Australian Government

Australian Transport Safety Bureau

Loss of main rotor drive – Robinson Helicopter Company R44, VH-ZWC

83 km E of Darwin Airport, Northern Territory | 28 July 2011

Investigation

ATSB Transport Safety Report

Aviation Occurrence Investigation

AO-2011-088

Final

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ATSB TRANSPORT SAFETY REPORT

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VH-ZWC
Robinson Helicopter Company R44

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

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SAFETY SUMMARY

What happened

On 28 July 2011, at around 1615 Central Standard Time, a Robinson R44 *Raven II* helicopter, registered VH-ZWC, departed Darwin Airport on a charter flight to Bamurru Plains, Northern Territory. Approximately 30 minutes into the flight, the aircraft lost main rotor drive and the pilot conducted an autorotative descent and landing. There were no reported injuries.

What the ATSB found

The ATSB's investigation found that the loss of main rotor drive was associated with corrosion and subsequent fatigue failure of the main rotor gearbox gear carrier, as a result of water present in the main rotor gearbox.

What has been done as a result

The helicopter manufacturer has modified the design of the gear carrier to incorporate a metallic cadmium surface plating to improve the corrosion resistance of the assembly.

In May 2012, the Civil Aviation Safety Authority (CASA) released Airworthiness Bulletin 63-008, to raise awareness among operators and maintenance providers of Robinson R44 helicopters of the hazards associated with gearbox internal corrosion due to water ingress. The bulletin made several recommendations aimed at reducing the associated risks.

Safety message

Operators and maintainers of Robinson R44 helicopters are alerted to the potential for the ingress of water into the main rotor gearbox, and for the subsequent corrosion and possible fatigue cracking of componentry, which could lead to a loss of main rotor drive while in flight. Responsible persons are referred to the recommendations contained within CASA AWB 63-008, which are aimed at limiting the likelihood of water ingress and provide guidance on remedial action should water ingress be suspected.

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

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

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

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

Purpose of safety investigations

The object of a safety investigation is to identify and reduce safety-related risk. ATSB investigations determine and communicate the safety factors related to the transport safety matter being investigated. The terms the ATSB uses to refer to key safety and risk concepts are set out in the next section: Terminology Used in this Report.

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

Developing safety action

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

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

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

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

TERMINOLOGY USED IN THIS REPORT

Occurrence: accident or incident.

Safety factor: an event or condition that increases safety risk. In other words, it is something that, if it occurred in the future, would increase the likelihood of an occurrence, and/or the severity of the adverse consequences associated with an occurrence. Safety factors include the occurrence events (e.g. engine failure, signal passed at danger, grounding), individual actions (e.g. errors and violations), local conditions, current risk controls and organisational influences.

Contributing safety factor: a safety factor that, had it not occurred or existed at the time of an occurrence, then either: (a) the occurrence would probably not have occurred; or (b) the adverse consequences associated with the occurrence would probably not have occurred or have been as serious, or (c) another contributing safety factor would probably not have occurred or existed.

Other safety factor: a safety factor identified during an occurrence investigation which did not meet the definition of contributing safety factor but was still considered to be important to communicate in an investigation report in the interests of improved transport safety.

Other key finding: any finding, other than that associated with safety factors, considered important to include in an investigation report. Such findings may resolve ambiguity or controversy, describe possible scenarios or safety factors when firm safety factor findings were not able to be made, or note events or conditions which 'saved the day' or played an important role in reducing the risk associated with an occurrence.

Safety issue: a safety factor that (a) can reasonably be regarded as having the potential to adversely affect the safety of future operations, and (b) is a characteristic of an organisation or a system, rather than a characteristic of a specific individual, or characteristic of an operational environment at a specific point in time.

Risk level: the ATSB's assessment of the risk level associated with a safety issue is noted in the Findings section of the investigation report. It reflects the risk level as it existed at the time of the occurrence. That risk level may subsequently have been reduced as a result of safety actions taken by individuals or organisations during the course of an investigation.

Safety issues are broadly classified in terms of their level of risk as follows:

- **Critical** safety issue: associated with an intolerable level of risk and generally leading to the immediate issue of a safety recommendation unless corrective safety action has already been taken.
- **Significant** safety issue: associated with a risk level regarded as acceptable only if it is kept as low as reasonably practicable. The ATSB may issue a safety recommendation or a safety advisory notice if it assesses that further safety action may be practicable.
- **Minor** safety issue: associated with a broadly acceptable level of risk, although the ATSB may sometimes issue a safety advisory notice.

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

FACTUAL INFORMATION

History of the flight

On 28 July 2011, at around 1615 CST[1], a Robinson R44 *Raven II* helicopter, registered VH-ZWC, departed Darwin Airport on a charter flight to Bamurru Plains, Northern Territory, with the pilot and three passengers on board.

Approximately 30 minutes into the flight, while descending through an altitude of around 650 ft, the pilot reported experiencing an unusual airframe vibration that appeared to be associated with a minor, but persistent rotor ‘bounce’[2]. This prompted the pilot to identify a suitable site for a precautionary landing and inspection of the helicopter.

Around 30 seconds after the first observation, the vibration increased in severity, with the pilot reporting a loud ‘bang’ from the back of the helicopter and illumination of the clutch light. The pilot immediately conducted an autorotative descent and landing, resulting in distortion of the skids and minor damage to the tailboom from contact with a main rotor blade. There were no injuries.

Initial inspection of the helicopter established that the loss of main rotor drive was associated with a failure within the main rotor gearbox. The gearbox was subsequently removed and shipped to a maintenance facility, where it was disassembled in the presence of an Australian Transport Safety Bureau (ATSB) investigator.

Aircraft information

VH-ZWC was a Robinson Helicopter Company R44 *Raven II*, (serial number 11753), which was manufactured in the United States in 2007 and first registered in Australia in the same year.

The main rotor gearbox assembly (part number C006-5, serial number 4169), had accumulated 2,036 hours time in service (TIS), out of a 2,200 hour mandatory overhaul life. The gearbox had not been previously overhauled, but was serviced per the maintenance manual requirements, with the most recent service occurring during the previous 100-hourly inspection in May 2011, at 1,963.5 hours TIS. Work carried out at that time included a main rotor gearbox oil change and an inspection and cleaning of the magnetic chip plug. No defects or abnormalities were noted on the relevant maintenance documentation.

Main rotor gearbox examination

Removal of the main rotor gearbox sump revealed a fracture within the gear carrier (Figures 1 and 2). The bulk of the oil had been drained prior to removal of the gearbox from the helicopter. However, examination of the remnant oil showed liquid water droplets and pools within the lubricant.

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

2 ‘Rotor bounce’ describes a low-frequency vibration through the vertical axis of the helicopter.

The gear carrier exhibited small paint blisters over much of the part surfaces (Figure 3) and paint adhesion to the steel substrate in some of these areas was very low. The general appearance of the steel substrate was consistent with an as-machined surface and showed minimal paint surface preparation. Each of the paint blisters was associated with an underlying corrosion cell, and as a result, extensive corrosion pitting was evident across the steel surfaces (Figures 4 and 5).

The fracture surface on the gear carrier flange showed evidence of fatigue cracks originating from surface corrosion pits (Figure 6). Numerous crack origins were observed around the circumference of the fracture (Figure 7).

Figure 1: Gearbox sump removed showing fractured gear carrier

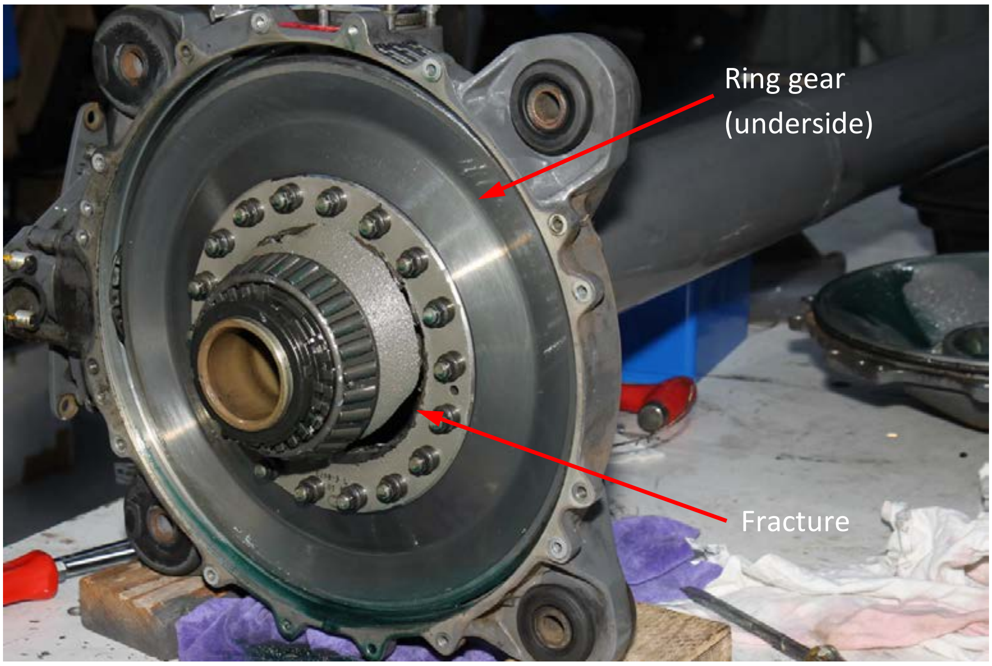


Figure 2: Two halves of the gear carrier (ring gear attached)

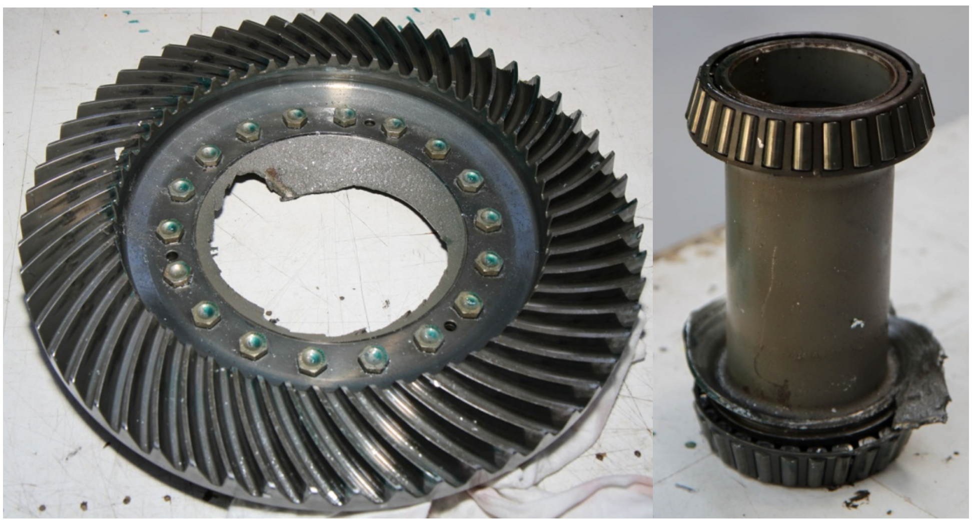


Figure 3: Paint blisters

Figure 4: Corrosion pitting on gear carrier flange

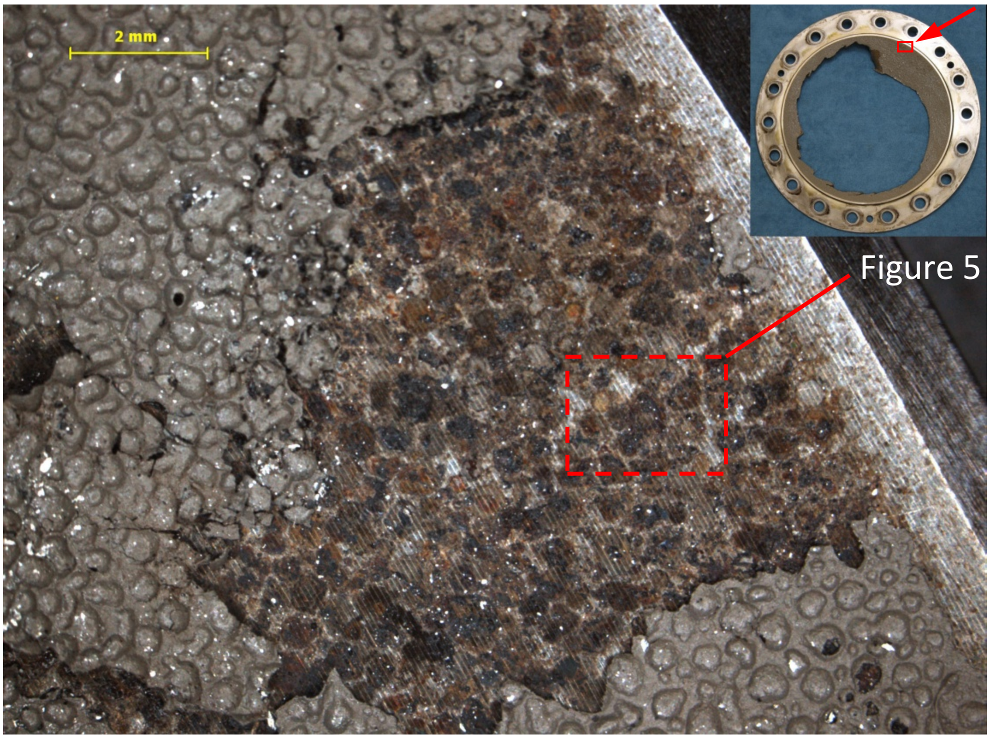


Figure 5: Detail of Figure 4

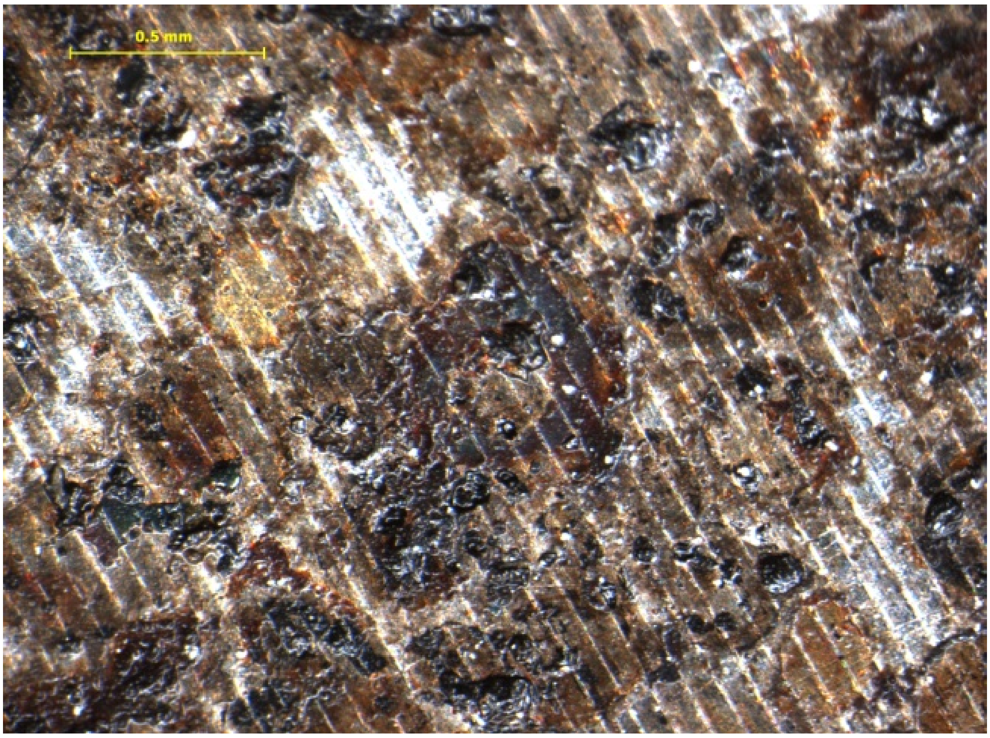


Figure 6: Fatigue cracking on gear carrier flange fracture surface

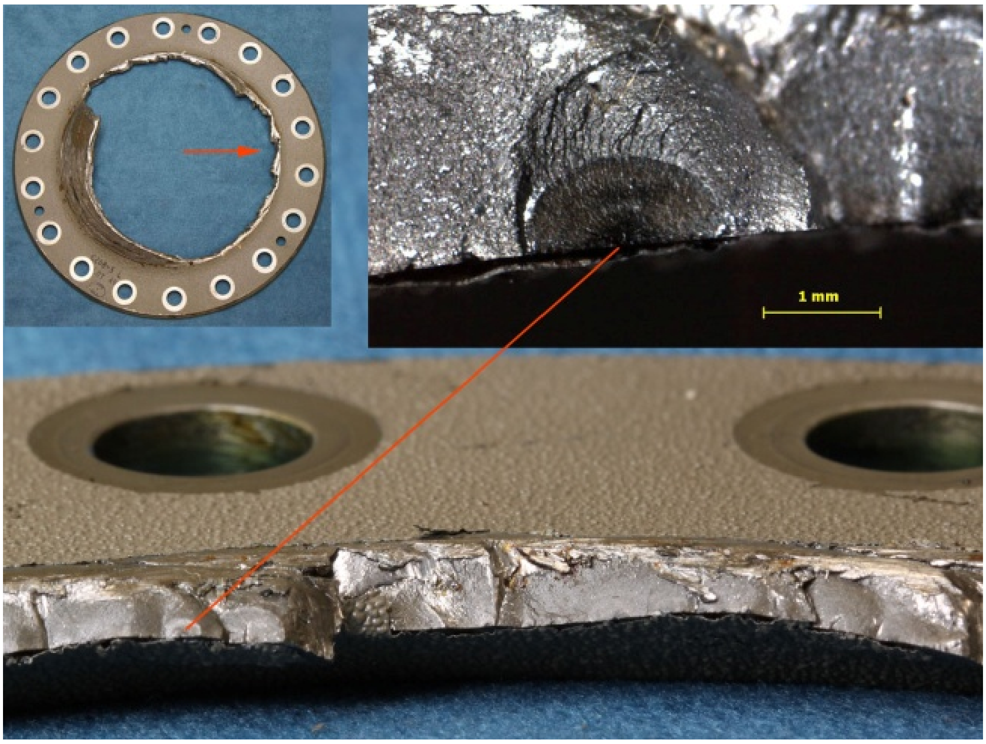
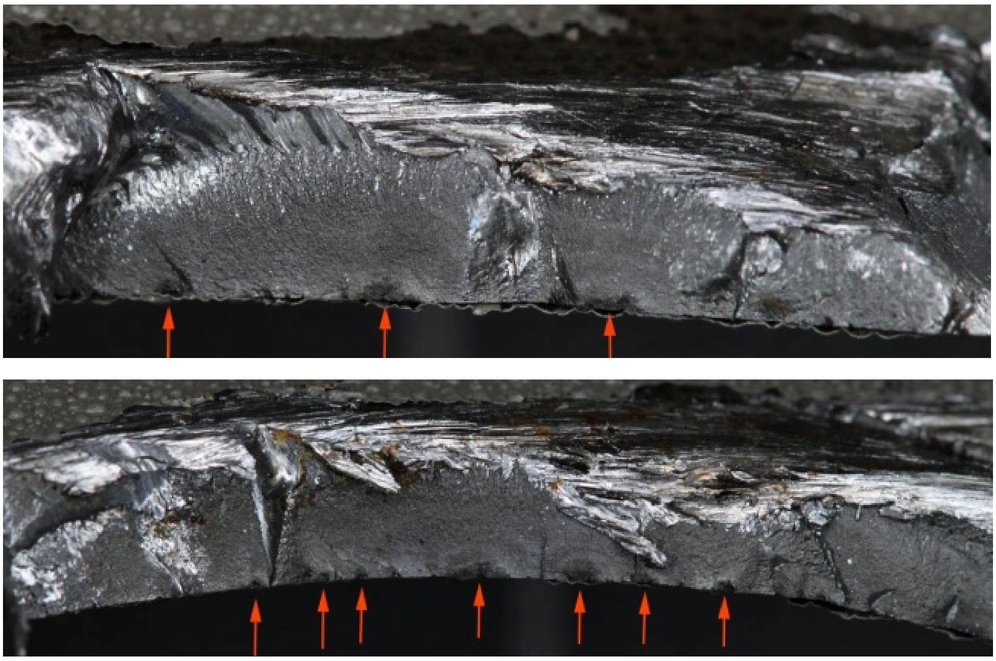


Figure 7: Corrosion pitting associated with the fatigue cracking



Other occurrences

The helicopter manufacturer advised the ATSB of one other recent occurrence of corrosion-related gearbox failure on an Australian-registered R44 helicopter. In that event, the helicopter landed normally after the magnetic chip detector warning illuminated, with the gearbox subsequently returned to the manufacturer for repair. The gear carrier was found fractured between the upper and lower bearings, allowing the gearbox to continue transmitting drive to the main rotor. The paint had disbonded from much of the part surface and the exposed steel surface had corroded.

Following the 28 July 2011 failure, the operator of VH-ZWC requested the precautionary removal of the gearbox from another R44 helicopter in its fleet. That helicopter had been operated under similar climatic conditions and its gearbox was of the same age, but had lower operational hours (1575.6 hours). The gear carrier subsequently showed similar levels of paint wrinkling and disbonding, exposing large areas of the steel surface. The interior surface showed paint blistering as well as minor corrosion pitting; however, there was no evidence of fatigue cracking.

Operation, storage and inspection

All of the helicopters that had sustained gear carrier paint degradation had been operated and stored in similar, tropical, northern-Australian climates. They had been stored outside utilising a standard bubble (cabin) / fuselage cover which did not cover the top of the rotor mast. Covering the mast was not a requirement of the helicopter maintenance manual; however, the manual did specify storage of the helicopter in a protected, fully-enclosed, dry (dehumidified) environment, if the helicopter remained unused for periods greater than 30 days.

The helicopter manufacturer indicated that the mechanism by which a sufficient quantity of water was entering the gearbox was not well understood at this time. It was thought that extended periods of outdoor storage may have allowed the accumulation of water in the gearbox. However, it was also believed that the normal operating temperature of the gearbox (around 100°C/212°F), would have been sufficient to evaporate any resident water. A review of the VH-ZWC maintenance releases over the past 10 months showed that the helicopter had not had any periods of extended storage in that time.

At the time of writing, there was no practical method for the direct inspection for corrosion on the gear carrier. The helicopter manufacturer advised that the periodic draining of a sample of fluid from the gearbox sump may be beneficial in the detection of gearbox water, especially after periods of operation, parking or storage in wet conditions.

ANALYSIS

The loss of main rotor drive that compelled the pilot of VH-ZWC to conduct an immediate autorotation was a direct result of the fracture and separation of the helicopter’s main rotor gearbox gear carrier. That failure itself, stemmed from the initiation and propagation of multiple fatigue cracks that grew to the point where the carrier could no longer sustain the transfer of drive loads. The initiation of fatigue cracking was associated with corrosion pitting of the steel under the paint coating.

In this application, the paint was used as a protective barrier between the part and the gearbox environment. However, in particularly wet or humid environments, water can permeate through organic coatings to initiate corrosion cells on the underlying steel. The absence of visible defects (pores, scratches) in the coating and the relative uniformity of the blistering over much of the painted surface indicated that this was likely the case.

While the precise mechanism for water ingress into the main rotor gearbox was not well-understood by the helicopter manufacturer, the operation and storage of R44 helicopters in the humid and wet environment of tropical northern Australia was a common factor in the three instances examined. As such, it was evident that operation and storage of R44 helicopters in tropical locations was a key factor relating to the ingress of water into the main rotor gearbox.

In any corrosion-related failure, the associated risk can be reduced by removing one of the elements necessary for corrosion. In this case, this could be achieved by either preventing the gearbox water ingress, or improving the corrosion resistance of the affected parts. At the time of writing, there were no documented measures available for the prevention or control of water ingress, with the exception of the extended-storage requirements specified in the helicopter maintenance manual.

FINDINGS

From the evidence available, the following findings are made with respect to the loss of main rotor drive on the Robinson R44 *Raven II* helicopter, registered VH-ZWC, and should not be read as apportioning blame or liability to any particular organisation or individual.

Contributing safety factors

- The loss of main rotor drive was the result of the initiation and propagation of multiple fatigue cracks originating from corrosion pits on the surface of the gear carrier inside the main rotor gearbox.
- Corrosion of the gear carrier occurred due to the presence of water within the main rotor gearbox.
- Paint application to the main rotor gearbox gear carrier did not effectively protect the part from corrosion resulting from gearbox water ingress. *[Minor safety issue]*
- The main rotor gearbox was susceptible to water ingress and there are currently no documented preventative actions available. *[Minor safety issue]*

Other key findings

- At the time of writing, there was no practical method available for the in-service detection of gear carrier corrosion.

SAFETY ACTION

The safety issues identified during this investigation are listed in the Findings and Safety Actions sections of this report. The Australian Transport Safety Bureau (ATSB) expects that all safety issues identified by the investigation should be addressed by the relevant organisation(s). In addressing those issues, the ATSB prefers to encourage relevant organisation(s) to proactively initiate safety action, rather than to issue formal safety recommendations or safety advisory notices.

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

Robinson Helicopter Company

Inadequate corrosion protection

Minor safety issue

Paint application to the main rotor gearbox gear carrier did not effectively protect the part from corrosion resulting from gearbox water ingress.

Action taken by Robinson Helicopter Company

The helicopter manufacturer has modified the gear carrier design to improve the corrosion resistance by cadmium plating the part.

Civil Aviation Safety Authority

Action taken by CASA

CASA released Airworthiness Bulletin (AWB) 63-008 on 1 May 2012 to raise awareness among operators and maintenance providers of the potential safety hazard associated with corrosion of Robinson R44 gearboxes and to make recommendations to reduce the associated risk.

APPENDIX A: SOURCES AND SUBMISSIONS

Sources of Information

The sources of information during the investigation included the:

- Owner of VH-ZWC
- Pilot of VH-ZWC
- Helicopter manufacturer
- The operator of a second R44 that had sustained a similar failure

Submissions

Under Part 4, Division 2 (Investigation Reports), 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. 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 helicopter owner, the pilot in command, the helicopter manufacturer, the operator of a second R44 that had sustained a similar failure, the Civil Aviation Safety Authority (CASA) and the US National Transportation Safety Board (NTSB). Responses were received from all parties and there were no submissions seeking amendment to the draft report.

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