Aviation Investigation Final Report

Location:	Lino Lakes, Minnesota	**Accident Number:**	CEN17FA012
Date & Time:	October 6, 2016, 16:45 Local	**Registration:**	N4035G
Aircraft:	Fairchild Hiller FH 1100	**Aircraft Damage:**	Destroyed
Defining Event:	Mast bumping	**Injuries:**	2 Fatal
Flight Conducted Under:	Part 91: General aviation - Personal		

Analysis

The airline transport pilot was conducting a local flight with one passenger. The accident flight was the pilot's third flight in the helicopter on the day of the accident; before that day, he had not flown the helicopter in nearly one year. One witness stated that he saw the helicopter rocking back and forth before it "spun sideways" and "a bunch of parts" departed the airframe. Some reported hearing a "clunk" sound, and others reported hearing a "pop" sound. Another witness saw the main rotor blades "seize," then "snap off," followed by the tail rotor departing the helicopter. The witness stated that the helicopter then "dropped out of the sky." The fuselage impacted in an open field, and a postcrash fire erupted. The separated main rotor blades and hub were found in a pond about 500 ft south of the main wreckage.

Examination of the rotor mast showed deformation and fractures consistent with overstress under bending and torsion loads but no evidence of preexisting cracks or corrosion. The observed deformation of the mast was consistent with a mast bumping event. Mast bumping can occur in low acceleration of gravity (G) flight conditions, causing the rotor blade to exceed its flapping limits and resulting in the main rotor hub bumping into the rotor shaft. This often results in structural failure of the rotor shaft and a subsequent separation of the main rotor.

Due to the extensive thermal damage to the wreckage, only a limited examination could be conducted; however, no mechanical malfunctions or anomalies were noted that would have precluded normal operation.

The pilot had accumulated about 15,000 flight hours in airplanes but only had about 55 hours flight time in helicopters, most of which were accumulated more than 1 year before the accident. Although the pilot had received instruction on how to avoid mast bumping, given his low helicopter experience relative to his airplane experience, it is possible that he made a large, abrupt flight control input that resulted in a low-G flight condition and led to the observed mast bumping. However, the pilot's control inputs are unknown, and the initiating event for the mast bumping could not be determined.

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this accident to be: The separation of the main rotor assembly due to mast bumping.

Findings

Personnel issues	Recent experience w/ equipment - Pilot
Personnel issues	Incorrect action performance - Pilot
Aircraft	Main rotor mast/swashplate - Capability exceeded

Factual Information

History of Flight

Enroute	Mast bumping (Defining event)
Enroute	Flight control sys malf/fail
Uncontrolled descent	Collision with terr/obj (non-CFIT)

On October 6, 2016, about 1645 central daylight time, a Fairchild Hiller FH-1100 helicopter, N4035G, was destroyed when it impacted the ground near Lino Lakes, Minnesota, following an in-flight separation of the main rotor assembly. The airline transport pilot and passenger sustained fatal injuries, and the helicopter was destroyed. The helicopter was registered to Helicopter Connection LLC, and operated by the pilot under the provisions of 14 Code of Federal Regulations Part 91 as personal flight. Day visual meteorological conditions prevailed, and no flight plan was filed for the local flight, which originated from the Anoka County-Blaine Airport (ANE), near Minneapolis, Minnesota, about 1620.

According to a pilot-rated passenger who had flown with the accident pilot in the helicopter earlier in the day, the accident pilot had not flown the helicopter for about a year and wanted the passenger to "ride along" as a safety pilot. Both the pilot and passenger performed a preflight inspection of the helicopter, which revealed no anomalies. About 1000, they departed on a 5-minute flight then returned and went to lunch. After lunch, they departed on a local flight, which lasted about 45 minutes. After the flight, the passenger asked the pilot if he wanted help moving the helicopter into the hangar, and the pilot indicated that he may fly the helicopter later.

Later that day, several witnesses saw the helicopter flying in a northerly direction. One witness stated that he observed the helicopter rocking back and forth before it "spun sideways" and "a bunch of parts" departed the helicopter. Some reported hearing a "clunk" sound, and others reported hearing a "pop" sound. One witness saw the main rotor blades "seize," then "snap off," followed by the tail rotor departing the helicopter. The witness stated that the helicopter then "dropped out of the sky." Several of the witnesses saw parts departing the helicopter as it descended to ground contact.

Pilot Information

Certificate:	Airline transport; Commercial; Flight engineer; Flight instructor	**Age:**	48,Male
Airplane Rating(s):	Single-engine land; Single-engine sea; Multi-engine land	**Seat Occupied:**	Right
Other Aircraft Rating(s):	Helicopter	**Restraint Used:**	4-point
Instrument Rating(s):	Airplane	**Second Pilot Present:**	No
Instructor Rating(s):	Airplane multi-engine; Airplane single-engine; Instrument airplane	**Toxicology Performed:**	Yes
Medical Certification:	Class 1 With waivers/limitations	**Last FAA Medical Exam:**	August 16, 2016
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	September 5, 2015
Flight Time:	(Estimated) 15000 hours (Total, all aircraft), 55.5 hours (Total, this make and model)		

The 48-year-old pilot held an airline transport pilot certificate with an airplane multi-engine land rating. He held commercial pilot privileges in airplane single engine land, airplane single engine sea, and rotorcraft-helicopter. The pilot also held a flight instructor certificate with airplane single- and multi-engine and instrument airplane ratings. He held a flight engineer certificate with a turbojet rating. The pilot held a Federal Aviation Administration (FAA) special issuance first class medical certificate, dated August 16, 2016, with limitations for corrective lenses and not valid for any class after February 28, 2017. The pilot reported that he had accumulated 15,000 total hours of flight time and 400 hours of flight time during the six months before the medical exam. The last entry in the pilot's logbook was dated September 4, 2015, which was the date he passed his commercial rotorcraft-helicopter checkride. The pilot accumulated 55.5 hours of total flight experience in helicopters at the time of that entry, of which about 38 hours were in the accident helicopter make and model.

The pilot's helicopter flight instructor reported that, from April 15, 2015, to August 4, 2015, he provided instruction to the pilot in the accident helicopter to prepare him for his checkride to obtain a rotorcraft-helicopter rating. The flight instructor stated that the pilot had some trouble at first in the transition from fixed wing to helicopter and that this is fairly common for high-time fixed-wing pilots, such as the accident pilot. After some time, the accident pilot seemed to handle the transition as well as any other of his students that had previous fixed-wing time.

The instructor stated that he gave the pilot ground instruction on teetering rotor systems. When asked how the pilot responded during training situations that could precipitate mast bumping, the instructor stated that the pilot responded correctly to flight in turbulent conditions. He added that, during power loss simulations, the pilot initially was slow to lower the collective and would allow the nose to drop. Eventually, the pilot demonstrated proper entry into and proficiency in autorotations.

The pilot's helicopter flight instructor reported that all the instruction he provided to the pilot took place near Lake Charles, Louisiana, and, after passing his rotorcraft-helicopter checkride, the pilot trailered the helicopter to the Minneapolis area. During the trip, one of the doors of the helicopter came open and cracked the windshield of the helicopter. According to the flight instructor, the pilot had just completed replacement of the windshield a short time before the accident.

Aircraft and Owner/Operator Information

Aircraft Make:	Fairchild Hiller	**Registration:**	N4035G
Model/Series:	FH 1100 NO SERIES	**Aircraft Category:**	Helicopter
Year of Manufacture:	1982	**Amateur Built:**	
Airworthiness Certificate:	Normal	**Serial Number:**	502
Landing Gear Type:	Skid	**Seats:**	5
Date/Type of Last Inspection:	June 18, 2015 Annual	**Certified Max Gross Wt.:**	2750 lbs
Time Since Last Inspection:		**Engines:**	1 Turbo shaft
Airframe Total Time:	501.7 Hrs as of last inspection	**Engine Manufacturer:**	Allison
ELT:	Installed	**Engine Model/Series:**	C20B
Registered Owner:	On file	**Rated Power:**	274 Horsepower
Operator:	On file	**Operating Certificate(s) Held:**	None

The accident helicopter was issued an FAA standard airworthiness certificate on October 20, 1982, and was certificated for normal category operations. The Allison (Rolls Royce) model M250-C20B engine powered a two-bladed, teetering main rotor system. The engine manufacturer indicated that the rated horsepower for the M250-C20B engine is 420 shaft horsepower. According to the helicopter's type certificate data sheet, the engine had a takeoff power rating of 274 shaft horsepower (hp) for a maximum of 5 minutes, and a maximum continuous power rating of 233 shaft hp. The helicopter had a maximum gross weight of 2,750 lbs and could be configured to accommodate a pilot, another pilot or passenger in the cockpit, and three passengers in the cabin. The helicopter's flight manual had limitations to prohibit acrobatic flight and to avoid abrupt control movements when flying in turbulence. The helicopter's most recent annual inspection was completed on June 18, 2015, at a total time in service of 501.7 hours.

In January 2004, the helicopter manufacturer issued Alert Service Letter 23 - 5. The letter indicated that several instances of internal and external mast corrosion had been discovered even when the mast was properly sealed. The corrective action was to remove the transmission top case, with the mast attached, and ship the assembly to the factory for non-destructive inspections. A special coating was to be applied on the interior surfaces. This process is only approved at the factory and cannot be performed in the field. Subsequent to the initial inspection, this process must be done at each overhaul of the transmission or every 10 years whichever comes first.

Meteorological Information and Flight Plan

Conditions at Accident Site:	Visual (VMC)	**Condition of Light:**	Day
Observation Facility, Elevation:	KANE,912 ft msl	**Distance from Accident Site:**	4 Nautical Miles
Observation Time:	16:45 Local	**Direction from Accident Site:**	232°
Lowest Cloud Condition:		**Visibility**	10 miles
Lowest Ceiling:	Overcast / 6000 ft AGL	**Visibility (RVR):**	
Wind Speed/Gusts:	6 knots /	**Turbulence Type Forecast/Actual:**	/
Wind Direction:	10°	**Turbulence Severity Forecast/Actual:**	/
Altimeter Setting:	29.95 inches Hg	**Temperature/Dew Point:**	15°C / 6°C
Precipitation and Obscuration:	No Obscuration; No Precipitation		
Departure Point:	MINNEAPOLIS, MN (ANE)	**Type of Flight Plan Filed:**	None
Destination:	MINNEAPOLIS, MN (ANE)	**Type of Clearance:**	VFR
Departure Time:	16:20 Local	**Type of Airspace:**	

At 1645, the recorded weather at ANE, about 4 miles southwest of the accident site, included wind from 010° at 6 knots, visibility 10 statute miles, overcast clouds at 6,000 feet; temperature 15°C, dew point 6°C, and an altimeter of 29.95 inches of mercury.

Wreckage and Impact Information

Crew Injuries:	1 Fatal	**Aircraft Damage:**	Destroyed
Passenger Injuries:	1 Fatal	**Aircraft Fire:**	On-ground
Ground Injuries:	N/A	**Aircraft Explosion:**	None
Total Injuries:	2 Fatal	**Latitude, Longitude:**	45.193332,-93.137779(est)

The main wreckage came to rest on its right side about 4 nautical miles and 52° magnetic from ANE, on a heading about 20° magnetic. The area around the main wreckage was discolored and charred, consistent with a postaccident ground fire. The remaining sections of wreckage did not exhibit any evidence of pre- or postimpact fire.

The initial piece of wreckage was a section of composite material located about 1,675 ft south of the main wreckage. A debris path extended to the main wreckage and contained the floor mats, a section of white interior material, an exhaust stack, exhaust duct, a section of the tailboom, the engine cowl, a section of exterior metal with the rotating beacon, a seat cushion, and a section of the tail, including the tail rotor and its gearbox. The separated main rotor blades and hub were found east of this debris path in

a pond about 500 ft south of the main wreckage. All major components were accounted for at the scene.

The main wreckage, consisting of the cockpit and cabin, was destroyed by impact and postimpact fire. Cyclic, collective, and tail rotor control continuity could not be established due to substantial damage to the cockpit and cabin areas. However, all observed control discontinuities were consistent with overload or thermal damage.

The engine, transmission, and tail rotor driveshafts exhibited separations. All observed separations were consistent with torsional overload and overload. Circumferential witness marks were observed on the exterior of the tail rotor driveshaft.

The main transmission exhibited sections with thermal melting damage, soot-colored discoloration, and deformation. The separation surface at the top of the mast exhibited overload fractures. The mast could not be rotated by hand.

The main rotor blades and hub exhibited overload fractures on the separation surface. Examination of the main rotor system and components found outside the main wreckage site did not exhibit soot colored discoloration or thermal damage.

Examination of the engine revealed that several compressor blades were missing. The remaining compressor blades were found bent opposite the direction of rotation.

A section of the transmission's main rotor mast and the section of mast from the main rotor hub were removed and were sent to the National Transportation Safety Board (NTSB) Materials Laboratory for detailed examination.

Medical and Pathological Information

An Anoka County Coroner arranged for the Midwest Medical Examiner's Office, Ramsey, Minnesota, to conduct an autopsy on the pilot. Toxicological samples were taken during the autopsy. The cause of death was listed as multiple blunt force injuries and the manner of death was indicated as an accident.

The FAA Bioaeronautical Sciences Research Laboratory, Oklahoma City, Oklahoma, performed toxicology testing on the pilot. Testing was negative for carbon monoxide, ethanol, and all tested-for drugs.

Tests and Research

The retained sections of rotor mast were examined by the NTSB Materials Laboratory. The mast showed deformation and fractures on slant angles consistent with an overstress fracture under bending and torsion loads. Deformation to the mast associated with impact marks

adjacent to the fracture were consistent with mast bumping. No evidence of preexisting cracks or corrosion was observed.

Additional Information

The NTSB database was queried for previous mast bumping accidents with Fairchild-Hiller FH 1100 helicopters. The FTW68A0085, NYC83FA102, LAX83FA362, IAD98FA049, and DFW07FA198 investigations listed occurrences of mast bumping findings and their reports are appended to the docket material associated with this investigation.

The NTSB database also contained the CHI00FA266 investigation. Internal corrosion was observed within the main rotor mast on that helicopter. This previous investigation report is also appended to the docket material associated with this investigation.

The FAA Helicopter Flying Handbook (FAA-H-8083-21A), in part, stated:

Low-G Conditions and Mast Bumping
Low acceleration of gravity (low-G or weightless) maneuvers create specific hazards for helicopters, especially those with semirigid main rotor systems because helicopters are primarily designed to be suspended from the main rotor in normal flight with only small variations for positive G load maneuvers. Since a helicopter low-G maneuver departs from normal flight conditions, it may allow the airframe to exceed the manufacturer's design criteria. A low-G condition could have disastrous results, the best way to prevent it from happening is to avoid the conditions in which it might occur.

Low-G conditions are not about the loss of thrust, rather the imbalance of forces. Helicopters are mostly designed to have weight (gravity pulling down to the earth) and lift opposing that force of gravity. Low-G maneuvers occur when this balance is disturbed. An example of this would be placing the helicopter into a very steep dive. At the moment of pushover, the lift and thrust of the rotor is forward, whereas gravity is now vertical or straight down. Since the lift vector is no longer vertical and opposing the gravity (or weight) vector, the fuselage is now affected by the tail rotor thrust below the plane of the main rotor. This tail rotor thrust moment tends to make the helicopter fuselage tilt to the left. Pilots then apply right cyclic inputs to try to correct for the left. Since the main rotor system does not fully support the fuselage at this point, the fuselage continues to roll and the pilot applies more right cyclic until the rotor system strikes the mast (mast bumping), often ending with unnecessary fatal results. In mast bumping, the rotor blade exceeds its flapping limits, causing the main rotor hub to "bump" into the rotor shaft. The main rotor hub's contact with the mast usually becomes more violent with each successive flapping motion. This creates a greater flapping displacement and leads to structural failure of the rotor shaft. Since the mast is hollow, the structural failure manifests itself either as shaft failure with complete separation of the main rotor system from the helicopter or a severely damaged rotor mast.

In situations like the one described above, the helicopter pilot should first apply aft cyclic to bring the vectors into balance, with lift up and gravity down. Since helicopter blades carry the helicopter and have limited motion attachment, care must be given to those attachment limits. Helicopter pilots should always adhere to the maneuvering limitations stated in the [rotorcraft flight manual]. There may be more than one reason or design criteria which limits the helicopter's flight envelope. Heed all of the manufacturer's limitations and advisory data. Failure to do so could lead to dire, unintended consequences.

Administrative Information

Investigator In Charge (IIC):	Malinowski, Edward
Additional Participating Persons:	David R Nelson; Federal Aviation Administration; Minneapolis, MN David Riser; Rolls Royce; Indianapolis, IN
Original Publish Date:	May 16, 2017
Last Revision Date:	
Investigation Class:	Class
Note:	The NTSB traveled to the scene of this accident.
Investigation Docket:	https://data.ntsb.gov/Docket?ProjectID=94162