AVIATION INVESTIGATION REPORT
A02P0169

LOSS OF MAIN ROTOR DRIVE

CROMAN CORPORATION
SIKORSKY S-61L (HELICOPTER) N346AA
WENDLE CREEK, BRITISH COLUMBIA
08 AUGUST 2002

Aviation Investigation Report

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Summary

The Sikorsky S-61L helicopter (N346AA), serial number 61425, had just begun to lift a load of logs when the engine sound stopped. As the helicopter began to descend, the longline was dropped and the main rotor began to slow. The helicopter descended about 700 feet with the rotor continuing to slow until the aircraft struck trees and the ground. Company personnel arrived at the accident site within 15 minutes and extinguished a small fire in the wreckage. The helicopter was destroyed by the impact and both pilots sustained fatal injuries.

Ce rapport est également disponible en français.

Other Factual Information

The helicopter was engaged in heli-logging operations at Wendle Creek, British Columbia, about 42 nautical miles (nm) southeast of Prince George, British Columbia. The aircraft was owned and operated by Croman Corporation, a USA company operating in Canada, and was being flown by a crew of two Canadian pilots with the flying pilot in the left seat. The crew had begun flying at about 0610 Pacific daylight time[1] on the day of the accident and was about one hour into the third cycle[2] of the day at 1020 when the accident occurred. Visual meteorological conditions existed at the time with unlimited visibility and light winds. The helicopter was using a 200-foot longline and was picking up a load of logs from an area at 4200 feet above sea level (asl), uphill from standing timber at the edge of the cut-block. After the engine sound stopped, white smoke was seen coming from the engine exhaust area for about three seconds, and the main rotor began slowing as the helicopter flew down the hillside, over the standing timber, toward the log-landing area. The rotor continued slowing and several seconds later, the helicopter struck trees then the ground at 3700 feet asl in a logged-off area. Although the aircraft wreckage sustained some fire damage to the engines and engine area, it was determined that the fire was post-crash in origin. Neither engine fire extinguisher was discharged.

Both pilots were appropriately certificated and trained for the type of flight being conducted. A review of records revealed that the crews' flight and duty times were in accordance with existing regulations, and nothing remarkable was found regarding the pilots' activities prior to the accident. The pilot-flying held a valid class-1 medical certificate which included a limitation requiring corrective lenses to be worn; he was wearing glasses on the day of the accident. The investigation could not establish with certainty whether the shoulder harnesses were worn by the pilots. Nevertheless, the violence of the accident suggests that the crash was not survivable.

By design, the two fuel quantity gauge indicators retain their last position when electrical power is removed. On-site examination showed that the forward fuel gauge indicated 450 pounds, and the aft fuel gauge indicated 425 pounds. This would equate to about 104 imperial gallons of fuel on board the helicopter at the time of the accident. The aft fuel tank bladder remained intact following the impact, and the forward fuel tank bladder sustained a small tear which was slowly leaking fuel. A total of 82 imperial gallons of fuel were recovered from the wreckage. The flight manual states that .6 imperial gallon (5 pounds) is unusable fuel. Fuel samples taken from N346AA's fuel tank sumps in the morning, on the day of the accident, were sent for analysis following the accident. The samples were determined to be Jet A, which is an approved fuel for this helicopter, and contained inconsequential amounts of water and particulate matter.

The load of logs on the longline at the time of the accident was measured and found to weigh 8250 pounds. Weight and balance calculations show that with 104 imperial gallons of fuel and two pilots, the helicopter could have been loaded with up to 9950 pounds on the longline without exceeding the 22 000 pound helicopter gross weight limit or the 10 000 pound hook weight limit. The helicopter was determined to have been within weight and balance limits at the time of the accident.
The main- and tail-rotor blades demonstrated damage consistent with that found when there is little or no rotor rpm at impact.

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[1] All times are Pacific daylight time (Coordinated Universal Time minus seven hours) unless otherwise noted.

[2] A cycle is the length of time flown between refuelling stops which, in this operation, was usually about 80 minutes.

The helicopter is equipped with two General Electric CT58-140-1 engines. A post-accident teardown of the number-one engine (serial number 285-074L) and the number-two engine (serial number 295-083) revealed that both had damage consistent with that found on engines that were not operating at impact. Although the engines were severely damaged by the impact and post-crash fire, no malfunction was found that would have caused the engines to shut down. The engines are not equipped with auto-relight systems. Each engine, however, is equipped with an overspeed governor that is designed to shut it down in the event of an overspeed.

The main gear box (MGB), P/N S6135-20600-039, S/N A14-A24-64-580, had accumulated 1050 hours time since overhaul (TSO). The recommended time between overhauls (TBO) on MGBs used in repetitive external lift operations (REL), such as heli-logging, is 1100 hours. It is noteworthy that 11 months prior to installation in the accident helicopter, this MGB had been removed from another S-61 helicopter (N9119S) and repaired due to a series of input freewheel unit (IFWU) slips[3].

A post-accident teardown/inspection of the MGB was conducted at an approved Sikorsky main gear box overhaul facility. The inspection revealed normal wear on all components except the IFWUs. The chip detectors were found to be clean, and the main oil filter did not contain any significant debris, but fine bronze particles were found in the oil. The damage pattern in the MGB revealed that the main rotor was not turning at impact. Inspection of the MGB found that, with the exception of the IFWUs, all damage was impact-related.

An input freewheel unit (IFWU) is a mechanical device which functions as a one-way clutch, allowing a helicopter's engine to drive the rotor but preventing the rotor from driving the engine. Input freewheel units were originally installed on piston engine helicopters, their function being to allow a successful autorotation by preventing the main rotor from being slowed by engine drag.

The right and left IFWUs had been overhauled by the operator on 12 September 2001, using new camshafts, roller retainers, rollers, supports (oilites), gear housings and gear housing bearings. At the time of the accident, the IFWUs had accumulated 532 hours, which is within the recommended TBO of 500 ± 50 hours on IFWUs used for REL operations (this TBO had been recommended by Sikorsky as a direct result of the finding of increased IFWU wear in REL operations observed during the 1993 TSB investigation A93P0051). Following the accident, the IFWUs were disassembled, inspected, and several component parts were tested. The right and left IFWUs exhibited similar wear and damage. The dimension of the IFWUs gear housings, camshafts, and roller retainers, even in the worn areas, was not abnormal for IFWU components that had been in service on a logging aircraft for 532 hours.

However, the condition of the worn areas of those components, and in particular the condition of the rollers and oilites, was not typical for IFWU components seen at overhaul. The rollers exhibited multiple flat spots, smeared metal, and bronze contamination. Hardness testing of the rollers, which are required to be through-hardened to RC 60-64, revealed that, with the exception of locally damaged areas on the surface, the rollers were consistently one to two points below the minimum required hardness. Metallographic examination revealed that the locally damaged areas on the surface did not etch normally; they appeared as white zones. A darker etching zone was present adjacent to and below the white zones. There was transition from the darker zone to the expected tempered martensite microstructures. Microhardness measurements verified that the hardness of the white zones was significantly higher than the specified hardness of the rollers, and that the

[3] "Slip" is a term used to describe a disengagement followed by re-engagement of the rollers in an IFWU during operation.

hardness of the adjacent dark zone was significantly lower than the specified core hardness. The microstructure and microhardness observations are consistent with local overheating of the surface above the martensite temperature (approximately 1600 degrees Fahrenheit) followed by rapid cooling by the IFWU lubricant, thus forming untempered martensite. The softer zone adjacent to the untempered martensite consisted of over-tempered martensite due to exposure to temperatures below the martensite forming temperature but above the tempering temperature used during manufacture of the rollers.

The roller paths on the gear housings were pitted and showed signs of multiple disengagements and re-engagements (parallel dents left by the rollers). In Sikorsky's experience, this type of damage is not typical of over-running (freewheeling) in which the wear appears more uniform and without evidence of the parallel impressions and pitting.

The camshaft flats exhibited roller impressions which averaged 0.00106 inch but included impressions as deep as 0.0016 inch. The camshaft flats also had wave-shaped areas of raised metal up to 0.0019 inch high on the low (disengaged) side of the roller impressions. Any measurable wear on the camshaft flats is cause for rejection of the part at overhaul.

Oilite bushings support the roller retainer. The retainer maintains alignment of the rollers relative to the camshaft flats and gear housing. The oilites in both IFWUs exhibited a variety of damage types such as bending, cracking, crushing, and wearing. A significant amount of very fine particles of oilite material was found on the rollers, roller retainer, camshaft, gear housing, and in the oil pooled in the MGB front cover and sump. Comparison of oilite manufacture data to data gathered during the oilite inspection indicates that the oilites were manufactured within their specified limits.

During the post-crash inspection of N346AA's IFWUs, another heli-logging company operating a Sikorsky S-61 aircraft reported an IFWU slip. That unit was inspected and showed damage similar to that found on N346AA's IFWUs.

N346AA's ELT was not installed at the time of the accident; it had been removed and was being stored at the helicopter service/refuelling site, about one nm from the heli-logging area and accident site. Anecdotal information suggests that because normal heli-logging operations often trigger ELTs, it is common practice to remove ELTs for heli-logging operations and reinstall them for all other flights. The accident helicopter was being operated within sight of ground personnel who were able to locate the wreckage without the aid of an ELT. A review of the logbooks and maintenance records indicates that, with the exception of the ELT not being installed, the helicopter had been certificated, equipped, maintained, and operated in accordance with existing regulations and approved procedures.

Analysis

Because the investigation determined that the helicopter was within weight and balance limits, had sufficient fuel to conduct the flight, and weather was not a contributing factor, this analysis focuses on the mechanical issues.

The engines were not operating and the main rotor had little or no rpm at impact. Inspection of the engines did not find any anomalies that would have caused the engines to stop operating prior to impact. However, the white smoke coming from the engine exhaust area after the engine sounds stopped suggests that, although the engines were still turning and fuel was being introduced, the fuel was not being burnt. The most likely explanation for these events is an engine overspeed and shutdown.

An engine overspeed is possible for a variety of reasons, including a drive train interruption such as an IFWU spit-out[4] . The overspeed governors operate by cutting off the fuel to the engine if an overspeed is sensed but do not leave any indication that an overspeed has occurred. Once the fuel is cut off, the engine flames out, the rpm decreases and fuel is reintroduced. The engines are not equipped with auto-relight systems and therefore do not automatically relight after fuel is reintroduced to the engine. It is concluded that the engines shut down because of an overspeed condition, probably induced during IFWU spit-out.

Inspection of the MGB found that all damage, except that found on the IFWUs, was impact-related. Both right and left IFWUs were found to have similar damage. Metallographic examination of the area around the flat spots on the rollers showed an untempered martensite surface layer. Skidding and spit-out of the rollers is the most likely cause of these metallurgical anomalies. The rollers were not through-hardened to the required specification during their manufacturing process. It is not known what effect this defect may have had on the IFWU's ability to maintain engagement. The wave-shaped areas of raised metal on the camshaft flats on the low (disengaged) side of the roller impressions indicates that the rollers were forced in the disengaged direction with extreme and unusual force. Other damage to the IFWU components—smearing of the roller material, denting and pitting of the gear housing roller path, and breakup of the oilites—is also indicative of damage caused by slipping and spitting out.

Damage to the oilites can cause a loss of support to the roller retainer. This in turn can cause a loss of alignment of the rollers, which increases the likelihood of roller spit-out. During normal operation, the oilites are stationary and do not carry a load. However, the quantity of fine bronze particles found would indicate that the oilites were subject to repeated small loads and motion, such as would occur as the result of vibration. Contamination of the roller path with oilite material increased the likelihood of roller spit-out.

It is likely that when the first IFWUs spit-out, the affected engine oversped and shut down. As the other engine/IFWU took up the full load of the rotor, that IFWU spit-out and its associated engine oversped and shut down. The IFWUs disengaged one after the other, with so little time

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[4] "Spit-out" is a term used to describe the rapid, forceful, and complete disengagement of the rollers in the IFWU during operation.

between the disengagements that the disengagements could be considered simultaneous. It is unlikely that the helicopter entered fully-developed autorotative descent because of the loss of rotor rpm, the height available, and the manoeuvring required.

A history of accidents shows that when one engine or one IFWU fails on a Sikorsky S-61, a significant risk exists that the second IFWU will also fail, causing a dual engine power loss. It is reasonable to conclude that an aircraft with two components prone to failure is twice as likely to have that failure as an aircraft with only one such component. Pilots of dual engine helicopters reasonably expect that in the event of a power loss from the first engine, the second engine would be available. In part, this expectation forms the basis for the pilots' acceptance of the level of operational risk. Unlike helicopters that operate the majority of the time in cruise flight, a helicopter working in a high risk flight regime (such as heli-logging) is unlikely to be able to carry out a successful autorotation in the event of a total drive train power loss.

The TSB is aware of numerous Sikorsky S-61 IFWU slips. As well, the TSB has investigated several Sikorsky S-61 accidents prior to this investigation, including A01P0003, A00P0182 and A93P0051, in which the IFWU spit-out.

Findings as to Causes and Contributing Factors

1. The oilite bushings in the IFWUs deteriorated, causing instability of the rollers and bronze contamination in the roller path resulting in reduced ability of the IFWU to maintain engagement.

2. Both IFWUs malfunctioned in rapid sequence, causing the engines to overspeed and subsequently shut down.

3. Following the loss of power of the engines, drive to the main rotor was lost, leading to rotor rpm decay and loss of control of the helicopter.

Findings as to Risk

1. In the event that one engine or one IFWU fails on a Sikorsky S-61, a significant risk exists that the second IFWU will also fail.

2. Helicopters used in high risk operations such as heli-logging are often flown in an area of the flight envelope where a successful autorotation is unlikely in the event of a total drive train power loss.

3. The IFWU rollers were not through-hardened to the required specification during the manufacturing process.

Safety Action

Safety Action Taken

Sikorsky issued Alert Service Bulletin (ASB) No. 61B35-67A, dated October 11, 2002. In part, the ASB reduces the TBO of IFWUs used for repetitive external lift operations from 500 hours to 350 hours. The ASB also requires that certain IFWU components be measured and inspected during disassembly for overhaul, and that these measurements, as well as details of the condition of the components, be forwarded to Sikorsky.

Transport Canada is reviewing ASB No. 61B35-67A. The purpose of this review is to determine the rationale for reducing the time between overhauls of the IFWUs and the applicability of this Service Bulletin to Canadian operators of the S-61 aircraft. As well, Transport Canada is reviewing REL operations in general in an effort to determine the validity of established certification and maintenance practices.

This report concludes the TSB's investigation into this occurrence. Consequently, the Board authorized the release of this report on 05 May 2003.

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