Transportation Safety Board of Canada
Bureau de la sécurité des transports du Canada

AVIATION INVESTIGATION REPORT
A04P0314

COLLISION WITH WATER
ROBINSON R-22 BETA (HELICOPTER) C-FHGH
MCIVOR LAKE, BRITISH COLUMBIA
13 AUGUST 2004

Canada

Aviation Investigation Report

Collision with Water

Robinson R-22 Beta (Helicopter) C-FHGH
McIvor Lake, British Columbia
13 August 2004

Report Number A04P0314

Summary

The Robinson R-22 Beta helicopter (registration C-FHGH, serial number 1282) was on a short, daytime, VFR (visual flight rules) flight from Campbell River to a private airstrip near McIvor Lake, British Columbia. As the helicopter approached McIvor Lake, the engine noise increased with increased engine rpm, and the helicopter pitched up then entered a steep descent. The helicopter remained both directionally and laterally stable as it descended toward the lake. There were some popping or banging noises heard during the descent. In the latter stages of the descent, the forward motion of the helicopter slowed and the vertical descent rate increased. There was no apparent flare before water contact, and the helicopter struck the lake surface with high vertical velocity and low rotor rpm. The helicopter sank in about 30 feet of water. The pilot, who was the sole occupant of the helicopter, was fatally injured. The accident occurred at approximately 1232 hours Pacific daylight time.

Ce rapport est également disponible en français.

Other Factual Information

Visual meteorological conditions prevailed at the time of the accident. The pilot was qualified and current to perform the duties of the flight. The pilot held a valid private pilot licence–helicopter. He had completed his initial training and received his licence by April 2000 and, at the time of the accident, had accumulated about 490 hours of flight time on the Robinson R-22 helicopter type.

The damaged helicopter was recovered from the crash site and moved to the TSB regional office for examination. Scratches in the engine fan, shroud and baffles, and deformation of the baffle into the alternator fan, indicate that the engine crankshaft was rotating at impact with the water. The engine was checked for sticking exhaust valves and for internal damage that could have contributed to the accident. No indication of such damage was noted. Damage to the fuselage and main rotor blades was consistent with the helicopter striking the water with high vertical, and low forward velocity. The main rotor blades exhibited damage that was consistent with low rotor rpm at impact. Rubber deposits and damage patterns indicated that both drive belts had walked[1] forward off the sheaves[2] before water impact. This would have disconnected the engine output power from the helicopter's rotor system.

The helicopter had undergone a 2200-hour overhaul, which was completed on 19 May 2004. Following that overhaul, the pilot/owner had experienced an intermittent problem with the rotor engagement system. On 04 August 2004 he called the maintenance facility that had completed that overhaul and stated that the clutch would not engage at all. In response, an engineer flew to Nanaimo to examine the helicopter. During that examination, the engineer tapped the actuator motor to set it working. This temporary fix permitted the pilot/owner to bring the helicopter to the maintenance facility on 11 August when the actuator motor was replaced with a new one. Replacement of the actuator motor was completed and the helicopter was picked up on 13 August for a short flight to McIvor Lake. On departure for this flight, there was no noted delay in the engagement of the clutch after start-up, and it is considered unlikely that the pilot/owner would have left the maintenance facility if he had a concern about the rotor engagement system. It was on this flight to McIvor Lake that the accident occurred.

Engine power in the R-22 helicopter is transmitted from the engine crankshaft to the rotor drive system by two double V-belts carried on sheaves. One sheave is mounted on the aft end of the engine crankshaft and the other is mounted immediately above on the main gearbox/tail rotor drive shaft.

An electrically-driven, belt-tension actuator is mounted between the upper and lower sheaves, and it raises the upper shaft when a clutch switch on the centre console of the cockpit is set to ENGAGE. This repositioning of the upper shaft tensions the V-belts so power is transmitted from the engine to the rotor system. A device in the belt-tension actuator senses the compressive

---

1 "Walked" is a generally-accepted generic term used to describe the motion of a V-belt when it climbs out of a sheave's groove and moves laterally off the sheave assembly.

2 A sheave is a grooved wheel designed to accommodate one or more V-belts. It may also be called a grooved pulley or pulley.

load caused by the increasing belt tension and stops the actuator motor when the V-belt tension reaches a preset value. Flexible couplings accommodate shaft alignment changes that occur when the rotor drive is engaged and/or disengaged.

The belt-tension actuator assembly on the helicopter at the time of the accident and the actuator motor that had been removed by the maintenance facility prior to the accident were taken to the Robinson Helicopter facility. All components were tested, based on factory standards, and found to be serviceable.

The V-belts from the helicopter were also taken to the Robinson facility for inspection and testing. Robinson V-belts are manufactured by a sole-source sub-contractor and are to be fitted to each helicopter as a matched pair. As part of Robinson's quality control process, all belts received from the sub-contractor are measured to ensure that they meet specific dimensional standards. They are then "run-in" for five hours at full rotor rpm equivalent and operating tension before being released for installation on a helicopter. The belts are shipped with an FAA (United States Federal Aviation Administration) Form 8130-3 (Air Worthiness Approval Tag) which verifies the source and serviceability of the component. The maintenance file for the accident helicopter contains this tag. In addition, the outer surface of the belts bear the Robinson Helicopter imprint, confirming that they are factory-approved parts.

The damaged V-belts were re-measured using the factory's belt length test rig and were found to range from 0.1650 inch to 0.4760 inch shorter than the minimum allowable dimension. In addition to failing this dimensional check, investigators found that the accident belts were too short to fit onto the factory's actuator test rig. Under normal circumstances, they would also have been identified as unserviceable at that stage of the acceptance process. Finally, the installation of these belts during the helicopter's overhaul had not revealed any discrepancy in the drive belt length based on clutch shaft angle measurements that are taken as part of the drive train rigging.

During a later test, Robinson Helicopter personnel attempted to install the accident belts onto a serviceable helicopter and found that the installation of the shortest of the two belts was not possible. Although the longer of the two accident belts could be installed, it took excessive force, which would have been noticed during the original installation process.

As part of the post-accident testing process, a new set of V-belts was tested by Robinson to determine if they were susceptible to shrinkage on water immersion. These belts were run-up on the company's test stand for more than five hours with the test-stand cooling fans OFF to ensure the belts would be at or above the normal operating temperature. At the end of the run-in period, the belts were immediately cooled. The maximum measured change in belt length under these test conditions was negligible, in the order of 0.002 inches.

In a follow-on test to examine belt length versus temperature, a serviceable V-belt was measured, placed in a oven at 200°F and heated for about two minutes without tension. While still warm (179°F), the belt was re-measured and found to be more than 0.250 inch shorter than its original size; this new (shorter) length remained constant as the belt cooled to ambient temperature.

According to the *Gates Technical Information Library* and the company's *Heavy Duty V-Belt Drive Design Manual*, both internal and external heat is generated when a belt-drive operates. Internal heat (within the V-belt) is caused by flexing as the belt moves around the sheaves. External heat is created by slippage between the belt and the sheave. As a result, V-belt drives that use the belt as a clutch require special design consideration due to heat generated by belt slip during engagement and disengagement. If a belt drive that is being used as a clutch does not operate properly, an excess of heat may be generated, and this excess heat could cause the V-belt to shrink in length. The Robinson R-22 helicopter uses its V-belt drive system as a clutching mechanism to engage and disengage the rotors with the engine power.

R-22 helicopters (after serial number 0225) rely on a 1.5-amp fuse in the clutch circuit to prevent the belt-tension actuator from over tensioning the belts should its micro-switches fail. The integration of this fuse into the electrical circuit also provides warning of an impending failure of the drive belts, actuator bearings, or other drive system components.

The fuse holder installed on the accident helicopter was not an original Robinson part and was not installed (that is, connected and ty-wrapped) in the manner used by Robinson factory personnel. The time or originator of the change of the fuse holder is not recorded in the available maintenance logs. The following observations are based on an examination of the component following the accident:

- Solder joints were used to connect the replacement fuse holder to the helicopter's electrical wiring. Crimp connections are normally considered better for this type of application as solder joints are prone to break down when subjected to vibration.
- One of the connections was a cold-solder joint, and that joint did not contain all the available wire strands.
- Corrosion was present on the aft terminal of the fuse holder.
- The fuse holder was ty-wrapped to the helicopter frame in a manner that subjected the component to a bending load. The resultant bend in the holder reduced the effectiveness of the internal spring.
- The fuse holder contained a 10-amp fuse rather than the required 1.5-amp fuse.
- The aft portion of the 10-amp in-line fuse was corroded.
- The application of a slight bending force to the fuse holder caused a reduction of the clutch motor speed.

The presence of corrosion on both the in-line fuse and fuse terminal, coupled with the poor solder joint caused an increase in resistance in the electrical circuit to the belt tensioning actuator motor. Specifically, the electrical continuity across the fuse holder was measured before the fuse and holder were disturbed for examination (that is, before the ty-wraps were removed). During that test, the resistance across the fuse holder varied from as low as 1 ohm to as high as 1000 ohms with the variation being caused by a slight movement of the fuse holder. This variation in resistance adversely affected the operation of the actuator motor.

The Robinson Maintenance Manual (page 14.8) provides a *Clutch Actuator Electrical Trouble-shooting Guide*. That guide indicates that, when the actuator is disengaged and will not engage, two of the eight items that should be checked during maintenance for the fault include confirmation that the 1.5-amp fuse has not blown and confirmation that there is not an open circuit in the motor wiring.

There have been previous occasions when R-22 drive belts have either broken or walked off the sheaves. The FAA's Los Angeles Aircraft Certification Office (LAACO) recently reviewed an NTSB R-22 accident report along with 27 related service difficulty summaries of the R-22 drive-belt system problems. Based on that review, the LAACO determined that the current R-22 design, with accompanying advisory material for its safe operation, meets the R-22 certification basis and is safe to operate. That report noted that, in most cases, these problems have occurred with relatively new belts (less than 50 hours time-in-service) and have been associated with some combination of the following factors:

- helicopter operation at high weight, or above gross weight conditions (sometimes compounded by turbulence);
- improper sheave alignment at installation, or alignment shifts caused by initial belt wear-in;
- sheave surface condition (new belts mounted on worn or corroded sheaves);
- actuator tension being out of specification; or
- excessive belt slack at initial engagement.

Transport Canada's Helicopter Flight Training Manual, TP9982E, describes an autorotation as the condition of flight in which the rotor is driven by aerodynamic forces with no power being delivered by the engine. During autorotation a helicopter remains fully manoeuvrable, albeit in descending flight, and the airflow moves upward through the rotor disc rather than downward as in powered flight. A pilot must keep the rotor rpm within specific limits so that, in the latter stages of the autorotation, kinetic energy from the spinning rotor disc can be used to slow and arrest the descent for landing.

The main-rotor blade system of the Robinson R-22 helicopter is considered a "low-inertia rotor system." This term refers to the tendency for the rotor to deplete its stored energy quickly, leading to the decay of main-rotor rpm and thence to the aerodynamic stall of the rotor system. The Robinson Helicopter Company issued Safety Notice SN-24, entitled "*Low RPM Rotor Stall Can Be Fatal*," in September 1986. The notice warns that a very high percentage of accidents are caused by rotor stall due to low main-rotor rpm and explains the procedures that can be used to mitigate the risk. This company safety notice is disseminated to all R-22 owners, dealers, and Pilot Operating Handbook subscribers.

Analysis

The V-drive belts were found to be shorter than the minimum dimensional standard with significantly mis-matched lengths. For excessively short belts to get into the system, they would have to be manufactured improperly by the sub-contractor and would have to go un-noticed through Robinson's multi-level quality control checks. Following the accident, the shortest of the two involved belts could not be re-installed on the accident helicopter by TSB personnel, nor could it be installed on a serviceable helicopter by factory personnel. Although the longer of the two accident belts could be installed, it took excessive force and would have been noticed during the original installation process. It is considered unlikely that these belts were too short at the time of installation. It follows, therefore, that the drive belts had to change dimension at some point after they were originally installed.

The belt-tension actuator assembly that was on the helicopter at the time of the accident, as well as the actuator motor that had been removed at the maintenance facility just prior to the accident, were tested at the Robinson Helicopter facility. All of these components were found to be serviceable based on factory standards. It is unlikely, therefore, that these components precipitated the accident.

The presence of corrosion on both the in-line fuse and fuse terminal, coupled with the poor solder joint caused an increase in resistance in the electrical circuit to the belt-tension actuator motor. This would have either slowed or stopped the actuator motor. Slow operation of the actuator motor would increase the time required to properly tension the belts. Because heat is generated during the tensioning process, any increase in the tensioning time will increase the heat transfer to the belts. Belts are known to shrink if their temperatures reach levels that are beyond their normal heat range. It is, therefore, likely that the slow operation of the actuating motor precipitated the belt shrinkage.

Any change to the dimensions of the belts after installation will cause a change to the original rigging and alignment of the upper drive shaft and an increased mis-alignment of the sheaves. Mis-alignment of the drive train sheaves is known to contribute to drive train failure.

The drive belts shrunk by different amounts, and any belt mismatch would result in the shorter of the belts tensioning first and taking a higher percentage of the engine power. An excess of horsepower being applied to the drive belt system is known to increase the risk of belt failure.

In this accident, regardless of the specific cause, both belts came off the sheaves in flight, thus disconnecting the engine from the rotor system. The loss of power to the rotor system required the pilot to enter an autorotation. In the latter stages of that manoeuvre, the main rotor rpm decreased and the helicopter's rate of descent increased rapidly. Because of the Robinson R-22's low-inertia rotor system, recovery under these conditions is virtually impossible, even with the collective fully down. The helicopter entered the water with a high vertical descent rate and limited forward speed.

The pilot/owner had reported an intermittent problem with the rotor engagement system after the overhaul. Although tapping the tensioner motor to initiate engagement appeared to have worked as a temporary fix, it is not an approved maintenance procedure and, in part, led to an incorrect conclusion that the tensioner motor was the underlying cause of the engagement problem. The correct use of the Maintenance Manual's *Clutch Actuator Electrical Trouble-shooting Guide* would have provided an opportunity to identify the electrical defects that were subsequently noted following the accident.

Use of a 10-amp fuse in place of the required 1.5-amp fuse in the electrical circuit to the belt tensioning actuator eliminated the intended defence and, under certain circumstances, could have allowed the actuator to over-tension and damage the belts.

The following TSB Engineering Branch Report was completed:

LP 115/04 - Lamp Analysis

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

Findings as to Causes and Contributing Factors

1. At some point after installation, both V-drive belts were subjected to changes in dimension, probably as a result of shrinkage due to excess heat. Any changes to belt length would increase the risk of the belts coming off the sheaves and disconnecting the engine from the rotor system.

2. Corrosion on an in-line fuse end and improper connection of the fuse holder raised the resistance in the electrical circuit to the belt-tensioner and slowed the operation of the belt-tension actuator motor. This slower operation would have caused an increase in tensioning time and in belt temperature during engagement/disengagement, which likely precipitated the belt shrinkage.

3. During the latter stages of the autorotation, the helicopter's main-rotor rpm was allowed to drop below safe limits, resulting in insufficient rotor energy to arrest the descent.

Findings as to Risk

1. Use of a work-around procedure to engage the actuator motor (tapping the motor) increases the risk of component failure and, in this case, masked the actual cause of the engagement problem.

2. Use of a 10-amp fuse in place of the required 1.5-amp fuse in the electrical circuit to the belt-tension actuator motor eliminated the intended defence and, under certain circumstances, could have allowed the actuator to over-tension and damage the belts.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 25 October 2005.