Troubleshooting and Fault Analysis of Cabin Odors of Civil Aircraft

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Abstract. The cause of cabin odors is usually hard to be identified when there is no specific crew alerts or indications, which could have a catastrophic effect on civil aircrafts. Fault analysis has been conducted based on FTA (Fault Tree Analysis) in this paper to locate fault sources of cabin odors. A checklist is recommended to be performed during the flight or ground tests afterwards, which could provide quantitative references. An actual case applying the troubleshooting and analysis method above is shared at the end.

1. Introduction
Cabin odors of a civil aircraft could be caused by many reasons, such as wiring harness fire, oil leakage, and engine inlet contamination. Parts of odor problems occur with indications like EICAS (Engine Indicating and Crew Alerting System) message or obvious smoke which could lead to specific LRUs (Line Replaceable Unit) or structures. Those without indications are usually hard to be isolated to LRUs or systems. Most odors even occur temporarily and cannot be repeated during the flight or ground test afterwards, which increases the difficulty of troubleshooting. Safety of the flight cannot be guaranteed except the odor sources are isolated. Troubleshooting measures should be conducted until the odor problems are solved thoroughly [1].

This article focuses on civil aircrafts cabin odor problems without indications and provides a troubleshooting and fault analysis method based on FTA. A checklist which is designed to guide relevant crews to do flight or ground tests can provide quantitative references to help isolating the odor sources. At the end, an actual case is shared to prove the feasibility of this fault analysis method [2].

2. Fault tree analysis of cabin odors
FTA method is applied in cabin odors troubleshooting process. FTA is a diagram providing a model of the interactions between the components of a system or different systems when a failure occurs. FTA method is widely adopted to solve engineering problems due to high universality and flexibility.

As the cause of cabin odors could involve a variety of systems, it is not intuitive to define different system failure as second-leading events. The travel path has been chosen to be the group standard to analyse the source of cabin odors. When flight crew members smell odors in cabin or cockpit, it could diffuse directly from cabin and cockpit space or the ventilation outlet of the cabin and cockpit interiors. As the cabin and cockpit floors haven’t been designed gastight, the odors could also come from the area below the floors. The whole fault tree has been shown in figure 1. A detailed analysis is conducted as follows [3].
Figure 1. FTA of cabin odors.

2.1. Area below floor
The areas below cabin and cockpit floors usually include the E-E bay (Electronic Equipment bay) and the forward and aft cargos. Electronics of most systems are located in E-E bay, together with relevant wiring harness and cables. Some electronic units such as flight control devices are arranged in the triangular area of cargos. One or more electronic devices fault or wiring harness and cables ablating could produce odors of burnt taste. These odors may occur with EICAS messages and system failure. The sealing strip burning or the hydraulic grease leakage of landing gears also has a chance to produce odors through cargo to the cabin and recognized by crew members [4].

2.2. Interior ventilation outlet
In addition to the cabin and cockpit interiors’ odors, the odors from interior ventilation outlet all diffuse from the ACS (Air Conditioning System) of the aircraft. The ACS adjusts the high temperature, high pressure air from the pneumatic system to the conditioned air with proper flow, temperature and pressure through the pack. The conditioned air is sent to the cockpit and cabin, E-E bay and cargos through ducts. If the odors come from the bleed sources including out atmosphere, engines, APU (Auxiliary Power Unit) and ground air source, it could be sent to the cabin through the ACS. Some consumable materials of ground maintenance work such as thread lubricant or de-icing fluid ingestion may result in cabin odors of chemical taste through the ACS when operating improperly. If the aircraft is designed with a recirculation function, the recirculation fan may also send odors to the ACS from the recycling area.
2.3. Cockpit and cabin
Many control panels, electronics and electronics are located in cockpit, cabin, galley and lavatory area, which can produce odors. Besides, cabin items, passengers and dirty furnishings can also be the odor sources. These odors are usually localized and have a clear direction.

3. Odor checklist
According to the FTA of cabin odors, we can do a thorough inspection when odors are recognized. A flight or ground test should be designed and conducted in combination with the actual situation.

An odor checklist sample as shown in figure 2 is recommended to help with troubleshooting. When the flight crews report an abnormal odor event, it is needed to confirm relevant information immediately and record it. A ground test afterwards is helpful for the fault isolation. The checklist should be filled out based on the flight crew feedback and test results. We can get a preliminary evaluation result of scores and the highest scoring item points to the most possible odor cause. Combined with the FTA, a more detailed and specific inspection should be taken until the odor sources are located. If the crew members present are available, a controlled burning or heating experiment of suspected object is recommended to be compared with the odor recognized.

| ODOR CAUSE | ENG 1 | ENG 2 | APU | O/P | GROUND | PACK 1 | PACK 2 | INTERIORS | E-E BAY | CARGO |
|------------|------|------|-----|-----|--------|--------|--------|-----------|--------|-------|
| AFFECTED AREA | COCKPIT | 3 | 3 | 3 | 4 | 1 | 2 | 2 | 2 | 5 |
| CABIN | 3 | 3 | 3 | 3 | 1 | 2 | 2 | 2 | 1 | 3 |
| AFFECTED RANGE | ALL AREA | 4 | 4 | 4 | 2 | 3 | 3 | 3 | 2 | 2 |
| LOCALIZED | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 5 | 5 |
| GND/FLT | FLIGHT | 3 | 3 | 2 | 2 | 0 | 3 | 3 | 3 | 3 |
| TAXI | 3 | 3 | 5 | 3 | 0 | 2 | 2 | 2 | 2 | 2 |
| TAKE OFF | 0 | 4 | 1 | 1 | 0 | 2 | 2 | 2 | 2 | 2 |
| CLIMB | 4 | 4 | 1 | 1 | 0 | 2 | 2 | 2 | 2 | 2 |
| CRUISE | 3 | 3 | 1 | 1 | 0 | 2 | 2 | 2 | 2 | 2 |
| DESCENT & LAND | 3 | 3 | 1 | 3 | 0 | 2 | 2 | 2 | 2 | 2 |
| APU BLEED | ON | 0 | 5 | 2 | 0 | 2 | 2 | 2 | 1 | 1 |
| OFF | 3 | 3 | 0 | 3 | 0 | 1 | 1 | 3 | 3 | 3 |
| X BLEED | ON | 2 | 2 | 4 | 2 | 2 | 2 | 2 | 1 | 1 |
| OFF | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 |
| ACS PACKS CONFIGURATION | PACK 1 ON, PACK 2 ON | 5 | 5 | 1 | 2 | 0 | 3 | 3 | 1 | 1 |
| PACK 1 ON, PACK 2 OFF | 5 | 0 | 1 | 2 | 0 | 4 | 1 | 1 | 1 | 1 |
| PACK 1 OFF, PACK 1 ON | 0 | 5 | 1 | 2 | 0 | 1 | 4 | 1 | 1 | 1 |
| PACK 1 OFF, PACK 2 OFF | 0 | 0 | 1 | 1 | 3 | 1 | 1 | 3 | 3 | 3 |
| ENG BLEED | ENG 1 & 2 ON | 5 | 2 | 1 | 1 | 0 | 2 | 2 | 2 | 2 |
| ENG 1 BLEED ON | 0 | 5 | 1 | 1 | 0 | 2 | 1 | 1 | 1 | 1 |
| ENG 2 BLEED ON | 0 | 5 | 1 | 1 | 0 | 2 | 1 | 1 | 1 | 1 |
| ENG 1 & 2 OFF | 0 | 0 | 4 | 2 | 0 | 3 | 2 | 3 | 2 | 2 |
| RECYCLING FAN | OFF | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| TYPE OF ODOR | BURN RUBBER | 0 | 0 | 0 | 2 | 0 | 5 | 4 | 4 | 5 |
| HEATED CHEMICAL | 5 | 5 | 2 | 2 | 2 | 2 | 2 | 2 | 3 | 3 |
| MUSTY PLASTIC | 0 | 0 | 0 | 2 | 0 | 3 | 2 | 2 | 2 | 2 |
| OIL | 5 | 5 | 5 | 2 | 2 | 0 | 0 | 0 | 0 | 5 |

Figure 2. Odor checklist sample.

The record and check items should be adjusted according to the configuration of the aircraft. The scoring weight for each item can be optimized based on long-term data accumulation. However, the checklist can only help to narrow down the scope of the odor source. We should still take more detailed system tests or inspections to solve the problem and ensure the safety of flight.

4. Case studies
The flight crews on a certain type of aircraft reported an odor event. The odors were recognized during cruise phase with a height of 18000ft and an airspeed of 170kn. The odors last 6–8 minutes and diffused all over the cockpit and cabin. The odors smelt like heated or burnt chemicals. All systems operated
normally during the whole flight. The checklist has been applied to analyse the odor case and the results of evaluation are shown in table 1.

**Table 1. Checklist result of the odor case.**

| ODOR CAUSE | ENG 1 | ENG 2 | APU | OUT ATMOSPHERE | GROUND AIR SOURCE | PACK 1 | PACK 2 | INTERIORS | E-E BAY | CARGO |
|------------|------|------|-----|----------------|------------------|-------|-------|-----------|--------|-------|
| TOTAL      | 43   | 38   | 24  | 27             | 9                | 28    | 27    | 22        | 27     | 31    |

The result shows that the odor has a large possibility produced by the left engine. As the odor couldn’t be repeated during the ground tests afterwards, a large amount of inspections were conducted before the odor source was finally confirmed. The odor came from the excessive thread lubricant which was operated improperly during the machine thread plugs installation process of the borescope inspection before the flight. The extra thread lubricant was heated by the high-temperature air flow and entered the ACS through the bleed duct. Then the gasified thread lubricant flew into the cabin and cockpit from the interior ventilation outlet and recognized by the crew members.

5. Conclusion

Cabin odors of civil aircrafts are hard to be isolated and solved, which could have a catastrophic effect on flight safety. FTA method has been applied to analyse all possible odor causes and help with troubleshooting. An odor checklist is designed to give a quantitative evaluation results. At the end, an odor event case of a certain type of aircraft is used to prove the feasibility of the fault analysis method.

References

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