Transportation Safety Board of Canada

Bureau de la sécurité des transports du Canada

AVIATION INVESTIGATION REPORT
A04P0240

BLADE STRIKE AND ROLLOVER

HIGHLAND HELICOPTERS LTD.
EUROCOPTER AS350 B2 (HELICOPTER) C-GSHH
FLOURMILL VOLCANO, BRITISH COLUMBIA, 5 nm W
25 JUNE 2004

Canada

Aviation Investigation Report

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Highland Helicopters Ltd.
Eurocopter AS350 B2 (Helicopter) C-GSHH
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Summary

At 2020 Pacific daylight time, the pilot of the Eurocopter AS350 B2 (Astar) helicopter (C-GSHH, serial number 3192) landed on a recently prepared mountainside helipad, five nautical miles west of the extinct Flourmill Volcano, at 5200 feet elevation. With the helicopter still running at flying rotor rpm and light on the skids, four passengers boarded with a small amount of personal equipment and prepared for take-off. The pilot increased collective pitch to bring the helicopter into the hover, but the engine parameters were approaching their limits, and he discontinued the take-off and lowered the collective. The left rear passenger got out, and the pilot again raised the collective, lifting the helicopter into a stable five-foot hover over the pad. Satisfied this time with the engine readings, the pilot increased collective pitch and climbed to approximately 20 feet while purposely allowing the nose to swing to the left to turn downhill for the transition into forward flight.

As the helicopter turned through 100 degrees of left turn, the low rotor rpm warning horn sounded and the pilot decided to return to the pad. He allowed the left turn to continue but, by the time the helicopter returned to the original heading, it had drifted approximately 20 feet downhill from the pad and was still descending. The main rotor blades then struck a large tree stump adjacent to the pad and the helicopter rolled over, coming to rest on its left side, almost inverted. The three passengers quickly escaped from the helicopter, but the pilot delayed his exit to shut down the engine, which had continued to run. After he had secured the engine, fuel valve, and electrical switches, the pilot exited the cockpit. The four occupants received minor injuries, and the helicopter was substantially damaged. The emergency locator transmitter activated automatically at rollover. There was no fire.

Ce rapport est également disponible en français.

Other Factual Information

History of Flight

The accident helicopter was on contract to the British Columbia Forestry Service (BCFS) to transport firefighters and their equipment to various sites in the Williams Lake vicinity. The accident flight was to relocate 11 firefighters and light personal equipment from the mountainside pad for Fire 154 (BCFS fire number 154) to a staging area at the base of the mountain, a distance of approximately one nautical mile.

Pilot

The pilot was trained and licensed appropriately for the AS350 B2 helicopter and the firefighting support mission. He was an experienced and qualified helicopter pilot and had worked for the operator in forest fire-management for several years. He had accumulated over 3000 hours of flight time, including over 1000 hours in the AS350 model helicopter. A review of his flight and duty times for the period leading up to the accident revealed no deviation from Transport Canada (TC) regulations respecting flight and duty time limits, nor had he recently engaged in arduous operational activities.

Weather

No formal weather observation exists for the accident site, but weather reports in adjacent areas and reports from the witnesses at the site show that the general weather conditions were suitable for VFR (visual flight rules) flight. There was a light wind from the northeast on the surface and a moderate wind at the tree-top level, with a significant down-flowing wind over the accident site. The outside air temperature in the hours leading to the time of the accident was in the order of 24°C to 28°C. However, it had cooled following recent rain showers, and the helicopter's outside air temperature gauge was reading 22°C to 24°C. For the performance calculations included in this report, a temperature of 20°C was used.

Aircraft Maintenance

A review of all the aircraft technical logs and maintenance records indicates that C-GSHH was certificated and maintained in accordance with existing regulations and standards. No maintenance deficiencies were found, nor were there any deferred mechanical defects. This helicopter was manufactured in 1999 by Eurocopter in Marignane, France. At the time of the accident, the helicopter and its engine had accumulated approximately 1880 hours total flight time since new. Dual controls were not fitted to the helicopter, and the throttle control quadrant on the cockpit floor was protected from passenger interference by an approved throttle guard.

Fuel

The pilot had refuelled the helicopter approximately 40 minutes before landing at the Fire 154 helipad. The pilot estimated that approximately 68 per cent (650 pounds) of total fuel remained at the time of the accident. Investigators removed approximately 365 litres of fuel from the helicopter fuel tank after the accident, confirming that there were approximately 650 pounds of fuel on board at the time of the accident. Fuel samples taken from the engine and from the airframe fuel systems and filters were examined for contamination; none was found. Accordingly, fuel supply and quality are not considered to have contributed to this accident.

Aircraft Weight and Balance

The maximum certificated internal gross weight for this helicopter is 4961 pounds, and the limits of the centre of gravity (CG) range from 124.8 to 137.8 inches from the datum, depending on the helicopter's gross weight. The helicopter weighed approximately 4825 pounds at the time of the accident, with a CG of approximately 126.1 inches from the datum. At that weight, the CG was slightly less than the maximum permitted forward CG limit of 125.9 inches.

Helicopter Performance

Helicopter performance is predicated on altitude, temperature, and gross weight. The theoretical performance limits are readily available to pilots in Section 5, Regulatory Performance Data, of the Direction Générale de l'Aviation Civile-approved rotorcraft flight manual (RFM). In part, the performance curves in the RFM predict the weight that a helicopter should be able to carry, given certain in-flight conditions, as well as identify the maximum certificated weight for those same conditions. Specifically, the RFM contains two performance charts that accurately determine the maximum weight that the helicopter can hover in, or out of, ground effect, namely HIGE[1] (hover in-ground-effect) and HOGE[2] (hover out-of-ground-effect) performance charts. However, since the helicopter reached a height of 15 to 20 feet at take-off, and because the slope of the accident site terrain is quite steep, it is unlikely that any benefit from ground effect was gained during the events immediately leading up to this accident. Accordingly, the HOGE chart is the appropriate reference to determine the ability of the helicopter to take off from the accident helipad and hover successfully.

Using the HOGE curves (see Appendix A), assuming an outside air temperature of 20°C, a pressure altitude of 5200 feet, and a gross weight of 4825 pounds, at the second take-off attempt the helicopter was approximately 150 pounds less than the maximum weight permitted for those conditions. As ambient air temperature increased to 25°C, this margin would have been progressively eroded to zero. The actual performance of the helicopter would also have been affected by several other factors, including wind and wind gusts, pilot handling techniques, and engine and rotor system efficiency.

Calculations show that the vertical climb speed would have been in the order of 300 feet per minute for take-off engine power, and 590 feet per minute for maximum available power. Each would have been increased by 230 feet per minute as a result of left pedal input during the climb. Accordingly, the maximum possible rate of climb would have been 820 feet per minute in ideal conditions.

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1 The HIGE curve requires a hover height below five feet.

2 The HOGE curve requires no-wind conditions.

Engine Examination and Performance

This Astar helicopter was equipped at manufacture with the Turbomeca Arriel 1D1 turboshaft engine, serial number 9631. Following the accident, the engine was removed from the helicopter, examined, and run in a TC-approved test cell. The results of the examinations and test runs revealed no deficiency or degradation in performance that would have contributed to the loss of rotor rpm. The tests confirmed that the engine met the manufacturer's specifications for power delivery, with the following exception.

By calculation, the minimum power before engine repair is required[3] is 523 kW for ambient temperatures of 25°C and below. During the test for maximum power, the assessed value was 5 kW[4] below the repair limit of 523 kW, that is, the equivalent of approximately one per cent of the test-cell target value. This performance differential is not uncommon for engines with similar accumulation of flight time since new—in the order of 1900 hours—and is an anticipated and gradual deterioration. Since it represents a difference of available torque of approximately one per cent, it was considered negligible. With the engine installed in the helicopter, this differential in available power would have been overcome by the pilot applying collective pitch to increase the power demand up to and, if necessary, exceeding the certificated engine operating limits. The power differential seen in the test cell would not have precipitated the loss of rotor rpm experienced by the pilot in this accident.

Fuel Control Unit Examination and Testing

The engine fuel control unit (FCU) is composed of four main components, namely: the power turbine speed governor, the gas generator speed governor, the acceleration control unit, and the metering unit. The FCU was inspected, bench-tested, disassembled, and examined by Turbomeca in Montréal, Quebec, under the direct supervision of a TSB technical investigator. In summary—with the exception of the one minor anomaly noted in the next paragraph—no significant defect was found, and considering the acceptable performance during the engine test-cell runs earlier, no mechanical reason was found that would have caused the FCU to malfunction during the accident.

The portion of the FCU bench test that assessed the acceleration of the FCU from idle engine rpm (low fuel flow) to high rpm (high fuel flow) revealed a slight decrement in FCU acceleration characteristics. Information and analysis from Turbomeca reveals that, in the circumstances of this accident, the effect of such a decrement in FCU acceleration would have been unnoticeable to the pilot. In this accident, the engine rpm was already operating at high hover-power values—significantly greater than the idle rpm value used in the bench testing—and the delay in acceleration to full power, if any, would have been negligible and would not have precipitated the loss of rotor rpm experienced by the pilot.

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3 There are two specific performance limits that this engine overhaul facility uses in its test cell to determine if an engine should be either repaired or overhauled. Each limit varies with the total engine in-service time, and the ambient temperature and pressure.

4 Corrected to International Standard Atmosphere conditions.

The physical position of the throttle cable at the time of the accident had been preserved by the distortion of the engine/transmission deck at impact, kinking the cable at the engine fitting end. This position was recorded and examined in situ, and it was determined that the cable was immoveable as a result of the kinking. Furthermore, the position of the end fitting was consistent with a fully-opened throttle lever, despite the distortion of the engine deck.

The TSB Engineering Branch examined the kinked cable fitting to determine if it had been forcibly moved while bent. (Reference: LP 098/04) Witness marks on the cable and fitting show that the cable end had moved only 0.055 inch while bent, indicating that at impact the cable was trapped very nearly in the position that it had been in during hover flight. During the pilot's attempts to shut down the engine after the rollover, he repeatedly tried to retard the throttle to the stop position. However, the throttle cable was jammed and the lever could not be moved. Subsequently, in his efforts to move the throttle lever, it broke at the cockpit quadrant. He shut the engine down by closing the fuel shut-off control lever located in the same quadrant. Post-crash examinations of the throttle quadrant control tubes, linkages, and rigging revealed no other indication of malfunction or disconnect.

Engine Performance Assessment

The RFM prescribes that the normal main rotor speed for flight in this helicopter is between 385 and 394 rpm, and the low rotor warning horn sounds continuously when the rpm falls below 360.

Before the pilot landed at the accident site, he had carried out an engine N_g difference indicator check using the ΔN_g indicator gauge on the instrument panel. The result of this check was 101.4% rpm (N_g) for the prevailing ambient temperature and pressure altitude, which, according to Section 4, Normal Procedures of the RFM, was correct for those conditions. Once in the hover on the second take-off attempt, approximate values were as follows: N_g 96%, N_r stable at 390 rpm, T_4 temperature 720°C, and torque 90%. These parameters are consistent with normal, high-power engine performance. At the beginning of the hover–climb and left turn, the N_g and torque each increased past 97%. The RFM prescribes that, for this flight, the maximum take-off ratings for N_g, torque, and T4 were 101.4%, 100%, and 845°C respectively.

In-flight testing on a similar Astar helicopter revealed that these high-power engine performance values were achieved only with the throttle lever in the cockpit floor quadrant placed in the expected flight position at lift-off. In contrast, with the throttle placed outside this normal position, the helicopter did not hover with stable rotor rpm nor did it achieve the engine performance readings that the incident pilot observed and accepted before continuing the vertical climb and left turn. Accordingly, considering the physical FCU evidence and the exemplar in-flight testing, it appears that the throttle lever was placed in the appropriate and normally open (flight) position on the accident flight.

Accident Site Description

The general terrain at the accident site is a 30-degree slope, with the landing pad surrounded by tall conifers. The topography is conducive to down-flowing air at the time of day the accident took place. The temporary helipad had been constructed on a less steep area of the mountainside, and several trees had been felled to provide an unobstructed flight path into and out of the pad site. For all practical purposes, only one approach and departure path could be used; in this case, the approach was northerly, into the prevailing wind. A heel log had been positioned at the back edge of the touchdown area to provide rigid support for the heels of the landing skids when the helicopter landed facing up slope.

Helicopter Handling Techniques

A notable characteristic of conventional helicopters is that the application of left or right anti-torque pedal by the pilot will affect the total power required to hover.[5] In this Astar helicopter, in which the rotor blades turn clockwise when viewed from above, using right pedal to turn the helicopter to the right increases the power demand on the rotor system and can lead to insufficient power to maintain height in the hover, especially in high power-required situations. If full engine power is being used to hover, any application of right pedal demands more total power than is available and degenerates main rotor rpm and lift, leading to hover height loss.

A common handling technique to ameliorate this characteristic during situations of high power demand is to turn the helicopter in a direction that requires greater total power—that is, to the right for the Astar—with the benefit that stopping the turn requires less power. In this event, a pilot can frequently recover from a situation of insufficient power and return to the previous hover condition. By contrast, in turning left with the torque then trying to stop the turn by using right tail rotor input, the demand for power by the tail rotor to stop the turn, combined with the power required by the main rotor to maintain the hover height, increases the total power required. If the helicopter is already operating at full power to hover, applying right pedal in the Astar can demand more power than is available, resulting in a loss of rotor rpm and a descent, likely in an overpitched condition.

Analysis

No mechanical conditions were identified as contributing to this accident, therefore, this analysis focuses upon the operational factors surrounding the flight.

Down-Flow Wind

In the area of the accident, the topography and location are conducive to the formation of down-flowing winds, the velocity of which can change quickly. Unpredictable down flows are challenging for a helicopter pilot and can lead to uncommanded descent from which the helicopter may not have sufficient power to recover. In this accident, because of the down-flowing air in the area, the pilot may have unwittingly applied more collective pitch than he had intended to maintain his turning hover–climb, thus precipitating the rapid rotor rpm decay. Once the helicopter began to turn left and the tail rotor entered into the down-flowing air the situation would have worsened. Specifically, the controlled rate-of-turn that the pilot was trying to maintain may have accelerated to the left. To counter this increased rotation, the pilot would have had to apply right pedal, which would have reduced the engine power available to the main rotor system. Such operations in a near-maximum weight helicopter leaves slight margin for error, especially in mountainous terrain and at rudimentary landing sites.

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5 In general, a tail rotor system absorbs up to approximately 15 per cent of total available power.

Vertical performance calculations reveal that the helicopter could have achieved a maximum rate of climb of nearly 820 feet per minute under ideal conditions. Had the helicopter encountered down-flowing air, this rate would have been reduced proportionately until neutralized by a wind of 820 feet per minute or in the order of eight knots. Winds of at least such strength were reported at the accident site, and it is likely that the vertical performance was eroded by the down-flow wind, preventing the helicopter from climbing as required.

Rotor RPM Decay and Landing

The pilot turned left during the climbing take-off, allowing the transmission torque to assist the turn, thereby delaying the power demand by the tail rotor. This situation would have permitted the rotor system to absorb the maximum power available. Since reducing or stopping a left turn, which is the aerodynamic equivalent of making a right turn, demands more power from the engine and rotor system, had the power available reached its limit during the take-off climb, the pilot would have had insufficient power to reduce or stop the left turn. A demand for more power than available, in combination with the high collective pitch, would have resulted in rotor rpm decay and a descent with the rotor system in an overpitched condition. In contrast, had the pilot turned right and then reached the same maximum power situation, slowing or reversing the right turn would have reduced the tail rotor power demand and made it available to the main rotor, thus permitting the helicopter to recover or maintain rotor rpm and height, and to return to the pad in a more controlled manner.

The size, slope, construction, and orientation of the landing pad did not permit the accident helicopter to return and land successfully following the rotor rpm decay and the resulting uncommanded descent. Therefore, once the helicopter began its vertical, climbing turn from the hover, and the full power condition was reached, it was impossible to successfully land on the sloping pad.

In this circumstance, once the rotor system became overpitched, it was a rapidly degenerating condition from which the pilot was unable to recover, considering the adverse surface conditions beneath the helicopter. Once the rotor rpm decayed and the warning horn sounded, it was inevitable that the helicopter continued to descend in an overpitched condition, continuously losing rotor rpm, until the helicopter struck the terrain.

The following TSB Engineering Branch report was completed:

LP 098/04 - Throttle Cable Examination

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

Findings as to Causes and Contributing Factors

1. the helicopter climbed vertically out of the hover at near-maximum gross weight, it encountered down-flowing air, which resulted in a situation in which there was insufficient power to maintain controlled flight. As a result, the rotor rpm decayed rapidly, and the helicopter descended in an overpitched condition until it struck the terrain.

2. The physical characteristics of the landing area did not allow a successful landing following the rotor rpm decay and uncommanded descent.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 11 May 2005.

Appendix A – Hover Performance Out-of-Ground-Effect