Transportation Safety Board of Canada

Bureau de la sécurité des transports du Canada

AVIATION INVESTIGATION REPORT A07O0030

UNCONTROLLED FLIGHT INTO TERRAIN

THE HELICOPTER COMPANY INC.
ROBINSON R44 II, C-FGTN
CAMBRIDGE, ONTARIO
02 FEBRUARY 2007

Canada

Aviation Investigation Report

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Summary

The crew of the Robinson R44 II helicopter (registration C-FGTN, serial number 10210), operated by The Helicopter Company Inc., was conducting a series of maintenance check flights following a change of the aircraft's main rotor blades. The pilot and aircraft maintenance engineer were tasked with "blade tracking" and the engineer had made pitch link adjustments on the main rotor blades based on the results of two earlier flights. The occurrence flight was conducted with the intention of blade tracking and checking the rotor revolutions per minute during an autorotation procedure.

At approximately 1728 eastern standard time, in low light conditions, the aircraft entered the autorotation at 2400 feet above sea level and continued its descent until it impacted the snow-covered frozen field. The emergency locator transmitter activated and rescue and fire fighting teams responded. Both occupants suffered serious injuries and were ejected from the cockpit when the seat belt attachments failed. The aircraft was destroyed.

Ce rapport est également disponible en français.

Other Factual Information

History of the Flight

On 20 January 2007, the helicopter was flown to the Kitchener/Waterloo Regional Airport for a maintenance inspection. During the inspection, a small delamination was observed on one of the main rotor blades. The aircraft manufacturer requested that the blades be sent back to the factory and replacement blades were shipped in from Vancouver. After the new blades were installed, the aircraft maintenance engineer (AME) installed the strobe gear in preparation for blade tracking. Two maintenance check flights were conducted earlier on the day of the occurrence to track the blades; adjustments were made to one of the pitch links after each of these flights.

The occurrence flight departed the Kitchener/Waterloo Regional Airport at 1722 eastern standard time [1] and proceeded south to the Cambridge area at 2400 feet above sea level, which is approximately 1400 feet above ground level (agl). The intention was to track the blades and check the rotor revolutions per minute (RPM) while the helicopter was in an autorotation. This ad hoc procedure of tracking the main rotor blades in an autorotation differed from the manufacturer's procedures listed in the aircraft section below, and was reportedly based on trouble-shooting advice received on a previous occasion. A pre-flight briefing about this procedure was limited to asking the pilot if he was comfortable doing autorotations while the AME tracked the main rotor blades.

In preparation for the autorotation, the pilot flew the aircraft over open fields located southwest of Cambridge. During the autorotation, the AME's attention, which had been focused on the rotor blades, was diverted into the cockpit by an exclamation from the pilot. He observed that the engine/rotor per cent RPM gauge dual pointers were horizontal; indicating approximately 80 per cent, and that the aircraft was pitched nose down. There was no report of a low rotor horn or warning light which are normally set to trigger at 97 per cent [2]. The helicopter continued the descent into the snow-covered field. It struck the ground with the front section of both skids and came to rest on its left side, facing in a northerly direction.

Personnel Information

The pilot-in-command was certified and qualified for the flight in accordance with existing regulations and was operating in visual meteorological conditions. He received his private pilot aeroplane licence in July 2000 at the Moncton Flight College. He held a commercial pilot helicopter licence (obtained in October 2002) and had approximately

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1 All times are eastern standard time (Coordinated Universal Time minus five hours).

2 When the collective lever is full down, the low rotor horn and caution light are disabled.

1300 hours of total flying time; 1000 hours on rotary aircraft. The commercial helicopter flight test in October 2002 was conducted using the Bell 206 and a pilot proficiency check for that aircraft was issued at the same time. He completed his training on the R44 II helicopter on 29 June 2006 and obtained a licence certification of additional privileges in July 2006. He had accumulated approximately 300 hours on type at the time of the accident and had last conducted autorotation training in September 2006.

He was employed as a traffic pilot and was seated in the aircraft right seat during the occurrence flight. The pilot had previously conducted maintenance check flights on the Bell 206 and the R44.

The pilot was interviewed by TSB investigators; however, he did not remember any of the events pertaining to the day of the occurrence.

Aircraft Information

The aircraft was manufactured and imported to Canada in 2005. At the time it was flown to the Kitchener/Waterloo Regional Airport on 20 January 2007 for maintenance, it had accumulated a total of 1082 hours.

The manufacturer's procedure for in-flight track and balance of the main rotor blades is to first adjust the rotor track and balance while the helicopter is in a hover. Then the rotor track is checked at a series of increasing airspeeds. Autorotational RPM is checked after the rotor track and balance is complete. The worksheet recovered from the wreckage indicates the main rotor blades were adjusted twice following hover flights, but there was no record that the rotor tracking procedure at the various forward airspeeds had been completed.

The manufacturer's procedure for checking the rotor RPM in the autorotation specifies that the helicopter be at 1900 pounds gross weight or less and that three readings be taken at 500 to 1000 foot altitude intervals. The autorotation was initiated at 1400 feet agl and the weight of the helicopter was calculated to be 2279 pounds. Using the "AUTOROTATION RPM" chart in the manufacturer's maintenance manual and extrapolating linearly off the chart, the expected autorotation RPM would have been 110.5 per cent (2.5 per cent above the red line – 108 per cent).

The Robinson R44 II *Pilot's Operating Handbook* (POH) states in the Limitations section the rotor speed limits as follows:

	Tachometer Reading (R)	**Actual RPM**
Power On		
Maximum	102%	408
Minimum	101%	404
Power Off		
Maximum	**108%**	432
Minimum	90%	360

Photo 1. C-FGTN engine (E)/rotor (R) tachometer.

Conservation of rotor RPM is critical to a successful autorotation in any helicopter. Once engine power is lost, the pilot must immediately lower the collective lever and establish an autorotative descent at an airspeed recommended by the manufacturer.

The Robinson R44 maintenance manual procedure for checking the rotor RPM in an autorotation specifies that the collective be held firmly against the down-stop and that a descent speed of 50 knots indicated airspeed be maintained. During this procedure one of three scenarios could occur:

a. The rotor RPM could climb and, once it showed signs of going above the green arc, the pilot would initiate a recovery to straight and level powered flight.

b. The rotor RPM could drop and, once it showed signs of going below the green arc, the pilot would initiate a recovery to straight and level powered flight.

c. The rotor RPM could settle somewhere in the green arc, and the pilot would initiate a recovery to straight and level powered flight.

The engineer would take note of the RPM, and the helicopter would return to base for adjustments. The crew would then conduct further flight tests as described in the maintenance manual until the correct adjustment is achieved.

The main rotor blade system of the Robinson R44 II helicopter is considered a “low-inertia rotor system”. This term refers to the tendency for the rotor to quickly deplete its stored energy when it is no longer powered. If the collective is not fully lowered, the main rotor RPM will decay causing an aerodynamic stall of the rotor system. Once the main rotor is stalled, recovery is unlikely.

The POH Normal Procedures Section – Practice Autorotation contains a CAUTION which states: "During simulated engine failures, rapid decreases in rotor RPM will occur, requiring immediate lowering of collective to avoid dangerously low rotor RPM. Catastrophic rotor stall could occur if rotor RPM ever drops below 80per cent plus 1per cent per 1000 feet of altitude."

Meteorological Information

The aviation routine weather report (METAR) at 1700 for the Kitchener/Waterloo Regional Airport was as follows: wind 250˚ True (T) at 14 gusting to 20 knots; visibility 9 statute miles (sm); sky clear; temperature -6˚C, dew point -12˚C; altimeter setting 29.50 inches of mercury (in Hg); and remarks - sea level pressure 1009.0 hectopascals (hPa).

The METAR at 1800 was as follows: wind 250˚T at 16 knots; visibility 9 sm; few clouds at 2800 feet, ceiling 3900 feet overcast, 7500 feet overcast; temperature -6˚C, dew point -12˚C; altimeter setting 29.53 in Hg; and remarks: sea level pressure 1002.0 hPa.

Sunset was at 1734; the flight was conducted in low-light conditions.

Safety Notices

As a result of various accidents and incidents, the Robinson Helicopter Company has issued numerous safety notices. Safety Notice SN-10 states: "A primary cause of accidents in light helicopters is failure to maintain rotor RPM." Low RPM rotor stall can occur at any airspeed and when it does, the rotor stops producing the lift required to support the helicopter. Safety Notice SN-10 further states: "When the rotor stalls, the blades will either 'blow back' or cut off the tail cone or the rotor will just stop flying, allowing the helicopter to fall at an extreme rate." The following safety notices are relevant to this occurrence and have been included as Appendices to the report:

Safety Notice SN-10 (Appendix A)	Fatal Accidents Caused By Low RPM Rotor Stall
Safety Notice SN-24	Low RPM Rotor Stall Can Be Fatal (Appendix B)
Safety Notice SN-29 (Appendix C)	Airplane Pilots High Risk When Flying Helicopters

Examination of Wreckage

The helicopter struck the ground in a nose-down attitude. The forward section of the helicopter, including both front seats and seat belt attachments, was destroyed as a result of the impact. There were no pre-impact structural failures.

Examination of one of the main rotor blades revealed an upward bending, with chord-wise rippling along the span and on the upper skin surface of the blade. The second blade was severely damaged from ground impacts and rippling was not evident. One of the main rotor blade's counterweight had separated from the blade tip and was found near the wreckage site.

The tail rotor components were examined and found to be in serviceable condition with no pre-impact failures evident.

The jam nut on the main rotor pitch link that was being adjusted was tight but not secured with lock wire.

The engine compartment revealed no catastrophic failures. It was clean and free of any oil and hydraulic fluid.

A variety of instruments and two global positioning systems (GPSs) were recovered from the wreckage and forwarded to the TSB Engineering Laboratory to determine the instruments readings at the time of the crash and to extract any relevant data from the GPS's non-volatile memory. The results were as follows:

- The rotor RPM gauge was indicating 98per cent.
- The vertical speed indicator was indicating 800 ft/min down.
- The manifold pressure gauge had two indications. One was in the range of 18 to 19.3 inches of mercury ("hg.) and the other was in the range of 27.7 to 29.3 "hg.
- The Lowrance Airmap 2000c GPS did not record the occurrence flight track and the Garmin Apollo SL60 GPS does not retain flight track data in its non-volatile memory.

The following TSB Engineering Laboratory reports were completed:

LP019/2007 - Examination of Sony DVCAM
LP020/2007 – Examination of Instruments

These reports are available from the Transportation Safety Board of Canada upon request.

Analysis

Nothing was found to indicate that any mechanical malfunction initiated or contributed to the accident sequence. Weather conditions would not have affected the performance of the helicopter; therefore, the analysis will concentrate on the procedures and actions related to the autorotation.

The helicopter departed from Cambridge, Ontario on a maintenance test flight. The purpose of the flight was twofold. First, the aircraft maintenance engineer (AME) was attempting to track the main rotor blades while the helicopter was in an autorotation and, second, he wanted to check the autorotational revolutions per minute (RPM). There is a specific procedure in the maintenance manual for checking the autorotational RPM, though it was not reviewed before the flight and was not being followed. Tracking the main rotor blades in an autorotation is not a procedure that is described in the helicopter maintenance manual.

Without a detailed prefight briefing, the pilot might not have been fully aware of what to expect during this maintenance test flight. The consequences of not reviewing the autorotational RPM adjustment procedure prior to the flight included not having enough altitude to properly conduct the test and not being aware that, at its current weight, the target rotor RPM was above the main rotor RPM red line.

The flight was normal up to the point where the autorotation was initiated. At some point during the autorotation, the pilot allowed the rotor RPM to drop to approximately 80 per cent and he was unable to recover before the helicopter hit the ground. The upward bending of the rotor blade confirms that, at some point in the autorotation, the rotor RPM was low. Losing rotor RPM could be the result of incorrect technique when initiating the autorotation or it could have resulted from a failure to continually monitor the RPM throughout the autorotation.

If, during entry into the autorotation, the pilot rolled the throttle off before fully lowering the collective, there would be a sudden drop in rotor RPM. The low inertia rotor system is sensitive and reacts quickly to changes. In this scenario, the low rotor warning horn and light would be activated almost immediately. However, the warning horn may have been activated for a very short time because the standard reaction would be to immediately lower the collective. The pilot's exclamation may have been simultaneous with the low rotor warning and the AME may not have noted the warning horn.

A second scenario would be that the pilot correctly entered the autorotation but diverted his attention from watching the rotor RPM, perhaps to look outside the cockpit to find the strobe targets on the main rotor blades. If the main rotor blade pitch was correct, the relatively high gross weight of the helicopter would tend to overspeed the rotor system as the pilot entered the autorotation (approximately 2.5 per cent). If he noticed an excessively high rotor RPM, the normal reaction to prevent the rotor from overspeeding would be to increase collective, which in turn would increase the blade pitch angle and slow the rotor RPM. If the pilot overcorrected with the collective to the point of slowing the rotor system below 97 per cent, the warning horn and light should have activated as the collective would no longer be fully down. The normal corrective action would be to immediately lower the collective which would silence the warning horn and roll in the throttle.

If the main rotor blade pitch was excessively coarse, the rotor system would tend to slow down as soon as the pilot initiated the autorotation. With the collective lever in the full down position, the low rotor warning system would be disabled. The pilot's surprise exclamation suggests that he became aware that something was not right at some point during descent and it attracted the attention of the engineer who then noted that the rotor RPM was down to approximately 80 per cent. In this scenario, rotor RPM could only be regained by the use of engine power.

When the helicopter struck the ground, the rotor tachometer was indicating 98 per cent, the rate of descent was 800 feet per minute and the helicopter had very little forward speed. All of this indicates that although full throttle had been reapplied during descent, there was insufficient altitude and time to arrest the descent prior to impact.

Findings as to Causes and Contributing Factors

1. The aircraft maintenance engineer was attempting to track the main rotor blades while the helicopter was in an autorotation. This procedure was not described in the helicopter maintenance manual. Attempting to combine these two activities likely interfered with the pilot's ability to monitor aircraft performance during the autorotation.

2. The gross weight of the helicopter exceeded the maximum specified by the manufacturer for checking rotor revolutions per minute (RPM) in autorotation.

3. During the autorotation, the rotor RPM decayed to approximately 80 per cent and, although full throttle had likely been reapplied, there was insufficient altitude and time remaining to arrest the rate of descent prior to impact.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 21 August 2008.

Appendix A - Safety Notice SN-10

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Safety Notice SN-10

Issued: Oct 82 Rev: Feb 89; Jun 94

FATAL ACCIDENTS CAUSED BY LOW RPM ROTOR STALL

A primary cause of fatal accidents in light helicopters is failure to maintain rotor RPM. To avoid this, every pilot must have his reflexes conditioned so he will instantly add throttle and lower collective to maintain RPM in any emergency.

The R22 and R44 have demonstrated excellent crashworthiness as long as the pilot flies the aircraft all the way to the ground and executes a flare at the bottom to reduce his airspeed and rate of descent. Even when going down into rough terrain, trees, wires or water, he must force himself to lower the collective to maintain RPM until just before impact. The ship may roll over and be severely damaged, but the occupants have an excellent chance of walking away from it without injury.

Power available from the engine is directly proportional to RPM. If the RPM drops 10%, there is 10% less power. With less power, the helicopter will start to settle, and if the collective is raised to stop it from settling, the RPM will be pulled down even lower, causing the ship to settle even faster. If the pilot not only fails to lower collective, but instead pulls up on the collective to keep the ship from going down, the rotor will stall almost immediately. When it stalls, the blades will either "blow back" and cut off the tailcone or it will just stop flying, allowing the helicopter to fall at an extreme rate. In either case, the resulting crash is likely to be fatal.

No matter what causes the low rotor RPM, the pilot must first roll on throttle and lower the collective simultaneously to recover RPM **before** investigating the problem. It must be a conditioned reflex. In forward flight, applying aft cyclic to bleed off airspeed will also help recover lost RPM.

Appendix B - Safety Notice SN-24

ROBINSON
HELICOPTER COMPANY

Safety Notice SN-24

Issued: Sep 86 Rev: Jun 94

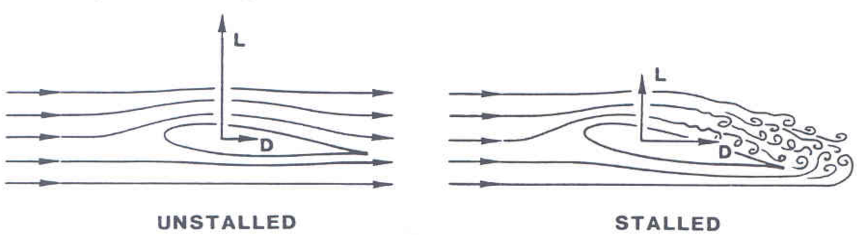
LOW RPM ROTOR STALL CAN BE FATAL

Rotor stall due to low RPM causes a very high percentage of helicopter accidents, both fatal and non-fatal. Frequently misunderstood, rotor stall is not to be confused with retreating tip stall which occurs only at high forward speeds when stall occurs over a small portion of the retreating blade tip. Retreating tip stall causes vibration and control problems, but the rotor is still very capable of providing sufficient lift to support the weight of the helicopter.

Rotor stall, on the other hand, can occur at any airspeed and when it does, the rotor stops producing the lift required to support the helicopter and the aircraft literally falls out of the sky. Fortunately, rotor stall accidents most often occur close to the ground during takeoff or landing and the helicopter falls only four or five feet. The helicopter is wrecked but the occupants survive. However, rotor stall also occurs at higher altitudes and when it happens at heights above 40 or 50 feet AGL it is most likely to be fatal.

Rotor stall is very similar to the stall of an airplane wing at low airspeeds. As the airspeed of an airplane gets lower, the nose-up angle, or angle-of-attack, of the wing must be higher for the wing to produce the lift required to support the weight of the airplane. At a critical angle (about 15 degrees), the airflow over the wing will separate and stall, causing a sudden loss of lift and a very large increase in drag. The airplane pilot recovers by lowering the nose of the airplane to reduce the wing angle-of-attack below stall and adds power to recover the lost airspeed.

The same thing happens during rotor stall with a helicopter except it occurs due to low rotor RPM instead of low airspeed. As the RPM of the rotor gets lower, the angle-of-attack of the rotor blades must be higher to generate the lift required to support the weight of the helicopter. Even if the collective is not raised by the pilot to provide the higher blade angle, the helicopter will start to descend until the



Wing or rotor blade unstalled and stalled.

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Safety Notice SN-24 (continued)

upward movement of air to the rotor provides the necessary increase in blade angle-of-attack. As with the airplane wing, the blade airfoil will stall at a critical angle, resulting in a sudden loss of lift and a large increase in drag. The increased drag on the blades acts like a huge rotor brake causing the rotor RPM to rapidly decrease, further increasing the rotor stall. As the helicopter begins to fall, the upward rushing air continues to increase the angle-of-attack on the slowly rotating blades, making recovery virtually impossible, even with full down collective.

When the rotor stalls, it does not do so symmetrically because any forward airspeed of the helicopter will produce a higher airflow on the advancing blade than on the retreating blade. This causes the retreating blade to stall first, allowing it to dive as it goes aft while the advancing blade is still climbing as it goes forward. The resulting low aft blade and high forward blade become a rapid aft tilting of the rotor disc sometimes referred to as "rotor blow-back". Also, as the helicopter begins to fall, the upward flow of air under the tail surfaces tends to pitch the aircraft nose-down. These two effects, combined with aft cyclic by the pilot attempting to keep the nose from dropping, will frequently allow the rotor blades to blow back and chop off the tailboom as the stalled helicopter falls. Due to the magnitude of the forces involved and the flexibility of rotor blades, rotor teeter stops will not prevent the boom chop. The resulting boom chop, however, is academic, as the aircraft and its occupants are already doomed by the stalled rotor before the chop occurs.

Appendix C - Safety Notice SN-29

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Safety Notice SN-29

Issued: Mar 93 Rev: Jun 94

AIRPLANE PILOTS HIGH RISK WHEN FLYING HELICOPTERS

There have been a number of fatal accidents involving experienced pilots who have many hours in airplanes but with only limited experience flying helicopters.

The ingrained reactions of an experienced airplane pilot can be deadly when flying a helicopter. The airplane pilot may fly the helicopter well when doing normal maneuvers under ordinary conditions when there is time to think about the proper control response. But when required to react suddenly under unexpected circumstances, he may revert to his airplane reactions and commit a fatal error. Under those conditions, his hands and feet move purely by reaction without conscious thought. Those reactions may well be based on his greater experience, ie., the reactions developed flying airplanes.

For example, in an airplane his reaction to a warning horn (stall) would be to immediately go forward with the stick and add power. In a helicopter, application of forward stick when the pilot hears a horn (low RPM) would drive the RPM even lower and could result in rotor stall, especially if he also "adds power" (up collective). In less than one second the pilot could stall his rotor, causing the helicopter to fall out of the sky.

Another example is the reaction necessary to make the aircraft go down. If the helicopter pilot must suddenly descend to avoid a bird or another aircraft, he rapidly lowers the collective with very little movement of the cyclic stick. In the same situation, the airplane pilot would push the stick forward to dive. A rapid forward movement of the helicopter cyclic stick under these conditions would result in a low "G" condition which could cause mast bumping, resulting in separation of the rotor shaft or one blade striking the fuselage. A similar situation exists when terminating a climb after a pull-up. The airplane pilot does it with forward stick. The helicopter pilot must use his collective or a very gradual, gentle application of forward cyclic.

To stay alive in the helicopter, the experienced airplane pilot must devote considerable time and effort to developing safe helicopter reactions. The helicopter reactions must be stronger and take precedence over the pilot's airplane reactions because everything happens faster in a helicopter. The pilot does not have time to realize he made the wrong move, think about it, and then correct it. It's too late; the rotor has already stalled or a blade has already struck the airframe and there is no chance of recovery. To develop safe helicopter reactions, the airplane pilot must practice each procedure over and over again with a competent instructor until his hands and feet will always make the right move without requiring conscious thought. AND, ABOVE ALL, HE MUST NEVER ABRUPTLY PUSH THE CYCLIC STICK FORWARD.

Also see Safety Notices SN-11 and SN-24.