Australian Government

Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY REPORT

Aviation Occurrence Investigation AO-2008-067

Final

Total power loss
Talbot Bay, Western Australia
25 September 2008
VH-NSH
Bell Helicopter Co 407

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Abstract

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Despite two of the occupants, one of whom was unconscious, requiring assistance to exit the partially-submerged aircraft, all of the occupants survived the accident. Sometime later, the helicopter sank.

The investigation found that there had been a 'burst' failure of the engine outer combustion case as a result of ongoing high-cycle fatigue cracking during normal engine operation.

As a result of this occurrence, the engine manufacturer conducted a computerised analysis of the design of the combustion case in an effort to more effectively address the relevant areas of high stress. In response to this, and a similar failure in another helicopter 2 weeks earlier, the Civil Aviation Safety Authority released an Airworthiness Bulletin highlighting the circumstances of the occurrence to Australian helicopter operators.

The operator of the helicopter has also advised its intention to change a number of the operational procedures employed during shipborne helicopter operations to better ensure passenger safety.

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THE AUSTRALIAN TRANSPORT SAFETY BUREAU

The Australian Transport Safety Bureau (ATSB) is an independent Commonwealth Government statutory agency. The Bureau 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 Commonwealth 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 fare-paying passenger operations.

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 safety factors related to the transport safety matter being investigated. The terms the ATSB uses to refer to key safety and risk concepts are set out in the next section: Terminology Used in this Report.

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 safety factor: a safety 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 safety factor would probably not have occurred or existed.

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

Other key finding: 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.

Safety issue: a safety factor that (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 operational environment at a specific point in time.

Risk level: The ATSB's assessment of the risk level associated with a safety issue is noted in the Findings section of the investigation report. It reflects the risk level as it existed at the time of the occurrence. That risk level may subsequently have been reduced as a result of safety actions taken by individuals or organisations during the course of an investigation.

Safety issues are broadly classified in terms of their level of risk as follows:

- **Critical** safety issue: associated with an intolerable level of risk and generally leading to the immediate issue of a safety recommendation unless corrective safety action has already been taken.
- **Significant** safety issue: associated with a risk level regarded as acceptable only if it is kept as low as reasonably practicable. The ATSB may issue a safety recommendation or a safety advisory notice if it assesses that further safety action may be practicable.
- **Minor** safety issue: associated with a broadly acceptable level of risk, although the ATSB may sometimes issue a safety advisory notice.

Safety action: the steps taken or proposed to be taken by a person, organisation or agency in response to a safety issue.

FACTUAL INFORMATION

History of the flight

On 25 September 2008 at about 0825 Western Standard Time[1], Bell Helicopter Co 407 (Bell 407) helicopter, registered VH-NSH (NSH), with a pilot and six passengers, lifted off from the helideck of the cruise ship *True North* on a 45-minute tourist flight (Figure 1). At the time, the ship was at anchor in Talbot Bay, Western Australia. As the pilot moved the helicopter clear to the right of the ship in order to transition to forward flight, and at a height of about 10 m above the surface of the sea, a loud bang was heard by the pilot, followed by a total power loss and a number of cockpit indications.

The helicopter rapidly descended to the water, impacting in a nose-low, right side-down attitude. The cockpit and cabin quickly filled with water and the helicopter rolled onto its side before rolling inverted. The helicopter floated for a time before sinking.

Figure 1: Departure from the cruise ship immediately prior to the power loss

A number of the ship's personnel entered the water and assisted the occupants of the helicopter to exit the aircraft (Figure 2). Of the occupants, two had been unable to free themselves from the cabin area, with one losing consciousness before being rescued.

1 The 24-hour clock is used in this report to describe the local time of day, Western Standard Time (WST), as particular events occurred. Western Standard Time was Coordinated Universal Time (UTC) + 8 hours.

Figure 2: Rescue of the occupants of the helicopter

Pilot information

The pilot was appropriately qualified for the flight and had logged a total of 6,050 hours flying experience, of which 5,960 hours were on helicopters. He had a total of 2,362 hours on the Bell 407.

The pilot held a valid current Class 1 medical certificate and had undergone a check flight on 1 February 2008, and a Biennial Flight Review on 8 November 2008.The pilot reported that he had completed helicopter underwater escape training (HUET).

Aircraft information

General

The helicopter had seating capacity for the pilot and six passengers, including one passenger in the front left seat. The helicopter had a current maintenance release that was issued on 19 July 2008.

An examination of the helicopter's Log Book Statement indicated that the airframe and engine were to be maintained in accordance with the manufacturer's requirements. The maintenance records indicated that the last maintenance carried out on the helicopter was a 300-hourly servicing in Kununurra, Western Australia between 17 and 19 July 2008.

The helicopter's all-up weight and centre of gravity were within the manufacturer's specified limits, and there was adequate fuel on board for the flight.

Helicopter details

Manufacturer	Bell Helicopter Co
Model	407
Serial number	53376
Registration	VH-NSH
Date of manufacture	August 1999
Certificate of registration issued	Issued to the present registration holder on 13 December 2005
Certificate of airworthiness	Issued 22 December 1999
Operational category	Aerial/Charter
Last maintenance release issued	19 July 2008 at 4,928.3 total time in service (TTIS), 4,823 cycles, 19,117 Retirement Index Numbers (RIN)[2]
Current maintenance release valid to	18 July 2009; 5,228.3 TTIS
Total airframe hours at the time of the occurrence	5,055.8 TTIS

Engine details

The engine was a Rolls Royce Corp model 250-C47B turboshaft[3] and had accumulated 5,055.8 hours since new. As at 19 July 2008, the engine had accumulated 4,923 cycles from new. [4]

The engine manufacturer's maintenance procedures for the continuing airworthiness of the 250-C47 series engine were laid down in the Operation and Maintenance Manual (OMM). Those procedures included periodic maintenance inspections, and detailed instructions on their completion.

2 For a number of years, Bell Helicopter Co has applied the RIN methodology to more accurately track cycle-lifed helicopter components. In that methodology, account is taken of the effect of cyclic and repetitive loading, such as; ground-air-ground events, external load lifts (for example external load operations and water bombing), and run-on landings.

3 A gas turbine (jet) engine that delivers power via a shaft, for example to power a helicopter.

4 No engine cycle data was available after 19 July 2008 as the relevant paperwork was lost during the occurrence.

The last maintenance on the engine was a 300-hourly maintenance inspection that was carried out in Kununurra 127.5 hours prior to the occurrence.

Compressor rinsing

The shipborne operation placed the helicopter in a known corrosive environment as defined by the engine manufacturer, requiring the routine water rinse of the engine compressor. The pilot reported that he performed a water rinse of the compressor at the end of each flying day.

The daily compressor rinse used desalinated sea water that was sourced from the ship's drinking water supply, mixed with a 2% solution of ZOK 27[5]. The operator indicated that the use of the 2% ZOK 27 solution was commenced as a precaution following the replacement of the engine's original outer combustion case due to corrosion problems.

The engine manufacturer recommended ZOK 27 among other solutions as suitable for use in the 250 engine type. However, the engine manufacturer indicated a preference for a further compressor rinse with clean water after the rinse with the ZOK 27 solution.

The engine manufacturer indicated that desalinated water was suitable for compressor rinses; however, the preference was for the use of de-ionized, distilled or de-mineralised water – if available.

Engine trend monitoring

The OMM[6] for the engine detailed a trend check analysis procedure that was 'strongly encouraged' for use by operators to monitor their engines' health. The trend check was designed to more effectively predict when preventative maintenance was required, and allowed operators to schedule some maintenance actions that were formerly unscheduled.

The trend checks were to be carried out during cruise flight, with the pilot recording engine and environmental parameters[7] on a 'trend check record' chart for later comparison with previously-recorded data. The operator carried out trend check analysis of the helicopter's engine and collated the collected data using a computerised data base that automatically 'trended' the engine.

The most recent trend data for the engine was for the period ending 28 July 2008, about 2 months prior to the occurrence. That check showed that the engine was operating well within the inter-stage turbine temperature (ITT) limit for a serviceable engine.

The operator stated that the trend check data for the period since that time was in the helicopter and was lost when the helicopter ditched.

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5 A product specifically designed to clean and de-carburise the inside of gas turbine engines. The manufacturer literature for ZOK 27 suggested that it contained a corrosion inhibiter and that, after rinses, 'Water rinse and dry out runs are not necessary unless recommended by the [relevant] engine manufacturer.'

6 Section 72-00-00, paragraph 14, page 68.

7 The recorded parameters included: pressure altitude, outside air temperature, gas producer RPM (N1), torque and measured gas temperature.

Outer combustion case

The relevant details for the outer combustion case (OCC) were as follows.

Manufacturer	Rolls Royce Corp
Part number	23030911-G
Serial number	33701
Date of manufacture	1989
Original engine fitted to	RR250-C30P; Serial number – CAE 895350[8]
Hours/cycles since new	Unknown; 'on-condition' item
Fitted to NSH	16 March 2005
Hours/cycles on NSH at installation	2,811.4 hours/3,024 cycles
Approximate combustion case in-service hours in NSH at the time of failure	2,244.4 hours

Inspection requirements

The combustion case was to be inspected at pre-determined intervals for the cracking of any welds. That included during:

- post-flight inspections, which required a 'general visual check'
- 150 and 300-hourly inspections, which required an examination of the affected areas using a 'bright light (flashlight or equivalent) and mirror'
- 2,000-hourly inspections, which required an examination of the areas 'utilizing the Leak-Tec or dye penetrant[9] method'. A Leak-Tec examination entailed the partial pressurisation of the combustion case by rotating the engine with the engine's electric starter motor and applying the Leak-Tec solution. Once applied, any 'bubbles' observed emanating from the outer surface of the case indicated a crack or other breach of the casing.

The last 2,000-hourly inspection on the combustion case was undertaken in conjunction with a more major servicing on 8 March 2008, at 4,647.9 airframe hours. That inspection included the examination of the brazed wire patch areas using the dye penetrant method. No cracks were found during that inspection.

Maintenance

The combustion case was fitted to the helicopter engine's turbine module on 16 March 2005, following the rejection of the original combustion case (serial

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8 The OCC was able to be fitted to a number of different model engines. When new the OCC had been fitted to an RR250-C30P engine that was shipped new from factory on 27 February 1989.

9 Dye Penetrant. A dye-containing liquid used for detecting cracks or other surface defects in metals.

number 41331) for ‘severe corrosion pitting in the armpit areas’. As the combustion case is an ‘on-condition’[10] component, its TTIS was not tracked.

The engine manufacturer’s records indicated that the combustion case was originally fitted to another RR 250 C30P engine that was shipped from the factory as a new engine on 27 February 1989. Since then, it had been fitted to at least one other engine, before being fitted to the engine in this helicopter. The combustion case had accumulated 2,244.4 hours since that last installation.

Meteorological information

The weather and sea state at the time were benign (see Figures 1, 2 and 5), and not a factor in the occurrence, nor did it adversely affect the rescue efforts required following the ditching.

Recorded information

Opportune video footage of the power loss

The accident was recorded on a hand-held video camera that was positioned on one of the cruise ship’s tender boats that was located to the right of the ship. An examination of the video footage from that camera showed that the time taken from the power loss to the helicopter entering the water was about 3 seconds.

Full-Authority Digital Engine Control

The helicopter was fitted with an EMC-35A Full-Authority Digital Engine Control (FADEC) system. The FADEC system comprised the hydromechanical unit, which was mounted on the engine, and the computerised engine control unit (ECU). The FADEC allowed for the automatic control of the engine.

The ECU included built-in test equipment that continuously monitored system operation and detected, displayed and recorded any system faults. The ECU also recorded engine performance history data.

The ECU was recovered and forwarded to the component manufacturer for possible download. Although water damaged, an automatically-recorded ‘snapshot’ of the last few seconds of engine operation was recovered.

That information was plotted onto a graph by the engine manufacturer and showed that the engine was operating normally until the power loss (Figure 3).

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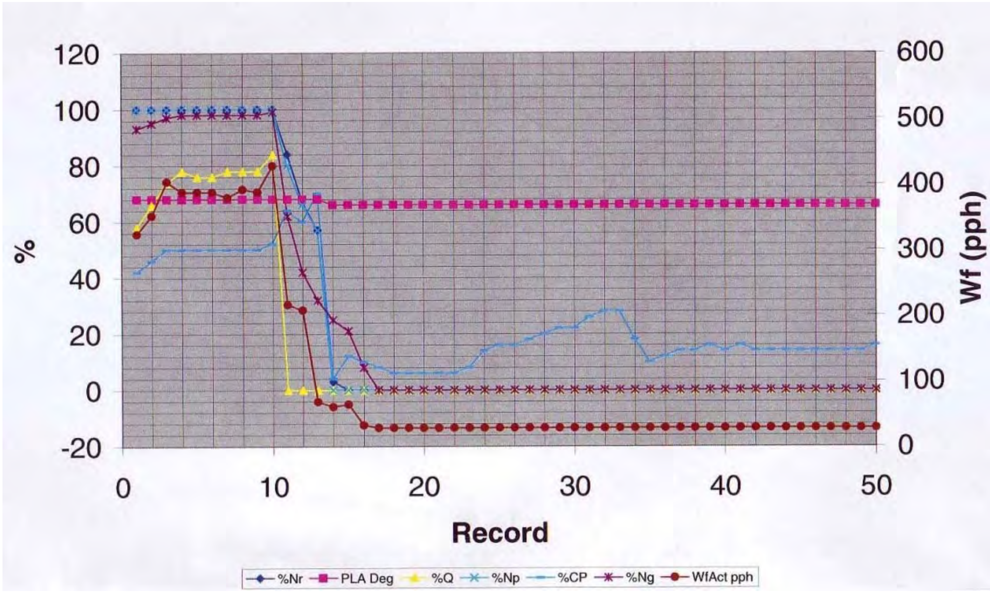
[10] Maintenance on such items was only carried out when the condition of the affected item required it.

Figure 3: Graphical representation of the recorded ECU data



Wreckage and impact information

General

An on-site examination of the helicopter's airframe and related systems showed damage consistent with the helicopter impacting the water with the main and tail rotors rotating. No defect in the airframe or its systems was identified, although the pilot's perspex chin window had broken on impact with the water.

Following an initial on-site examination, the helicopter's engine was transported to an approved engine facility for a more detailed examination under Australian Transport Safety Bureau (ATSB) supervision. In preparation for transit, the engine was coated with a corrosion preventative compound in an attempt to minimise the effects of the immersion in salt water.

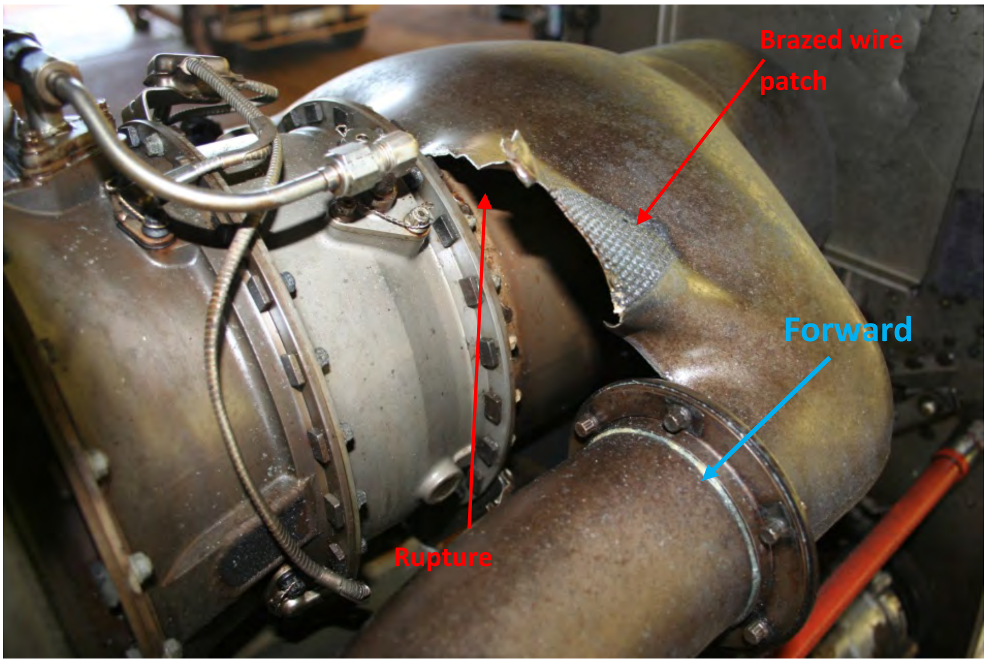
Engine examination

During the workshop examination, the engine was found to be intact; however, it was extensively corroded throughout from the salt water immersion. That corrosion had seized the engine's rotating parts. In addition, there was a significant 'rupture' failure of the combustion case in the area of the horizontal weld in the left 'armpit' region of the casing (Figure 4). The rupture passed through the approximate centre of a brazed wire patch on the left armpit, and a crack was located in a similar location in the right armpit region.

No other anomalies were noted on the engine that would have affected its pre-impact operation.

The combustion case was recovered to the ATSB facilities for technical examination.

Figure 4: Ruptured combustion case in-situ



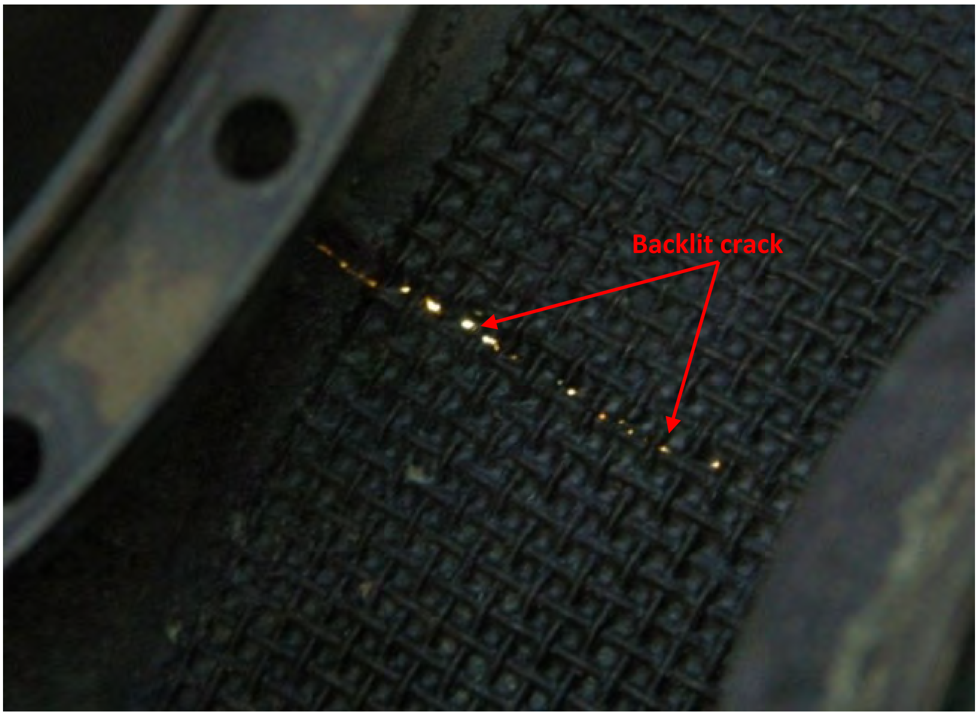
Combustion case technical examination

A metallurgical examination of the combustion case found that the rupture failure occurred as a result of high cycle fatigue cracking. That cracking had resulted from 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 failure (Appendix A).

A similar fatigue crack, of 51 mm in length, extended through the brazed wire patch on the right armpit (Figure 5). The manufacturer estimated a power loss as a result of such a crack of about 1%, which the manufacturer considered would probably not be detected during the daily power assurance checks[11].

[11] Power assurance checks can be used as a tool to gauge on-going engine performance. Such checks on the RR 250 engines are detailed in the Operations and Maintenance Manual, Section 72-00-00, page 73, and are a voluntary procedure.

Figure 5: Crack through the brazed wire patch on the right armpit (backlit to indicate extent)



The manufacturer indicated that 'Historically the parts [combustion cases] found with these smaller cracks have been found at turbine overhaul and not due to a [in-service] power issue.' The manufacturer advised that larger size cracks could be expected to result in increasingly significant power degradations.

Survival aspects

Helicopter emergency floatation

The helicopter was fitted with inflatable emergency floats that were contained within storage bags positioned on the top of each landing gear skid (Figure 6). In accordance with Bell 407 Normal Procedures for 'Overwater Operations'[12], the pilot armed the system via a red, guarded Float Arm switch that was located on the collective lever[13]. Arming the system illuminated the Float Arm advisory light on the central warning panel that was situated above the instrument panel.

In the case of a ditching[14], the pilot would operate the Float Inflate switch that was also mounted on the collective lever. Upon successful activation, the floats were inflated with nitrogen; allowing the helicopter to float on the surface of the water. Inflation of the floats was possible even if the floats were submerged. The floats were certified for operation in sea states greater than affected this ditching.

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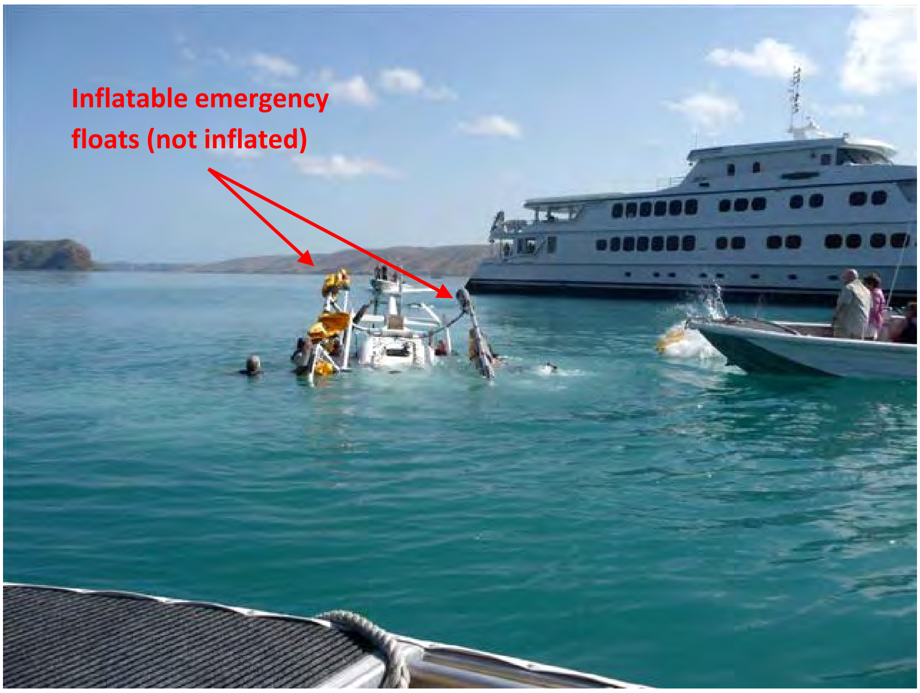
12 Bell BHT-407-FMS-1, Section 2, *Normal Procedures*, paragraph 2-9-A, Over Water Operations.

13 The collective lever is the primary control of a helicopter's altitude or vertical velocity.

14 Emergency alighting of an aircraft on water.

The pilot indicated that he armed the helicopter's emergency floatation system prior to the power loss. The pilot stated that, in this case, the rapidity of the ditching following the power loss did not allow sufficient time for their activation prior to the helicopter making contact with the water. Once out of the helicopter, he considered re-entering the helicopter to inflate the floats; however, he was discouraged from this course of action by one of the ship's crew.

Figure 6: Underside of the helicopter, floats not inflated

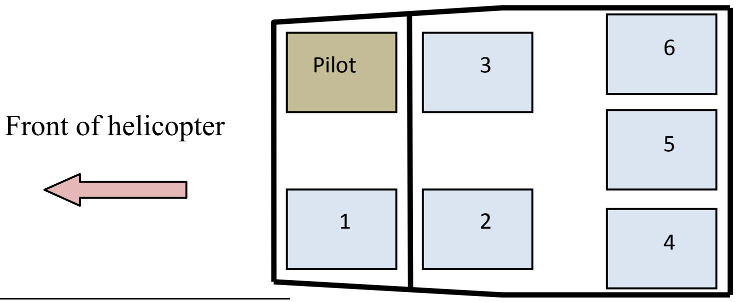


Survivor exit from the helicopter and recovery on board the cruise ship

In response to the ditching, the ship's crew sounded the alarm and directed the ship's tender boats, which were positioned at various locations around the ship, to assist the helicopter's occupants.

The pilot reported that he was unable to open the right cockpit door[15] due to the opposing water pressure. In response, he exited the helicopter through the left cockpit door, which had been opened by the passenger in the left-front seat (seat 1 in Figure 7) in order to exit the helicopter.

Figure 7: Plan view of the helicopter's seating layout



[15] In general, the pilot in command of a helicopter sits on the right side of the aircraft's cockpit.

Once clear of the helicopter, the pilot assisted the ship's crew to rescue the passengers. That included one of the ship's crew swimming around to each person and inflating their life jackets. The pilot, who was a competent swimmer, elected not to inflate his life jacket so he could better assist with the rescue of the passengers.

The second last passenger to be rescued from the helicopter reported that she had 'given up' after becoming disoriented and commenced ingesting water. The remaining passenger, who was still strapped into the left rear seat when rescued (seat 4 in Figure 7), had stopped breathing. Quick action by one of the tender boats' crew assisted the passenger to resume breathing.

Tests and research

Passenger survey

A survey was conducted of the cruise ship passengers, including those on board the helicopter at the time of the accident. Survey responses indicated that passengers had varying levels of experience in helicopters prior to going on the cruise. One respondent had never flown in a helicopter before.

All of the respondents reported that they received a safety briefing from the pilot at the start of the cruise, and that they clearly understood what was required of them during helicopter operations. Those briefings reportedly included; helicopter entry and exit procedures, lifejacket operation, emergency communications equipment use, and seatbelt operation. The briefings were reportedly reinforced by the ship's crew prior to each flight. About 30% of the respondents recalled seeing the helicopter's on board safety cards. However, four of the respondents indicated that they were unfamiliar with the operation of their seatbelts, as the ship's crew had generally done their seatbelts up for them.

A number of the survey respondents reported that, if occupied, the helicopter's three rear seats became 'crowded'. The inversion of the helicopter during the ditching exacerbated that overcrowding.

All of the survey respondents from the occurrence flight reported that their seatbelts were correctly fastened for the flight. They indicated that they were wearing manually-inflatable life jackets, and that they did not inflate the jackets during the rescue.

Other similar failures

The engine manufacturer reported being aware of only two combustion case failures of this type in more than 21 million flight hours with the 250 series of engines. That included 2 weeks prior to this occurrence, when a similar failure occurred on a 250-C30M[16] engine in a Bell 206 LongRanger 4 helicopter in Papua New Guinea

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[16] The RR250-C30M engine and the C47 engine that was installed in this helicopter shared the same part number combustion case.

(PNG). An investigation of that failure was carried out by the engine manufacturer, and the failed combustion case was provided to the ATSB for examination.

The ATSB examination of the PNG combustion case found that the failure resulted from high-cycle fatigue cracking as a result of engine start-stop cycles. The fatigue cracking extended through the wire mesh patch area and closely followed the horizontal weld line between the air discharge tube and the gas producer flange. The cracking extended for about 69 mm before unstable crack growth occurred, allowing the case to rupture (Appendix A).

Engine manufacturer's investigation of this occurrence

The engine manufacturer originally verified the serviceability of the 250-C47 series engine's combustion case design via the cyclic pressure testing of the component.

During their investigation of this occurrence, the manufacturer carried out computerised finite element analysis[17] on the combustion case design with the brazed wire patches installed. That analysis found that the existing patches did not satisfactorily cover the peak stress areas in the combustion case armpits, due to the size of the patch and the relative location of the peak stresses in the armpit.

Additional information

Wire patch history

In response to a number of in-service fatigue cracks in the armpit area of a number of RR (Allison) 250 series combustion cases in the early 1970s, that area of the case was reinforced via the application of wire patches.

Subsequently, on 15 May 1984, Commercial Engine Bulletins (CEB) CEB-A72-2113 and CEB-A72-3115[18] were introduced detailing the addition of reinforcing patches to the RR250-C28 and C30 series engines. That requirement came about following a combustion case rupture that had occurred on a RR250-C30 engine in a Sikorsky S76 helicopter.

The reinforcing wire patches were attached onto the outer surface of the left and right armpit areas of the combustion case, reinforcing that area and preventing further cracking (Figure 8). Those patches have been an integral part of the RR 250 series engine combustion case since that time.

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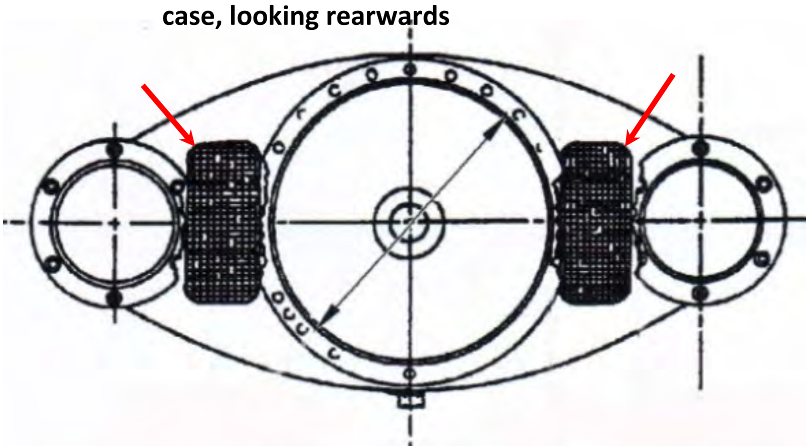
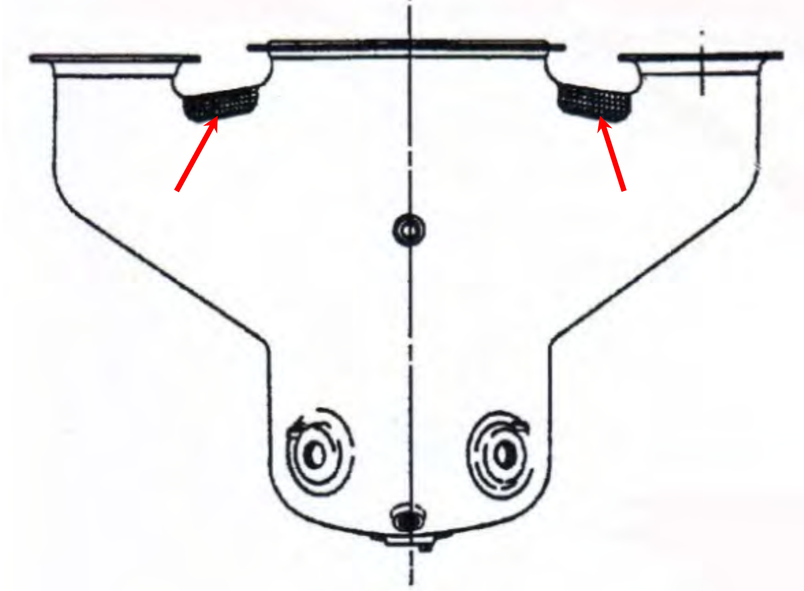
17 Finite element analysis is a computerised, three dimensional, structural analysis method.

18 RR Commercial Engine Bulletin, CEB-A72-2113/CEB-A72-3115, Titled 'Engine, Outer Combustion Case Assy – Add Reinforcement Wire Patch', dated May 15, 1984, Revn No. 4, dated September 1, 1994; mandated in the US by FAA AD 85-25-07 and later in Australia by CASA AD/AL 250/59.

Figure 8: Manufacturer's drawing showing the brazed wire patches in the armpit areas of the combustion case (arrowed in red)





ANALYSIS

There was sufficient fuel on board for the flight, and the helicopter was within the published weight and balance limits. No anomalies were found in the helicopter, its main and tail rotors, or its flight control systems with the potential to have contributed to the development of the occurrence. Similarly, no operational factors were identified.

The investigation determined that the loss of engine power was due to the rupture of the engine compressor case. This analysis will examine the factors that contributed to that rupture, and on the rescue and survival aspects of the ditching and recovery of the occupants of the helicopter.

Engine failure

The rupture of the combustion case resulted from a pre-existing, high cycle fatigue crack in the 'armpit' area of the combustion case. That cracking was a consequence of the cumulative effect of normal engine pressure cycles. The inadequately-sized wire mesh patches in the peak stress areas of the combustion case increased the likelihood that such cracks might occur.

The relatively recent dye penetrant-based leak check did not identify the crack in the combustion case. Whereas it may have been that the crack did not exist at that time, it could also have been that the crack was masked by the uneven surface of the wire mesh patch. In such areas, it may have been more reliable to have used the Leak-Tec method.

The predicted minimal power loss as a result of a 51 mm crack in the armpit area of the combustion case probably explained the inability of the operator's engine trend monitoring programme to identify the development of the crack in the intervening period between the leak check and power loss.

Rescue and survival

The reported insufficient time available for the pilot to deploy the helicopter's lightweight emergency flotation gear prior to the ditching minimised the likelihood that the helicopter would remain upright following impact. The inverted helicopter increased the difficulty experienced by the passengers to exit from the partially-submerged cabin. In contrast, the pilot's previous helicopter underwater escape training facilitated his exit from the helicopter, despite being unable to open his cockpit door.

The rapid rescue response by the ship's crew ensured that all of the occupants of the helicopter survived the accident.

FINDINGS

From the evidence available, the following findings are made with respect to the total power loss at Talbot Bay, Western Australia on 25 September 2008, and should not be read as apportioning blame or liability to any particular organisation or individual.

Contributing safety factors

- The design of the wire patches on the outer combustion case was ineffective in reducing operating stresses. *[Minor safety issue]*
- The outer combustion case failed due to fatigue cracking that originated in the area immediately beside the wire patch, leading to immediate engine power loss.
- The nature of the fatigue crack in the outer combustion case meant that it could be difficult to detect directly, or as a result of degraded engine performance, until catastrophic failure.*[Minor safety issue]*
- The pilot did not deploy the helicopter's lightweight emergency flotation gear prior to the ditching.
- Following the ditching, the occupants experienced difficulty exiting the inverting and partially submerged cabin of the helicopter.

Other key findings

- The rapid rescue response by the ship's crew ensured that all of the occupants of the helicopter survived the accident.
- The pilot's previous helicopter underwater escape training facilitated his exit from the helicopter, despite being unable to open his cockpit door.

SAFETY ACTION

The safety issues identified during this investigation are listed in the Findings and Safety Actions sections of this report. The Australian Transport Safety Bureau (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.

All of the responsible organisations for the safety issues identified during this investigation were given 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.

Engine manufacturer

Outer combustion case structural integrity

Safety issue

The design of the wire patches on the outer combustion case was ineffective in reducing operating stresses.

Action taken by the engine manufacturer

Following this occurrence, the engine manufacturer reassessed the structural integrity of the outer combustion casing (OCC). The results of that testing showed a deficiency in the wire mesh patch. The manufacturer provided the ATSB with the following advice:

> Cyclic pressure testing was originally conducted on the OCC to assess life. However, a finite element analysis has recently been performed on the OCC as part of the investigation into the subject failure [VH-NSH]. This analysis revealed that the patch does not optimally cover the peak stress areas in the armpit due to the size of the patch and the relative location of the peak stresses in the armpit. Consequently, the design group responsible for this part is currently looking at modifying the size and shape of the patch for an improved and more optimal area of coverage. This work is in progress and will be released to the field once the redesign has been tested and verified.

ATSB assessment of response/action

The ATSB is satisfied that the action taken by engine manufacturer should, once released to the field, will adequately address the safety issue.

Outer combustion case crack detection

Safety issue

The nature of the fatigue crack in the outer combustion case meant that it could be difficult to detect directly, or as a result of degraded engine performance, until catastrophic failure.

Action taken by the engine manufacturer

The engine manufacturer has advised that, following this occurrence, the inspection method for application to the wire patch and surrounding area is being re-evaluated. This process is ongoing.

ATSB assessment of response/action

The ATSB is satisfied that, depending on the outcome of the manufacturer's re-evaluation, it could be expected that any action taken by engine manufacturer would address the safety issue.

Helicopter operator

Passenger difficulty exiting the helicopter

Although no safety issue was identified in respect of the difficulty experienced by the occupants to exit the partially-submerged cabin due to the attitude of the helicopter after landing, the operator has advised of the following proactive safety action in response to this occurrence:

> Passengers who consider flying in the helicopter will be given the option to only use 4 of the 5 seats located in the back passenger compartment, that is, no middle seat. In addition, the operator will add a HEABS[19] bottle to the back seat compartment for use of the helicopter crew only to assist in the extraction of any passenger if required.

Civil Aviation Safety Authority

Outer combustion case crack detection

Safety issue

The nature of the fatigue crack in the outer combustion case meant that it could be difficult to detect directly, or as a result of degraded engine performance, until catastrophic failure.

[19] Helicopter Emergency Air Breathing System.

Action taken by the Civil Aviation Safety Authority

During the investigation, the ATSB alerted the Civil Aviation Safety Authority (CASA) of this safety issue. As a result of those discussions, CASA issued Airworthiness Bulletin AWB 72-003 Issue 1, *Rolls Royce 250 Engine Outer Combustion case (OCC) Failure* dated 23 October 2008 (Appendix B). The AWB sought to urgently advise operators and maintainers of the possibility of an unusual and catastrophic failure of the combustion case in that engine type, and to recommend a means and periodicity for the inspection of that area of the engine.

ATSB assessment of response/action

The ATSB is satisfied that the action taken by CASA adequately addresses the safety issue.

APPENDIX A: TECHNICAL ANALYSIS REPORT

ATSB TECHNICAL ANALYSIS
AO-2008-067
Final

Failure analysis of the outer combustion case from a Rolls-Royce 250-47B gas turbine engine

Power loss, Talbot Bay, Western Australia, 25 September 2008 VH-NSH, Bell Helicopter Textron 407

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

FACTUAL INFORMATION

Introduction

On 25 September 2008, a Bell Helicopter Textron Inc, model 407 helicopter, registered VH-NSH, took off from the rear heli-deck of the cruise ship *True North*, for a tourist flight through the northern Kimberley region of Western Australia. *True North* had been stationed within Talbot Bay, and on board the helicopter were the pilot and six passengers from the ship. The pilot reported that shortly after take-off, and at a height of about 10 m above the water surface, a loud bang was heard followed by a total loss of engine power. The helicopter subsequently descended and struck the water with a nose-low attitude, before rolling inverted. All those on board were able to escape the helicopter and were rescued by the ship's crew before the helicopter sank.

A post-accident examination of the helicopter's Rolls Royce 250-47B engine revealed substantial damage to the outer combustion case (combustion case). As a result, the engine was removed from the helicopter and shipped to an approved overhaul facility for disassembly and detailed examination under the supervision of investigators from the Australian Transport Safety Bureau (ATSB).

The engine examination confirmed that the combustion case had ruptured along the left side in the welded 'armpit' region. A crack was also found in the right side 'armpit' region, similarly located along the weld and through the brazed patch. The examination also showed that the engine had sustained severe post-accident corrosion damage from the sea water immersion, which resulted in seizure of many of the engine's rotating components.

Scope of the examination

At the completion of the engine disassembly, the combustion case was retained by the ATSB in order to further identify the factors that had contributed to the in-flight engine failure. Details of the accident helicopter and the engine are presented in Table A1.

Rolls Royce 250-47B engine information

The Rolls-Royce 250-47B gas turbine engine was an internal combustion turbo-shaft design that featured a two-stage free power turbine that was gas coupled to the gas generator turbine. The propeller reduction gearbox was shaft-connected to the power turbine. Performance specifications indicated that the engine was rated for 650 shp[20] during take-off operations.

Outer combustion case

The Rolls-Royce 250-47B's combustion assembly was comprised primarily of two compressor discharge air tubes, an outer combustion case (combustion case) and a combustion liner. During operation, the combustion case became pressurised as

20 Shaft horsepower (shp): unit of power measured at an engine output shaft.

compressed air from the upstream centrifugal compressor was delivered through two discharge air tubes to inlet ports located on either side of the combustion case. The compressed discharge air was then distributed into the combustion liner, where it was mixed with fuel and ignited for combustion. See Figure A1 for further detail.

Maintenance summary

Maintenance records indicated that the combustion case (part number 23030911-G, serial number 33701) had first been fitted to the engine (serial number CAE 847408) from VH-NSH in March 2005. Since that installation, the combustion case had accumulated a further 2,811 hours / 3,024 cycles. The total number of hours and cycles since the combustion case had first been manufactured was not able to be established.

Maintenance records also indicated that the combustion case had been non-destructively inspected using a dye-penetrant method on 8 March 2008; approximately 407 hours before the rupture occurred.

Table A1: Airframe and engine information for the Bell 407 (VH-NSH)

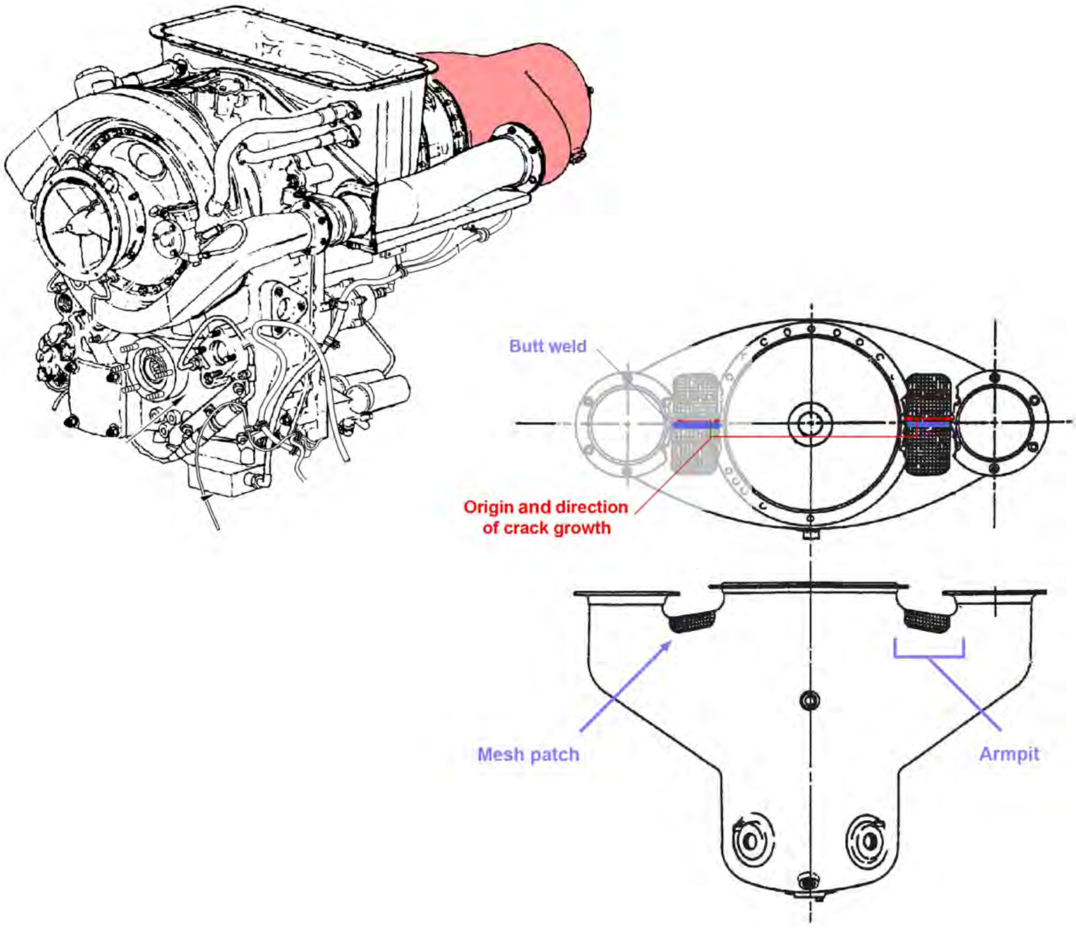
Aircraft manufacturer	Bell Helicopter Textron Limited
Model / serial number	407 / 53376
Registration	VH-NSH
Engine manufacturer	Rolls Royce Corp
Model	RR 250-47B
Serial number	CAE-847408
Date of manufacture	1999
Hours since last maintenance	127.5 hrs
Last maintenance type	300 hourly inspection
Outer combustion case	part number 23030911-G, serial number 33701
Hours / cycles since new	Unknown

Physical examination

VH-NSH: outer combustion case

The outer combustion case (combustion case) was a welded component that had been fabricated from a corrosion resistant stainless steel alloy. The combustion case housed the combustion liner and formed the outer walls of the combustion section. Reinforcing mesh patches were brazed over the horizontal welds in both ‘armpits’, which were the regions between the compressor air discharge tube and the gas producer attachment flanges.

Figure A5: Diagram of the 250-47B engine and the outer combustion case depicting the region of crack growth in relation to the butt weld and brazed mesh patch



Manufacturing identifiers that had been vibro-etched onto the surface of the combustion case confirmed the respective part and serial number to be 23030911-G and 33701.

The primary point of failure was located on the left-side of the component between the flange of the air discharge tube and the gas producer. Known colloquially as the ‘armpit’ region, the thin-wall stainless steel skin at that location had cracked and then ruptured in an outward manner. A mesh patch that had been brazed onto the horizontally welded surface of the combustion case had also fractured along with the case material. The crack path was observed to follow the horizontal weld between the air discharge tube and the gas producer.

Close examination of the right-side ‘armpit’ region confirmed that cracking had also developed in a similar manner - adjacent to the horizontal weld and through the brazed mesh patch. It was noted that the cracking was difficult to visually detect and required an additional source of illumination to observe.

Figures A2 to A4 provide photographic detail of the left-side ‘armpit’ rupture and Figures A4 to A6 provide detail on the observed crack growth in the right-side ‘armpit’.

Figure A6: The ruptured outer combustion case (part number 23030911, serial number 33701) as removed from the Rolls-Royce 250-47B engine

Figure A7: The primary point of failure in the left-side 'armpit' region

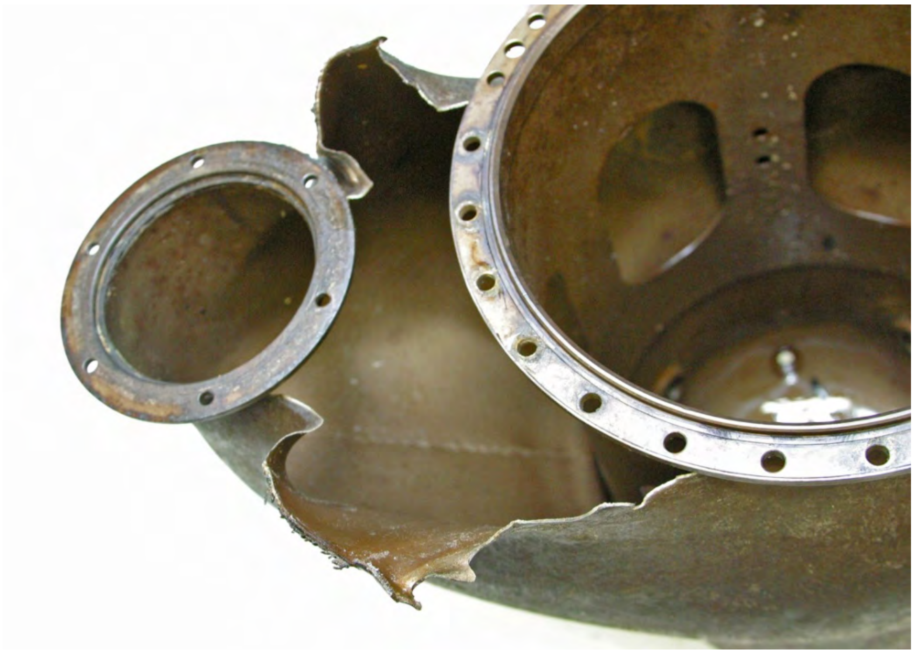


Figure A8: Close view of the primary fracture in relation to the mesh patch

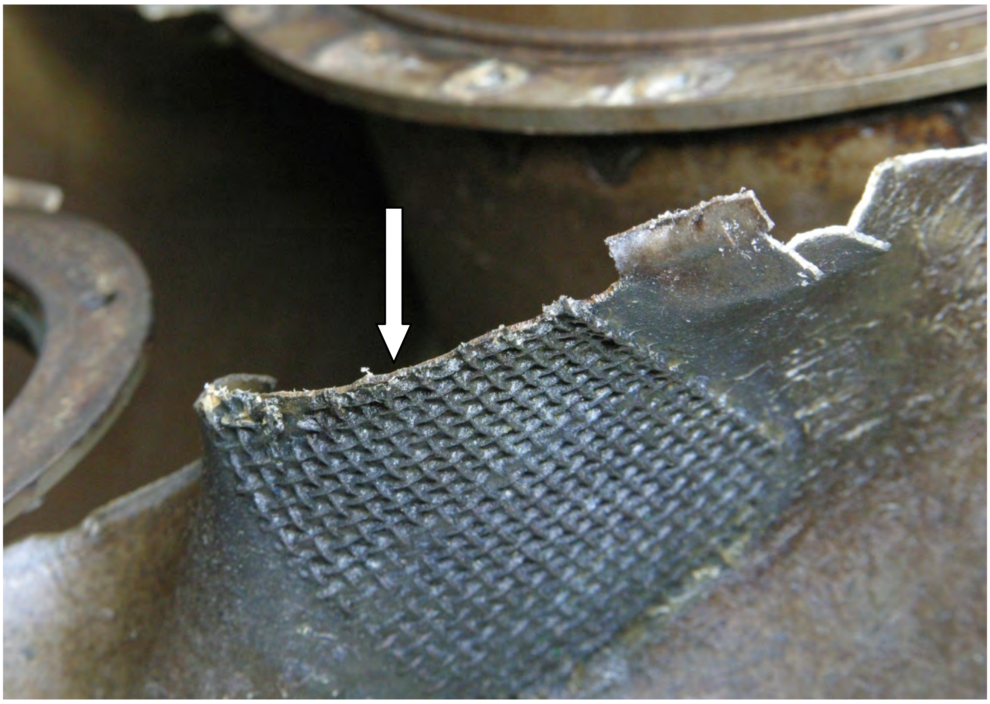
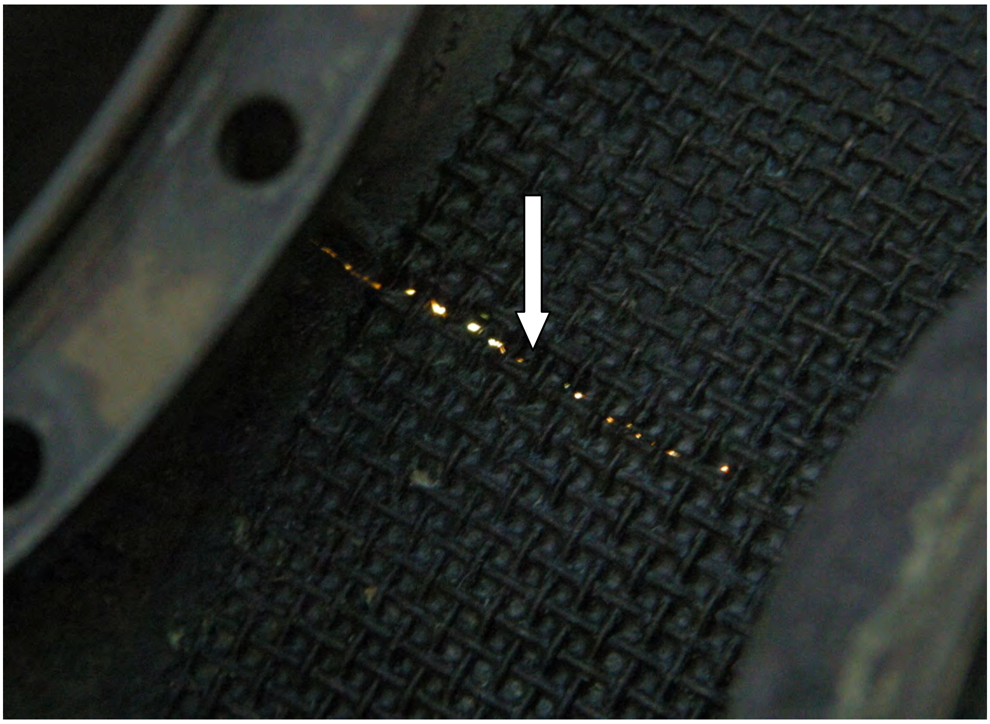
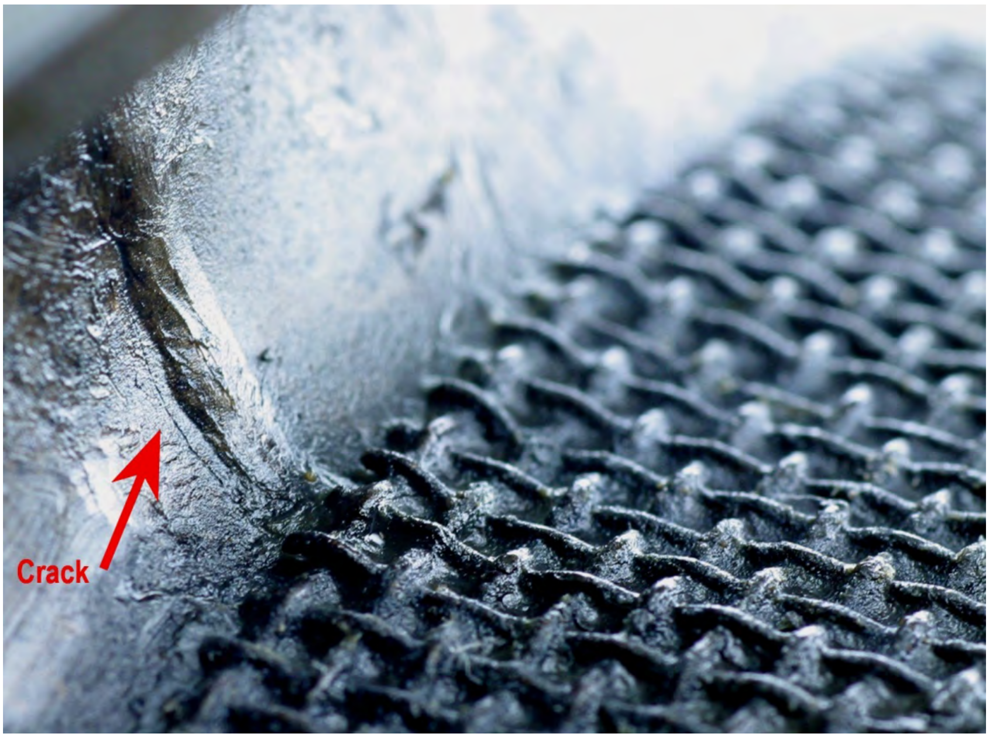


Figure A9: View of cracking through the mesh region in the right-side 'armpit' (arrowed)



Note: In order to adequately display the extent of crack growth, a light source was used to internally illuminate the combustion case.

Figure A10: Close view of the right-side 'armpit' crack, as shown in Figure A5



Fractography

Left 'armpit' - primary rupture

To examine the features of the ruptured 'armpit' region, destructive sectioning of the combustion case was performed to excise the cracks from the case structure. Magnified visual examination of the fracture surfaces showed evidence of the typical 'beach marks' associated with high-cycle fatigue cracking. While the crack path followed the horizontal weld line, the fatigue crack origin was identified underneath the mesh patch on the internal surface of the combustion chamber. See Figures A7 and A8 for detail.

A considerable degree of surface oxidation and staining had developed along the rupture surfaces, close to the fatigue crack origin. Discolouration of that nature was likely to have been produced from exposure to hot combustion gases that had escaped through the cracking during prior engine operation.

Measurements indicated that fatigue cracking in the left-side 'armpit' had propagated for approximately 59 mm in total before final fracture (unstable crack growth) occurred. The region of final fracture extended inward and around the circumferential weld at the gas producer flange, and resulted in the final 'ruptured' condition.

Right 'armpit'

Examination of the excised right-side 'armpit' crack surfaces showed that fatigue cracking had also initiated underneath the brazed mesh patch, and had propagated through the mesh and along the horizontal weld in the same manner as the left-side rupture. Measurements indicated a total fatigue crack length of 51 mm.

Figure A11: The primary fracture noting the fatigue crack origin (labelled)

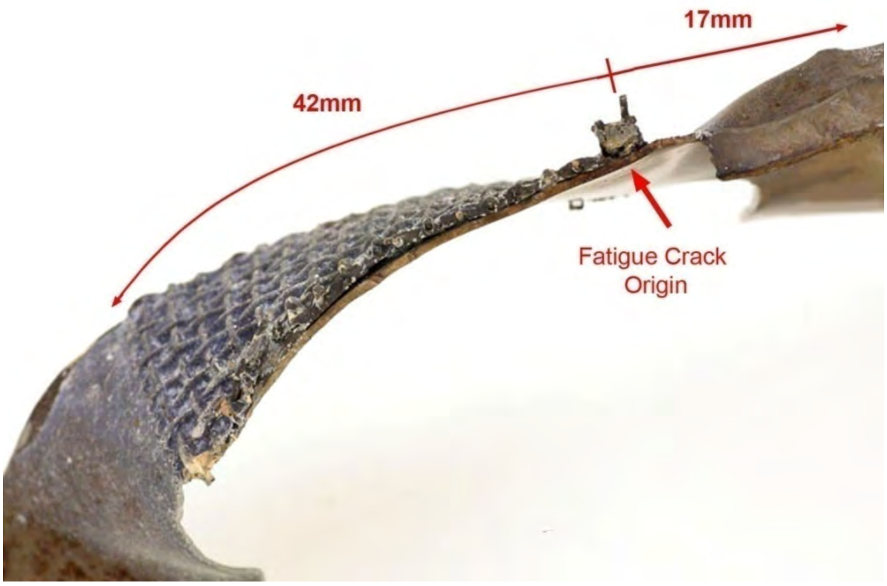
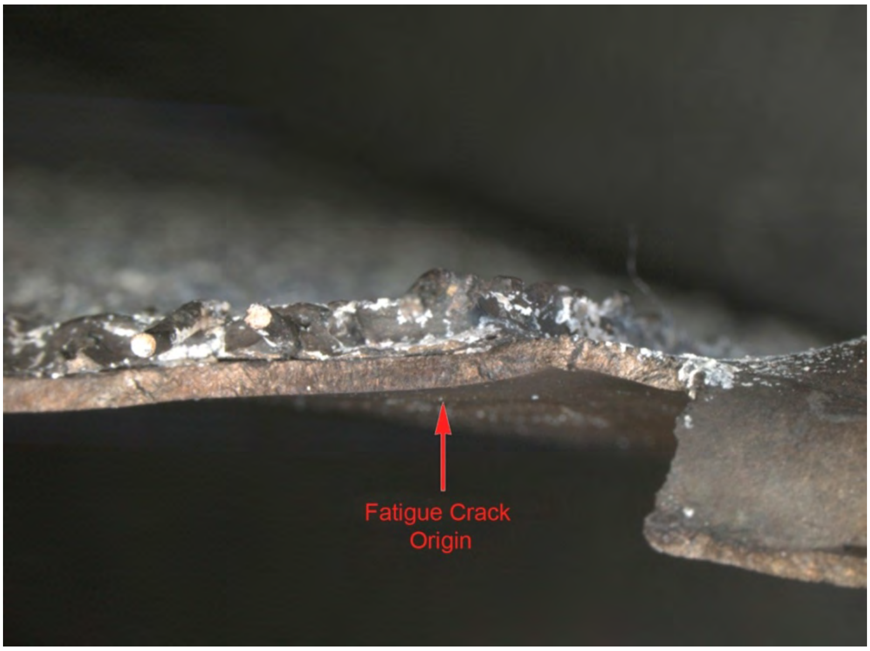


Figure A12: Close-up of the primary fracture surface showing the fatigue crack origin



Metallography

Close visual examination of the metal surfaces surrounding both the left and right 'armpit' mesh patches showed that a surface blasting process had been used to mechanically texture the surfaces prior to brazing.

It was also noted that pitting corrosion had developed on the external surfaces of the combustion case that surrounded the brazed mesh patch. Metallographic sectioning revealed that the corrosion pits did not extend underneath the brazed mesh patch, with no evidence of pitting or other corrosive metal-loss along the crack length.

Scanning electron microscopy

Scanning electron microscopy (SEM) techniques were used to closely examine and characterise the fatigue crack origins from both the left and right 'armpit' regions. The SEM examination confirmed that the cracks had progressed under high-cycle conditions and striation-like features were clearly apparent (Figure A9).

In both cases, it was confirmed that fatigue cracking had initiated on the internal surface of the combustion case (Figure A10). The origin of crack growth did not appear to be related to the corrosion pitting that had affected the adjacent surfaces. The electron microscopy did not show any evidence of mechanical damage or other localised features associated with the origin regions that might have contributed to the crack growth.

Figure A13: High magnification SEM image showing closely spaced progression markings on the rupture fracture surface

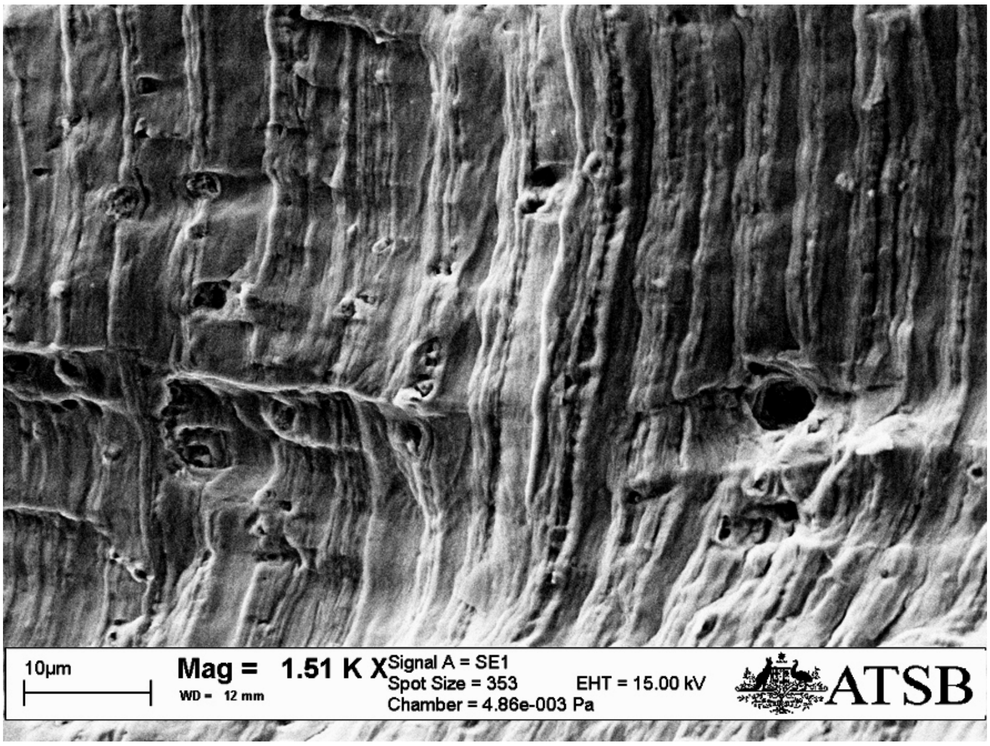
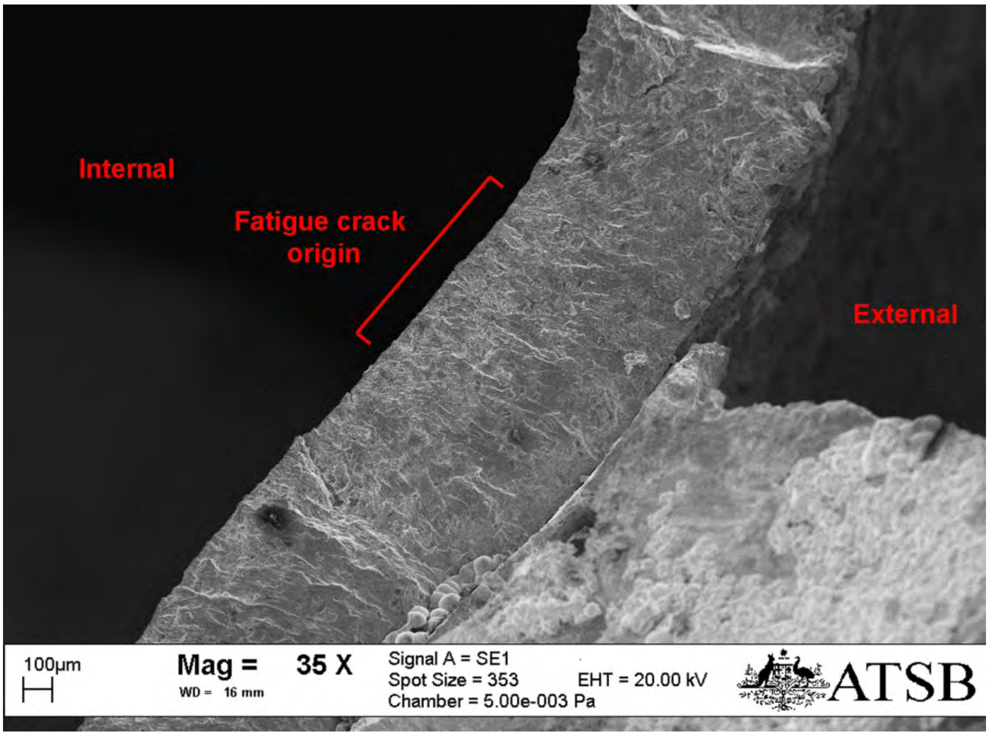


Figure A14: Low magnification SEM image of the fatigue origin (labelled)



Other combustion case failures

During the course of the ATSB investigation into the Talbot Bay accident, the ATSB was notified of combustion case failures from two other helicopters.

Combustion case failure: Bell 206L4 helicopter

On 28 July 2008, a Bell 206 L4 helicopter sustained an engine failure that resulted in the helicopter heavily impacting terrain. The accident occurred just after take-off from a remote jungle village, approximately 150 km from Port Moresby, Papua New Guinea. The helicopter was ferrying five passengers from the village and several of the occupants sustained serious injuries as a result of the occurrence.

After the helicopter had been recovered from the accident site, the engine was removed from the airframe and taken for bench testing in Manila (Philippines). During the engine testing, it was established that the outer combustion case (combustion case) had ruptured (Figure A11). The ruptured combustion case from the engine was subsequently forwarded to Rolls Royce in the US for an engineering failure analysis.

The known details for the helicopter, engine and the combustion case are presented in Table A2.

Figure A15: The ruptured outer combustion case from the Bell 206L4 helicopter

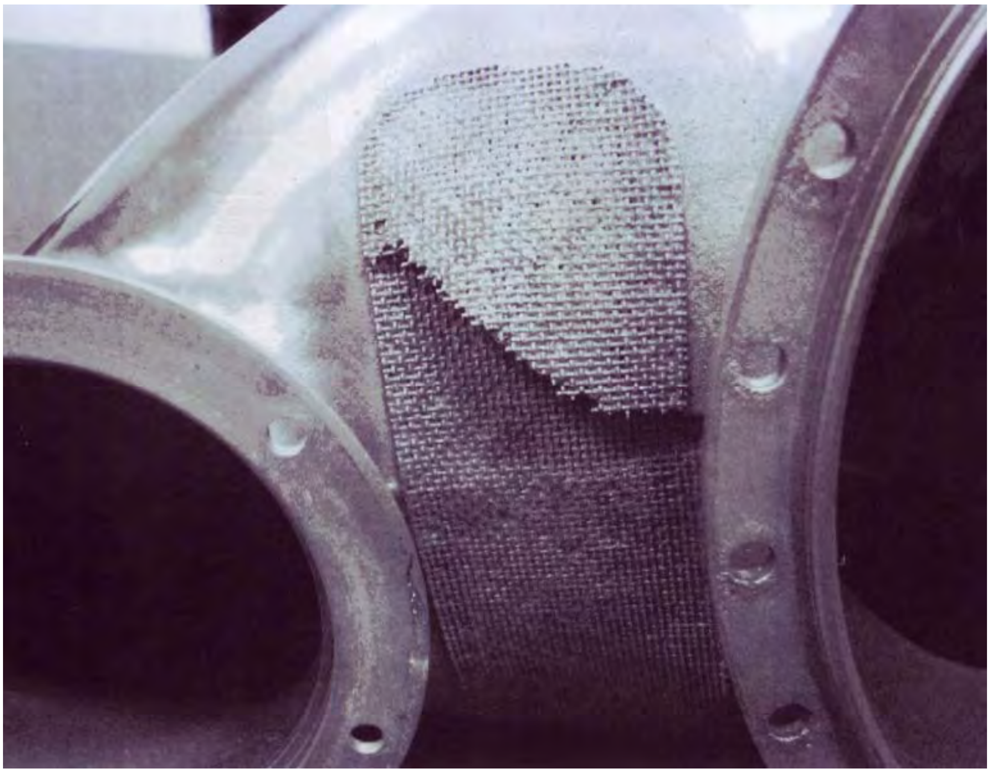


Table A2: Known details of the Bell 206L4 that crashed in Papua New Guinea

Aircraft manufacturer	Bell Helicopter Textron Limited
Model / serial number	206 L4 / 52029
Registration	P2-PBF
Engine manufacturer	Rolls Royce Corp
Model	RR 250-C30P
Serial number	CAE895036
Date of manufacture	1982
Hours since last maintenance	73.7 hrs
Last maintenance type	100 hourly inspection
Outer combustion case	part number 23030911-K, serial number 41243
Hours / cycles since new	Unknown

Bell 206L4: summary of ATSB examination findings

Following disassembly from the Rolls-Royce 250-C30P engine and the subsequent metallurgical examination by the engine manufacturer in the US, the combustion case (part number 23030911-K, serial number 41243) was sent to the ATSB's facilities in Canberra. The main observations from the ATSB examination are summarised below:

- High-cycle fatigue cracking had progressed adjacent to the horizontal weld in the left 'armpit' region until unstable fracture occurred and the component ruptured. The fatigue crack length measured 68 mm (Figures A12 and A13).
- High-cycle fatigue was also found to have developed through the mesh in the right 'armpit' and had grown to a length of 47 mm.
- The surface finish of the thin-wall stainless steel component at the point of fatigue crack initiation was poor. Prior to brazing of the mesh patch, a localised surface shot-peening process had been used to texture the external surfaces of both 'armpit' regions. The internal surfaces of the combustion case were also corroded and showed evidence of severe localised pitting damage close to the fatigue crack origin (Figures A14 to A16).
- Fatigue crack initiation in both 'armpits' may have been related to either internal surface corrosion damage that had developed during service, or from the shot-peening process that had been employed prior to brazing of the mesh patches. Due to the level of surface oxidation on the fracture surfaces, it could not be specifically established whether the external peening or the internal corrosion damage had contributed to the initiation of cyclic fatigue cracking in the component.

Figure A16: Section from the ruptured left-side 'armpit', as received

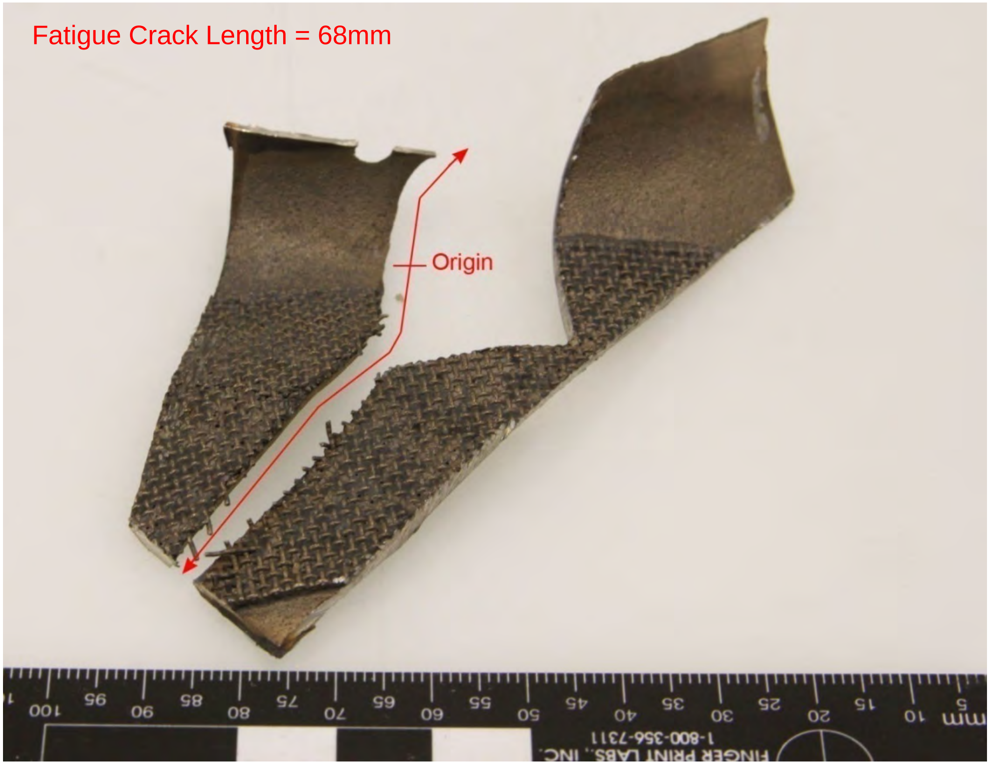


Figure A17: Fracture surface from the ruptured left-side 'armpit' region showing the origin of fatigue crack growth

Figure A18: Heavily corroded and oxidised fatigue crack origin from the left-side 'armpit'

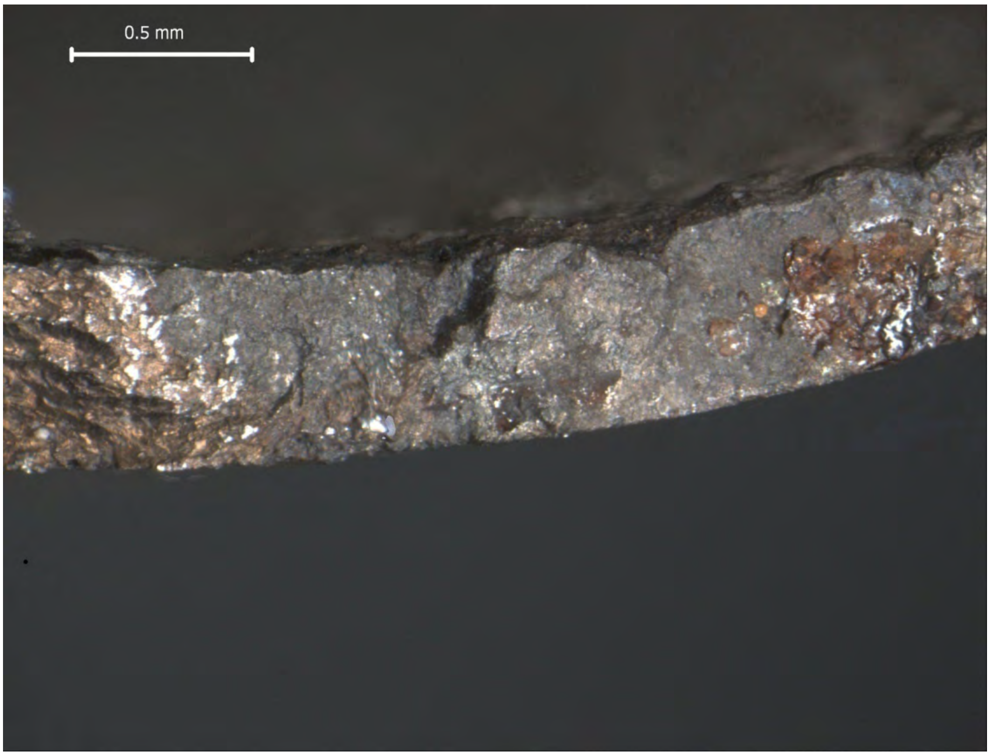


Figure A19: The internal surfaces of each 'armpit' contained similar levels of corrosion damage close to the fatigue crack origins

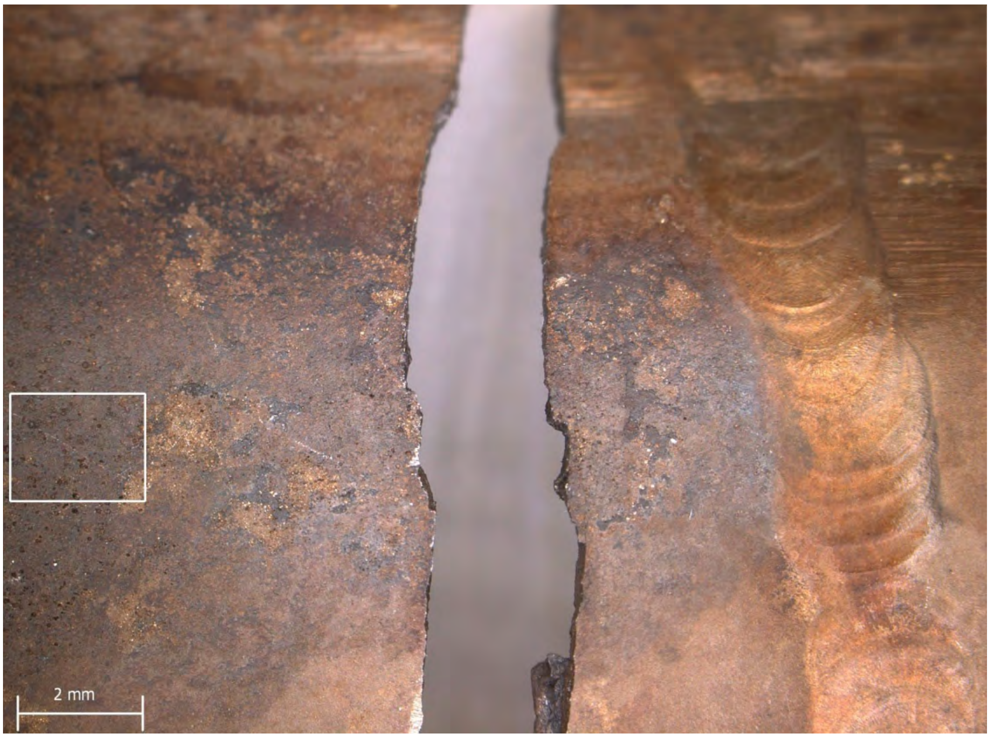
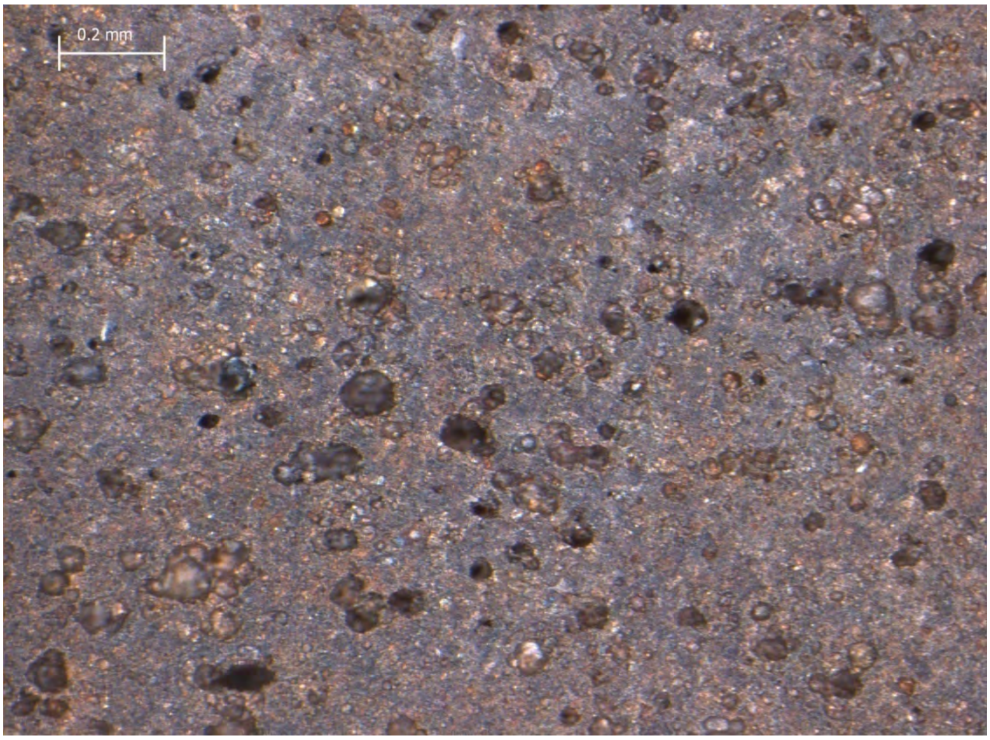


Figure A20: Close-up of the pitted surface, as highlighted in Figure A15

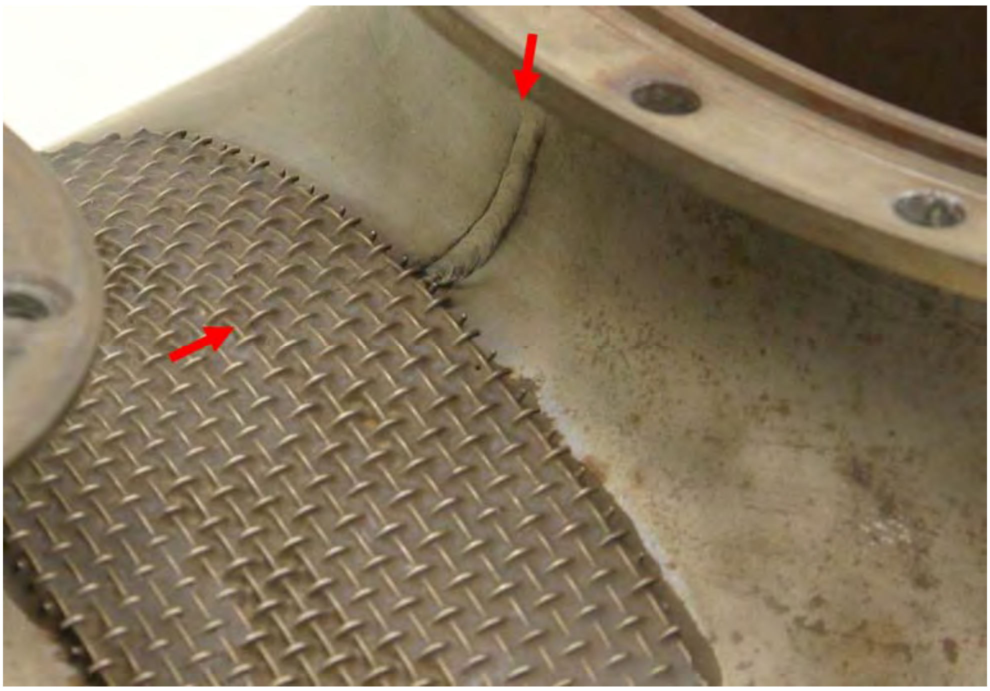


Combustion case failure: Sikorsky S-76A helicopter

During the course of the VH-NSH investigation, the ATSB was notified that a twin-engine Sikorsky S-76A helicopter, registered VH-XHS, had also been found with a crack in the outer combustion chamber of one of its Rolls Royce 250-C30 engines. The defect was found by the operator's maintenance personnel shortly after the publication of a Civil Aviation Safety Authority (CASA) Airworthiness Bulletin (AWB)[21] that advised operators and maintainers of Rolls Royce 250-series engines to urgently inspect the combustion case 'armpit' region for cracking. The AWB was published by CASA as a safety response to the Talbot Bay in-flight engine failure involving VH-NSH. At the time of the inspection, the Sikorsky helicopter was on a vessel being transported by sea to Antarctica. It was reported by the Sikorsky operator that the 'armpit' crack had been visually identified using a torch to aid illumination.

The defective combustion chamber (part number 23030910, serial number 29462) was removed from the engine and submitted to the ATSB. Non-destructive, visual examination confirmed that a crack had developed in the 'armpit' region along the centre-line weld at a location identical to the cracks found on both the Bell 407 (VH-NSH) and the Bell 206L4 (P2-PBF) helicopters. Measurements indicated that the crack extended for approximately 28 mm along the weld and into the reinforcement brazed mesh patch. No corrosion or other such external surface damage was evident that might have otherwise contributed to the development of cracking in the component.

Figure A21: 'Armpit' cracking as observed in the combustion case from the Sikorsky S-76A (VH-XHS)



[21] CASA AWB 72-003 'Rolls Royce 250 Outer Engine Combustion Case (combustion chamber) Failure', published 23 October 2008.

History of combustion case cracking history

Cracking of the outer combustion case for the 250-series engine was first identified by the manufacturer in the early 1970s. CEB-A-72-2113/3115 was introduced in 1984 that requested operators of Rolls Royce C28- and C30-series engines to modify or replace the existing outer combustion case with a redesigned component[22]. The replacement outer combustion case was manufactured with a mesh patch that had been brazed in place to reinforce the welded sections within the 'armpit' region.

In August 1986, the US Federal Aviation Administration (FAA) acknowledged the susceptibility to cracking within the earlier model combustion cases by publishing airworthiness directive (AD) 85-25-07. That AD required operators perform a daily inspection of the outer combustion case welds until the redesigned case that contained the brazed mesh patch could be fitted.

In light of the development of cracking in Rolls Royce 250-series outer combustion cases that had been manufactured with the reinforcement mesh patch, a search of several international safety databases[23] was performed for evidence of other related events. As summarised in Table A3, the records showed that from 1993 to 2008 there have been 23 reported occurrences of cracking in the 'armpit' region. The search also showed that cracking was prevalent across the different Rolls Royce engine models that had been fitted to various helicopter types. In all cases, cracking was found on inspection during routine maintenance, unlike the Talbot Bay and Papua New Guinea accidents where a total engine power loss had been experienced during flight.

Table A3: Summary of database reports for Rolls Royce 250-series combustion case 'armpit' cracking

Helicopter model	Engine type	Reported occurrences
Bell 407	RR 250-47B	4
MBB[24] BO 105 S	RR 250-C20B	5
Hughes 369 D	RR 250-C20B	2
Bell 206 (B/L/J models)	RR 250-C20B/30P	10
Sikorsky S76	RR 250-30B	2

[22] Replace all 'old' existing combustion cases (part numbers 6899237 and 23009569), with a 'new' part number 23030910 or 23030911.

[23] a) CASA Service Difficulty Report (SDR) database
b) ATSB Safety Information and Investigation Management System (SIIMS)
c) US Federal Aviation Administration (FAA) SDR database
d) US National Transportation Safety Board (NTSB) investigation database
e) Transportation Safety Board of Canada (TSB) investigation database.

[24] Messerschm itt-Bolkow-Blohm.

ANALYSIS

Engine failure

The Rolls-Royce 250-47B gas turbine engine from the Bell 407 helicopter sustained a rapid loss of power as a result of a catastrophic rupture within the engine's outer combustion case (combustion case). The rupture occurred in the left-side 'armpit' region of the combustion chamber. Structural integrity of the combustion case was a critical requirement for ongoing reliability and continued engine performance. One function of the combustion case was to direct the compressed discharge air from the compressor section and keep it pressurised within the combustor liner. Any reduction in the capability of the combustion case to keep the discharge air pressurised would have resulted in reduced engine performance by not supplying a sufficient flow rate of air to sustain combustion. Once the fatigue crack in the left-side 'armpit' region had grown to a critical size that allowed the case to rupture, the combustion case would not have been able to maintain pressure, which led to an immediate loss of engine power.

Combustion case failure mechanism

From the fracture surface appearance, it was apparent that high-cycle fatigue cracking had been developing through the thin-wall stainless steel skin of the combustion case for some time. Cracks had formed in both the left and right 'armpit' regions, and generally followed the horizontal weld seam between the gas producer and compressor discharge flanges, driven by the stresses generated within the combustion case during engine operation.

While the combustion case had been non-destructively inspected approximately 407 hours prior to the failure, it was possible that sub-critical cracking was present in the casing, but was not detected at that time. Significantly, it was noted that fatigue cracking in the underside 'armpit' region could be difficult to visually detect, due primarily to the physical arrangement of the ducts and the concealing effect of the brazed mesh patch.

Due to its history of cracking problems within the 'armpit' region, the engine manufacturer had redesigned the combustion case in the mid-1980's, incorporating an external wire mesh patch around the 'armpit' region. The brazed patch was intended to reduce the magnitude of the cyclic stresses generated within the 'armpit' region; thus reducing the potential for fatigue crack initiation in that area.

While all three combustion case failures examined during this investigation were the result of a fatigue mechanism, it was apparent in each instance that cracking had initiated within different regions of the combustion case 'armpit' area. In all cases there was evidence of surface discontinuities (pitting corrosion, weld profile changes and shot-peening effects), which could present a localised stress concentration influence. However, there was no suggestion of a common factor among the failures. As such, the principal factor contributing to the initiation of fatigue cracking was considered to have been the general operating stress environment within the combustion case 'armpit' region. While the redesigned combustion case included a mesh patch to strengthen the region, it was apparent in these instances, that the effective reduction in cyclic stress magnitude had been insufficient to negate the initiation of cracking.

Other combustion case failures

ATSB research showed that a complete rupture leading to total engine power loss is a rare event for the Rolls-Royce 250 series engine. Only two complete ruptures were identified; the Australian registered Bell 406 (VH-NSH) from Talbot Bay, and the Papua New Guinea registered Bell 206L4 (P2-PBF). A third combustion case from a Sikorsky S-76 was examined and found to have been also cracked in the ‘armpit’ region. While a total rupture of the casing as sustained in case of VH-NSH is a low-probability event, a search of the international databases indicated that cracking was still an ongoing issue for operators around the world. Although the combustion cases are now manufactured with a reinforcing mesh patch, the events examined during this investigation would suggest that the patch is not completely effective at limiting the susceptibility of the combustion case component to fatigue cracking within the ‘armpit’ region.

CONCLUSIONS

The following conclusions are made with respect to the engine and component examination:

- the sudden power loss of the Rolls Royce 250-47B engine was consistent with a catastrophic rupture of the outer combustion case (combustion case)
- crack growth in the combustion case was due to high-cycle fatigue that was most likely to have been initiated and driven by stresses developed within the combustion case during engine operation
- crack growth in the combustion case had been occurring slowly over a considerable period of service
- the design of the brazed wire mesh patches on the outside of the housing of the combustion case was ineffective in reducing operational stresses below the limiting threshold for fatigue crack initiation.

APPENDIX B: CASA Airworthiness Bulletin

Australian Government
Civil Aviation Safety Authority

AIRWORTHINESS BULLETIN

Rolls Royce 250 Engine Outer Combustion Case (OCC) Failure

AWB 72-003 **Issue :** 1
Date : 23 October 2008

1. Applicability

All Rolls Royce (RR) 250 Series engines with Outer Combustion Case (OCC) Part Number (P/N) 23030911 eligible for installation 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

This AWB has been raised in co-ordination with the ATSB in order to urgently advise operators and maintainers of an unusual and catastrophic failure of the OCC of a RR 250 C47 engine. There is one CASA Service Difficulty Report (SDR) relating to a RR 250 C30 engine which also suffered similar OCC cracking.

3. Background

The ATSB is currently conducting an investigation into the burst rupture of an OCC. See Figure 1, below. The rupture occurred immediately after take-off, resulting in the complete engine power loss. This resulted in the helicopter, a Bell 407, ditching.

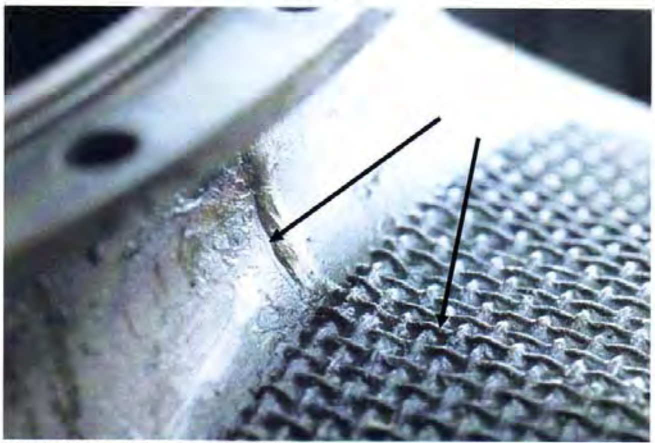
Figure 1.

RR 250 C47B OCC Rupture failure (RH Side).

At this point of the ATSB investigation, it appears the failure is likely to have originated from somewhere either under or adjacent to the reinforced area of the OCC ("the armpit area") on the inside bend of the duct, close to the welded seam. See Figures 2 & 3, which show cracking in the other side of the same OCC in which the rupture occurred.

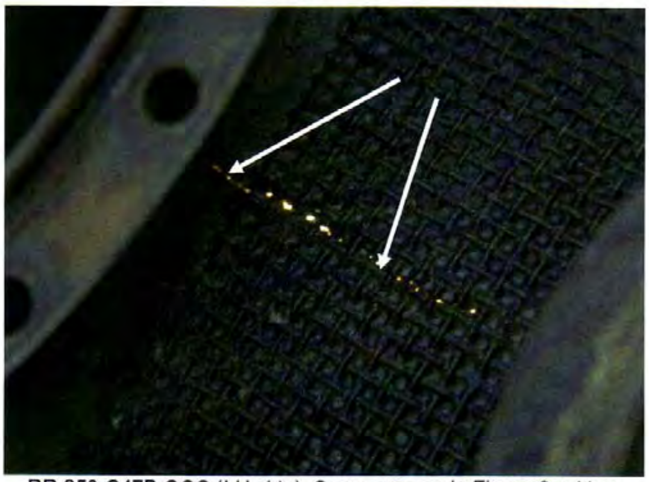
CASA has one Service Difficulty Report of cracking in a C30 OCC, where cracking occurred under (or in) the same reinforced area located on the inside bend as the occurrence duct.

Figure 2.



RR 250 C47B OCC (LH side). Area of cracking, but on the other side of the duct shown in Figure 1.

Figure 3.



RR 250 C47B OCC (LH side). Same area as in Figure 2, with a strong light placed inside the OCC, beneath the suspect area described in this AWB.

Since the ATSB investigation is in its early stages, it is more than likely that this AWB will be amended to include further recommendations as the ATSB investigation proceeds and additional information becomes available.

4. Recommendation

In order to detect cracking at the earliest opportunity, CASA urgently recommends that operators and maintainers immediately and frequently thereafter, conduct an inspection of the suspect areas of the duct, paying close attention to the area on inside bends of both sides of the duct.

Such inspections should be conducted using a suitable inspection technique, such as a close inspection using a 10X magnifying glass. One suggestion has been to apply a leak check bubble solution to the suspect area while motoring the engine, but CASA is open to proposals describing other inspection methods which may prove to be effective.

All instances of cracked OCC's should be reported to CASA via the SDR system. This includes cracked OCC's discovered during operation or overhaul, which may not have been previously reported. Such information will assist the ATSB in their investigation and allow CASA to develop a comprehensive response to the problem.

5. Enquiries

Enquiries with regard to the content of this Airworthiness Bulletin should be made via the direct link e-mail address:
AirworthinessBulletin@casa.gov.au

Or in writing, to:

Airworthiness Engineering Group
Systems and New Technologies,
GPO Box 2005, Canberra, ACT, 2601

APPENDIX C: SOURCES AND SUBMISSIONS

Sources of information

The sources of information during the investigation included the:

- pilot of VH-NSH
- Chief Pilot/owner operator
- maintenance provider
- engine manufacturer
- component manufacturer for the engine control unit
- passengers from the flight
- cruise ship passengers
- Civil Aviation Safety Authority (CASA).

Submissions

Under Part 4, Division 2 (Investigation Reports), Section 26 of the *Transport Safety Investigation Act 2003*, 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 the pilot, Chief Pilot/owner operator, helicopter and engine manufacturers, maintenance provider, Transport Safety Board of Canada, US National Transportation Safety Board and CASA.

Submissions were received from the helicopter manufacturer via the Canadian Transportation Safety Board and the aircraft operator. The submissions were reviewed and where considered appropriate, the text of the report was amended accordingly.

Total power loss, Talbot Bay, Western Australia, 25 September 2008,
VH-NSH Bell Helicopter Co 407.