Aviation Investigation Final Report

Location:	Bel Air, Maryland	**Accident Number:**	ERA22LA117
Date & Time:	February 9, 2022, 16:28 Local	**Registration:**	N9159F
Aircraft:	Hughes 369D	**Aircraft Damage:**	Substantial
Defining Event:	Loss of engine power (partial)	**Injuries:**	1 None
Flight Conducted Under:	Part 91: General aviation - Positioning		

Analysis

The pilot reported that he had heard a whistling sound with the engine while conducting powerline operations and landed out of precaution. He examined the engine and consulted with maintenance personnel, but no mechanical anomalies were found. The helicopter was grounded for the workday; however, at the end of the day, a decision was made to try and return the helicopter back to its base of operations. During the flight, the engine chip light illuminated followed by the smell of engine oil and a grinding noise. The pilot attempted a precautionary landing to a field, but smoke filled the cabin, reducing his visibility while in the landing flare. The pilot attempted to slow the rate of descent and impacted the ground in a near-level attitude. During the ground run the front portion of the skids dug into the ground, causing the helicopter to pitch forward. The pilot applied aft cyclic to keep the helicopter level. During the landing sequence the main rotor blades struck the tail boom, which resulted in the horizontal and vertical stabilizers and the tail rotor assembly separating from the helicopter.

Postaccident examination of airframe and engine revealed residual oil on the interior and exterior of the engine access doors and on the interior of the engine compartment. The oil supply line that feeds oil to the Nos. 6 and 7 bearings was fractured along with its support bracket. Numerous other components including the gearbox housing, N1 coupling, gas producer (GP) turbine support assembly (which included a sump nut, retaining ring and plate, the No. 8 oil supply jet, and a fractured shear pin), No. 8 bearing, No. 8 rotating seal, No. 8 stationary seal, and the outer combustion chamber, had also fractured and/or sustained high heat damage. Evidence of fretting damage was also observed on multiple components.

The National Transportation Safety Board (NTSB) Materials Laboratory analyzed these components and determined that the engine most likely failed due to bearing failures in the turbine section resulting from the high-cycle fatigue fracture of the oil supply line that fed oil to the Nos. 6 and 7 bearings. The oil line failure led to rapid deterioration of the bearings from oil starvation, resulting in misalignment of rotating components and interference with stationary components within the engine, producing the grinding noise noted by the pilot. The oil line fracture was also likely associated with the smell of oil followed by the smoke in the cockpit reported by the pilot.

Further examination of the engine revealed that the engine failure likely started with the No. 8 bearing stationary seal. The outside diameter of the seal was undersized, so it did not have the specified interference fit with the GP support hub. The improper fit likely led to insufficient support for the No. 8 bearing and excessive flexing of the No. 8 stationary seal cup wall. As a result, the stationary seal developed fatigue cracks and eventually fractured.

The lack of interference fit with the No. 8 stationary seal likely affected the effectiveness of the seal between the stationary and rotating seals, which could have allowed oil to escape forward past the seal and into the gas path. The fracture of the No. 8 stationary seal reduced the support for the rotating turbine components at the No. 8 bearing, which likely led to increased vibrations in the engine. Fractures in the outer combustion chamber, oil line clamp, and gearbox case housing all had indications of high-cycle fatigue fracture from vibration loading. These failures likely resulted from excessive vibrations associated with the reduction in support for the turbine section rotating components. The fractured oil line support clamp failed followed by the oil supply line.

According to overhaul records, the turbine section was last overhauled in July 2020, when the GP turbine wheels were replaced due to service time limits. A review of the engine manufacturer’s overhaul maintenance manual (OHM) revealed the condition of the No. 8 stationary seal should have been inspected; however, there was no indication in the overhaul records that the No. 8 stationary seal had been inspected, removed, or replaced.

The turbine module was removed by the operator a few months after the overhaul due to a N2 lockup and sent to a repair facility. The repair facility ended up removing the GP support and sending the unit to another facility where the 4th stage wheel was replaced. According to the engine manufacturer, the repair facility should have been following the same OHM inspection criteria that included inspection of the No. 8 stationary seal. According to the repair facility, they had no record that the No. 8 stationary was repaired/replaced at the time the GP support/4th stage wheel was replaced.

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this accident to be:

A loss of engine power due to bearing failures in the turbine section resulting from a fatigue fracture of the oil supply line that fed oil to the Nos. 6 and 7 bearings. The oil line failure led to rapid deterioration of the bearings from oil starvation. Contributing to the power loss was the installation of a No. 8 stationary seal with an undersized outside diameter, which resulted in a reduction of support for the turbine section rotating components and resulted in high vibration loads in the engine, which ultimately caused the oil supply line to fatigue and fail. Also contributing was the improper or inadequate inspections of the No. 8 stationary seal by maintenance personnel.

Findings

Aircraft	(general) - Failure
Aircraft	(general) - Failure
Aircraft	(general) - Inadequate inspection

Factual Information

History of Flight

Enroute-cruise	Loss of engine power (partial) (Defining event)
Landing-flare/touchdown	Hard landing

HISTORY OF FLIGHT

On February 9, 2022, at 1628 eastern standard time, a McDonald Douglas MD-369D helicopter, N9159F, was substantially damaged when it was involved in an accident near Bel Air, Maryland. The commercial pilot was not injured. The helicopter was operated as a Title 14 *Code of Federal Regulations* Part 91 positioning flight.

The pilot stated that while conducting powerline inspection work earlier in the day, line personnel reported that the helicopter was making a strange "whistle" noise. The pilot inspected the helicopter and no anomalies were noted or observed. The pilot continued with normal operations, but the noise continued and one of the operator's superintendents took a video, where a "whistle"-like sound could be heard. The pilot landed and ceased all human external cargo operations. He then reviewed the video, re-examined the helicopter, and spoke with company maintenance personnel. Though no obvious mechanical issues were observed, the pilot "parked" the helicopter for the remainder of the workday.

At the end of the workday, the pilot again inspected the aircraft and found no mechanical reason not to reposition the helicopter back to its normal base of operations. He and another company helicopter departed as a flight of two. Several minutes into the flight, the pilot said the ENGINE CHIP light illuminated. He told the other pilot that even though the engine seemed to be operating normally, he would need to land as soon as practicable. Shortly after, the engine began to make a "grinding" noise along with an odor of engine oil, which eventually became smoke in the aft section of the passenger compartment. With the presence of smoke and the potential for an inflight fire, the pilot initiated an emergency descent-to-land to a suitable landing area. During the descent the engine noise and smoke in the aft section of the cabin intensified and began moving to the forward section of the cockpit. Descending through the landing flare, as the pilot leveled the helicopter to land, the engine stopped producing power and smoke in the cockpit reduced his visual reference to the ground. The pilot attempted to slow the rate of descent and impacted the ground in a near-level attitude. During the ground run the front portion of the skids dug into the ground, causing the helicopter to pitch forward. The pilot applied aft cyclic to keep the helicopter level. During the landing sequence, the main rotor blades struck the tail boom, which resulted in the horizontal and vertical stabilizers and the tail rotor assembly separating from the helicopter. Residual oil was observed on the interior and exterior surfaces of the engine access doors and on the interior of the engine compartment.

AIRFRAME AND ENGINE EXAMINATION

The helicopter was recovered by the operator and taken to their facility in Gettysburg, Pennsylvania. Before the engine was removed, an external examination of the lubrication system between the airframe and the engine was conducted. Neither the aircraft-mounted oil reservoir nor the oil cooler were damaged, and no residual oil was noted within the cabin area (where the cooler and reservoir were located). The engine was then removed from the airframe and shipped to Keystone Turbine Services, Coatesville, Pennsylvania, where a full engine examination was conducted under the supervision of the NTSB.

Examination of the engine revealed that each of the external oil lines were secure except for the oil line which supplies pressure oil to the turbine sumps. The line connected to a horizontal fire shield and a T-fitting near the Nos. 6 and 7 bearing sump. The line was fractured at the horizontal fire shield and misaligned. Also, the clamp that secured the line to the turbine module was fractured.

The scavenge oil filter was clean and full of oil. A small amount of ferrous debris was observed on the filter. The pending bypass button was not extended. Both the upper and lower engine magnetic chip detector plugs were removed, and ferrous debris was observed on both.

The gas producer turbine rotor (N1) was seized but the power turbine (N2) turned and was connected to the powertrain. No damage was noted on the first stage compressor blades or compressor inlet. The fourth stage turbine wheel was normal in appearance when viewed from the exhaust collector.

The accessory gearbox was intact except for one fractured compressor mount pad. As the compressor was removed, the mount was found liberated from the gearbox housing. The gearbox housing and cover were split apart, and all the internal gears and bearings were intact, except for the No. 2 ½ bearing. The No. 2 ½ bearing was missing 6 rollers, consistent with having fallen out during the compressor removal, and were recovered from the bottom of the engine stand. The rollers were undamaged. The compressor bore on the gearbox cover displayed a wear step between the 1:00 to 12:00 position.

The combustion section was not damaged. The inner surface of the outer combustion case barrel was missing material and was cracked. Several pieces of barrel material were recovered from the turbine inlet. The combustion liner was covered in carbon, but no mechanical damage was observed.

Several areas within the turbine module displayed evidence of oil starvation:

• No. 8 bearing cavity

• No. 8 bearing sump oil scavenge line (was also clogged with debris/dry residue)

• No. 8 bearing sump oil supply tubes

• No. 6/7 bearing cavity

• No. 6/7 bearing scavenge orifice

• No. 6/7 bearing oil supply tube

• No. 6/7 bearing external sump can

The No. 6 bearing rollers were disintegrated, which precluded inspection of the No. 7 bearing.

The No. 8 bearing balls were also disintegrated and the remaining components (inner race, outer race, and separator) were removed. The bearing components displayed thermal signatures consistent with overtemperature operation.

The gas producer (GP) rotor tie bolt nut was loose but remained in position within the locking feature; the GP rotor was intact. The trailing edge blade tips of the first stage turbine wheel displayed mechanical damage and the upstream face of the wheel was circumferentially gouged and smeared. The energy absorbing ring location tabs and corresponding slots in the GP support displayed heavy wear.

The No. 5 bearing turned freely and smoothly and displayed some brown discoloration. The N2 rotor was removed and all airfoils were intact. The upstream face of the third stage turbine wheel was coated in a gray carbon-like substance. The N2 shaft was intact with some discoloration and carbon noted on the exterior surface. The N1 shaft was intact and exhibited some slight bulging at the end of the shaft.

The engine compressor turbine assembly, gearbox housing, oil pump, oil supply line with fittings and clamp assembly, N1 coupling, GP turbine assembly, GP turbine support (which included a sump nut, retaining ring and plate, and the No. 8 oil supply jet), No. 8 bearing, No. 8 rotating and stationary seal, No. 8 bearing spanner nut, and the outer combustion chamber, were sent to the NTSB Materials Laboratory for examination.

Examination of these components by the NTSB Materials Laboratory determined numerous instances of high heat damage and fracture due to high-cycle fatigue.

The gearbox housing support lug located on the upper left side of the gearbox exhibited fracture surfaces consistent with high-cycle fatigue. The oil pump, which was installed on the interior of the gearbox, was intact. There were no fretting contact marks noted on the pump mating to blended area on gearbox housing. Pitting consistent with cavitation damage were noted on gear teeth in the pressure body.

The oil supply line that was found fractured during the engine exam, and its associated support clamp, also exhibited fracture surfaces consistent with high-cycle fatigue. This oil line supplied oil to the Nos. 6 and 7 bearings in the turbine section. The fracture of this line most likely led to the rapid deterioration of the bearings from oil starvation.

The GP support and its related components revealed the retaining plate shear pin was fractured. The fracture surfaces showed curving crack arrest lines and dark tinting consistent with fatigue. The retaining plate was installed on the aft side of the GP support hub and had multiple recesses machined into the outer diameter, including those for accommodating the shear pin and the No. 8 oil supply jet. A mark was observed on the clockwise side of the recess for the shear pin corresponding to contact with the aft piece of the shear pin that was not recovered. A separate mark was observed near the clockwise end of the recess for the No. 8 oil jet, and a corresponding contact mark was observed on the lower inboard side of the No. 8 oil supply jet body. The marks on the retaining plate recesses corresponded to contact with the shear pin and the oil jet, respectively, as the retaining plate rotated counterclockwise relative to the GP support hub.

On the forward side of the retaining plate, damage from fretting contact with the No. 8 bearing outer race was observed near the retaining lug on the forward face next to the inside diameter. The surfaces of the retaining lug on both the clockwise and counterclockwise sides showed damage from fretting contact with the No. 8 bearing outer race. The contact damage was more extensive on the lower (clockwise) side of the lug, consistent with the bearing outer race rotating counterclockwise relative to the retaining plate. (The GP turbine and No. 8 bearing inner race normally rotate clockwise).

Fretting contact marks were observed on the sump nut face corresponding to contact with the outer diameter of the retaining plate. A wear contact mark was observed on one of the castellation surfaces on locking flange on the aft side of the sump nut. The wear mark corresponded to contact with the retaining ring with the sump nut flange approximately flush to the aft side of the GP hub.

The retaining ring for the sump nut is installed in a groove at the aft side of the castellated GP support hub. The aft side of the GP support hub was deformed radially outward at five of the castellations. As a result of the deformation, the retaining ring did not fully seat in the groove around the diameter of the GP support hub. However, the deformation did not appear to affect full engagement of the retaining ring with the sump nut lock flange.

The e-ring seal was not located, and there was no documentation confirming the presence or absence of the e-ring seal in any photographic documentation or notes taken at the time of the engine teardown.

The No. 8 bearing inner race, cage, and outer race were intact, and all rolling elements were missing. The No. 8 bearing outer race and cage were held within the fractured aft piece of the stationary seal. The notch on the aft side of the No. 8 bearing outer race and the corresponding lug on the forward face of the retaining plate were intact but marks consistent with heavy contact were observed. The shear pin restraining rotation of the forward end of the stationary seal was intact in the GP support. The components of the No. 8 bearing were substantially darkened consistent with high heat and loss of lubrication.

The stationary seal for the No. 8 bearing was tinted consistent with high heat exposure and was fractured at the forward end of the bearing cup adjacent to the shoulder for the bearing outer race. Flat oxidized areas with curving boundaries were observed consistent with fatigue. The fatigue initiated from multiple origins at the inner diameter of the cup wall around the circumference. The planes associated with each origin were slightly angled relative to the circumferential plane consistent with torsional loading combined with flexure or tension loads. The relative orientation of the angle was consistent with torsion loading associated with the aft end of the seal loaded counterclockwise relative to the forward end, which is consistent with the rotation observed associated with the retaining plate. Ratchet marks were rubbed from contact with the mating side of the fracture, consistent with counterclockwise rotation of the aft side of the fracture relative to the forward side following fracture.

The fracture surface on the No. 8 stationary seal was further examined using the scanning electron microscope (SEM). The fracture surface showed substantial damage from post-fracture rubbing contact, and fatigue striations were also observed.

The shoulder on the No. 8 stationary seal adjacent to the fracture surface showed heavy fretting contact damage on the aft face adjacent to the inside diameter of the shoulder, consistent with contact with the No. 8 bearing outer race. Fretting damage was also observed on the outside diameter of the stationary seal where it contacted the GP support hub.

According to information provided by representatives for the engine manufacturer, the No. 8 stationary seal should have an interference fit in the GP support hub within approximately ¼-inch of the shoulder against which the bearing cup portion of the seal rests, and the stationary seal has two part-number options available to achieve the proper interference fit. The "-1" part has an outside diameter that is slightly larger than the "-2" part.

The inside diameter of the GP support hub was measured, and the measured value could be within the specified maximum inside diameter after accounting for the range of accuracy of the measuring device. The outside diameter of the No. 8 stationary seal was measured on the forward piece in the interference fit region using calipers. Several measurements were taken including areas that appeared to have original machining markings, and none would provide an interference fit with the as-measured or the as-specified inside diameter of the corresponding area on the GP support. It was undersized by 0.008 inch or more, depending on which part number had been installed. A part number for the No. 8 stationary seal could not be obtained due to heat and impact damage.

Examination of the No. 8 rotating seal revealed heavy circumferential rubbing damage and high heat damage. White deposits were observed in the rotating seal ridges. The flange in the middle of the rotating seal was fractured around the circumference, and the remaining portion was deformed aft.

The No. 8 spanner nut lock flange was deformed in one location and had a semicircular section removed from a second area. The size of the semicircular cutout was consistent with removal of a deformed flange segment from a prior installation.

Pieces of the interior wall of the outer combustion case were re-assembled and two of the pieces were darkened relative to the mating piece, consistent with post-fracture heat exposure. Examination of the fractured pieces showed substantial rub damage with lips on either side of the surface consistent with vibratory contact damage. After an initial optical examination using a stereo microscope, the fracture surfaces on the two pieces without heat damage were further examined using the SEM. Although most of the surfaces were obliterated by rub damage, striations consistent with fatigue fracture were observed.

The compressor assembly was intact and rotated freely. Some impact marks were observed on the aft end face of the impeller stub shaft.

MAINTENANCE RECORDS

According to overhaul records, the turbine section was last overhauled on July 2, 2020, when the GP turbine wheels were replaced due to service time limits. A review of the engine manufacturer's overhaul maintenance manual (OHM), section 72-50-00 L, revealed the following inspections were required when the turbine module was removed to address life expired 1st or 2nd stage turbine wheels:

(1) Visually inspect the No. 1 and No. 2 turbine nozzle assembly for any damage or discrepancies.

(2) Inspect the gas producer tie bolt, 2nd-stage splined adapter and compressor to turbine coupling shaft. Replace if necessary.

(3) Inspect all oil nozzles and passages for carbon formation and/or obstructions. Clean as necessary. During assembly, make sure oil will pass through all designated nozzles and that they are targeted appropriately.

(4) Inspect the power turbine rotating labyrinth 9--12 and 13--18 seals.

(5) Inspect 3rd-- and 4th--stage turbine wheels for obvious cracks or damage.

(6) Visually inspect the power turbine inner shaft I.D. for excessive carbon buildup. Clean any excessive carbon from the power turbine inner and outer shaft.

The required inspections necessitate disassembly, inspection, and reassembly for the turbine module components, including the GP support bore diameter and the condition of the No. 8 stationary seal; however, there was no indication in the overhaul records that the No. 8 stationary seal had been inspected, removed, or replaced.

A few months after this overhaul, in September 2020, the turbine module was removed from the engine by the operator and sent to a repair facility due to a N2 lockup. The repair facility ended up removing the GP support and sending the unit to another facility where the 4th stage wheel was replaced. According to the engine manufacturer, the repair facility that received the GP support should have been following the same OHM inspection criteria as stated above, which included inspection of the No. 8 stationary seal at the time the 4th stage wheel was replaced. There was no entry in the maintenance record that the No. 8 stationary was repaired/replaced at the time the GP support/4th stage wheel was replaced.

Pilot Information

Certificate:	Commercial; Flight instructor	**Age:**	41,Male
Airplane Rating(s):	Single-engine land	**Seat Occupied:**	Left
Other Aircraft Rating(s):	Helicopter	**Restraint Used:**	4-point
Instrument Rating(s):	Helicopter	**Second Pilot Present:**	No
Instructor Rating(s):	Helicopter	**Toxicology Performed:**	
Medical Certification:	Class 2 Without waivers/limitations	**Last FAA Medical Exam:**	August 30, 2021
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	January 24, 2021
Flight Time:	7958 hours (Total, all aircraft), 3152 hours (Total, this make and model), 6520 hours (Pilot In Command, all aircraft), 53 hours (Last 90 days, all aircraft), 69 hours (Last 30 days, all aircraft), 5.6 hours (Last 24 hours, all aircraft)		

Aircraft and Owner/Operator Information

Aircraft Make:	Hughes	**Registration:**	N9159F
Model/Series:	369D	**Aircraft Category:**	Helicopter
Year of Manufacture:	1979	**Amateur Built:**	
Airworthiness Certificate:	Normal	**Serial Number:**	1090605D
Landing Gear Type:	None; Skid	**Seats:**	4
Date/Type of Last Inspection:	November 17, 2021 Continuous airworthiness	**Certified Max Gross Wt.:**	3000 lbs
Time Since Last Inspection:	43 Hrs	**Engines:**	1 Turbo shaft
Airframe Total Time:	17681 Hrs at time of accident	**Engine Manufacturer:**	Rolls Royce
ELT:	Not installed	**Engine Model/Series:**	M250-C20B
Registered Owner:	TVPX AIRCRAFT SOLUTIONS INC TRUSTEE	**Rated Power:**	425 Lbs thrust
Operator:	On file	**Operating Certificate(s) Held:**	Rotorcraft external load (133), Commuter air carrier (135)

Meteorological Information and Flight Plan

Conditions at Accident Site:	Visual (VMC)	**Condition of Light:**	Day
Observation Facility, Elevation:	APG,44 ft msl	**Distance from Accident Site:**	9 Nautical Miles
Observation Time:	16:58 Local	**Direction from Accident Site:**	120°
Lowest Cloud Condition:	Clear	**Visibility**	7 miles
Lowest Ceiling:		**Visibility (RVR):**	
Wind Speed/Gusts:	8 knots /	**Turbulence Type Forecast/Actual:**	None / None
Wind Direction:	190°	**Turbulence Severity Forecast/Actual:**	N/A / N/A
Altimeter Setting:	29.92 inches Hg	**Temperature/Dew Point:**	10°C / -2°C
Precipitation and Obscuration:	No Obscuration; No Precipitation		
Departure Point:	Bel Alr, MD	**Type of Flight Plan Filed:**	None
Destination:	Hartford CO, MD (0W3)	**Type of Clearance:**	VFR
Departure Time:	16:28 Local	**Type of Airspace:**	Class G

Wreckage and Impact Information

Crew Injuries:	1 None	**Aircraft Damage:**	Substantial
Passenger Injuries:	N/A	**Aircraft Fire:**	None
Ground Injuries:	N/A	**Aircraft Explosion:**	None
Total Injuries:	1 None	**Latitude, Longitude:**	39.5359,-76.3483(est)

Administrative Information

Investigator In Charge (IIC):	Read, Leah
Additional Participating Persons:	Steven O'Rourke; FAA/FSDO; Baltimore, MD Jon-Adam Michael; Rolls Royce; Indianapolis, IN Brandon Jackson; Haverfield Aviation; Gettysburg, PA
Original Publish Date:	February 21, 2024
Last Revision Date:	
Investigation Class:	Class 3
Note:	The NTSB did not travel to the scene of this accident.
Investigation Docket:	https://data.ntsb.gov/Docket?ProjectID=104620