Australian Government

Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY INVESTIGATION REPORT

Aviation Occurrence Report – 200600979

Final

Collision with terrain
10 km west of Gunpowder Mine, Qld
21 February 2006

VH - HBS

Robinson Helicopter Company R44

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

Published by: Australian Transport Safety Bureau
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ISBN and formal report title: see 'Document retrieval information' on page iv.

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DOCUMENT RETRIEVAL INFORMATION

Report No.	Publication date	No. of pages	ISBN
200600979	2 October 2007	33	978-1-921165-30-6

Publication title

Collision with terrain – 10 km west of Gunpowder Mine, Qld – 21 February 2006, VH-HBS, Robinson Helicopter Company R44

Prepared by

Australian Transport Safety Bureau
PO Box 967, Civic Square ACT 2608 Australia
www.atsb.gov.au

Reference No.

OCT2007/DOTARS 50363

Abstract

On 21 February 2006, a Robinson Helicopter Company R44 'Astro' helicopter, registered VH-HBS, was being operated on a series of aerial survey flights approximately 100 km to the north of Mt Isa Airport, Qld. The helicopter was operating from Gunpowder airstrip and had completed three flights by 1254 Eastern Standard Time. The pilot refuelled the helicopter and at 1341 departed for a survey flight with three passengers on board. When the helicopter did not arrive at a pre-arranged rendezvous point, a search was initiated. Searchers found the burnt wreckage of the helicopter 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 at the survey altitude, which was estimated to be about 1,000 ft above ground level. The investigation considered that the helicopter probably descended contrary to the pilot's intentions, possibly influenced by a partial engine power loss or downdraft, and induced the pilot to apply collective, which developed into overpitching and ultimately main rotor stall.

The investigation found that the helicopter was being operated at gross weights that exceeded the specified maximum take-off weight. The investigation also found that the operator's procedures did not provide a high level of assurance that a relatively low time pilot could conduct aerial survey operations safely.

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

The Australian Transport Safety Bureau (ATSB) is an operationally independent multi-modal Bureau within the Australian Government Department of Transport and Regional Services. ATSB investigations are independent of regulatory, operator or other external bodies.

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 enhance safety. To reduce safety-related risk, ATSB investigations determine and communicate the safety factors related to the transport safety matter being investigated.

It is not the object of an investigation to determine blame or liability. However, 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 proactively initiate safety action rather than release formal recommendations. However, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organisation, a recommendation may be issued either during or at the end of an investigation.

The ATSB has decided that when safety recommendations are issued, they will focus on clearly describing the safety issue of concern, rather than providing instructions or opinions on the method of corrective action. As with equivalent overseas organisations, the ATSB has no power to implement its recommendations. It is a matter for the body to which an ATSB recommendation is directed (for example the relevant regulator in consultation with industry) to assess the costs and benefits of any particular means of addressing a safety issue.

About ATSB investigation reports: How investigation reports are organised and definitions of terms used in ATSB reports, such as safety factor, contributing safety factor and safety issue, are provided on the ATSB web site www.atsb.gov.au.

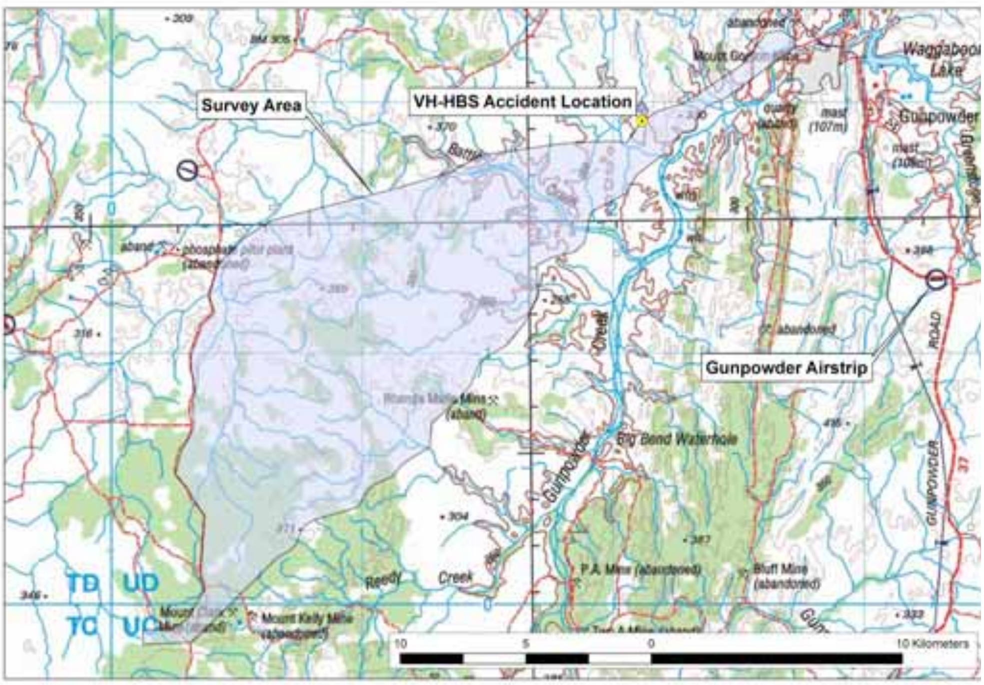
FACTUAL INFORMATION

History of the flight

On 21 February 2006, at about 0625 Eastern Standard Time[1], a Robinson Helicopter Company R44 'Astro' helicopter (R44), registered VH-HBS, departed Mt Isa Airport, Qld, with the pilot and one passenger on board. The helicopter tracked to the Gunpowder airstrip (approximately 100 km to the north) to meet with a survey party.

Upon arrival at the airstrip, two of the survey party boarded the helicopter and it departed for survey operations in the area between the Mt Gordon Mine and the Mt Kelly Mine, approximately 30 km to the south-west (Figure 1). During the morning, the helicopter returned to the airstrip at Gunpowder on three occasions to refuel from drum stock and change passengers.

Figure 1: Accident location and survey area



At about 1300, the helicopter was refuelled for the last time and was reported to have departed shortly after with four people on board to continue survey operations in the designated area. The helicopter was expected to rendezvous with the other members of the survey team at approximately 1530. When the helicopter failed to arrive, communication checks with the helicopter and the helicopter operator were conducted, and when no contact with the helicopter was established, search and

1 The 24 hour clock is used in this report to describe the local time. Eastern Standard Time was Coordinated Universal Time (UTC) + 10 hours.

rescue procedures were instigated. The search continued into the night using a FLIR[2] equipped aircraft. There were no reported distress calls from the pilot.

The following morning, additional helicopters and fixed wing aircraft joined the search. Shortly before midday, the burnt wreckage of the helicopter was located and rescuers confirmed that all four persons on board had received fatal injuries.

Aerial survey flight information

One of the survey party had been on survey flights earlier that morning prior to the accident flight. He recounted that the survey speed had not been fast and that on occasions the pilot had orbited to allow observation of ground features. There were also times that the pilot hovered over some features to record waypoints in one of the GPS[3] units used by the survey party. He also recalled that during the morning flight, while hovering to collect a GPS position, he noticed that a warning light on the instrument panel had 'flashed on then off'; however the pilot did not seem concerned by it and had commented that everything was alright. The passenger was able to confirm the name, the colour and position of the light when interviewed following the accident. This information corresponded to the low rotor RPM warning light. He did not however, recall hearing the warning horn. All the electronic devices such as GPS units and cameras carried by the survey party were destroyed in the accident. The survey height was estimated to be between 500 to 1,000 ft above ground level and was confirmed from photographs that had been taken during earlier flights on the day of the accident.

An impact and fire-damaged *Garmin GPS III Pilot* navigation unit fitted to the helicopter was found at the accident site and was recovered to the Australian Transport Safety Bureau (ATSB) laboratories for examination. Using the manufacturer's software, the data retained in the unit was downloaded. The data included the date, time, latitude and longitude. Altitude and speed was not recorded.

The manufacturer's software performed calculations on that data to obtain the time and distance between recorded track points. Using that information, ground speed between track points was derived. Due to the lack of altitude data, the derived ground speed does not necessarily represent airspeed.

Data was initially recorded at 0626 and covered the operation of the helicopter from just north of Mt Isa to a point coincident with the accident site. The data showed that the helicopter conducted the following survey flights:

2 Forward-looking infrared imaging.

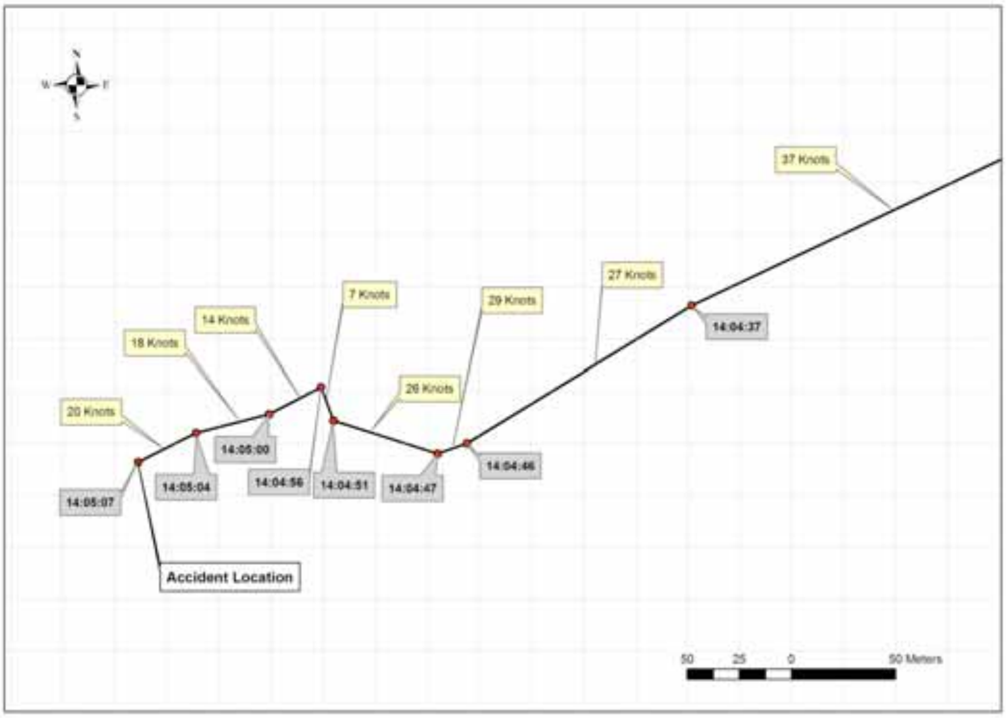
3 Global Positioning System.

Flt	Depart Gunpowder	Arrive Gunpowder	Time airborne
1	0703	0758	55 minutes
2	0836	1043	2 hours and 1 minute[4]
3	1109	1254	1 hour and 45 minutes
4	1341	Accident at 1405	24 minutes

The recorded position at the time the data stopped recording was coincident with the accident location. The last valid recorded time was 1405:07, which matched the time indicated on a watch which was recovered by the Police from the wreckage.

The last recorded data revealed that the helicopter was tracking in a south-westerly direction at derived groundspeeds between 26 and 37 knots. Six recorded positions before the last valid data, the track changed to a westerly and then a northerly direction and the derived groundspeed decreased to 7 knots (see Figure 2). In the absence of additional data and evidence or witnesses, the investigation was unable to determine the possible reasons for this change of direction.

Figure 2: Recovered data showing last recorded track positions – derived groundspeeds above track and recorded times below track



Helicopter information

The helicopter, serial number 33, was manufactured in the US and first registered in Australia in 1997. In contrast to later models of the R44 type, the helicopter did not

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4 During this flight the helicopter landed at a pre-arranged location to exchange survey personnel and was on the ground for 6 minutes. No landings other than those represented above were observed in the data.

have hydraulically assisted flight controls or carburettor heat assist. At the time of the accident, the helicopter had been operated for a total of approximately 2,652 flight hours.

The helicopter was equipped with a six-cylinder Lycoming O-540-F1B5 piston engine. Prior to installation in VH-HBS, the engine had been fitted to a different R44. After operating for 2,000 hours, it was overhauled in June 2004. Since being fitted to VH-HBS, the engine had been operated for about 656 hours.

A review of the engine logbook entries made after the engine was fitted to VH-HBS showed that in September 2004, at about 114 hours since overhaul, the left magneto failed to operate and was repaired. In October 2004, the left magneto failed again and was repaired. There were no other recorded magneto failures.

In January 2005, a 2,200-hour overhaul[5] of the helicopter airframe was completed. Since that overhaul, the helicopter had flown approximately 450 hours. According to the helicopter logbook, the last maintenance was conducted in December 2005. At that time, a 100-hourly inspection was carried out, including a 500-hour inspection performed on both magnetos. Since that maintenance, the helicopter had flown approximately 30 hours[6].

According to the maintenance documentation, at the time of the accident, all applicable maintenance requirements had been complied with.

The helicopter manufacturer included safety notices in the *R44 Pilot's Operating Handbook* (POH). One of the safety notices, SN-34, was titled 'Photo Flights – Very High Risk', and is reproduced at Appendix A.

Wreckage and impact information

The accident site was on the top of a hill, situated on the edge of the survey area. The area in which the helicopter was located was not considered to be suitable as a normal landing area for a R44 helicopter.

Onsite examination of the wreckage indicated that the helicopter had impacted the ground with the skids approximately level and in a nose down attitude. It had contacted the top of a small tree before impacting the ground. The helicopter came to rest on its right side (Figure 3). A severe fuel-fed, post-impact fire destroyed the cabin and cockpit structure and surrounding flight and engine control systems.

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5 A 2,200-hour overhaul entails disassembly of the helicopter and inspection and/or replacement of a number of components. Major components renewed include main rotor gearbox, main rotor blades, drive shaft elements, tail rotor gearbox, tail rotor blades and drive belts.

6 Actual hours flown since the maintenance were not able to be accurately calculated as the helicopter's maintenance release was destroyed in the accident.

Figure 3: Helicopter wreckage

The helicopter impacted the ground with significant vertical force, sufficient to compress the stainless steel vertical engine firewall to less than half of its original height and to separate both landing skids from the helicopter. The engine air induction and oil sump systems, located at the bottom of the engine, both sustained significant crushing damage.

The main rotor blades displayed evidence of low rotational energy at the point of impact and there was significant compression wrinkling (coning) of the upper outer surface of both main rotor blades (Figure 4). One main rotor blade had contacted the ground, resulting in the rotor tip being torn from the blade. That tip was located within the wreckage area of the helicopter. The main rotor blades had not contacted the tail boom of the helicopter, and there was no indication that they had contacted the cabin area.

The control rod linkages to the swash-plate[7] had failed in overload as a result of impact forces. The pitch change linkages above the swash-plate remained attached to their respective rotor blades. Control linkage continuity to the flight controls within the cabin was not able to be confirmed due to fire damage. Examination of the main rotor gearbox internal structures on site did not reveal any evidence of internal failure.

7 The swash-plate referred to here is a circular device that translates the movement of the flight controls to the main rotor blades.

Figure 4: Compression wrinkling on main rotor blade upper surface

The tail rotor blades also displayed evidence of low rotational energy at the point of impact. One tail rotor blade had separated from the tail rotor as a result of ground impact and was found approximately 35 metres from the main wreckage. The other tail rotor blade remained attached to the tail rotor hub. Driveshaft continuity between the main rotor system and the tail rotor was intact. The tail rotor pitch change controls were intact as far forward as the tail boom attachment area. Examination of the pitch change controls forward of this point was not possible due to fire damage.

The cockpit instruments were destroyed by fire and no information was able to be obtained from them. The clutch activation switch was found in the engaged position and was caged[8]. Fire damage precluded a complete examination of the main rotor drive belt system. However, there were drive belt remnants in the lower drive sheaves (pulleys). No evidence of a failed drive belt was located outside of the fire damaged area of the wreckage.

Examination of the fuel tanks, lines and main fuel filter was not possible due to fire and impact damage.

Complete examination of the helicopter electrical system was not possible due to fire damage. The alternator was recovered and examined in the ATSB laboratories. There were indications that the alternator was rotating at the point of impact.

The engine was recovered from the accident site and was disassembled at an approved engine overhaul facility (see below for details).

There was no evidence of impact with wildlife on any of the rotating components of the helicopter. There was also no evidence of fire prior to the helicopter's impact with the ground.

The fixed emergency locator transmitter (ELT) was destroyed in the fire. The satellite telephone carried by the pilot was also destroyed in the fire. No evidence of the portable ELT reported to be carried by the pilot was found in the wreckage.

8 The clutch switch was fitted with a spring-loaded cover that protected the switch from inadvertent deselection. The cover was found in place.

Engine examination

The engine was disassembled and examined at an approved engine overhaul facility under the supervision of the ATSB. Other than impact and fire damage, no mechanical defects or abnormalities were detected.

A number of cylinders contained pieces of fractured magnesium alloy castings, which were identified as coming from the engine air induction and oil sump housings. The location and condition of those fragments was consistent with momentary rotation of the engine during the breakup of the sump area. The rotational speed of the engine and the amount of power that the engine was producing at impact was not able to be determined.

The carburettor was substantially intact and was recovered to the ATSB laboratories for further examination. That examination revealed that the fuel 'finger' filter was intact and had no evidence of contamination. There were no defects or abnormalities observed. Due to impact and fire damage, functional testing of the carburettor was not possible.

Fire damage precluded testing of the ignition harness. The ignition leads were securely attached to the spark plugs, which were securely fitted to the cylinders. Engine oil found on some of the plugs was consistent with the disruption of the engine sump and the post-impact helicopter attitude. After the plugs were washed, 11 of the 12 plugs operated on test equipment. The non operational plug had sustained internal damage.

Although the right magneto was found detached from the engine, there was evidence that both magnetos had been securely attached before the impact. Examination of the magnetos found that the internal condition of both magnetos was severely compromised as a result of intense heat. As a result, the examination was inconclusive.

An article[9] 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 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%.

The operator indicated that the failure of a single magneto was likely to result in a power loss of 10 to 20%. An experienced helicopter engineer indicated that a single magneto failure would most likely result in the loss of approximately 2 inches of manifold pressure and in the conditions under which the helicopter was operating, would result in the helicopter not being able to hover without exceeding placarded engine limitations.

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9 The article was sourced from the *Key Reprints* publication available from the engine manufacturer's website at http://www.lycoming.com/support/tips-advice/key-reprints/pdfs/Key%20Operations.pdf.

Fuel

The helicopter departed from Mt Isa with full fuel tanks. To facilitate the survey operation, two 200 L sealed fuel drums had been positioned at the Gunpowder airstrip and the helicopter had refuelled during the day from those drums. Following the accident, both drums were quarantined and returned to Mt Isa. One drum contained a small amount of fuel and the other drum contained approximately 150 L of fuel. Samples were drawn from those drums for laboratory testing.

Laboratory testing of the sample from the empty drum found that it did not meet the prescribed specification for gum limits. However, as the drum was nearly empty and had been subjected to temperatures in excess of 37 degrees C, evaporation of the volatile component of the fuel would have accounted for this discrepancy. The helicopter had operated for over 3 hours using the fuel from this drum without any apparent problems.

Testing of the sample from the remaining drum found it to be clear and free of visible solid matter. It met the relevant specifications for AVGAS 100 but did show evidence of minute particulate matter. The laboratory report indicated that the fuel was acceptable for use as filters are normally used to remove such particulate matter.

The fuel in the drums had been taken from a larger batch of fuel which had been delivered to suppliers that dispatched it to most of northern Queensland. The ATSB did not receive any reports of engine problems associated with fuel contamination either immediately before or after this accident.

Witnesses that had been on board the helicopter during the morning flights reported that the helicopter had been refuelled on each of the three occasions that it had returned to the Gunpowder airstrip. On at least one of those occasions a witness reported that he had assisted with the refuelling. He confirmed that during that refuelling the helicopter was refuelled to full tanks. He also recalled hearing the pilot comment that the helicopter fuel consumption had been less than she had planned due to the slower speeds that they had been flying.

Using fuel consumption data provided by the engine and helicopter manufacturers, the fuel remaining in the drums and the flight times taken from the GPS, it is probable that the helicopter was also refuelled to full tanks on the other two occasions that it had been refuelled in the morning. No witnesses could be found to confirm this as the persons who conducted those refuellings were fatally injured in the accident. Using this information, it is probable that the amount of fuel on board the helicopter at the time of the accident was approximately 160 litres. The extent of the fire damage to the helicopter also supported this figure.

Meteorological conditions

Weather conditions in the area were forecast to be fine with light easterly winds. The Bureau of Meteorology determined that the surface temperature in the vicinity of the accident site would have been about 38 degrees C. Based on the same sources, the surface temperatures in the survey area earlier in the day were derived. At 0800 the temperature would have been about 28 degrees, rising to about 33 degrees at 1000 and 36 degrees at 1200.

Isolated convective cloud had formed during the afternoon. However, the base of these clouds was reported as being about 8,000 ft AMSL[10]. Turbulence from thermal activity was forecast to be moderate below 8,000 ft. Reported weather conditions in the area were consistent with these forecast conditions.

The Bureau of Meteorology estimated that the surface relative humidity in the vicinity of the accident site would have been between 26 and 31%. A carburettor icing probability calculation was carried out and showed that there was a possibility of light carburettor icing at cruise or descent power settings.

Pilot information

In May 2005, the Civil Aviation Safety Authority issued the pilot with a commercial pilot (helicopter) licence. In the same month, the pilot completed low flying training and qualified for an R44 helicopter endorsement.

In July 2005, the pilot commenced employment with the operator of VH-HBS, based primarily at Mt Isa. The operator's chief pilot conducted a check flight that covered circuits, slope landings and confined areas. The chief pilot reported that the pilot was safe and competent. The pilot was primarily engaged in the ferry flying of helicopters, joy flight operations and, in the month prior to the accident, had undertaken some survey flying operations.

The pilot's logbook showed that the pilot had logged 327.8 hours total rotorcraft flight time, including 143.9 hours logged on the R44 helicopter type. In the 30 days prior to the accident, the pilot had flown 56.4 hours, 44 hours of which were on the R44 helicopter type.

The pilot underwent an emergency procedures proficiency check as part of a helicopter safety course in September 2005. The flight, conducted in an R22 helicopter, included autorotations, overpitching and vortex ring state. (Terms are explained in 'Main rotor dynamics' following)

The last recorded training/check flight was a refresher flight performed in a Bell 47 G helicopter at a flight school on 19 December 2005. That flight included emergencies, low flying and limited power operations.

The pilot held a class one medical certificate with no restrictions. People in contact with the pilot in the days leading to the accident reported that there had been no indications of illness.

Post mortem examination of the pilot did not reveal any evidence of physiological factors that may have contributed to the accident. No evidence of drugs was detected during toxicological testing. Testing for the presence of alcohol was not able to be performed due to the unsuitability of the sample.

Operator policy and procedures

The operator conducted charter and airwork operations such as mustering, scenic flights and aerial survey. The operator published an operations manual that included

10 Above mean sea level.

a sub part regarding aerial survey. The sub part emphasised the administrative and low flying aspects of the task. There was no reference to any minimum pilot experience and training requirements. There was also no specific mention of minimum survey speeds or required helicopter performance in regard to the task.

The aerial survey sub part stated that:

> Prior to departure the Pilot in Command shall be briefed by the Chief Pilot and/or survey personnel on the proposed task, outlining the schedule of events and respective duties and responsibilities of all personnel carried.

Weight and balance

It was reported that there was food, water and personal equipment carried by the passengers and other equipment relating to the operation of the helicopter on board at the time it departed from Gunpowder airstrip on the accident flight. Using the basic weight of the helicopter, the weights of the occupants provided to the investigation by next of kin, an allowance of 14 kg for the food, water and equipment, and the weight of full fuel, the calculated weight of the helicopter when it departed the airstrip was 1,110 kg. That weight was 21 kg above the maximum certificated take-off weight of 1,089 kg for the R44 helicopter as prescribed in the rotorcraft flight manual (RFM) and the type certificate data sheet (TCDS).

Data recovered from the GPS indicated that the helicopter had flown for approximately 24 minutes after departing the airstrip. At the time of the accident, the weight of the helicopter would have been approximately 1095 kg. That weight was slightly above the maximum certificated operating weight of the helicopter.

Although the weight was above the maximum allowable limit, the centre of gravity of the helicopter was within the allowable limits prescribed in the RFM and the TCDS.

Operation of helicopters in an overweight condition has previously been commented upon by a State Coroner following a fatal accident involving the R44 helicopter type.[11] The coroner commented that:

> This case has highlighted the importance of complying with requirements as to the maximum take-off weight of a helicopter, particularly in the context of the R-44 helicopter in respect of which it appears that if three passengers are carried, it is extremely easy for the maximum weight limit to be exceeded.

Helicopter performance

Hover performance

Hover performance is essentially a product of engine power available and engine power required. The main factors affecting engine power required in a hover are helicopter weight, density of air and proximity to the ground (ground effect).

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11 Western Australia State Coroner's findings at Inquest – Crash of R44 Helicopter VH-YKL, Kununurra WA, 8 November 2003.

To maintain a steady hover or climb, an increase in the weight of a helicopter requires more main rotor thrust to act as lift, which in turn requires more engine power.

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 more engine power.

When a helicopter is hovering within about one rotor diameter[12] 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 out-of-ground-effect (OGE).

The accident elevation was approximately 820 feet above mean sea level. A passenger on board the helicopter during the morning flights reported that the helicopter was being operated approximately 1,000 feet above ground level. The investigation used charts in the R44 POH to calculate the hover performance in the conditions prevailing on the survey flights. It should be noted that the performance calculations are predicated on the availability of maximum allowable engine power.

Calculations of the helicopter’s IGE hover performance showed that at maximum gross weight, in the conditions prevailing on all the survey flights, the helicopter was capable of hovering IGE at the approximate survey altitude. Data was not provided in the performance chart for weights in excess of maximum gross weight.

Calculations of the helicopter’s OGE hover performance showed that at maximum gross weight, in the conditions prevailing on all the survey flights, it was not possible to hover OGE at the approximate survey altitude. Data was not provided in the performance chart for weights in excess of maximum gross weight.

To achieve OGE hover performance at the approximate survey altitude on the first flight, the helicopter weight was required to be 32 kg less than the maximum allowable. On the accident flight, the weight was required to be 64 kg less than the maximum allowable.

Climb and cruise performance

Helicopter climb and cruise performance is essentially a product of engine power available and engine power required. The main factors affecting engine power required are helicopter weight, density of air and airspeed. The effect of weight and air density is essentially the same as described above.

At an airspeed of about 55 kts, the engine power required by a helicopter is at its minimum. Any reduction of airspeed will result in an increase in the engine power required. There is a further increase in the engine power required when a helicopter slows to a speed known as the translation speed. At this speed, which is usually about 15 kts, the main rotor becomes less aerodynamically efficient.

12 The Robinson R44 main rotor diameter is 33 feet.

Main rotor dynamics

During flight, a helicopter is subject to the equivalent of the basic aerodynamic forces of lift, weight, forward thrust and drag. In contrast to an aeroplane, the thrust produced by the main rotor provides both the vertical lift force (instead of the wing) that opposes weight and the forward thrust (instead of propeller/jet engine) that opposes drag.

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 transmitted through a drive train and gearbox. The angle of attack of the blades is influenced by the pilot varying the blade pitch angles through the collective[13] control.

At high collective settings and corresponding high angles of attack, the rotor blades create a relatively large amount of drag and require a sufficiently large amount of engine power to overcome the resistance and maintain rotor RPM. So in general terms, the maximum amount of rotor thrust available is limited by the amount of engine power available. It should be noted that the engine is also required to power the tail rotor and some 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. That situation is termed overpitching and can lead to a critical condition known as blade stall. The R44 helicopter is equipped with a warning horn and light which activate at 97% main rotor RPM to alert the pilot of a low main rotor RPM condition. A governor is fitted to the helicopter which normally maintains the main rotor RPM between 101 and 102%.

Once overpitching occurs, the decreased main rotor RPM results in coning and a decrease in rotor thrust. A descent will usually follow. If the pilot increases the collective to compensate, the situation rapidly deteriorates into a vicious cycle of further rotor RPM reduction, greater coning, less lift and increasing descent rate.

During a descent, if the helicopter is at slow speed and the pilot raises the collective to apply moderate to high engine power, it may also enter a condition called vortex ring state.[14] If that occurs, the helicopter rate of descent increases significantly and control is compromised. To recover, the pilot should lower the nose and increase speed to fly out of the affected area and, if altitude permits, lower the collective.

Recovery from overpitching requires the simultaneous application of more throttle (if there is more engine power available) and lowering of the collective control. That 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 descending helicopter at low altitude.

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13 The collective lever is the pilot control in helicopters that simultaneously directly affects the pitch of all main rotor blades, irrespective of their azimuth position. It is the primary control of a helicopter’s altitude or vertical velocity.

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

If a pilot does not correctly diagnose a condition of overpitching and does not take corrective action in a timely manner, rotor RPM can reduce to low levels very quickly resulting in the blades stalling. Once the blades are stalled, in flight recovery is almost impossible.

Engine power loss increases the exposure of a helicopter to overpitching. In the case of 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. A freewheeling unit in the clutch assembly automatically disengages the engine from the main rotor allowing the main rotor to rotate freely.

As the helicopter descends, an upward flow of air through the rotor system is produced. That upward flow of air through the rotor 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. That process is known as autorotation.

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 rate of descent and ground speed. At a low height above the ground, the collective is raised to utilise the remaining energy in the main rotor blades to cushion the touchdown.

The helicopter manufacturer had included information on blade stall in the R44 pilot's operating handbook. It was in the form of safety notices, specifically SN-10 and SN-24. These safety notices are reproduced at Appendix A.

ANALYSIS

Introduction

The severe vertical impact of the helicopter was almost certainly the result of insufficient main rotor thrust that was a consequence of low main rotor RPM. The investigation was not able to conclusively determine the factors leading to the accident due to the lack of known detail in regard to the manoeuvring of the helicopter immediately before the impact and the damage to some of the helicopter systems.

The available evidence suggested that the main rotor blades were stalled at the point of impact and low main rotor RPM may have been experienced by the pilot during an earlier flight on the day of the accident. This analysis will examine how that condition can develop in the context of the aerial survey operation and will highlight some operational safety considerations.

Low main rotor RPM

An engine power loss was a possible factor in the development of low main rotor RPM. The nature of the ingestion of the crushed induction system and alternator rotation indicated that the engine was rotating momentarily immediately after impact. That evidence meant that the engine was probably operating before the impact, but it didn’t allow any conclusion regarding the amount of power.

The engine was mechanically sound and was considered to be capable of normal operation prior to the impact. However, it was not possible to establish the pre-impact serviceability of the magnetos, and a loss of magneto functionality with some power loss could not be discounted. The quantity and quality of fuel was considered to be adequate. There was a risk of carburettor icing, but icing was unlikely at the power settings probably required during the survey. Based on the available evidence, the engine was probably able to produce a substantial amount of power.

A drive-train component failure was another possible factor in the development of low main rotor RPM. However, there was no evidence of a drive train failure to break the connection between an operating engine and main rotor assembly. Given the engine was probably operating and delivering power via the drive train to the main rotor, it is unlikely that the pilot needed to enter autorotation.

In the likely absence of a major engine power loss or drive train failure, main rotor drag in excess of the applied drive torque was also a possible factor. The main rotor blades were intact and showed no signs of delamination or other faults that may have decreased aerodynamic efficiency. In the absence of any identifiable flight control system defects, the investigation considered that overpitching was probably the source of the low rotor RPM.

The relatively low airspeed used in the aerial survey and the high weight of the helicopter were conducive to overpitching. At the survey altitude and prevailing air density, the helicopter was not capable of hovering out-of-ground-effect (OGE). Had the pilot slowed the helicopter, possibly to near or below the translation speed to collect waypoint information as per previous flights, the available engine power may have been insufficient to maintain rotor RPM. The momentary illumination of the low main rotor RPM warning light during a hovering flight in the morning supported this. That may have resulted in an inadvertent descent.

In that situation, if the pilot had reacted to the unintended descent and selected more collective, the increase in main rotor drag and consequent decrease in main rotor RPM would have further increased the descent rate. With the ground rapidly approaching, the pilot may have applied even more collective. It is possible that vortex ring state contributed to the descent rate.

The low rotor RPM warning horn and light should have activated at 97% main rotor RPM and alerted the pilot to the developing low rotor RPM situation. In the context of the aerial survey operation at 1,000 ft above ground level or below, there was limited height available to allow recovery from a surprise low rotor RPM event. In that case, in the few seconds to assess the situation, the pilot's training to lower the collective may have been overridden by a natural instinctive desire to reduce the rate of descent.

At the point of impact, the rotational energy of the main rotor was low, which suggests that the main rotor was stalled before impact. Once a main rotor is stalled, there is no provision for a pilot to retard the rate of descent or control the attitude of the helicopter. The attitude of the helicopter at impact did however indicate that the pilot may have had some limited control of the helicopter suggesting that any stalling of the rotor blades occurred immediately before impact. Also the absence of evidence of the main rotor blades contacting either the cabin or the tailboom is suggestive of main rotor blade stall occurring later in the accident sequence rather than earlier.

Although the helicopter did not have out-of-ground-effect hover performance on any of the survey flights, the pilot had avoided developing overpitching on the three previous flights. On the accident flight, the pilot may have overpitched because the air density had decreased relative to the previous flights and/or because of a minor engine power loss or turbulence.

There was no evidence of any physiological or psychological factor having affected the pilot's performance on the day of the accident. A sudden or unexpected incapacitation was considered to be unlikely in a young and apparently well person and there was no evidence of loss of control.

Operational safety considerations

Helicopter weight considerations

In the context of this accident, the weight of the helicopter was significant primarily in the exceedance of the out-of-ground-effect hover weight rather than the exceedance of the specified maximum. Nevertheless, exceedance of the maximum weight for a helicopter will have performance and component fatigue consequences.

The investigation was not able to determine if the pilot was aware of the performance limitations applicable to the aerial survey flights. The carriage of three passengers and full fuel on one flight and probably on every flight suggests that the pilot was not aware. Given the helicopter was conducting operations within an approximately 30 km radius of the Gunpowder airstrip, where fuel was available, there was no operational reason for the pilot to carry full fuel on every survey flight.

Risk management of aerial survey operations

The investigation considered that aerial survey operations presented similar challenges to aerial photography. In both operations, there is often a benefit to the passenger(s) in slowing the helicopter and there can be additional mission-orientated pilot workload. As Robinson Safety Notice SN-34 (Appendix A) described, if a pilot slows the helicopter to less than 30 kts, the helicopter can rapidly lose translational lift and settle, leading to low main rotor RPM and main rotor stall.

The safety notice went on to specify minimum experience and training requirements for pilots conducting photo flights. The pilot of VH-HBS had less than the specified minimum of 500 hours pilot-in-command-of-helicopters, but had more than the specified minimum of 100 hours in the model flown. Based on the pilot's logbook, the pilot had not recorded extensive training in low RPM and settling-with-power recovery techniques.

Operators of R44 helicopters utilised in aerial survey operations should consider applying the Robinson minimum experience and training guidelines for aerial photography to their aerial survey operations.

Procedures and guidelines in operations manuals are a way of capturing and communicating the safest way to perform an airborne task such as aerial survey. While there is no guarantee they will prevent accidents, procedures and guidelines increase the likelihood that pilots are aware of likely risks and ways to manage them.

A chief pilot is usually an experienced pilot who is able to draw from that experience to anticipate the risks likely to be present in a particular operation with regard to the features of the geographic area, task-related pilot workload and the expected environmental conditions. In tasking relatively inexperienced pilots, the chief pilot is able to facilitate safety by imposing practical limits on passenger numbers or weight that provides the pilot with a healthy margin of safety.

FINDINGS

Contributing safety factors

- The helicopter was being used for aerial survey activity that included hovering or operating at slow speed for survey purposes, between 500 and 1,000 ft above ground level.
- At the time of the accident, the helicopter did not have the performance to slow below translation speed at any altitude outside of ground-effect as a result of its gross weight and the ambient air density.
- The helicopter probably descended contrary to the pilot's intentions, possibly influenced by a partial engine power loss or turbulence, and induced the pilot to apply an inappropriate amount of collective, which developed into overpitching and finally main rotor stall.
- The helicopter impacted the ground with significant vertical force as a result of low main rotor RPM.

Other safety factors

- The helicopter was being operated at gross weights that exceeded the maximum take-off weight specified in the R44 pilot's operating handbook.
- The operator's procedures and practices did not provide a high level of assurance that a relatively low time pilot could conduct aerial survey operations safely.

SAFETY ACTIONS

Helicopter manufacturer

The manufacturer of the helicopter indicated that it had reviewed the information contained in Safety Notice SN-34 and was in the process of revising the content to include information pertaining to the conduct of aerial survey operations. The manufacturer indicated that the revised safety notice would be issued to all holders of the rotorcraft flight manual at the next amendment.

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.

Safety Notice SN-24

Issued: Sep 86 Rev: Jun 94

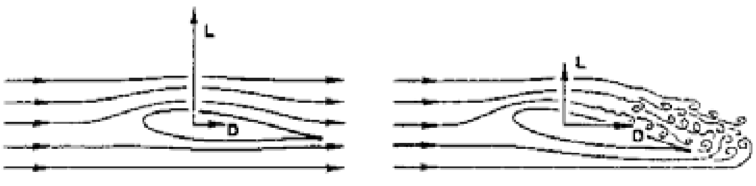
LOW RPM ROTOR STALL CAN BE FATAL

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.

ROBINSON
HELICOPTER COMPANY

Safety Notice SN-34

Issued: Mar 99

PHOTO FLIGHTS - VERY HIGH RISK

There is a misconception that photo flights can be flown safely by low time pilots. Not true. There have been numerous fatal accidents during photo flights, including several involving R22 helicopters.

Often, to please the photographer, an inexperienced pilot will slow the helicopter to less than 30 KIAS and then attempt to maneuver for the best picture 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.

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 no to the photographer and only fly the aircraft at speeds, altitudes, and wind angles that are safe and allow good escape routes.

Please reread Safety Notice SN-24

APPENDIX B: MEDIA RELEASE

Final ATSB investigation report on 4-fatality helicopter accident near Gunpowder, Queensland

The ATSB's final investigation report into the fatal crash of an R44 Helicopter west of the Gunpowder airstrip in Queensland on 21 February 2006 found that the operation of the helicopter at weights that did not allow for adequate performance in the high temperatures experienced in the area may have contributed to the development of the accident.

The Australian Transport Safety Bureau report states that the helicopter, with a pilot and three passengers on board was engaged in aerial survey operations between the Mt Gordon and Mt Kelly mines in northern Queensland. It was reported overdue at a scheduled stop and was located the following day, burnt out on the top of a hill. All four persons on board had received fatal injuries.

The helicopter had impacted the ground with significant force, with the main rotor displaying evidence of low rotational energy. Other than impact and fire damage, there were no identified mechanical defects or abnormalities found with the helicopter.

At the estimated helicopter weight and the prevailing atmospheric conditions, the helicopter did not have the performance to hover at the survey altitude, which was estimated to be about 1,000 ft above ground level.

The investigation found that the helicopter was also being operated at gross weights that exceeded the specified maximum take-off weight. In addition, the operator's procedures did not provide a high level of assurance that a relatively low time pilot could conduct aerial survey operations safely.

While the ATSB could not conclusively determine that factors leading to the accident, as a result of this investigation, the helicopter manufacturer has commenced a revision of safety information that it provides to pilots highlighting the dangers of operations at low level in high temperatures.