Transportation Safety Board
of Canada

Bureau de la sécurité des transports
du Canada

AVIATION INVESTIGATION REPORT
A01O0099

LOSS OF CONTROL—COLLISION WITH TERRAIN

CANADIAN HELICOPTERS LIMITED
ROBINSON R22 BETA (HELICOPTER) C-GVAR
TORONTO / BUTTONVILLE MUNICIPAL AIRPORT, ONTARIO,
10 NM NW
04 APRIL 2001

Canada

Aviation Investigation Report

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Robinson R22 Beta (Helicopter) C-GVAR
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Report Number A01O0099

Summary

The Robinson R22 Beta helicopter, serial number 2110, with an instructor and one student pilot on board, was on a day visual flight rules training flight 20 nautical miles north of the Toronto / Buttonville Municipal Airport, Ontario. After 45 minutes of practicing autorotations, the student was flying the helicopter back to the airport. At 1700 feet above ground level, the instructor simulated an engine failure. The student selected a field and executed a forced approach. At 40 feet above ground level, he began to flare the helicopter by moving the cyclic aft. As the descent continued, the helicopter was approaching tall trees at the end of the field, and the student pulled up hard on the collective. At that time, the instructor opened the throttle to initiate a recovery; however, the engine rotor rpm was low, and the engine did not respond. The descent could not be arrested, and the aircraft struck the ground. The tip of the left skid dug into the semi-frozen ground, and the helicopter pivoted forward onto its right side. Both pilots evacuated through the left door of the aircraft. Neither pilot was injured, although the helicopter was substantially damaged. The accident occurred at 1040 eastern daylight time.

Ce rapport est également disponible en français.

Other Factual Information

The Robinson R22 Beta helicopter, manufactured in 1992, had accumulated 4699 hours. The helicopter was equipped for visual flight rules operations, and the operator used it mainly as a primary, rotary-wing trainer. Records indicate the helicopter was equipped, maintained, and certified in accordance with existing regulations and approved procedures. There were no known defects before the flight. The aircraft's weight and centre of gravity were within approved limits.

The instructor pilot held a valid Canadian Airline Transport Pilot Helicopter licence on BH04, BH06, BH47, HU50, RH22, S350, and SK76 helicopters. He held a Class 2 instructor rating and a Group 4 instrument rating. He had accumulated over 8950 hours total of rotary wing time, of which approximately 1800 hours were on the Robinson R22 Beta. During the previous 90 days, he had flown 90 hours, including 35 hours during the previous 30 days.

The student pilot held a valid Canadian Student Pilot Helicopter permit. He had accumulated 20 hours of flying time, all on the Robinson R22 Beta. He had flown all 20 hours in the 90 days before the accident, including 10 hours during the previous 30 days.

At 1000 eastern daylight time,[1] the weather at the Toronto / Buttonville Municipal Airport was reported as follows: sky clear, visibility greater than 12 statute miles, temperature 8°C, dew point –3°C, wind 350° true at 6 knots, and altimeter setting 30.38 inches of mercury.

Transport Canada's *Helicopter Flight Training Manual*, TP9982E, describes an autorotation as the condition of flight where the rotor is driven by aerodynamic forces, with no power delivered by the engine. During autorotation, the helicopter is still flying. It remains fully manoeuvrable, albeit in descending flight. The airflow is now upward through the rotor disc rather than downward as in powered flight. The value of this rate-of-descent flow from underneath the helicopter is controlled by the aircraft's airspeed. A successful autorotation requires coordinating altitude, airspeed, and main-rotor rpm. Kinetic energy from the spinning rotor disc slows and finally arrests the descent. One of the key factors affecting the amount of energy available from the main rotor is the air passing through the rotor disc. As with any aerofoil, exceeding the critical angles of attack of the blades can lead to an aerodynamic stall. Rotor rpm must therefore be maintained within acceptable parameters during the autorotation procedure.

The *Robinson R22 Pilot Operating Handbook* describes the recommended procedure for an autorotation as follows:

1) lower collective immediately to maintain main rotor rpm and enter normal autorotation;
2) establish a steady glide at approximately 65 KIAS;
3) adjust collective to keep rotor rpm in the green arc;
4) select landing area and if altitude permits, manoeuver so landing is into wind;
5) at 40 feet agl [above ground level], begin cyclic flare to reduce rate of descent and forward airspeed; and

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[1] All times are eastern daylight time (Coordinated Universal Time minus four hours).

6) at 8 feet agl, apply forward cyclic to level the ship and raise collective before touchdown to cushion the landing. Touchdown in a level attitude with the nose straight ahead.

The main-rotor blade system of the Robinson R22 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 an aerodynamic stall of the rotor system. The Robinson Helicopter Company issued *Safety Notice* SN-24 (see Appendix A-1 and A-2), “Low RPM Rotor Stall Can Be Fatal”, in September 1986. The notice states that a very high percentage of accidents are caused by rotor stall due to low main-rotor rpm.

The *Robinson R22 Pilot Operating Handbook* states that a warning horn and an illuminated amber caution light indicate that rotor rpm is below safe limits. The horn stops and the amber caution light extinguishes when rotor rpm is increased to safe limits or the collective control is full down. The “green arc” for safe operation of main-rotor rpm is between 97% and 104%. The warning horn and the amber light activate at 97% rpm. The “danger” area on the rpm gauge is 90% rpm and is indicated by a red line. The danger of low rotor rpm leading to a main-rotor aerodynamic stall during autorotation is covered during ground school but is not required as a review item during pre-flight briefing.

When the instructor presented the student with the simulated engine failure, the student picked a less-than-desirable field. The field was uneven, with a pronounced upslope from 4° in the west to 6° in the east. The autorotational flight path of the helicopter ran in a line west to east, and numerous tall trees stood at the eastern end of the field. The instructor saw that the field was inappropriate but judged it to be safe to continue the exercise. He planned to have the student perform a power-on recovery to a hover and use the opportunity to discuss with the student why that particular field was a poor selection.

As the helicopter approached approximately 40 feet agl, the student began to pull rearward on the cyclic to begin the flare and bleed off excess airspeed. When the student saw that he was approaching the trees at the east end of the field, he began pulling up aggressively on the collective and rearward on the cyclic to avoid the trees. At that time the low-rotor-rpm warning horn sounded. The instructor opened the throttle, but the engine did not respond. At approximately 30 feet agl, the rotor rpm was below 50% and still dropping.

The helicopter contacted the ground in a level attitude with a forward speed of approximately 10 knots. The emergency locator transmitter activated automatically. It was found mounted inside the helicopter, with the switch in the ARM position and the self-contained antenna stowed. Ground scarring created by the initial impact of the helicopter skids indicated that the aircraft was heading approximately 040° magnetic. The wreckage trail was 40 m long, on a heading of 320° magnetic. The tail boom was severed by the retreating main-rotor blade and thrown 25 m north of the main crash site. The advancing main-rotor blade struck the ground as the helicopter pivoted forward and was bent to –85°. Neither main-rotor blade separated from the rotor mast. The cockpit was not structurally compromised; however, the left and right windshields and the right door window were broken. Examination of the wreckage revealed that the main rotor and the tail rotor were in a low-energy state at impact. Continuity of the drive train and flight control systems was confirmed. There was no indication of any pre-impact airframe failure or aircraft system malfunction.

The two pilots were not injured in the crash and were wearing lap belts, shoulder harnesses, and helicopter flight helmets.

Analysis

The rotor of a helicopter with a low-inertia rotor system loses energy quickly as the collective is raised and the engine is not producing adequate power. Without corrective action, this leads to an aerodynamic stall of the rotor blades. As the occurrence helicopter was sinking, the upward rushing air continued to increase the angle of attack on the slowly rotating rotor blades, making recovery virtually impossible, even with the collective fully down. When the low-rotor-rpm warning horn sounded and the throttle was opened, the engine did not respond because the main rotor was fully stalled. The aerodynamic drag induced by the stalled rotor blades acted as a brake further decreasing the rotor rpm. Because of the low altitude, the pilots were unable to recover before the helicopter struck the ground.

Transport Canada's *Helicopter Flight Instructor's Guide*, TP4818E, outlines safety precautions for autorotation. It directs instructors that this exercise should only be practised in areas known to be safe and suitable for landing. Consideration should be given wherever possible to using an area where crash facilities are available. The guide also states a law of learning: learning can be enhanced through the use of dramatic, realistic, or unexpected things (the law of intensity). The instructor wanted to deepen the student's understanding of a poor emergency landing field; however, he allowed the exercise to continue beyond the point from which a safe recovery could be achieved.

Findings as to Causes and Contributing Factors

1. During a practice autorotation, the helicopter's main-rotor rpm was allowed to drop below safe limits, leading to an aerodynamic stall of the main-rotor blades.

2. The instructor pilot allowed the student pilot to conduct a practice forced approach and autorotation into a field that was inappropriate for the exercise.

Findings as to Risk

1. Before the exercise, the instructor placed inadequate emphasis on the dangers of low main-rotor rpm and rotor-blade stalls.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 10 April 2002.

Appendix A-1

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Safety Notice SN-24

Issued: Sep 86 Rev: Jun 94

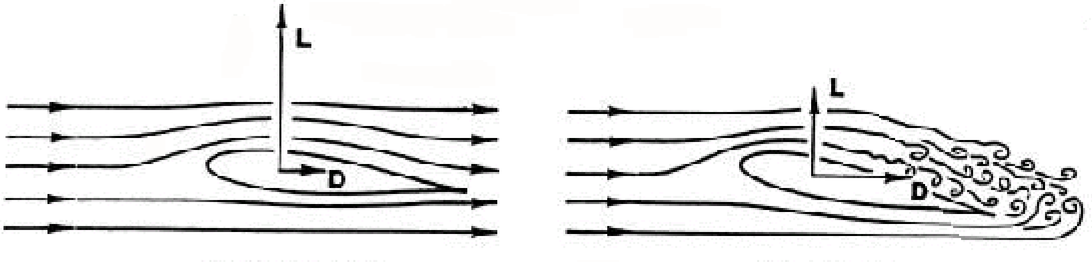
LOW RPM ROTOR STALL CAN BE FATAL

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.

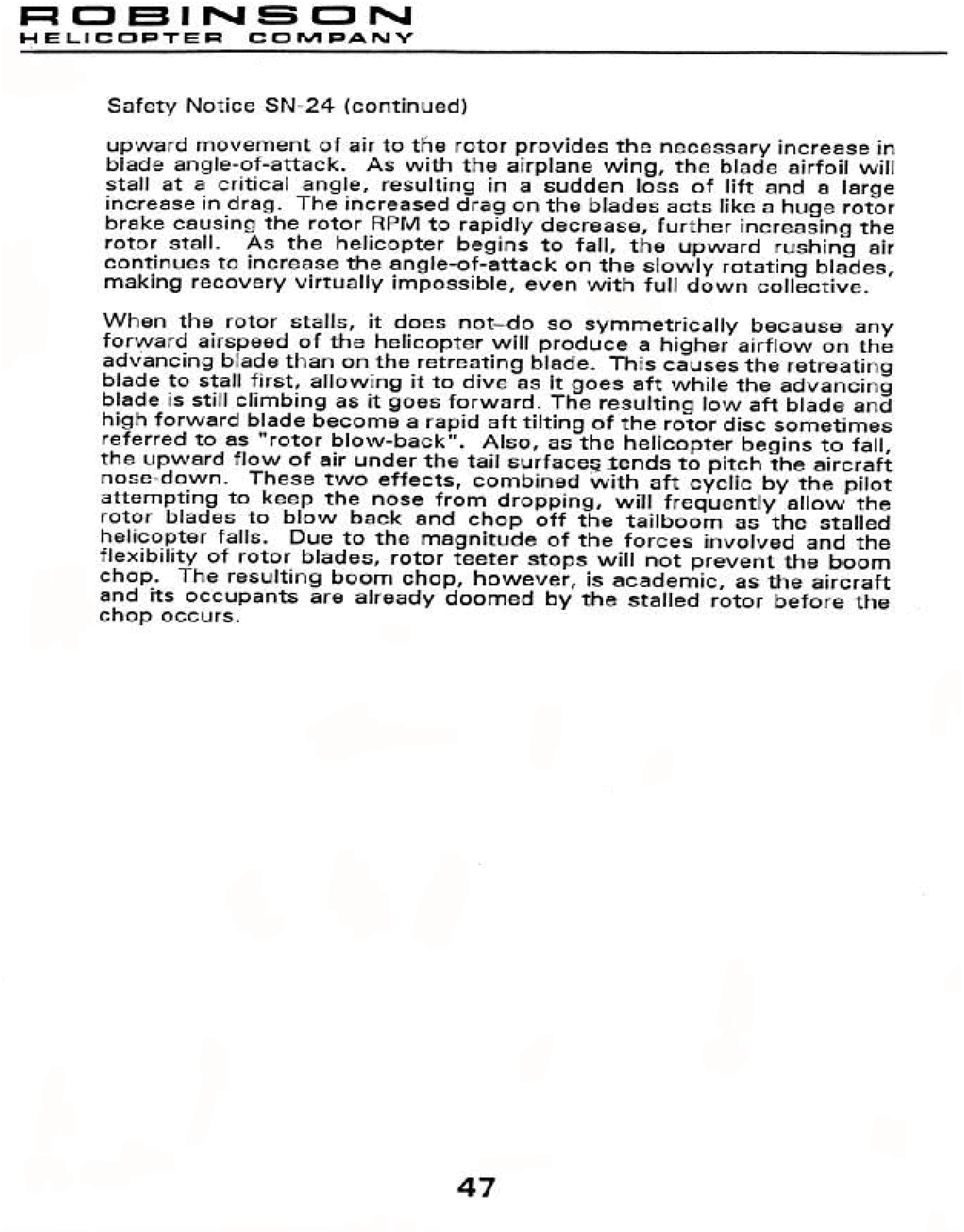
The same thing happens during rotor stall with a helicopter except it occurs due to low rotor RPM instead of low airspeed. As the RPM of the rotor gets lower, the angle-of-attack of the rotor blades must be higher to generate the lift required to support the weight of the helicopter. Even if the collective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



UNSTALLED STALLED

Wing or rotor blade unstalled and stalled.

Appendix A-2



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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.