REPORT
SERIOUS INCIDENT

Fire on engine n° 2 during initial climb, turn-back, emergency landing and evacuation

Aircraft	ATR 72- 212A registered F-OIQN
Date and time	12 January 2013 at about 03 h 30(1)
Operator	Air Tahiti
Place	Tahiti Faa'a Airport (French Polynesia)
Type of flight	Public transport
Persons on board	Captain (PF), copilot (PNF), 2 cabin crew, 53 passengers
Consequences and damage	Engine n° 2 damaged
Note: the following elements are based on data recorded on the FDR and the CVR, crew's and firefighter's accounts, as well as videos of the incident.	

This is a courtesy translation by the BEA of the Final Report on the Safety Investigation. As accurate as the translation may be, the original text in French is the work of reference.

1 - HISTORY OF FLIGHT

The crew was performing a flight between Tahiti Faa'a Airport and Raiatea aerodrome (French Polynesia).

During the takeoff roll after the engine power-up, the interstage turbine temperature (ITT) and fuel flow (FF) values on the two engines showed some differences. The copilot did not notice them and called out "*takeoff power checked*" at about 45 kt. The ITT on engine n° 2(2) then exceeded 765 °C(3) while the torque on engine n° 2 increased, then fluctuated. Two seconds after the "*70 knots*" callout by the copilot, the ITT on engine n° 2 exceeded 800 °C for three seconds, theoretically triggering illumination of the amber light on the ITT display (*see figure 1*) during this time.

The crew did not detect these anomalies and continued the takeoff.

At an altitude of 500 ft, the ENG OIL(4) warning appeared. The captain called out "*continue*"(5). The copilot read this back.

At an altitude of 750 ft, the ENG FIRE(6) warning appeared. The crew applied from memory the "*ENG FIRE on takeoff*" procedure to engine n° 2: they shut down the engine and pulled the fire handle. The copilot declared an emergency situation and asked for landing priority on runway 04. The crew began to turn back. Ten seconds later, the fire handle having remained illuminated, the crew fired the n° 1 fire extinguisher. Thirty seconds after pulling the fire handle, the latter remained illuminated so the crew fired the n° 2 fire extinguisher. The fire handle remained lit.

The Captain warned the cabin crew of the presence of a fire warning on engine n° 2 and asked for confirmation of the presence of any flames. The cabin crew said they saw some flames.

(1)Except where otherwise mentioned, the times in this report are UTC.

(2)Right engine.

(3)Corresponding to the end of the green arc.

(4)Repeated aural warning, MASTER WARNING red flashing warning light and ENG OIL red warning light on the CAP (Crew Alerting Panel).

(5)The acceleration altitude is 500 ft.

(6)Repeated aural warning, MASTER WARNING red flashing warning light and ENG FIRE 2 red warning light, associated fire handle in red, FUEL SO indication illuminated in red on the associated propeller control.

The crew then carried out the *"ENG FIRE or serious mechanical damage in flight"* check-list and decided not to carry out the *"one-engine flight"* procedure item. However, they calculated the landing conditions in N-1.

The Captain announced on the radio that *"there is an engine fire warning that has not been controlled"*, stated that he was going to stop on the runway and asked for a rescue and fire-fighting service intervention.

After the aeroplane stopped on the runway, the copilot called out that the fire was not under control. The crew proceeded to shut down engine n° 1. The firefighters worked on engine n° 2. After having detected the presence of a fire, they asked the crew to start evacuating the passengers via the left side.

The crew ordered an emergency evacuation and the passengers evacuated without incident.

2 - ADDITIONAL INFORMATION

2.1 Aircraft Information

a. ITT displays

The ITT displays include a green arc up to 765 °C, then an amber arc up to 800 °C.

Figure 1: ITT displays

An ITT higher than 800 °C triggers the following:

- an amber light illuminates on the lower right of this instrument;
- an ENGINE OVERTEMP[7] warning, which is inhibited[8] before takeoff by the selection of the TO INHI button, and as long as the landing gear is locked down. When the triggering condition disappears during the inhibition phase, the warning is not triggered.

During the incident, the ITT exceeded 800 °C while the landing gear was locked down. The warning was not triggered because it was inhibited during the takeoff and the triggering condition had disappeared at the time of landing gear retraction.

b. Fire detection system

Each engine is equipped with a fire detection system made up of:

- two continuous detection loops (cables), that are identical and mounted in parallel, installed on the engine nacelle;
- a fire detection control unit (FDCU).

[7] Single Chime aural warning, MASTER CAUTION amber flashing worning flight and ENG warning light on the CAP.

[8] This inhibition can be removed manually by pushing on the RCL button on the CAP.

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The detection principle is based on variation in the cables' resistance and capacity with temperature.

The ENG FIRE red warning light illuminates on the CAP when the temperature exceeds 258 °C on the two loops or on only one loop if the other fails[9]. The light remains illuminated as long as the temperature measured in the nacelle is greater than 258 °C or if a short-circuit occurs on one of the two loops.

[9] A detection loop fails if it is short-circuited or if it is in open circuit. A short-circuit is signalled in real time in the cockpit, except if a fire condition is present. A circuit loop can always detect the fire. This condition is carried over to the next pre-flight test.

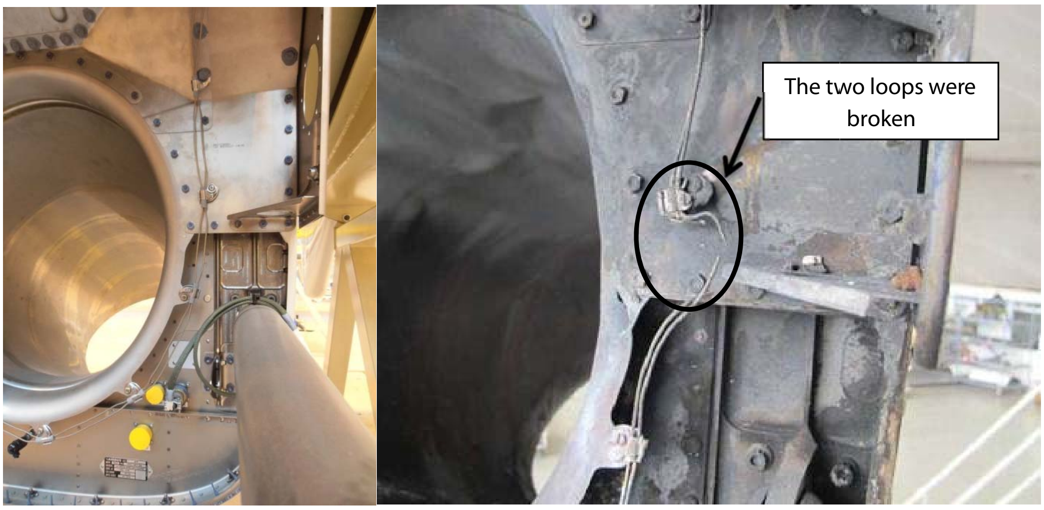

Figure 2: Fire detection system of a production aeroplane (left photo) and that of F-OIQN after the incident (right photo)

2.2 Information on engine n°2

Engine n° 2 was a PW127F engine manufactured by Pratt and Whitney Canada, serial number EB0235. It was manufactured in May 2006, installed in June 2006 then on the F-OIQN on 8 March 2012 after an overhaul.

Engine n° 2 had not yet been subject to the inspection required by Service Bulletin (SB) n° 21823 (*see following paragraph 2.4*).

2.3 Technical examinations

The technical examinations performed on engine n° 2 showed:

- that the blades on two stages of the two power turbines PT1 and PT2 had failed and, more generally, that the moving parts of the turbine assembly had been destroyed (shafts and bearings);
- that at least one of the two loops in the fire detection system was in open circuit.

A blade of a power turbine (PT1 or PT2) had probably failed generating an imbalance leading to significant vibrations that caused secondary damage, including the failure of the lubrication system that led to the engine fire through projecting oil on the hot parts.

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2.4 Failure of power turbine blades

a. In-service experience

Some cases of blade failure were reported between 2002 and 2013:

- 15 occurrences caused by a PT1 blade failure were reported to ATR and 29 to Pratt and Whitney on all types of PW100 [10] engine;
- 11 occurrences caused by a PT2 blade failure were reported to Pratt and Whitney on type PW127 engines.

An increase in cases of PT1 blade failure occurred in 2008. Some of them caused an engine in-flight shutdown or caused the beginnings of a fire. The cases with fire occurred during takeoff or climb phases. The origin of these failures was attributed to a shrinkage porosity[11], a defect that occurs during blade manufacture.

An increase in cases of PT2 blade failure occurred in 2013. One case of fire after the failure of a PT2 blade was identified.

[10] The PW127F is a version of the PW100.

[11] Defect consisting of a cavity that forms in the solid part of a cast metal part, due to the contraction of the metal during solidification.

b. Actions taken by the manufacturers and the oversight authorities for PT1 blades

In April 2008, Pratt and Whitney Canada brought into production an improved X-Ray inspection methodology.

Service Bulletin (SB) n°21823 of September 2012 recommended the inspection, when the engine was disassembled and access to the necessary sub-assembly was possible, of all blades manufactured between 2005 and April 2008 using the new X-Ray inspection methodology and the replacement of blades with any defect. A service information letter (SIL N° PW100-151) was sent out at the time of the publication of this SB in order to inform operators of the in-service events reported and of the importance of this inspection.

Following the publication of SB n° 21823, Air Tahiti had decided to apply the inspection during maintenance operations that gave access to the sub-assembly involved.

Following the incident, Air Tahiti decided to replace all the PT1 blades on all of the engines involved, without waiting for the constraints of SB n° 21823.

On 22 January 2013, Transport Canada issued an Airworthiness Directive n°AD 2013 02, applicable on 31 January 2013, which made SB n° 21823 mandatory (revision 2 or any later revision). The inspection had to be made when the engine was dismantled or if not within the 60 months from the effective date of the AD. EASA repeated this directive on 24 January 2013.

After the incident to F-OIQN, other SBs relating to PT1 blades were issued, recommending the replacement of any blades judged to be defective.

A new method using a resonance test was also implemented, but only for production.

Finally, Pratt and Whitney Canada designed a new PT1blade, installed on engines in production since September 2015 and available since October 2015 for retrofit on engines in service.

2.5 Operators procedures

a. Takeoff procedure

The operator's takeoff procedure requires the PNF to check the engine parameters after power-up. The latter must call out "*ARM power set*", when the following conditions are met:

- the ATPCS ARM is illuminated;
- the torque values correspond to computed values;
- the FDAU index displays the RTO value;
- the NP reach 100 %;
- the parameters are "in the green".

He then monitors the speed and the engine instruments until the « seventy knots » callout then makes the *"V1"* and "*rotation*" callouts.

ATR's procedure is slightly different and requires a specific check of the ITT, in addition to the other parameters mentioned above.

Crews are not made particularly aware of monitoring the differences between the left and right engines, neither through the above procedure, nor during their training. Taking into account the number of checks to perform during the copilot's visual check, it can be difficult to monitor these differences.

b. ENG FIRE procedure

The airline's ENG FIRE procedure requires pilots to perform the following actions from memory: shut down the engine, pull the fire handle then, if the condition persists, fire the two fire extinguishers on the engine 10 and 30 seconds after the warning is triggered. The procedure requires "*landing as soon as possible*" and applying the "*single engine operation*" procedure.

In commentaries, it states that "*the fire handle remains illuminated for as long as the fire persists*".

The ATR procedure is similar. In the FCOM [12], in the commentaries, it states that the "*fire handle remains illuminated as long as a fire is detected*".

[12] Flight Crew Operating Manual.

There is no mention of actions to take in case of a continuing indication of fire.

ATR told investigators that it expects crews to evaluate the situation before taking any decision, for example by asking the cabin crew for visual confirmation of a continuing fire.

There are no details on a method for visual confirmation of a continuing fire.

2.6 Continuing Fire

Analysis of the amateur videos of the incident did not make it possible to determine if the engine was still on fire during the approach and landing. During the firefighters' intervention, immediately after the aeroplane stopped, a fire was clearly visible on engine n° 2.

Figure 3: fire on engine n° 2 during the firefighters' intervention

2.7 Meteorological Conditions

The meteorological conditions were as follows:

- wind from 360° at 6 kt;
- visibility above 10 km;
- FEW at 2,000 ft;
- SCT at 30,000 ft;
- temperature 29 °C;
- dewpoint temperature 22 °C;
- QNH 1010 hPa.

3 - LESSONS LEARNED AND CONCLUSION

3.1 Blade Failures

The damage on engine n° 2 very likely resulted from the failure of a blade that occurred during the takeoff roll, without it having been possible to determine if it was a PT1 or a PT2 blade.

Cases of failures of PT1 blades have been attributed to production defects. Inspections and defective blade replacements were implemented regularly by the manufacturer and some were made mandatory by the oversight authorities. Indeed, the risk of an uncontrolled engine fire is critical in the case of an operation where conditions do not make it possible to land in a very short time in case of emergency.

The blades installed on F-OIQN had not yet been subject to these inspections as they had not yet reached the limits defined in the service bulletin.

In-service experience has shown that the number of reported cases since implementation of these inspections had dropped considerably.

3.2 Monitoring Parameters

The operator's takeoff procedure requires that the copilot check the engine parameters before calling out "*power set*", then that he monitors the speed and the engine instruments. In the seconds that followed the power-up, the differences in ITT and in the fuel flow were indications showing that there was an anomaly. The increase in engine n° 2's ITT beyond 765 °C, the fluctuation in torque after the "*power set*" callout by the copilot, as well as the illumination of the amber light on the ITT display for three seconds confirmed this anomaly but the crew did not detect them and continued the takeoff.

Taking into account the number of checks to perform during the copilot's visual circuit, it can be difficult to detect these anomalies. The illumination of the amber light on the ITT display could have made detection easier but the brevity of this warning contributed to the non-detection of this failure before V1.

In the absence of the ITT check item in the operator's takeoff procedure, the crew's attention was not specifically drawn to monitoring this parameter.

Since the incident, Air Tahiti has modified the takeoff procedure by including this item.

3.3 Conclusion

A PT1 or PT2 blade from engine n° 2 probably failed during the takeoff roll, leading to abnormal variations in the engine parameters then a fire during the initial climb. The fire resulted from the failure of the lubrication system caused by significant vibrations that followed the blade failure.

The investigation was not able to determine the cause of this failure. However, in-service experience shows that PT1 blade failures are caused by a production defect that inspection procedures found it hard to detect and eliminate both during production and during maintenance operations. In-service experience indicates that a fire following such a failure has only occurred in a takeoff or landing situation.

The engine instruments displays during takeoff could have alerted the crew to the presence of an anomaly before V1.