



Australian Government

Australian Transport Safety Bureau

Engine failure involving Airbus Helicopters AS355F-1, VH-SEV

Bankstown Airport, New South Wales on 12 March 2018

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Addendum

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Safety summary

What happened

At about 0828 Eastern Daylight-saving Time (EDT), on 12 March 2018, an Airbus Helicopters AS355F-1 helicopter, VH-SEV, operated by Rotor Head, air taxied from the hangar to the maintenance facility at Bankstown Aerodrome, New South Wales with the pilot and one passenger on board.

After about 5 minutes in flight, the pilot commenced the landing. As the skids touched the ground, the pilot observed the right-hand engine chip light illuminate and smoke coming from the right-hand side of the aircraft. The pilot immediately shut down the right-hand engine. Mechanics from a nearby workshop ran out and extinguished the engine fire.

The aircraft sustained significant damage to the engine and minor heat damage to the surrounding structure.

What the ATSB found

A single third-stage turbine wheel blade failed due to fatigue cracking, resulting in secondary damage to the engine and total engine failure. The rapid fatigue crack progression was probably caused by a momentary dwell in the speed avoidance range.

A number of fatigue cracks were present but not detected during the last inspection of the third-stage wheel. The size and nature of the cracks meant there was a low probability of detection using the method specified.

What's been done as a result

Rolls-Royce are in the process of redesigning the third-stage turbine wheel to improve its tolerance to fatigue cracking and operation at responsive wheel modes.

Safety message

Any operator, irrespective of their level of experience, can find themselves confronted with an unexpected failure. Therefore, it is important for operators to monitor aircraft performance parameters continuously for abnormal indications. Acting quickly to shut down malfunctioning hardware and following failure management procedures will ensure the best possible safety outcome, as demonstrated by the pilot in this occurrence.

During this investigation, Rolls-Royce advised the ATSB of a few key points regarding the operation of the Rolls-Royce 250 enhanced power turbine engine:

- A dwell in the order of a few seconds can be enough to initiate damage and propagate a crack to failure.
- The best way for an operator to monitor the transition through the speed avoidance range is to watch the needle on the N2 tachometer. If the needle stops, that constitutes a dwell.
- If an operator recognises or suspects an inadvertent dwell in the speed avoidance range, contact Rolls-Royce for advice.



Source: ATSB

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The occurrence

At about 0828 Eastern Daylight-saving Time (EDT)¹ on 12 March 2018, an Airbus Helicopters AS355F-1 Helicopter, registered VH-SEV (SEV), operated by Rotor Head, air taxied from the hangar to the maintenance facility at Bankstown Airport, New South Wales for a routine maintenance inspection with the pilot and one passenger on board.

After about 5 minutes in flight, the pilot commenced the landing. As the skids touched the ground, the pilot recalled hearing a loud squeal from the right-hand side of the aircraft. The pilot scanned the instrument panel and observed the engine gas generator speed (Ng) drop to 55 per cent and the right-hand engine chip light illuminate. A few seconds later, the pilot saw smoke coming from the right-hand side of the aircraft and he immediately shut down the right-hand engine. Mechanics from a nearby workshop witnessed the event and acted quickly to extinguish the fire on the right-hand engine.

The incident resulted in substantial damage to the right-hand engine and minor heat damage to the surrounding structure on the aircraft.

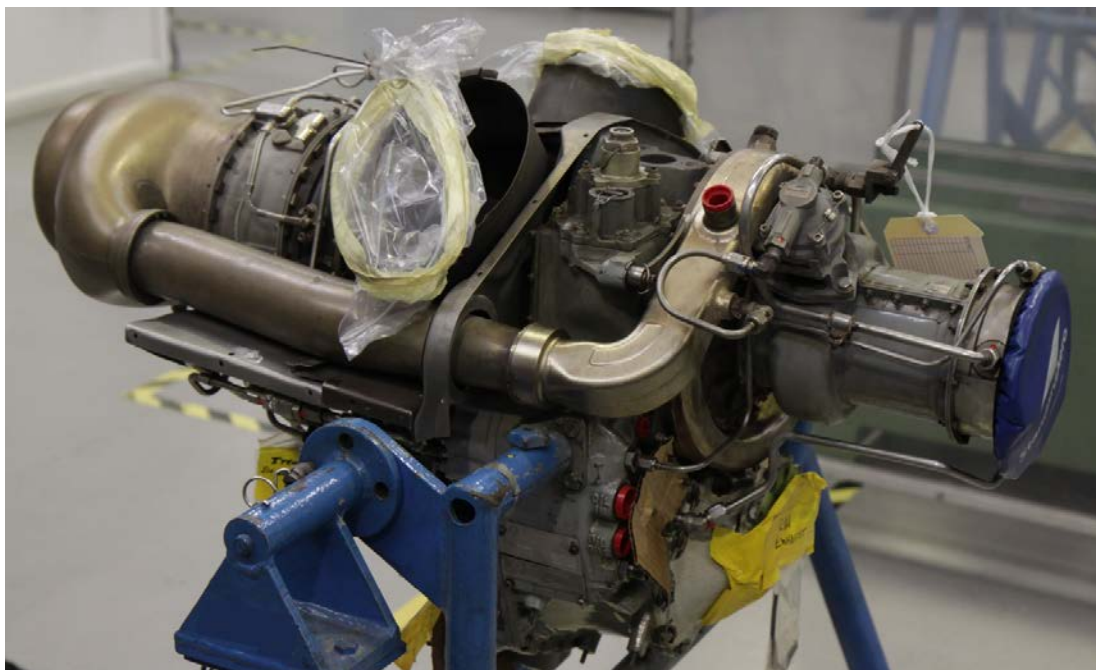
¹ Eastern Daylight-saving Time (EDT): Coordinated Universal Time (UTC) + 11 hours.

Context

Aircraft information

The aircraft was an AS355F-1 helicopter manufactured in 1982 and first registered in Australia in 1994 (VH-SEV). It was a six-seater, twin-engine helicopter powered by two Allison 250-C20F turboshaft engines (Figure 1), with enhanced power turbine wheels.

Figure 1: Right-hand engine from VH-SEV



Source: ATSB

Engine maintenance

On 31 January 2018, a heavy maintenance inspection was conducted on the engines installed on SEV. The maintenance included actions required for compliance with the relevant airworthiness directive (AD) and commercial engine bulletins (CEB) (see the section titled *Aircraft safety alerts*). Some of the maintenance items on the turbine section (Figure 2) of the right-hand engine included:

- replacement of the first-, second- and fourth-stage turbine wheels
- fluorescent penetrant inspection (FPI) on the third-stage turbine wheel (there were no crack indications identified during the inspection).

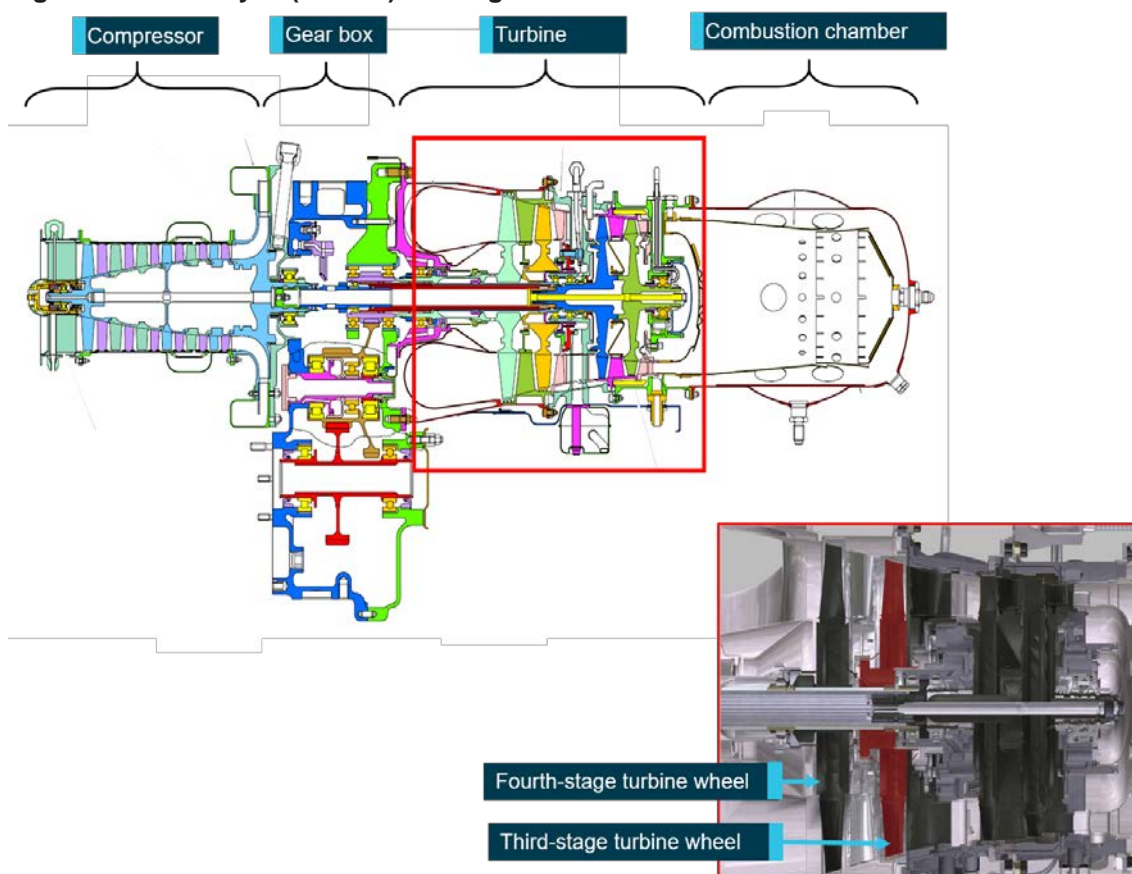
The reliability of FPI is measured in terms of probability of detection (POD) and is dependent upon the component material and geometry in addition to the nature of the defect.² The engine manufacturer had not developed POD curves specifically for the third-stage wheel, however, based on industry reports, they advised that the POD of a 0.070 inch³ long crack was 0.95 and for cracks smaller than 0.045 inches in length, the POD was considered to be around 0.4.

The aircraft was returned to service on 5 February 2018 and operated for 24 flight hours (22 cycles) before the right-hand engine failed.

² Experimental estimation of POD usually requires a large number of service-expired engine turbine disks. Alternatively, the POD studies can also be carried out using laboratory induced samples containing various sizes of defects.

³ The imperial unit for length. 1 inch (in) is equal to 25.4 mm.

Figure 2: Rolls-Royce (Allison) 250 engine cross section



Source: Rolls-Royce, annotated by the ATSB

Aircraft safety alerts and operations manual

Airworthiness directive 2017-18-14 and commercial engine bulletin 1407

AD 2017-18-14 was released in October 2017.⁴ The AD was initially prompted by turbine wheel blade failures on the third- and fourth-stage wheels, which led to engine failure and damage to the aircraft.

The AD stipulated a number of measures that affected SEV, which included:

- Every 1,775 hours, remove the third-stage turbine wheel to perform a visual inspection and FPI for cracks.
- Remove and replace any turbine wheels found to have cracks at the trailing edge (near the fillet at the rim) of the turbine blades.

CEB 1407 was released in association with AD 2017-18-14 and provided additional guidance on how to conduct the FPI and visual inspection on the third-stage turbine wheels.

Commercial engine bulletin 1400

CEB 1400 provided advanced notification of actions pertaining to the third- and fourth-stage turbine wheels that were later incorporated into all applicable Model M250 Series II engine operation and maintenance manuals.

⁴ The AD was first released as AD 2012-14-06 in 2012. The AD was subsequently revised and replaced with AD 2015-02-22 in 2015 and then again in 2018 by AD-2017-18-14

CEB 1400 was first released in December 2006. At the time of the incident, CEB 1400 revision 5 was in effect. The bulletin enforced a speed avoidance range for some Rolls-Royce M250 engines, which included the C20 series. The speed avoidance range was designed to reduce engine vibrations at resonant frequencies (or responsive wheel modes), which are known to accelerate fatigue cracking on the third- and fourth-stage wheel turbine blades.

For the parts installed on VH-SEV⁵, a mandatory 75-88 per cent engine N2⁶ steady-state speed avoidance range was required for all flight and ground maintenance operational practices. Transient operation only was permitted in the speed avoidance range 75-88 per cent N2. All other operation in the band was prohibited; in particular steady-state or continuous operations (any dwell of more than 1 second).

The Rolls-Royce service bulletin did not provide actions to carry out in the event of an inadvertent dwell in the speed avoidance range. Rolls-Royce advised, however, that operators should contact them for further advice should this occur.

M-250 C20 Operations and maintenance manual

At the time of the occurrence, the operations and maintenance manual for the engine specified the speed avoidance range and directed the user back to CEB 1400 for further guidance relating to the speed avoidance restriction.

Above the speed avoidance range notation, the consequence of not complying with the limitations was stated as:

WARNING: TO PREVENT SERIOUS ENGINE MALFUNCTION OR CRUCIAL LOSS OF POWER,
DO NOT OPERATE THE ENGINE IN EXCESS OF ANY SPECIFIED LIMIT.

Pilot-related information

The pilot of VH-SEV (SEV) was an experienced helicopter pilot, with about 10,600 hours total flying time and about 4,400 hours on type.

The 71-88 per cent N2 speed avoidance range observed by the pilot was a conservative range that encompassed the engine manufacturer's guidance (see the section titled *Aircraft safety alerts and operations manual*). The avoidance range was marked at the bottom of the instrument panel (Figure 3). The pilot's standard start-up and shut-down procedures were to transition between ground idle (approximately 63 per cent N2) and 100 per cent N2 in a continuous motion through the speed avoidance range. The pilot stated that there were no operational parameters that required operation in the avoidance range.

⁵ SEV was fitted with third-stage wheel part number 23065818 and fourth-stage wheel part number M250-10445.

⁶ N2: the rotational speed of the power turbine.

Figure 3: VH-SEV instrument panel showing decal with speed avoidance range



Source: Rotor Head

Engine examination specialist reports

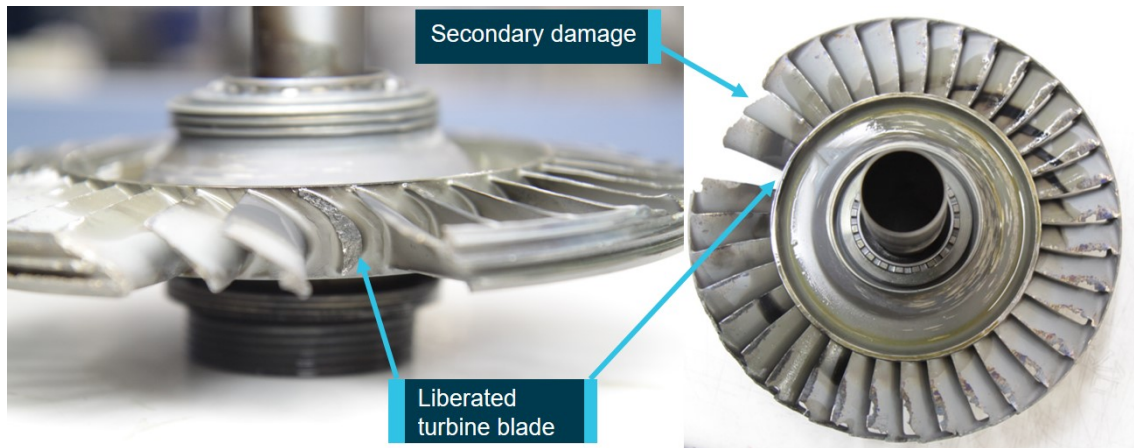
Engine examination report

Following the incident, an engine examination was conducted at an engine maintenance facility with the assistance of Rolls-Royce. The following observations were made during the examination:

- The damage was limited to the turbine section of the engine.
- One blade on the third-stage turbine wheel had liberated, resulting in substantial secondary damage to the wheel (Figure 4).
- Damage to the other engine components was consistent with secondary damage caused by rotor imbalance and impact damage from debris (Figure 5).⁷

⁷ Based on the manufacturer's previous experience and comparison with examination of other engines known to have a liberated blade on the third-stage wheel.

Figure 4: Third-stage turbine wheel removed from VH-SEV showing damage



Source: ATSB

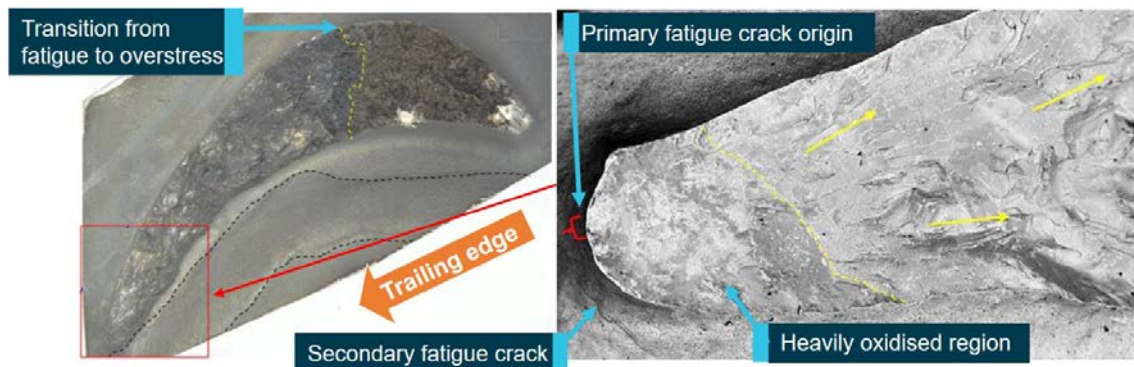
Rolls-Royce failure analysis

Following the engine examination, Rolls-Royce conducted metallurgical failure analysis on the third-stage wheel. The laboratory report included the following findings:

- The microstructure, chemistry and hardness of the third-stage turbine wheel were consistent with the engineering requirements.
- Using FPI, 21 of the remaining 34 third-stage turbine wheel blades were found to have crack-like indications on the trailing edge. The indications ranged in length from 0.007 inches to 0.045 inches.
- One third-stage turbine wheel blade fractured and separated due to fatigue cracking. The fracture surface showed two distinct fatigue regions:
 - The initial portion of the crack was consistent with the crack-like indications in the trailing edge of the blades. It was 0.069 inches in length and characterised by oxidation across the fracture surface. The number of fatigue striations indicated that this portion of the crack was present at the time of the maintenance inspection. However, the exact size of the crack at the time of the inspection could not be determined.
 - The crack then transitioned to a high cycle fatigue cracking mechanism, progressing towards the leading edge, before the blade liberated in overload (Figure 5).

One of the blades with crack-like indications was selected for further analysis. The blade was lab-fractured and the fracture surface compared to that of the liberated blade. The crack was measured to be 0.045 inches in length and the crack morphology was found to be consistent with the initial portion of the failed blade.

Figure 5: Fracture surface of liberated blade on third-stage turbine wheel



Source: Rolls-Royce, annotated by the ATSB

Third-stage turbine wheel failures

Since the release of the enhanced third-stage turbine wheel (as installed on SEV) in 1999, there have been nine reported in-service failures. At the time of writing this report, the enhanced fleet (C20 Series, C20R Series, B17 Series, and B17F Series engines) had accumulated approximately 8.2 million flight hours. The failure rate of the third-stage wheels is therefore 1 in 911,111 flight hours. Rolls-Royce is working on design changes to reduce the risk to 'As low as reasonably practicable' (ALARP).

Additionally, 21 third-stage wheels have been returned to Rolls-Royce after crack-like indications were identified during the maintenance inspections required by AD 2017-18-14 (and previously released versions).

Of the nine reported in-service failures:

- Four investigations were conducted (three by the National Transportation Safety Board (USA) and one by the Transportation Safety Board (Canada)) between 2003 and 2017.
- In each instance, at least one blade on the third-stage turbine wheel liberated because of fatigue, resulting in an engine failure. Analysis showed similar crack morphology to that found on the third-stage wheel of SEV.
- At the time of those investigations, Rolls-Royce was unable to identify a single root cause for the liberation of the turbine blades.

Examination of the returned turbine wheels and further simulated analysis enabled Rolls-Royce to develop a better understanding of the failures. With improved knowledge, Rolls-Royce has now stated that high cycle fatigue crack progression only occurs when there is steady-state operation of the engine at a responsive wheel mode. The responsive wheel modes were identified in CEB 1400 and are specified as the speed avoidance range.

In 2011, Rolls-Royce learnt that there was an issue with the maintenance practices for MD Helicopters (in particular the MD-500, which had seen 2 blade failures in the 1999-2009 period). This error resulted in the maintenance personnel sometimes dwelling the engine in the speed avoidance range while doing track and balancing of the main rotors. In 2011, MD changed their track and balance procedure specifically to address this issue.

Additional information

Rolls-Royce provided the following additional information to the ATSB regarding the engine failure:

- Fatigue crack growth under normal operational loading is very slow. Cracks initiated under this regime on the trailing edge of the turbine wheel blade will not propagate to failure in the life of the wheel (4,550 flight hours, 6,000 flight cycles) if the aircraft is operated in accordance with CEB 1400.
- There does not need to be a pre-existing fatigue crack on a blade for the steady-state engine operation at a responsive wheel mode to cause blade failure.
- The blade failure event and operation on a responsive wheel mode may not have occurred simultaneously.
- A dwell in the order of a few seconds in the speed avoidance range is sufficient to cause a crack to propagate in high cycle fatigue.
- A pilot can identify a dwell by watching the needle on the tachometer. If the needle remains stationary for any period of time this would indicate a dwell.

The pilot did not recall any incidents where the N2 speed had dwelled in the speed avoidance range between the last maintenance inspection (see the section titled *Engine maintenance*) and the incident flight. The pilot indicated that while he was aware of the speed avoidance range and

was careful to avoid continuous operation within it, he was not aware that a dwell in the order of a few seconds could result in total failure of the engine.

Safety analysis

Engine failure

Metallurgical analysis of the fracture surface of the single liberated turbine blade showed conclusively that the blade had failed under fatigue loading. The fracture type and location of the primary crack was as described in AD-2017-18-14.

Damage was limited to the turbine section of the engine, with the power turbine exhibiting a significant amount of scoring inside the engine casing and a fractured turbine to compressor coupling shaft. This damage is consistent with damage from rotor imbalance resulting from the release of a turbine blade. With the exception of the third-stage wheel, the remainder of the damage was identified as impact damage from debris. In addition, Rolls-Royce stated that the damage to the SEV engine was consistent with that found during previous examinations on engines known to have third-stage wheel failures.

In summary, a single third-stage turbine wheel blade failed due to fatigue cracking, resulting in secondary damage to the engine and total engine failure.

Third-stage turbine wheel fatigue cracks

Rolls-Royce's analysis of the failed and lab-fractured blade concluded that at least two fatigue cracks existed at the time of the last maintenance inspection. Given the large number of blades found with crack-like indications, it is likely that some or all of the indications on the remaining blades were present at the time of the inspection.

In the event that any of the cracks had been detected, the correct course of action (per the requirements of AD-2017-18-14) would have been to remove the wheel from service. The primary fatigue crack on the liberated blade was measured to be 0.069 inches and the remainder of the crack-like indications were a maximum of 0.045 inches long. The probability of detection of any one crack less than 0.045 inches was estimated to be 0.4. Therefore, the indications existing at the time of inspection were likely to be so small that the probability of detecting any one of the cracks in the turbine blades was low.

It was therefore concluded that a number of fatigue cracks were present but not detected during the last inspection of the third-stage wheel. However, due to the size and nature of the cracks there was a low probability of detection using the specified method.

Rapid fatigue crack progression

The primary fatigue crack on the liberated blade was no greater than 0.069 inches in length at the time of the inspection. Within 24 flight hours (22 flight cycles) the fatigue crack progressed to more than 50 per cent of the blade cross section. That is, it propagated to the critical crack length in under 0.5 per cent of the expected life of the wheel.

The manufacturer's analysis showed that under normal operational loading, a crack indication at the trailing edge of the blade would not progress to failure within the life of the wheel (4,550 flight hours, 6,000 flight cycles). Physical examination of the fracture surface verified that the blade did not fail because of a material or component defect, or impact damage. Rolls-Royce identified that the crack propagated under high cycle fatigue loading, which it determined was the result of steady state operation of the engine at a responsive wheel mode (defined as the speed avoidance range). Without recorded flight data, however, a dwell in the speed avoidance range could not be verified.

The pilot had significant experience on this aircraft and had never had any previous engine failures using his standard power up/down process. The pilot was aware of the speed avoidance range and did not recall dwelling in the range between the engine maintenance and the incident

flight. However, given that the damage can occur in the order of a few seconds, it is possible that a momentary distraction during the power-up or -down phase could have resulted in an inadvertent, unnoticed dwell.

While it was not possible to verify the operation of the aircraft, based on examination of the fracture surfaces and expert opinion, the rapid fatigue crack progression in the third-stage wheel was probably caused by a momentary dwell in the speed avoidance range.

Findings

From the evidence available, the following findings were made with respect to the engine failure involving Airbus Helicopters AS355F-1, registered VH-SEV at Bankstown Aerodrome, New South Wales on 12 March 2018. These findings should not be read as apportioning blame or liability to any particular organisation or individual.

Contributing factors

- A single third-stage turbine wheel blade failed due to fatigue cracking, resulting in secondary damage to the engine and total engine failure.
- The rapid fatigue crack progression in the third-stage wheel was probably caused by a momentary dwell in the speed avoidance range.

Other factors that increased risk

- A number of fatigue cracks that would have required removal of the third-stage turbine wheel from service were present, but not detected during the last inspection. The size and nature of the cracks meant there was a low probability of detection using the specified inspection method.

Safety issues and actions

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

Rolls-Royce

To reduce the risk of engine failure events, Rolls-Royce is re-designing the third-stage turbine wheel to improve the strength and durability of the component. The main feature of the new design is a larger fillet at the blade trailing edge, which will reduce the stress at the critical location, resulting in a more durable component with greater tolerance to fatigue cracking and operation at responsive wheel modes. The new design was expected to be released at the end of 2020.

Since this occurrence, Rolls-Royce has also updated CEB 1400 (Revision 7) and the operations manual to simplify the speed avoidance range and more clearly articulate the possible consequence of dwelling. The operations manual now states:

WARNING: TO PREVENT POSSIBLE POWER TURBINE FAILURE, TRANSIENT OPERATION ONLY IS PERMITTED IN THE N2 SPEED AVOIDANCE RANGE. ALL OTHER OPERATION IN THIS RANGE IS PROHIBITED.

Airbus Helicopters

Airbus Helicopters published Safety Information Notice No. 3289-S-72 in October 2018 (Appendix A and available at www.airbushelicopters.com/techpub/) to highlight CEB 1400 and the risk of malfunction from an engine dwell within the identified resonant ranges.

General details

Occurrence details

Date and time:	12 March 2018 – 0828 EDT	
Occurrence category:	Serious incident	
Primary occurrence type:	Technical – Engine failure or malfunction	
Location:	Bankstown Aerodrome, New South Wales	
	Latitude: 33° 55.47' S	Longitude: 150° 59.3' E

Aircraft details

Manufacturer and model:	Airbus Helicopters, AS355F1	
Year of manufacture:	1982	
Registration:	VH-SEV	
Operator:	Rotor Head	
Serial number:	5272	
Type of operation:	Aerial Work	
Persons on board:	Crew – 2	Passengers – Nil
Injuries:	Crew – Nil	Passengers – Nil
Damage:	Minor	

Sources and submissions

Sources of information

The sources of information during the investigation included the:

- engine manufacturer (Rolls-Royce)
- engine maintenance provider
- aircraft owner
- pilot.

Submissions

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

A draft of this report was provided to the pilot, the aircraft owner/operator, the engine manufacturer (Rolls-Royce), the engine maintenance provider, the Civil Aviation Safety Authority and the French Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile (BEA).

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

Appendices

Appendix A – Airbus Helicopters safety information notice


No. 3289-S-72

SAFETY INFORMATION NOTICE

SUBJECT: ENGINE
Rolls Royce engine 250C20-F - Compliance with CEB 1400A


AIRCRAFT CONCERNED	Version(s)	
	Civil	Military
AS355	F, F1, F2	
AS555		AF

Airbus Helicopters would like to draw your attention to the consequences of compliance with CEB 1400A (rev. 6 dated April 2018) issued by Rolls Royce, concerning engines 250C20F.

This CEB 1400A describes a risk of malfunction on some power turbines (3rd and/or 4th stage), depending on the exposure to a power range.

Rolls Royce found a risk of resonance according to the combination of frequency N2 + high power level, depending on the turbine standard:

- *Enhanced wheel*: resonance mode between 71-88% engine N2, i.e. 280-347 rpm NR equivalent,
- *Non-Enhanced wheel*: resonance mode between 87-95% engine N2, i.e. 343-374 rpm NR equivalent

Rolls Royce prohibits remaining in these power ranges in continuous operation and authorizes transient crossing for a duration of 1s maximum.

In AEO mode, each engine of the AS355 F, F1, F2 / AS555 AF helicopters remains outside the prohibited range in nominal operation, take-off excluded. The nominal N2 of AS355 F, F1, F2 / AS555 AF helicopters is between 97 and 100%, which corresponds to NR = 390+4/-5 rpm.

If an OEI engine failure occurs, depending on the aircraft weight and the power required in the different failure phases, there is a strong possibility of incursion of N2 < 95% (NR 374 rpm NR equivalent).

It is more likely that the power range to be avoided during real OEI operation is entered if the engine is equipped with a "Non Enhanced Wheel" power turbine. However, it is still possible that the range is entered if the engine is equipped with an "Enhanced Wheel" power turbine.

This is why Rolls Royce requests the removal of the engine and the replacement of the turbine if an OEI event occurs.

Also, engine power can be voluntarily reduced to perform engine failure training. The consequences for N2 are identical to those of a real engine failure when one of the engines operates asynchronously. As for real engine failure, it is probable that N2 cannot systematically be maintained above 95% during various training phases.

Thus, Airbus Helicopters asks you to contact the engine manufacturer to study the possible options if engine failure training is scheduled.

Revision 0 2018-10-29

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 This document is available on the internet: www.airbushelicopters.com/techpub/

Australian Transport Safety Bureau

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

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

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

Purpose of safety investigations

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

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

Developing safety action

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

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

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

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

Terminology used in this report

Occurrence: accident or incident.

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

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

- (a) the occurrence would probably not have occurred; or
- (b) the adverse consequences associated with the occurrence would probably not have occurred or have been as serious, or
- (c) another contributing factor would probably not have occurred or existed.

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

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