Australian Government

Australian Transport Safety Bureau

Rotor RPM decay and hard landing involving Robinson R44, VH-HGX

5 km south of Ayers Rock Airport, Northern Territory, on 17 January 2018

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Addendum

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Safety summary

What happened

In the evening of 17 January 2018, a Professional Helicopter Services Robinson R44 helicopter, registered VH-HGX, departed the Yulara Town helipad, Northern Territory, for a 15-minute scenic flight with the pilot and three passengers onboard. Shortly after take-off, the rotor RPM began to decay and the low rotor RPM warning activated. The rotor RPM continued to decay to a level from which the pilot could not recover. The pilot attempted a forced landing, but was unable to arrest the rate of descent, resulting in a hard landing. The pilot and two passengers were seriously injured, and the remaining passenger experienced minor injuries. The helicopter was substantially damaged.

What the ATSB found

The ATSB found that the take-off was conducted at a high density altitude[1] at near maximum weight. Therefore, a high engine manifold pressure (MAP) would be expected for the take-off. However, passenger video evidence indicated the rotor RPM (revolutions per minute) decay started at a relatively low MAP, and that the MAP increased slowly as the RPM steadily decayed. The ATSB found that the engine was producing the published rated take-off power earlier on the day of the accident and that the pilot had flown the same departure with a full load of passengers on three previous flights. The rotor RPM decay was consistent with the low observed MAP. As such, the ATSB concluded the helicopter's rotor RPM steadily decayed due to a likely limited opening of the engine throttle during take-off. Fine-tuning of the engine throttle is controlled automatically by the engine governor, but it can be manually overridden by the pilot. The reason for the limited opening of the throttle could not be determined.

Following activation of the low rotor RPM warning, the pilot initially did not apply full throttle (for at least 5 seconds), and the helicopter maintained a positive rate of climb. At the time, the pilot was conducting the departure procedure low over the tree tops with an early left turn, which required visual attention outside of the helicopter for the majority of time. As a result, it was likely that the pilot had no spare attentional capacity at this time to immediately comprehend and respond to the deteriorating situation. In consideration of the potential power margin available at the time, if the pilot had applied full throttle in the first 5 seconds, and then lowered the collective lever sufficiently to prevent the helicopter from climbing, the low rotor RPM was likely recoverable.

The helicopter continued flight for about another 90 seconds, during which it climbed to about 200 ft at a low airspeed. This resulted in the rotor RPM decaying further to a level from which the pilot could not recover (likely below 80 per cent).

The ATSB further established that the pilot had inadvertently adopted a practice of conducting the rotors running turn-around (for passenger transfers) with the governor switched off. This was not in accordance with the Robinson Helicopter Company R44 checklist requirement for the governor to remain on from start until shut-down, nor the operator’s procedure for the governor to be selected on for the engine run-up. Although the pilot reported that the governor was selected on and checked before lift-off, this practice increased the risk of an inoperative governor not being detected before take-off.

The operator used individual passenger weights for their loading calculations, which was considered best practice. However, it was found that the operator’s passenger scales were not calibrated and were under-reading the actual occupant weights. This resulted in the helicopter operating at a higher weight than planned, but less than the maximum weight. While the operating

[1] Density altitude is pressure altitude corrected for non-standard temperature. Pressure altitude is the altitude corrected for non-standard atmospheric pressure.

weight was within the published limits, the under-reading scales increased the risk of their helicopters not achieving their take-off performance.

The ATSB also found that the Robinson Helicopter Company's R44 pilot operating handbook emergency procedure for low rotor RPM recovery did not include reference to the minimum power airspeed. Knowledge of this as a subsequent consideration to the immediate actions could assist pilots in the recovery from this safety-critical condition.

What has been done as a result

The operator temporarily suspended their tourist flights at their Uluru Base (including the Yulara Town helipad). Their chief pilot then conducted check flights with the local base pilots to ensure they could safely resume operations. In addition, the operator completed an audit of the helipad and updated their helicopter landing site register in accordance with the latest recommendations from the Civil Aviation Safety Authority (2014), and introduced a calibration schedule for their passenger scales.

The ATSB have issued a safety recommendation to the Robinson Helicopter Company to review the R44 pilot's operating handbook low rotor RPM recovery procedure for consideration to include a reference to the minimum power airspeed (Vy) for pilot awareness. Robinson reported that this will be reviewed by their engineering staff for possible revision to the pilot operating handbook.

Safety message

The intent behind checklist actions is not always apparent when learning procedures. Pilots should ensure they understand the purpose behind all checklist items, and if any doubt exists, seek clarification to reduce the likelihood of misunderstanding the requirements.

Low rotor RPM may develop in various flight conditions, but it is the low airspeed-low height condition, which is most likely to result in an accident. Helicopter pilots should ensure they are familiar with the power curve, the associated airspeeds for their particular helicopter, and be prepared to respond immediately to a low RPM warning.

Robinson Helicopter Company reported that pilots of their piston-engine helicopters should roll on throttle while lowering the collective lever, as per the low RPM recovery procedure, so that the throttle remains open. There is an overtravel spring in the throttle linkage that may, or may not, compress during the recovery. Pilots should not be concerned if the spring is, or is not, compressed, they should continue to roll the throttle on and lower the collective lever until the RPM is recovered.

In addition, the Robinson Helicopter Company website provides training videos for higher risk flight conditions that have resulted in fatal accidents. They include several presentations on energy management, tailored specifically for Robinson helicopter pilots, which could be beneficial to pilots during their initial training, upgrades and flight reviews.

Contents

The occurrence

On 17 January 2018, at about 1828 Central Standard Time,[2] a Professional Helicopter Services Robinson R44, registered VH-HGX, sustained a rotor revolutions per minute (RPM) decay on take-off from Yulara Town helipad, Northern Territory (NT), resulting in a hard landing about 0.63 km south of the helipad (5 km south of Ayers Rock Airport, NT) at about 1830.

Background

In the month of January 2018, the accident pilot became aware of an upcoming large charter group visit (115 people). The flights were scheduled to be from the operator's Uluru Base[3] Yulara Town helipad. On 17 January, the pilot started the day with ground duties until lunchtime. Ground duties included passenger safety briefings and bus driving. At 1300, the area manager and deputy area manager held a meeting with staff to brief them on the charter group operation, which was scheduled to start at 1500. The staff briefing included the passenger manifest and scenic route to be flown to separate the helipad departures with arrivals.

After the charter group arrived at 1500, the pilot conducted two short flights in another R44 and then about 40 minutes of ground duties. The pilot then took over VH-HGX from another company pilot, who had been operating the helicopter on scenic flights since about 1000. According to the run sheet, the pilot took one load of three passengers on the scenic flight before flying to Ayers Rock Airport to refuel. The helicopter departed the airport at 1727 with 100 L of fuel. The pilot reported that the fuel loading was predetermined from the staff meeting and believed the helicopter would be within the weight and balance requirements for the passenger manifest.

After returning to the Yulara Town helipad, the pilot took two groups of three passengers on the scenic flight. Ten litres of fuel consumption was recorded for the return flight from the airport and for each of the scenic flights.

Accident flight

At about 1827, the helicopter was loaded with three passengers from the Yulara Town helipad for a planned 15-minute scenic flight, with 70 L of fuel on board. This was the third scenic flight for the pilot in the accident helicopter since the last refuel earlier that afternoon. After the passengers boarded, the pilot accelerated the engine and rotor RPM from idle to 90 per cent, conducted a low RPM warning horn check (90 to 98 per cent RPM), selected the governor on (extinguishes the governor off light), and checked the engine and rotor indications were stable.

The pilot reported conducting a confined area[4] take-off[5] profile to clear some low trees in the departure path, which provided a headwind component for the departure. Passenger phone footage and helicopter tracking data indicated lift-off from the helipad was at about 1828. The departure consisted of the helicopter climbing about 17 ft vertically before the pilot applied forward cyclic[6] about 5 seconds after lift-off to accelerate forwards for take-off while continuing to climb. Helipad surveillance camera and passenger phone cameras recorded the departure of the helicopter. The pilot reportedly checked the instruments were in the 'green' (normal operating range) in the hover prior to take-off, and the passenger videos indicated the 'governor off' light was extinguished for the departure.

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2 Central Standard Time (CST): Coordinated Universal Time (UTC) + 9.5 hours.

3 The Uluru Base included a maintenance facility at Ayers Rock Airport and helipad operations at Kings Canyon and the Yulara Resort, known as the Yulara Town Pad.

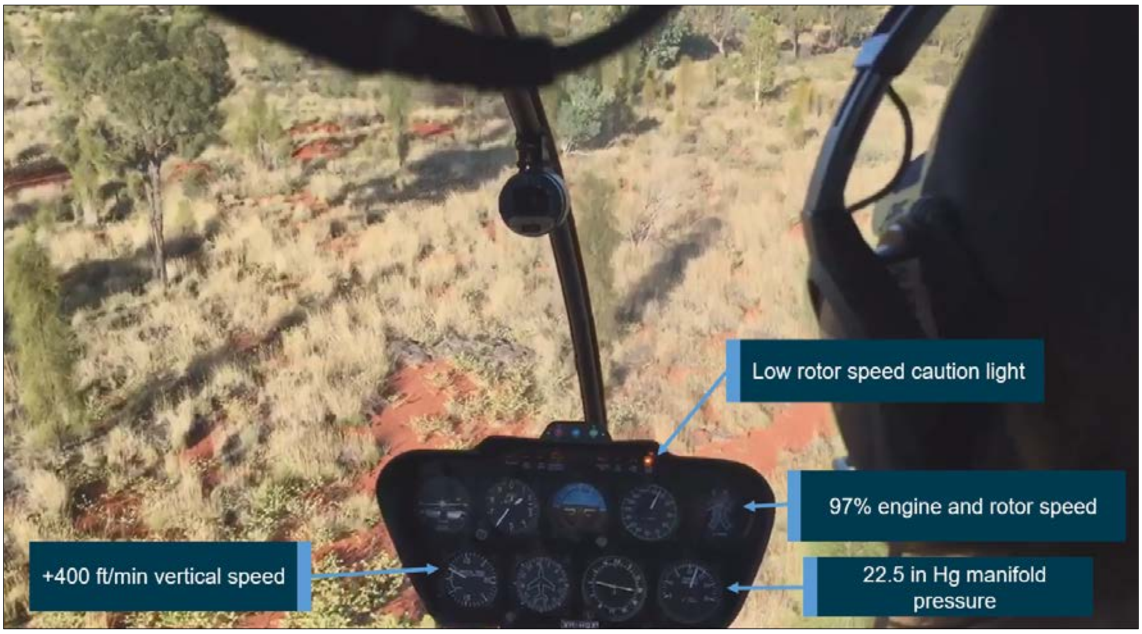
4 A confined area is an area where the flight of the helicopter is limited in some direction by terrain or the presence of obstructions, natural or man-made.

5 Lift-off refers to the helicopter rising from contact with the surface of the helipad into the air. Take-off refers to the helicopter accelerating forward for departure.

6 Cyclic: a primary helicopter flight control that is similar to an aircraft control column. Cyclic input tilts the main rotor disc, varying the attitude of the helicopter and hence the lateral direction.

About 3 seconds after take-off, and just prior to passing overhead the first trees in the departure path, the helicopter's low rotor RPM warning horn and caution light activated (Figure 1). This indicated that the rotor RPM had decayed from 101–102 per cent (normal operation) to 97 per cent. The engine and rotor RPMs were matched and decreasing. The engine manifold pressure (MAP) was at 22.5 in Hg[7] and the airspeed at 25 kt; both were increasing. Based on estimates from a combination of the helipad surveillance video and passenger video of the flight instruments, the low rotor RPM warning occurred at approximately 37 ft above ground level (20 ft climb above take-off height).

Figure 1: Activation of low rotor RPM warning



Source: Passenger, annotated by the ATSB

The helicopter continued to climb and increase forward airspeed, and the rotor RPM decayed to 90 per cent. A left turn was commenced shortly after take-off to avoid a no-overfly zone (Yulara Resort and Township) and join the scenic flight traffic pattern. During the left turn, the airspeed reached a maximum of about 38 kt before the helicopter pitched up slightly, resulting in a decay in airspeed as the helicopter continued to climb.

About 15 seconds after take-off, the engine and rotor RPM had decayed to 80 per cent, with a MAP of 26 in Hg, airspeed of 33 kt, height of about 87 ft above ground and vertical speed of 300 ft/min (Figure 2).[8] The onset of vibrations became noticeable in the final seconds of the passenger video of the departure, which ended about 17 seconds after take-off. The helicopter continued to turn left onto a southerly track, instead of following the planned scenic flight departure pattern to the west.

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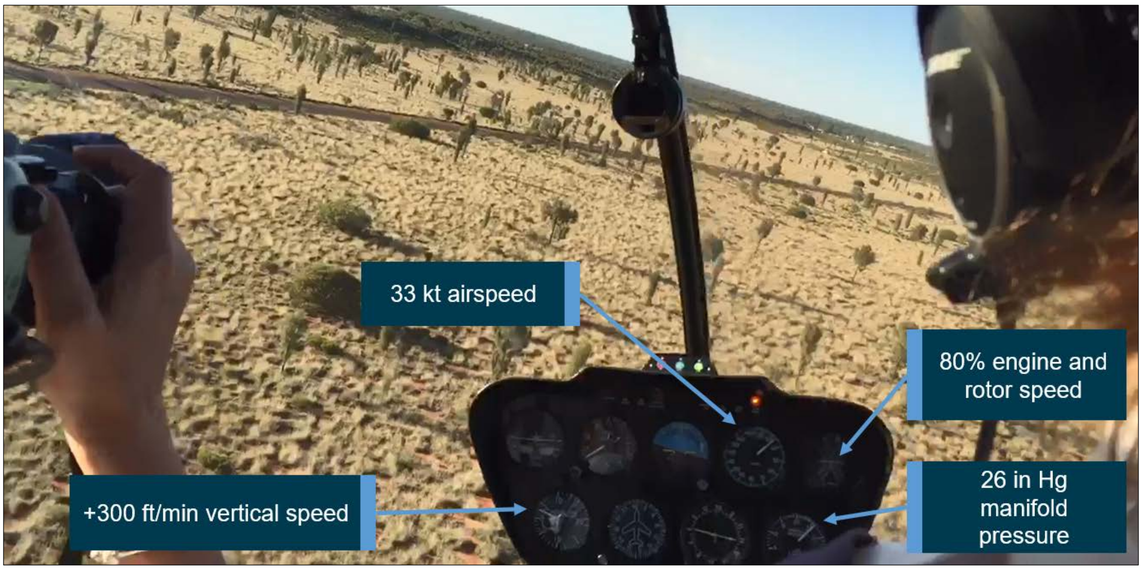
7 The units for manifold pressure are inches of mercury (in Hg).

8 This was the last footage of the cockpit instruments.

Figure 2: Rotor RPM decay



Source: Passenger, annotated by the ATSB

The pilot initially reported that they applied full throttle in response to the low RPM warning horn, and that there was ‘not enough height to do much else’. This initial recollection was associated with the warning activating at a height of 300 ft, after the left turn, with 22–23 in Hg MAP. In response to the draft report, the pilot submitted that they had been taught to ‘open throttle and lower the collective’ in response to the low RPM warning, and that is what they would have done regardless of the height. Helipad footage indicated the helicopter was at a height of about 200 ft when it was abeam the helipad and in relatively level flight until it passed out of the camera view 42 seconds after take-off.

About 91 seconds after take-off, the pilot broadcast an emergency radio call ‘going down’. The deputy area manager immediately responded with a radio call to the pilot to ‘put it [helicopter] into wind’, and the pilot attempted a forced landing to what appeared to be a clear patch of sand. The pilot was unable to recall any other actions, but that there was a ‘couple of kicks’ of the helicopter just prior to the final descent. The front left seat passenger reported that the helicopter was climbing and descending during the flight, and then a ‘big shudder’. Both rear seat passengers reported that the helicopter started shaking from side to side (vibrations) at about 15 seconds after take-off and that the intensity of the shaking increased from moderate to extreme until the final descent.

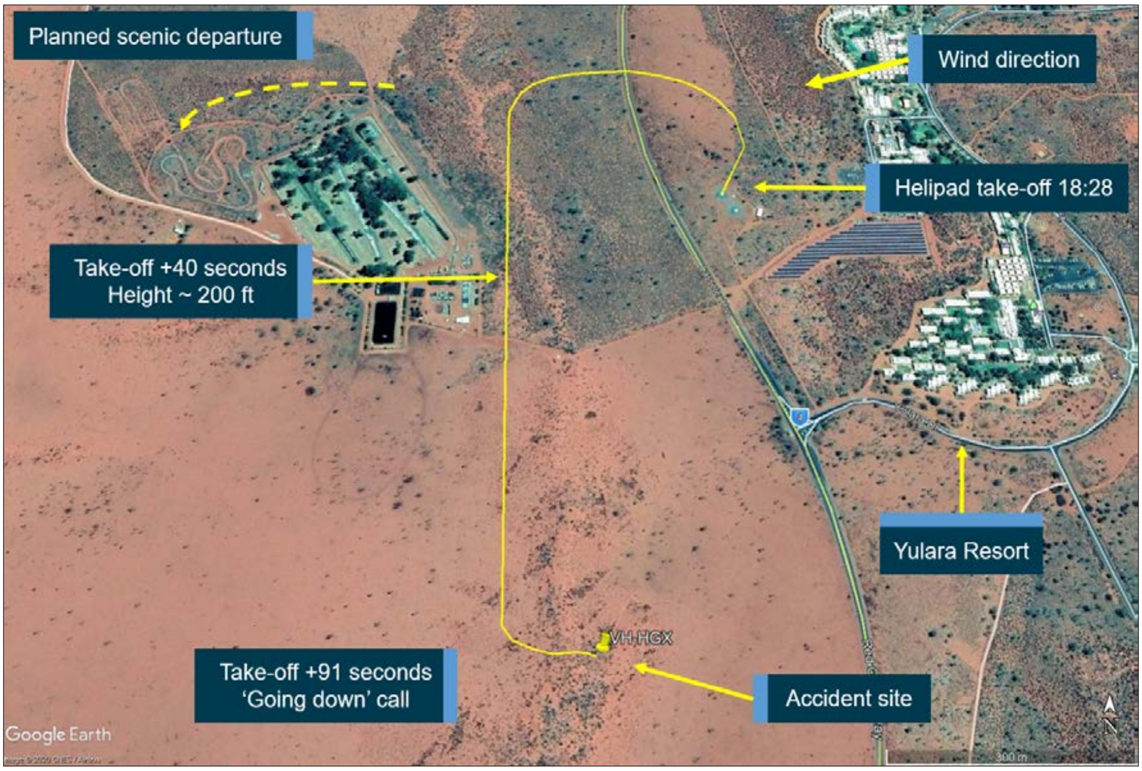
During the descent, the rotor RPM was too low for the pilot to be able to arrest the helicopter’s rate of descent to a safe vertical speed, resulting in a hard landing. The landing area was a small knoll with a steep bank, which resulted in the helicopter rolling over. The pilot and two passengers were seriously injured, and the remaining passenger experienced minor injuries. The helicopter was substantially damaged.

The rear right seat passenger’s phone camera was activated intermittently in video mode several times during the flight. The low rotor RPM warning was audible throughout the recordings, which included the ground impact, and was reported by the passenger as sounding continuously throughout the flight. Figure 3 depicts the accident site. Figure 4 depicts the accident flight path, based on tracking data provided by the operator. The flight track was about 1.0 NM (1.85 km) at an average ground speed of about 40 kt.

Figure 3: VH-HGX wreckage

Source: Northern Territory Police

Figure 4: Accident flight path



Source: Google earth, annotated by the ATSB

Context

Pilot information

The pilot held a Commercial Pilot (Helicopter) Licence with about 300 hour's total flying experience and a Class 1 Aviation Medical Certificate with no restrictions. The pilot's training was conducted on the Robinson R22 and R44 helicopters with the operator. The pilot was offered a job at the operator's Uluru Base on completion of training. After passing a company check flight in the R44 on 12 July 2017, the pilot moved to the Uluru Base and started work the same month.

The pilot was initially employed in-command-under-supervision. On 21 September 2017, the pilot was cleared by the operator as pilot in command for passenger flights after successfully completing the operator's line training for the local airport procedures, helipad procedures, scenic flight patterns, radio procedures and no-fly zones. The pilot had accumulated about 180 hours on the R44 from July 2017 until the accident flight.

72-hour history

The pilot had a couple of rest days prior to starting work at 0930 on 17 January and had been on duty for about 8 hours and 52 minutes at the time of the accident. The pilot had completed six scenic flights, which was about 1 hour and 30 minutes of flight time, plus a return flight to the airport for refuelling (about 5 minutes each direction). When asked about fatigue management, the pilot reported that it was a good work-rest schedule and that it was a comfortable work arrangement. Business was normally performed with a morning and afternoon crew. The morning crew would start at sunrise, if required, and end at 1400 when the afternoon crew would take over. The pilot reported being well rested and fit for duty on the day of the accident.

Helicopter information

General details

The Robinson Helicopter Company (RHC) R44 Raven 1 is a four seat piston-engine helicopter, powered by a Lycoming O-540-F series six-cylinder carburetted engine. VH-HGX was manufactured in 2000 and registered in Australia in May of the same year. The last 100-hourly maintenance inspection was completed on 15 January 2018, at which time it had accumulated 3,489.5 airframe hours. That inspection included an engine governor system functional check and cylinder compression check. They were all assessed serviceable.[9] In addition, the engine air filter was 'replaced for company convenience'.

Engine power and drive

The engine take-off power (TOP) is rated at 260 horse-power (hp) at 2,800 revolutions per minute (RPM), which can be maintained up to a pressure altitude of 800 ft. Maximum continuous power (MCP) of 235 hp can be maintained up to a pressure altitude of 4,000 ft.[10] Robinson provide pilots with the de-rated figures of 225 hp and 205 hp for TOP and MCP respectively at 2,718 RPM. This allows the helicopter to maintain engine performance on a climb from sea level to several thousand feet before the power available will start to decay below their published TOP.

The rotors are driven by the engine with a V-belt drive system and gearboxes. The drive system reduces the engine RPM of 2,718 to the main rotor RPM of 408. The engine and rotor RPM are both presented to the pilot as a percentage on the cockpit tachometer gauges, so that they are

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9 The cylinder compression test results were: 79, 77, 74, 77, 78 and 76 pounds per square inch. According to the engine manufacturer, the test is conducted with an air supply pressure of 80 pounds per square inch. The engine is assessed satisfactory if the readings for all cylinders are equal (within 5 pounds per square inch) and above 70.

10 As no temperature compensation is provided, it has been assumed that the pressure altitude figures are for standard atmospheric conditions and therefore equate to the same density altitude figures.

matched under normal operating conditions. An engine governor system is installed to provide automatic control of engine RPM, which will control the rotor RPM via the associated drive-train.

Engine throttle control and governor system

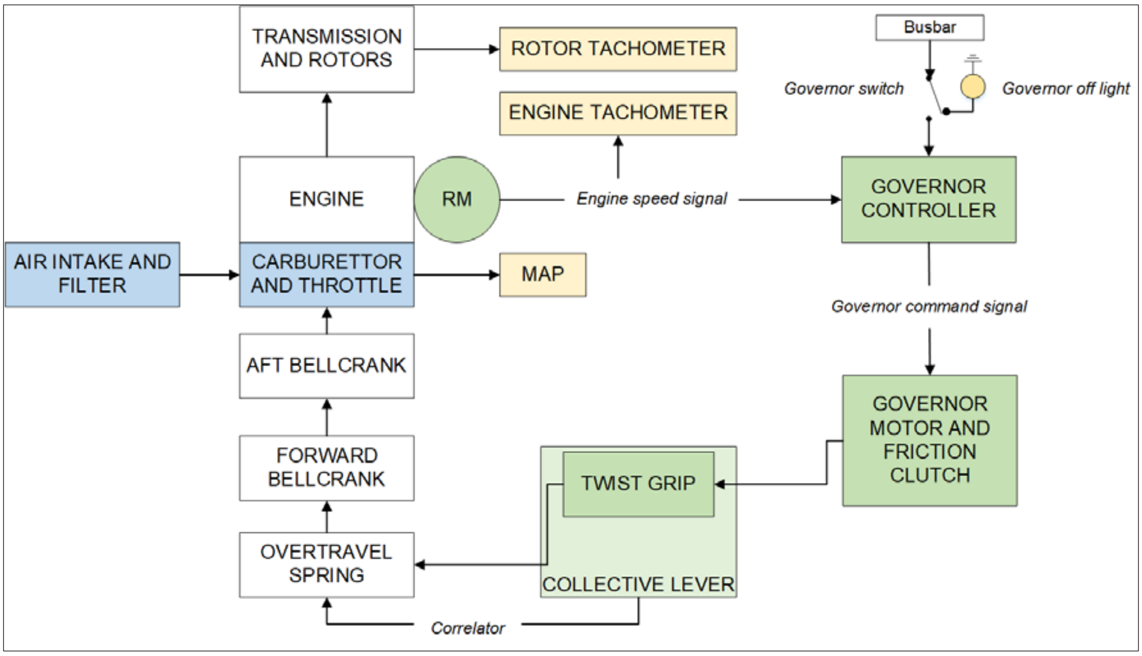
RHC reported that there are three ways the engine throttle can be manipulated, via the same mechanical input at the carburettor, as follows:

> The correlator: a linkage between the collective lever[11] and the throttle. As the collective is raised, the throttle is opened and as the collective is lowered, the throttle is closed. This performs the majority of the throttle control in-flight. Provided the throttle is already partially open to achieve 102 per cent RPM on the ground, full throttle can be achieved by the correlator.
>
> The governor: an electronic throttle control using a controller unit and motor to fine tune the engine RPM through a friction clutch, which applies a twisting force to the pilot's throttle grip. The further away from the target speed (102 per cent), the faster the controller will move the throttle to return to the target, but for the most part, it is very small, slow movements.
>
> The pilot: in normal flight the pilot is not required to manipulate the throttle, but more aggressive manoeuvres or demanding environments may require the pilot to make manual adjustments. The governor can be overridden by the pilot gripping the throttle (twist grip located on the end of the collective lever) and turning as needed.

The MAP sensor measures air pressure downstream of the throttle, which is less than atmospheric pressure when the engine is running. The MAP will increase if the throttle is opened, or if the engine RPM decays, or combination of the two.

The engine throttle control is depicted in Figure 5. The engine right magneto (RM) senses engine RPM, which is sent to the governor controller. The governor controller provides the correction signal to the engine throttle via the governor motor, friction clutch and pilot's twist grip on the collective lever. This provides a closed-loop system to maintain RPM. Figure 5 shows the components in green that were tested during the investigation, the components in yellow are the cockpit gauges and those in blue represent the air intake path.

Figure 5: R44 engine throttle control



Source: ATSB

[11] Collective: a primary helicopter flight control that simultaneously affects the pitch of all blades of a lifting rotor. Collective input is the main control for vertical speed.

In Figure 5, the governor switch is represented in the off position, which will illuminate the 'governor off' light. The governor switch is located at the end of the collective lever, and was not visible in any videos. When the switch is closed (on position) by the pilot, the 'governor off' light will extinguish to indicate the controller is receiving electrical power - the light does not provide a fault indication.

If there is a fault with the right magneto points, a faulty signal will be sent to the controller, which will respond accordingly. The engine tachometer in the cockpit receives a signal from the same source as the controller (RM). Therefore, irregular engine RPM indications (erratic movement) will be present if the points are producing a faulty signal. This was not observed on the passenger video or reported by the accident pilot.

The governor controller is active from 79–111 per cent engine RPM. Within the active range there is a 1 per cent wide dead-band from 101.5–102.5 per cent where it will not take action provided the RPM is steady. At 101.5 per cent there is a step change in the controller output voltage, followed by a ramp increase to maximum voltage output at about 97 per cent, which is maintained to the cut-off at 79 per cent. The controller dead-time[12] was not published, but the advice received from RHC was as follows:

> From the pilot's perspective, the output response is typically immediate, but the result may not be. For example, if the throttle is half open and the collective is aggressively raised, causing the RPM to drop, the governor will immediately open the throttle aggressively, but if the load on the engine is greater than power available (at that lower RPM), the RPM will be slow to increase.

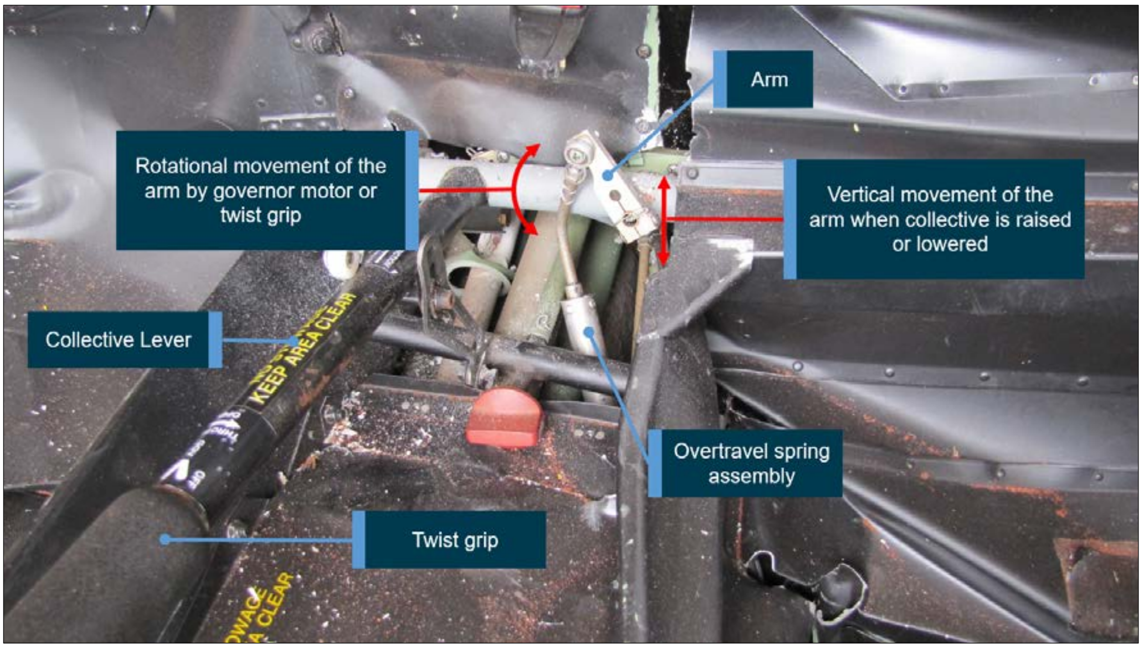
Overtravel spring

During the ATSB's examination of the wreckage (refer to section titled *Post-accident tests and inspections*), the overtravel spring assembly was found bent (Figure 6), most likely as a result of the ground impact. Robinson reported that, from the overtravel spring to the engine throttle valve, the system can be considered to be a purely mechanical link and extension or compression of the overtravel spring does not occur during normal flight regimes, only at the extremes of throttle travel.

With reference to Figure 6, the arm connected to the collective lever assembly and overtravel spring assembly can move vertically or in rotation. When the collective lever is raised or lowered, it will move vertically to increase or decrease engine throttle. When the pilot rotates the twist grip, or driven by the governor motor, it will rotate to increase or decrease engine throttle.

[12] Controller dead-time is the time required for a change in input to produce a change in output.

Figure 6: VH-HGX collective lever assembly and overtravel spring assembly



Source: ATSB

Post-accident tests and inspections

The ATSB did not conduct an on-site visit to inspect the wreckage and impact. However, from the various video recordings, the ATSB and RHC noted the engine operation 'sounded good' until the sound of the engine RPM being retarded by the decaying rotor RPM became noticeable.

The pilot who flew the accident helicopter earlier on the day reported that it was achieving the pilot's operating handbook (POH) published TOP range of 24.2–25.8 in Hg MAP and that the movement of the twist grip could be felt as the governor adjusted the throttle to maintain RPM. In addition, the accident pilot reported that the helicopter was 'operating correctly' at take-off. As a result of this information, the ATSB was primarily interested in the helicopter information related to the engine power and RPM control.

Right magneto, light bulb and switch

Following the accident, at the request of the ATSB, the right magneto was removed from the helicopter by the insurance surveyor. An inspection and test of the right magneto and associated wiring was conducted. No fault was found with the right magneto tachometer points used for the engine tachometer and the governor controller, and the magneto tested serviceable. No fault was found with the associated wiring. The 'governor off' light bulb and governor switch were later tested and also found to be serviceable, but with the limitation that each item was tested in isolation as the instrument panel was already removed from the airframe.

Governor controller test

Following the inspection of the magneto and wiring, the governor controller was removed and sent to RHC to perform an inspection and functional test of the unit under the supervision of the United States National Transportation Safety Board. There were no indications of tampering or thermal damage, and the unit's electrical connector was clean and pins straight. A functional test was performed in accordance with the RHC process. The test results were observed to be within specifications and no fault was found.

ATSB post-onsite wreckage examination

Following the serviceability assessment of the governor controller, the ATSB examined the stored wreckage to inspect and test the governor motor, friction clutch and pilot's throttle twist grip, in accordance with RHC's procedures. After removal of the damaged surrounding structure, and disconnection of the deformed overtravel spring, the components were found to be in a satisfactory condition to be tested in situ.

Each test was repeated with no fault found and assessed to be serviceable. The ATSB noted the governor motor was capable of rotating the pilot's twist grip from full closed to full open in about 8 seconds. The friction clutch operated as designed when hand pressure was increased on the twist grip, which provided override of the governor motor and full manual control of the arm in both vertical and rotational movement.

The governor switch was in the off position when the ATSB attended the wreckage. The operator reported a witness at the accident site noted the switch was in the off position, but this was only observed after the occupants had been removed from the wreckage. Therefore, it was possible that the switch was disturbed after impact.

The governor circuit breaker and low RPM light and horn circuit breakers were in. The warning lights' circuit breaker (includes 'governor off' light) was out. However, several other circuit breakers for systems that were observed to be working during the flight were also out, which indicated that some circuit breakers tripped during the accident.

Robinson helicopters have been subject to isolated cases of obstruction to the air induction systems from a deterioration of components, such as air filters. This has resulted in several service defect reports in Australia, including reports of loss of power, and several RHC service bulletins on the subject of air filter deterioration.

The R44 maintenance manual low power troubleshooting checklist included inspecting the air induction system for obstructions. Therefore, the ATSB reviewed post-accident images of the condition of the air filter fitted to VH-HGX. The air filter was found to have been pushed up through the carburettor by the ground impact while the engine was running, resulting in considerable damage to the air filter and the carburettor ingesting sand and debris. As such, the ATSB was unable to determine the condition of the air filter prior to impact.

Engine performance study

According to the R44 POH, the MCP limit was 24.2 in Hg MAP at 2,000 ft pressure altitude and 40 °C (205 hp). An additional 1.6 in Hg can be added to MCP for a 5-minute TOP rating of 25.8 in Hg MAP (225 hp). Passenger footage of the previous flight revealed the helicopter climbed to about 3,500 ft pressure altitude at 22–23 in Hg MAP, which indicated the engine was producing 187–197 hp at an elevation about 1,700 ft above the helipad. This was consistent with the performance of the engine as reported by the pilot who operated the helicopter earlier on the day of the accident.

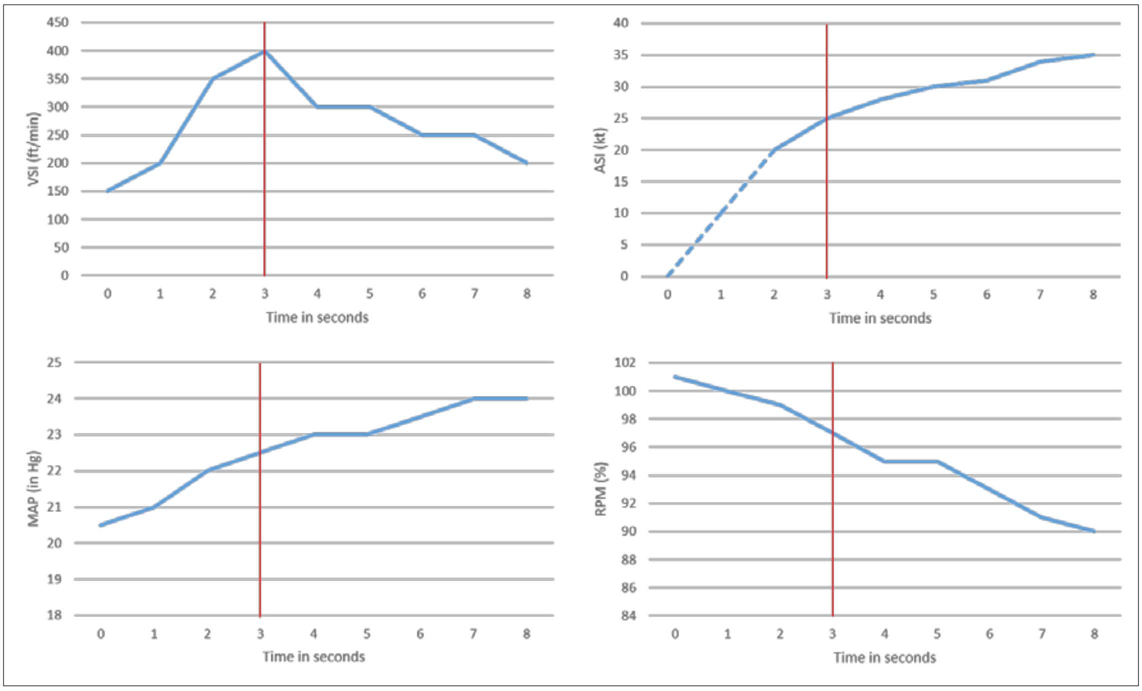
The right rear seat passenger's video provided an uninterrupted view of the cockpit instruments during the first 8 seconds of the departure, which was sufficient time for the MAP to indicate a response from either governor or pilot throttle input. Therefore, the video recording period of t=0 to t=8 was chosen for the engine performance review. The video indicated the low rotor RPM warning started about 3 seconds after take-off (t=3).

Cockpit instrument indications

The cockpit instrument indications for vertical speed (VSI – ft/min), airspeed (ASI - kt), MAP (in Hg) and engine RPM (%) were plotted (Figure 7). The measurements were based on passenger video footage of instrument readings using 1 second time intervals. Therefore, the accuracy of any individual data point should be treated with caution. As the engine and rotor RPM decayed together (within the tolerance of 1 per cent of each other), the rotor RPM trend can be inferred from the engine RPM trend.

The top left graph of Figure 7 shows that the vertical speed reduced after the low rotor RPM warning activated, but remained positive (climbing). A number of factors could have accounted for this change, such as a loss of ground effect, increase in forward cyclic or reduced collective setting. The top right graph shows the airspeed steadily increased after it started to provide a reliable indication. The bottom left graph shows the MAP steadily increased and the bottom right graph shows the RPM steadily decreased.

Figure 7: Data plot of instrument indications



Note: The data plots of instrument indications include a red vertical line for the low rotor RPM warning at t=3 seconds. The dashed line at the start of the airspeed indicates unreliable indications.
Source: ATSB

Engine power

Using the RPM, MAP, environmental conditions and the Lycoming O-540-F series performance chart, the ATSB plotted the engine horse-power from t=0 to t=8 seconds (Table 1). The lowest RPM on the chart was 2,500 (93.8 per cent RPM), therefore, the results for t>=6 were based on extrapolated data, but considered to provide a reliable trend based on the helicopter’s increasing airspeed and positive rate of climb. As the RPM continued to decay, data points beyond t=8 did not appear to change the trend, but resulted in the need for greater extrapolation of the charts, which increased uncertainty in the results obtained. Therefore, these have not been included.

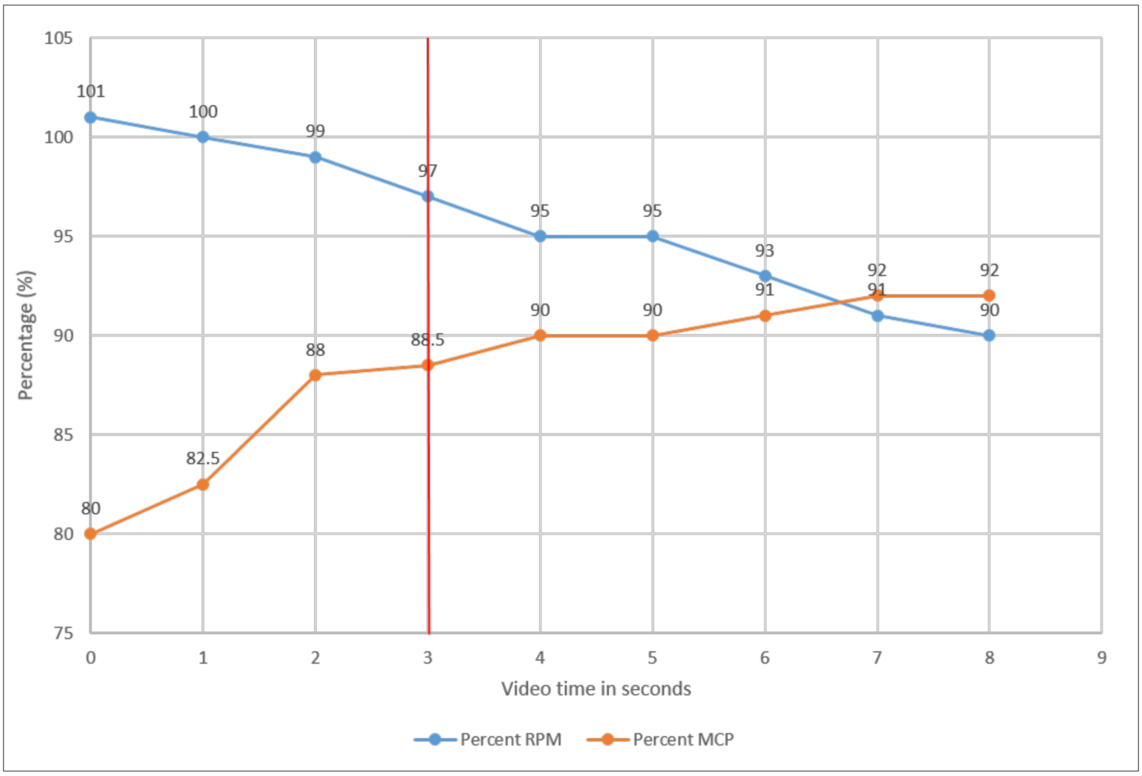
Although engine power is proportional to RPM, it is also proportional to mechanical and volumetric efficiency, which may improve as the RPM decays. This can result in a relationship between power and RPM that is not strictly linear. The engine manufacturer was unable to provide a power (or torque) curve for the engine, so it could not be determined at what RPM the engine power would start to decay, but the ATSB accept that the power available would have reduced at some stage during the departure as the RPM decayed.

The Table 1 figures indicate that MAP and engine power were increasing during take-off, but at a decreasing rate. The engine manufacturer’s fuel consumption charts indicate that the same throttle setting will produce a higher MAP at a lower RPM. Therefore, a MAP equivalent to the MCP throttle setting did not appear to have been achieved in this period. Figure 8 depicts the trend in engine power as a percentage of 205 hp (MCP) and the trend in RPM decay.

Table 1: Engine power

Time (s)	RPM (%)	MAP (in Hg)	Power (hp)	Percent 225 hp	Percent 205 hp
0	2,691 (101)	20.5	164	73	80
1	2,665 (100)	21.0	169	75	82.5
2	2,638 (99)	22.0	180	80	88
3	2,585 (97)	22.5	181	80.5	88.5
4	2,531 (95)	23.0	184	82	90
5	2,531 (95)	23.0	184	82	90
6	2,478 (93)	23.5	187	83	91
7	2,425 (91)	24.0	189	84	92
8	2,398 (90)	24.0	189	84	92

Figure 8: Trend in engine power and RPM



Note: The trend in engine power and RPM includes a red vertical line for the low rotor RPM warning at t=3 seconds.
Source: ATSB

Airflow restriction

The low MAP and power during take-off indicated the engine was producing good suction power, but receiving inadequate airflow. Therefore, the limited power output from the engine during take-off was considered by the ATSB to potentially be the result of a partial obstruction of the intake airflow or restriction of the throttle butterfly valve (stuck throttle), upstream from the MAP sensor. This would produce a low MAP and decay in RPM when the collective lever was raised. However, engine power increased during take-off at the same time that the RPM was decaying, which indicated that the throttle was opening and intake airflow was able to increase. Passenger footage of the helipads revealed they were clean and free of debris, and that the passengers were escorted to and from the helicopters on the pad. This suggested the RPM decay was unlikely to be the result of a foreign object obstruction or stuck throttle.

Overpitching

Overpitching is a phenomena that happens when the collective pitch is increased to a point where the main rotor blade angle of attack creates so much drag that all available engine power cannot maintain or restore normal operation rotor RPM.[13]

There are two commonly understood mishandling techniques, which can result in a pilot overpitching the helicopter during take-off. If a pilot raises the collective lever to a point beyond the full throttle position (where full throttle was required to maintain RPM), then there will be more power required by the rotors than power available from the engine, resulting in a rotor RPM decay. However, during the accident flight, the rotor RPM started to decay when the MAP was below the published MCP rating. There was also an indication that power increased after the decay started. Therefore, a rotor RPM decay as a result of the pilot raising the collective lever beyond the full throttle position was considered very unlikely.

A second mishandling technique involves a pilot raising the collective lever at a rate that is faster than the rate at which the correlator and governor open the throttle, and the pilot does not compensate by adding more throttle. In this case, the rotor RPM may rapidly decay to a level that is too low for the engine power available to recover. According to RHC, the further away from the target RPM, the faster the governor will move the throttle, and for the R44, the engine power response to a throttle input is almost instantaneous. Therefore, as the engine RPM decays the throttle setting should increase and provide a corresponding increase in the MAP as the governor attempts to recover the engine RPM.

The rotor RPM decayed at a relatively steady rate of 11 per cent over 8 seconds. During this period, the MAP did not increase to a value representative of full throttle. Therefore, the decay in RPM as a result of the pilot raising the collective lever at a rate faster than the governor could immediately respond to, was considered unlikely.

Summary

The instrument indications, and subsequent plots of power and throttle, were consistent with the pilot raising the collective lever during the initial climb and acceleration phase of the take-off. This indicated there was mechanical continuity between the collective lever and the engine throttle. In addition, the engine run-up from idle prior to lift-off indicated there was mechanical continuity from the pilot's twist grip to the engine throttle.

As the helicopter was operating at near maximum all-up-weight and a high density altitude environment, a high collective lever setting, requiring a high engine power, would have been expected for this phase of flight. Therefore, it was concluded that, as the power required by the rotors increased during take-off, the engine throttle position did not increase by a corresponding amount to produce sufficient power to maintain RPM. In addition, there was no MAP indication of a corrective input to the throttle, equivalent to MCP–TOP, in response to the RPM decay in the initial 8 seconds of the video.

Operational information

Yulara Town helipad

The Yulara Town helipad was part of the operator's Uluru Base, which included scenic flight operations from Kings Canyon and a maintenance facility at Ayer's Rock Airport. The Uluru operations were managed by an area manager and deputy area manager. The Yulara Town helipad comprised two concrete pads and a building located on the west side of the Yulara Resort facility. In support of the operation, the operator published local 'PHS Town Helipad Procedures'.

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13 International Civil Aviation Organization (ICAO) *Manual of Aircraft Accident and Incident Investigation*. Chapter 15: *Helicopter investigation*.

The local procedures included housekeeping, general safety and operational rules, flight procedures and record keeping.

Oversight

The operator's senior management reported that their oversight of the Uluru Base included regular phone calls with the area manager and deputy area manager, and site visits. The site visits included conducting company check and training flights, and holding staff meetings.

In the 2017 calendar year, the chief pilot visited the base for pilot training, supervision and staff meetings in April, May, August and September. The general manager operations visited the base in April, May, July and August. In addition to the visits made by senior management, the operator reported there were multiple visits by their instructors throughout the year for training and check flights to ensure standardisation against company procedures.

Charter group weights

On the day of the accident, the area manager was involved in the flying activities for the afternoon charter group and the deputy area manager was responsible for managing the ground operations. Prior to the activity day, the operator sent the charter group organiser a blank manifest for them to fill in the names and weights of the passengers. This was returned to them with names only and no weights recorded. Therefore, when the passengers arrived at the helipad on the day, they were individually weighed using the operator's scales.

After weighing, the passengers were divided into groups and allocated to helicopters on the manifest in a manner to ensure the maximum weight limits were not exceeded. The operator used one Aerospatiale AS350 helicopter and three R44 helicopters for the operation. The practice of weighing individual passengers for a flight was in accordance with best practice for aircraft with small seating capacities, rather than using standard weights.[14] However, at the time of the accident, the operator's passenger scales were not subject to a calibration schedule.[15]

The passengers on board the accident helicopter and on other flights reported that the scales under-recorded their weights. Personal reports of weights indicated an error of 6–9 per cent, and hospital records indicated an error of 11.8–12.2 per cent for the pilot and one passenger. The overall error for the occupants on the accident flight was an under-estimation of 9.6 per cent.

Running turn-around procedure

The passenger boarding and disembarkation from the helicopters was conducted as a running turn-around (RTR) procedure. There is no RTR procedure in the normal procedures section of the POH, therefore the operator developed their own procedure. According to the operator, the RTR procedure was for the pilot to run the engine down to idle and turn off the governor prior to passenger disembarkation. After passenger boarding, the pilot should turn on the governor and run the engine and rotors up to 102 per cent RPM. There was no requirement during the RTR to check the low rotor RPM warning.

Turning the governor on before running the engine up from idle during the RTR was consistent with the RHC R44 'starting engine and run-up' checklist. The operation of the governor can be checked by allowing it to accelerate the engine from 79 to 102 per cent. Robinson reported that 'the pilot should ensure the governor is operating properly when rolling the throttle open during the start-up checks'.

During the RTR, the accident pilot would run the engine down to idle and turn off the governor for the passenger disembarkation. However, after passenger boarding the pilot would run the engine

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[14] Civil Aviation Advisory Publication 235-1(1): *Standard passenger and baggage weights*, advised that the use of standard passenger weights results in a high probability of overloading.

[15] Calibration of measuring equipment is performed to ensure the product operates to within a defined acceptable error or accuracy limit. A calibration interval is set to ensure continued conformance with those accuracy limits.

up manually, with the governor off, check the operation of the low rotor RPM warning from 90 to 98 per cent RPM, then turn the governor on, make a radio call, and check indications were in the 'green'[16] in the hover after lift-off.

Passenger phone footage of the pilot's previous flight RTR revealed the low rotor RPM warning check was being conducted with the governor off, consistent with the pilot's reported practice. The pilot submitted that they were trained to check the governor was on and working before take-off, and that they were confident this was done after the low rotor RPM horn check. The passenger footage of the accident flight departure indicated the 'governor off' light was extinguished, which would have provided a visual indication to the pilot that the governor was selected on.

The Civil Aviation Safety Authority (CASA) reported that this practice was not in accordance with the POH procedures, which indicated that the governor should be on prior to engine start and remain on until shut-down. Robinson safety notice 36, issued in 2000, required ensuring the governor was selected on before increasing RPM above 80 per cent. The Civil Aviation Safety Authority also reported that if the 'governor off' light globe had extinguished without the governor being selected on, the pilot may not have been alerted to the possibility that the governor was off.

Take-off procedures

The operator had published normal (in-ground-effect[17] - IGE) and confined area (out-of-ground-effect - OGE) take-off procedures in their operations manual. In addition, they had published a local departure procedure for the Yulara Town helipad, which required their pilots to avoid overflying the Yulara Resort on departure and approach. The operator's take-off procedures were as follows:

Normal take-off profile:

> Adopt a 3 foot hover at take-off RPM and note the power being used. **For passenger carrying charter operations the power margin[18] MUST BE sufficient to ensure there is no height loss during the initial take-off phase**. Conduct the pre take off checks. Lower the nose slightly and wait for the helicopter to move. As the speed builds up, keep gradually lowering the nose until you get an accelerating attitude that is **NOT** excessive. **This ensures that you are in the best possible configuration to handle an engine failure during this phase of take-off**.
>
> As you pass effective translational lift[19] (ETL) speed maintain the selected attitude and raise the collective slightly to commence climbing. Don't use excessive power prior to reaching the BROC [best rate of climb] speed, as this is the most critical part of the take-off. **This ensures that you remain outside the height/velocity curve [avoid area]**.[20]

Confined area / Steep (when obstacles preclude the use of a normal take-off profile):

> Before lifting off, check for obstructions around the helicopter and plan to make maximum use of the available space for take-off. Before commencing the take-off, check for overhanging trees **ABOVE THE HELICOPTER** and **ALONG THE TAKE-OFF PATH**. **For passenger carrying charter operations, there MUST BE sufficient power to maintain an OGE hover before commencing the take-off**.
>
> Commence a vertical climb and check the RPM and power before moving forward. If these parameters are not acceptable, descend vertically back to the pre take-off position and re-assess

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16 The green operating range for the engine tachometer was 101–102 per cent RPM.

17 Ground effect is usually defined as within one rotor diameter of the ground (33 ft for the R44; note that the rotor mast is 10.75 ft when the helicopter is on the ground). At less than one rotor diameter the ground resists the rotor downwash and less power is required to hover. As the helicopter climbs vertically from ground level, the downwash dissipates into the surrounding air and more power is required to hover and take-off.

18 Power margin: difference between the power required and the power available. In this report it is also used to refer to the difference between the power required and the power produced during RPM decay in flight.

19 Translational lift normally occurs at about 12–15 kt airspeed and provides a reduction in the power required for flight.

20 The avoid area in the height-velocity diagram is a combination of height and airspeed, within which, it may not be possible to safely land the helicopter after an engine failure.

> the situation. Aim to clear the obstacles by a minimum of 15 ft. Do not climb higher than necessary to achieve this.

The normal take-off profile allowed the helicopter to accelerate forward at a height of typically less than one rotor diameter until it reached its best rate of climb speed before initiating a positive rate of climb. The confined area take-off required the helicopter to climb vertically and initiate the take-off from a height greater than one rotor diameter, and therefore the helicopter required OGE performance. The operator reported that their confined area take-off procedure was designed to ensure there is sufficient power available to clear obstacles by 15 ft, while minimising exposure to the avoid area of the height-velocity diagram.

Accident flight take-off

Helipad camera video footage captured the accident helicopter arrive at the far pad (pad 2), and change passenger loads for what would be the accident flight.[21] The footage showed the helicopter lift-off and continue to climb vertically to a height of about half a rotor diameter (16.5 ft)[22] before transitioning into forward flight 5 seconds after lift-off, while continuing to climb. The take-off direction selected by the pilot required the helicopter to clear smaller trees closer to the pad and then larger trees beyond the smaller trees (Figure 9).

Figure 9: Departure path from pad 2

Source: Passenger footage from previous flight

At the start of the passenger video, the helicopter had started to transition forward. The altimeter then indicated a climb of about 20 ft in the 3 seconds from the start of the recording to the activation of the low rotor RPM warning. The airspeed increased from no positive indication to about 25 kt in this period, which was consistent with a take-off into wind. Consequently, it was likely the helicopter had reached a height of about 37 ft, and accelerated through translational lift, when the low rotor RPM activated (Figure 10). The proximity of the trees at the time of the low rotor RPM warning did not permit a safe abort.

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[21] The local time displayed on the helipad camera was estimated to be about 8 minutes behind the actual time.

[22] The R44 rotor diameter is 33 ft. The rotor radius/diameter was the dimension used to estimate the height of events on the helipad camera footage.

Figure 10: Approximate position of the low rotor RPM warning

Source: Operator, annotated by the ATSB

The operator noted that the MAP at the start of the passenger video indicated the helicopter had sufficient power margin for the take-off profile, and that the observed profile complied with their procedural requirement to 'not climb higher than necessary'.

Helicopter performance

Meteorological information

Ayers Rock Airport is at 1,626 ft in elevation. On the day of the accident at 1830, the recorded airport weather was temperature of 38 °C, QNH[23] 1007 hPa and wind of 9 kt from 080° (the pilot reported the helipad windsock indicated about 5–10 kt).[24][25] This resulted in a pressure altitude of 1,788 ft and density altitude of 4,936 ft. Based on the Ayers Rock Airport weather and helicopter tracking data provided by the operator, the ATSB estimated the pilot's take-off direction included about a 6 kt headwind component and 7 kt cross wind component from the right. However, the increase in airspeed on take-off suggested the local wind above tree height might have been stronger.

Take-off weights, profiles and power

The helicopter's published maximum weight was 1,089 kg. The planned weight for the flight (group 9) was 1,046 kg.[26] Using the actual weights provided by the passengers following the accident and hospital records for the pilot and right rear seat passenger, the ATSB calculated the take-off weight was about 1,080 kg.[27] The two previous flights for VH-HGX were at the planned weights of 1,038 kg (80 L fuel – group 8) and 1,073 kg (90 L fuel – group 7) respectively. Applying the error from the accident flight to the occupants of the two previous flights produced estimated weights of 1,067 kg and 1,105 kg, 22 kg below and 16 kg above the maximum weight of the helicopter.

The accident flight take-off weight was within the helicopter's published weight for an IGE take-off, but it exceeded the weight for an OGE take-off, which was about 1,025 kg. The deputy area manager reported that the traffic pattern for the flights permitted either an IGE or OGE take-off

[23] QNH: the altimeter barometric pressure subscale setting used to indicate the height above mean sea level. Standard atmospheric pressure is 1013.2 hPa.
[24] The wind speed is a mean speed over a 10-minute period.
[25] The helipad was fitted with a windsock to provide local wind conditions for arrivals and departures.
[26] This was based on the helicopter basic empty weight 675 kg, plus 320 kg for the occupants and 51 kg (70 L) for fuel.
[27] This was based on the helicopter basic empty weight 675 kg, plus 354 kg for the occupants and 51 kg (70 L) for fuel.

option, noting the OGE was more into wind. He also commented that the accident flight departure looked similar to the pilot's previous departures, and that none of the pilots had provided a reduced operating weight for OGE performance.

It was initially unclear to the ATSB why the pilot reported following the procedure for the confined area take-off, but had not provided a reduced OGE operating weight. The operator explained that the OGE chart is used for a flight planned to a confined area to ensure there will be an adequate power margin for the arrival and departure. The Yulara Town helipad was not a confined area and there was no requirement to use the OGE chart. In addition, the operator had recommended that a confined area take-off could be conducted/continued if the IGE MAP during the hover power check was 2 in Hg below TOP, which the passenger video indicated the accident flight had.

Although the pilot reported following the confined area procedure, the helipad and passenger video indicated the take-off started from IGE and translational lift was likely achieved at, or close to, a height equivalent to OGE. The operator described this as a steep profile, rather than a confined area profile. The Civil Aviation Safety Authority (CASA) reported that there is no strict definition for a confined area and that the avoid area of the height-velocity diagram (used for a steep or OGE take-off) for this category of operation is a recommendation and not mandatory.

The Civil Aviation Safety Amendment (Part 133 – Australian air transport operations – rotorcraft) Regulations 2018 are scheduled to commence in December 2021. They will see the introduction of performance class operations, which CASA reported will provide greater regulatory effect to the avoid area in the height-velocity diagram and take-off weight performance criteria, similar to the current standards for this type of operation in the United States[28] and Europe.[29]

Low rotor RPM recovery procedure

Immediate actions

According to the R44 POH, the recommended procedure to recover from a low rotor RPM warning condition (warning horn and caution light) was as follows:

> To restore RPM, immediately roll throttle on, lower collective and, in forward flight, apply aft cyclic.

Lowering the collective lever will reduce the power required by the rotors to aid the recovery of rotor RPM. However, in the R44 helicopter the correlator will decrease the throttle when the collective is lowered and reduce engine power unless the pilot rotates the twist grip to roll throttle on. This is a standard response, irrespective of the operational state of the governor system, because the pilot can apply throttle faster than the governor.

The operator reported that if the collective lever is lowered in an attempt to recover RPM in the R44 Raven 1 with the throttle already fully open, then the pilot must hold the twist grip open against overtravel spring pressure to keep the engine throttle fully open and prevent a loss of engine power during the recovery.

Robinson reported that if the throttle is fully open and the collective is lowered, the correlator linkage will decrease the throttle accordingly. If the pilot rolls on throttle while lowering the collective, as per the procedure, the throttle will remain open and may, or may not, compress the overtravel spring. Pilots should not be concerned if the spring is compressed or not, they should continue to roll the throttle on and lower the collective until the RPM is recovered.

A pilot may not necessarily know if the throttle is fully open or not, when the low RPM warning is activated. If the throttle is not fully open and the collective is lowered, followed by the pilot instantly rolling on throttle enough to compress the overtravel spring, an overspeed is probable.

The ATSB and Robinson noted that lowering the collective lever from level flight may result in a descent, and therefore this action may be inappropriate when the helicopter is close to obstacles.

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28 United States Code of Federal Regulation Part 136 – Commercial air tours and national parks air tour management. Subpart A – National air tour safety standards. Part 136.13: Helicopter performance plan and operations.

29 European Aviation Safety Agency CAT.POL.H.405: Take-off.

However, in the accident flight, the helicopter continued to climb on departure and Robinson indicated that, 'if the pilot performed the recovery procedure, reducing collective just enough to stop the ascent [climb] and acceleration, the RPM would most likely have recovered and increased immediately'.

Minimum power airspeed (V_Y)

The minimum power airspeed (Vy) for the R44 is 55 kt. This will provide the greatest power margin in-flight (lowest collective lever position to maintain airspeed and altitude), and correspondingly the best rate of climb (maximum excess power). However, there was no reference to this airspeed in the POH low rotor RPM recovery procedure. Robinson reported the reason for this as follows:

> The recovery procedure is designed for immediate correction of low RPM, it would be the pilot's responsibility to determine the best course of action to prevent a recurrence depending on the circumstances. The power margin would be a consideration.

With respect to airspeed and the immediate actions for low rotor RPM recovery, CASA reported the following:

> Aft cyclic should only be applied with substantial forward speed. When at slower speeds, which is when low rotor RPM is dangerous, forward cyclic should be applied very gently to gain airspeed.

The ATSB discussed low rotor RPM recovery with one of the operator's Robinson helicopter flight instructors who had viewed the passenger video footage. The instructor noted from the footage that the MAP appeared to be low for the departure and that, after initially increasing airspeed, the helicopter pitched up in the turn and the airspeed decayed. Consequently, the helicopter remained on the 'back-end of the power curve'.

The instructor suggested that the recovery technique, while departing over obstacles where there is no suitable landing, should be to 'apply full throttle, get speed on and reduce the collective to reduce pitch as speed increases… [to attain the] bottom of the power curve'. This will increase the power margin to facilitate RPM recovery. The instructor reported that the techniques for RPM recovery are taught and assessed in the 'governor malfunctions' element of the operator's pilot training syllabus.

The pilot who flew the accident helicopter earlier in the day reported that they were taught to increase throttle and lower the collective lever to regain rotor RPM. Following the accident the pilot 'learned…some [pilots] would increase airspeed to gain lift to overcome RPM droop [decay]'. The ATSB reviewed various online training videos for R44 low rotor RPM recovery and noted there were references to 55 kt as a target speed during the recovery, but that recovery would occur as soon as there was a sufficient power margin available.

Robinson have produced a series of instructional videos to support the training of R22 and R44 pilots in several subject areas, which are associated with high risk flight conditions. They include the following:

- energy management
- mast bumping
- low rotor RPM (blade stall)[30]
- low-G hazards
- rotor RPM decay.

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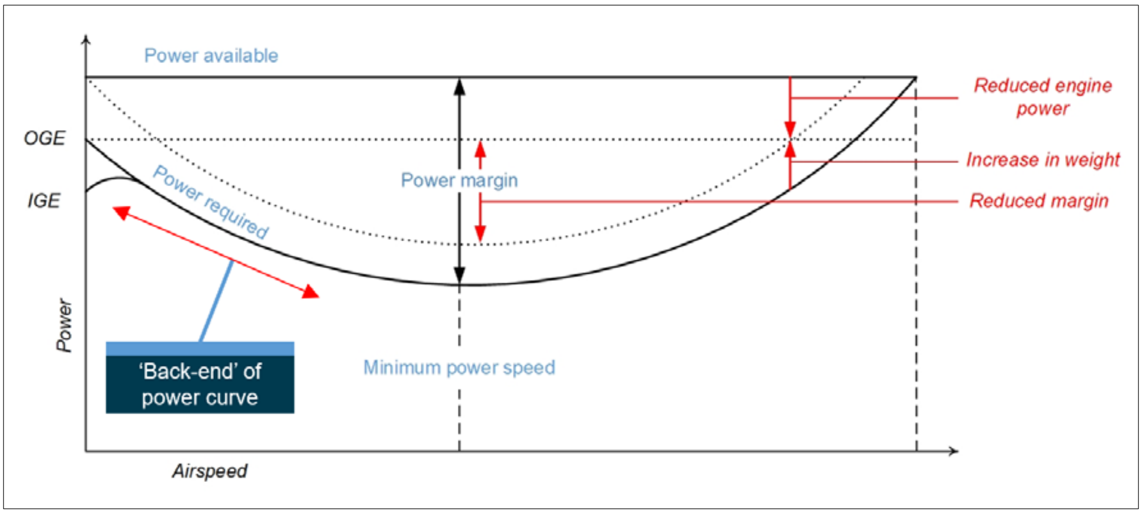
30 According to the R44 POH, a main rotor blade stall will either 'cut off the tailcone' or the helicopter will 'just stop flying and fall at an extreme rate'.

These videos are publicly available from their company website.[31] In their training video: *Energy Management*, RHC reported that the three forms of energy available to a pilot are rotor RPM, airspeed and height. The minimum power airspeed is highlighted as providing the greatest power margin. The 'back side' of the power curve is described as the situation where the helicopter will require more power to fly slower, which makes it an unstable region for power and airspeed. They reported that one of the most common causes of helicopter accidents is the situation where the pilot allows the rotor RPM and airspeed to decay.

Figure 11 depicts a generic power curve for a helicopter in stable level flight. As airspeed increases, the power required to produce lift reduces, and the power to overcome fuselage drag increases, producing a bucket-like curve. A reduction in engine power and/or increase in weight will reduce the power margin available. At low airspeeds, a combination of high weight, high density altitude and low RPM could result in the power required becoming greater than the power available. To recover rotor RPM, a positive power margin is required. That is, the power produced (normally limited by the power available) must exceed the power required.

Figure 11: Generic power curve for stable level flight



Source: ATSB

To accelerate the helicopter in level flight, the pilot applies forward cyclic control, which tilts the main rotor disc forward. This increases the power required, which is why CASA advise to apply forward cyclic 'very gently' if at slower airspeeds. Hence, any loss of airspeed below Vy will result not only in an increase in the power required for level flight, but also a further increase in the power required if an attempt is made to accelerate to regain Vy.

The flight envelope power requirements for many light helicopters, such as the R44, are not published. However, RHC reported that the Vy power requirement would be approximately 60 per cent of the zero airspeed (OGE hover) power. The ATSB applied a correction for half a rotor diameter height to the accident flight helicopter's power, taking 164 hp as the hover power prior to the pilot initiating take-off. The correction for ground effect provided an approximate zero airspeed power of 188 hp.[32,33] This resulted in a Vy power of approximately 113 hp. Therefore, the power produced on departure would have provided a margin of about 76 hp to the power required at Vy.

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[31] The training videos can be found through Robinson Helicopter Company/Training/SFAR 73 Training: http://www.gyronimosystems.com/SFAR/

[32] Hayden JS 1976, *The effect of the ground on helicopter hover power required*, in 32nd AHS Annual Forum, Washington DC, cited in Filippone A 2006, *Flight performance of fixed and rotary wing aircraft*, American Institute of Aeronautics and Astronautics Inc., USA.

[33] The formula did not include a variable for the surface condition, which may influence the actual result obtained.

The R44 POH emergency procedures section includes references to recommended airspeeds for pilots to fly in various emergency situations. They include the autorotation airspeeds for the minimum rate of descent and for the maximum range. The ATSB selected another light helicopter, the Aerospatiale AS350, certified to similar standards as the R44, and reviewed the emergency procedure checklists for evidence of recommended airspeed information. It was noted that there were numerous references to recommended airspeeds to assist a pilot in either their immediate or subsequent emergency procedure recovery actions.

Pilot's training

The pilot was trained by the operator on a commercial pilot licence (helicopter) course from the period June 2016 to June 2017. In consideration of the pilot's performance during training, the operator offered the pilot a job at their Uluru Base.

The pilot's training records indicated that handling governor failures in the R22 was covered in July 2016, for which the instructor recorded 'good RPM recovery and monitoring'. The ATSB discussed the pilot's throttle handling with two of the pilot's instructors. They reported that the technique of a pilot over-riding the governor input with a tight grip on the collective lever twist grip was well known throughout the industry (known as 'strangling the throttle'). This was a focus point for students at the beginning of their training and was not identified as an ongoing problem for the accident pilot. There was no report of this problem in the pilot's training records to indicate otherwise.

During the pilot's company check flight on 12 July 2017 the governor failure sequence and limited power were assessed. The check pilot reported that the pilot's 'general flying was excellent', limited power was 'very good' and confined area operations were 'all ok', but included a focus point for the pilot to 'check PWR/RPM [power margin, engine and rotor RPM] before rolling out of a confined [confined area]'.

Calculating IGE and OGE performance was captured in the pilot's training, which included confined area flying training. However, according to one of the pilot's line training instructors,[34] it was not specifically assessed during the line training at the Uluru Base, where the pilot was cleared to fly the line on 21 September 2017. The line training sign-off flights for the helipads were conducted without passengers, but with an emphasis on the safest departures and approaches. The pilot's training report included out-landings, confined area, weight and balance, and flight planning.

A minimum of three take-offs and landings were flown to each pad during the line training. The instructor did not note any problems, which would have prevented a recommendation for the pilot's release to line, and there was no indication the pilot was 'strangling the throttle'. The pilot's grip on the collective lever was not visible in the passenger video of the accident flight take-off, but it was noted that the pilot appeared to hold the cyclic with a light grip in the video of the accident flight and an earlier flight.

Survival factors

The helicopter came to rest inverted with significant damage to the landing gear, airframe and seating. The rear left seat and front left seat passengers were able to exit from the wreckage, but the pilot and rear right seat passenger required assistance to exit from the wreckage. A company AS350 helicopter tracking behind VH-HGX provided first response with the operator's personnel. On arrival at the accident site, they assisted the remaining occupants to egress from the wreckage.

After the occupants of VH-HGX were removed from the wreckage, the AS350 was used to ferry emergency response personnel and equipment to the accident site. The Yulara Clinic Manager triaged the occupants based on the assessment of the nature of their injuries and administered

[34] There were two instructors involved in the pilot's three line training flights.

medical assistance to stabilise them before their evacuation. They were subsequently evacuated to the local medical clinic by helicopter and emergency services vehicles when last light precluded further flights to the accident site.[35]

The iBrace Survivor Questionnaire[36] was completed for the pilot and passengers with the following results:

- The pilot, seated in the front right seat, was wearing a 3-point harness and was unable to exit unassisted from the wreckage. The pilot suffered a broken back, spinal cord injury and a wound to the right arm.
- The front left seat passenger was wearing a 3-point harness and was able to exit unassisted from the wreckage. The passenger suffered multiple fractures, which included back, ribs, chest, pelvis and heel, and a laceration to the elbow. The passenger did not recall being shown a brace position, and reported that the pilot did not make a 'brace' call prior to impact, but did announce 'we are going down'.
- The rear right seat passenger was wearing a 3-point harness, which reportedly broke during the accident. The passenger reported that they were not provided with a 'brace' warning prior to impact and that they were unable to exit unassisted from the wreckage. The passenger suffered an eye injury, broken back, spinal cord injury, and fractures to the chest, abdomen and pelvis area, and a deep cut to the ankle.
- The rear left seat passenger was wearing a 3-point harness and was able to exit unassisted from the wreckage. The passenger suffered cuts and bruises to the head and face, and bruising and soft tissue injuries to the torso. The last announcement the passenger heard from the pilot was that they were 'going down'. The passenger braced for impact, but was not shown a brace position and reported that the pilot did not make a 'brace' call prior to impact.

The helicopter's certification standard for emergency landing conditions was based upon providing the occupants with a reasonable chance of escaping serious injury in a minor crash. This was based on the helicopter absorbing the landing loads with an ultimate descent velocity of five feet per second.[37] The damage to the underside of the helicopter (refer Figure 3), suggested that the landing was outside of the certification standard to prevent serious injuries.

Previous occurrences

Governor malfunctions

A review of the CASA service defect reporting system revealed three prior reported incidents of R44 governor malfunctions, dated 26 May 2017, 23 October 2014 and 7 September 2012. No part number information was provided for the report dated 7 September 2012, but the other two reports indicated the governor controllers had the same part number as the accident helicopter, D278-1.

The report dated 23 October 2014 stated: 'Pilot reported the governor was not functioning correctly. Governor was replaced with serviceable item. AC [aircraft] tested serviceable.'

The report dated 26 May 2017 stated: 'While in cruise, pilot noticed the main rotor RPM decayed and low rotor horn activated. Pilot maintained RPM by manually opening the throttle and established that the governor controller was u/s [unserviceable]. The helicopter was flown manually on the throttle per the approved flight manual. The Governor controller was replaced with an overhauled item per RHC MM [maintenance manual].'

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35 The evacuation priority of the injured occupants to medical facilities was based on the assessment by emergency response personnel in attendance at the site.

36 Davies JM, Wallace WA, Colton CL & Yoo KI (in press). Two aviation accident investigation questionnaires for passenger & crew survival factors & injuries. *Aviation Medicine and Human Performance*.

37 United States Code of Federal Regulations Part 27.561, issued 2 October 1965.

Low airspeed-low rotor RPM accidents

A review of previous ATSB investigations, which involved low airspeed-low rotor RPM conditions in the R44, was conducted. The review found two fatal accidents involving low experience commercial pilots, operating their helicopters in a high density altitude environment with a full load of passengers on board.

- 200600979: A commercial pilot and three passengers were fatally injured while conducting aerial work – survey. The helicopter had insufficient performance to hover or operate at slow speed OGE and collided with terrain following an over-pitching event. The pilot had 327.8 hours total helicopter flight time, which included 143.9 hours in the R44.
- AO-2008-062: A commercial pilot and three passengers were fatally injured during a scenic charter flight. The investigation found the helicopter was operated OGE in the hover or at slow speed with marginal performance for the purpose of photography. The pilot had recorded about 477 hours flight time, which included 346 hours in the R44.

Previous related safety issue

In response to the AO-2008-062 accident sequence of events, the ATSB raised, and closed, safety issue AO-2008-062-SI-01: *Robinson-specific training*, on 7 July 2010.

> **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.
>
> **Proactive action 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 Instructors Manual.

Civil Aviation Safety Authority update to safety issue

The Civil Aviation Safety Authority reported that as a result of the review into helicopter pilot training, they undertook to conduct all flight tests for the initial issue of helicopter instructor ratings and their renewals in an effort to raise the standard of flight training activities. The CASA *Helicopter Flight Instructors Manual* was amended in 2012 to include a new section 25: *Hazards*.

A project to develop a Civil Aviation Advisory Publication (CAAP) 5.14-3(0): *Helicopter Flight Instructor Training*, was started, but not completed due to work commitments to the *Civil Aviation Safety Regulations 1998* Part 61: *Flight crew licensing - Manual of Standards*. The Part 61 Manual of Standards incorporated aeronautical knowledge and practical flight standards to address the risks identified in AO-2008-062-SI-01. The current training standards for the Commercial Pilot Licence (Helicopter) were transferred from the previous licensing scheme to Part 61, including the competency standards from the previous day visual flight rules syllabus to the Part 61 Manual of Standards.

The introduction of Part 61 required pilots of R22 and R44 helicopters to complete initial flight training and a flight review on each type. In addition, it is a condition for pilots operating the R22 or R44 to complete a flight review on either type within the preceding 24 months.

Cockpit image recording equipment

The absence of recording equipment can result in limiting fatal accident investigations to the basic mechanics of the accident, without insight into the operational and human factors. In the event of a non-fatal accident with serious injuries, the physical and psychological trauma may adversely affect the memories of the occupants, resulting in a limited and, or, erroneous recollection of events. This severely limits the ability of the investigation to communicate safety lessons to the industry and provide policy makers with informed safety recommendations.

The Robinson family of helicopters, including the R44, do not currently have the option for flight data, cockpit voice or image recorders. However, RHC reported they are in the final phases of getting United States Federal Aviation Administration approval for a cockpit video system, and expect to begin deliveries in 2020. There are versions available for all their helicopter models. The system will start recording on helicopter start-up and record video and audio for the entire flight, and will capture the final seconds before power is lost.

Robinson are also certifying a new governor for their piston-powered helicopters. The governor has recording capabilities, which include multiple parameters (including rotor RPM) that will be available for maintenance and accident investigation purposes. The new governors will be standard on all R22s and R44s ordered since late January 2020. In addition, RHC is finalising a control position recorder, which will record limited information on cyclic and collective position, rotor and engine RPM, and global positioning system location. Robinson are installing prototype units on their eight company-owned helicopters, which are flown regularly, to collect reliability data before the units are provided to owners. The product is intended to become standard on all models of RHC helicopters.

The *Civil Aviation Safety Regulations 1998* Part 133 will introduce the regulatory requirement for flight data and cockpit voice recorders into rotorcraft air transport operations in Australia. However, the requirement will not include light helicopters, and it is this sector of the industry that comprise the vast majority of the ATSB's fatal helicopter accident investigations. The need to introduce cockpit image recorders has been recognised and advocated by several investigation bodies. These include:

- United Kingdom Air Accidents Investigation Branch: *Report on the accident to AS332 L2 Super Puma helicopter, G-WNSB on approach to Sumburgh Airport on 23 August 2013*. Safety Recommendations 2016-014 and 2016-015 issued to the European Aviation Safety Agency.
- New Zealand Transport Accident Investigation Commission: *Aviation inquiry AO-2015-002 Mast bump and in-flight break-up, Robinson R44, ZK-IPY, Lochy River, near Queenstown, 19 February 2015*. Safety Issue 014/16 issued to the Secretary of Transport.
- US National Transportation Safety Board: *Loss of control at take-off, Air Methods Corporation Airbus Helicopters AS350 B3e, N390LG, Frisco, Colorado, July 3, 2015*. Safety Recommendations A-13-12 and A-13-13 issued to the Federal Aviation Administration.[38]

[38] These followed earlier recommendations for crash resistant flight data recorders to be fitted to new and existing aircraft that were not already required to have them fitted.

Safety analysis

Introduction

During the departure from the Yulara Town helipad, Northern Territory, VH-HGX experienced a rotor speed (revolutions per minute - RPM) decay at a point from which the take-off could not be safely aborted. The rotor RPM continued to decay to a level from which the pilot could not recover, resulting in a hard landing when the pilot attempted a forced landing. The pilot and two passengers were seriously injured, and the remaining passenger experienced minor injuries. The helicopter was substantially damaged.

This analysis will discuss the pilot's running turn-around, the most likely reason for the rotor RPM decay, and the pilot's response to the low rotor RPM condition. It will further discuss the increased risk to the flight associated with inaccurate passenger scales, an opportunity to improve the helicopter's emergency procedures for a low rotor RPM recovery, and the benefits and limitations of the recordings.

Running turn-around

The operator reported that the governor would be turned off during the turn-around procedure for transferring passengers, and then selected on for the engine run-up. However, the pilot had adopted a practice of manually running the engine from idle, with the governor turned off, until completion of the low rotor RPM warning check at 98 per cent engine RPM. The ATSB considered that this practice could have inadvertently resulted in the pilot running the engine up into its green operating range (101–102 per cent engine RPM) before the governor was turned on.

The pilot submitted that they were confident the governor was on and working before take-off. However, any movement of either the twist grip throttle or the collective lever by the pilot after engine run-up that produced an RPM response could have been mistaken for a governor response. Therefore, an RPM indication in the green operating range, combined with the 'governor off' light extinguished, could have provided a false positive confirmation that the system was operating before take-off.

The extinguished 'governor off' light only indicated that the circuit for the light was open. This occurs when the governor switch is selected to the on position to provide electrical power to the controller, but will also occur if the light's circuit breaker trips. It did not provide an indication that the controller was operative. If the governor is not functionally checked from its low RPM operating range to 102 per cent, then a take-off may occur with an undetected problem.

Therefore, the pilot's practice of engine run-up with the governor off increased the risk of an inoperative governor (either selected off or with a fault) not being detected prior to take-off. Since it was the operator's procedure to turn the governor off during the running-turn-around, the ATSB considered it likely that the pilot had adopted this practice inadvertently.

Rotor RPM decay

The engine performance study used manifold pressure (MAP), engine RPM, the local environmental conditions and the engine manufacturer's charts to determine the engine power and throttle movement. The passenger phone footage started at about the time of the take-off (start of forward flight), at which time the RPM was at about 101 per cent. That review concluded that the engine throttle and power initially increased while the engine and rotor RPMs decayed during the departure.

The take-off was conducted at a high density altitude at near maximum weight. Therefore, a high MAP would be expected on departure under these conditions. However, the passenger video indicated the RPM started to decay at a relatively low MAP, which increased slowly, as the RPM steadily decayed to 90 per cent over an 8 second time period. The decay continued to 80 per cent over the following 7 seconds.

The engine was operated in the maximum continuous power (MCP) to take-off power (TOP) range on the day of the accident. The pilot had flown the same departure with a full load of passengers on three previous flights (including one at a higher planned operating weight), which indicated it was capable of flying the departure. The decay in RPM at a relatively low MAP indicated that it was likely associated with insufficient airflow to the engine to enable it to produce the power required. Therefore, the ATSB evaluated the evidence against the scenarios of (1) overpitching, (2) air induction obstruction, (3) inoperative governor and (4) throttle mishandling. An inoperative governor or throttle mishandling were considered the most likely scenarios.

The increase in power during take-off indicated the engine was capable of producing more power than it did initially produce and found no evidence of a corrective throttle response from the governor system in the first 8 seconds of the engine and rotor RPM decay. Therefore, an overpitching event, in which the governor system would attempt to recover RPM, was considered unlikely.

The increase in MAP and power during take-off, as the RPM decayed, indicated the engine throttle was not stuck and that there was unlikely to be an obstruction of the air induction system preventing engine power from increasing. Therefore, an obstruction of the engine air induction was also considered unlikely to be the reason for the RPM decay.

Inoperative governor

The engine run-up and increase in power on take-off indicated there was mechanical continuity between the pilot’s controls and the engine throttle. The throttle opening is increased by the correlator when the pilot raises the collective lever and by the governor if it detects the engine RPM is low. Both inputs will result in an increase in MAP and power, but the correlator is an open loop process that does not monitor or manage engine RPM. It is the governor system that provides the closed loop process to correct for excursions in RPM by adjusting the engine throttle. Without a corrective input from the governor, as the pilot introduces control inputs via the collective, cyclic or tail rotor pedals, the engine throttle may not open to a position where the power produced is sufficient for the power required. This may produce an RPM decay at a low MAP, which was consistent with the observed indications.

The rise in MAP from 20.5 to 22.5 in Hg was in the same period that the vertical speed and airspeed increased, which was consistent with the pilot raising the collective lever for take-off. The RPM decayed during this period from 101 to 97 per cent and engine power increased, which suggested the rise in MAP was a result of the correlator increasing the throttle opening as the pilot raised the collective lever. After the low rotor RPM warning, there was a continued decay in RPM from 97 to 90 per cent in the following 5 seconds, with only a small increase in MAP and engine power. This period provided no indication of a corrective throttle response from the governor in terms of a rise in MAP to a value equivalent to a full throttle setting.

The governor system was tested serviceable at the previous 100-hour maintenance inspection 2 days before the accident, and it was reported to be working on the day. Robinson (RHC) testing of the governor controller found no fault and ATSB testing of the governor motor, friction clutch and pilot’s twist grip indicated that the governor system should have been capable of producing full throttle within the first 8 seconds.

Although, the ATSB and RHC found no faults with the components that were tested following the accident, the governor system could not be tested in its entirety under the accident conditions due to the damage sustained. Therefore, in consideration of the possibility that the governor operation was not verified before lift-off, the ATSB could not rule-out the possibility of a rotor RPM decay as a result of an inoperative governor.

Throttle mishandling

The pilot can inhibit the governor input to the throttle if the twist grip is held with a firm grip (known as ‘strangling the throttle’). This will provide the same instrument indications (and result) as an inoperative governor. The correlator will still increase and decrease the throttle when the collective lever is raised and lowered, providing a power response, but the pilot’s grip will inhibit corrective input from the governor to the throttle if an RPM excursion (over-speed or under-speed) occurs.

In consideration of the potential for mishandling the throttle, the ATSB reviewed the pilot’s training records and interviewed several of the pilot’s instructors. The phenomena of ‘strangling the throttle’ was well known, but there was no evidence of this problem in the accident pilot’s training records or from interviews. On review of the passenger video footage, the ATSB was unable to sight the pilot’s grip on the collective throttle twist grip, and therefore could not determine what technique was employed on take-off. However, as no individual governor system component was found to be unserviceable during post-accident testing, the ATSB could not rule-out the possibility that the pilot’s grip inhibited the governor input to the throttle.

Low rotor RPM response

The low rotor RPM warning activated when the helicopter was climbing over trees in the departure path. The RHC published low rotor RPM recovery procedure required the pilot to ‘immediately roll throttle on, lower collective and, in forward flight, apply aft cyclic’.

The pilot initially reported that when the low rotor RPM warning activated, they opened the throttle, but ‘could not do much else’. Although the pilot’s recollection was that this occurred at 300 ft, video evidence indicated the helicopter was at about 37 ft, and there was no significant increase in throttle for at least 5 seconds after the warning activated.

In the 5 seconds following activation of the low RPM horn, the MAP had only reached 24.0 in Hg and therefore the throttle position was likely still below the full throttle setting. The collective lever twist grip was found to be serviceable in post-accident testing. The engine run-up before lift-off, and the increase in power on departure indicated there was mechanical continuity from the pilot controls to the engine throttle. Therefore, it was likely that the pilot did not apply full throttle prior to the rotor RPM decaying to 90 per cent, as this action would have resulted in a rapid rise in MAP to a value in the vicinity of 25–26 in Hg.

The pilot later submitted that they would have applied full throttle and lowered the collective lever, irrespective of the height available. In addition, the operator submitted that the simultaneous action of opening the throttle and lowering the collective lever might have produced the observed MAP indications. However, the steady decay in RPM on departure indicated there was no significant change in the difference between power delivered and power required by the rotors.

If the power margin changes, then the RPM rate of decay will also change, reaching zero when the power applied to the rotors is equal to the power required by them. As there was no reduction in the engine power produced (as indicated by MAP) when the RPM decayed from 97–90 per cent during the departure, the steady decay in rotor RPM indicated that there was no significant reduction in the power required by the rotors. This, in combination with the continued climb to about 200 ft, suggested the collective lever was not lowered.

It is possible that during the early stages of the rotor RPM decay the pilot’s attentional resources were consumed with the departure over the tree tops, and an early left turn to avoid a no-overfly area. This manoeuvre required the pilot’s visual attention outside of the helicopter for the majority of time. As a result, while the pilot may have perceived the low RPM warning, it was likely that they did not have the spare attentional capacity to immediately comprehend and respond to the warning in the early stages of the decay.

Allowing the helicopter to climb and lose airspeed during the take-off resulted in the power margin decreasing, at a time when the opposite was required. The passenger video of the take-off ended before the helicopter levelled off, and it continued flight for about another 70–80 seconds. This suggested the engine was continuing to produce power. As the rotor RPM had reached 80 per cent at about 87 ft above the ground, and the helicopter was still indicating a climb of 300 ft/min, it was likely that the rotor RPM continued to decay below 80 per cent, resulting in less engine power available for RPM recovery.

The front seat passenger’s report of the helicopter climbing and descending suggested the pilot may have lowered the collective lever in an attempt to recover rotor RPM. This section of the flight was not recorded, and the pilot had no recollection of it, so it could not be determined exactly what was occurring. However, it was likely that there was insufficient height, airspeed and engine power to recover from the low RPM condition that had developed on departure, resulting in the need for a forced landing.

With minimal height available above obstacles at the time the low rotor RPM activated, the optimum flight condition for RPM recovery was full throttle with the lowest collective lever position. For the R44, the lowest collective lever position in level flight is achieved at 55 kt, which would have provided a power margin of about 76 hp to the power produced on departure. In consideration of the potential power margin available, if the pilot had applied full throttle in the first 5 seconds and then lowered the collective lever sufficiently to prevent a climb, the low rotor RPM was likely recoverable.

Hard landing

Tracking of the main rotor blades and balancing of the main rotor system is conducted to minimise in-flight vibrations that occur at the normal operating speed of the main rotor. However, as RPM decays, the rotor blades will lose their rigidity, allowing them to flap up and down with greater amplitude. Excessive flapping of the main rotor blades may result in the blades rotating out-of-track and the rotor system operating out-of-balance. According to Kroes et al. (2013), incorrect tracking of rotor blades will produce a vertical vibration and an unbalanced main rotor system will produce a lateral vibration.

The development of low frequency vibrations (main rotor vibrations) associated with low RPM, as described by the passengers, may be a precursor to a main rotor blade stall event if corrective action is not taken immediately. Whether or not these vibrations precede a stall is situational dependent – a main rotor blade stall could occur without this warning if the RPM decay is rapid. According to the R44 pilot operating handbook, a main rotor blade stall will either ‘cut off the tailcone’ or the helicopter will ‘just stop flying and fall at an extreme rate’. A video review of other R44 low RPM incidents suggested the vibrations reported by the passengers were consistent with an RPM of 70–80 per cent.

Either due to the lack of identified suitable landing sites, a belief that the low rotor RPM was recoverable, or a combination of the two, the pilot continued to fly the helicopter for about 70–80 seconds after the RPM had decayed to 80 per cent. The continued decay of the RPM below 80 per cent at low height and airspeed meant that recovery was not going to be possible. At the time the pilot made a distress call and selected a forced landing site, the RPM was likely too low for it to be recovered and used to arrest the rate of descent before touchdown, resulting in a hard landing and serious injuries.

Passenger scales

On the day of the accident, the passengers were weighed on arrival at the helipad with the operator’s scales. Their weights were entered into a spreadsheet along with the helicopter empty weight, pilot weight and planned fuel load for each flight.

When the ATSB compared the recorded occupant weights on the accident flight with their actual weights, it was noted that the individual recorded weights for the accident flight were underestimated by about 9.6 per cent.

This discrepancy was also noted for passengers on other flights, in addition to those on the accident flight. Consequently, while the helicopter was likely operating below the maximum weight, it was operating at a higher weight than the planned weight, and was potentially overweight on an earlier flight. The under-reading of the passenger scales was likely due to them not having a calibration schedule.

A high weight in favourable environmental conditions could result in a pilot incorrectly assessing the helicopter's power margin in the hover as adequate for take-off. If unfavourable conditions subsequently develop during take-off, such as a change in the wind conditions, then the observed power margin from the hover could prove to be insufficient to safely continue.

The under-reading scales increased the likelihood that the helicopters would be operated overweight, which could have resulted in the power required being in excess of the power available. This condition increased the risk that the operator's helicopters would not achieve their expected take-off performance.

Pilot operating handbook

The R44 pilot operating handbook emergency procedure for low rotor RPM recovery required the pilot to 'immediately roll throttle on, lower collective and, in forward flight, apply aft cyclic'. These factors will maximise the likelihood of the pilot successfully recovering rotor RPM, but are dependent on the energy available, in the form of height or airspeed, to convert to rotor speed.

While these actions are listed in the handbook as immediate actions, lowering the collective lever may not always be practicable, such as low flying over obstacles. Further, the application of aft cyclic to use the forward airspeed as a driving force for the main rotor disc will also decelerate the helicopter. Therefore, the power required will increase if this is performed on the back-end of the power curve. In these situations, there is little energy available in terms of height or airspeed to convert to rotor speed. Consequently, there may be more benefit in allowing the airspeed to gently increase to the minimum power airspeed to reduce the power required for level flight, which will allow the pilot to progressively lower the collective lever and increase the power margin.

The minimum power required airspeed of 55 kt was published in the pilot operating handbook – *normal procedures,* as the recommended airspeed for maximum rate of climb. It was also included in the emergency procedures section of the handbook for the minimum rate of descent procedure with a power failure, but there was no reference to this airspeed in the low rotor RPM recovery procedure. However, there was reference to 55 kt as a target airspeed to recover from overpitching events in on-line educational videos. This suggested that it was a known and recognised target airspeed within the industry.

The ATSB selected another light helicopter and reviewed the emergency procedure checklists for evidence of advisory airspeed information. It was noted that there were numerous instances throughout the various checklists of advisory airspeeds to assist a pilot in their recovery actions. These included immediate actions and subsequent considerations.

The ATSB noted that the low airspeed-low RPM accidents were often associated with operations at low heights where lowering the collective lever may not be an option. These circumstances may require a variation to the published procedure, such as an overshoot (known as an escape manoeuvre) with full throttle to increase airspeed so that the collective lever can then be lowered to reduce the power required. If a pilot has not been exposed to this in a risk managed training environment, and their response to this scenario is instead based upon rote learning the procedure, they may not have the knowledge and handling skills to apply to the situation.

Therefore, the ATSB considered that the inclusion of the minimum power airspeed as a subsequent consideration to the immediate actions for low rotor RPM recovery could improve the safety-critical information available to pilots. In addition to making less experienced pilots aware of this airspeed, the inclusion of it in the procedure may lead to the promotion of broader discussion and understanding of the power curve, the risks associated with low airspeed-low rotor RPM conditions, and how to adapt the emergency procedure actions to the various scenarios in which it might be encountered.

On-board recordings

In this investigation, it was fortunate that the operator and passengers volunteered video recordings of the accident flight. This enabled the ATSB to focus on the relevant technical and human factors, without expending resources on unnecessary inspections and tests in an attempt to rule-in or rule-out out potential contributing factors. However, several key pieces of evidence from the accident flight, such as the pilot's grip on the throttle twist grip and attempts to recover rotor RPM, were not recorded. The development of the low rotor RPM condition on take-off was captured by chance alone.

The availability of the helipad and passenger video recordings assisted the investigation in the identification of operational factors that were not all apparent from the various interviews and statements obtained. This enabled the ATSB to focus the safety lessons on the actions needed to reduce the risk of future similar accidents.

Findings

ATSB investigation report findings focus on safety factors (that is, events and conditions that increase risk). Safety factors include 'contributing factors' and 'other factors that increased risk' (that is, factors that did not meet the definition of a contributing factor for this occurrence but were still considered important to include in the report for the purpose of increasing awareness and enhancing safety). In addition 'other findings' may be included to provide important information about topics other than safety factors.

Safety issues are highlighted in bold to emphasise their importance. A safety issue is 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 operating environment at a specific point in time.

These findings should not be read as apportioning blame or liability to any particular organisation or individual.

From the evidence available, the following findings are made with respect to the rotor RPM decay and hard landing involving a Robinson R44 helicopter, registered VH-HGX, 5 km south of Ayers Rock Airport, Northern Territory, on 17 January 2018.

Contributing factors

- During take-off, the helicopter's rotor RPM steadily decayed due to a likely limited opening of the engine throttle, which resulted in the engine power produced being less than the power required. The reason for the limited opening of the throttle could not be determined.
- Following activation of the low rotor RPM warning, the pilot initially did not apply full throttle and lower the collective lever to avoid a climb, which resulted in the rotor RPM decaying further to a level from which the pilot could not recover.
- While attempting a forced landing, the rotor RPM decayed to an extent that the pilot was unable to arrest the rate of descent sufficiently to prevent a hard landing, resulting in serious injuries to the occupants.

Other factors that increased risk

- The pilot had inadvertently adopted a practice of running the engine up manually with the governor off during passenger transfers, which increased the risk of an inoperative governor not being detected prior to take-off.
- **Professional Helicopter Services did not have a calibration schedule for their passenger scales, which were under-reading. This increased the risk of their helicopters not achieving their expected take-off performance. [Safety Issue]**
- **The Robinson R44 pilot's operating handbook low rotor RPM recovery procedure did not include reference to the minimum power airspeed for the helicopter as a consideration, which may assist a pilot to recover from a low rotor RPM condition. [Safety Issue]**

Other findings

- The passenger and helipad video recordings of the flight provided essential data to understand how the accident developed. However, this investigation would have benefited from flight data recorder or image recorder data to maximise the safety lessons for industry.

Safety issues and actions

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues. The ATSB expects relevant organisations will address all safety issues an investigation identifies.

Depending on the level of risk of a safety issue, the extent of corrective action taken by the relevant organisation(s), or the desirability of directing a broad safety message to the aviation industry, the ATSB may issue a formal safety recommendation or safety advisory notice as part of the final report.

All of the directly involved parties were provided with 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.

The initial public version of these safety issues and actions are provided separately on the ATSB website, to facilitate monitoring by interested parties. Where relevant, the safety issues and actions will be updated on the ATSB website as further information about safety action comes to hand.

Passenger scales

Safety issue description

Professional Helicopter Services did not have a calibration schedule for their passenger scales, which were under-reading. This increased the risk of their helicopters not achieving their expected take-off performance.

Issue number:	AO-2018-006-SI-01
Issue owner:	Professional Helicopter Services
Transport function:	Aviation: Air transport and General aviation
Current issue status:	Closed - Adequately addressed
Issue status justification:	A calibration schedule introduced by Professional Helicopter Services addresses the safety issue risk for their other bases in addition to their Uluru Base, where the accident occurred.

Proactive safety action taken by Professional Helicopter Services

Action number:	AO-2018-006-NSA-010
Action organisation:	Professional Helicopter Services
Action status:	Closed

Professional Helicopter Services have advised that they introduced a quarterly calibration schedule for their passenger scales at all their bases. These schedules will be tracked in their safety management system database.

Pilot's operating handbook

Safety issue description

The Robinson R44 pilot's operating handbook low rotor RPM recovery procedure did not include reference to the minimum power airspeed for the helicopter as a consideration, which may assist a pilot to recover from a low rotor RPM condition.

Issue number:	AO-2018-006-SI-02
Issue owner:	Robinson Helicopter Company
Transport function:	Aviation: Air transport and General aviation
Current issue status:	Monitor - not addressed
Issue status justification:	Safety action pending.

Response from Robinson Helicopter Company

Depending on airspeed, it may take significant time to get the helicopter to the minimum power airspeed (Vy). The low rotor RPM condition requires immediate response, for this reason the Robinson Helicopter Company pilot’s operating handbook describes the ‘immediate result’ technique of rolling on throttle and lowering collective. Helicopter pilots should be trained about Vy and how it affects the helicopter performance, and have this knowledge in their inherent thought process. Therefore, if conditions permit, the pilot can attempt to speed up or slow down to get the helicopter to Vy to maximize performance.

When the helicopter is close to the ground, attempting to speed up to Vy can be risky. If it improves performance enough to keep the helicopter flying it is a worthwhile technique. If it does not, it results in the helicopter hitting the ground with higher speed, leading to greater injury and damage. Nevertheless, the recommendation to include additional references to the minimum power speed (Vy) will be reviewed by Robinson engineering personnel for possible revision to the pilot’s operating handbook.

ATSB response

The ATSB have noted that the use of the minimum power airspeed (Vy) during a low RPM recovery is situationally dependent, but that it is a technique taught by some instructors in the industry. As safety action is still pending, the ATSB issues the following safety recommendation.

Safety recommendation to Robinson Helicopter Company

The ATSB makes a formal safety recommendation, either during or at the end of an investigation, based on the level of risk associated with a safety issue and the extent of corrective action already undertaken. Rather than being prescriptive about the form of corrective action to be taken, the recommendation focuses on the safety issue of concern. It is a matter for the responsible organisation to assess the costs and benefits of any particular method of addressing a safety issue.

Recommendation number:	AO-2018-006-SR-053
Responsible organisation:	Robinson Helicopter Company
Recommendation status:	Released

The ATSB recommends that the Robinson Helicopter Company reviews the R44 pilot's operating handbook low rotor RPM recovery procedure for consideration to include a reference to the minimum power airspeed (Vy) for pilot awareness.

Safety action not associated with an identified safety issue

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

Professional Helicopter Services

As a result of this occurrence, Professional Helicopter Services has advised the ATSB that they have taken the following safety actions:

Check flights

They temporarily suspended commercial operations at their Uluru Base in order to enable the chief pilot to conduct several check flights with each pilot before resuming operations.

Helipad procedures

They completed an audit of the Yulara Town helipad and amended the published departure and approach procedures to align with designs recommended, but not mandated, by the Civil Aviation Safety Authority in Civil Aviation Advisory Publication 92-2(2): *Guidelines for the establishment and operation of onshore Helicopter Landing Sites*.

General details

Occurrence details

Date and time:	17 January 2018 – 1830 CST	
Occurrence category:	Accident	
Primary occurrence type:	Operational – aircraft control – control issue	
Location:	5 km south of Ayers Rock Airport, Northern Territory	
	Latitude: 25° 16.57’ S	Longitude: 130° 58.10’ E

Pilot details

Licence details:	Commercial Pilot (Helicopter) Licence, issued 20 June 2017
Endorsements:	Gas turbine engine
Ratings:	Single-engine helicopter
Medical certificate:	Class 1, valid to 26 May 2018
Aeronautical experience:	Approximately 300 hours (approximately 180 hours R44)
Last flight review:	12 July 2017

Aircraft details

Manufacturer and model:	Robinson Helicopter Company R44 Astro	
Year of manufacture:	2000	
Registration:	VH-HGX	
Operator:	Professional Helicopter Services	
Serial number:	0762	
Total Time In Service	3,489.5 (as of last 100 hourly)	
Type of operation:	Charter - Passenger	
Persons on board:	Crew – 1	Passengers – 3
Injuries:	Crew – 1 (serious)	Passengers – 3 (2 serious; 1 minor)
Damage:	Substantial	

Sources and submissions

Sources of information

The sources of information during the investigation included the:

- Civil Aviation Safety Authority
- Insurance Senior Surveyor
- Northern Territory Police
- Professional Helicopter Services
- witnesses
- Robinson Helicopter Company.

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Submissions

Under Part 4, Division 2 (Investigation Reports), Section 26 of the *Transport Safety Investigation Act 2003* (the Act), 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, pilot, passengers, Civil Aviation Safety Authority, Insurance Senior Surveyor, Northern Territory Police, Robinson Helicopter Company and United States National Transportation Safety Board.

The submissions from those parties were reviewed and where considered appropriate, the text of the draft report was amended accordingly.

Australian Transport Safety Bureau

About the ATSB

The ATSB is an independent Commonwealth Government statutory agency. It is governed by a Commission and is entirely separate from transport regulators, policy makers and service providers.

The ATSB's purpose is to improve the safety of, and public confidence in, aviation, rail and marine transport through:

- 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, as well as participating in overseas investigations involving Australian-registered aircraft and ships. It prioritises investigations that have the potential to deliver the greatest public benefit through improvements to transport safety.

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

Purpose of safety investigations

The objective of a safety investigation is to enhance transport safety. This is done through:

- identifying safety issues and facilitating safety action to address those issues
- providing information about occurrences and their associated safety factors to facilitate learning within the transport industry.

It is not a function of the ATSB to apportion blame or provide a means for determining 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. The ATSB does not investigate for the purpose of taking administrative, regulatory or criminal action.

Terminology

An explanation of terminology used in ATSB investigation reports is available on the ATSB website. This includes terms such as occurrence, contributing factor, other factor that increased risk, and safety issue.