Australian Government
Australian Transport Safety Bureau

Engine malfunction involving Airbus Industrie A330-323, registered 9M-MTM

37 km north of Curtin Airfield, Western Australia on 18 January 2018

ATSB Transport Safety Report
Aviation Occurrence Investigation
AO-2018-007
Final – 6 November 2019

Released in accordance with section 25 of the *Transport Safety Investigation Act 2003*

Publishing information

Published by: Australian Transport Safety Bureau
Postal address: PO Box 967, Civic Square ACT 2608
Office: 62 Northbourne Avenue Canberra, Australian Capital Territory 2601
Telephone: 1800 020 616, from overseas +61 2 6257 2463 (24 hours)
Accident and incident notification: 1800 011 034 (24 hours)
Email: atsbinfo@atsb.gov.au
Internet: www.atsb.gov.au

Addendum

Page	Change	Date

Safety summary

What happened

On 18 January 2018, a Malaysia Airlines Berhad (MAB) Airbus A330-323 aircraft registered 9M-MTM was operating a scheduled passenger flight designated MH122, which departed from Sydney, New South Wales, for Kuala Lumpur, Malaysia. On board were two flight crew, 10 cabin crew and 243 passengers. During the flight, the left engine malfunctioned, necessitating a diversion to Alice Springs where the aircraft landed safely.

What the ATSB found

The left engine, a Pratt & Whitney PW4170, had a third stage outer transition duct (OTD) segment liberation, which created a rise in exhaust gas temperature and significant turbulent airflow within the engine. That in turn led to low pressure turbine blade failure, high vibration and compressor stall/surge events. There have been a total of 16 similar events globally within the past 4 years that were all attributed to an engine modification, including five involving MAB aircraft. The modification increased the gas path temperature at the outer diameter of the flowpath, which led to distortion and liberation of OTD segments.

What's been done as a result

The engine manufacturer Pratt & Whitney had ceased production of PW4000-100 series engines for the Airbus A330 in July 2017. They have also redesigned the OTD to withstand higher temperatures. The newly designed hardware will be available for purchase from November 2019 and recommended by service bulletin for installation at the customers' discretion in affected engines when they are next scheduled for disassembly at an overhaul facility. Engines that have scheduled overhauls and repairs before the redesigned OTDs are available will receive a full new set of current OTDs. This will remove ducts that were potentially exposed to elevated temperatures.

While the ATSB welcomed the availability of the redesigned OTD, as their fitment is not mandatory, safety recommendations were issued to Pratt & Whitney and the United States Federal Aviation Administration (FAA) to maximise fitment of the improved components.

MAB has implemented scheduled borescope inspections that are designed to identify precursors to an OTD failure. One of the five MAB events was identified while conducting a borescope inspection.

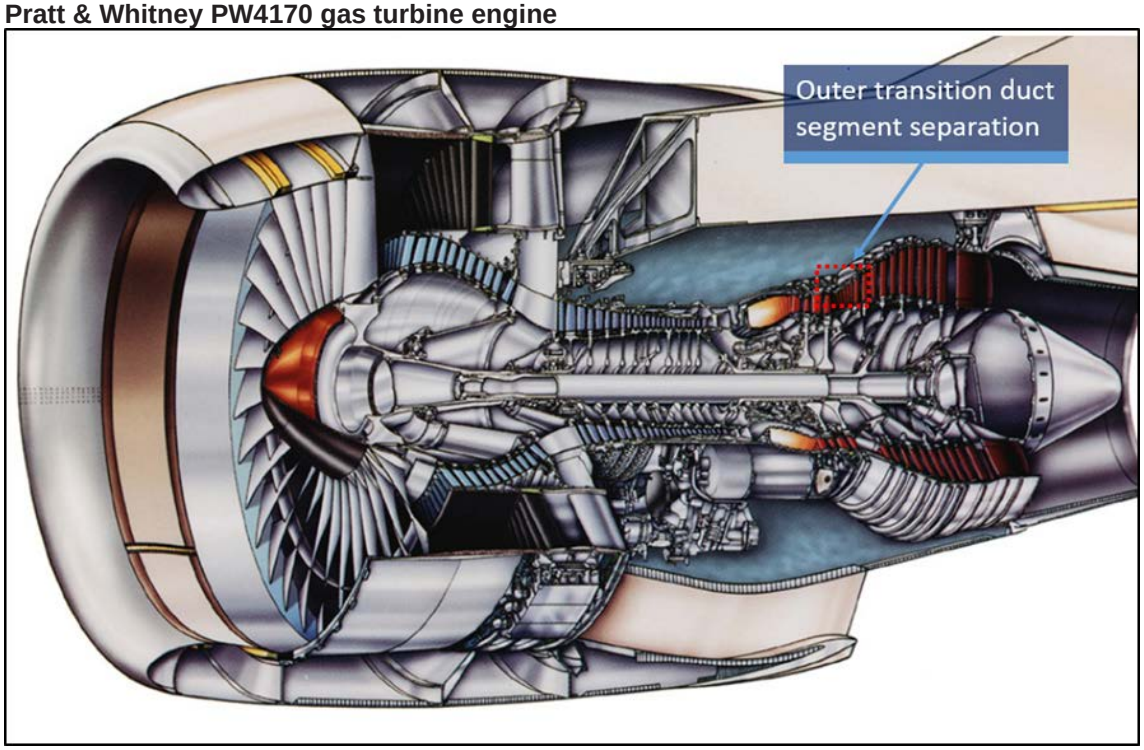
Safety message

This incident is an example of an engine modification that had undesirable consequences. The negative effect of the redesign was identified by the engine manufacturer during analysis of a previously unseen failure mode in the PW4000-100 series engine.

The engine manufacturer has taken timely and significant safety action to redesign the outer transition duct. If fleet-wide replacement is implemented, the safety issue is expected to be addressed.

Finally, while the crew's response to the elevated temperature was in accordance with the required procedure, this occurrence highlights that significantly abnormal indications are often symptomatic of a developing problem. In such circumstances, the safest course of action is to discontinue the flight as soon as possible.

Pratt & Whitney PW4170 gas turbine engine



Source: Pratt & Whitney, modified by the ATSB

Contents

The occurrence

What happened

On 18 January 2018, a Malaysia Airlines Berhad Airbus A330-323 (A330) aircraft, registered 9M-MTM, was operating a scheduled passenger flight designated MH122, from Sydney, New South Wales, to Kuala Lumpur, Malaysia. On board were two flight crew, 10 cabin crew and 243 passengers.

The aircraft departed Sydney at 1306 Eastern Daylight-Saving Time[1] and while passing an altitude of about 1,500 ft, the flight crew received an electronic centralised aircraft monitoring (ECAM) exhaust gas temperature (EGT) 1 OVERLIMIT message, which indicated a fault with engine number 1 (left engine). The crew performed the checklist actions and reduced the left engine thrust to maintain the EGT within limits.

The aircraft continued to climb, and the left engine was restored to full climb thrust at flight level[2] (FL) 240. The EGT of the left engine was observed by the crew to be about 70°C higher than the right engine EGT, however it did not exceed its limits during the climb and cruise phase.

About four hours into the flight, while cruising at FL 360 about 37 km north of Curtin Airfield, Western Australia, the crew received an ECAM notification, ENG 1 STALL[3], with corresponding 'bang' sounds heard emanating from the engine on three or four occasions. The engine vibration monitor indicated significant vibration increases during the engine stalls. The flight crew carried out the ECAM action and thrust was reduced to flight idle. A PAN-PAN[4] call was made and the aircraft turned left and initiated a descent to the single engine flight altitude of FL 240.

During the descent, an attempt was made to restore thrust to the left engine, however this had a corresponding effect of increased vibration. Consequently, the engine thrust was reduced back to flight idle, and the descent was continued to FL 240. The engine was not shut down. The flight crew reviewed the nearest suitable airport to conduct a landing. With the weather at Darwin, Northern Territory (NT), assessed as unsuitable, a decision was made to land at Alice Springs, NT.

During the diversion to Alice Springs, the cabin crew were told to prepare the cabin for an emergency landing. That request was later revised following a reassessment of the situation and several passenger announcements were made to inform passengers to expect a normal landing. The aircraft landed safely at Alice Springs at 1746 Central Standard Time[5] and taxied to the parking apron under its own power.

---

1 Eastern Daylight-Saving Time: Universal Coordinated Time +11 hours

2 Flight level: at altitudes above 10,000 ft in Australia, an aircraft's height above mean sea level is referred to as a flight level (FL). FL 240 equates to 24,000 ft.

3 Indication of pressure fluctuations and turbulent airflow within the engines compressor section.

4 PAN PAN: an internationally recognised radio call announcing an urgency condition which concerns the safety of an aircraft or its occupants but where the flight crew does not require immediate assistance.

5 Central Standard Time (CST): Universal Coordinated Time +9.5 hours.

Context

Engine information

An engineering inspection conducted on the day of the incident found that despite the left engine operating at flight idle until it was shut down on the apron at Alice Springs, the N1 rotor (fan) was unable to be rotated by hand. Molten debris was found in the exhaust, and the last turbine stage had numerous nicks and dents. The following day, when the engine had cooled, the fan was able to be turned by hand. The engine was deemed to be unserviceable, removed from the aircraft and shipped to a suitable engine overhaul facility so that a detailed disassembly and inspection could be conducted by the engine manufacturer.

Engine history

The Pratt & Whitney PW4170 high by-pass turbine engine serial number 735135 had not been removed from the aircraft since it was fitted during the aircraft's manufacture in 2013. It had accumulated 22,591 hours and 3,415 cycles in service.

Advantage 70™ engine

The engine was an upgraded version of the PW4168 engine, called the Advantage 70™. It was specifically redesigned to increase the Airbus A330's maximum take-off weight. The modifications could be retrofitted to legacy engines, and was introduced as standard in the A330 fleet from 2010. The modifications included:

- the inclusion of high pressure turbine technology with new thermal barrier coatings
- a redesigned combustor
- a redesigned ring compressor case
- software enhancements.

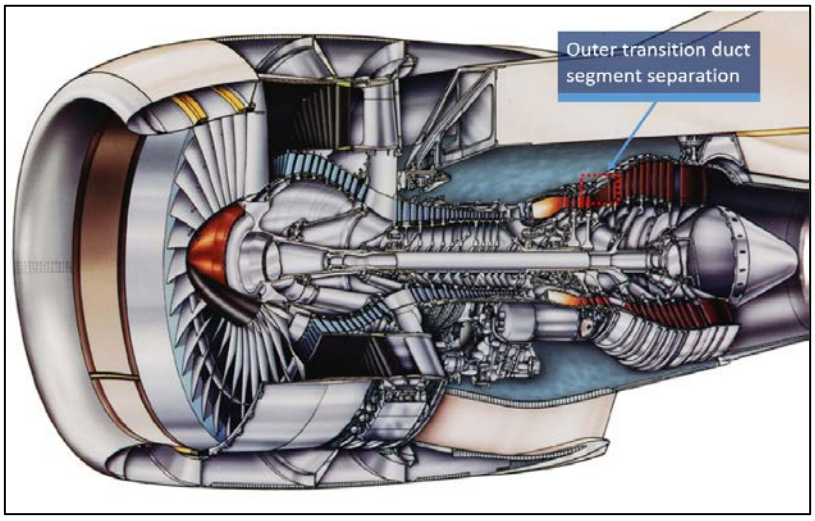
The effects of the modifications were:

- a 1 per cent decrease in fuel consumption and 2 per cent increase in thrust
- an increase in the gas path outer end wall temperature.

Engine disassembly and inspection

The engine disassembly and inspection identified that a third stage outer transition duct (OTD) segment had separated at the gas path entry point of the low pressure turbine. (Figure 1).

Figure 1: Cutaway view of the PW4170 showing outer transition duct location

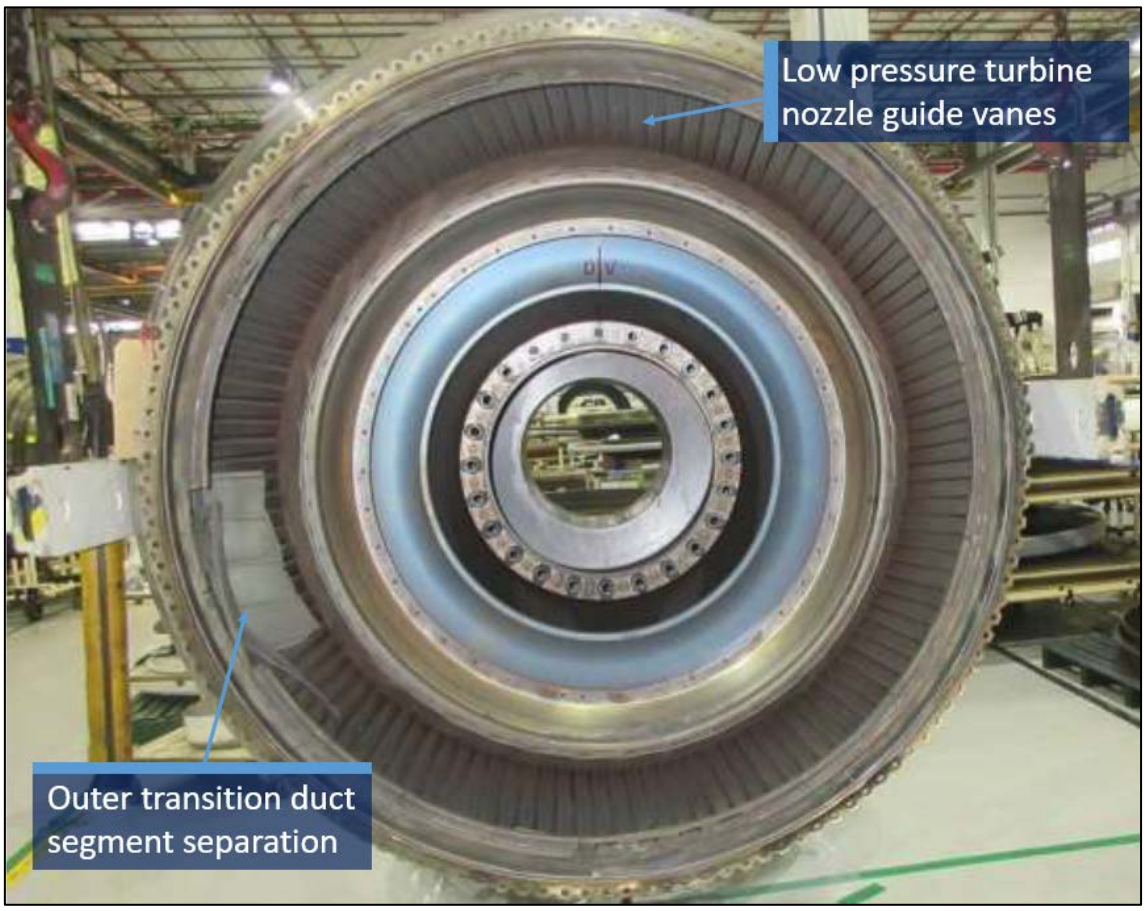


Source: Pratt & Whitney, modified by the ATSB

Specifically, the OTD at the number 5 position distorted, partially released from the front retaining hook and fractured so that a large section moved to a position that lay across the gas path of the low pressure turbine nozzle guide vanes (Figure 2). That partial blockage created turbulent airflow within the engine, and caused an increase in exhaust gas temperature. Downstream engine damage, including separation of some low pressure turbine blades, was attributed to the turbulent airflow and impact damage from sections of the OTD and released turbine blades.

Various components, including the OTDs, were sent to the manufacturer's materials analysis facility for further examination.

Figure 2: Front view of low pressure turbine section showing the outer transition duct segment separation and movement into the low pressure turbine airflow path



Source: Pratt & Whitney, modified by the ATSB

Material failure analysis

A material analysis report was supplied to the ATSB by the engine manufacturer on 12 February 2019. The summary and conclusions stated that:

> Review of the low pressure turbine outer transition duct segments found that the segment identified as #5 had fractured. Examination of the fracture surfaces found that the features appeared dendritic [microstructure affected by heat]; no evidence of fatigue was observed.
>
> Metallographic sections were prepared through two outer transition duct segments selected based on the condition of the corresponding high pressure turbine 2nd stage blade outer air seals and dimensional inspection of the segments. Examination of the sections found evidence of microstructural changes indicative of exposure to elevated temperatures.

Figure 3 shows the fractured and recovered sections of the number 5 OTD that were examined.

Figure 3: Non gas path side of the failed number 5 outer transition duct sections

Source: Pratt & Whitney

The ATSB asked the engine manufacturer if they were aware of the reason why there appeared to be degradation of the OTD due to elevated temperatures. The engine manufacturer stated that:

> The elevated temperature exposure of the OTD identified during the failure analysis activity is attributed to the OD [Outer Diameter] of the gas path being hotter in engines configured with the Talon IIB-combustor (includes all Advantage70 engines). Spallation of the 2nd Stage Blade Outer Air-seals (BOAS) immediately upstream of the OTD is an additional contributor.

Similar occurrences

At the time of drafting this report, the PW4000-100 series engines with the Talon IIB combustor or configured as PW4170 Advantage 70™ (as fitted to the Airbus A330-300) have had 16 OTD separation events dating back to 2015, including this incident. A further two engines were identified following a shift in engine parameters requiring borescope inspections and unscheduled engine removals.

There have been a total of 306 modified engines produced, with the 16 engine events representing 5.22 per cent of the entire fleet requiring unscheduled removal due to this issue within the last 4 years.

The consequence of these events have been EGT increases, engine surges and diversions or air turn-backs, with two in-flight engine shut-downs. None of these events were uncontained engine failures, but all resulted in engine damage which necessitated unscheduled engine removal for

repair. All of the OTD liberations occurred within 3,104 to 8,887 flight cycles since installation at manufacture or incorporation of the Advantage 70™ modification.

Five of the 16 events occurred on the incident operator's aircraft, with one being identified during a borescope inspection following a shift in engine parameters.

Flight data

Data from the incident flight showed a significantly elevated temperature on the left engine from take-off, four hours before the engine vibration and surging occurred.

The operator supplied engine trend data for the failed engine. That data did not show any increase or exceedance in engine exhaust gas temperature, or any other parameter in the 18 months preceding the incident.

Safety analysis

Occurrence event

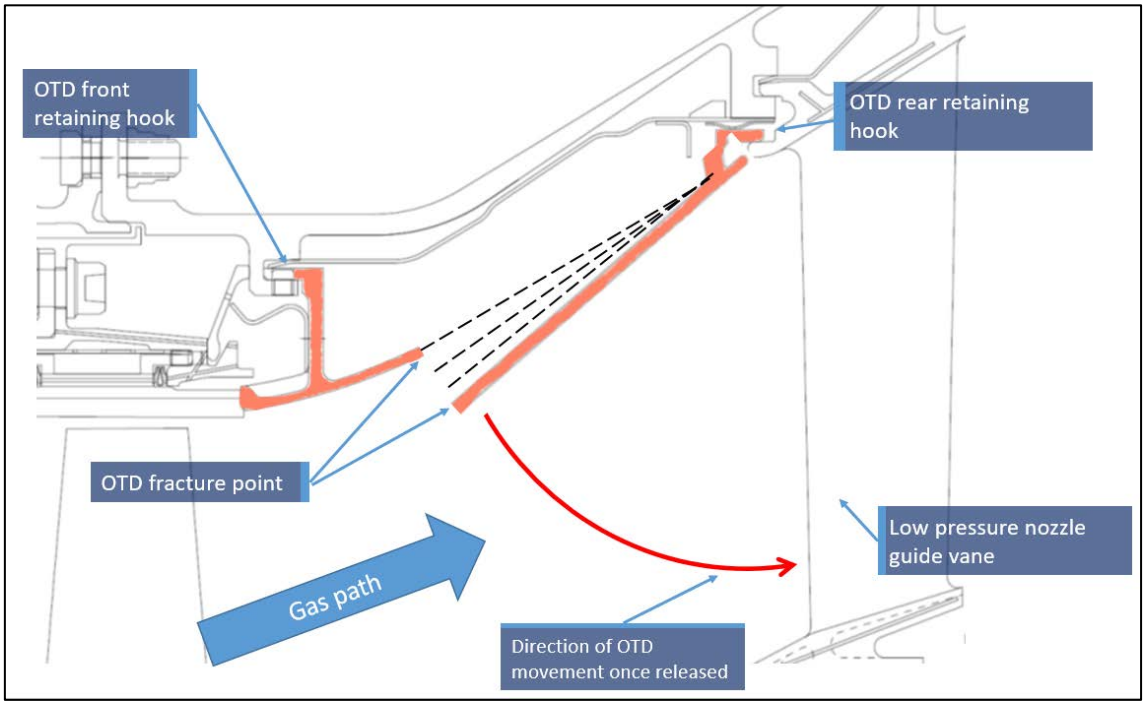
The flight crew handled the engine malfunction in accordance with the non-normal checklist, reducing the engine's thrust to idle, and safely diverting and landing the aircraft at the closest suitable location. Recognising that the crew's response to the elevated temperature shortly after take-off was in accordance with the electronic centralised aircraft monitoring procedure, this occurrence highlights that significantly abnormal indications are often symptomatic of a developing problem. In such circumstances, crews should give serious consideration to returning and landing the aircraft rather than continuing with the flight.

Engine failure analysis

The engine manufacturer identified that the outer transition duct (OTD) distorted over a period of time to a point where the axial length was reduced enough for the front hook to disengage. Once disengaged, the OTD partially moved into the gas path which elevated its temperature. The temperature and gas path loads fractured the OTD, and the rear section rotated and came to rest on the low pressure nozzle guide vanes. That created significant turbulent airflow within the engine which led to low pressure turbine blade failure, high vibration and the compressor stall/surge events (Figure 4).

There had been a total of 16 OTD liberations in service since 2015, with all but one occurring within the Advantage 70™ modified engine. The engine that did not have the modification did have the newer Advantage 70™ Talon IIB combustor fitted. Those figures represented over 5 per cent of all modified engines requiring unscheduled removal for repair. The modifications had an effect of increasing the outer duct gas path temperature. This increase in temperature led to the distortion and degradation of the OTD's, which ultimately led to the failures. It is likely that OTD liberations will continue in Advantage 70™ engines until modifications are made to rectify the issue. Refer to the *Safety action* section for the engine manufacturer's proactive safety action.

Figure 4: Plan view of the low pressure outer transition duct, front and rear attachment points, the fracture point, the engine gas path and the low pressure nozzle guide vane.



Source: Pratt & Whitney, modified by the ATSB

Findings

From the evidence available, the following findings are made with respect to the engine malfunction involving Airbus Industrie A330-323 registered 9M-MTM that occurred near Curtin Airfield, Western Australia, 18 January 2018. These findings should not be read as apportioning blame or liability to any particular organisation or individual.

Safety issues, or system problems, are highlighted in bold to emphasise their importance. A safety issue is an event or condition that increases safety risk and (a) can reasonably be regarded as having the potential to adversely affect the safety of future operations, and (b) is a characteristic of an organisation or a system, rather than a characteristic of a specific individual, or characteristic of an operating environment at a specific point in time.

Contributing factors

- While in the cruise the left engine experienced surging and increased vibration, which necessitated a power reduction and diversion for a precautionary landing.
- The engine malfunction was a result of a third stage outer transition duct segment liberation that partially blocked a stage of the low pressure turbine vane inlet, creating a rise in exhaust gas temperature, turbulent internal engine airflow, and consequent failure of the low pressure turbine blade/s.
- **There were a total of 16 engine malfunction events globally over a 4-year period attributed to modification of the Advantage 70™ engine. The modification increased the engine outer duct gas path temperature, which led to distortion and liberation of the outer transition duct segments. [Safety issue]**

Safety issues and actions

The safety issue identified during this investigation is listed in the Findings and Safety issues and actions sections of this report. The ATSB expects that all safety issues identified by the investigation should be addressed by the relevant organisation(s). In addressing those issues, the ATSB prefers to encourage relevant organisation(s) to proactively initiate safety action, rather than to issue formal safety recommendations or safety advisory notices.

Depending on the level of risk of the safety issue, the extent of corrective action taken by the relevant organisation, or the desirability of directing a broad safety message to the aviation industry, the ATSB may issue safety recommendations or safety advisory notices as part of the final report.

All of the directly involved parties were provided with a draft report and invited to provide submissions. As part of that process, each organisation was asked to communicate what safety actions, if any, they had carried out or were planning to carry out in relation to each safety issue relevant to their organisation.

The initial public version of these safety issues and actions are provided separately on the ATSB website to facilitate monitoring by interested parties. Where relevant the safety issues and actions will be updated on the ATSB website as information comes to hand.

Advantage 70 engine modification

Safety issue number: AO-2018-007-SI-01

Safety issue owner: Pratt & Whitney

Operation affected: High capacity air transport

Who it affects: All operators of Airbus A330 aircraft fitted with Pratt & Whitney PW4170 engines or Advantage 70™ engine modification.

Safety issue description

There were a total of 16 engine malfunction events globally over a 4-year period attributed to modification of the Advantage 70™ engine. The modification increased the engine outer duct gas path temperature, which led to distortion and liberation of the outer transition duct segments.

Proactive safety action

Action taken by: Pratt & Whitney

Action number: AO-2018-005-NSA-01

Action date: 21 March 2019

Action type: Proactive safety action

Action status: Released

Safety action taken

As a result of this occurrence and other similar incidents, the engine manufacturer Pratt & Whitney have advised the ATSB that they are taking the following proactive safety actions:

> P&W has processed an engineering change that revises OTD material with higher temperature capability. The redesigned hardware will be available from November 2019 and will be recommended for incorporation when the LPT [Low Pressure Turbine] module is disassembled at a minimum.
>
> …
>
> All engines are planned to incorporate redesigned OTDs at the next shop visit when a major engine flange is separated for the purposes of performing maintenance regardless of planned LPT maintenance. This interval is approximately 3000 cycles on average, but can vary depending on the specifics of each carriers' operating characteristics. This recommendation will be made with P&W

> Service Bulletin numbered PW4G-100-A72-261, which is pending release at this time.
> …
> New production PW4000 100" Advantage70 engines are no longer being produced. At overhaul, engines that are re-built prior to November 2019 will not receive the redesigned OTD. However, every engine shop visit prior to November 2019 where the LPT is disassembled will be recommended for installation of a full set of non-engine run, current design OTDs. This practice will provide a benefit to the fleet by removing OTDs that were potentially exposed to elevated temperatures.

ATSB comment

The ATSB welcomes the proactive safety action taken by Pratt & Whitney to develop an improved outer transition duct. However, the ATSB believes that Service Bulletin PW4G-100-A72-261 should hold a mandatory compliance status due to the significant number of OTD failures in a relatively short space of time. This will also ensure a fleet-wide compliance with the service bulletin. Additionally, as the installation of the redesigned components is at the operators' cost, this has the potential to hamper incorporation of the improved components.

As a result, the ATSB issues the following safety recommendation.

ATSB safety recommendation to Pratt & Whitney

Action number: AO-2018-007-SR-021

Action Status: Released

The ATSB recommends that Pratt & Whitney, together with the United States Federal Aviation Administration, take action to maximise incorporation of the redesigned outer transition duct as detailed in Service Bulletin PW4G-100-A72-261.

Safety issue number:	AO-2018-007-SI-01
Safety issue owner:	United States Federal Aviation Administration
Operation affected:	High capacity air transport
Who it affects:	All operators of Airbus A330 aircraft fitted with Pratt & Whitney PW4170 engines or Advantage 70™ engine modification.

Safety issue description

There were a total of 16 engine malfunction events globally over a 4-year period attributed to modification of the Advantage 70™ engine. The modification increased the engine outer duct gas path temperature, which led to distortion and liberation of the outer transition duct segments.

Response to the safety issue by the United States Federal Aviation Administration

At the time of writing, the Federal Aviation Administration advised that they are considering the implementation of an airworthiness directive to mandate the corrective action proposed by the engine manufacturer.

ATSB comment

The ATSB supports action that will increase fitment of the redesigned outer duct transition and therefore issues the following safety recommendation.

ATSB safety recommendation to the United States Federal Aviation Administration

Action number: AO-2018-007-SR-022

Action Status: Released

The ATSB recommends that the United States Federal Aviation Administration, together with Pratt & Whitney, take action to maximise incorporation of the redesigned outer transition duct as detailed in Service Bulletin PW4G-100-A72-261.

Additional safety action

Whether or not the ATSB identifies safety issues in the course of an investigation, relevant organisations may proactively initiate safety action in order to reduce their safety risk. The ATSB has been advised of the following proactive safety action in response to this occurrence.

Malaysia Airlines Berhad (MAB), the aircraft operator advised they have:

implemented scheduled borescope inspections that will identify precursors to an outer transition duct (OTD) failure. The MAB fleet will be upgraded in stages once the new designed OTD is introduced in November 2019.

General details

Occurrence details

Date and time:	18 January 2018 – 1550 CST	
Occurrence category:	Incident	
Primary occurrence type:	Engine vibration, surge, power reduction and diversion for precautionary landing	
Location:	37 km north of Curtin Airfield, Western Australia	
	Latitude: 17° 14.82’ S	Longitude: 123° 50.53’ E

Aircraft details

Manufacturer and model:	Airbus Industrie A330-323	
Registration:	9M-MTM	
Operator:	Malaysia Airlines Berhad	
Serial number:	1431	
Type of operation:	High capacity public transport	
Departure:	Sydney, New South Wales	
Destination:	Kuala Lumpur, Malaysia	
Persons on board:	Crew – 12	Passengers – 243
Injuries:	Crew – Nil	Passengers – Nil
Aircraft damage:	Minor damage	

Sources and submissions

Sources of information

The sources of information during the investigation included the:

- aircraft operator
- engine manufacturer
- National Transport Safety Board
- Federal Aviation Administration.

Submissions

Under Part 4, Division 2 (Investigation Reports), Section 26 of the *Transport Safety Investigation Act 2003* (the Act), the ATSB may provide a draft report, on a confidential basis, to any person whom the ATSB considers appropriate. Section 26 (1) (a) of the Act allows a person receiving a draft report to make submissions to the ATSB about the draft report.

A draft of this report was provided to Malaysia Airlines Berhad, National Transportation Safety Board, Pratt & Whitney, Bureau d'Enquêtes et d'Analyses, Airbus Industries and the Civil Aviation Safety Authority.

Submissions were received from Malaysia Airlines Berhad, National Transportation Safety Board, Pratt & Whitney, Bureau d'Enquêtes et d'Analyses, Airbus Industries and the Civil Aviation Safety Authority. The submissions were reviewed and where considered appropriate, the text of the report was amended accordingly.

Australian Transport Safety Bureau

The ATSB is an independent Commonwealth Government statutory agency. The ATSB is governed by a Commission and is entirely separate from transport regulators, policy makers and service providers. The ATSB's function is to improve safety and public confidence in the aviation, marine and rail modes of transport through excellence in: independent investigation of transport accidents and other safety occurrences; safety data recording, analysis and research; fostering safety awareness, knowledge and action.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia that fall within the ATSB's jurisdiction, as well as participating in overseas investigations involving Australian registered aircraft and ships. A primary concern is the safety of commercial transport, with particular regard to operations involving the travelling public.

The ATSB performs its functions in accordance with the provisions of the *Transport Safety Investigation Act 2003* and Regulations and, where applicable, relevant international agreements.

Purpose of safety investigations

The object of a safety investigation is to identify and reduce safety-related risk. ATSB investigations determine and communicate the factors related to the transport safety matter being investigated.

It is not a function of the ATSB to apportion blame or determine liability. At the same time, an investigation report must include factual material of sufficient weight to support the analysis and findings. At all times the ATSB endeavours to balance the use of material that could imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner.

Developing safety action

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues in the transport environment. The ATSB prefers to encourage the relevant organisation(s) to initiate proactive safety action that addresses safety issues. Nevertheless, the ATSB may use its power to make a formal safety recommendation either during or at the end of an investigation, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organisation.

When safety recommendations are issued, they focus on clearly describing the safety issue of concern, rather than providing instructions or opinions on a preferred method of corrective action. As with equivalent overseas organisations, the ATSB has no power to enforce the implementation of its recommendations. It is a matter for the body to which an ATSB recommendation is directed to assess the costs and benefits of any particular means of addressing a safety issue.

When the ATSB issues a safety recommendation to a person, organisation or agency, they must provide a written response within 90 days. That response must indicate whether they accept the recommendation, any reasons for not accepting part or all of the recommendation, and details of any proposed safety action to give effect to the recommendation.

The ATSB can also issue safety advisory notices suggesting that an organisation or an industry sector consider a safety issue and take action where it believes it appropriate. There is no requirement for a formal response to an advisory notice, although the ATSB will publish any response it receives.

Terminology used in this report

Occurrence: accident or incident.

Safety factor: an event or condition that increases safety risk. In other words, it is something that, if it occurred in the future, would increase the likelihood of an occurrence, and/or the severity of the adverse consequences associated with an occurrence. Safety factors include the occurrence events (e.g. engine failure, signal passed at danger, grounding), individual actions (e.g. errors and violations), local conditions, current risk controls and organisational influences.

Contributing factor: a factor that, had it not occurred or existed at the time of an occurrence, then either:

(a) the occurrence would probably not have occurred; or

(b) the adverse consequences associated with the occurrence would probably not have occurred or have been as serious, or

(c) another contributing factor would probably not have occurred or existed.

Other factors that increased risk: a safety factor identified during an occurrence investigation, which did not meet the definition of contributing factor but was still considered to be important to communicate in an investigation report in the interest of improved transport safety.

Other findings: any finding, other than that associated with safety factors, considered important to include in an investigation report. Such findings may resolve ambiguity or controversy, describe possible scenarios or safety factors when firm safety factor findings were not able to be made, or note events or conditions which ‘saved the day’ or played an important role in reducing the risk associated with an occurrence.