Failure Analysis and Research of Wing Anti-ice Pressure Release on Civil Aircraft

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Abstract. CAS alert message ‘PSW FAIL’ shows up frequently during civil aircraft test flights. This thesis provides an in-depth study of the problem by describing the fault phenomena and analyzing the fault based on historical data, system principles, and fault tree analysis. For the AT version after IASC 2nd stage software upgrade, pressure release response is triggered on the wing anti-ice valve when unilateral throttle lever is pushed over 40 degrees with both PACKs off and both WAIVs closed. Test flight data will be analyzed and verified. With respect to the flaws of pressure release response, this study optimizes the logic of ECS IASC software by analyzing trigger mechanism, adding pressure release response pre-requisites such as both PRSOV shut and signals off, with no APR mode initiated, and not under single engine startup. The study of the thesis helps to essentially improve the software, avoiding frequent occurrence of the pressure release response, enabling an accelerated production test flight and delivery test flight of Civil aircrafts.

1 INTRODUCTION

Wing Anti-Ice System consist of two Wing Anti-Ice Valve, two Anti-Ice Flow Sensor Venturi, two Anti-Ice Flow Sensor, two Anti-Ice Check Valve, Anti-Ice Pressure Sensor, Anti-Ice Pressure Switch, Anti-Ice Temperature Switch and corresponding pipe. Bleeding air of the Wing Anti-Ice System is from the bleeding air of engine[1].When flying in icing conditions, depending on conventional icy condition or the icy warning signal from the ice detector, the pilot is required to manually open the wing’s anti-ice switch. The temperature- and pressure-regulated hot air from the air system is supplied to the Wing Anti-Ice System, which is passed through two flow transducers of anti-ice and two Wing Anti-Ice Valves, respectively, to ensure that the flow rate of the Wing Anti-Ice System meets the anti-ice requirements. The pressure- and flow-regulated hot air enters the two check valves of anti-ice, whose function is to prevent the backflow of hot air. It then joins together and flows through the airtight rear fuselage, through the wing’s anti-ice switch, the wing’s anti-ice pressure sensor and the wing’s anti-ice temperature switch before separating and entering the ducts for air supply of the left and right wings respectively [2][3].

2 ANALYSIS OF AIRCRAFT PRINCIPLES

2.1 Logic control of the pressure release

The aircraft bleeds air from the engine. After it regulates pressure through PRSOV, adjust temperature through the precooler, it supplies the air to the main user Wing Anti-Ice System (via WAIV) and the air conditioning system (via FCV). When the PRSOV, FCV and WAIV are all closed, the leakage of PRSOV is greater than the combined leakage from the FCV and WAIV, so that the pipelines among PRSOV to FCV and WAIV can accumulate the bleeding air and exert pressure on the pipelines.

To solve this problem, the IASC AT software has added a pressure release function to the CAS phase 2 optimisation process. When the pressure in the pipelines between PRSOV, FCV and WAIV is judged to be high, the WAIV will be opened to release the leaky air and relief the pressure. The principle of pressure release is shown in the figure 1.

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Figure 1. Principle of anti-ice and pressure release for wings

2.2 Analysis of flight data

During the test flight, the aircraft was on the ground, the air conditioning units were switched off, the engine pushes the idle with thrust reverse and the WING A/I DEGRADE cyan CAS message appeared. From the analysis of the QAR data, it was noted that the aircraft had a right-hand TLA value of 75.03° between 8:59:16 and 8:59:32. At the same time the anti-ice switch on the air conditioning and wings on both sides were switched

off, and between 09:00:04 and 09:00:28 the left TAL exceeded 40°, reaching a maximum value of 74.59°. The right throttle lever was then pushed again between 9.01.12 and 9.01.20 seconds, with a maximum value of 74.96°. When the TAL on one side of the aircraft is greater than 40° and the air conditioning FCV and wing's anti-ice control switch are both closed, this operation triggers the automatic pressure release procedure that is automatically initiated, thereby triggering the WING A/I DEGRADE cyan CAS message.

Figure 2.QAR flight data

2.3 Conclusion

A troubleshooting analysis revealed that the false alarm for the wing's anti-ice pressure switch was caused by the Wing Anti-Ice Valve's pressure release procedure being initiated and the Wing Anti-Ice Valve's open when the unilateral throttle lever's angle is greater than 40°, the control valve for the entrance flow of bilateral refrigeration equipment is closed and the bilateral Wing Anti-Ice Valve is closed. Since control of Wing Anti-ice Valve have a balancing control for flow in them, this causes the bilateral Wing anti-ice Valve to open. When the throttle lever Angle on the other side is less than 40°, no pressure release signal is sent. At this time, the monitoring system of IASC software on this side will think that the Wing anti-ice Valve on this side has not received the instruction to open, but there is pressure

downstream of the valve, thus triggering the failure signal of the anti-ice pressure switch on the Wing.

3 ANALYSIS OF IMPACTS AND RISK ASSESSMENT

3.1 The necessity of the pressure release

There is leakage amount in valve of air management system, and the leakage amount is related to the use time of valve. The leakage of new valve is small, while that of old valve is large. When the leakage from an upstream valve is greater than that from a downstream valve, pressure builds up in the pipelines between the valves and has an effect on the system. Figure 3 shows the accumulative pressure architecture of the air management system.

Figure 3. The accumulative pressure architecture of the air management system

The results show that, with the exception of scenarios 1 and 3, all six scenarios require pressure release to ensure the safety of the pipelines' structure.

3.2 Risk assessment

The Wing Anti-Ice System's pressure release triggers the following scenarios and risk analyses:

- The bilateral FCV ends the ground test. Pay attention to the opening time on the anti-ice diagram page for Wing Anti-ice Valve. The hot gas over 30 seconds may damage the structure of the wing leading edge slats.
- The engine is started by crossfeed bleed air and attention is paid to the opening time on the sketch sheet for the Wing Anti-Ice Valve, as hot air in excess of 30 seconds may damage the structure of the wing leading edge slats.
- Thrust of engine is affected when the engine enters APR thrust mode: in twin-engine operation, the effect on aircraft performance is negligible. In single-engine operation, the engine performance is reduced by 1-2%.
- Turning off the flight modes of the bilateral FCVs (e.g. taking off in the Highlands, pilot error, failure of the air conditioning, etc.) will slightly affect the engine thrust.

In addition to the effects described above, pressure release is accompanied by the alarm of Wing Anti-Ice System WING A/I DEGRADE and the alarm of wing's anti-ice pressure switch (CMS message showing PSW FAIL).

4 Optimisation

The pressure release has been designed with the intention that all the valves of the air management system should have a leak volume, which is dependent on the time the valve has been in use. The amount of leakage is dependent on the time the valve has been in use. New valves have a small amount of leakage and old valves have a large amount of leakage. When the leakage from an upstream valve is greater than that from a downstream valve, pressure builds up in the pipelines between the valves and has an effect on the system. Consider changing the HPV and PRSOV hardware to reduce the upstream internal leakage based on the above factors. The old configuration WAIV was used to increase the amount of leakage downstream and thus reduce the pressure build-up. The pressure release before and after the final optimisation is shown in Figure 4.

Figure 4. After the final optimisation of the pressure release

5 Summary

In this paper, we study the frequent occurrence of PSW FAIL CMS alarm messages in civil aircraft during production test flights. The first step is to introduce the phenomenon of fault occurrence, which is analysed in terms of historical fault phenomena, system principles and fault tree analysis. For the AT version optimized in the second stage of IASC software, when the angle of the unilateral throttle lever is greater than 40°, the bilateral PACKs are closed, and bilateral Wing anti-ice Valves are closed, Wing anti-ice Valve will be started to release pressure, and the flight data of test flight will be analyzed and verified.

The research conducted in this paper will help to radically optimise and avoid the frequent occurrence of this automatic pressure release. This will help to increase the rate of civil aircraft's test flights for production and delivery.

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