Australian Government

Australian Transport Safety Bureau

Engine power loss and forced landing involving Robinson R22 Beta, VH-HCX

4 km south-west of Geraldton Airport, Western Australia on 20 February 2021

ATSB Transport Safety Report

Aviation Occurrence Investigation (Short)

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Addendum

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Safety summary

What happened

On the morning of 20 February 2021, a Robinson R22 Beta helicopter, registered VH-HCX, was being repositioned from a storage depot near Geraldton Airport to Murchison House Station near Kalbarri, Western Australia. Shortly after lifting off, at about 30–40 ft above the ground, the engine's performance reduced and the helicopter began to descend. The pilot completed a forced running landing in a yard adjacent to the point of departure. The pilot then elected to reposition the helicopter. However, on becoming airborne, the helicopter began to rotate nose-right. In response the pilot landed the helicopter.

What the ATSB found

The ATSB found that an inlet valve in the engine's number-four cylinder sustained thermal damage, which led to reduced engine performance and required the pilot to conduct a forced landing. The loss of directional control during the subsequent lift-off resulted from a loss of drive to the tail rotor due to the tail rotor drive shaft fracturing in torsional overstress close to its connection with the tail rotor gearbox.

Safety message

This occurrence serves as a reminder for pilots of piston engine helicopters, like the R22, to be alert for unexpected yawing and transient reduced engine performance during flight. These characteristics may be symptomatic of developing engine intake valve damage. If this condition remains unattended it can lead to an increased risk of induction backfire events, and significant loss of engine power.

Additionally, when a loss of engine power or abnormal operation is encountered, an appropriately licensed maintenance engineer should complete an engine cylinder inspection in accordance with the helicopter and engine manufacturer's most recent service instructions before further flight. Maintenance organisations should note that when completing a differential compression test of the engine cylinders, an accompanying borescope inspection of the cylinders and valves will provide an effective method to visually assess the condition of these components.

The investigation

Decisions regarding whether to conduct an investigation, and the scope of an investigation, are based on many factors, including the level of safety benefit likely to be obtained from an investigation. For this occurrence, a limited-scope investigation was conducted in order to produce a short investigation report, and allow for greater industry awareness of findings that affect safety and potential learning opportunities.

The occurrence

On 20 February 2021, a Fortescue Helicopters-operated, Robinson R22 Beta, registered VH-HCX, was to be repositioned from a storage depot near Geraldton Airport, to Murchison House Station, near Kalbarri Western Australia. Once at the station, the helicopter was to be utilised for aerial goat mustering.

At about 0830 Western Standard Time,[1] the pilot arrived to prepare the helicopter for flight. The pre-flight check was completed with no anomalies identified. The pilot reported that prior to departure the engine was started and allowed to warm-up. The helicopter was then maintained in a low hover, a few feet above the ground, for about 30 seconds. With no abnormalities detected, the pilot transitioned the helicopter to forward flight and commenced climbing away.

At approximately 30–40 ft above the ground, the pilot detected increased vibration and described the engine sound changing to like a 'chaff cutter.' The engine then emitted a loud backfire and the helicopter yawed[2] 'savagely' nose-left an estimated 40–45°. The pilot reported a significant reduction in engine power and the helicopter started to descend. A bystander at the depot, who was watching the departure, observed a plume of smoke behind the helicopter.

Aware that a forced landing was imminent, the pilot prepared to conduct a running landing onto a yard adjacent the departure point. The helicopter landed heavily, in a slightly nose high attitude, resulting in the skids rocking in a heel-toe manner several times along the gravel surface before coming to a stop in line with the helicopter's flight path (Figure 1).

The pilot remained in the helicopter with the engine and rotor system running and completed several checks to determine the serviceability of the engine. The pilot identified that the rough engine running had eased. With no further engine issues evident the pilot elected to reposition the helicopter. Upon lifting off the pilot identified an uncommanded right yaw and a loss of anti-torque response from the tail rotor foot pedals. In response, with the helicopter having yawed through about 150°, the pilot landed and shutdown the engine.

[1] Western Standard Time (WST): Coordinated Universal Time (UTC) + 8 hours

[2] Yaw - the rotational movement of an aircraft about its vertical axis.

Figure 1: VH-HCX at the landing site

Several heel-toe skid marks were created during the landing. The helicopter subsequently yawed right after the pilot attempted to reposition the helicopter.
Source: Fortescue Helicopters

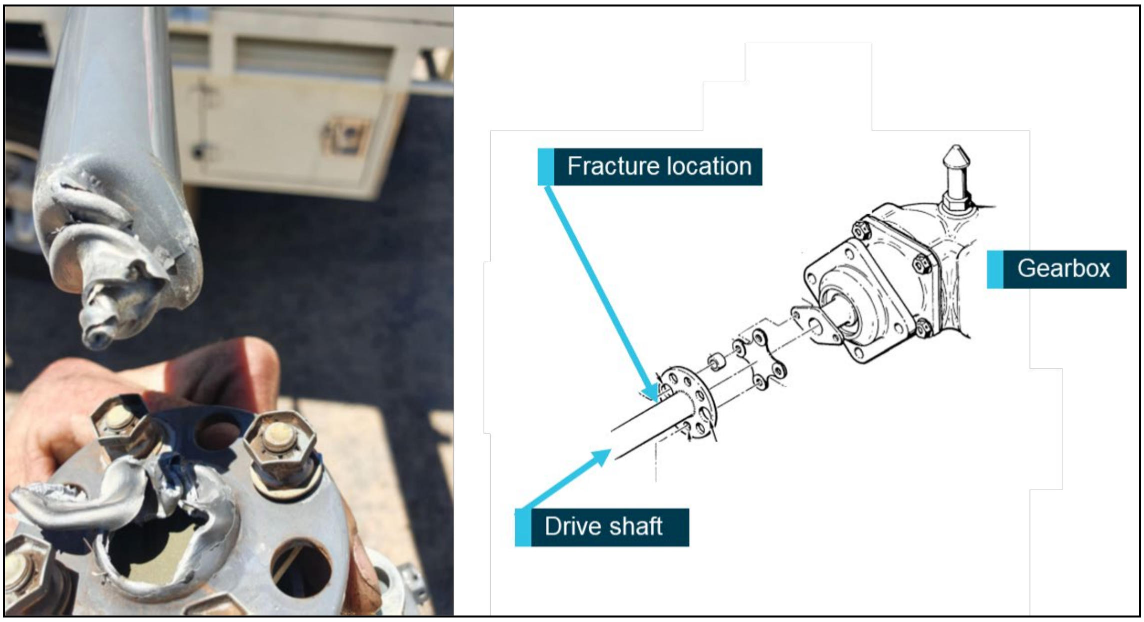
Context

Helicopter damage

The pilot examined the helicopter after landing and identified that the tail rotor drive shaft had fractured at its connection to the tail rotor gearbox (Figure 2). The helicopter was grounded, and the operator contracted a maintenance organisation that specialised in Robinson helicopters to complete an engineering examination and damage assessment.

In their report, the maintenance organisation noted that the tail rotor gearbox was correctly installed and free to rotate with no internal damage. All hardware that attached the tail rotor drive shaft, rear flex plate, and tail rotor gearbox input coupling was in place and in the manufacturer's specified assembly order. The tail rotor blades were inspected and found serviceable with no evidence of foreign object damage to their surfaces. There were no indications that the tail section had contacted the ground. Although assessed as non-contributory to the shaft fracture, the maintenance organisation also reported that the friction from a bolt within the tail rotor drive shaft damper assembly was found to be less than manufacturer's specification. Excluding the fractured shaft, no significant defects were identified with the tail rotor drive line components.

Figure 2: Tail rotor drive shaft fracture and schematic of the general area of the fracture



Source: Fortescue Helicopters, Robinson Helicopter Company, annotated by ATSB

During the post-occurrence inspection of the engine, maintenance engineers identified that the number-four cylinder was unable to hold pressure when subjected to a compression check. That cylinder was removed and, on further inspection, localised thermal damage to the inlet valve was identified (Figure 3). Reduced cylinder compression and valve damage can lead to engine power reduction, induction backfires, and aircraft yawing. No further defects were identified with the helicopter.

Figure 3: Internal view showing localised heat damage to the inlet valve from the number-four cylinder of the engine

Source: Azimuth Aviation, annoted by the ATSB

ATSB technical examination

Partial disassembly and examination of the helicopter's tail rotor gearbox and the fractured tail rotor drive shaft was completed at the ATSB's technical facilities in Canberra. No anomalies with the gearbox bevel gears and bearings that could have overloaded the drive shaft were identified. A runout check confirmed the drive shaft to be straight.

The fracture surfaces of the drive shaft were examined at high magnifications using both an optical and scanning electron microscope (SEM). The optical examination confirmed that the shaft fracture was located close to the welded flange with the entire section of shaft twisted and its cross-section inwardly necked in a ductile manner (Figure 4). The SEM examination confirmed the presence of gross ductile overstress features. There were no pre-existing defects identified from manufacture, or operational damage such surface scoring, fatigue cracking, denting or corrosion that might have otherwise weakened the shaft and predisposed it to fracture.

Figure 4: Gross ductile twisting and overstress fracture of the drive shaft

Source: ATSB

Operational and maintenance history

The helicopter was manufactured in the United States in 1991 and first registered in Australia in the same year. It was fitted with a Lycoming O-320-B2C four-cylinder reciprocating piston engine. The airframe had accumulated 9,700 hours total time in service. The helicopter had last been overhauled in December 2018 and had since accrued 1,484.2 hours in service to the occurrence flight. The tail rotor drive shaft was replaced with a new item at the overhaul in 2018.[3]

The operator advised the ATSB that in August 2020, approximately 320 hours prior to the occurrence flight, one tail rotor blade had sustained a dent to the leading edge that required replacement of the rotor blade assembly. The tail rotor drive shaft was inspected at that time and all shaft runout measurements were found to be within the manufacturer's limits.

The operator further reported that in December 2020 the engine had been running roughly due to a fouled spark plug in the number-four cylinder. Additionally, in the few weeks prior to the occurrence, the helicopter had been flown in the Geraldton area, and during that time the engine had exhibited periods of reduced engine performance and associated momentary uncommanded yawing. On the day of the occurrence, the pilot had elected to conduct the precautionary 30-second hover due to uncertainty associated with the previous period of intermittent engine performance.

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3 The tail rotor drive shaft was life-limited to 2,200 hours service, or 12 years of service, which ever came first.

Manufacturer's advice

The helicopter manufacturer advised that the VH-HCX tail rotor drive shaft fracture was highly consistent with a slowing (extreme drag) or sudden stoppage of the tail rotor blades and that in certain instances, contact with a foreign object such as water, tall grass, plastic bags or small birds may not result in visible damage to the blades.

The ATSB sought further advice from the helicopter manufacturer as to whether the fracture could have resulted from the helicopter being operated at a resonant engine/shaft speed. They noted that it would require an extended operational period at a resonant speed for the shaft to become damaged. Resonant shaft vibrations of concern exist at engine speeds of 15 per cent (below engine idle speed), 60 percent and 132 per cent (above red line). The manufacturer advised that a tail rotor drive shaft will permanently bend and fracture if operated at the higher resonant speed. The damper bearing will dampen the resonance at the two lower speeds.

The manufacturer also indicated that there has been no recorded instance within their R22 fleet of damage to the tail rotor drive shaft due to a rough running engine.

Other occurrences

Cylinder head inlet valve distress

In 2018, prompted by increasing industry reports of engine issues involving Robinson R22 and R44 helicopters, the Civil Aviation Safety Authority issued an *Airworthiness Bulletin (AWB) 85-025 Robinson R22/R44 Engine Intake Valve and Valve Seat Distress,* which examined in detail many of the factors that may contribute to cylinder head intake valve damage. The AWB noted that intake valve wear, the formation of solid oil deposits (coke) on the valve stem, and valve leakage can be avoided by:

- not exceeding the cylinder head upper temperature limit (red line) of 500 °F (260 °C) during operation
- minimising the duration of extended ground operations in high-temperature ambient conditions
- ensuring adequate engine cool down prior to shut down in accordance with the manufacturer's recommendations. The R22 Pilot's Operating Handbook noted that:

> If ambient temperatures are greater than 38 °C, an extended cool down is recommended. Operate at cool down RPM for at least 1 minute before reducing to idle.

CASA advised that a failure to comply with these recommendations may result in an induction backfire, engine power loss and airframe yaw. In a severe event this could lead to a loss of engine power. The following maintenance recommendation was provided:

> The LAME should listen for the sound of leakage at each intake valve while performing a differential compression test in accordance with the latest revision of Lycoming SI No. 1191. A cylinder borescope inspection should also be performed.

Tail rotor drive shaft fracture

A search of the Australian, Canadian and United States Federal Government aviation service difficulty reporting databases[4] identified only one other[5] similar reported instance of a Robinson R22 tail rotor drive shaft fracture event. The defect report noted that the failure occurred during take-off and that the helicopter may have sustained an overspeed or had been operated within a resonant speed range.

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[4] Civil Aviation Safety Authority *Defect Reporting Portal*
Transport Canada *Web Service Difficulty Reporting System*
United States Federal Aviation Administration *Service Difficulty Reporting*

[5] Civil Aviation Safety Authority, defect report number 611649334, dated 21 November 2016

Safety analysis

Engine power loss

Shortly after the Robinson R22 departed from the Geraldton storage depot, the helicopter sustained an engine power loss that required the pilot to conduct a forced landing. The investigation of this occurrence identified that the power loss was due to thermal damage to an inlet valve from the number-four engine cylinder.

The clearance created by in-service thermal damage to the valve head reduced the inlet valve sealing capacity. This, in turn, likely permitted combustion gases to bypass the valve seat and extend back through the intake of the engine producing the reported backfire, power loss and associated airframe yaw. The previous instances of yawing and reduced engine performance while the helicopter was operated in the Geraldton region provided an indicator of the developing inlet valve damage.

Furthermore, the damage to the valve and its associated effects on engine performance was consistent with the information contained within the industry advice produced by the Civil Aviation Safety Authority.

Tail rotor drive shaft

The ATSB examination identified that the drive shaft fractured in overstress from torsional loading that led to total separation of the shaft from its connection to the rear flex plate and tail rotor gearbox. It was while attempting to reposition the helicopter following the forced landing that the pilot was unable to maintain directional control of the helicopter due to the complete loss of anti-torque thrust from the tail rotor system. The ground contact marks created by the helicopter skids during the forced landing were relatively straight, which indicated that the drive shaft was probably intact at the time of ground contact.

The ATSB was unable to conclusively determine the reasons for the driveshaft fracture, which probably occurred during the running landing. The surfaces around the drive shaft fracture contained no evidence of pre-existing damage, mechanical rubbing or rotational contact damage. There was no evidence that the engine was operated at a resonant speed nor was there damage identified to the tail rotor blades from contact with a foreign object that could have overstressed the shaft. The previous damage to one of the rotor blades was considered unlikely to have been contributory as the shaft had been inspected following that occurrence and found to be serviceable.

A search of several databases revealed limited previous instances of similar failures in R22 helicopters. Additionally, the manufacturer reported no instances of tail rotor drive shaft fracture due to a rough running engine.

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.

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 engine failure and forced landing of a Robinson R22 Beta helicopter that occurred 4 km south-west of Geraldton Airport on 20 February 2021.

Contributing factors

- The inlet valve from the number-four cylinder of the engine sustained thermal damage, which led to reduced engine performance during the occurrence flight and the requirement for the pilot to perform a forced landing.
- During subsequent repositioning, the pilot was unable to maintain directional control of the helicopter due to the tail rotor drive shaft fracturing in torsional overstress close to its connection with the tail rotor gearbox.

Sources and submissions

Sources of information

The sources of information during the investigation included:

- Fortescue Helicopters
- the pilot of VH-HCX
- Heli-Flight
- Azimuth Aviation
- Robinson Helicopter Company
- Civil Aviation Safety Authority
- Lycoming Engines

Submissions

Under section 26 of the *Transport Safety Investigation Act 2003*, the ATSB may provide a draft report, on a confidential basis, to any person whom the ATSB considers appropriate. That section 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 following directly involved parties:

- Fortescue Helicopters
- the pilot of VH-HCX
- Heli-Flight
- Azimuth Aviation
- Robinson Helicopter Company
- Civil Aviation Safety Authority
- Lycoming Engines

Submissions were received from:

- Heli-Flight
- Azimuth Aviation
- Robinson Helicopter Company
- Civil Aviation Safety Authority
- Lycoming Engines

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

General details

Occurrence details

Date and time:	20 February 2021 – 0830 WST	
Occurrence class:	Incident	
Occurrence categories:	Technical failure mechanism	
Location:	4 km south-west of Geraldton Airport, Western Australia	
	Latitude: 28º 49.452' S	Longitude: 114º 41.050' E

Aircraft details

Manufacturer and model:	Robinson R22 Beta	
Registration:	VH-HCX	
Operator:	Fortescue Aviation	
Serial number:	1582	
Type of operation:	Aerial work	
Activity:	General Aviation	
Departure:	near Geraldton Airport, Western Australia	
Destination:	near Kalbarri, Western Australia	
Persons on board:	1	0
Injuries:	0	0
Aircraft damage:	Minor	