Australian Government
Civil Aviation Safety Authority

AIRWORTHINESS BULLETIN

AWB 72-003 Issue 2 – 27 September 2016

Rolls Royce (Allison) 250 Series Engine Outer Combustion Case (OCC) Failures

1. Applicability

All Rolls Royce (Allison) 250 Series engines with Outer Combustion Cases (OCC) installed in all versions of model C28, C30, C40 engines installed in, but not limited to: Eurocopter AS350, Bell 230, 206, 407 and Sikorsky S76 series helicopters.

2. Purpose

Bring to the attention of operators and maintainers factors to be considered when operating and maintaining the affected engines, based on the findings of the Australian Transport Safety Bureau (ATSB) Final Report AO-2008-067, the Transport Safety Board of Canada (TSB) Investigation Report A12P0134 and recent CASA defect reports describing extensive OCC duct cracking in the 'armpit' area, in order to prevent OCC duct rupture and loss of power.

3. Background

This AWB was initially raised in conjunction with the ATSB during the initial stages of investigation AO-2008-067 into the Talbot Bay occurrence, in order to urgently advise operators and maintainers of an unusual and catastrophic rupture failure of a Rolls Royce (Allison) 250 C47 engine OCC Part Number (P/N) 23030911 installed in a Bell 407 (VH-NSH), pending the ATSB Final Report.

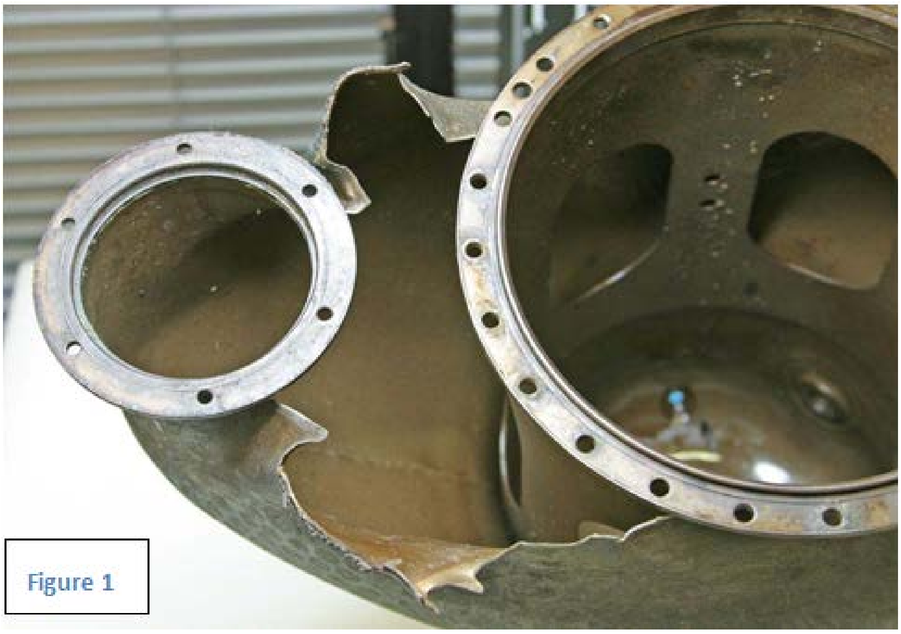
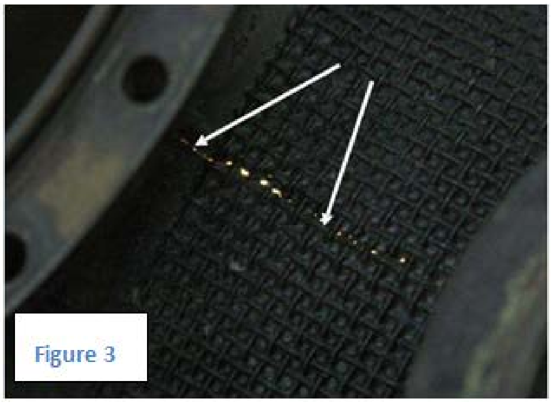


Figure 1. RR 250 C47B OCC Rupture failure (RH Side) Source: ATSB AO-2008-067.

The OCC rupture failure at Talbot Bay, Australia, occurred immediately after take-off from a ship's heli-deck, and resulted in complete engine power loss. The helicopter ditched in the sea and turned over with passengers trapped inside the cabin.

The ATSB final report confirms that that the rupture failure originated from somewhere either under or adjacent to the reinforced area of the OCC 'armpit' area on the inside bend of the duct, close to the welded seam. See Figures 2&3, which show cracking in the 'armpit' area of the other duct of the same ruptured OCC installed on the occurrence engine.



Figures 2 and 3 Depict RR 250 C47B OCC (LH side) showing two views of cracking in the same OCC duct shown in Figure 1. Fig 2 shows external indications, Figure 3 the same crack viewed with a strong light placed inside the OCC. (Source: ATSB AO-2008-067)

A metallurgical examination of this combustion case found that the rupture failure occurred as a result of high cycle fatigue cracking, due to alternating pressure cycles in the combustion section of the engine as part of normal engine operation, and had been growing for some time. The cracking had started from a point immediately beside the brazed wire patch on the left armpit area and had extended for about 59 mm before rapid OCC failure. Source: ATSB AO-2008-067

Using data from several National Airworthiness Authorities defect databases, including CASA, the ATSB identified 23 similar armpit cracking occurrences between1993 and 2008. In all these cases, cracking was found during routine a maintenance inspection, unlike the Talbot Bay incident (VH-NSH), and similar incidents in Canada (C-GHJT), and Papua New Guinea (PNG) where a sudden total engine power loss was experienced during take-off, following catastrophic rupture of the OCC. (Figures 4&5)


Figure 4

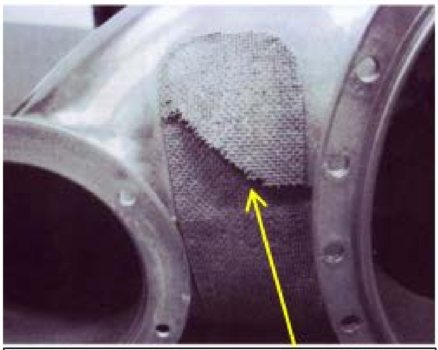


Figure 5, (above) The OCC had ruptured through wire mesh patch

On 28 July 2008, A Bell 206 L4 helicopter was departing the remote village of Oruribo, approximately 150 km East of Port Moresby, Papua New Guinea (PNG). Shortly after lift-off and while entering transition to climb, the pilot heard the engine wind down with immediate loss of power, and prepared to make a run-on autorotation landing on a grassy patch of open ground on a river bank. The helicopter rolled over during the landing due to the slope of the landing area. Several of the passengers from the village sustained injuries and the helicopter was deemed a total loss. It was later established that the outer combustion case (OCC) had ruptured. Figure 4 & 5 (above).

The ATSB report AO-2008-067 includes an investigation into another OCC duct which was removed upon discovering a crack which ran along one edge of the weld line. (Figure 6).

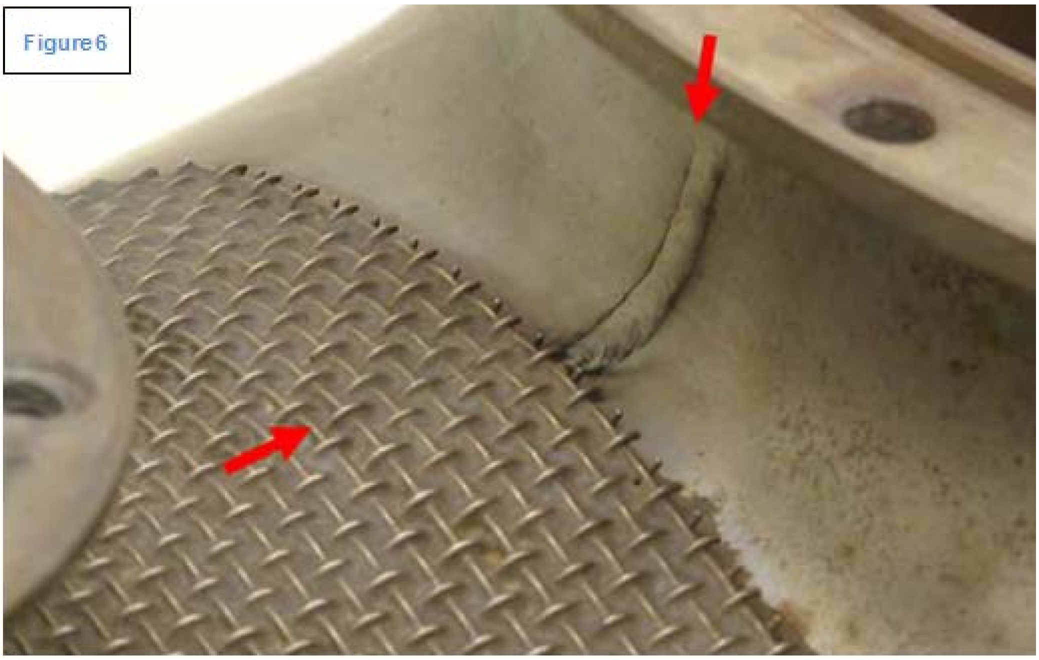


Figure 6

Figure 6 - Sikorski S-76-A / Rolls Royce (Allison) 250 C47B.

"No1 engine outer combustion case cracked for approximately 12.7mm (0.5in) at weld line. Crack extends 6.35mm to 12.7mm (0.25in to 0.5in) into reinforced wire patch area. Found during inspection IAW AWB 72-003." (Sic).

The OCC currently does not have a retirement life and is an 'On Condition' item. The continuing airworthiness of the OCC depends entirely on continually inspecting the OCC to detect cracking before the OCC fails in service. (See AWB 02-001 'On Condition Maintenance'). Unfortunately, the factors which determine when cracks initiate, and the rate at which cracks develop to the point of combustion case leakage, power loss and catastrophic failure are difficult to determine, but appear mainly related to pressure cycles, such as starting. Any cracked OCC should be immediately removed from service.

In 2014, the Transport Safety Board of Canada (TSB) released Investigation Report A12P0134, which describes engine power loss in a Sikorsky S-76 A (C-GHJT) and ditching following an OCC rupture incident which occurred in British Columbia.

"The helicopter was on short final to land when there was a loud bang, the engine-out warning horn sounded, and the No. 2 engine (Allison/Rolls Royce 250-C30S) lost power. The OCC had suffered an in-flight rupture. The OCC was sent to the TSB Laboratory in Ottawa, Ontario, where a more in-depth examination found the following:

- *This OCC had undergone repairs (replacement of wire mesh patches) in the armpit areas.*
- *The rupture of the OCC occurred in the left-side armpit; it was the result of an overstress extension of a pre-existing fatigue crack when this crack had grown to a critical length.*
- *The main fatigue crack was formed by merging small cracks initiating from numerous separate points along the inside and outside surfaces of the horizontal butt weld and surrounding areas.*
- *Two other small cracks were observed in the left-side armpit. One fatigue crack was located at the circumferential seam weld under the gas producer attachment flange. This crack eventually merged with the main fatigue crack via an overstress crack. The other crack was parallel to the main crack on the other side of the horizontal butt weld.*
- *Two short cracks were also found in the right-side armpit region.*
- *The fatigue cracking was driven by pressure cycles (engine start-stop cycles) in the OCC as part of normal engine operation. The fatigue cracks were located under the reinforcing wire mesh patches/ which made the cracks difficult to detect at the initial formation stage.*
- *At the main fatigue crack location/ the OCC skin was thinner than elsewhere, and its thickness was below the minimum specified value for the skin wall thickness. It is likely that the thin areas facilitated fatigue cracking.*

During the course of the TSB investigation, the Canadian operator performed one-time inspections of its fleet to assess the condition of its helicopters equipped with Rolls Royce (Allison) 250-series engines. These included 3 Bell 206L1 helicopters equipped with single 250-C28 or C30 engines, and 5 Sikorsky S-76A helicopters with 250-C30S engines. The company performed unscheduled Leak-Tek inspections on these helicopters and recorded the findings.

A total of 6 engines were found to have cracked OCCs with a mean time between failures (since last 2000-hour inspection) of about 1000 hours. The operator replaced all defective OCCs and returned the helicopters to service. It also instituted a mandatory inspection of OCCs using the Leak-Tek method every 150 hours for the S-76A model helicopters/ and every 100 hours for the Bell 206L; this correlates with the scheduled compressor inspection times. Since the new inspection cycle was initiated, a 150-hour inspection found 1 more cracked OCC (P/N: 6899237, modification 23030910). This OCC was on a 250-C30S engine in a Sikorsky S-76A.

The cracks in the OCC likely started because thin metal was exposed to pressure and heat cycles. The thinning of the OCC skin also facilitated the propagation of fatigue cracks. The manufacturer-recommended inspections and period between inspections of the engine OCC did not provide an adequate means of detecting cracks. As demonstrated in this occurrence, undetected cracks can propagate and cause OCCs to fail in flight, thereby risking the safe termination of flight. With limited inspection standards and no life limits/ there is an ongoing risk of OCC failures.

Safety Action taken by Rolls-Royce has been to amend the inspection cycle instructions for the M250-C30-series engine to require, in addition to the 100 hour visual inspection for cracks, a Leak-Tek check or fluorescent penetrant inspection (FPI) every 150 hours. The inspection descriptions have been changed accordingly. Additionally, a new design for the outer combustion case with reinforced armpits was released in December of 2013".

(Adapted from: Transport Safety Board of Canada Investigation Report A12P0134)

Failures in the region of the 'armpit' reinforcing area have been occurring for many years. In 1984, the engine manufacturer issued Commercial Engine Bulletin (CEB) CEB A-72-2113 and CEB A72-3115. These CEBs provided inspection details and reinforcement patch procedures for OCCs of 250-series engines. In 1986, the Federal Aviation Administration (FAA) issued Airworthiness Directive (AD) AD 85-25-07 R1, which is reflected in CASA AD/AL 250/59 Amdt 3.

Essentially, the AD mandated frequent inspections until modified with a re-enforcement patch installed on the armpit area of the OCC diffuser scroll elbow. Any OCCs modified in this manner were re-identified as P/N 23030910 and were to be inspected using the inspection techniques described in CEB A-72-2113/CEB A-72-3115 which the TSB found to be inadequate.

It has been suggested to CASA that loss of power and increasing turbine outlet temperature (TOT) may be useful indicators to detect the initial stages of OCC cracking between inspections. The following defect report might even seem to support this notion. (Figure 6)

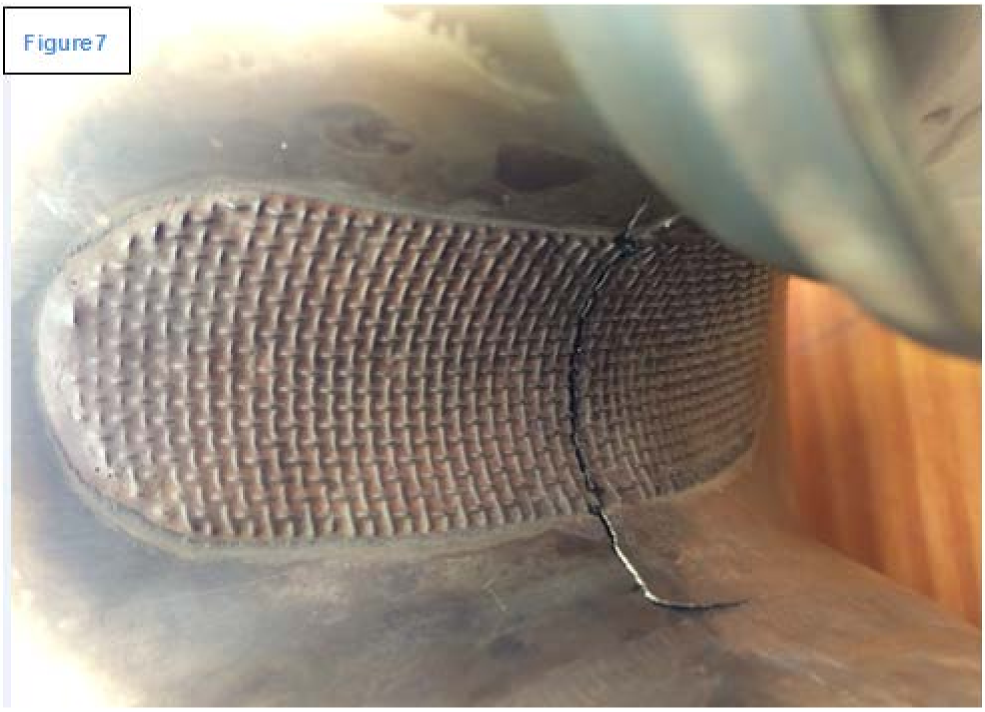


Figure 7 - AS355 F1; RR 250-C20F

SDR text: "High TOT noticed during cruise. Power check was c/o and failed to make power. During investigation into power loss it was discovered that the combustion can was cracked". (Sic)

However, the manufacturer, Rolls Royce, has estimated that the power loss as a result of a typical 51 mm long crack as shown in Figures 2 & 3 would be about 1%, which the manufacturer considers would probably not be detected during the daily power assurance checks. *(Source: ATSB Report AO-2008-067)*

Although larger size cracks can be expected to result in increasingly significant power degradation, it is likely that by the time that power loss has been observed, that OCC rupture and total loss of power may be imminent. Unfortunately, the total hours in service, and the number of engine start and take-off cycles at which OCC fatigue cracks are typically first detected, and the rate at which cracks grow from the point when they are first detected to the point of catastrophic failure has not been determined.

Summary:

Based on the ATSB and TSB reports, key factors in OCC duct cracking and catastrophic rupture failures appear to be impacted by:

- Undetected cracks and an undetermined rate of fatigue crack propagation.
- Number of engine starts (pressure cycles).
- Number of take-offs / landings / practice auto-rotations, etc. (pressure cycles).
- OCC skins eroded to below the minimum serviceable limit.
- Inadequate OCC duct repairs.
- Lack of finite OCC retirement life.

4. Recommendations

In order to detect OCC duct cracking in all Rolls Royce (Allison) 250 Series engines at the earliest opportunity, and thus help prevent catastrophic OCC rupture and loss of power, CASA urgently recommends that in addition to the inspection techniques at the frequencies required by the engine manufacturer, that operators and maintainers:

- Conduct critical inspections on any used and/or repaired OCC before installation and consider rejecting any OCC which has not been repaired in accordance with approved data, including evidence of anomalous welding, peening, and/or reduction in skin thickness, etc.
- Consider implementing the manufacturers OCC inspections for the M250-C30-series engine which requires a Leak-Tek check or fluorescent penetrant inspection (FPI) for all Rolls Royce (Allison) 250 Series OCCs, particularly for suspected high time in service OCCs.
- Carry out vigilant periodic visual inspections, including required visual inspections using a 10X magnifying glass, bright light, mirror etc., and more frequently than 100 flight hours for suspected high time in service OCCs.
- Not rely on loss of power and increasing turbine outlet temperature (TOT) to detect the initial stages of OCC cracking.
- Include an inspection of the OCC for cracking when troubleshooting loss of power and increased TOT.
- Consider recording OCC operating history, such as hours in service, number of starts, torque events such as take-offs, training auto rotations with power recovery, environment particularly marine operations, and repairs.
- Remove any cracked OCC from service.

5. Reporting

All instances of cracked OCCs should be reported to CASA via the SDR system. This includes cracked OCCs discovered during operation as well as overhaul, which may not have been previously reported. Providing information such as number of starts, take-offs, type of operation and environment, such as marine operations, repair history, and hours in service should further assist the manufacturer in developing a comprehensive response to the problem.

6. Enquiries

Enquiries with regard to the content of this Airworthiness Bulletin should be made via the direct link email address:

AirworthinessBulletin@casa.gov.au