Australian Government

Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY REPORT

Occurrence Investigation Report AO-2008-062

Final

Collision with terrain
6 km NE Purnululu ALA, Western Australia
14 September 2008
VH-RIO
Robinson Helicopter Company R44 Raven

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Abstract

On 14 September 2008, a Robinson Helicopter Company R44 Raven helicopter, registered VH-RIO, was being operated on a series of scenic flights in the Bungle Bungle ranges area of the Purnululu National Park, which was about 250 km south of Kununurra, Western Australia. At about 1230 Western Standard Time, the helicopter departed the Purnululu Aircraft Landing Area for an 18-minute scenic flight with the pilot and three passengers. When the helicopter did not return by the nominated time, a search was initiated. Shortly after, the burnt wreckage of the helicopter was located. The four occupants were fatally injured.

The pilot had deviated from the regular scenic flight track, speed and profile to operate out of ground effect (OGE) in close proximity to the terrain at a low airspeed or at the hover. The helicopter's estimated OGE hover performance was marginal. It is likely that the high level of engine power required to sustain a hover in the local conditions was not available, or not fully utilised by the pilot, resulting in; an uncommanded descent, overpitching of the main rotor as a result of the pilot's attempts to arrest that descent, and a main rotor RPM decay that significantly increased the rate of descent.

As a result of the investigation into this occurrence, two minor safety issues were identified:

- There was no Australian requirement for endorsement and recurrent training conducted on Robinson Helicopter Company R22/R44 helicopters to specifically address the preconditions for, recognition of, or recovery from, low main rotor RPM.
- There was a lack of assurance that informal operator supervisory and experience-based policy, procedures and practices minimised the risk of pilots operating outside the individual pilot's level of competence.

In response, the aircraft operator has since formalised the operating parameters applicable to pilots conducting scenic flights. In addition, the Civil Aviation Safety Authority will be reviewing the training requirements affecting R22/44 helicopters. The Australian Transport Safety Bureau has issued a Safety Advisory Notice to encourage operators to address the risk of their pilots operating outside the individual pilot's level of competence.

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.

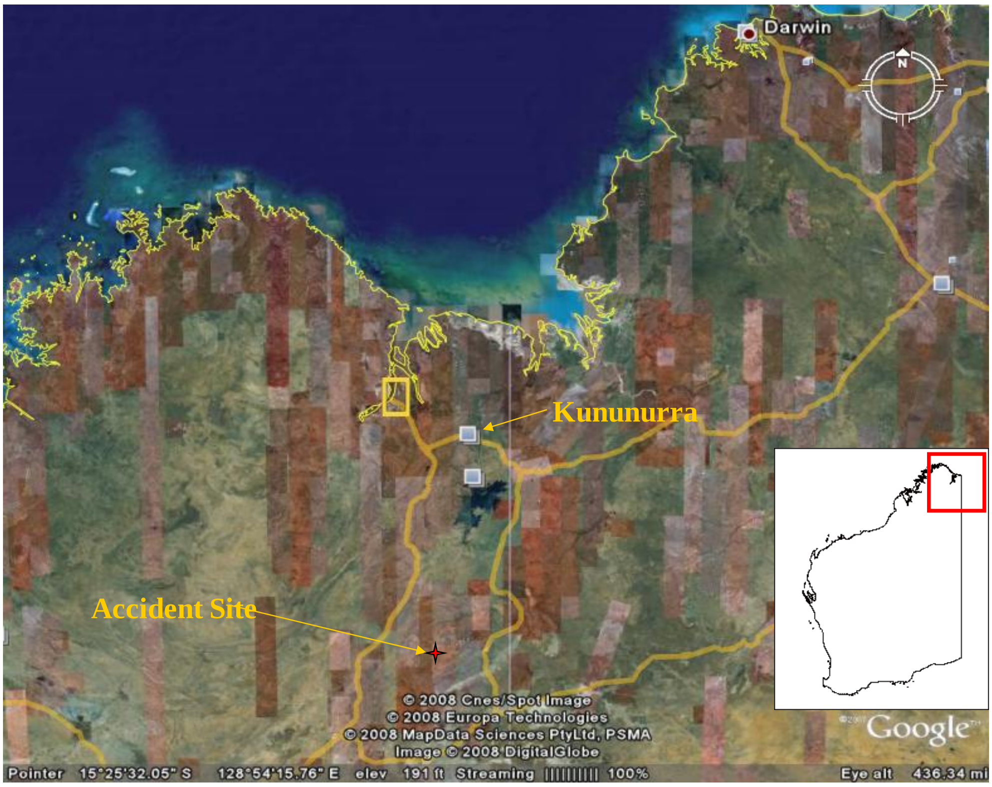
Safety action: the steps taken or proposed to be taken by a person, organisation or agency in response to a safety issue.

FACTUAL INFORMATION

Sequence of events

On 14 September 2008, a Robinson Helicopter Company R44 Raven helicopter, registered VH-RIO (RIO), was being operated on a series of scenic flights in the Bungle Bungle ranges area of the Purnululu National Park, which was about 250 km south of Kununurra, Western Australia (Figure 1).

Figure 1: General location of the accident



The helicopter was one of four R44 helicopters operated from the operator's sub-base at Purnululu Aircraft Landing Area[1] (ALA), which was located at the south-western tip of the ranges. Between 0853 and 1100 Western Standard Time[2], three scenic flights were conducted in the helicopter by other pilots without incident. At about 0900, the occurrence pilot completed an uneventful scenic flight with two passengers in another R44 helicopter.

Shortly before 1230, the occurrence pilot, with three passengers, started the engine in readiness for an 18-minute scenic flight that included the over-flight of Deep and Piccaninny Gorges, the Domes and Coalition (Figure 2). A company pilot on the

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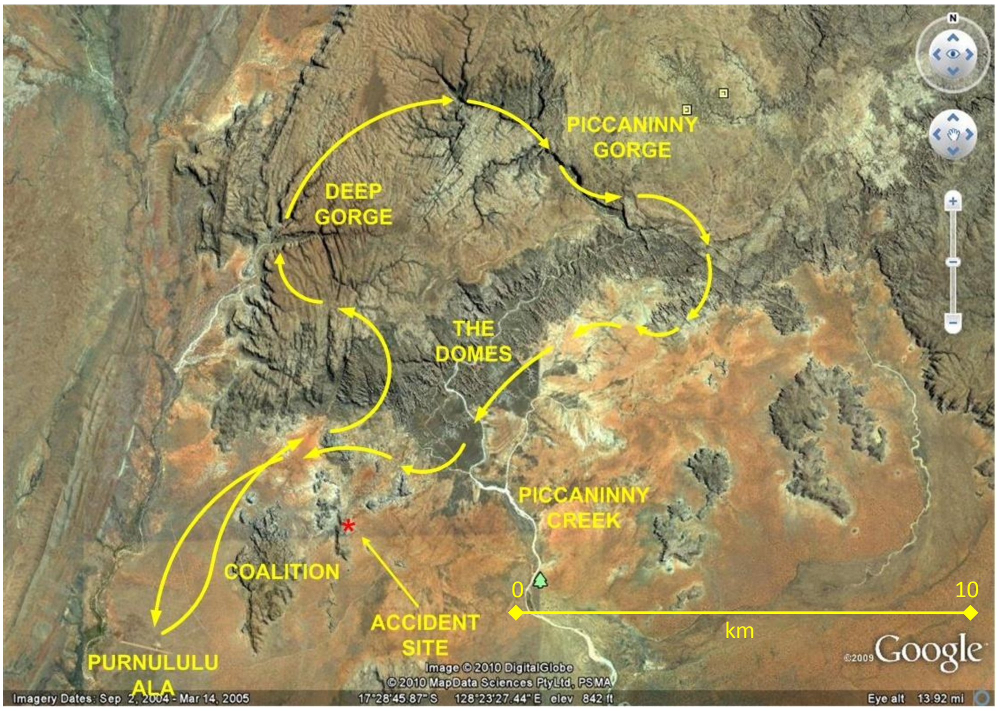
1 Aircraft landing area (ALA) means a place that may be suitable for the landing and takeoff of an aircraft of appropriate certification and performance, but that may not fully meet formal standards of construction, marking, maintenance or reporting.

2 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.

ground at the ALA recalled hearing the helicopter's low rotor RPM horn being tested in preparation for departure, and confirmed that time to have been about 1230. Shortly after, the helicopter departed to the north-east without any noticeable abnormalities.

Figure 2: Indicative route for the 18-minute Bungle Bungle scenic flight



The pilot had nominated a search and rescue (SAR) time (SARTIME[3]) of 1250 for the flight. The SARTIME was monitored by other company pilots at the ALA.

At about 1250, when the helicopter had failed to return to the ALA, a company pilot at the ALA attempted to contact the pilot via ultra high frequency (UHF) and very high frequency (VHF) radios, but without success.

At about 1253, a company pilot departed the ALA in another helicopter with the expectation that communications may be established at a higher altitude.[4] Shortly after becoming airborne, that pilot noticed smoke to the north-east of the ALA and flew to its location. On arrival in the area of the smoke, the pilot observed that the helicopter had collided with the ground. After assessing the situation, the pilot returned to the ALA and notified the operator of the accident.

Officers from the Department of Conservation and Environment responded to the fire and arrived at the accident site at about 1330. Those officers confirmed that the pilot and three passengers had been fatally injured.

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3 SARTIME. The time nominated by a pilot for the initiation of SAR action if a report has not been received by the nominated party.

4 UHF and VHF radios operate line-of-site. Any intervening terrain or other obstacle can impact radio reception.

The helicopter was seriously damaged[5] by impact forces and an intense post-impact fire. A number of time pieces on board the helicopter ceased operating at about 1251. The precise reason for those stoppages could not be determined.

On-board photography

A camera that was recovered from the accident site contained a number of digital images that were taken by one of the passengers. Some of those images provided an indication of the helicopter's flight path and relative timing in hours and minutes during the flight. The properties of an image taken as the aircraft was departing the ALA showed that it was recorded at 1230.

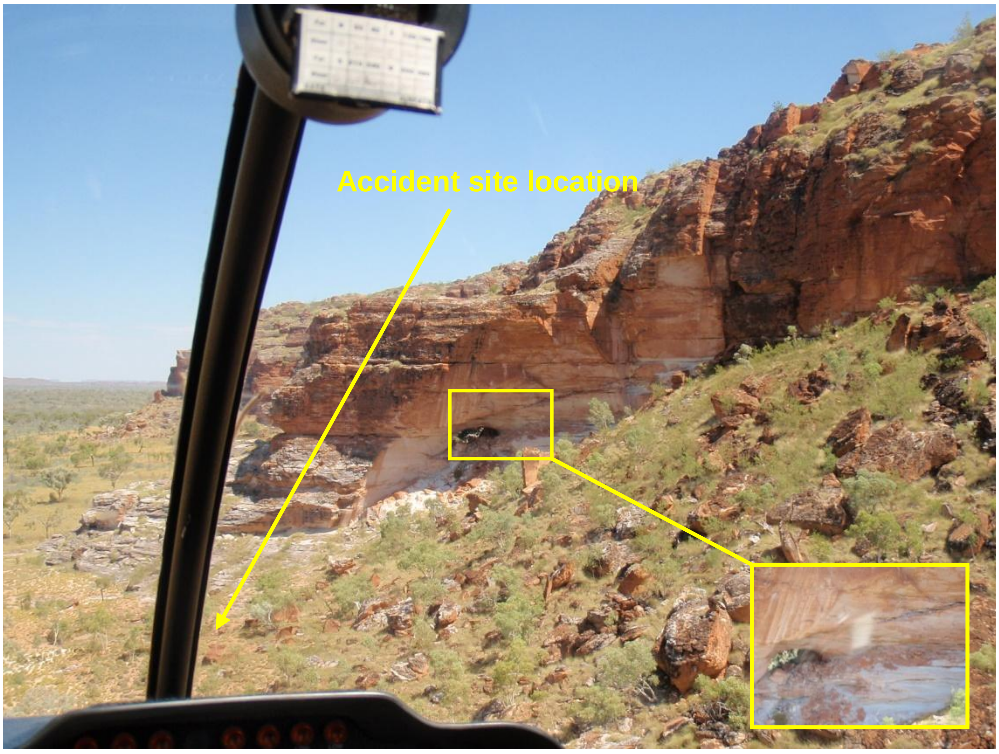
A series of images taken between 1244 and 1245 showed the helicopter diverging from the regular scenic route and tracking to the south towards an area that contained distinctive rock formations (Figures 3, 4 and 5). The helicopter's speed and height, as derived from this sequence of images, was not consistent with the standard scenic flight parameters.

Figure 3: Approaching the distinctive rock formations (looking south)

Recorded image data: Focal length 7 mm – equivalent to 38 mm in 35 mm format

5 The *Transport Safety Investigation Regulations 2003* define 'serious damage' as including the 'destruction of the transport vehicle'.

Figure 4: Approaching the distinctive rock formations, showing the helicopter's relative position to those formations (the inset to this image is a reduction in size of Figure 5 (below))



Recorded image data: Focal length 7 mm – equivalent to 38 mm in 35 mm format

Figure 5: Last image recovered from camera

Recorded image data: Focal length16 mm – equivalent to 90 mm in 35 mm format

The last image recovered was taken close to overhead the accident site (Figure 5). Based on the recorded focal length of 16 mm, and the camera's image sensor size, it was estimated that the helicopter was about 80 m from the rock face when the image was taken. At that position, the helicopter would have been about 100 ft above the level of the accident site.

The time interval between the last recorded image and the stoppage of the time pieces could not be conclusively accounted for.

Pilot information

The pilot held a Commercial Pilot (Helicopter) Licence (CPL) that was issued by the Civil Aviation Safety Authority (CASA) in 2002.

Most of the pilot's flying training for the CPL was conducted in the Hughes Helicopters H269 helicopter type, with the balance of the training conducted in a Bell Helicopter Co. B47G and a few hours in a Robinson Helicopter Company R22. That training was certified as satisfying the low-flying training component of the aerial stock mustering approval requirements of Civil Aviation Order (CAO) 29.10.

The pilot's flying logbook showed that after the CPL was issued, there was a break from flying until a short flight in 2005, and some refresher training in 2006 before the pilot successfully completed a flight review. There was another break by the pilot from flying until commencing refresher flying training with the operator in August 2007.

That refresher training involved operations in the R44 including; confined areas, power limitations, autorotations and a check of the pilot's understanding of overpitching.[6] The training notes indicated that the pilot's flying improved to a satisfactory standard and, in January 2008, the pilot was endorsed on the R44 and certified as having satisfactorily completed a flight review.

After some general flying in the Kununurra area, the pilot was checked by the operator on 1 May 2008 to conduct scenic flights in the Bungle Bungle ranges. The pilot commenced those flights on 9 May 2008 and conducted them regularly until the occurrence flight.

On 14 July 2008 the operator conducted a Standard 180 Day Flight Check in an R44 that included autorotations, low-level manoeuvring and 'quickstops', and confined area flight training. In addition, the ground component of that check:

> ...ensure[d] that the pilot under review is knowledgeable and proficient in all areas listed to a satisfactory standard

and included the requirement for the pilot to:

> ...[understand] the basics of overpitching, vortex ring, dynamic rollover and the appropriate recovery technique[s].

The pilot's flight check report included the note that '...confined areas need[ed] more work.' There was no record of what that might have entailed.

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6 See *Main rotor stall* discussion at pages 15 and 16.

At the time of the accident, the pilot had about 477 hours total helicopter flying, including 346 hours in the R44. Almost all of the pilot's commercial flying experience was scenic flying from the operator's Purnululu ALA base.

The pilot held a Class 1 Aviation Medical Certificate with no restrictions that was valid until March 2009. Post-mortem examination of the pilot did not reveal any physiological factors likely to have contributed to the accident. No evidence of drugs or alcohol was detected during toxicological testing. The operator's other pilots at the ALA reported that there was no indication that the pilot was not fit for duty.

A review of the operator's flight and duty time records indicated that the pilot was operating within the applicable limitations.

Aircraft information

The four-seat helicopter was manufactured in the United States (US) in 2006 and was first registered in Australia in April 2006. At the time of the accident, the helicopter's total time in service (TTIS) was about 1,533 hours. The engine was new when fitted to the helicopter at manufacture and was top-overhauled[7] at 822.7 hours TTIS. A major overhaul of the helicopter was due at 2,200 hours TTIS.

The helicopter had operated for about 76 hours since a 100-hourly inspection on 20 August 2008 that was carried out by the operator's normal maintenance organisation. There was no significant additional work recorded during that inspection.

The most recent recorded maintenance was carried out on 29 August 2008. At that time, new bearings were fitted to the main rotor hub and adjustments made to the associated components. A main rotor track and balance[8] followed.

The pilot who flew the helicopter on a scenic flight before the accident flight reported that the helicopter performed well, with no apparent defects. It was reported that after that flight, the helicopter was refuelled from the operator's fuel storage facility to a total of 100 L. There was no documentation available to confirm that information. An image that was retrieved from the camera recovered from the accident site, showed about 80 L of usable fuel on board after engine start for the flight.

The helicopter's weight at engine start was estimated to be about 1,033 kg, which was 56 kg below the gross weight limit of 1,089 kg for the R44. Taking into consideration the estimated fuel consumed for the flight of 12 L, by the time of the accident, the aircraft would have weighed about 1,024 kg.

Meteorological information

A Bureau of Meteorology (BoM) analysis of the meteorological conditions in the vicinity of the accident site indicated that overall, the conditions were hot and dry

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7 The overhaul of the engine cylinder assemblies. Typically involves the restoration of cylinder wall and valve/valve seat surfaces and the replacement of the piston rings. Usually, the engine remains in-situ while its cylinders are removed, overhauled, and then reinstalled.

8 The as-required adjustment of the main rotor system components to reduce vibration.

with light winds, often variable in direction. There was no cloud, but a band of middle level cloud was observed about 100 km to the south of the accident site.

The nearest meteorological observation site that recorded hourly observations was located at Halls Creek, about 100 km to the south-west. The Meteorological Aerodrome Reports (METARs) that were recorded at Halls Creek around the time of the accident showed that the surface winds in that area were south-westerly to south-easterly at less than 5 kts, gusting to 10 kts. The temperature was about 35 °C with a dewpoint of about 3 °C and the QNH was 1013 hPA. The maximum recorded temperature was 35.5 °C at 1300. Based on the temperature at Halls Creek, moderate thermal turbulence was likely below about 9,000 ft. The observed conditions at Halls Creek were reasonably consistent with the relevant area forecast.[9]

A meteorological observation site located at Warmun, about 55 km to the north-north-west of the accident site, recorded a maximum temperature of 38 °C. That temperature occurred at a time between the site's 0900 and 1500 observations.

The search pilot who departed the ALA soon after the accident reported that the temperature was probably between 36 °C and 38 °C at that time.

The temperature at Halls Creek at the time of the accident was used for performance calculations. However, based on the search pilot's reported temperature, the absence of cloud at the accident site (compared to that observed at Halls Creek) and the proximity of terrain, the investigation considered that the actual temperature affecting the helicopter could have been higher than 35 °C.

The pressure height[10] at the likely helicopter operating altitude just prior to the accident was estimated based on information obtained from the image that was taken as the helicopter was preparing to depart, the pressure altitude of the ALA was estimated to be about 870 ft. Based on the accident site being about 130 ft higher than the ALA, and the helicopter being at about 100 ft above ground level, the pressure height of the helicopter immediately prior to the accident was about 1,100 ft.

In the days following the accident, a number of 'willy willies'[11] were observed in the vicinity of the accident site, including between 1200 and 1400. The BoM forecast of likely thermal turbulence associated with the high temperatures on the day of the accident was consistent with the formation of willy willies on that day.

Accident site and wreckage information

The wreckage of the helicopter was located on a relatively flat, stony and sandy site at the base of a rocky area that sloped upwards towards high, steep terrain (Figure 6). The helicopter was seriously damaged by the impact with the ground and post-impact fire that spread in a north-easterly direction from the accident site,

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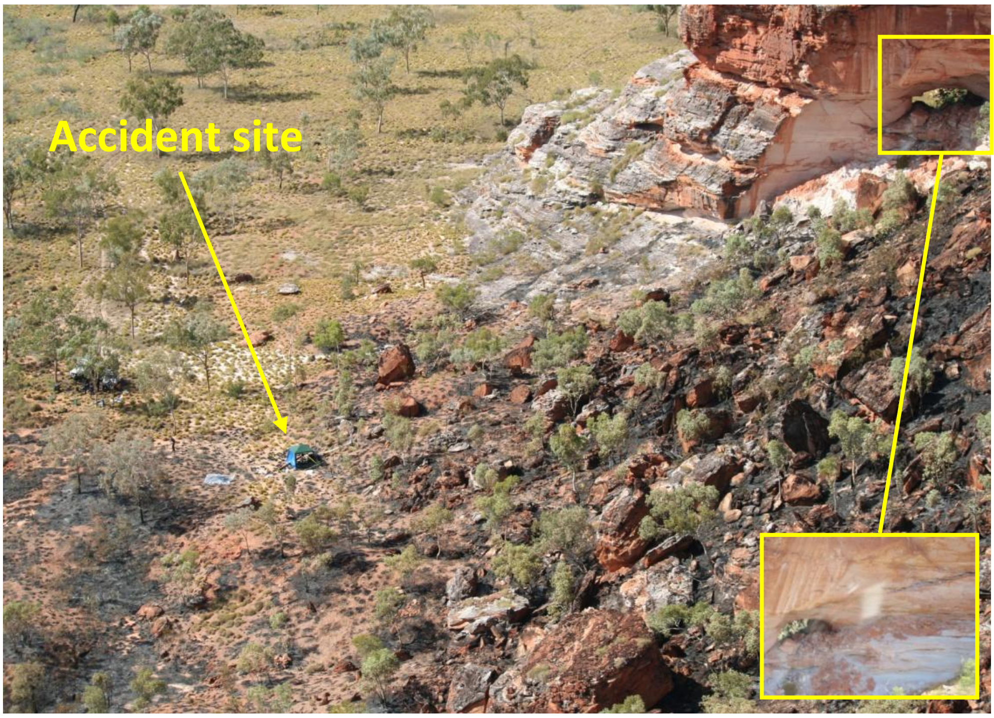
9 For the purposes of providing aviation weather forecasts to pilots, Australia is sub-divided into a number of forecast areas. The accident flight took place in Area 69.

10 The vertical distance above the standard pressure datum of 1013.2 hPa.

11 Willy willies or 'dust devils' can develop where local hot spots on the ground draw in cooler air causing the air to spiral.

suggesting a locally south-westerly wind at that time. All of the critical helicopter components were accounted for at the site.

Figure 6: Accident site looking south (the inset is Figure 5)[12]



Damage to the engine firewall and skids showed that the helicopter impacted the ground generally upright, in a right skid-low attitude and with high vertical velocity. The absence of surface or vegetation disturbance in the vicinity of the wreckage indicated little or no forward speed at impact. Fire damage allowed the helicopter to subside onto its right side.

The main rotor blades were securely attached to the hub, which remained connected to the mast. One of the main rotor blades had in-plane rearward bending at the tip, but otherwise there was little impact damage to either blade. There was also no sign of pre-impact delamination of either blade's surface. Both main rotor blades were curved upwards consistent with coning[13] (Figure 7). The main rotor blades had not contacted the helicopter's tail boom or cabin. Overall, the main rotor blades displayed low rotational energy at ground impact.

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12 The rock feature highlighted in this figure is located about 100 m from, and 100 ft above the accident site.

13 The coning angle is the angle between the longitudinal axis of a lifting rotor blade and its tip path plane or plane of rotation (assuming no blade bending).

Figure 7: Main rotor blade coning (reference lines in red added)

The tail boom was lying adjacent to a small tree with evidence on the tail rotor blades, vertical fin and the tree of a low energy, lateral contact. One of the tail rotor blades had separated from the hub and was located about 1 m away.

Continuity of the rotor drive systems and functionality of the critical components was established with the exception of the rotor drive vee-belts. The charred remnants of the vee-belts in the upper and lower sheaves and on the ground below the sheaves was consistent with belt engagement at the time of the accident.

Due to the severity of the post-impact fire, it was not possible to verify the integrity of the flight control system. However, all of the steel components associated with the collective[14], cyclic[15] and tail rotor[16] controls were intact and secure. The pilot's left pedal was fractured as a result of impact-related forces.

Examination of the fuel, electrical and cockpit systems was unproductive due to the fire damage.

The engine and associated components were removed from the accident site for further technical examination.

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14 The collective lever varies the pitch of all main rotor blades simultaneously, irrespective of their azimuth position. It is the primary control of a helicopter's altitude or vertical velocity.

15 The cyclic control varies the tilt angle of the main rotor disc (and total rotor thrust) by changing the pitch of each main rotor blade individually. It is the primary control of a helicopter's direction of travel or position over the ground when in the hover. Robinson helicopters are equipped with a teetering-bar cyclic control.

16 The tail rotor pedals vary the pitch of the tail rotor blades to counteract the torque effect of the main rotor, to balance the aircraft in flight, or to turn the aircraft in the hover.

Engine examination

The engine was disassembled and examined at an approved engine overhaul facility under the supervision of the Australian Transport Safety Bureau. Other than impact and fire damage, no mechanical defects or anomalies were noted. The investigation was unable to establish if the engine was rotating at impact.

The carburettor, air induction system, magnetos and ignition harness were too fire damaged to establish their pre-impact functionality.

All but one of the 12 spark plugs were fitted to the cylinders. Those 11 plugs produced a spark when tested. The spark plug electrodes were worn to the extent that replacement was likely at the next 100-hourly inspection.

The missing spark plug was subsequently located with debris that was collected from beneath the main wreckage. Specialist metallurgical examination of the host engine cylinder and spark plug established that the intense post-impact fire in the vicinity of that cylinder had softened the aluminium thread around the installed plug, and allowed it to fall out of the cylinder.

An article published by the engine manufacturer indicated that the failure of one magneto would result in an approximate power loss of 3%. The article went on to comment that, in the case of a helicopter, the failure of a magneto could be serious during the takeoff, hover, or landing because there were regular demands on power such as the tail rotor, cooling fan, alternator and transmission. In the same article, the power loss with a failed spark plug at high power was deemed to be less than 1%.

Medical and pathological information

The post-mortem examinations for all occupants of the helicopter described varying degrees of injuries consistent with the high vertical velocity impact. All sustained extensive thermal injury.

The pilot's post-mortem report indicated that he was found '...a slight distance from the damaged aircraft.'

Organisational and management information

Operator policy, procedures and practices

The operator's operations manual permitted flight below 500 ft in a number of specific circumstances. Those circumstances did not include scenic flight operations over the Bungle Bungle ranges.

While the operations manual section regarding scenic flights over the Bungle Bungles did not provide specific operational parameters, a number of pilots stated that they were generally trained to follow a specified route. Altitude was varied during flight to maintain a minimum of 500 ft above ground level while maintaining about 80 kts indicated airspeed.

The operator reported that the pilots operating the scenic flights over the Bungle Bungles were selected, trained and checked to the standard required to safely conduct those flights. For any flights requiring a higher level of pilot qualification and/or experience, the senior pilot at the operator's Kununurra base would be involved in the tasking of a suitable pilot.

Pilots operating from the Purnululu sub-base had access to a set of maximum payload figures specific to each pilot/helicopter/standard fuel load configuration. Those payload figures enabled the operating pilot to readily identify the maximum combined passenger weight permitted while ensuring that a helicopter's maximum operating weight was not exceeded. It was reported that the passengers on the accident flight were weighed, and the passengers for the flight and their weights were found recorded on the passenger manifest.

The operations manual included sections applicable to aerial photography and aerial survey. Aerial photography was described as extremely demanding, and a pilot assigned to such a task was expected to have a '...thorough understanding of the limitations of the helicopter when operating out of ground effect [OGE[17]] at high gross weights, low indicated airspeeds and out of wind on air to ground photographic operations.'

For field operations away from base involving two or more company helicopters, the operator assigned a pilot as a 'senior pilot' to be responsible for a number of administrative tasks. The occurrence pilot was the designated senior pilot at the Purnululu sub-base.

Helicopter pilot training standards and guidelines

From January 1993, the standards for commercial helicopter pilot licence training were promulgated in the *Day VFR Syllabus – Helicopters* that was produced by CASA. Since 2002, when the pilot completed his commercial licence training, the syllabus has been changed to present flying standards in a competency based format, and to introduce human factors and threat and error management standards.

A review of the version of the *Day VFR Syllabus – Helicopters* that was current at the time of writing this report found that the aeronautical knowledge syllabus included the requirement for a knowledge by pilots of the power available/power required curves and of overpitching. The flying training syllabus included:

- avoidance of the manufacturer's height velocity (H-V) diagram avoid area in hovering flight (see Appendix A)
- confirmation of helicopter performance, including power checks as applicable, when landing in a confined area
- execution of limited power takeoff, approach and landing.

There was no specific reference to the risks associated with an OGE hover, or to low rotor RPM avoidance and recovery.

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[17] Helicopters require less power to hover close to the ground due to a cushioning effect created by the main rotor downwash striking the ground. Under those conditions, the helicopter is operating 'in ground effect'. The US Federal Aviation Administration's *Rotorcraft Flying Handbook* stated that flight in ground effect usually occurs at less than one rotor diameter above the surface (33 ft (10 m) for an R44 helicopter). Operations above that height are defined as being conducted 'out of ground effect'.

The *Flight Instructors Manual - Helicopter* published by CASA and the Civil Aviation Authority (CAA) New Zealand was a basic guide to elementary flight training. There was no specific guidance regarding OGE hover, overpitching or low main rotor RPM avoidance and recovery in that manual.

The Civil Aviation Advisory Publication (CAAP) relating to the conduct of flight reviews included a suggested format for the conduct of a Helicopter Flight Review. The suggested pre-flight items for review included:

- calculate aircraft flight performance
- discuss vortex ring/reduced power operations/dynamic rollover.

There was no specific guidance in the CAAP regarding the review of operations in the OGE hover, or the avoidance of and recovery from overpitching or low main rotor RPM.

Civil Aviation Order 40.3.0 contained the requirements for helicopter type and class endorsements. The CAO specified that for a pilot flying only piston helicopters, the conversion course was to be not less than 3 hours. The minimum requirements for a syllabus of flight training including vertical operations, limited power operations, and all other emergency procedures specified in the aircraft's flight manual. There was no specific reference to low main rotor RPM avoidance and recovery.

The US Federal Aviation Administration (FAA) introduced Special Federal Aviation Regulation (SFAR) No. 73 *Robinson R-22/R-44 Special Training and Experience Requirements* in 1995. The SFAR required specific awareness training, aeronautical experience, endorsements and flight reviews for pilots operating Robinson helicopters as follows:

- instruction in energy management, low rotor RPM (blade stall) and rotor RPM decay
- in regard to the R44, aeronautical experience of:
  - at least 200 helicopter flight hours, with at least 50 hours in the R44; or
  - 10 hours dual instruction in the R44, including low rotor RPM recognition and recovery.
- to act as pilot in command of an R44, a pilot was required to have completed a flight review in an R44 within the preceding 12 months.

At the time of writing this report, SFAR No. 73 was still in effect.

Industry survey

The investigation conducted an informal, qualitative survey of eight experienced helicopter Chief Flying Instructors, Chief Pilots and other pilots with R44 flight instruction and commercial operating experience. The objective was to understand the perspective of a small sample of the helicopter industry of the residual risk of pilots conducting slow speed flight OGE.

Overall, the participants did not perceive that there were significant deficiencies in the generic pre-licence training requirements. There was general agreement amongst the participants that pre-licence training was 'basic training', and was conducted in a relatively benign environment that was inherently limited in its capacity to prepare pilots for all possible helicopter operating environments. In that context, operator training, checking, tasking and supervision were considered important and necessary risk controls. A number of the respondents to the survey indicated that they applied informal supervisory and experience-based requirements to their operations.

There was also general agreement that the Robinson R22 and R44 helicopters, with their relatively low inertia rotor system, engine governor, throttle correlation system and derated engines, were different to other piston-engine helicopters. It was reported that pilots flying the R22 and R44 were not always aware of the applicable engine power limits, and did not always adhere to those limits.

Additional information

Helicopter performance

Helicopter performance is essentially the difference between the engine power available and engine power required. The main factors affecting the engine power required include the helicopter's weight, the density of the air (density altitude)[18] and the speed of the helicopter.

Hover performance

In addition to the factors affecting helicopter performance in forward flight, in the hover, the proximity of the helicopter to the ground also has an effect (ground effect[19]). To maintain a steady hover or climb, an increase in the weight of a helicopter requires more main rotor thrust (or effectively lift), which in turn requires more engine power to overcome the associated increase in rotor drag.

As air density decreases with an increase in altitude and/or temperature, a normally-aspirated engine produces less power. Additionally, if the same amount of rotor thrust is needed, the rotor blades need a higher angle of attack, which creates more drag and generates a requirement for even more engine power. That is, the helicopter's performance degrades.

When a helicopter is hovering within about one rotor diameter of the surface, the performance of the main rotor is affected by ground effect. A helicopter hovering in ground effect (IGE) requires less engine power to hover than a helicopter hovering OGE. In general, after leaving the hover and moving into forward flight, the power required initially decreases before increasing with increasing speed.

The application of a temperature of 35 °C, and an estimated pressure height of 1,100 ft at the time of the accident to the *R44 Pilot's Operating Handbook* (POH) 'OGE Hover Ceiling VS Gross Weight' chart, suggested that the maximum weight possible for an OGE hover at that time was 1,042 kg. Similarly, the application of the helicopter's estimated weight of 1,024 kg to those conditions suggested that the maximum altitude for an OGE hover was about 2,100 ft.

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18 Pressure altitude corrected for other than International Standard Atmosphere (ISA) temperature.

19 Increased lift caused by the interaction of a powered lift system with the ground.

When solar radiation reaches the earth's surface it is, depending on the nature of the surface, absorbed and reflected to varying degrees.[20] The proportion of solar radiation reflected by the earth's surface to that falling on the surface varies from 0.1 to 0.2 for land surfaces such as forests, grasslands, ploughed fields and rocky deserts. In that case, there was the potential for the temperature at the site of the accident to differ from that measured at the Halls Creek observation site.

A temperature increase at the accident site would have affected the maximum weight possible for an OGE hover, and the maximum hover OGE altitude at the helicopter's estimated weight. As the temperature increases, the maximum weight possible for an OGE hover at a given altitude reduces.

The R44 POH performance section contained the following caution:

> Performance data presented in this section was obtained under ideal conditions. Performance under other conditions may be substantially less.

Engine power available

The helicopter was powered by a Lycoming Engines 0-540-FIB5 six-cylinder, normally-aspirated reciprocating engine, which had a maximum rating of 260 BHP at 2,800 RPM. In normal operation, the engine was derated[21] by restricting the available engine power applied by the pilot to a:

- maximum continuous rating of 205 BHP at 2,718 RPM (102% on tacho)
- maximum take-off rating (5 min) of 225 BHP at 2,718 RPM.

Maintenance of the above limits was contingent on the pilot interpreting tabulated data about the ambient temperature and pressure height that was placarded in the helicopter. A manifold pressure value was derived that corresponded to the maximum continuous and take-off ratings respectively. The pilot was then expected to monitor the manifold pressure during flight, and limit the amount of collective selected so those values were not exceeded. There was no action required if a manifold pressure limit was exceeded.

The helicopter manufacturer advised that a nominal R44 helicopter, at the same estimated weight and operating in the same estimated conditions as affected RIO, would require about 210 BHP (25 in. manifold pressure) to hover OGE. Significantly, the manufacturer cautioned that individual helicopter variations could vary the engine power required from that calculated by as much as 10%, which equates to a range of between about 190 to 230 BHP required for RIO to have hovered OGE.

If the nominated engine power limits were not observed, the theoretical full throttle power available in the same operating conditions at the governed engine RPM of 2,718 was 240 BHP. An increase in RPM to 2,800 by pilot override of the governor through rolling on or increasing the throttle may give an increase of 8 BHP.

The engine power available figures provided by the helicopter manufacturer do not take reduced main rotor RPM into account. Any decrease of RPM below the

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20 Manual of Meteorology Part 1, *General Meteorology*. Bureau of Meteorology, Australian Government Publishing Service , Canberra 1975.

21 Setting maximum usable engine powers that were lower than able to be produced by the engine.

minimum governed RPM of 101% will inhibit the capacity of the engine to produce power.

Autorotation

In the case of a complete engine power loss, a pilot is required to immediately enter autorotation by lowering the collective to reduce the drag generated by the main rotor blades, and to establish the appropriate speed for the autorotative descent. A freewheeling unit in the clutch assembly automatically disengages the engine from the main rotor allowing the main and tail rotors to rotate freely.

As the helicopter descends, an upward flow of air through the rotor system is produced. That upward flow provides an autorotative force to create rotor thrust that, if properly managed, will maintain rotor RPM throughout the descent and provide a steady rate of descent. Amongst other factors, the rate of descent in autorotation is affected by the forward airspeed of the helicopter. If the airspeed is zero, the rate of descent will be high, and the pilot can expect to have to manipulate the collective to maintain the rotor RPM within limits. As a result, the potential for a safe landing from a zero airspeed autorotation from height is reduced.

In general, autorotative descents are carried out at speed. When landing from an autorotation, most of the rotational energy stored in the main rotor is used by the pilot to progressively reduce the helicopter's rate of descent. The speed is reduced by flaring the helicopter, which offers the added benefit of increasing the rotor RPM, adding to or maintaining the rotational energy therein. At a low height above the ground, the helicopter is established in the landing attitude and the collective is raised to utilise the remaining energy in the main rotor blades to cushion the touchdown.

Autorotative performance is limited at various height and speed combinations. The limitations applicable to the R44 are depicted as a shaded or avoid area on an H – V Diagram[22] that is produced by the helicopter manufacturer and included in the R44 POH. Operating at the altitudes and airspeeds shown within the shaded areas of the H-V diagram may not allow enough time for the critical transition from powered flight to autorotation, or result in autorotative profiles from which safe recovery cannot be guaranteed.

The helicopter manufacturer advised that there was no data available to predict an indicative descent rate for an R44 sustaining a complete engine failure in a hover at 100 ft. In addition, the manufacturer highlighted that there were a number of variables influencing the outcome from a complete failure, including the wind conditions and pilot technique.

Aircraft handling

Main rotor stall

During flight, a helicopter is subject to: the equivalent of aerodynamic lift, which is termed rotor thrust; weight; engine power, which can be measured as torque; and rotor drag. In contrast to an aeroplane, the main rotor thrust provides both the

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22 Can also be known as the 'Avoid Curve' or 'Dead Man's Curve'.

vertical lift force (instead of the wing) that opposes weight, and the forward thrust (instead of propeller/jet engine thrust) that provides for forward flight.

The main rotor produces rotor thrust in proportion to the normally-constant rotor RPM and the angle of attack of the blades. In normal operation, the main rotor RPM is generated by engine power that is transmitted through a drive train and gearbox. The pitch, and therefore angle of attack of the blades is primarily influenced by the pilot through the collective control.

At high collective settings and correspondingly high angles of attack, the rotor blades create a relatively large amount of rotor drag and require a sufficiently large amount of engine power to maintain rotor RPM. In general terms, the maximum amount of rotor thrust available is limited by the amount of engine power available. The engine is also required to power the tail rotor and a number of accessories.

If a pilot selects a high collective setting that, in the prevailing conditions, produces rotor drag greater than the available engine power, the main rotor RPM will decrease below the governed RPM of between 101 and 102%. That situation is termed overpitching, and can develop into a critical condition known as blade stall.

If the pilot does not respond quickly and appropriately to a low rotor RPM situation, the main rotor RPM will decrease further with coning of the blades and an associated loss of lift. The result can be an accelerating rate of descent. Any associated loss of tail rotor RPM decreases tail rotor thrust, increasing the likelihood for the helicopter to rotate nose right.

Any application of collective to arrest the descent further increases rotor drag and reduces rotor RPM. The situation can rapidly deteriorate into a vicious cycle that culminates in the rotor blades effectively stalling and losing all lift. Once the blades are aerodynamically stalled, in-flight recovery is almost impossible.

The R44 helicopter was equipped with a low RPM warning horn and caution light, which activates at 97% main rotor RPM. The R44 POH emergency procedure in response to the activation of the low RPM horn and associated caution light stated:

> A horn and an illuminated caution light indicate that rotor RPM may be below safe limits. To restore RPM, immediately roll throttle on, lower collective and, in forward flight, apply aft cyclic. The horn and caution light are disabled when collective is fully down.

That procedure decreases the blade pitch angle and reduces blade drag while maximising engine power in an effort to increase rotor RPM. This may be counter instinctive to the pilot of a helicopter at low altitude.

Safety notices SN-10 and SN-24 in respect of blade stall and the associated risks and recovery actions were available from the helicopter manufacturer for inclusion in owner/operators’ R44 pilot’s operating handbooks. Those safety notices are reproduced at Appendix B.

Vortex ring

The generally low-level nature of helicopter operations increases the risk associated with vortex ring state.[23] Vortex ring state can develop when the helicopter has:

- low or zero airspeed
- power applied (collective input)
- a moderate rate of descent (depending on the reference text, perhaps 400 to 800 ft/min).

If a helicopter sustains vortex ring, its rate of descent increases significantly and control is compromised. To recover, a pilot should cease the application of the collective and lower the nose to increase speed and fly away. If altitude permits, the pilot should also lower the collective.

Loss of tail rotor effectiveness

In 1995, the US Federal Aviation Administration (FAA) produced an advisory circular (AC)[24] on the aerodynamic phenomena, 'loss of tail rotor effectiveness' (LTE) (also referred to as 'unanticipated right yaw'[25]). The circular stated that:

> LTE is a critical, low-speed aerodynamic flight characteristic which can result in an uncommanded rapid right yaw rate which does not subside of its own accord and, if not corrected, can result in loss of aircraft control.
>
> LTE is not related to a maintenance malfunction and may occur in varying degrees in *all* single main rotor helicopters at airspeeds less than 30 knots.
>
> Any maneuver which requires the pilot to operate in a high-power, low-airspeed environment with a left crosswind or tailwind creates an environment where unanticipated right yaw may occur.

The results of flight and wind tunnel testing identified three relative wind azimuths that either singularly, or in combination, can increase the risk of LTE by allowing the development of accelerating right yaw rates:

- wind from the left front of the helicopter at between 285° to 315° relative to the nose of the helicopter, at 10 to 20 kts
- tailwind from 120° to 240° relative to the nose of the helicopter, at 5 to 17 kts

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[23] A description of vortex ring state is included in the ATSB report (200600738) into the R44 loss of control at St Kilda, Victoria on 12 February 2006. That report is available on the ATSB website at www.atsb.gov.au

[24] Federal Aviation Administration (1995) *Unanticipated Right Yaw in Helicopters* (Advisory Circular 90-95), available at: http://rgl.faa.gov/Regulatory_and_Guidance_Library%5CrgAdvisoryCircular.nsf/list/AC%2090-95/$FILE/ac90-95.pdf

[25] On US-manufactured helicopters, the main rotor rotates counter clockwise as viewed from above. A loss of tail rotor effectiveness in these helicopters will result in the nose of the helicopter rotating to the right. On some European and Russian-manufactured helicopters, the main rotor rotates in the opposite direction resulting in the nose rotating to the left if tail rotor effectiveness is lost. The FAA Advisory Circular discussion of LTE focussed on US-manufactured helicopters.

- left crosswind between 210° and 330° relative to the nose of the helicopter, at between 7 and 17 kts.

It was also established that exposure to those relative winds did not result in the aerodynamic stall of the tail rotor.

The FAA AC also advised that, irrespective of the relative wind affecting a helicopter, operation below effective translation lift (ETL)[26] can also increase the risk of LTE, due to the higher power demand and corresponding anti-torque requirements. If the additional power required exceeds that available, those requirements can lead to a reduction in main and tail rotor RPM, and a corresponding loss of tail rotor thrust.

<u>Factors affecting the severity of the onset of LTE</u>

The FAA AC stated that the severity of the onset of LTE was affected by the following factors:

> a. Gross Weight and Density Altitude. An increase in either of these factors will decrease the power margin between the maximum power available and the power required to hover. The pilot should conduct low-level, low-airspeed maneuvers with minimum weight.
>
> b. Low Indicated Airspeed. At airspeeds below translational lift, the tail rotor is required to produce nearly 100 percent of the directional control. If the required amount of tail rotor thrust is not available for any reason, the aircraft will yaw to the right.

<u>Recommended recovery techniques</u>

On encountering LTE, the FAA AC advised the following recovery action:

> Apply full left pedal. Simultaneously, move cyclic forward to increase speed. If altitude permits, reduce power.[27]
>
> As recovery is effected, adjust controls for normal forward flight.
>
> If the rotation cannot be stopped and ground contact is imminent, an autorotation may be the best course of action. The pilot should maintain full left pedal until rotation stops, then adjust to maintain heading.

In regard to the application of collective during the recovery, the AC further stated:

> Collective pitch reduction will aid in arresting the yaw rate but may cause an increase in the rate of descent. Any large, rapid increase in collective to prevent ground or obstacle contact may further increase the yaw rate and decrease rotor rpm.
>
> The amount of collective reduction should be based on height above obstructions or surface, gross weight of the aircraft, and the existing atmospheric conditions.

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26 Any component of airflow over the main rotor acts to reduce the effect of the main rotor downwash, making the rotor more efficient and resulting in less power required to maintain altitude. This beneficial effect is known as effective translational lift (ETL), and is most noticeable at forward airspeeds of about 10 to 20 kts.

27 In the R44, power can be reduced by lowering the collective or by overriding the governor and reducing throttle.

Related occurrence investigations[28]

200600979

On 21 February 2006, a Robinson Helicopter Company R44 'Astro' helicopter, registered VH-HBS, was being operated on a series of aerial survey flights from Gunpowder airstrip, about 100 km to the north of Mt Isa, Queensland. At 1341 Eastern Standard Time the pilot departed for a survey flight with three passengers. The helicopter did not return and the burnt wreckage of the helicopter was found the next day. The four occupants were fatally injured.

The helicopter had impacted the ground with significant force in a nose-down, fuselage-level attitude. The main rotor displayed evidence of low rotational energy and coning. Other than impact and fire damage, there were no identified mechanical defects or abnormalities. There was evidence that the engine was rotating at impact, but the amount of engine power being developed was not able to be established.

The previous aerial survey flights were reported to have included low speed flight and occasional hovering. At the estimated helicopter weight and the prevailing air density, the helicopter did not have the performance to hover out of ground effect.

The investigation found that the helicopter probably descended contrary to the pilot's intentions, possibly influenced by a partial engine power loss or downdraft, resulting in the pilot applying collective, which developed into overpitching and ultimately main rotor stall. In addition, the operator's procedures were found to not provide a high level of assurance that a relatively low time pilot could conduct aerial survey operations safely.

AO-2008-043

At 1026 Eastern Standard Time on 18 June 2008, a Robinson Helicopter Company R44 Clipper II helicopter, registered VH-RYW, departed Cairns Aerodrome, Queensland to film a residential development site that was located in the vicinity of False Cape, about 10 km east of the aerodrome. On board the helicopter were the pilot and three passengers.

The occupants of the helicopter reported that while conducting the second period of filming, there was a sudden and violent movement of the nose of the helicopter to the right, which continued into a rapid rotation of the helicopter. The pilot's reported attempt to reduce the rate of right yaw was unsuccessful, and he entered autorotation and attempted to reach a clear area. The helicopter subsequently collided with trees before impacting the ground, seriously injuring the pilot and front seat passenger.

The accident highlighted the risk of LTE associated with the conduct of aerial filming/photography and other similar flights involving high power, low forward airspeed and the action of adverse airflow on a helicopter. In addition, there was the potential for a pre-flight brief by the chief pilot to have mitigated the risk of LTE during the flight, and to have lessened the possibility of an inappropriate response by the pilot.

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28 Available on the ATSB website at www.atsb.gov.au

ANALYSIS

Introduction

The position and height of the helicopter as derived from the last on board photographic image, in conjunction with the lack of forward speed evident at the accident site, was consistent with the helicopter being at or approaching a hover prior to the accident. The degree of impact damage to the helicopter was consistent with a high rate of descent as a consequence of low main rotor RPM. This analysis will examine how that condition could have developed during hovering flight, and highlights some operational safety considerations.

Low main rotor RPM

In simple terms, low main rotor RPM is a product of the availability of insufficient engine power relative to the engine power required. That condition, by definition, is termed overpitching.

Engine power available

A lack of engine power can be due to a complete engine failure, a partial engine power loss, the effect of the ambient conditions, or the pilot's technique.

Complete engine failure

The inability to establish whether the engine was rotating at impact could indicate a complete engine failure. The unsuitability of the accident site for landing after an engine failure, and availability of more suitable landing areas close by would suggest that such a failure had not occurred from the cruise height and speed applicable to the anticipated scenic flight profile.

In comparison, a complete engine failure at about 100 ft above the ground with little or no forward speed provides a pilot with little option than to effectively land vertically. That was consistent with the proximity of the accident site to the estimated position of the helicopter as the last photograph was taken. As indicated in the helicopter's Height - Velocity (H-V) avoid area, an engine failure in that configuration resulted in autorotative profiles from which safe recovery could not be guaranteed. The probable difficulty experienced by a pilot in such circumstances; in particular, the critical management of main rotor RPM, could explain the evidence of low main rotor RPM at impact in this case.

However, the maintenance history for the engine, and pilot report of there being no engine defects in the previous scenic flight that day, would suggest that there was no enduring problem with the engine. In addition, there was no evidence of the internal disruption or discontinuity of the engine or of drive-train discontinuity, while there was corroborating evidence of adequate fuel on board for the flight. On that basis, and despite being unable to categorically state that a complete engine failure had not occurred, insufficient available engine power as a result of a complete engine failure was considered to be unlikely.

Partial engine power loss or decrement

The estimated hover out of ground effect (OGE) performance affecting the flight highlighted the potential influence of a partial engine power loss as the pilot reduced speed towards the hover, or was hovering. The extensive impact and fire damage to the carburettor, air induction system, magnetos and ignition harness precluded the examination of a number of the potential sources of a partial engine power situation. To the extent that the engine and its accessories were able to be examined, insufficient engine power as a result of a partial engine power loss was a possibility for which there was no evidence but, could not be discounted.

Ambient conditions

Given the distance from the Halls Creek weather observation site, it could be expected that the temperature might differ at the accident site from that recorded at Halls Creek. Any temperature increase from that measured at Halls Creek, such as reported by the search pilot, and possible as a result of the local heating of the rock face, would have increased the estimated density altitude, and adversely affected the power available from the engine. That would have decreased the maximum weight at which the helicopter was able to hover OGE, reducing the margin between that and the estimated weight of the helicopter.

Pilot technique

Engine power was normally controlled by the electronic governor through the governor-initiated movement of the throttle to maintain 2,718 RPM. If the pilot had inadvertently gripped the throttle while manipulating the collective, he might have prevented the governor from adjusting the engine RPM. That would have prevented the delivery of the available engine power. Alternatively, had a reduction in RPM occurred, if the pilot did not roll on throttle to override the governor, he might have missed the opportunity to utilise all of the available engine power. In either case, the helicopter’s performance would have been adversely affected.

Engine power required

The engine power required to maintain main rotor RPM in an OGE hover or at low speed was primarily influenced by the condition of the rotor system and collective setting, commensurate with the weight of the helicopter and the local environmental conditions.

In addition, it is reasonable to assume that a pilot with about 500 hours, such as the occurrence pilot, would not manipulate the helicopter controls with the same precision as a more experienced pilot. Any tendency to overcontrol the helicopter, perhaps in response to local wind, or other effects would increase the engine power required.

Condition of the rotor system

There was no evidence of any pre-impact mechanical or physical anomalies of the main rotor blades, such as blade delamination, that would have increased rotor or drive train drag and required an abnormal amount of engine power. The as-found condition of the collective and other rotor system controls was consistent with their being functional prior to ground impact.

Weight of the helicopter

The manufacturer's caution that the actual power required to hover OGE could vary by 10% from that calculated could have meant a reduction in the anticipated power required to hover. Any excess performance in that case would have reduced the risk of a performance-related loss of main rotor RPM. However, it could be expected that a helicopter with about 1,533 hours total time in service would not perform as efficiently as when new. Although unable to be quantified, it could be expected that the power required to hover at the weight of the occurrence helicopter was higher in a given set of conditions than predicted for a newer, similar weight helicopter.

Local environmental conditions

Although the helicopter's weight was estimated to be 18 kg below the derived maximum OGE hover weight, the POH cautioned that performance in conditions other than ideal may be substantially less than that presented in the graph. Consistent with the observations of a number of experienced helicopter pilots, that caution suggests that the POH hover performance data represented the 'best case' scenario. The local conditions not taken into account by the hover performance data included the effect of: any turbulence, such as the thermal turbulence that was forecast by the Bureau of Meteorology; any adverse wind as a result of the interface of the rock face and ridge line with the forecast wind; and of any willy willies.

More particularly, the elevated local temperature as noted by the search pilot suggested an increased density altitude than estimated based on the temperature at Halls Creek. In that case, the increased power required to hover OGE would have eroded the performance margin available to the pilot.

Loss of tail rotor effectiveness

The combination of the local south-westerly wind and the pilot's southerly approach alongside the rock face resulted in a right-front relative wind affecting the helicopter as it approached the hover. That was not consistent with any of the wind azimuths that were associated by the US Federal Aviation Administration (FAA) with an increased risk of LTE.

However, irrespective of the relative wind affecting the helicopter, the low main rotor RPM; tail rotor RPM, and therefore tail rotor thrust; and little or no forward speed at impact with the ground; was consistent with the identification by the FAA in those circumstances of an elevated risk of LTE. In that context, any LTE was, if present, likely to have occurred as a consequence of the reduced main and therefore tail rotor RPM.

Performance summary

In terms of helicopter performance, the effect of pilot technique, the ambient conditions, and condition of the helicopter were compounding, and would have reduced the helicopter's performance as follows:

- Had the pilot constrained the action of the governor, the engine power available would have been restricted. Any inappropriate action by the pilot to control the helicopter in the OGE hover would have required additional engine power to maintain rotor RPM and the hover.

- An increase in the local ambient temperature would have increased the density altitude affecting the engine and, as a result, reduced the available engine power to hover OGE. Similarly, that increase in density altitude would have increased the power required to hover.
- The efficiency of a 1,533-hour helicopter and systems could be expected to reduce from when new, increasing the power required to hover in a given set of conditions.

In summary, the deviation by the pilot from the standard scenic flight profile to hover OGE at low level and in proximity to the rock face, reduced the performance margin below that expected by the pilot. Notwithstanding the potential additional adverse influence of any local turbulence and other effects of the conditions on the day, the relevant performance data and cautions associated with the application of that data would suggest that the helicopter's OGE hover performance was likely to have been marginal. In consequence, the risk that the power required would exceed that available was elevated, resulting in reduced main rotor RPM.

Conclusion

Given the wreckage and other evidence at the accident site, the most likely scenario is that at slow speed or the hover, the engine power required exceeded the engine power available or selected with a consequent descent. The pilot probably responded instinctively by raising the collective lever, which further increased main rotor drag and therefore the power required, leading to main rotor RPM decay (overpitching), a low rotor RPM warning and an increased descent rate. That scenario would result in the low main rotor energy at impact that was observed at the accident site.

The close proximity of the helicopter to terrain would have minimised the time for the pilot to roll on throttle and lower collective in accordance with the R44 POH emergency procedure in response to the activation of the low RPM warning horn. In addition, it would likely have been counter instinctive for the pilot to have lowered the collective when already descending towards the ground. This highlights the need for pilots to assess the risks associated with slow speed flight, particularly at performance limiting weights.

Operational safety considerations

The departure by the pilot from the reported 'normal' scenic flight profile negated the operator's risk control for those flights to not be conducted below 500 ft above ground level. In addition, by slowing towards or hovering OGE, the pilot committed to a more difficult manoeuvre than that intended by the operator for the scenic flight. Had the operator been aware of the pilot's intent, the informal requirement for the senior pilot at the operator's Kununurra base to be involved in the tasking of a suitable pilot may have meant that the flight did not occur, or that a different pilot was involved.

Although an engine failure was considered to be unlikely in this occurrence, the pilot was operating the helicopter at a height and speed combination which greatly increased the risk of serious damage and occupant injuries in the event of an engine failure. While operation in the H-V avoid area was not prohibited, helicopter pilots were generally expected to keep clear of the area unless operationally necessary. In addition, the unauthorised operation below 500 ft above ground level reduced the margin for recovery prior to collision with terrain in the event of any other occurrence or failure. That action negated a number of specific risk controls that are introduced for such specialised operations.

The ground and flight training given to commercial helicopter pilots covers OGE hover performance. Although there were opportunities to include more guidance and flying sequences in the syllabus, it is intended as basic, generic training, and there is a practical limit in the ability of pre-licence training to prepare a pilot for the variety of helicopter types and operations in the commercial environment.

Given the flight characteristics particular to the R22 and R44, it is important that any endorsement and recurrent training address those characteristics, especially the types' susceptibility to critical conditions such as low main rotor RPM. The United States Federal Aviation Administration had implemented various additional risk controls for pilots operating Robinson helicopters, by mandating additional pilot knowledge and safety training requirements in Special Federal Aviation Regulation No.73. At the time of writing this report, there were no Australian requirements that applied specifically to R22 and R44 flight training, which increased the risk of pilots not appreciating the insidious and critical nature of low main rotor RPM in those helicopter types.

This accident and the R44 accident near Gunpowder airstrip in 2006 highlight the helicopter performance risks associated with low speed and low altitude operations. The performance planning aspects of those accidents are consistent, and indicate the risk of assuming that pilots will always have the knowledge and skills proficiency to safely conduct the wide range of operations available to helicopters. In that environment, helicopter operators are well placed to assess pilot qualifications and experience, and to formalise their policies, procedures and practices to minimise the risk of their pilots operating outside their individual levels of competence. That could include the application of relevant supervisory and experience-based requirements before authorising pilots for particular tasks.

A number of the respondents to the informal industry survey indicated that they did apply supervisory and experience requirements to their operations to facilitate their pilots' post-training development. However, the reported informal nature of those requirements meant that there was a lack of assurance that the intended risk controls would reliably have effect.

FINDINGS

From the evidence available, the following findings are made with respect to the operational aspects of the collision with terrain involving Robinson Helicopter Company R44 helicopter, registered VH-RIO that occurred 6 km north-east of Purnululu Aircraft Landing Area, Western Australia on 14 September 2008 and should not be read as apportioning blame or liability to any particular organisation or individual.

Contributing safety factors

- The pilot deviated from the regular scenic flight track, speed and profile to operate in close proximity to the terrain at a slow airspeed or hover, out of ground effect.
- The out of ground effect hover performance of the helicopter was likely to have been marginal.
- It is likely that the high level of engine power required to sustain a hover in the local conditions either was not available, or was not fully utilised by the pilot; resulting in the sequential development of an uncommanded descent, overpitching, significant main rotor RPM decay, a high rate of descent and collision with terrain.

Other safety factors

- The pilot was operating the helicopter in the specified Height - Velocity avoid area and at less than the minimum permitted altitude for the scenic flight operation which, in the event of a loss of engine power, increased the risk of serious damage and fatal injuries.
- There was no Australian requirement for endorsement and recurrent training conducted on Robinson Helicopter Company R22/R44 helicopters to specifically address the preconditions for, recognition of, or recovery from, low main rotor RPM. *[Minor safety issue]*
- There was a lack of assurance that informal operator supervisory and experience-based policy, procedures and practices minimised the risk of pilots operating outside the individual pilot's level of competence. *[Minor safety issue]*

Other key findings

- The investigation established the continuity of the drive train and flight controls, and the integrity of the rotor blades, and did not find any engine related defect.
- The helicopter was below the specified maximum gross weight limit.
- The operation of the low rotor RPM warning system was verified before the flight.

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.

Helicopter operator

Scenic flight operations

Although no safety issue was identified in respect of the operator's scenic flight operations, in a letter dated 28 July 2009, the operator advised of the following proactive safety action in response to this occurrence:

- on 19 September 2008, a memo from the operator's Chief Executive Officer was released to remind company personnel of the company policy in respect of the authorisation of flights
- pilots were further reminded that it was unnecessary to operate any helicopter within the Height Velocity avoid area during routine charter and scenic flights
- pilots were directed to operate at a speed not less than 50 kts when operating below 1,000 ft above ground level on scenic flights, except for takeoff and landing
- pilots were notified that deviation from published scenic flight paths was not permitted, except in an emergency or as deemed necessary by the pilot in command. Any such deviation was to be reported to the Chief Pilot
- prior to the commencement of the tourist season, check flights by experienced Grade 1 instructors were to be carried out with each pilot, with follow-up checks conducted throughout the season
- the content of Robinson Helicopter Company Safety Notice SN-34 was promoted, reminding pilots of the hazards associated with low slow flight, such as during survey and photographic flights and of the danger of rotor stall [see Appendix B]
- a web-based management and safety reporting tool was established that was accessible by all pilots, including remotely-based pilots, to facilitate the communication of operational requirements.

Civil Aviation Safety Authority

Helicopter-specific training

Safety issue

There was no Australian requirement for endorsement and recurrent training conducted on Robinson Helicopter Company R22/R44 helicopters to specifically address the preconditions for, recognition of, or recovery from, low main rotor RPM. *[Minor safety issue]*

Action taken by the Civil Aviation Safety Authority

The Civil Aviation Safety Authority (CASA) has advised that it will review the requirements for initial pilot training and endorsement and recurrent training on all helicopters. This will include a review of the Helicopter Flight Instructor's Manual.

ATSB assessment of response/action

The ATSB is satisfied that, depending on the outcome of CASA's review, it could be expected that any action taken by CASA would address the safety issue.

Australian Transport Safety Bureau

Operator policy, procedures and practices

Safety issue

There was a lack of assurance that informal operator supervisory and experience-based policy, procedures and practices minimised the risk of pilots operating outside the individual pilot's level of competence. *[Minor safety issue]*

Action taken by the ATSB

In response to this safety issue, the ATSB issues the following Safety Advisory Notice (SAN).

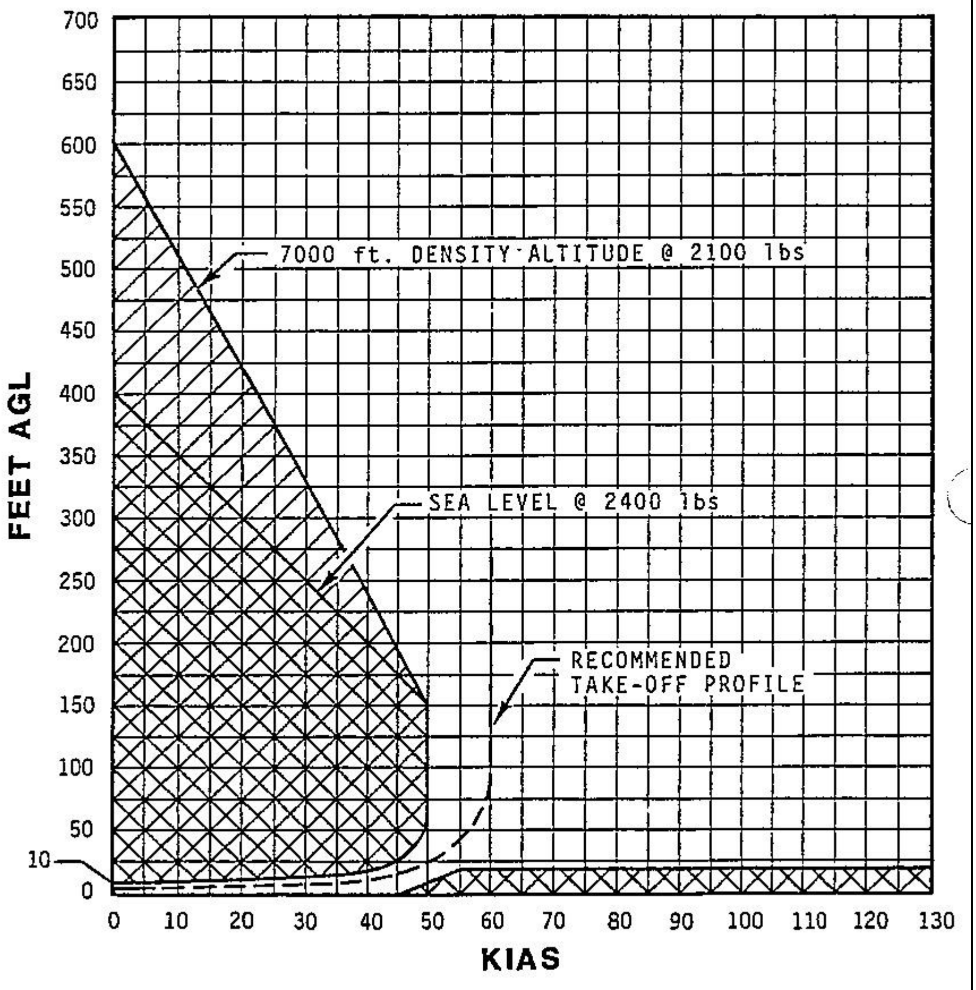
ATSB safety advisory notice SAN AO-2008-062-SAN-098

The Australian Transport Safety Bureau (ATSB) draws the attention of all operators to the potential lack of assurance that informal operator supervisory and experience-based policy, procedures and practices minimise the risk of their pilots operating outside the individual pilot's level of competence. Operators are encouraged to consider the safety implications of this safety issue and take action where considered appropriate.

APPENDIX A: R44 HEIGHT – VELOCITY DIAGRAM

DEMONSTRATED CONDITIONS:
SMOOTH HARD SURFACE
WIND CALM
GOVERNOR ON

AVOID OPERATION IN SHADED AREAS



HEIGHT - VELOCITY DIAGRAM

APPENDIX B: ROBINSON SAFETY NOTICES

ROBINSON
HELICOPTER COMPANY

Safety Notice SN-10

Issued: Oct 82 Rev: Feb 89; Jun 94

FATAL ACCIDENTS CAUSED BY LOW RPM ROTOR STALL

A primary cause of fatal accidents in light helicopters is failure to maintain rotor RPM. To avoid this, every pilot must have his reflexes conditioned so he will instantly add throttle and lower collective to maintain RPM in any emergency.

The R22 and R44 have demonstrated excellent crashworthiness as long as the pilot flies the aircraft all the way to the ground and executes a flare at the bottom to reduce his airspeed and rate of descent. Even when going down into rough terrain, trees, wires or water, he must force himself to lower the collective to maintain RPM until just before impact. The ship may roll over and be severely damaged, but the occupants have an excellent chance of walking away from it without injury.

Power available from the engine is directly proportional to RPM. If the RPM drops 10%, there is 10% less power. With less power, the helicopter will start to settle, and if the collective is raised to stop it from settling, the RPM will be pulled down even lower, causing the ship to settle even faster. If the pilot not only fails to lower collective, but instead pulls up on the collective to keep the ship from going down, the rotor will stall almost immediately. When it stalls, the blades will either "blow back" and cut off the tailcone or it will just stop flying, allowing the helicopter to fall at an extreme rate. In either case, the resulting crash is likely to be fatal.

No matter what causes the low rotor RPM, the pilot must first roll on throttle and lower the collective simultaneously to recover RPM **before** investigating the problem. It must be a conditioned reflex. In forward flight, applying aft cyclic to bleed off airspeed will also help recover lost RPM.

ROBINSON
HELICOPTER COMPANY

Safety Notice SN-24

Issued: Sep 86 Rev: Jun 94

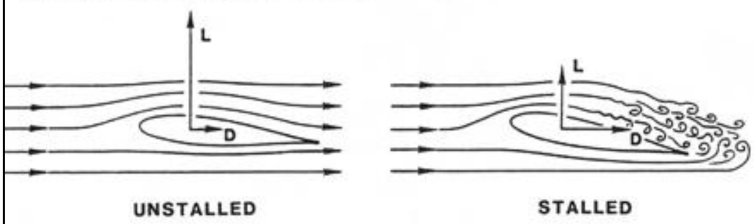
LOW RPM ROTOR STALL CAN BE FATAL

Rotor stall due to low RPM causes a very high percentage of helicopter accidents, both fatal and non-fatal. Frequently misunderstood, rotor stall is not to be confused with retreating tip stall which occurs only at high forward speeds when stall occurs over a small portion of the retreating blade tip. Retreating tip stall causes vibration and control problems, but the rotor is still very capable of providing sufficient lift to support the weight of the helicopter.

Rotor stall, on the other hand, can occur at any airspeed and when it does, the rotor stops producing the lift required to support the helicopter and the aircraft literally falls out of the sky. Fortunately, rotor stall accidents most often occur close to the ground during takeoff or landing and the helicopter falls only four or five feet. The helicopter is wrecked but the occupants survive. However, rotor stall also occurs at higher altitudes and when it happens at heights above 40 or 50 feet AGL it is most likely to be fatal.

Rotor stall is very similar to the stall of an airplane wing at low airspeeds. As the airspeed of an airplane gets lower, the nose-up angle, or angle-of-attack, of the wing must be higher for the wing to produce the lift required to support the weight of the airplane. At a critical angle (about 15 degrees), the airflow over the wing will separate and stall, causing a sudden loss of lift and a very large increase in drag. The airplane pilot recovers by lowering the nose of the airplane to reduce the wing angle-of-attack below stall and adds power to recover the lost airspeed.

The same thing happens during rotor stall with a helicopter except it occurs due to low rotor RPM instead of low airspeed. As the RPM of the rotor gets lower, the angle-of-attack of the rotor blades must be higher to generate the lift required to support the weight of the helicopter. Even if the collective is not raised by the pilot to provide the higher blade angle, the helicopter will start to descend until the



Wing or rotor blade unstalled and stalled.

upward movement of air to the rotor provides the necessary increase in blade angle-of-attack. As with the airplane wing, the blade airfoil will stall at a critical angle, resulting in a sudden loss of lift and a large increase in drag. The increased drag on the blades acts like a huge rotor brake causing the rotor RPM to rapidly decrease, further increasing the rotor stall. As the helicopter begins to fall, the upward rushing air continues to increase the angle-of-attack on the slowly rotating blades, making recovery virtually impossible, even with full down collective.

When the rotor stalls, it does not do so symmetrically because any forward airspeed of the helicopter will produce a higher airflow on the advancing blade than on the retreating blade. This causes the retreating blade to stall first, allowing it to dive as it goes aft while the advancing blade is still climbing as it goes forward. The resulting low aft blade and high forward blade become a rapid aft tilting of the rotor disc sometimes referred to as "rotor blow-back". Also, as the helicopter begins to fall, the upward flow of air under the tail surfaces tends to pitch the aircraft nose-down. These two effects, combined with aft cyclic by the pilot attempting to keep the nose from dropping, will frequently allow the rotor blades to blow back and chop off the tailboom as the stalled helicopter falls. Due to the magnitude of the forces involved and the flexibility of rotor blades, rotor teeter stops will not prevent the boom chop. The resulting boom chop, however, is academic, as the aircraft and its occupants are already doomed by the stalled rotor before the chop occurs.

Safety Notice SN-34

Issued: Mar 99 Rev: Apr 2009

AERIAL SURVEY AND PHOTO FLIGHTS - VERY HIGH RISK

There is a misconception that aerial survey and photo flights can be flown safely by low time pilots. Not true. There have been numerous fatal accidents during aerial survey and photo flights, including several involving Robinson helicopters.

Often, to please the observer or photographer, an inexperienced pilot will slow the helicopter to less than 30 KIAS and then attempt to maneuver for the best viewing angle. While maneuvering, the pilot may lose track of airspeed and wind conditions. The helicopter can rapidly lose translational lift and begin to settle. An inexperienced pilot may raise the collective to stop the descent. This can reduce RPM thereby reducing power available and causing an even greater descent rate and further loss of RPM. Rolling on throttle will increase rotor torque but not power available due to the low RPM. Because tail rotor thrust is proportional to the square of RPM, if the RPM drops below 80% nearly one-half of the tail rotor thrust is lost and the helicopter will rotate nose right. Suddenly the decreasing RPM also causes the main rotor to stall and the helicopter falls rapidly while continuing to rotate. The resulting impact is usually fatal.

Aerial survey and photo flights should only be conducted by well trained, experienced pilots who:

1) **Have at least 500 hours pilot-in-command in helicopters and over 100 hours in the model flown;**

2) **Have extensive training in both low RPM and settling-with-power recovery techniques;**

3) **Are willing to say <u>no</u> to the observer or photographer and only fly the aircraft at speeds, altitudes, and wind angles that are safe and allow good escape routes.**

Also see Safety Notice SN-24.

APPENDIX C: SOURCES AND SUBMISSIONS

Sources of Information

The sources of information during the investigation included:

- the operator of VH-RIO
- a number of the operator's pilots
- a number of other R44 operators
- the helicopter manufacturer
- the Civil Aviation Safety Authority (CASA)
- the Bureau of Meteorology (BoM).

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 operator, the senior pilot at the time of the occurrence, the helicopter manufacturer, the United States National Transportation Safety Board, CASA, the BoM, a number of other R44 operators and the Australian Helicopter Advisory Group (AHAG). Submissions were received from CASA and the AHAG. The submissions were reviewed and, where considered appropriate, the text of the draft report was amended accordingly.

Collision with terrain, 6 km NE Purnululu ALA, Western Australia
14 September 2008, VH-RIO, Robinson Helicopter Company
R44 Raven