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ATSB TRANSPORT SAFETY REPORT
Aviation Occurrence Investigation AO-2011-034
Final

Engine oil leaks VH-OQG and VH-OQC en route Singapore to London, United Kingdom 24 February and 3 November 2011

Abstract

On 24 February 2011 and 3 November 2011 respectively, two different Airbus A380-842 (A380) aircraft were being operated by Qantas Airlines on scheduled passenger services from Singapore to London, United Kingdom.

About 8 hours into the flight on 24 February 2011, the flight crew detected a reduction in the indicated oil tank quantity for the No 3 engine. The crew reduced the thrust on the affected engine to idle and continued to the planned destination. Maintenance personnel found that one of the engine's external oil feed pipes was finger tight and had leaked. This was the fourth event involving similar in-flight oil loss from engines installed on the operator's fleet of A380 aircraft.

Examination and testing by the engine manufacturer found that the oil leaks were the result of a loss of clamping force on the oil feed pipe connection at the engine casing. Potential factors in the loss of clamping force were identified and were subject to ongoing engineering analysis. In the interim, the aircraft operator checked the engine oil feed pipes every five flight cycles, then every 20 cycles for evidence of oil leakage.

On 3 November 2011, a different aircraft was about 3 hours into the flight when the flight crew received a low oil quantity advisory for the No 4 engine. Forty minutes later, the crew received a low oil pressure warning from that engine. The crew shut down the engine and diverted the aircraft to Dubai, United Arab Emirates. Maintenance personnel found that one of the engine's oil feed pipes had leaked in the same location as the earlier A380 engine oil loss events.

By the time the November event occurred, there had been 15 engine oil leaks across the A380 fleet worldwide. The engine manufacturer conducted an ongoing investigation into the oil leaks and at the time of writing this report had identified high pipe deflection loads as a significant factor. Subsequent action by the engine manufacturer included modification of the oil pipe clipping arrangement and revised securing methods for the pipe connection and deflector assembly. In addition, trend monitoring of engine oil consumption was enhanced and work continued to develop a new oil pipe design.

FACTUAL INFORMATION

Background

Following a series of incidents involving the in-flight loss of engine oil from engines installed on Airbus A380 aircraft that were operated by Qantas Airlines, the Australian Transport Safety Bureau (ATSB) initiated a short investigation into the third occurrence (see ATSB investigation number AO-2011-026, available at www.atsb.gov.au). In response to a fourth event

on 24 February 2011, the ATSB commenced this investigation to further review the factors involved.

During the preparation of this investigation report, another incident occurred on 3 November 2011, which resulted in a commanded shutdown of the engine and aircraft diversion. The examination of the 3 November event was incorporated into this investigation.

Sequence of events

On 24 February 2011, an Airbus A380-842 (A380) aircraft, registered VH-OQG (OQG) was being operated on a scheduled passenger service from Singapore to London, United Kingdom. On board the aircraft were 396 passengers and 26 crew.

At 0430 Universal Coordinated Time (UTC) the aircraft was near Ashgabat, Turkmenistan and about 8 hours into the planned 13.5 hour flight. The flight crew detected that the No 3 engine oil tank quantity had reduced to 4.9 quarts (qt)[1] (4.6 L).[2]

By 0441, the indicated oil tank quantity had decreased to 4.2 qt (4 L). The flight crew used the aircraft's satellite telephone to liaise with the operator's maintenance watch[3] and the A380 fleet captain. After that liaison, the flight crew reduced thrust on the No 3 engine to idle and continued to the planned destination.

At 0450, the indicated oil tank quantity had stabilised and remained at 4.2 qt (4 L) for the remainder of the cruise. Shortly after commencing descent into Heathrow Airport, London the indicated oil tank quantity slowly decreased to 0.7 qt (0.6 L).

The flight crew configured the aircraft for the final approach/landing and moved the engine thrust levers to the CLIMB detent. Soon afterwards, the ECAM[4] displayed an amber ENG 3 OIL PRESS LO warning. The crew responded to the ECAM and returned the thrust lever for the No 3 engine to IDLE, landing the aircraft in that configuration.

The flight crew reported that the ECAM displayed a red ENG 3 OIL PRESS LO warning as the aircraft was vacating the runway. The warning self cleared but recurred several more times. The crew shut down the engine as they were taxying to the passenger terminal.

Maintenance personnel found that oil had leaked from the external oil feed pipe where it connected to the high-pressure/intermediate-pressure (HP/IP) turbine bearing support casing. The long-reach union nut connector was found to be 'finger tight'. Maintenance personnel replaced the oil feed pipe, tested engine operation and returned the aircraft to service.

Aircraft information

Powering each of the operator's A380 aircraft were four Rolls-Royce plc Trent 972-84 (Trent 900) engines. Those engines are triple-shaft, high bypass ratio turbofans with low pressure, intermediate pressure and high pressure compressors that are driven by turbines through co-axial shafts and supported by lubricated bearings. The external HP/IP bearing oil feed pipe supplied engine oil to lubricate and cool the HP/IP bearing pack. The turbine bearing support casing also had connections for two oil scavenge and two air/oil vent pipes.

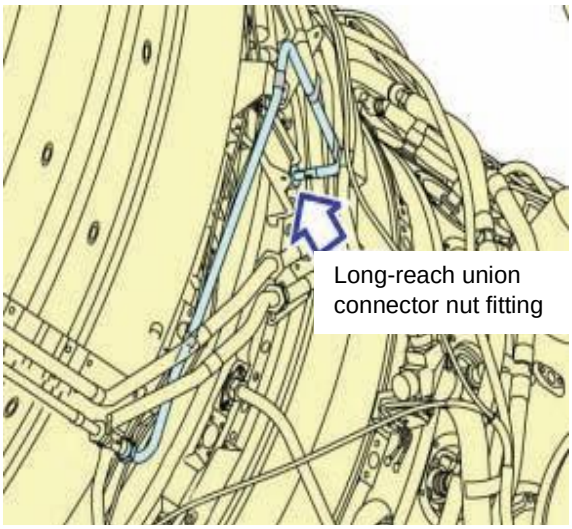
1 The quantity measurements used by the engine manufacturer, US quarts, are referred to in this report (1 US quart is equivalent to 0.946 L).

2 The maximum capacity of the engine's oil tank was 18.4 qt (17.4 L).

3 Staffed by maintenance personnel who can provide technical assistance and advice to flight crews.

4 Electronic Centralised Aircraft Monitor, which displays aircraft system information and indicates required flight crew actions in most normal, abnormal and emergency situations.

Figure 1: External HP/IP oil feed pipe connection



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Engine health monitoring

The engine manufacturer monitored various operational parameters from its engines that were installed on the A380 airframes. That included real-time monitoring of individual oil tank quantity, which augmented the routine monitoring of engine parameters by flight crews and operators. In addition, the uplift of engine oil was being analysed to identify abnormal trends in oil consumption.

In-service history of HP/IP oil feed pipes

In December 2010, all of the engines fitted to the operator's fleet of A380 aircraft were subject to a number of inspections as a result of an engine failure that occurred on another aircraft within the fleet (see ATSB investigation number AO-2010-089, also available at www.atsb.gov.au). As part of the safety action in response to that accident, an internal inspection of the HP/IP turbine area was mandated on Trent 900 engines via borescope[5]. To provide access to that area, the external HP/IP oil feed pipe was removed from each engine, the inspection was conducted and the pipe was replaced.

On 20 January 2011, maintenance personnel detected engine oil leaking from the external HP/IP oil feed pipe connection on one of the operator's other A380s. The operator consulted the engine manufacturer and instigated a one-off, fleet-wide torque integrity check of the HP/IP oil feed connections on the engines of its A380 aircraft. This check involved the removal and reinstallation of the HP/IP oil feed pipe. Following this fleet-wide check, during January and February that year there were three additional oil leaks in the operator's aircraft, including this occurrence.

After the fourth oil leak, the operator implemented a recurring inspection program that examined the long-reach union connection area for traces of oil wetting/staining. Those inspections were initially conducted every five flight cycles between February and September 2011, then every 20 flight cycles.

Worldwide, there were a total of ten reported occurrences of Trent-powered A380 external HP/IP oil feed pipe leaks between August 2010 and March 2011. Another four leaks were reported between August and October 2011. Each of those leaks was from the long-reach union nut connector, where the external oil feed pipe connected to the HP/IP bearing support casing.

Of the first ten reported oil leaks, nine involved pipes that had been removed/reinstalled since the original build of the affected engine. Of the most recent four reported oil leaks, only one involved a pipe that had been removed/reinstalled since the original build of the affected engine.

The engine manufacturer performed an analysis of the oil leak history. That analysis indicated that the likelihood of an oil leak decreased with the number of flight cycles.

An additional leak occurred to one of the operator's A380 aircraft in November 2011 and is discussed in the section titled *Later developments.*

Examination of the external HP/IP oil feed pipe from OQG

The external HP/IP oil feed pipe from OQG was released to the engine manufacturer for examination and testing (Figure 2). The long-reach union nut connector showed no evidence of thread degradation or material distortion. There

5 A slender optical periscope that usually incorporates illumination and can be inserted into narrow apertures to inspect the interior of machinery.

was, however, fine radial scoring 'gramophone' marking of the pipe's ferrule surface, along with surface pitting/bedding marks. The gramophone marks on the ferrule's surface finish did not conform to the engineering specification.

Figure 2: External HP/IP oil feed pipe

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Examination and testing of external HP/IP oil feed pipes

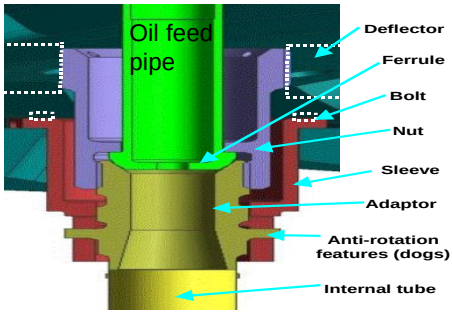
The engine manufacturer also examined the external HP/IP oil feed pipes from a number of other Trent 900 engines that sustained similar oil leaks and oil feed pipes that were returned from service overhaul activity.

Of those, and similar to the oil feed pipe from OQG, the pipes from seven engines that sustained oil leaks between August 2010 and March 2011 also had non-compliant gramophone scoring to the surface finish of the ferrule. Those pipes were traced to two production batches, and action was taken to identify the affected pipes and remove these from stores and new engines. Pipes were not removed from in-service engines unless there was an increased risk of leakage due to disturbance of the connector fitting. Where pipes were left in service, they were subject to enhanced monitoring.

The ferrule surface finish for pipes from the four reported events between August and October 2011 complied with the engineering specifications of the engine manufacturer.

In analysing the design of the pipe connection (Figure 3), the engine manufacturer found that the anti-rotation features (dogs) could allow the adaptor to move during the tightening of the nut. That could reduce the effective torque on the nut and consequent clamping force on the connection.

Figure 3: Cross-section of the external HP/IP oil feed pipe connection to the engine



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The engine manufacturer also determined that the reinstallation of oil feed pipes could result in an increased risk of oil leaks due to contamination on the threads of the long reach connector fitting.

At the time of writing this report, the effects of the flexing and deflection of the external HP/IP oil feed pipe during engine operation due to a combination of thermal loads was being investigated by the engine manufacturer. Preliminary testing of an instrumented pipe that was mounted on a test-cell engine indicated the pipe was subject to higher than anticipated in-service loads.

Thermal effects on the pipe connection were also assessed, but were not considered to have any significant effect on the security of the connection.

Later developments

On 3 November 2011, another Qantas Airlines A380, registered VH-OQC (OQC) was being operated on a scheduled passenger service from Singapore to London, United Kingdom.

About 3 hours after departure, the flight crew received an advisory indication of a low oil quantity on the engine warning display. The oil quantity continued to reduce and, about 30 minutes later, the crew commenced descent from flight level[6] 340 (FL340). When the crew levelled off at FL280, the ECAM displayed an ENG 4 OIL PRESS LO warning. The crew shut down

6 The aircraft's altitude referenced to the International Standard Atmosphere, expressed in hundreds of feet.

the engine and diverted the aircraft to Dubai, United Arab Emirates.

Maintenance personnel found oil had leaked from the external oil feed pipe on the No 4 engine where it connected to the HP/IP turbine bearing support casing. Maintenance personnel replaced the oil feed pipe, tested engine operation and returned the aircraft to service.

This engine had sustained a similar oil leak on 15 February 2011. The operator reported that since that time, the engine had been operated for 286 cycles and 3,110 flight hours.

As of 1 December 2011, there had been a total of 16 reported oil leakage events involving the external HP/IP oil feed pipe connection on Trent engines across the worldwide A380 fleet. In three of those events, the engine thrust was reduced to idle, and in one of those events the engine was shut down in flight.

At the time of writing this report, the engine manufacturer had identified that clipping the external HP/IP oil feed pipe to an adjacent hot air tube and a rigid support bracket was contributing to excessive deflection loads on the oil feed pipe connection. Those loads were also increasing sensitivity of the pipe to secondary factors, such as manufacturing and build variability.

ANALYSIS

The engine oil leaks sustained by the No 3 engine on OQG and the No 4 engine on OQC were part of a wider pattern of Trent 900 series engine oil leaks in A380 aircraft that were reported to the engine manufacturer between August 2010 and November 2011. Those oil leaks occurred at the external oil feed pipe connection to the high-pressure/intermediate-pressure turbine bearing support casing.

Oil leaked when the seal between the external HP/IP oil feed pipe ferrule and adaptor was compromised by the connector nut loosening and reducing the clamping force between the two parts. Loosening of the connector nut was initially associated with maintenance-related pipe disturbance and below-specification ferrule surface finish.

In response, the aircraft operator carried out torque integrity checks on the oil pipe connector nuts and increased its maintenance inspections of the affected area. The engine manufacturer removed the nonconforming oil pipes from the A380 fleet and enhanced its oil quantity monitoring methodology. However, after a period of 4 months, oil leaks started to occur again, indicating that there was an additional factor involved.

From ongoing analysis, the engine manufacturer identified higher-than-anticipated deflection loads on the external HP/IP oil feed pipe connection. The engine manufacturer indicated that was probably the common and significant factor in the loosening of the long-reach connector nut and the consequent oil leaks.

Mitigations by the aircraft operator and engine manufacturer have now reduced the occurrence and effect of in-flight oil leaks while a longer term solution is being developed.

FINDINGS

From the evidence available, the following findings are made with respect to the engine oil leaks involving Airbus A380 aircraft that occurred on 24 February 2011 and 3 November 2011 and involved Airbus A380-842 aircraft, registered VH-OQG and VH-OQC respectively, both fitted with Rolls-Royce plc Trent engines. They should not be read as apportioning blame or liability to any particular organisation or individual.

Contributing safety factors

- The A380 engine oil leaks occurred at the external oil feed pipe connector to the high-pressure/intermediate-pressure turbine bearing support casing because the connection became loose, reducing the clamping force and compromising the seal between those components.
- The oil feed pipe connection to the high-pressure/intermediate-pressure turbine bearing support casing was subject to deflection loads that were higher than anticipated by the engine manufacturer and the effects of those loads were not required to be considered during the engine design and testing process.

SAFETY ACTION

Any safety issues identified during the conduct of an investigation are listed in the Findings and Safety Actions sections of the report. However, whereas an investigation may not identify any particular safety issues, relevant organisation(s) may proactively initiate safety action in order to further reduce their safety risk.

Although no organisational or systemic issues were identified during this investigation, the following proactive safety action was advised by Rolls-Royce plc, Qantas Airlines and Airbus in response to the oil leaks.

Action taken by Rolls-Royce plc

During the course of the investigation, a root cause analysis was carried out incorporating all of the reported oil leaks. During that process the below-specification high-pressure/intermediate-pressure (HP/IP) oil feed pipe ferrule finish was identified and the affected batches removed from service.

At the time of publishing this report, the engine manufacturer was in the process of modifying the way that the external HP/IP oil feed pipe was secured to adjacent pipes. In addition, the locking arrangement for the long-reach union nut connector/deflector assembly was being revised and oil tank quantity trends were being monitored for early identification of oil leaks.

Action taken by Qantas Airlines

Qantas Airlines inspected the long-reach union nut connectors for traces of oil wetting/staining at regular intervals.

Action taken by Airbus

In March 2011, Airbus issued an Operators Information Telex that informed all operators of the A380 that were fitted with Trent 900 engines of the pipe inspection and other short-term measures.

SOURCES AND SUBMISSIONS

Sources of Information

The sources of information during the investigation included the:

- aircraft operator
- engine manufacturer.

Submissions

Under Part 4, Division 2 (Investigation Reports), Section 26 of the *Transport Safety Investigation Act 2003* (the Act), the Australian Transport Safety Bureau (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 Qantas Airlines, Rolls-Royce plc, Airbus, the Civil Aviation Safety Authority, the United Kingdom Air Accidents Investigation Branch and the Bureau d'Enquêtes et d'Analyses (BEA).

Submissions were received from Rolls-Royce plc, the BEA and Qantas Airlines. The submissions were reviewed and where considered appropriate, the text of the report was amended accordingly.