AVIATION OCCURRENCE REPORT
A98C0070

LOSS OF POWER/LOSS OF CONTROL

YUKON HELICOPTERS LTD.
HUGHES 369HS C-FZXC (HELICOPTER)
WAASAGOMACH, MANITOBA
23 APRIL 1998

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Summary

The Yukon Helicopters Ltd. Hughes 369HS helicopter, serial number 310308S, was engaged in air taxi operations in the vicinity of St. Theresa Point, Manitoba. On the day of the occurrence, the pilot flew multiple flights until approximately 1012 central standard time. After a short break, he flew to the Waasagomach Band Office for another pick-up. After loading four passengers, the pilot took off and climbed the helicopter to about 500 feet above ground level (agl) for the five-mile flight back to St. Theresa Point. Ground-based observers heard unusual engine sounds and saw the helicopter slow down and descend about one-quarter mile from the Band Office. When the helicopter was about tree-top height above the frozen lake surface, the tail of the helicopter dropped rapidly and the helicopter tilted abruptly to its left side. The helicopter descended and struck the ice, left-side first, and bounced back into the air. The main rotor blades severed the tail rotor and tail boom assembly. The helicopter turned 180 degrees, and then slid to rest with the rear of the helicopter facing in the original direction of travel. The pilot and two passengers were fatally injured; two surviving passengers were seriously injured. The accident occurred at approximately 1100 in daylight at latitude 53°54' N, longitude 094°56' W, at an elevation of 740 feet above sea level (asl).

Ce rapport est également disponible en français.

Other Factual Information

During the spring break-up and fall freeze-up, Yukon Helicopters Ltd. provided an air taxi service to several remote communities from two airports, Island Lake and St. Theresa Point, Manitoba. The air taxi operations involved short flights of a few minutes' duration with frequent loading and unloading of passengers. The flights were generally flown at 500 feet agl[1] into small landing sites scattered throughout the communities in the vicinity of the two airports. At the time of the occurrence, the company was the registered owner of one Bell 47, two Hughes 369HS, and one Bell 206L. The company was managed by the owner who acted as chief pilot, operations manager and director of maintenance. Yukon Helicopters Ltd. operated an Approved Maintenance Organization (AMO) authorized to conduct all non-specialized maintenance work on its helicopter fleet. The company employed an aircraft maintenance engineer (AME) in support of the AMO. The company had a trained safety officer on retainer to administer the dangerous goods exam and represent safety concerns raised by the pilots. Information indicated that the company pilots did not feel under pressure to fly in situations that compromised safety. The owner ensured adherence to company policies; for example, he spot-checked the minimum fuel level when pilots landed. The owner had established the practice of conducting autorotations to landing rather than to power recoveries at altitude during recurrent training in the belief that it was crucial to safe operations. Company policy required that practice autorotations be conducted with a minimum headwind of five knots. Practice autorotations were conducted with only two pilots on board and to landing areas that had features which assist the pilot to judge the height above ground.

The 32-year-old pilot held a commercial helicopter pilot licence valid for daylight flying. His medical re-examination had been completed on 20 March 1998 and his medical certificate had no restrictions. He had begun flying training on helicopters in October 1996 with Yukon Helicopters Ltd. His training was on the Bell 47 and Hughes 369 helicopters and completed in March 1997. He then flew with Yukon Helicopters Ltd. for spring break-up and fall freeze-up in 1997. He began flying again in March 1998, after a three-month lay-off. The pilot received a
1.1-hour training trip which included autorotations and then passed a pilot proficiency check on the Hughes 369 on 24 March 1998. The flight test was conducted by a Transport Canada inspector and completed on the occurrence aircraft. The inspector noted that all emergencies, which included a simulated engine failure and autorotation, were performed to acceptable standards. At the time of the accident the pilot had approximately 400 hours' total time, all on helicopters, and had flown about 60 hours in the occurrence aircraft during the month of April.

The pilot, his co-workers and the company owner lived together in company accommodation near the Island Lake airport and knew each other closely. The pilot was well liked by his co-workers and considered to be a positive individual with no apparent stress either in his personal life or employment. The pilot maintained a good level of physical fitness and enjoyed sports. A review of his 72-hour history revealed that he had eaten and slept well in the three days before the accident and that there was no indication that fatigue was a factor in the accident. The autopsy found no pre-existing conditions that would have contributed to the accident. The toxicology report was negative for common drugs, carbon monoxide or alcohol.
The occurrence helicopter was normally operated from St. Theresa Point and refuelled from five-gallon

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1 Units are consistent with official manuals, documents, reports, and instructions used by or issued to the crew.

containers flown in from the company hangar at Island Lake. After the occurrence, 10 five-gallon fuel containers belonging to the company were examined at St. Theresa Point; three containers were found empty. The other Hughes 369HS normally operated from Island Lake airport, and refuelled from the company refuelling vehicle. The fuel containers and the refuelling vehicle were fuelled from a common source, a main fuel tank adjacent to the company hangar, and the fuel delivered from this tank was filter-protected. After striking the ice, the helicopter fuel tank was ruptured, allowing all fuel to leak onto the ice. Fuel staining in the vicinity of the helicopter indicated that there had been ample fuel on board. Impact forces loosened the fuel nozzle line allowing some fuel to leak from the engine, but the small amount of fuel that remained within the engine was sampled and found to be clear and free of contaminants. The fuel filter cartridge was clean, and there was no indication of contaminants in the filter bowl.

The certificated maximum gross weight of the helicopter is 2 550 pounds and the centre of gravity (c of g) range at the helicopter's occurrence weight is 99 to 104 inches aft of datum. The fuel load of the helicopter at the time of the occurrence could not be determined precisely because the fuel tanks had ruptured and the fuel had drained onto the ice. However, there was sufficient information to postulate an upper limit to the fuel weight at the time of the occurrence and, thus, estimate whether the weight and balance of the helicopter was within the allowable range. The occurrence pilot would have departed in the morning with full fuel on board in accordance with company policy. The helicopter operated for two hours until likely refuelling at St. Theresa Point, adding fuel from the three five-gallon containers. The helicopter then flew for about another 20 minutes before the occurrence. Starting with a maximum fuel weight of 540 pounds, and using best range fuel flow calculations, the helicopter would have had 190 pounds of fuel at the time of the occurrence. Applying the actual weights of the people on board and the calculated fuel, the weight of the helicopter was calculated to have been about 2 530 pounds and the c of g was 99.7 inches. Given the nature of the flights that were conducted, the fuel usage would have been greater than the best range listed in the pilot operating handbook (POH). When operated within approved weight and balance limits, the helicopter is designed to be capable of autorotation.

A 1000[2] weather observation at Island Lake, 13 miles east of Waasagomach, indicated that there were a few clouds at 2 000 asl and 10 000 asl and that the visibility was 15 miles. The wind was reported to be 290 degrees at seven knots with a temperature of five degrees Celsius. The 1000 weather report for St. Theresa Point gave the same sky condition and visibility. The wind was reported as 300 degrees at eight knots. Pilots flying on the day of the occurrence reported that the winds were strong and that there was some turbulence. The pilots and Royal Canadian Mounted Police (RCMP) officers who attended the accident indicated that the winds in the area of the accident were stronger than reported. The ice surface of the lake was not uniformly white; most of the snow had melted and large portions of the ice surface were black. There was no open water in the vicinity of the accident.

2 All times are central standard time (Coordinated Universal Time (UTC) minus six hours) unless otherwise stated.

The occurrence helicopter was certificated in accordance with Type Certificate H3WE and was equipped with an Allison 250-C18C turbine engine, serial number CAE801795B. Between the time that Yukon Helicopters Ltd. began operating the helicopter in July 1992 and the date of the occurrence, the helicopter accumulated just over 1 000 air hours. Records indicated that the helicopter was being maintained in accordance with the requirements of the approved maintenance control manual. The most recent inspection had been a 300-hour inspection, completed at the operator's main base on 06 April 1998. In the 17 days from that inspection, and up to the time of the occurrence, the helicopter had flown more than 200 flights accumulating just over 27 hours of air time. Post-occurrence examination revealed that the ports on the fuel pump/filter assembly, where a fuel filter pressure differential switch (P/N 369H8144) would normally be installed, were capped off, and the fuel filter warning light on the instrument panel was not placarded as inoperative. The system is designed to bypass fuel and provide a warning to the pilot if the fuel filter element becomes plugged; however, after the occurrence, the filter element was clean. The helicopter manufacturer indicated that a pressure differential switch would have been installed at the time that the 369HS model helicopter was type certificated. Company personnel indicated that the helicopter had been purchased and maintained in this configuration. Company records indicated that applicable airworthiness directives were being accomplished, and there were no outstanding defects at the time of the occurrence. The fuel control system was pneumatically checked at the occurrence site, and the system showed no leakage.

The wreckage trail on the ice surface was approximately 220 feet long, oriented on a heading of 140 degrees magnetic. The helicopter was in a nose-high and left-side-down attitude when it struck the ice. Within the first 100 feet after initial impact, the helicopter bounced twice, the main rotor blades severed the tail boom and tail rotor assembly, and the remainder of the helicopter turned rearwards sliding to rest approximately 120 feet further on. The limited damage to the main rotor system and spacing of three rotor blade impact marks to the left of the initial impact site indicated that the main rotor system had little rotational energy at impact. Continuity was confirmed throughout the flight control system, and all damage was found to be impact related. After sliding along the ice, the left rear section of the combustion outer case and the engine exhaust pipes were resting on the snow-covered surface of the ice. There was no apparent melting of the ice from residual heat in this area. Inside the cockpit, the battery switch was off, and the auto re-light switch was guarded off. Police, who arrived on the scene about one hour after the accident, observed that the landing light was illuminated and turned off the battery switch and the emergency locator transmitter (ELT).

The damaged engine was transported to an overhaul facility for teardown and testing of accessory components. During the engine teardown, white flaky material was found in the discharge tubes and in the outer combustion case; dark-coloured deposits were found in and beyond the combustion section on components in the gas path. Samples of these materials were subsequently sent to the TSB Engineering Branch Laboratory where analysis confirmed that both were consistent with the plastic material of the compressor bell mouth, portions of which had shattered during the impact. Pieces of paper-like insulating material from an engine compartment insulating blanket were found adjacent to the compressor intake with smaller-sized pieces of the material inside the initial stages of the compressor. Shredded material of a similar nature was found adhering to components within the flow path of the compressor.

Samples of the materials from inside the compressor were confirmed to be from the insulating blanket material. The engine teardown did not disclose any condition that would have resulted in a disruption or loss of engine power.

The engine accessories were functionally tested. The fuel nozzle was carbon coated and produced some streaks and voids in its spray pattern but was considered serviceable. The fuel control unit was found to have a slightly low acceleration time with low start acceleration fuel flows and slightly low idle fuel flows. The power turbine governor was found to be governing approximately 200 rpm early. The double check valve, compressor bleed valve, thermocouple harness, and the ignition exciter assembly tested serviceable. The anomalies noted during testing of the foregoing components were not considered to be sufficient to cause a loss of engine power in flight. The spark igniter assembly was damaged during impact and could not be tested.

At the time of the occurrence, the engine had a fuel control unit (Allison P/N 6871119, S/N 300741). The engine had previously been equipped with a fuel control unit (Bendix P/N 2524463-3, S/N 310077) that accumulated 762.4 air hours while on the occurrence engine; it was removed in February 1997 with 142.9 hours remaining before overhaul. Inspection of the inlet screen for the S/N 310077 fuel control showed one small sliver of what appeared to be non-ferrous metal; after the accident, the S/N 300741 fuel control unit showed considerable metal contamination. Neither of the fuel controls had reached its 1 000-hour inlet screen inspection time frame, thus any debris from the fuel pump or other upstream fuel system components was not detected before the occurrence.

Engine assembly records showed that, on 15 November 1976, Standard Aero Ltd. repaired a 250-C18B engine and installed the subject fuel pump (P/N 024731-132, serial number PE3142A), with a time since overhaul of 5 hours and 40 minutes. The company that owned the engine and components at that time dealt with Standard Aero Ltd. for their engine and component repairs. Regulations do not require overhaul facilities to maintain repair and overhaul records; there were no records available at Standard Aero Ltd. to confirm if that company had overhauled the pump before that installation. The engine was removed from service in April 1987, when the pump had accumulated 1 035.1 hours' time since overhaul. Yukon Helicopters Ltd. purchased the engine with its accessories, and in August 1992, they sent the fuel pump to Standard Aero Ltd. for functional testing and repair. After accomplishment of minor repairs, the pump tested within limits and it was returned to Yukon Helicopters Ltd. with a serviceable release. The scope of the work had not required complete disassembly and re-build of the pump, so the pump was repaired and not overhauled. Almost five years later, at the time of the occurrence, the pump had accumulated 1 967.8 air hours and 282.2 hours' time remained before overhaul.

The first post-occurrence test of the dual element pump measured the output of each element of the pump separately. With the check valves removed from the pump and the flow measured at each check valve port, it was found that the No. 1 element of the pump was not pumping fuel. Inspection of the pump's two check valves revealed that both check valves were held open by metal contamination trapped between the valve and valve seat. A second test was run to measure the combined output of both elements of the pump with a used-serviceable check valve installed at the No. 2 element of the pump and a check valve body without piston installed at the No. 1 element. This test revealed that the pump produced no net outflow until higher rpm operation, when the pump produced momentary grinding noises accompanied by fleeting flow spikes of approximately 100 pounds per hour.

Disassembly of the fuel pump revealed that the splines of the No. 1 element of the fuel pump had been worn away so that they no longer engaged. The external gears of the B-spline of the pump drive shaft (P/N 02-16054) were worn away where they made contact with the internal gear splines of the No. 1 element drive spur gear (P/N 02-14624) and the internal splines of the drive spur gear were also worn away. The pump body exhibited scoring in the tip rub zones of both pump elements.

The pump components were forwarded to the TSB Engineering Branch Laboratory, along with the metal particles that were removed from the pump check valves. Analysis of the particles that jammed the pump check valves revealed that they comprised mostly aluminium with a significant presence of silicon and copper. Both had evidenced iron peaks but this was attributed to smaller steel particles from the failing splines embedded in the larger aluminium ones. The major elements in the particles from both check valves matched closely those of the pump housing which is an AMS 4215 aluminium casting.

Splines A, B and C of the pump drive shaft (P/N M/C 02-16054) were examined and the major dimensions were in agreement with blueprint requirements. The drive shaft material in the area of the splines was tested and found to meet the designed case hardness and all were appropriately chrome plated.

The drive spur gears (P/N 02-14624) were analysed and found to agree with the design criteria for the spur gear. The internal splines showed an absence of chrome plating, consistent with the criteria for this part number spur gear. The case hardness was well developed, and a continuous white layer was evident. A significant wear step was detected on the face of the internal spline of the No. 2 element spur drive gear, also P/N 02-14624. An upgraded drive spur gear
(P/N 02-16057), with chrome plating on the internal splines, is currently recommended for installation as part of a matching drive and driven gearset.

All spline components exhibited the white layer, whether continuous or discontinuous, of varying thickness, not exceeding the maximum allowed by Pesco specification P-135. However, note 5 on drawing D77200 02-16054 for the drive shaft specified that spline teeth were to be free of any nitride white layer. The white layer is a by-product of the nitriding process used to
case-harden steel components. The white layer is generally undesirable because of its brittle nature. The accelerated wear and failure of the No. 1 element pump splines was the result of the combined effects of the chromed drive shaft splines operating against the non-chromed splines of the drive spur and the abrasive influences of material produced by the breakdown of the brittle nitride white layer.

The pairing of the chromed drive shaft with the non-chromed driven spur gears resulted from the incorporation of components and re-work of the pump in accordance with a commercial engine bulletin (Allison 250-C18 CEB-161) that was likely accomplished at the time of the pump overhaul before 15 November 1976.

The pump manufacturer, Pesco/Sundstrand, amended the overhaul manual, assembly drawings, and illustrated parts list (IPL) for the pump in 1983. The amended overhaul procedures required the replacement of the old drive spur gear with the newer, chromed gears in the IPL. There were no calendar time limitations for the pump, and there were no directives issued to mandate incorporation of the amended overhaul requirements before reaching the time limit of the time between overhauls (TBO). The occurrence pump had not reached TBO thus the component changes outlined in the amended overhaul manual were not applied.

Analysis

The wear on the drive splines of the No. 1 element of the pump resulted from the mismatching of chromed and non-chromed components and the progressive breakdown of a nitride white layer. Overhaul procedures amended in 1983 required replacement of the non-chromed components, but the pump had not attained TBO time limits during its 20-year in-service life, and no directives had been issued to require pre-overhaul replacement. Functional testing and repair of the pump, conducted in 1992, was limited in scope and did not require complete disassembly and re-build. Consequently, the progressive wear went undetected. When the No. 1 element drive splines disengaged and the No. 1 element check valve jammed open, pump flow from the No. 2 element re-circulated within the pump and little or no fuel flow was provided to the engine. As failed spline pieces jammed between spline remnants in the No. 1 element of the pump, it is likely that momentary engine power reductions would be followed by short periods of normal power. Eventually, the wear would have progressed to a point that temporary engagement of the drive was impossible and the engine lost all power. The pilot was faced with power interruptions and engine indications that were initially difficult to analyse.

The helicopter was being operated without a fuel pressure differential switch, and the attendant bypass warning system was therefore inoperative. However, because post-accident examination of the fuel filter showed no evidence of filter contamination or restriction, if the pressure differential switch had been installed and the system had been working, the fuel filter bypass warning would not have been activated. The absence of the pressure differential switch and warning system would not have contributed to the occurrence.

While there was insufficient information to determine the exact weight and balance of the helicopter, the maximum upper weight limit of 2 530 pounds that was approximated using the POH best range charts is less than the certificated maximum gross weight of 2 550 pounds. Because it was unlikely that the maximum range fuel flows could have been achieved during the operations flown that morning, more fuel would have been used, there would have been less fuel on board and the weight of the helicopter would likely have been somewhat less than 2 531.5 pounds. The helicopter was being flown at less than the maximum gross weight, within its flight envelope, and an autorotation should have been possible. However, the helicopter would have been significantly heavier than it was at the time that the pilot had practised autorotations in training.

Company policy required that the pilot transit at an altitude of 500 feet agl, and although there is no hard information to confirm that the pilot climbed to the transit altitude, there is no information that he did otherwise on this flight. It is likely that he was at the transit altitude when the engine problems began. Since he was flying downwind when the engine-driven fuel pump failure occurred, the correct procedure would have been to turn into wind. There was no information available to explain why the pilot did not turn immediately to prepare for an emergency landing into wind. However, it is possible that the time that he used to reassure the passengers and time that he may have spent analysing the power interruptions resulted in an altitude or airspeed loss that eliminated the possibility of a turn into wind. Therefore, when the engine failed completely, the pilot was faced with executing an autorotation with a strong tailwind, over a relatively featureless surface. His perception of forward speed and cues to judge height above the surface would have been significantly different from his normal experience in practice autorotations. There was little information as to the manner in which the pilot reacted to these abnormal conditions and flew the autorotation; however, the lack of main rotor system rotational energy at impact indicates that the pilot did not maintain rotor rpm throughout the manoeuvre. The available information indicates that the helicopter appeared to be flared, tail down, at about tree-top height before its abrupt descent. Once this flight attitude was reached without engine power and at low rotor rpm, there was insufficient airflow through the rotor to sustain rotor rpm. The rotor rpm would have decayed further, and without rotor rpm, the pilot was unable to control the helicopter. The helicopter tilted to its left side and descended abruptly as it was carried forward by the residual speed and tailwind.

The following Engineering Branch reports were completed:

LP 075/98 - Analysis of Plastic and Asbestos

LP 110/98 - Engine Driven Fuel Pump

Findings

1. The company records indicated that the helicopter was inspected, certified and maintained in accordance with approved schedules.

2. The helicopter was being operated without a fuel filter pressure differential switch or fuel filter bypass warning system; however, post-accident inspection confirmed that the fuel filter was free from contamination and the non-functioning filter bypass warning system would not have contributed to the occurrence.

3. The damage sustained by the main rotor and tail rotor components and their respective control systems resulted from the impact of the helicopter and its components with the ice.

4. The engine-driven fuel pump failed as a result of a progressive failure of the drive splines of the No. 1 element of the pump and subsequent metal contamination of the No. 1 element check valve.

5. The failure of the pump splines resulted from the combined effects of continued operation of chromed drive shaft splines against non-chromed spur gear splines, and the effects of the breakdown of a nitride ‘white layer’.

6. The pairing of a chromed drive shaft against non-chromed spur gear splines resulted from the incorporation of Allison Engine 250-C18 CEB-161, which likely occurred when the pump was overhauled some time before 15 November 1976.

7. In 1983, the pump manufacturer amended the overhaul manual to reflect deletion of pump models 024731-112 and 024731-113 which contained the P/N 02-14624 (non-chromed) drive spur gears. Current pump models 024731-132, -133, -135, and -136 require installation of P/N 02-16057 (chromed) drive spur gears.

8. The pump does not have a calendar life overhaul limit, and there were no directives issued to require change out of the spur drive gears before TBO time limits.

9. Despite being in service for more than 20 years, the pump had not accumulated sufficient service time to require an overhaul.

10. The progressive failure of the pump likely resulted in short-duration power deviations that became more exaggerated until the engine suffered a complete loss of power.

11. The weight and center of gravity of the helicopter were within the prescribed limits.

12. The pilot was qualified and certified for the flight in accordance with existing regulations.

13. There was no indication that the pilot's performance was degraded by physiological factors.

14. It could not be determined why the pilot did not maintain sufficient rotor rpm to control the helicopter while conducting an autorotation.

Causes and Contributing Factors

The helicopter engine suffered power excursions and finally a complete power loss as a result of the failure of the engine-driven fuel pump. The helicopter crashed onto the frozen lake surface when the pilot allowed the rotor rpm to decay and lost control of the helicopter while attempting an autorotation.

Safety Action

The company has indicated that it will no longer be using the dual element fuel pumps on its helicopters.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 28 July 1999.