Australian Government
Australian Transport Safety Bureau

Rotor drive v-belt failure involving Robinson R22 helicopter, VH-HRX

100 km SW of Borroloola, Northern Territory | 27 March 2014

Investigation

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Addendum

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Safety summary

What happened

Accident site

Source: ATSB

On 27 March 2014 the pilot of a Robinson R22 helicopter, registered VH-HRX, departed from Mullapunyah station, Northern Territory, for a short flight to the north-west. About 10 minutes after departure the pilot radioed that the drive v-belts had failed and the station owner, in another R22, saw the helicopter enter a steep descent.

Soon after, the station owner found the helicopter complete and upright in a relatively clear area. The pilot of VH-HRX, who was laying a few metres from the helicopter, had sustained a serious head injury. The station owner tended the casualty and alerted emergency services at Borroloola of the accident, as well as personnel at the station homestead. Station personnel accessed the accident site over the rough terrain and started to transport the injured pilot on the back of a utility vehicle. The casualty was later transferred to a Bell 206 Jetranger helicopter for transfer to Macarthur River Mine. An aeromedical service then transported the injured pilot to Darwin where he was hospitalised for a number of weeks.

What the ATSB found

During the initial engine start/clutch engagement process following an extended period of static belt stretching, one or both rotor drive v-belts were displaced on the lower sheave with consequent increase in v-belt slack. Although the pilot, who was not qualified to conduct such maintenance, adjusted the clutch actuator to correct the excessive v-belt slack, the v-belt displacement went undetected. While being operated in that abnormal configuration, one of the belts weakened and failed with consequent failure of the remaining belt, loss of drive to the rotors, and a forced landing.

Although Robinson Helicopter Company Safety Notice SN-33 provided guidance to pilots on how to stretch new v-belts statically, it did not specifically warn pilots that this process can increase the risk of belt displacement during the subsequent start.

Safety message

This accident highlights that in addition to having a good working knowledge of Robinson Helicopter Company Safety Notice SN-33, R22 pilots and engineers should be especially aware that, if the rotors do not turn within 5 seconds after clutch engagement, it is critical to perform the shutdown procedure and check the slack and position of the v-belts on both the lower and upper sheaves, before flight.

Pilots and operators of helicopters should also consider the residual risk of their operation and the benefit of occupants wearing helmets to reduce the risk of head injury in the event of an emergency landing.

Contents

The occurrence

Early on 27 March 2014, the pilot of a Robinson R22 helicopter, registered VH-HRX, was preparing for a short private flight from Mallapunyah station, 100 km south-west of Borroloola, Northern Territory (Figure 1). The pilot had just returned to the station after having 10 days away on the east coast of Australia and was intending to meet with the station owner who was going to be mustering to the north-west of the station homestead. Winds in the area were forecast to be light and variable and no significant weather was forecast or reported.

Figure 1: Area map

Source: Google Earth, modified by the ATSB

While still on the ground, the pilot used the helicopter radio to call the station owner who was already airborne and flying nearby in another R22. The station owner reported that the pilot advised that he was adjusting the drive belts, that it was taking 30 seconds for the rotor blades to turn (presumably after engine start and clutch engagement), and it was taking 2 minutes and 6 seconds for full clutch engagement. The station owner was not sure whether those periods were before or after any adjustment by the pilot.

The pilot would have been airborne at about 0645 Central Standard Time[1] and was in regular radio contact with the station owner who had commenced mustering to the west of Heartbreak Hotel. In the early stages of the flight there was no indication from the pilot of any problem with the helicopter and nothing more was said about the drive belts or clutch engagement.

At about 0700, when the station owner sighted VH-HRX, he contacted the pilot of VH-HRX by radio and provided the pilot with directions to his airborne location. The helicopter was seen at about 500 ft and in stable flight. Shortly after, the pilot of VH-HRX was reported to have transmitted that the '…belts are gone'. The station owner saw the helicopter turn to the right and

[1] Central Standard Time (CST) was Coordinated Universal Time (UTC) + 9.5 hours.

descend steeply in what appeared to be autorotation (where, in the absence of engine drive, the airflow from a steep descent drives the rotor system and allows a controllable descent and landing).

The station owner flew to where the helicopter had descended out of sight and landed near to where the pilot had landed (Figure 2). The station owner found the pilot lying on the ground about 5 m from the helicopter, which was already shut down. The pilot, who was not wearing a helmet during the flight, had sustained neck/head injuries and was disoriented and distressed. The station owner attended to the injured pilot and used his satellite phone to call the station homestead and the Borroloola health clinic for help. The clinic dispatched an ambulance with two clinic nurses towards the site and advised local police who mobilised a rescue team from the nearby Macarthur River Mine, as well as dispatching police towards the site.

Figure 2: Accident site from the air showing VH-HRX

Source: ATSB

The station owner considered transporting the injured pilot in the other seat of his R22, but was concerned about take-off performance and the potential for control interference. Instead, he flew to a nearby station and returned with someone to assist. He then got airborne again and directed station personnel in vehicles towards the site.

The emergency responders assembled at Heartbreak Hotel, about 20 km to the east, where one of the local residents volunteered to guide the ambulance to the accident site. The ambulance crew departed for the site but were only able to go part of the way due to rough terrain. A pilot in a third R22 landed near the ambulance and took one of the nurses to the accident site. The casualty was treated for head trauma and placed on a mattress on the tray-back of a utility that had been able to access the site. The utility was then driven slowly over the rough terrain towards the nearest access road.

Meanwhile, a pilot in a Bell 206 Jetranger helicopter was inbound to the general area of the accident site. He had been refuelling at Borroloola and heard of a helicopter accident. Having completed a charter, the pilot was available to assist and this information was passed to the search and rescue agency. After a period of time the pilot was provided with vague position information and tasked by that agency with flying to the area to provide assistance.

The Jetranger pilot arrived in the general area and landed near a vehicle to find out more information. The pilot was also able to talk by radio to the pilot of a nearby R22, who was able to guide him towards the accident site. While en route to the accident site, the Jetranger pilot spotted the utility carrying the casualty and landed nearby. Due to the necessarily slow progress of the utility, it was decided to use the Jetranger to transfer the injured pilot and nurse to Macarthur River Mine (about 60 km away).

On arrival at the mine, the injured pilot was taken to the mine's medical centre for treatment until an aeromedical crew arrived by aeroplane. The aeroplane landed at the Macarthur River Mine Airport at 1210 and arrived back in Darwin at 1710. The pilot's condition was critical, requiring intensive care and hospitalisation for a number of weeks. One of the enduring effects of the pilot's injuries was a loss of memory about the occurrence.

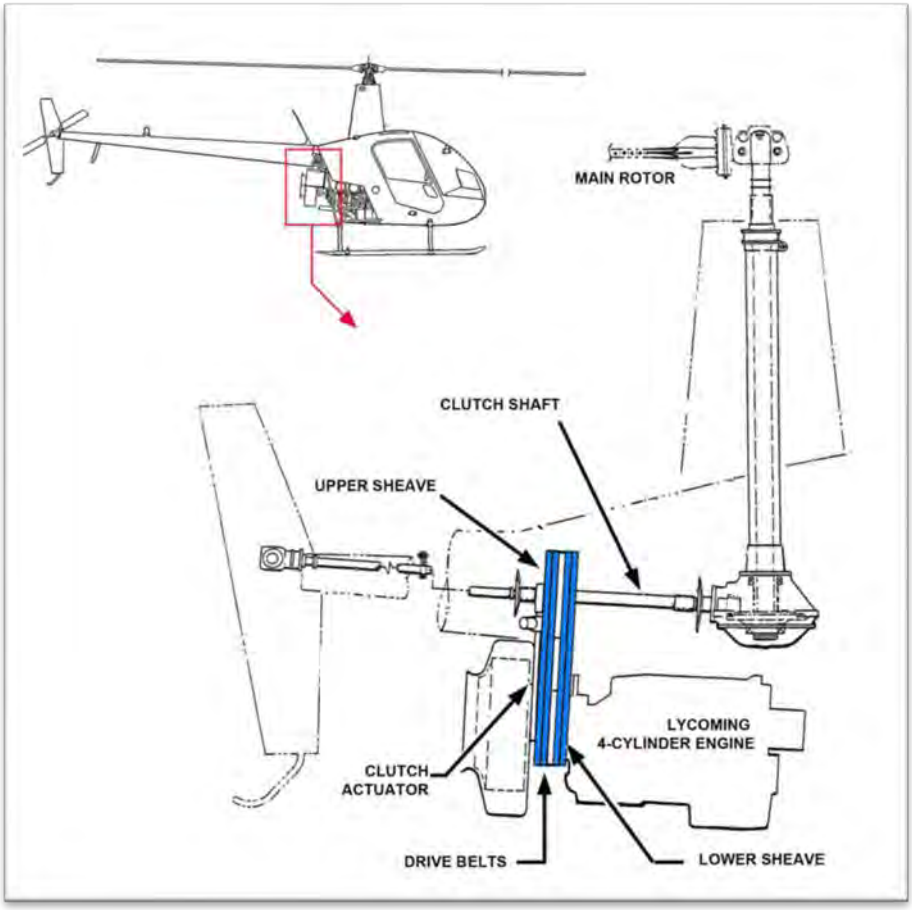
Context

Rotor drive system

Principles of operation

In the Robinson R22 the rotational energy produced by the horizontally-mounted piston engine is transmitted to the main and tail rotor systems by dual doubled-banded v-belts running on two sheaves (pulley assemblies) (Figures 3 and 4). The lower sheave is bolted to the output flange of the engine crankshaft and is mechanically connected to the upper sheave by an electrically-driven clutch actuator. The upper sheave incorporates a free-wheeling clutch which allows for free movement of the drive shafts and rotors when the engine is not operating or not otherwise driving the system.

Figure 3: Diagram of the Robinson R22 rotor drive system

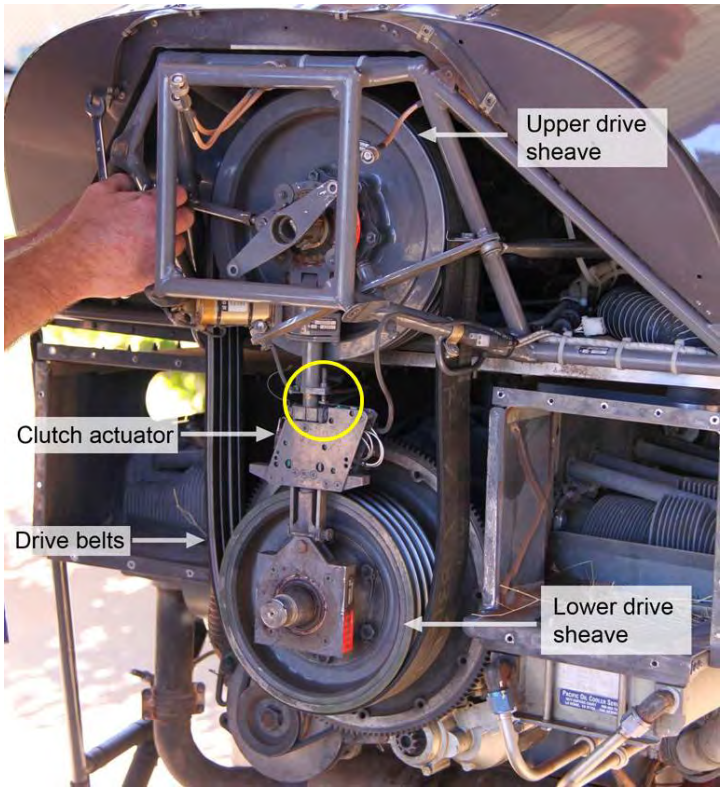


Source: Robinson Helicopter Company (edited by the ATSB)

Before the engine is started the clutch actuator needs to be in the disengaged (retracted) position so that the v-belts have the proper amount of slack to allow the engine to start without excessive load while retaining the belts in their sheave grooves. Immediately after engine start the pilot is required to initiate the belt tensioning process by switching the clutch to ENGAGE. The electric motor then extends the clutch actuator to gradually raise the upper sheave and tension the v-belts such that the rotor blades should start to turn in less than 5 seconds. A clutch caution light that is located in the cockpit directly in front of the pilot illuminates when the clutch motor is operating.

A column spring arrangement within the clutch actuator compresses at a pre-set value corresponding to the requisite v-belt tension and actuates two micro-switches, either of which can stop the actuator motor. During normal operation the clutch switch is left in the ON position until the helicopter is being prepared for shutdown on the ground.

Figure 4: Typical mechanical arrangement of the R22 drive system (viewed from the rear with tailcone and cooling fan assembly removed) with the down limit stop circled



Source: ATSB

In operation the v-belts become warm and can stretch slightly, lowering tension. When the belt tension is low enough to decompress the column springs, the clutch motor runs momentarily to restore the requisite tension. While brief (3–6 seconds) and occasional clutch actuator operation is normal, illumination of the clutch light for longer than 10 seconds is an indicator of a drive system problem. In that case the pilot is required to isolate power to the clutch by pulling the clutch circuit breaker, reduce power, and land immediately while being prepared to enter autorotation.

Maintenance requirements

Before the first flight of the day, pilots are required to ensure that a daily inspection in accordance with a designated schedule has been carried out on their aircraft and certified as such in the maintenance release. In this case, the schedule was provided in section 4 of the *R22 Pilot's Operating Handbook* (POH).

Included in the list of POH daily inspection items was a check of v-belt condition and slack. This check was explained in Safety Notice SN-33in section 10 the POH. With the clutch disengaged, belt slack was to be established by pressing on the belts at a specific location and measuring the amount of deflection. This deflection was to be approximately 1.5 in (4 cm) and, if the belts were significantly looser than that, the actuator required adjustment. Such adjustment was also required if, after start up, the rotor blades failed to turn within 5 seconds of clutch engagement.

The instructions for clutch adjustment were in the *R22 Maintenance Manual*. If the measured belt slack was outside the prescribed limit, the manual specified that with the clutch disengaged the

down limit stop (circled in Figure 4) from the clutch actuator should be adjusted to ensure the correct drive belt deflection.

Safety Notice SN-33 also addressed the issue of new belts being too tight (assuming that the down limit stop was wound to its limit) with consequent straining of the starter motor and drive system during the engine start sequence. The notice stated that, if necessary, new belts could be stretched by leaving the clutch engaged during shutdown. After the battery master switch was turned off, the clutch switch was to be put to DISENGAGE to prevent battery drain while leaving the clutch engaged. The third step was to switch the battery on and allow the clutch to disengage during the next pre-flight check. No time limit was given for this belt-stretch procedure. A copy of Safety Notice SN-33 is attached at appendix A.

In addition to the daily inspections, the rotor drive system was subject to more extensive and specialist inspection at 12-month or 100-operating-hour intervals, whichever came first. In this periodic inspection, and whenever v-belts or other key components were changed, the following belt-drive parameters were checked with the clutch engaged and the v-belts fully tensioned:

- engine height relative to the upper rear frame (related to engine mount condition and shimming)
- clutch shaft angle (proportional to v-belt stretch and related to engine height)
- sheave alignment in plane, direction and orientation (related to engine mount condition and shimming).

Helicopter operational and maintenance history

The helicopter was maintained by an approved maintenance organisation, located about 6 hours flying time from the pilot's operating base at Mallapunyah station. The organisation had maintained the helicopter since it was new in 2012.

The last recorded maintenance performed on the helicopter was a 100-hour inspection documented as carried out in accordance with the Robinson R22 *Maintenance Manual*. This inspection was certified completed on 14 February 2014 at 1,056.9 hours total time in service, and was accompanied by the issue of a maintenance release.

During the course of the 100-hour inspection the sheave alignment was found to be out of limits, the engine mounts needed replacement, and the engine cooling fan was cracked. The v-belts were not excessively worn but were at the stretch limit. New engine mounts, v-belts, and a cooling fan were fitted, and the sheave alignment and other belt-drive parameters were checked.

The certifying licenced aircraft maintenance engineer recalled that during installation, even with the clutch down stop screwed all the way in (or retracted) to its limit, the v-belts were tight to fit and did not allow the engine to start without immediately driving the rotors. After post-maintenance ground running and a test flight the new v-belts were still tight and required the main rotor to be manually turned during engine start to unload the starter motor. The engineer recalled that, during that period of maintenance activity, the clutch was left engaged overnight to stretch the belts, as per Safety Notice SN-33. The pilot who did the post-maintenance test flight also flew the helicopter the next day for 4.5 hours without any reported problems.

The engineer was confident that by the time the maintenance organisation ferried the helicopter to an intermediate location for the owner-pilot to pick up, the belt-drive parameters had been rechecked on a number of occasions with no detected anomalies. As the v-belts were still tight, the clutch actuator down stop was almost certainly in the minimum extension position on departure from the maintenance organisation.

On 17 February 2014 the pilot arrived back at Mallapunyah station in the helicopter after a total of 5.9 hours ferry time that day. That was the last recorded flight in the maintenance release, which now recorded 11 hours flown since the 100-hourly, and a total of 1,067.9 hours. The aircraft was not flown again until the day of the occurrence.

On or around 18 March 2014 the pilot left Mallupunyah station for a holiday on the east coast of Australia. The engineer who certified the recent 100-hourly inspection recalled that at some time prior to the pilot leaving for the holiday, he received a phone call from him in relation to leaving the clutch engaged to stretch the v-belts. The engineer recalled that his advice to the pilot confirmed the belts could be stretched in accordance with Safety Notice SN-33 and warned the pilot to turn the clutch off once the belts were tensioned to stop the battery running flat. The pilot did not provide any more information during that conversation and no further communication between the pilot and the maintenance organisation was reported.

The pilot arrived back at Mallapunyah station on 26 March 2014, the day before the accident. As the pilot operated independently at the station, little was known about the pilot's activities other than the radio calls made on the morning of the accident.

Helicopter examination

On-site examination

ATSB investigators travelled to the accident site and examined the helicopter (Figure 5). This examination found that the helicopter was relatively intact and the damage observed to the fuselage and skid-type landing gear was consistent with a hard landing with some forward-right drift. The main rotor blades had dents and scratches from contact with saplings in the rotor arc but were otherwise undamaged. The tail boom was bent from contact with a tree during the landing but the tail rotor was undamaged. The two fuel tanks held a substantial amount of fuel and the engine contained sufficient oil.

Figure 5: Accident site from an on-ground perspective

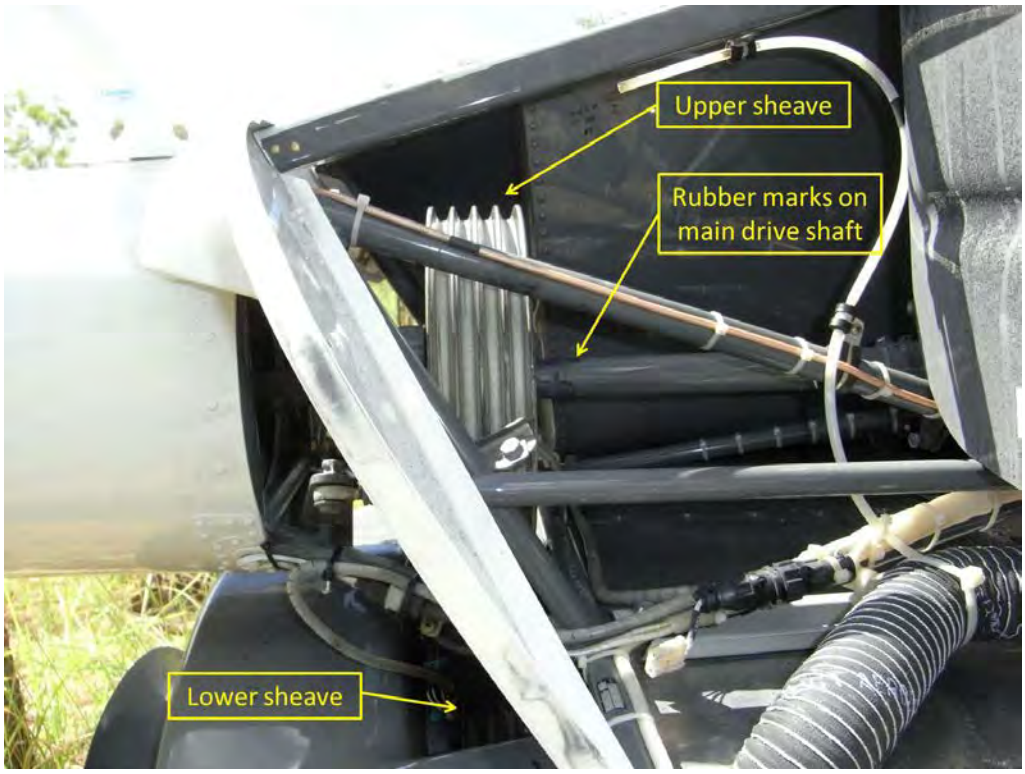
Source: ATSB

The rotor drive system from the upper drive sheave rearward to the tail rotor and forward to the main gearbox demonstrated continuity but the v-belts were not present on the sheaves (Figure 6). There were rubber-transfer marks forward of both sheaves, and small belt fragments and rubber dust scattered around the upper sheave. Some larger belt fragments were found on the ground in the vicinity of the lower sheave.

Both sheaves were in good condition and the free-running clutch within the upper sheave responded appropriately to manual rotation in both directions. The clutch actuator had almost fully extended to the point where the over-travel limit micro switch, which was damaged, would be expected to stop it. The clutch down stop was in an extended position (Figure 7A), which was not consistent with the reported position on release from the recent 100-hour inspection (Figure 7B).

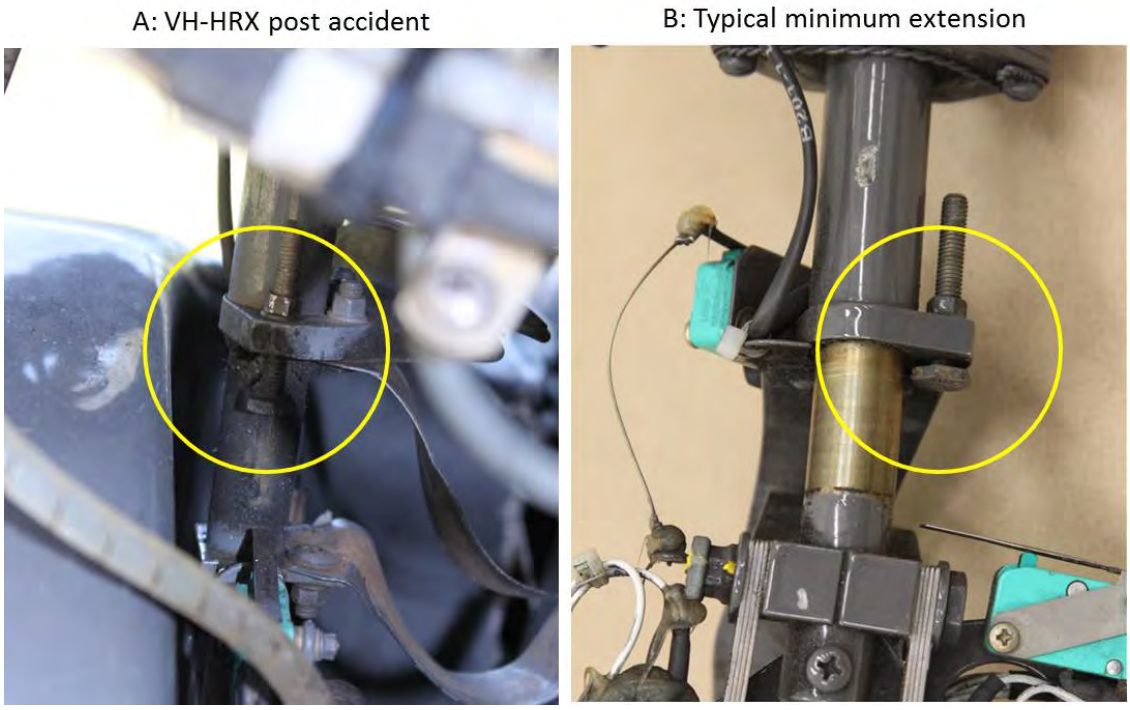
In the cockpit, the clutch was still selected to ENGAGE and the clutch circuit breaker was in the normal (un-pulled) position. The clutch caution light and actuator overload fuse were both intact. The mixture control had been pulled to cut off fuel to the engine and the master switch had been selected off to shut down the electrical system. Two hand tools found in the helicopter cabin were of suitable size for adjustment of the clutch down stop.

Figure 6: View of the upper sheave and main rotor drive shaft as found onsite (cowls removed)



Source: ATSB

Figure 7: Clutch down stop comparison



Source: ATSB

Further examination

After the helicopter was recovered to an aircraft maintenance facility, the ATSB arranged for an independent engineer to conduct a series of in situ checks of the clutch system. By necessity these checks were static and conducted with a new set of v-belts.

To facilitate the fitment of the new v-belts, the clutch was disengaged and the necessary disassembly was carried out. As was typical for the installation of new v-belts, the clutch down-stop was adjusted to achieve minimum extension (corresponding to maximum available v-belt slackness when the clutch was disengaged).

When battery power was applied and the clutch first engaged, the motor operated to extend the clutch actuator and tension the belts. However, the column springs inside the actuator did not activate the micro switches and the motor ran on until the clutch overload fuse interrupted the circuit. No defects were apparent, so the clutch actuator was removed for specialist testing and a spare actuator was installed to allow completion of the checks.

The replacement actuator functioned correctly so the v-belt drive parameters could be measured with the belts properly tensioned. The engine height and sheave alignment parameters were found to be moderately out of limits while the clutch shaft angle lacked a reliable zero reference angle and was not meaningful. The ATSB assessed that the out-of-limit parameters could be attributed to the forces sustained during the accident sequence and the associated distortion to the airframe.

Following initial clutch engagement, the v-belt slack was measured as a deflection of 1.1 in (28 mm). The clutch was then engaged for 24 hours to stretch the belts, after which the slack deflection was 1.2 in (30 mm). The clutch was engaged again, and after 10 days of belt tensioning the slack deflection was 1.42 in (36 mm). These results were within the specifications of 1.25 in (32 mm) minimum deflection for new v-belts and 1.4 to 1.6 in (36 to 41 mm) deflection for broken-in v-belts.

The original clutch actuator removed from the helicopter in the early stages of the in situ checks was sent to the helicopter manufacturer for further examination under the supervision of the United States National Transportation Safety Board. When tested, the actuator malfunctioned by continuing to extend until the clutch overload fuse interrupted the circuit, as it had during the previous testing. It was found that the actuator required 1,700 lb (770 kg) to activate the micro switches rather than the specified 1,200 lb (545 kg). The springs were removed and found to be undamaged but the clutch shaft surface was damaged and the lower fitting was seized to the actuator shaft, hindering movement of the springs. After these defects were rectified, actuator calibration was within specifications.

ATSB investigations

In 2009, following a number of accidents and serious incidents involving Robinson R22 helicopters where a failure of either one or both rotor drive v-belts contributed to the occurrence, the ATSB initiated a safety issue investigation (AI-2009-038) into the broader question of Robinson R22 v-belt operational reliability.

No organisational or systemic issues in relation to the v-belts that might adversely affect the future of aviation operations were identified as a result of the investigation. However, drive belt reliability was found to be negatively influenced by a broad range of operational and maintenance-related factors, including:

- high gross or overweight operations
- high or excessive engine power settings (manifold pressures)
- sheave misalignment and/or poor drive system condition
- inadequate or infrequent inspections of the rotor drive system.

Subsequently, in May 2011 the ATSB commenced an investigation into a rotor drive failure involving Robinson R22 Beta II, registered VH-DSD, which occurred 83 km north-west of Julia Creek, Queensland on 9 May 2011. As part of this investigation, in July 2011 the ATSB issued safety advisory notice AO-2011-060-SAN-001, reinforcing the need for continued vigilance by operators and maintenance organisations regarding the routine inspection of the R22 drive system. Also during the course of this investigation the Robinson Helicopter Company released an updated 'Revision-Z' v-belt. Since that change, R22 industry feedback has indicated an overall improvement in the stability of the drive system and a reduction in failure rates.

As a result of these investigations, the ATSB has published the following safety messages:

- The Robinson R22 helicopter is the most popular light utility helicopter used in Australia and has a reputation for being an extremely reliable machine. Owners and operators should fully appreciate the nature and effects of the operational stresses placed on the helicopter, particularly if the machine is utilised in a dynamic and demanding manner such as required for cattle mustering operations.
- Pilots, operators and maintainers should pay particular attention to the installation and condition of R22 drive belts and other components of the drive system, and should ensure that the manufacturer's requirements for inspection and maintenance of the drive system are adhered to at all times.
- The continued safe flight of an R22 helicopter that has sustained a v-belt failure can be assisted by the pilot's awareness of the indications of a drive system malfunction, and the appropriate management of the emergency autorotation in accordance with published procedures.

The full reports are available at www.atsb.gov.au.

Additional v-belt information

The Robinson Helicopter Company advised the ATSB that since the more consistent and durable Revision-Z v-belts were introduced the number of damaged belts had dropped significantly. Revision-Z belts tended to be on the short end of the length tolerance and accordingly were more difficult to install. They stretched most in the first 50 hours of operation and it was during this time that the slack was required to be monitored closely and adjusted as necessary.

Robinson also advised that v-belts are subject to a number of operational variables and therefore wear and stretch at different rates. Insufficient data was available to predict the amount of stretch during a 10-day clutch engagement period. If kept within the overall limits, belt length does not have any effect on operation of the belts provided the clutch actuator is adjusted to maintain the proper amount of slack.

In relation to a v-belt running half off a sheave during engine start/clutch engagement, Robinson was unable to determine the time for the blades to start turning or how long the belts would last in that configuration. In any event, provided the remaining belt stayed in the sheave grooves and did not get interfered with by the failed belt or other material, Robinson considered that a single belt was strong enough to transmit enough power to maintain powered flight and make a precautionary power-on landing.

Separately, as part of this investigation, the ATSB was advised of an occurrence where new Revision-Z v-belts were stretched overnight and on the subsequent flight, after 10 minutes flying time, the pilot smelled burning rubber and noticed the clutch light on. The pilot reported that he pulled the clutch circuit breaker and initiated an autorotative descent and power-on landing. It was found that the v-belts were running truly in the upper sheave but both belts were displaced forward by one groove in the lower sheave.

Safety analysis

Introduction

The pilot's radio call reporting the failure of the belts and the subsequent autorotative-type descent indicated that the helicopter had sustained a loss of drive to the rotor system. Although the pilot approached into a relatively clear area, the helicopter had significant downward and some forward-right momentum on landing. This was not unexpected in the context of the emergency, but in the hard landing the pilot sustained a serious head injury, probably as a result of him pitching forward when the helicopter's right skid hit embedded rock.

It was fortuitous that the station-owner was in a position to hear the radio call, locate the helicopter, and call for assistance in a short period of time. The remoteness of the accident site and the rough terrain were complicating factors in the pilot's rescue, but the combined actions of the station owner, other R22 pilot, Borroloola clinic, and Bell 206 Jetranger pilot minimised the elapsed time between the accident and the pilot receiving the necessary medical treatment.

The analysis following considers the factors that affect the reliability of the Robinson R22 rotor drive system and whether those factors existed and influenced the development of this occurrence. Also considered are the safety implications of this occurrence for R22 operations more generally.

Rotor drive system failure

The ATSB established at the accident site that, consistent with the pilot's radio call, the v-belts were not in position on the sheaves and had been severely disrupted. In the absence of any other drive train discontinuity, it was evident that in-flight failure of the v-belts was the critical factor in the loss of drive to the rotors.

The v-belts fitted to VH-HRX were of the latest design. These Revision-Z belts had proven to be more robust and reliable than preceding belt types. Nevertheless, v-belt reliability was still contingent on how the helicopter was operated and on a number of helicopter-specific factors: sheave alignment, sheave condition, and v-belt tension with the clutch engaged and disengaged.

Between installation of the new v-belts and the day of the accident, the helicopter had only been operated for 11 hours with most of that time being single-occupant ferry flying. In that context, there was limited exposure to the high gross weight or high engine power operations that have been associated with previous v-belt problems. As this was also the case for the occurrence flight it is unlikely that operating conditions or techniques had any influence on the accident.

Given the sheaves were aligned and rechecked at the recent 100-hour inspection by qualified personnel and the post-accident sheave misalignment was attributed to impact damage, sheave misalignment was not considered to be a factor. Sheave groove condition was also not considered to be a factor as there was no problem reported at the 100-hour inspection or identified post-accident.

Belt tension is reliant on correct operation of the clutch engagement mechanism. During the recent 100-hour inspection the condition and operation of the clutch actuator was assessed with no defects identified. Post-maintenance and up to the day of the accident, there were no reported problems with the clutch actuator or belt tension. During the occurrence flight, the pilot, who was in radio contact with the station owner, did not report any in-flight problems until the v-belts failed. In addition, the pilot had not pulled the clutch circuit breaker as was required if the clutch caution light illuminated for an extended period of time, and the clutch overload fuse was intact. Although clutch actuator operation was found to be anomalous in post-accident testing, there was no evidence of actuator malfunction having occurred during the flight.

In principle, with good-condition sheaves that are aligned, and essentially new v-belts operating at the prescribed tension, it is highly unlikely that either belt would have been able to move from their respective positions on the sheaves. There were some on-site indications, though, that one or both the v-belts had been displaced from their proper positions on the sheaves during the engine start/clutch engagement process and then operated in that condition until failure.

One of the indicators of an abnormality on the morning of the occurrence was the pilot's report of excessive time taken for the blades to start turning (after clutch engagement) and for the clutch to fully engage. The likely scenario is that the pilot started the helicopter, assessed the belts were too slack, and then shut down the helicopter to investigate the problem.

It is probable that during that period the pilot adjusted the clutch actuator down limit stop screw to reduce the amount of v-belt slack and thus the time for the rotor blades to turn after clutch engagement. This was consistent with the pilot's advice to the station owner that he was adjusting the v-belts, and the down limit stop having been extended significantly since noted at the 100-hour inspection.

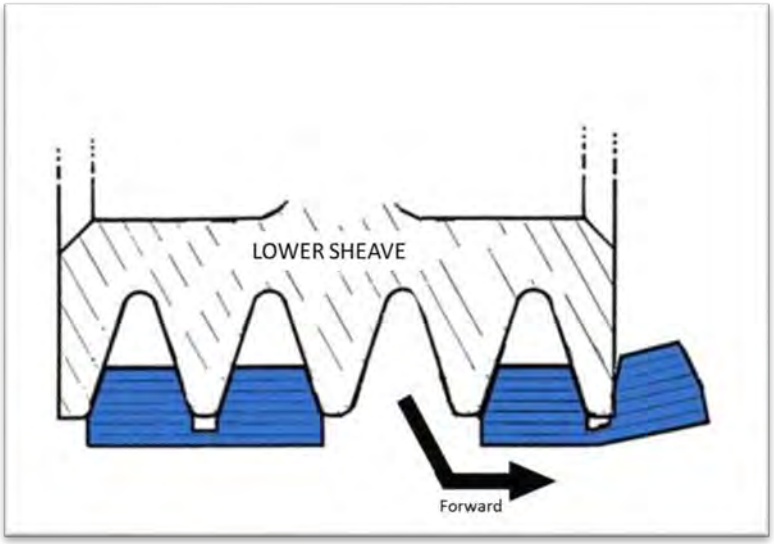
Although there is a regulatory aspect to the pilot's adjustment of the clutch actuator (addressed later) there was nothing to suggest that the adjustment itself contributed to the v-belt failure. In his response to the excessive v-belt slack; however, it appears that the pilot overlooked a problem with the v-belts that was not apparent until they failed.

When the pilot went on holidays prior to the occurrence it is likely that he left the clutch engaged with the belts under tension to stretch the v-belts, as allowed by Robinson Helicopter Company Safety Notice SN-33, and as he had discussed with the licenced aircraft maintenance engineer. With the v-belts left under tension in that one position on the sheaves for a period of at least 10 days, they would have stretched and developed a degree of shape-set.

On the morning of the occurrence the pilot would have ensured that the clutch was disengaged as was necessary for engine start. However, it is not known if the pilot inspected the v-belts between clutch disengagement and engine start and if he was aware of any excessive belt slack or shape-set at that point.

Whatever the case, when the pilot first started the engine and engaged the clutch, the disposition of the v-belts probably allowed one (or both) rotor drive v-belts to move on the lower sheave so that the forward belt was only partially in contact with the sheave (Figure 8). That partial contact would contribute to the longer clutch engagement time periods reported to the station owner by the pilot.

Figure 6: Diagrammatic representation of belt displacement



Source: ATSB

While the pilot's adjustment of the clutch compensated for any belt stretch and belt displacement, it did not correct the underlying problem. The rubber dust, rubber transfer marks, and fragmentation of the belts indicate that one or both belts were deteriorating during the occurrence flight consistent with abnormal positioning. The elapsed time before belt failure was consistent with the experience of another pilot who had this problem with the same revision v-belts.

Safety implications

As explained above, the critical factor in this occurrence was the likely v-belt displacement on engine start/clutch engagement as a result of excessive v-belt slack. This risk had been identified by the Robinson Helicopter Company and communicated to pilots and maintainers through Safety Notice SN-33 issued in 1998 and revised in 2013.

By careful reference to Safety Notice SN-33 a pilot or maintainer could be expected to understand the importance of checking v-belt slack during a pre-flight inspection and the associated time in which the rotor should be turning after engine start/clutch engagement. It is not known if the pilot had a good understanding of Safety Notice SN-33 or if he checked the v-belt slack prior to departure on the accident flight. However, it is evident that the pilot was aware of the rotor-turning time limit after start and the need to have the clutch actuator adjusted prior to flight.

Although Safety Notice SN-33 addressed the risk of v-belt slack generally, the notice did not specifically warn pilots that statically stretching the belts increased the risk of belt displacement during the subsequent start. It is therefore critical that if the rotors do not turn within 5 seconds after start, the pilot performs the shutdown procedure and examines the position of the v-belts on both the lower and upper sheaves.

Although the pilot's adjustment of the clutch actuator was not considered to be contributory, the pilot did not hold the required aircraft maintenance engineer licence or airworthiness authority to perform that maintenance. Aside from the regulatory aspects, maintenance conducted by unqualified persons, even experienced pilots, inevitably diminishes the level of safety assurance.

It is unclear if the pilot's injuries would have been less severe if he was wearing a helmet. As it was in this case, the R22 is commonly operated at low heights above ground level and as a result there is limited time to respond to emergencies and restricted choice in landing areas. In those circumstances, pilots and operators should consider the benefit of occupants wearing helmets to reduce the risk of head injury in case of an accident or serious incident.

Findings

From the evidence available, the following findings are made with respect to the rotor drive system failure involving a Robinson R22, registered VH-HRX, which occurred 100 km south-west of Borroloola, Northern Territory on 27 March 2014. These findings should not be read as apportioning blame or liability to any particular organisation or individual.

Contributing factor

- The clutch was engaged for an extended period of time to statically stretch the recently-installed rotor drive v-belts and during the subsequent engine start, one or both of the v-belts probably became displaced on the lower sheave, resulting in an abnormally long time for the rotors to start turning after clutch engagement.
- Although the pilot adjusted the clutch actuator, the likely v-belt displacement went undetected and while being operated in that abnormal configuration, one of the belts weakened and failed with consequent failure of the remaining belt, loss of drive to the rotors, and a forced landing.

Other factor that increased risk

- The pilot adjusted the clutch disengage position but did not hold an aircraft maintenance engineer licence or an airworthiness authority to perform that type of maintenance, decreasing the safety assurance of that task.
- Although Robinson Helicopter Company Safety Notice SN-33 provided guidance to pilots on how to stretch new v-belts statically, it did not specifically warn pilots that this process can increase the risk of belt displacement during the subsequent start.

General details

Occurrence details

Date and time:	27 March 2014 – 0700 CST	
Occurrence category:	Accident	
Primary occurrence type:	Mechanical failure	
Location:	100 km south-west of Borroloola, Northern Territory	
	Latitude: 16° 37.70' S	Longitude: 135° 32.77' E

Pilot details

Licence details:	Commercial Pilot (Helicopter) Licence, issued June 2007
Endorsements:	Robinson R22 and R44
Ratings:	Permission to conduct mustering low flying ops in helicopters
Medical certificate:	Class 1, valid to October 2014
Aeronautical experience:	Approximately 3,800 hours
Last flight review:	April 2013 (R44 Endorsement)

Aircraft details

Manufacturer and model:	Robinson Helicopter Company R22 Beta II	
Year of manufacture:	2012	
Registration:	VH-HRX	
Serial number:	4558	
Total Time In Service	1,068 hours	
Type of operation:	Private	
Persons on board:	Crew – 1	Passengers – 0
Injuries:	Crew – Serious	
Damage:	Substantial	

Sources and submissions

Sources of information

The sources of information during the investigation included the:

- Mallapunyah station owner
- VH-HRX aircraft maintenance organisation
- Civil Aviation Safety Authority (CASA)
- Robinson Helicopter Company
- United States National Transportation Safety Board (NTSB).

References

Australian Transport Safety Bureau (ATSB) 2013, AI-2009-038 *Reliability of the Robinson R22 helicopter belt drive system*, Canberra, Australian Capital Territory.

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 pilot of VH-HRX, aircraft maintenance organisation, CASA, Robinson Helicopter Company and the NTSB. Submissions were received from the Robinson Helicopter Company and CASA. The submissions were reviewed and where considered appropriate, the text of the report was amended accordingly.

Appendices

Appendix A – Safety Notice SN-33

ROBINSON
HELICOPTER COMPANY
2901 Airport Drive, Torrance, California 90505 Phone (310) 539-0508 Fax (310) 539-5198

Safety Notice SN-33

Issued: March 1998 Revised: July 2013

DRIVE BELT SLACK

R22 and R44 drive belts must have the proper slack prior to engine start. Belts which are too loose may jump out of their sheave grooves during engine start while clutch is engaging.

1. During preflight, with clutch disengaged, press in on belts with fingers just above fan scroll. Verify belts deflect approximately 1½ inches (4 cm). If belts are significantly looser than this, have actuator adjusted prior to engine start.

2. After engine start, engage clutch and verify rotor turns within 5 seconds. If rotor does not turn within 5 seconds, shut down and have actuator adjusted prior to flight.

New drive belts may be tight and cause the rotor to turn during engine start. This places unnecessary strain on the starter and drive system. If necessary, stretch new belts as follows:

1. During shutdown, do not disengage clutch.

2. After battery switch is off, put clutch switch in DISENGAGE position. If the clutch switch is left in ENGAGE position, the tachometers still draw power and can drain the battery.

3. Switch battery on and allow clutch to disengage during next preflight.

Australian Transport Safety Bureau

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

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

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

Purpose of safety investigations

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

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

Developing safety action

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

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

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

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

Australian Transport Safety Bureau

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Investigation

ATSB Transport Safety Report
Aviation Occurrence Investigation

Rotor drive v-belt failure involving Robinson R22 helicopter, VH-HRX 100 km SW of Borroloola, Northern Territory on 27 March 2014

AO-2014-058
Final – 17 December 2014