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Helicopter Strikes Terrain During External-load Aerial Logging Operation

The investigation report said that a fatigue fracture in the main-rotor mast resulted in an in-flight separation of the main rotor from the helicopter.

FSF Editorial Staff

About 0915 local time Aug. 27, 1997, during an external-load aerial logging operation near Skykomish, Washington, U.S., the main rotor on a US Helicopter UH-1B restricted-category former military helicopter separated from the helicopter. The helicopter collided with terrain and was damaged substantially; the airline transport pilot — the only person on board — was killed.

The U.S. National Transportation Safety Board (NTSB) said in its final report that the probable cause of the accident was "a fatigue fracture in the main-rotor mast, which resulted in an in-flight separation of the main rotor from the helicopter." A related factor, NTSB said, was "insufficient FAA [U.S. Federal Aviation Administration] airworthiness standards and requirements for the aircraft."

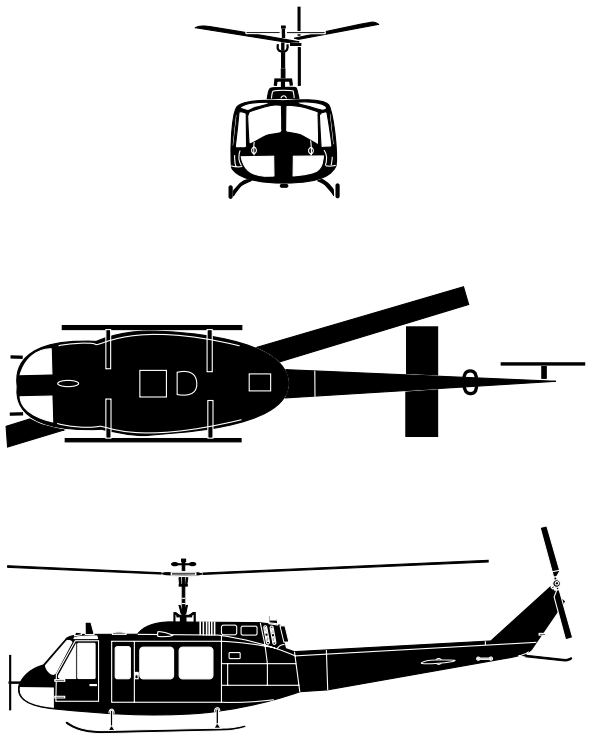
The helicopter, which was operated by Horizon Helicopters of Rancho Murieta, California, U.S., departed from a service landing near the accident site in the Mount Baker-Snoqualmie National Forest. Logging ground crewmembers said that the helicopter was flown for about 45 minutes before the accident. At the time of the accident, visual meteorological conditions were reported at Paine Field in Everett, Washington, 38 nautical miles (70 kilometers) west of the accident site, with rain showers over nearby mountains.

The ground crewmembers said that, immediately before the accident, the pilot tried to lift two logs but that the logs "became hung up in trees." Trees in the area were about 120 feet to 130 feet (37 meters to 40 meters) tall.

"The pilot then released the load, and the ground crew subsequently started to reconnect the larger of the two logs to the helicopter's external load line," NTSB said. "The witnesses then reported that they heard a loud 'pop' and the [sound of the] engine RPM [revolutions per minute] increasing, upon which the helicopter fell to earth."

The helicopter fuselage came to rest upside down on sloping terrain. A witness said that the main rotor continued to rotate for 30 seconds to 45 seconds after the impact.

The UH-1B helicopter was manufactured by the Bell Helicopter Co. for the U.S. Army. Civil type certification was granted under U.S. Federal Aviation Regulations, originally to Southern Aero Corp. of Ozark, Alabama, U.S., and later to US Helicopter, also of Ozark. In 1990, the



Garlick (Bell) UH-1B

Bell Aircraft developed the Model 204 to compete for a U.S. Army contract to build a utility helicopter suitable for evacuating casualties from front-line battle areas and for instrument flight training. The Model 204 won the contract in 1955 and was given the military designation HU-1. The U.S. Army named the helicopter the "Iroquois," but the HU-1 designation prompted the nickname "Huey." The military designation later was changed from HU-1 to UH-1, and the first production helicopters were designated UH-1A.

The UH-1A is a six-seat helicopter with an 860-shaft-horsepower Lycoming T53-L-1A turboshaft engine derated to 770 shaft horsepower. The UH-1B, produced from 1961 to 1965, has accommodations for two crewmembers and seven passengers. Early production helicopters have a 960-shaft-horsepower Lycoming T53-L-5 engine; later versions have a 1,100-shaft-horsepower Lycoming T53-L-11 engine. Bell built about 76 Model 204Bs — commercial versions of the UH-1B.

Garlick Helicopters Inc. of Hamilton, Montana, U.S., refurbishes military versions of the helicopter for civilian use. Garlick UH-1B helicopters are type-certificated under U.S. Federal Aviation Regulations.

Basic empty weight of the UH-1B is 4,502 pounds (2,026 kilograms). Maximum takeoff weight is 8,500 pounds (3,825 kilograms). Maximum speed is 120 knots (222 kilometers per hour). Hovering ceiling out of ground effect is 12,500 feet.

Sources: *Jane's All the World's Aircraft* and Garlick Helicopters Inc.

accident helicopter was issued a restricted-category FAA airworthiness certificate.

The accident helicopter was modified by the installation of a 1,400-shaft horsepower ([SHP] 1,044-kilowatt) AlliedSignal (formerly Lycoming) T53-L-13B turboshaft engine, which replaced the original 1,100-SHP (820-kilowatt) T53-L-11D engine. Garlick Helicopters of Hamilton, Montana, U.S., which refurbishes UH-1B helicopters for civilian use and which held the supplemental type certificate for installation of the T53-L-13B engine, said that the T53-L-13B engine was designed to "enhance high-altitude and hot-day performance." The T53-L-13B can produce maximum allowable horsepower to a higher density altitude than the T53-L-11D engine, but the drivetrain is limited to 1,100 SHP, or 50 pounds per square inch torque pressure; an increase in drivetrain loads for the T53-L-13B engine is not authorized.

The helicopter's main-rotor mast bore a hand-inscribed data plate that identified the mast as Bell part no. 204-011-450-1, serial no. H9-2007. NTSB said that the "most reliable manufacture[r] records" kept by Bell Helicopter Textron indicated that the actual serial number was N9-2007, that the mast was manufactured for Bell Helicopter Textron by Textool and that the mast originally was installed Feb. 16, 1967, on a UH-1D helicopter manufactured for the U.S. Army.

An Army Safety of Flight Emergency Message issued July 18, 1984, ordered the removal of "thin-walled" mast tubes (Bell part no. 204-040-366-9) that had been installed in mast assemblies with Bell part no. 204-011-450-001. The message ordered the immediate grounding of Army UH-1 series helicopters equipped with those thin-walled mast tubes until the mast tubes were replaced by "thick-walled" mast tubes (Bell part no. 204-040-366-15). The message did not explain why the action was taken.

The operator's commercial historical service record for the mast on the accident helicopter said that the mast assembly was equipped with a mast tube whose part number was 204-040-466-9, but Bell said that the number is not a valid Bell part number. The commercial historical service record said that the mast was installed on a civil-registered helicopter on Nov. 15, 1988, and that the mast later was installed on a UH-1B helicopter that subsequently was involved in an accident.

In that accident, in Smith Cove, Alaska, U.S., on May 22, 1991, the pilot said that he "was maneuvering just above the tree level when the engine quit."[1] The operator's accident report said that the helicopter landed hard and that the main rotor struck tree stumps. The main-rotor-mast service record said that the mast was removed from the helicopter after the accident, having been operated for 1,500.8 hours since new and 215.8 hours since overhaul. The service record said that the reason for the removal was a "hard landing." The mast was overhauled by Garlick Helicopters Inc. and installed June 11, 1993, on another helicopter. On June 15, 1996, after another

overhaul, the mast was installed on the accident helicopter; at the time, the mast had been in operation 2,879.7 hours.

When the accident occurred, the mast had a total time since new of 4,006.7 hours. Airframe total time was 9,176.6 hours.

U.S. Army Technical Manual (TM) 55-1520-219-20, the FAA-approved maintenance manual for Southern Aero UH-1Bs, says that the mast must be replaced in instances in which the main rotor stops suddenly with the power on. The manual says that, after any hard landing — which is defined as "any incident in which the impact of the aircraft with the ground causes severe pitching of the main rotor, allowing static stops to severely contact the mast" — the mast should be inspected for "indentation caused by hard contact and static stop for flattened or distorted condition."

If an inspection reveals "yielding or deformation in the area which would be contacted by the main-rotor static stops or other obvious damage," the mast assembly should be considered unserviceable and irreparable, the manual says. If the inspection does not reveal those conditions, the mast assembly should be returned to the depot for evaluation overhaul.

An airworthiness directive (AD) issued by the FAA on June 27, 1997, two months before the accident, directed operators of some Bell helicopter models — but not the UH-1 or other type surplus military helicopters manufactured by Bell — to remove masts at periodic intervals. AD 97-14-12, which applied to Bell model 204B, 205A, 205A-1 and 212 civil helicopters, said that helicopters with Bell part no. 204-011-450-001 main-rotor masts and other main-rotor masts must create component history cards or equivalent records using a retirement-index-number (RIN) system, track increases in the main-rotor mast's RIN and remove the mast from service at a specified RIN.

The AD said that operators of helicopters with part no. 204-011-450-001 masts must calculate the RIN by multiplying total flight hours on the mast by 50 and remove the masts from service before they attained 6,000 hours in service or 300,000 RIN, whichever occurred first.

The main-rotor mast on the accident helicopter had accumulated a RIN of 200,335 when the accident occurred.

AD 97-14-12 was superseded Nov. 23, 1998, by AD 98-24-15, which added Bell model 205B helicopters to the list of those subject to the directives.

At the time of the accident, the most recent AD that applied to Southern Aero UH-1B helicopters with part no. 204-011-450-001 main-rotor masts was AD 98-17-03, which took effect Sept. 5, 1989, and required that masts be removed from service at 15,000 hours time in service. (The AD applied only to masts with less than 14,000 hours time in service when the measure took effect.)

"AD 89-17-03 does not contain any requirement to establish or track RIN on the masts, nor to retire the masts at any particular RIN," NTSB said.

Nevertheless, one month after the accident, Garlick Helicopters told NTSB that, in response to the accident, the company issued Alert Service Bulletin UH1-97-06, directing the removal of part no. 204-011-450-001 main-rotor-mast tubes from service on Garlick UH-1 type helicopters. (External dimensions of part no. 204-011-450-001 main-rotor masts allow them to be interchanged with specific other Bell main-rotor masts, even though part no. 204-01-450-001 main-rotor masts have thinner mast-tube walls.)

Accident investigators found the main-rotor assembly about 50 yards (46 meters) north-northeast of the main wreckage; both rotor blades were attached to the rotor hub and the top of the fractured main-rotor mast.

The helicopter had a maximum gross weight of 8,500 pounds (3,856 kilograms) and an external load limit of 3,600 pounds (1,633 kilograms). With fuel weight at the time of the accident estimated at 250 pounds (113 kilograms), the maximum external-load weight would have been 3,488 pounds (1,582 kilograms). A logging ground crewmember who witnessed the accident estimated that the two western hemlock logs that the pilot first tried to lift totaled 3,100 pounds (1,406 kilograms) and that the larger log, which the pilot tried to lift in his second attempt, weighed 2,400 pounds to 2,500 pounds (1,089 kilograms to 1,134 kilograms).

Accident investigators found the main-rotor assembly about 50 yards (46 meters) north-northeast of the main wreckage; both rotor blades were attached to the rotor hub and the top of the fractured main-rotor mast. There was no evidence that there had been a foreign-object strike before the mast separated, and there was no evidence (other than the fractured main-rotor mast) of any pre-impact airframe structural failure, any disruption of the continuity of engine-to-main-rotor power transmission or engine-to-tail-rotor power transmission or disruption of flight control linkage. There also was no evidence of fire or in-flight loss of engine power.

The main wreckage was at the south end of the two north-south-oriented western hemlock logs that the pilot had been attempting to lift immediately before the accident. The larger log was 95 feet (29 meters) long and had a diameter at its base of 14 inches (36 centimeters). The smaller log was broken, with one section 32 feet (10 meters) long and the other section 20 feet (6 meters) long; diameters of both sections were about seven inches (18 centimeters).

The helicopter's external load line was still attached to the helicopter, and the helicopter's external load indicator registered about 1,100 pounds (499 kilograms). The external load line extended 60 feet to 70 feet (18 meters to 21 meters) into the trees and back to the ground, where the external load hook lay adjacent to the logs, with one end of a choker attached.

Laboratory examination of the top portion of the fractured main-rotor mast revealed that the mast was "circumferentially fractured just below the [damper] support splines," NTSB said. "The upper-mast section also contained a gapped open crack, spiraling upward away from the fracture through the support splines. From the fracture, the crack spiraled almost completely around the circumference of the mast, ending about three inches above the damper splines.

"Magnified examinations of the surfaces of the circumferential fracture disclosed features typical of a torsional overstress separation. The fracture was determined to be an extension of the crack in the upper-mast section. Inspections of the crack and fracture faces found fatigue fracture features on the crack faces adjacent to the upper spirolox groove on the damper splines. The fatigue portion of the crack generally ran circumferential and followed the upper spirolox groove."

The examination revealed that the fatigue origin was on the trailing-corner chamber of the no. five spline near the bottom of the spirolox groove and that the fatigue progressed inward through the wall of the mast and circumferentially, 1.17 inches (3 centimeters) counterclockwise and 0.8 inch (2 centimeters) clockwise from the point of origin. Data obtained from an examination of the area with a scanning electron microscope revealed that at least 7,300 fatigue cycles were present between the origin and a point 0.62 inch (1.6 centimeters) from the origin, where the fracture face texture became coarser and the striations became less distinct.

Examination of the mast tube also revealed several other cracks in the upper spirolox groove of the lower spline. There were cracks in splines 6, 8, 9, 17, 19, 23, 24, and 25, generally at the trailing edges of the spline teeth — the same relative locations on the spline teeth as the fatigue origin of the fracture. All cracks were confined to a single spline tooth, except the crack at tooth 19, which extended to both sides and across three teeth, on the same relative path as the fatigue area of the fracture.

At least three other Bell 205 helicopters or surplus military UH-1 type helicopters experienced similar main-rotor mast fatigue fractures during the 1990s — two in Switzerland and one in Sweden. In two of the three events, the problem was discovered after a fatal accident.

At least three other Bell 205 helicopters or surplus military UH-1 type helicopters experienced similar main-rotor mast fatigue fractures during the 1990s — two in Switzerland and one in Sweden.

In the first event, on Sept. 10, 1991, the main-rotor mast (part no. 204-011-450-105) was removed from a Swiss-registered Bell 205 because of heavy vibrations during flight. The Swiss helicopter operator said in a malfunction report that a fatigue crack had begun in a fillet in the upper lock-ring groove, about one-third of the distance from the top of the mast. The crack had penetrated the thickness of the material and had spread around one-third of the circumference. The mast's operating time was 8,474 hours, and the RIN was estimated at 338,960, about 13 percent more than the maximum allowable RIN of 300,000 specified by AD 98-24-15.

In the second event, on Oct. 17, 1991, the main-rotor mast fractured on a Bell 205A-1 during logging operations in Switzerland, and the pilot was killed. The Swiss Accident Investigation Commission said that the fracture occurred after a fatigue crack developed in the mast (part no. 204-011-450-007). The crack began in a fillet on the lower lock-ring groove of the splines, about one-third of the distance from the top of the mast. The mast's operating time was 5,000 hours, including 2,800 hours since overhaul, and the RIN was estimated at 200,000.

The Swiss commission said that "the existing design of the mast had created many fractural impressions in the sharp corners between the rifling of the splines and lock-ring groove" and that the accident was caused by "fatigue failure of the main-rotor mast following overload, and exceeding operational limits." The commission recommended that the main-rotor masts of Bell 205 helicopters used in logging be inspected for cracks every 200 to 300 operating hours. A subsequent AD required replacement of the mast type.

In the third event, on March 15, 1997, the main-rotor mast of a Bell 205A-1 separated during an external load operation south of Lake Lofssjon, Sweden. The helicopter was destroyed and one person on the ground was killed; the pilot received minor injuries.[2]

In the final report on the accident, the Swedish Board of Accident Investigation (SKH) said that the main-rotor mast had failed because of a fatigue crack that began in a fillet at the bottom of the lower of the two lock-ring grooves that were machined into the spline on the mast about one-third the distance from the top of the mast.

"When the crack had penetrated the thickness of the material of the mast and increased in length to … 3.5 [inches (8.9 centimeters)] …, which corresponds to approximately one-third of the circumference of the mast, the mast failed under load," SKH said.

SKH said that the probable cause of the accident was "a manufacturing error in the main-rotor mast, which led to a mast fracture." Contributing factors were that "the mast type is inappropriately designed from a strength safety point of view," that "the safety margin to a mast fracture is insufficient" and that "the instructions for calculation of the RIN value are unclear and difficult to interpret."

At the time of the Swedish accident, the mast's total operating time was 11,712 hours and the RIN was calculated at 334,917, about 12 percent more than the maximum specified in FAA ADs 97-14-12 and 98-24-15. The mast's most recent overhaul had been about 14,000 load-peak events before the accident. Metallurgical examination of the mast revealed that the fillet in which the fatigue crack began had been machined to a 45-degree chamfer with a fillet radius of 0.0024 inches (0.06 millimeter), compared with 0.020 inch to 0.030 inch (0.51 millimeter to 0.76 millimeter) specified by an engineering drawing.

Because of the accident, SHK recommended that the Swedish Civil Aviation Administration (CAA) "seek the certification and introduction into service of a new type of main-rotor mast." The CAA subsequently issued an AD — LVD 2788 — limiting the life of part no. 204-011-450-001 masts on Bell model 204B, 205A/205A-1 and 212 helicopters to 6,000 hours or 200,000 RIN (compared with FAA AD 98-24-15, which set limits of 6,000 hours or 300,000 RIN) and the life of part no. 204-011-450-007 on the same helicopter models to 10,000 hours or 200,000 RIN (compared with FAA AD 98-24-15, which set limits of 15,000 hours or 300,000 RIN).

After FAA's civil type certification of the Southern Aero UH-1B, the U.S. Army issued a follow-on maintenance manual for the helicopter (TM 55-1520-219-23), which said that the main-rotor sudden-stoppage procedure should be performed and the mast should be removed for overhaul after a main-rotor sudden stoppage with or without power. (The previous requirement, outlined in TM 55-1520-219-20, called for the procedure only after a main-rotor sudden stoppage with power and said that the mast should be removed and replaced.)♦

[Editorial note: This article, except where specifically noted, is based entirely on U.S. National Transportation Safety Board factual report and brief of accident report SEA97FA196. The reports comprise 80 pages and include photographs and diagrams.]

References and Notes

1. U.S. National Transportation Safety Board accident report ANC91LA059. The pilot received minor injuries in the accident. The report said that examination of the engine revealed that the turbine wheel had disintegrated in flight, causing total loss of power.

2. Swedish Civil Aviation Administration accident report C 1998:30e.

Further Reading From FSF Publications

Veillette, Patrick R. "Engine, Transmission Failures Lead Causes of Accidents in U.S. Helicopter Logging Operations." *Helicopter Safety* Volume 26 (May–June 2000).

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