing gear (MLG) door of civil aircraft, deeply studies the logic of the Uplock opening, improves the understanding of the MLG door extension/retraction system, and avoids the fault caused by similar human factors, plays a key role in improving the safety production at the assembly site.

2. Main landing gear door extension and retraction principle
The MLG door extension and retraction system is a typical civil aircraft door extension/retraction mechanism, as shown in Figure 1. One end of the MLG door is installed on the body structure, the door Uplock is fixed on the Uplock bracket, and when the door is closed, the Uplock hooks the door lock ring. The MLG is extended and retracted by means of electric control and hydraulic drive, when the command of controlling LG extension is received, the landing gear control valve (LGCV) opens, the hydraulic drives the Uplock actuator to unlock, the Uplock hook put down, and the door is opened to the down position by actuator driving. When the MLG door is retracted, the door is closed by actuator driving. At the end, the lock hook is rotated by the door lock ring to achieve locking[4].
3. Fault description
On-site operators need to close the doors when trimming the left and right inner doors of the MLG of the aircraft. When the left door is normally closed and locked, during the retracting and closing operation of the right door, the left inner door that has been locked suddenly opens and falls, and then collides with the keel beam connection joint, resulting in a split at the connection between the door skin and the joint in the MLG, causing damage to some extent. The split position and range are shown in Figure 2.

After investigation, during the trimming of the inner door of the MLG, the aircraft is also testing the avionics system at the same time, the whole aircraft is powered, and the cockpit LGCL was in the down position. When retracting and closing the right MLG door, the operator found that the Uplock of the right door could not be locked, judging that it might be caused by the internal cam mechanism of the lock hook is not reset. In 90 seconds after operating the door maintenance switch to the "normal (closed)" position to reset the right lock hook, the left door is opened (at this time, the door actuator is not connected due to the door trimming), and free to fall and collide with the on-board joints to produce cracks. The specific fault causes are analyzed as follows.

4. Fault analysis
When the right door Uplock cannot be locked, relevant personnel consume that the fault cause may be an electrical fault during troubleshooting. Therefore, re-tighten the electrical plug and move the door maintenance switch from the "maintenance (opened)" position to the "normal (closed)" position,
thereby reset the lock hook to lock it normally, but the fault has not been eliminated. In fact, when the trimming of the door, the external hydraulic tanker directly acts on the hydraulic system of the Uplock hook of the door, and the pressure in the hose of the tanker is not completely relieved, this should be the cause of the fault of the right MLG door Uplock[5]. Then, 90 seconds after the door maintenance switch is set to the "normal (closed)" position, what caused the left inner door of the MLG to open abnormally? It can be known by reviewing the relevant specifications: after the door maintenance switch is switched to the "closed" position, within 90 seconds, if the door is not fully closed, LGCU will automatically reset the "closed door" command to "opened door". In the following, according to the electrical schematic diagram of the LG control system, the logic of opening the inner door in the 90 seconds self-test is analyzed.

4.1. Logical analysis of opening the inner door in 90 seconds self-test

Working conditions for the electric unlocking of LG door Uplock: relay 1 and relay 3-5 work. Relay 1 works to provide 28V voltage for the high level of the door Uplock. When relay 3 works, the low level of the door Uplock is grounding. When relay 5 works, the alternate extension valve (AEV) in the LGCV is placed in the Pos0 position, causing the inlet and outlet ports of the door actuator are connected to the oil return pipeline.

Working conditions for relay 1 and relay 3-5: the landing gear control lever (LGCL) is in the down position and the LGCU sends an electrical unlocking command, or the alternate extension switch (AES) is in the opened position (dial down). When the LGCL is in the down position, the low level of the relay 1 and relay 3-5 are grounding. When LGCU sends an electrical unlocking command, it provides 28V voltage for the high level of the relay 1 and relay 3-5.

Conditions for sending electric unlocking command of LGCU: the door maintenance switch is in the opened position (dial down) and the airspeed don’t exceed 60 knots, or 90 seconds after the door maintenance switch is changed from the opened position (dial down) to the normal position (dial up), any door is not closed and the airspeed don’t exceed 60 knots. When the AES is in the opened position, it provides 28V voltage for the high level of relay 1, relay 2, and relay 3-5. When the door maintenance switch is in the opened position (dial down), LGCU sends an electrical unlocking command, it provides 28V voltage for the high level of the relay 1 and relay 3-5. After the door maintenance switch is changed from the opened position (dial down) to the normal position (dial up), LGCU sends a command to close the door and stops providing 28V voltage for the high level, and AEV in the LGCU is placed in the Pos2 position, then close the door through the hydraulic system, if any door isn’t closed after 90 seconds, the system judges the door is in an abnormal working status, then LGCU sends the electric unlocking command to provide 28V voltage for the high level of relay 1, relay 3-5. The specific workflow is shown in the figure below.
Uplock opening

relay 1, relay 3-5 working
notes: relay 1 only works for
5s, and will not unlock
repeatedly after 5s

Or

LGCL is in the
down position

LGCU sends an
electrical unlocking
command

AES is in the
opened position

And

Door maintenance
switch is set to the
maintenance
position (opened)

90s after moving the door
maintenance switch from the
“maintenance (opened)” position
to the “normal (closed)” position,
any door isn’t closed

Or

the airspeed don’t exceed 60 knots

Figure 3. Logical analysis of opening the inner door in 90 seconds self-test

4.2. Logical analysis of automatic door shedding

Based on the above logical analysis, when the LGCL is in the down position, the relay 1, relay 3-5 low
level are grounding, and the door maintenance switch changes from the opened position (dial down) to
the normal position (dial up), LGCU sends command to close the door, stop providing 28V voltage of
relay 1, relay 3-5 high level, and AEV in the LGCU is placed in the Pos2 position, then close the door
through the hydraulic system, if any door isn’t closed after 90 seconds, the system judges that the door
is in an abnormal working status. At this time, the LGCU sends an electrical unlocking command to
provide 28V voltage to the relay 1, relay 3-5 high level, so that the relay 1, relay 3-5 works again,
thereby activating the electrical unlocking to open door.

At this point, the specific reason for the abnormal opening of the door is clear. Because the
pressure in the hose of the external hydraulic tanker has not been completely relieved, the Uplock of
the right MLG door is faulty. During the troubleshooting process, the relevant personnel judged there
was an electrical fault, so re-tighten the electrical plug and move the door maintenance switch from
the "maintenance (opened)" position to the "normal (closed)" position, expect to reset the lock hook,
make it locked normally. But, within the following 90 seconds, the system's LGCU will have a
self-test if any door isn’t closed. When the LGCU self-test found that the right door was unclosed and
locked, LGCU automatically issued a reset command to open all doors and re-closed, 90 seconds after
the maintenance switch is set to the "normal (closed)" position, causing the left inner door is unlocked
and free to fall.
5. Conclusion
In summary, the reason why the MLG door is not opened normally can be summarized as follows: 1) The hydraulic tanker directly acts on the hydraulic system of the lock hook. The tanker isn’t completely relieved pressure, resulting in the right Uplock isn’t completely reset. On site, the door maintenance switch is operated to reset the Uplock, and the switch is set to the "normal" (closed) position, this method doesn’t eliminate the fault, and resulting in accidental drop and damage of the left door. 2) Aircraft power-on testing and door trimming work are carried out in parallel, creating conditions for on-site operation of the door maintenance switch.

Therefore, in order to avoid the recurrence of similar faults, to achieve safe production and ensure quality, the following points should be noted at the subsequent assembly site: 1) The trimming work of the MLG door and the power-on testing of the aircraft should not be arranged in parallel and should be avoided operating while the aircraft is powered. If the aircraft is electrified, the electrical plug of the MLG door Uplock should be unplugged and electrically isolated to avoid accidents. 2) The operation of the door should be performed after the actuator is installed. 3) When using a hydraulic tanker to operate the hydraulic mechanism, the pressure relief situation must be checked. 4) The on and off positions of the door grounding maintenance switch should be marked.

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