Transportation Safety Board of Canada

Bureau de la sécurité des transports du Canada

AVIATION INVESTIGATION REPORT

A04P0422

DRIVE-BELT FAILURE AND COLLISION WITH TERRAIN

FLYING DOG HELICOPTER LLC

ROBINSON R44, RAVEN II, N313AL (HELICOPTER)

FAIRMONT HOT SPRINGS, BRITISH COLUMBIA, 15 nm SW

28 DECEMBER 2004

Canada

Aviation Investigation Report

Drive-Belt Failure and Collision With Terrain

Flying Dog Helicopter LLC
Robinson R44 Raven II, N313AL (helicopter)
Fairmont Hot Springs, British Columbia, 15 nm SW
28 December 2004

Report Number A04P0422

Summary

The Robinson R44 Raven II helicopter, N313AL (serial number 10056), landed at the Cranbrook airport, British Columbia, at 1237 mountain standard time (MST), where the pilot filled the fuel tanks to capacity and obtained weather and flight-planning information. The helicopter departed Cranbrook at 1343 MST for Revelstoke, evidently following the visual flight rules route north along the Columbia River, towards Fairmont Hot Springs. The flight was expected to take two hours. At 1415 MST, the helicopter struck steep terrain 33 nautical miles north-northwest of Cranbrook, at the 4200-foot level in a mountainous region. The pilot was fatally injured and the helicopter destroyed by impact forces and a severe post-crash fire.

Ce document est également disponible en français.

Other Factual Information

The 1300 mountain standard time[1] (2000 Coordinated Universal Time) METAR[2] for Cranbrook recorded cloud at 200 feet above ground level (agl), with a measured ceiling at 1100 feet agl; the wind was light from the west at 3 knots and the temperature was -4°C. At the time of the accident, the observed weather at the accident site was suitable for a visual flight rules flight, with an overcast layer at 5000 feet above sea level, no precipitation, visibility of 5 miles, and the temperature estimated at -12°C.

Robinson R44 Raven II, N313AL, was manufactured in March 2003. A review of the logbooks and maintenance records indicates that the helicopter had been certificated, equipped and maintained in accordance with existing regulations and approved maintenance procedures. At the time of the accident, the helicopter had accumulated 343 hours of flight time.

The accident site is on steep mountainous terrain, surrounded by tall conifers. The helicopter first struck a tree in its downhill flight path and began to break up. It then continued in the air for a further 100 feet, struck the ground at the base of another tree and rolled 25 feet downhill, coming to rest against the bases of several other trees. The damage to the helicopter, trees and terrain indicate that the helicopter was in a steep descending flight-path when it first struck the trees, and then continued into a steep nose-down attitude as it entered the trees in a vertical profile. Wreckage information shows that the rotor was turning at first impact with the trees and more slowly at final impact with the terrain.

To transfer engine power to the main transmission, the R44 helicopter employs four double-vee drive-belts running around two sheaves – the lower "driving" sheave and the upper "driven" sheave. Engaging (or disengaging) the vee-belts is accomplished by the pilot raising (or lowering) the upper sheave using an electric actuator. In flight, the actuator unit senses and maintains vee-belt tension. In this accident, one of the four vee-belts was damaged, but intact, and found around the upper and lower shafts. A second vee-belt was found broken and was trapped in the wreckage between the upper sheave and the tail boom structure. No trace was found of the other two vee-belts.

The eight grooves of the upper sheave had been partly coated with light soot from the post-impact fire. The eight grooves in the lower sheave contained rubber vee-belt residue. The four rear grooves had light vee-belt residue, but there was considerable rubber deposit on the four forward grooves. The paint primer surface of all eight grooves showed wear that was assessed as normal and acceptable. The consistency of the heavy rubber deposits on the forward grooves shows that the rubber transfer occurred at the same time for each vee-belt pair.

The usual extension of the electric actuator that adjusts the vee-belt tension on the R44 helicopter is between 0.8 and 1.0 inches; the accident actuator had a 1.3-inch extension. In the event that a vee-belt breaks during operation, the remaining vee-belts would carry the power

---

[1] All times are mountain standard time (Coordinated Universal Time minus seven hours).

[2] METAR – aviation routine weather report.

transmission load between them, and the individual tensions would increase.[3] This increase would be accomplished by the actuator operating (extending) until the total vee-belt tension was restored. Should a second vee-belt fail, the actuator would again operate to restore the total required tension. Controlled tests of vee-belt failure on an exemplar R44 helicopter revealed that with two vee-belts removed, the actuator extended to 1.3 inches to apply the necessary tension to maintain normal rotor rpm. The tests showed that the actuator takes 18 seconds to extend from 1.0 to 1.3 inches.

The engine installed in this R44 helicopter was a Textron Lycoming 6-cylinder reciprocating engine, model IO-540-AE1A5 (serial number L-28579-48A), and it had been installed in N313AL at the time of manufacture in March 2003. It had accumulated 343 hours total since new (TSN). The post-crash examination of the engine showed that it was operating at moderate to high rpm at impact. A review of the engine maintenance records reveals that this engine had been removed from the helicopter at 299 hours TSN on 25 August 2004, at the first 300-hour maintenance inspection, because of sticking exhaust valves in cylinder numbers 3 and 5, and spalling[4] on the number 5 exhaust valve tappet and cam. The engine was returned to Lycoming for inspection and repair, and was reinstalled in N313AL on 11 November 2004.

The examination of the engine by the Transportation Safety Board of Canada (TSB) revealed that the ends of the intake valve stems all exhibited "lipping" damage in the keeper channel. This was caused by an engine overspeed event, after the inspection and repair at Lycoming, within the last 43 hours. Furthermore, a microscopic examination of the damage suggested that the overspeed event occurred in the last minutes of engine operation. If one or more vee-belts broke, the sudden loss of belt tension would cause the remaining belts to slip on the driving sheave, in turn causing a rapid increase of engine rpm, likely an overspeed.[5]

Cylinder numbers 3 and 5, including new valves and valve guides, had been installed as-new by Lycoming 43 flight hours before the accident. The post-accident examination of the exhaust valve guides for those cylinders revealed excessive wear for the time in service. The cause for such high wear could not be determined.

The engine fuel control unit was examined and no anomaly was found. The throttle valve and metering orifice were in the full-open positions at impact, and the mixture mechanism was likely in the full-rich position.

---

[3] The actuator is not designed nor intended to compensate for broken vee-belts.

[4] "Spalling" is a type of fatigue cracking caused by very high compressive stresses.

[5] R44 Accident Investigation (Australia) revealed belt loss and engine overspeed. Australian Transportation Safety Board (ATSB) 199905646.

The engine cooling fan is attached to the engine by a taper-fit between the end of the drive shaft and the socket of the fan. Several technical reports[6] record severe galling damage[7] from in-flight usage, requiring rejection and replacement of the fan assembly. The effect of the galling on this joint introduces abnormal wear, imbalance and vibration, which in turn amplifies the galling mechanism and accelerates the wear process. The end result is a fan assembly that imparts increasing vibration to the lower sheave and the vee-belts. Vibration in the belt-drive system is one known factor in vee-belt failure, misalignment and loss.[8]

A metallurgical examination of both the tapered shaft and the tapered fan socket on the accident helicopter revealed remarkable galling, which was determined to have occurred within the last few hours of engine operation. Furthermore, the eight mounting bolts and washers, which attach the fan unit to the tapered socket, demonstrated remarkable fretting. The bolt holes in the fan backplate were elongated and the metal stretched at the inside diameter. None of this damage was present at the last maintenance inspection at 299 hours TSN. The TSB Engineering Branch analysis of the bolt/washer fretting and elongation revealed that the wear mechanism had occurred over a similar period to the galling of the taper-fit fan joint, and most likely concomitant with it. The stretching was assessed to have been caused by impact forces.

TSB Engineering Branch completed LP021/05 - *Fan Assembly and Drive Train Examination*.

This report is available from the Transportation Safety Board of Canada upon request.

Analysis

The reason for the excessive wear in the exhaust valve guides for cylinder numbers 3 and 5 remains unexplained. It is unlikely that a brief overspeed event would have caused the wear, and without the physical signs of valve-train misalignment, no mechanical reason for the wear can be determined. It is possible that the two subject valve guides were incorrectly dimensioned when installed as-new.

The even and normal wear on the primer paint on the driving sheave shows that when the engine was re-installed, the sheaves were correctly aligned. The engine cooling fan taper-fit shaft and socket joint is subject to galling damage from engine operation. Such damage can impart vibration to the vee-belts and sheaves, which is a known factor in vee-belt failure, misalignment and loss. The TSB Engineering Branch determined that the fan joint galling and the fretting on the bolts and washers found on the accident helicopter occurred in the last few hours of engine operation. It is most likely, therefore, that this amplifying vibration initially caused the two rear vee-belts to come off the sheaves. Robinson Helicopters asserts, however,

---

6 Transport Canada Service Difficulty Reporting database, and National Transportation Safety Board/Federal Aviation Administration (U.S.) and ATSB files.

7 "Galling" is the pitting or marring of a finished surface, especially a bearing surface, because of fretting (the rubbing together of solid surfaces).

8 *Heavy Duty V-Belt Drive Design Manual.* Denver: The Gates Rubber Company, 1999.

that even though galling on the fanshaft has been discovered on fans being removed during normal maintenance, the galling has not been directly associated with drive-belt system problems.

It is possible that the valve guide dimensional anomaly precipitated a vibration in the engine, which in turn was transmitted to the vee-belts and sheaves; however, no direct evidence was found to confirm this event. Such vibration, if it existed, could have exacerbated the vibrations stemming from the cooling fan, thereby leading to the loss of the vee-belts. However, if such vibration existed, it would likely have been discernable.

The loss of two vee-belts and the sudden reduction of belt tension would cause the remaining belts to slip on the driving sheave. The sudden slip would cause a significant loss of power to the transmission system, resulting in the rapid decay of main rotor rpm and the rapid increase of engine rpm, likely to engine overspeed. The slippage would cause the accumulation of rubber on the driving sheave grooves.

The loss of rotor rpm coupled with an engine overspeed would have been difficult to diagnose and handle in a timely manner, and the pilot would have been unable to prevent descent into the trees. Had the rpm decayed beyond effective cyclic control, he would have lost control of the helicopter. Once the helicopter struck the first tree, the damage prevented the pilot from recovering, and the collision with the terrain was inevitable.

Findings as to Causes and Contributing Factors

1. Galling on the engine cooling fan taper-fit joint within the previous few hours of flight operations introduced vibration to the belt-drive system, which in turn caused the misalignment of the belts within the sheave grooves and led to two vee-belts running off the sheaves in flight.

2. The sudden loss of vee-belt tension caused the remaining two vee-belts on the driving sheave to slip, leading to a rapid loss of main rotor rpm. This, in turn, prevented the pilot from avoiding the trees and led to a collision with the terrain and the destruction of the helicopter.

Findings as to Risk

1. The engine cooling fan taper-fit shaft and socket joint is subject to galling damage, which imparts vibration to the vee-belts and sheaves, a known factor in vee-belt failure, misalignment and loss.

2. The wear found in the exhaust valve guides for cylinder numbers 3 and 5 was excessive for their time in service and indicated a deviation from manufacturing quality control.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 30 September 2005.

*Visit the Transportation Safety Board's Web site (**www.tsb.gc.ca**) for information about the Transportation Safety Board and its products and services. There you will also find links to other safety organizations and related sites.*