Aviation Investigation Final Report

Location:	Gulf of Mexico,	**Incident Number:**	DFW07IA184
Date & Time:	August 16, 2007, 15:13 Local	**Registration:**	N433PH
Aircraft:	Bell 407	**Aircraft Damage:**	None
Defining Event:		**Injuries:**	1 Minor, 1 None
Flight Conducted Under:	Part 135: Air taxi & commuter - Non-scheduled		

Analysis

Shortly after departing in a single-engine helicopter from a platform in the Gulf of Mexico, the commercial pilot heard a "high pitched winding noise" and a "pop" followed by a loss of engine power . The pilot landed the helicopter safely on the water with the floats fully inflated. Shortly thereafter, a large wave impacted the helicopter and broke out the right windshield and rolled the helicopter inverted. The pilot and the passenger were able to exit the helicopter and deploy one of the on-board life rafts. They were later rescued by a local boat and the USCG. Examination of the engine revealed the power turbine (PT) outer shaft was intact; however, there were two spiral fractures observed on the shaft. One spiral fracture was approximately 3-inches-long and originated between a crack within one curvic tooth and the mid-shaft. At the mid-shaft location, as the shaft wall thickens, the spiral direction changed 90 degrees and continued for approximately another half-inch. The second spiral fracture was approximately 180 degrees from the first and was approximately one half-inch in length with one end starting at the root of a curvic tooth. The loaded faces of the curvic-coupling teeth were galled. The fourth stage turbine connector nut was in its proper location and appeared to be undamaged. The deformable lock feature was still engaged with the nut. The easy removal of the nut from the shaft was hampered by the presence of a piece of curvic tooth fragment that was wedged between the nut and the shaft. Once the tooth fragment was removed, the nut rotated freely and was removed. The ring described by the forward face of the shaft, exhibited areas of polishing consistent with contact against the ring described by the aft face of the pinion gear. According to the Rolls-Royce metallurgical examination report, the fracture surfaces exhibited evidence of fatigue. The manufacturer also stated that there have been 16 other instances where the power turbine outer shaft had cracked since 1990; however, none of these resulted in an engine shut down. The only damage noted in these cases was fretting on the mating wheel. Each of the cracks initiated in the curvic coupling, and fretting was found at the fracture origin. The fretting was attributed to a loss of clamp load either from inadequate torque on the PT nut, or raised metal on the curvics that prevented proper seating. As a result of these 16 events, and prior to the PHI accident, Rolls Royce implemented several mitigating

actions to prevent a future occurrence. These included changes to the assembly process, enhanced instructions in the overhaul manual on better handling practices to better protect the curvic couplings. The source of the fractures could not be determined.

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this incident to be: Fatigue failure of the power turbine outer shaft for undetermined reasons.

Findings

Occurrence #1: LOSS OF ENGINE POWER(TOTAL) - MECH FAILURE/MALF
Phase of Operation: CRUISE

Findings
1. (C) TURBINE ASSEMBLY,TURBINE WHEEL - FAILURE,TOTAL

Occurrence #2: FORCED LANDING
Phase of Operation: DESCENT - EMERGENCY

Occurrence #3: ROLL OVER
Phase of Operation: CLIMB

Factual Information

HISTORY OF FLIGHT

On August 16, 2007, at 1513 central daylight time, a single-engine Bell 407 helicopter, N433PH, was not damaged during an emergency landing to the water in the Gulf of Mexico. The commercial pilot sustained minor injuries and the passenger was not injured. The helicopter was registered to and operated by Petroleum Helicopters Incorporated (PHI), of Lafayette, Louisiana. A company visual flight rules flight plan was filed for the on-demand air taxi flight that departed the East Cameron 109 (EC109) offshore platform at about 1507, and was destined for the West Cameron 98 (WC98) offshore platform. Visual meteorological conditions prevailed for the flight conducted under 14 Code of Federal Regulations Part 135.

In a written statement, the pilot reported that he departed the EC 109 platform and climbed to an altitude of approximately 1,000 feet and filed his flight plan with the operator's communications center. Approximately five minutes after departure, the engine chip light illuminated and the pilot immediately turned back to the departure platform. While in the turn, the pilot reported hearing a "high pitched grinding noise" and a "pop" before the engine stopped producing power.

The pilot entered an autorotation to the ocean as he made a Mayday call to his company's communications center. When the helicopter was approximately 75 to 100-feet-high above the water, the pilot initiated a flare to slow the helicopter's descent and attempted to deploy the emergency floats; however, he did not pull the handle hard enough. The pilot made a second attempt, which was successful, and the floats deployed when the helicopter was approximately 10-feet-high above the water. The pilot "pulled pitch" and the helicopter landed safely on the water with the floats fully inflated. Shortly thereafter, a large wave impacted the helicopter and broke out the right windshield and rolled the helicopter inverted.

The pilot and the passenger were able to exit the helicopter and deploy one of the on-board life rafts. Once both individuals were in the life raft, the pilot activated the EPIRB and another PHI helicopter was able to direct a nearby shrimp boat to the life raft. The pilot and the passenger were taken onto the boat and were later recovered by a United States Coast Guard helicopter.

PERSONNEL INFORMATION

The pilot held a commercial pilot certificate for rotorcraft-helicopter with a helicopter instrument rating. In addition, he was also a certificated flight instructor for rotorcraft-helicopter and instrument helicopter. The pilot held a current second-class FAA medical certificate and reported having accumulated a total of 1,855-hours, of which 139-hours were in the same make and model.

METEOROLOGICAL INFORMATION

The pilot reported the weather as wind between 180 and 220 degrees at 20, gusting to 25 knots, visibility 10 miles, broken ceiling 2,000 feet, and seas 6 to 10 feet.

ENGINE EXAMINATION

The engine was a Rolls-Royce M250-C47B, serial number S/N 847233. The M250 engine was a 2-spool turbo-shaft engine. Two power turbine (PT) stages drive the output shaft through a reduction gearbox. The gas producer consists of a compressor section, which has a single centrifugal stage driven by a 2-stage turbine. The combustion chamber is a cylindrical type. The engine power management system consists of a Hydro-Mechanical Unit (HMU), which is controlled by an Electronic Control Unit (ECU).

According to PHI maintenance records, the engine had accumulated 8,606.49 hours time since new (TSN) and of the turbine assembly had accumulated 1,904.7 hours time since new, 282.03 hours time since overhaul (TSO), and 439 cycles since overhaul at the time of the accident.

The engine was removed from the airplane at PHI facilities in Lafayette, Louisiana. The engine was partially disassembled under the supervision of the FAA with representatives from PHI, Bell, and Rolls Royce in attendance. Examination of the engine revealed signs of an uncontained engine failure near the area of the third stage turbine wheel. After the initial examination at PHI, the engine was shipped to Rolls Royce in Indianapolis, Indiana, where a Safety Board Power plants Engineer supervised a more detailed examination.

According to the NTSB Power Plants Group Chairman report, the examination included the removal of the upper and lower gearbox chip detectors, which both contained metallic debris. This debris was also found in the N2 speed pickup, oilcan and the oil filter. Scoring was noted on the oil scavenge pump's #6 and #7 bearing scavenge gear elements and cavities. The #1 and #8 bearing scavenge gear elements and cavities were not damaged.

The turbine module, which included the combustor and the gas producer turbine, were also examined. The combustor liner was intact. The fuel nozzle had previously been removed. The fuel nozzle swirler boss was cracked at the combustor chamber interface. The first stage nozzle shield was intact. The #8 bearing sump cover was deformed near the center consistent with contact with the gas producer turbine tie bolt. The third stage rotating labyrinth seal was intact. Approximately 150 degrees of the inner diameter was severely rubbed, which was consistent with contact against the #6 and #7 bearing housing. A 90-degree segment was worn completely through. The knife-edges were circumferentially and unevenly deformed, with an approximately 90-degree segment almost completely rolled-over. The PT inner shaft was intact; however, the inner race of the #6 bearing was severely deformed and spalled. The mid-shaft pilot ridge was deformed through approximately 120 degrees. The inner surface was corroded. The mating thread for the PT inner shaft spanner nut appeared to be undamaged.

The PT inner shaft spanner nut appeared to be undamaged. The inner diameter of the PT inner shaft at the plane of the #6 bearing displayed rotational scoring as well as metal transfer, which was consistent with contact against the outer diameter of the turbine-to-compressor coupling.

The PT outer shaft was intact; however, there were two spiral fractures observed on the shaft. One spiral fracture was approximately 3-inches-long and originated between a crack within one curvic tooth and the mid-shaft. At the mid-shaft location, as the shaft wall thickens, the spiral direction changed 90 degrees and continued for approximately another half-inch. The second spiral fracture was approximately 180 degrees from the first and was approximately one half-inch in length with one end starting at the root of a curvic tooth. The loaded faces of the curvic-coupling teeth were galled. The fourth stage turbine connector nut was in its proper location and appeared to be undamaged. The deformable lock feature was still engaged with the nut. The easy removal of the nut from the shaft was hampered by the presence of a piece of curvic tooth fragment that was wedged between the nut and the shaft. Once the tooth fragment was removed, the nut rotated freely and was removed. The ring described by the forward face of the shaft, exhibited areas of polishing consistent with contact against the ring described by the aft face of the pinion gear. According to the Rolls-Royce metallurgical examination report, the fracture surfaces exhibited evidence of fatigue.

The gas producer tie bolt was fractured in two locations, which corresponded to the axial front and aft face planes of the first stage turbine disk segment. The outer case of the gas producer turbine bearing support was fractured in three locations. All three fractures were in the axial orientation and through the forward flange. One fracture had progressed through approximately 75 percent of the housing length and the other two had progressed through approximately 95 percent of the housing length. The #8 bearing cavity was wetted with oil and the bearing retainer sleeve appeared to be undamaged. All five inner housing support struts were deformed and one was fractured. The #8 bearing was intact but was rough when rotated by hand. A fractured portion of the aft stub shaft from the first stage turbine wheel was retained in the #8 bearing. The first stage nozzle was intact but ovalized and deformed. Additionally it was corroded on the vane surfaces, leaving an orange-brown discoloration. The trailing edge face was deformed and smeared due to impact in the radial direction consistent with non-concentric contact against the first stage turbine wheel.

The first stage turbine wheel was fractured into multiple pieces. Several of the peripheral fractured pieces were missing. Only four heavily deformed aft teeth of the curvic coupling remained attached to the hub. The first stage turbine energy-absorbing ring was deformed outward. The second stage nozzle was intact but deformed. The leading edge face was deformed and smeared due to impact in the radial direction consistent with non-concentric contact against the first stage turbine wheel. The first stage blade track and several vanes were fractured and missing. The trailing edge inner rim face was rotationally scored consistent with contact with the front face of the platform of the second stage turbine wheel.

The second stage turbine wheel was intact. All the curvic teeth were present but were all

deformed and displayed score marks in the radial orientation. The leading edge blade platform was rotationally scored, consistent with contact against the vane platform of the trailing edge side of the second stage nozzle. The blade leading edges were dented and fractured due to impact. Small wedges of material were missing from the outer half-inch of all the leading edges. The forward stub shaft bearing land and spline appeared to be undamaged. The front pilot stub was rotationally scored. The PT bearing support was intact but the aft flange was deformed. Only the #7 bearing and the #6 to-#7 bearing spacer remained installed in the bearing support hub sleeve. The #6 and #7 bearing support hub was fractured in line with 5 of 48 the #6 bearing plane. The #6 bearing was intact but could not be rotated. The inner housing support struts were intact and appeared to be undamaged. The inner housing was coated with corrosion.

The third stage nozzle was intact and the vane leading edges were undamaged. The trailing edges were deformed due to impact. Several vane trailing edges had tears associated with a fingernail size loss of material. The trailing edge facing flange of the housing was heavily battered. All the blades of the third stage turbine wheel were fractured near the platform. The length of the stubs ranged from approximately 1/16 to 1/8 of an inch. The aft facing surface of blade platform was rotationally scored consistent with contact against the fourth stage stator front sealing surface. The scoring was of a sufficient depth to also deform the material of the blades' trailing edges. The deformed material of the platform caused a raised sharp lip on the edges. The curvic coupling teeth appeared to be undamaged. Eleven blades or shroud fragments were recovered and returned in plastic bags. The inter-stage knife seals were rubbed throughout 360 degrees. The knife-edges were unevenly deformed due to circumferential rubbing, with an approximately 30 degrees segment almost completely worn away.

The fourth stage nozzle was intact, but missing approximately 40 percent of the third stage turbine blade track. The fragments of the fractured blade track were received in plastic bags. The inner sealing diaphragm was separated and fractured. The remaining blade track inner surface was rotationally scored and dented. The vane platform leading edge face was rotationally scored consistent with contact against the trailing edge face of the third stage turbine platform. One-fourth stage vane, at approximately the six o'clock location was missing. The vane leading edges were dented due to impact and the inboard half of the airfoils were plastically deformed in the direction of engine rotation. The vane trailing edges exhibited sharp edged tears with associated fingernail size loss of material. The fourth stage turbine wheel was intact. All but 5 of the blades were missing the outer shrouds and were fractured at approximately 7/8 of the span. The front curvic teeth edges were slightly rounded on the load side corresponding to the damage on the PT outer shaft curvic teeth. The aft curvic teeth were only slightly damaged. The leading edge platform front face was rotationally scored consistent with contact against the 4th stage nozzle aft sealing platform. The leading and trailing edges of the blades were dented due to impact.

Examination of the exhaust collector support housing revealed that it was pock marked in several locations, which was consistent with impact on the internal surface. There were two

tears at the 10 o'clock position. The #5 bearing retainer bore in the exhaust collector housing was galled and was consistent with the marks on the #5 bearing outer race. There were axial score marks noted on the #5 bore diameter forward of the snap ring groove; however, these marks are consistent with the act of #5 bearing removal.

During the preliminary field teardown at the PHI facilities in Lake Charles, Louisiana, the #5 bearing spiral lock ring was not located in its retaining groove and was found loose on the shaft and intact. The #5 bearing spiral lock ring exhibited wear marks on both faces consistent with contact against the #5 bearing shim and the retaining groove in the exhaust collector support housing. The inner diameter of the spiral lock ring was not scored. The aft face of the #5 bearing shim was scored, which was consistent with contact against the forward surface of the #5 bearing. The score pattern appeared to be conical shape. The #5 bearing was intact and a roughness was felt when it was rotated. The outer diameter of the bearing exhibited galling through 360 degrees, which was consistent with the galling observed on the #5 bearing bore. The bearing was disassembled and examined. There was a localized area on the outer race near the manufacturing fracture and exhibited spalling. The castellated (speed signal generator) nut was not damaged.

The six threaded fasteners that mate the gearbox and the turbine modules were measured during the initial examination at PHI. During assembly, the relative angular tolerance of the two mating modules is adjusted using shims clamped by these fasteners. The shim sizes and gaps were measured during the preliminary teardown at the PHI facilities. These measurements were: 12 o'clock, 0.014 (3 shims); 2 o'clock, 0.004 (1 shim); 4 o'clock, 0.004 (1 shim); 6 o'clock, 0 (no shim); 8 o'clock, 0.010 (2 shims); 10 o'clock, 0.014 (3 shims)

The following notes were made in the original teardown report: "Performed visual inspection of turbine mount studs. Noted all studs to have at least three threads showing thru nut. Able to insert a .004" feeler gauge at 12 o'clock, a .002" feeler gauge at 4:00 and 10:00, and unable to insert a feeler gauge at remaining locations. 12:00 turbine nut found without torque, all other nuts found torqued. All turbine mount nuts had nut drag."
The fraying surfaces of 5 shims in contact with the stainless steel bracket and the gearbox cover had a black corrosion residue consistent with fretting activity. It was reported that all the clamping nuts were present. The breaking torque of these nuts was not recorded. Additionally, the shims were battered, corroded, ovalized, and in two cases, torn.

ADDITIONAL INFORMATION

According to Rolls Royce, there have been 16 other instances where the PT Outer Shaft had cracked since 1990; however, none of these resulted in an engine shut down. The only damage noted in these cases was fretting on the mating wheel. Each of the cracks initiated in the curvic coupling, and fretting was found at the fracture origin. The fretting was attributed by Rolls Royce to a loss of clamp load either from inadequate torque on the PT nut, or raised metal on the curvics that prevented proper seating.

As a result of these 16 events, and prior to this PHI incident, Rolls Royce implemented several mitigating actions to prevent a future occurrence. These included changes to the assembly process, enhanced instructions in the overhaul manual on better handling practices to better protect the curvic couplings.

Pilot Information

Certificate:	Commercial	**Age:**	29,Male
Airplane Rating(s):	None	**Seat Occupied:**	Right
Other Aircraft Rating(s):	Helicopter	**Restraint Used:**	
Instrument Rating(s):	Helicopter	**Second Pilot Present:**	No
Instructor Rating(s):	None	**Toxicology Performed:**	No
Medical Certification:	Class 2 Without waivers/limitations	**Last FAA Medical Exam:**	January 1, 2007
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	July 1, 2007
Flight Time:	1855 hours (Total, all aircraft), 139 hours (Total, this make and model), 1601 hours (Pilot In Command, all aircraft), 109 hours (Last 90 days, all aircraft), 50 hours (Last 30 days, all aircraft)		

Aircraft and Owner/Operator Information

Aircraft Make:	Bell	**Registration:**	N433PH
Model/Series:	407	**Aircraft Category:**	Helicopter
Year of Manufacture:		**Amateur Built:**	
Airworthiness Certificate:	Normal	**Serial Number:**	53679
Landing Gear Type:	Skid	**Seats:**	7
Date/Type of Last Inspection:	August 1, 2007 AAIP	**Certified Max Gross Wt.:**	5250 lbs
Time Since Last Inspection:		**Engines:**	1 Turbo shaft
Airframe Total Time:	2215 Hrs at time of accident	**Engine Manufacturer:**	Rolls-Royce
ELT:	Installed, not activated	**Engine Model/Series:**	C-47-B
Registered Owner:	PHI, Inc.	**Rated Power:**	650 Horsepower
Operator:		**Operating Certificate(s) Held:**	None

Meteorological Information and Flight Plan

Conditions at Accident Site:	Visual (VMC)	**Condition of Light:**	Day
Observation Facility, Elevation:		**Distance from Accident Site:**	
Observation Time:		**Direction from Accident Site:**	
Lowest Cloud Condition:	Clear	**Visibility**	10 miles
Lowest Ceiling:	Broken / 2000 ft AGL	**Visibility (RVR):**	
Wind Speed/Gusts:	20 knots / 25 knots	**Turbulence Type Forecast/Actual:**	/
Wind Direction:	180°	**Turbulence Severity Forecast/Actual:**	/
Altimeter Setting:		**Temperature/Dew Point:**	
Precipitation and Obscuration:			
Departure Point:	E Cameron 109	**Type of Flight Plan Filed:**	Company VFR
Destination:	W Cameron 98	**Type of Clearance:**	None
Departure Time:	15:07 Local	**Type of Airspace:**	

Airport Information

Airport:	None	**Runway Surface Type:**	
Airport Elevation:		**Runway Surface Condition:**	
Runway Used:		**IFR Approach:**	None
Runway Length/Width:		**VFR Approach/Landing:**	Forced landing

Wreckage and Impact Information

Crew Injuries:	1 Minor	**Aircraft Damage:**	None
Passenger Injuries:	1 None	**Aircraft Fire:**	None
Ground Injuries:	N/A	**Aircraft Explosion:**	None
Total Injuries:	1 Minor, 1 None	**Latitude, Longitude:**	29.256111,-92.847778

Administrative Information

Investigator In Charge (IIC):	Yeager, Leah
Additional Participating Persons:	Lewis Smith; FAA/FSDO; Baton Rouge, LA Harald Reichel; NTSB; Washington, DC Jon Michael; Rolls Royce; Indianapolis, IN Michael Block; PHI; Lafayette, LA
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