# Aviation Investigation Final Report

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| **Location:** | Oktaha, Oklahoma | **Incident Number:** | ENG24LA028 |
| **Date & Time:** | July 26, 2024, 10:40 Local | **Registration:** | N793SF |
| **Aircraft:** | Bell 407 | **Aircraft Damage:** | Minor |
| **Defining Event:** | Uncontained engine failure | **Injuries:** | 3 None |
| **Flight Conducted Under:** | Part 135: Air taxi & commuter - Non-scheduled - Air Medical (Unspecified) | | |

## Analysis

The helicopter exhibited multiple impact marks and penetrations in the exhaust duct, exhaust collector, and horizontal fire shield, all consistent with turbine debris exiting out the back of the engine through the exhaust as well as radially outward at the gas producer support case. The gas producer stage 1 turbine wheel experienced a contained disk burst and was fragmented into multiple pieces. After the disassembly and examination of the engine was completed, various turbine parts were sent to the Rolls-Royce Material Laboratory for metallurgical examination.

The parts were subjected to scanning electron microscope (SEM) examination to determine the fracture origin(s), fracture type, and any anomalies at the fracture origin as well as energy dispersive x-ray spectroscopy (EDS) and hardness measurements to determine if the parts were manufactured in accordance with the drawing specifications. All the turbine parts examined met the drawing specification with no material anomalies identified and all fractured parts, except for the power turbine stage 3 turbine wheel, fractured due to overload.

The power turbine stage 3 turbine wheel was completely corn-cobbed with almost all the airfoils fractured transversely across the platform; one airfoil exhibited features indicative of a high cycle fatigue (HCF) fracture with initiation at the trailing edge and progressing forward approximately a half inch before the blade ultimately failed in overload. The rest of the power turbine stage 3 turbine wheel fracture surfaces showed indications consistent with overload. No anomalies were found in the material composition of the part, and no anomalies were found at the fracture origin. According to the maintenance records, the power turbine stage 3 turbine wheel was visually and fluorescent penetrant inspected at the last engine overhaul, approximately 45.5 hours and 99 cycles, prior to the accident flight.

The power turbine stage 3 wheel crack was most likely not present during the last inspection, 99 cycles prior to the event. HCF is typically categorized as high frequency loading usually associated with resonance/natural frequency of the material driven by low energy levels or forced vibration at higher energy levels. Striations are markings found on cyclic fractures that correlate to alternating stress cycles where one striation typically equates to a single stress cycle.

HCF striation counting to determine the length of time the crack propagated before failure is difficult because striations are hard to resolve (count) due to the low alternating stress condition and high number of stress cycles.  Low cycle fatigue (LCF), on the other hand, is generally mission driven and occurs at lower frequencies and higher stresses, where the stress cycles correlate to a flight cycle. LCF striations are easier to observe and count to estimate of crack propagation time. One feature of HCF failures is that HCF striations will typically exceed the known mission flight cycles; therefore, it was unlikely that the crack was present during the last inspection, 99 flight cycles prior to the event.

The engine's electronic control unit (ECU) was downloaded and the engine operating and fault data showed that the first indications of an engine problem were a reduction of power turbine speed and torque. Several seconds later, a drop in fuel flow and gas producer turbine speed were observed, indicating a problem with the gas turbine section. The initial engine failure was due to the observed HCF fracture of a single power turbine stage 3 turbine wheel blade and the subsequent loss of the remaining blades in overload followed by the gas producer stage 1 turbine wheel burst.

The most likely cause of the gas producer stage 1 turbine wheel burst was an overspeed event resulting in stresses that exceeded the material's capability. A rotor disk burst is typically caused by either a material anomaly, such as a crack, that compromises the material design or an overspeed condition where the centrifugal loads exceed the capability of the material to withstand those stresses. Examination of all recovered gas producer stage 1 turbine wheel fragments exhibited overload features with no observed material anomalies.

There were no overspeed events recorded on the ECU. The turbine-to-compressor coupling shaft connects the gas producer turbine rotor, which is located at the back of the engine, to the compressor rotor and accessory gearbox towards the front of the engine. The gas producer turbine speed sensor is located in the accessory gearbox. The accessory gearbox gears, the turbine-to-compressor coupling, and the compressor impeller were all in good condition and showed no signs of damage, which indicated the whole gas producer gear train did not overspeed.

The gas producer stage 1 wheel most likely decoupled from the gas producer stage 2 wheel, which allowed it to overspeed while the remainder of the gas producer gear train continued to drive the accessory gearbox and compressor impeller. With the loss of the gas producer turbine stage 1 wheel, the Ng spool would decelerate. The drop in gas producer speed was observed in the engine control unit data shortly after the observed power turbine speed and torque reduction.

The power turbine and gas producer turbine rotors are not mechanically coupled, but the power turbine bearing support provides a load path between the two spools. The power turbine bearing support provides support for the front (stage 2 turbine wheel) of the gas producer turbine rotor by the No. 7 roller bearing and the rear (stage 3 turbine wheel) of the power turbine rotor by the No. 6 roller bearing.

The gas producer stage 3 turbine wheel failure created a sufficient imbalance where the power turbine rotor rotated "off-center' or in an eccentric motion. This results in contact and rub which imparted high radial and axial loading from the power turbine rotor to the power turbine bearing support. Indications of "off-center" rotation of the power turbine rotor included: 1) stage 3 turbine wheel and the power turbine support contact with the power turbine labyrinth seal, 2) 360° circumferential rub on the power turbine shaft and the No. 6 bearing inner race land, and 3) rub on the power turbine bearing support front face outer diameter with corresponding contact on the inner diameter of the power turbine rotating labyrinth seal.

The high radial and axial loading imparted through the power turbine bearing support to the gas producer rotor resulted in static hardware contact and rub on the gas producer stage 2 turbine wheel which caused increased drag and a speed mismatch between the gas producer stage 1 and stage 2 wheels. The gas producer stage 1 and stage 2 wheels are held together by a high compressive preload on the tie bolt that keeps the curvic coupling teeth properly aligned and loaded so that the gas producer transmits the torque at the same rotation speed. Since the gas producer wheels rotate at the same speed, there is minimum torsional/rotational load on the tie-rod during normal operation. However, when a mismatch occurs, the tie-rod will experience an unintended high torsion load that can cause the tie-rod to fracture.

Metallurgical examination of the tie rod confirmed that it fractured due to torsional overload. The fracture of the tie-rod allowed the gas producer stage 1 and stage 2 wheels to separate and the gas producer stage 1 wheel to overspeed. All the stage 1 turbine wheel aft curvic coupling teeth and the corresponding stage 2 turbine wheel forward curvic coupling teeth were rotationally smeared over with very little tooth height remaining consistent with rotational speed mismatch between the two gas producer turbine wheels.

## Probable Cause and Findings

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

The loss of engine power due to high cycle fatigue failure of a power turbine stage 3 turbine wheel blade. The resulting engine imbalance caused a decoupling of the gas producer stage 1 and stage 2 turbine wheels leading to a stage 1 turbine overspeed and subsequent turbine wheel burst.

## Findings

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| **Aircraft** | Turbine section - Failure |
| **Aircraft** | Turbine section - Fatigue/wear/corrosion |
| **Aircraft** | Turbine section - Incorrect use/operation |

# Factual Information

## History of Flight

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| **Emergency descent** | Uncontained engine failure (Defining event) |

On July 26, 2024, at 10:40 Central Daylight Time, a Viking Aviation LLC, doing business as Survival Flight, Bell 407 helicopter, powered by a single Rolls-Royce Corporation model M250-C47B turboshaft engine, experienced an uncontained engine failure while traveling to refuel after dropping off a patient. The engine failure necessitated a forced landing in a field. The pilot reported the incident occurred during the third flight of the day while using night vision goggles (NVG) from Oklahoma City, Oklahoma (OK) to Okmulgee, OK with the autopilot engaged and the helicopter in level flight at 2,000 feet mean sea level (MSL), 1,400 feet above ground level (AGL). The pilot reported that the cockpit gauges indicated the engine torque to be 78%, the gas producer temperature (NGT) 707°C-710°C, and gas producer rotor speed (Ng also commonly referred to as N1) at 98.6%.

Shortly after completing a fuel check, the pilot heard a loud boom and saw a bright flash of light out the left side of the helicopter, and the helicopter lost engine power. The bright light and explosion were also reported by the paramedic on board. The helicopter then yawed and rolled left. The pilot corrected for the yaw and roll and entered an autorotation, making a turn to a field to his right.

During the descent, the pilot noticed wires running left to right across the flight path and pitched the nose down to avoid the wires. The pilot and the paramedics stated that prior to the engine failure, there were no abnormal cockpit indications or warning lights. The pilot stated that an engine power assurance check was completed at the beginning of the shift and that the check was good. The pilot also stated that the oil levels were normal and there were no bypass indications.

The paramedics reported that this particular helicopter had a high pitch “whine” since it was received at their operations base; other helicopters at their operations base did not have the same “whine” sound. None of the three occupants on board were injured. The helicopter was operated as a Title 14 *Code of Federal Regulations* (CFR) Part 135 on-demand helicopter air ambulance operation.

Persons from Survival Flight and the Federal Aviation Administration traveled to the accident site to document the wreckage. The wreckage was then transported to the Viking Aviation facility in Batesville, Arkansas where Rolls-Royce joined the investigating team to assess the aircraft and engine damage, download the flight data from the engine control unit, and witness the engine removal from the helicopter for additional examination. The NTSB did not travel for the initial on-scene examination of the airframe and engine nor for the follow-on examination at the Viking Aviation facility.

Initial examination of the helicopter revealed that it was intact but the following damage was identified: 1) the main landing gear skids were slightly splayed out with the helicopter still resting on the skids and not on its belly, 2) the tops of the tail rotor right- and left-hand finlets were damaged, and 3) engine exhaust duct was pock-marked outwards and exhibited impact damage and two exit penetration through-holes.

Examination of the engine through the engine exhaust duct revealed that the exhaust collector support exhibited impact marks and multiple penetrations. Additionally, debris impact marks/tears were also observed on the horizontal firewall shield. Bolts used to secure the gas producer support case to the power turbine support case were fractured and the two cases flanges were separated creating a gap where the energy absorbing ring was visible.

The containment ring located around the outside of the gas producer nozzle assembly appeared distorted but intact. The containment ring is designed to absorb energy in the event of gas producer turbine stage 1 rotor failure. Multiple pieces of turbine engine debris were found in the engine bay on top of the horizontal firewall shield. One piece was consistent with part of the gas producer stage 1 turbine wheel.

The engine was shipped to the Rolls-Royce facility in Indianapolis, Indiana where the engine was examined, disassembled, and documented with persons from the Federal Aviation Administration, Rolls-Royce, Arrow Aviation LLC., Viking Aviation, and National Transportation Safety Board in attendance. The gas producer stage 1 turbine wheel experienced a disk burst and fragmented into multiple pieces. Approximately 80% (by weight) of the wheel fragments were recovered within the engine and helicopter airframe.

The stage 1 and stage 2 disk curvic coupling teeth were rotationally smeared and very little tooth height remained. The stage 2 turbine disk was intact, and all the blades were present. The tie bolt that secures the stage 1 and stage 2 turbine wheels together was found fractured in-line with the stage 1 turbine wheel. All the fragments of the gas producer stage 1 turbine wheel and the tie bolt were sent to the Rolls-Royce materials laboratory for metallurgical evaluation. The stage 2 turbine nozzle inner stationary air seal exhibited rotational damage, distortion radially outwards, and the knife edges were flattened. All eight anti-rotation lugs that engage with the gas producer turbine support were fractured.

The power turbine support includes the stage 3 turbine nozzle support and the Nos. 6 and 7 roller bearing housing. The Nos. 6 and 7 roller bearing housing is attached to the stage 3 turbine nozzle support by four struts. All four bearing radial support struts were fractured, and the bearing support was loose within the power turbine section; the Nos. 6 and 7 bearings were intact but dry.

The power turbine stage 3 turbine wheel was completely corn-cobbed with almost all the airfoils fractured transversely across the platform while all the power turbine stage 4 turbine wheel blades were present and exhibited hard body impact damage and were fractured transversely across the airfoil at various lengths along the outer 25% of the blade span. Both the power turbine stage 3 and stage 4 nozzle assemblies exhibited vane impact damage and circumferential scoring and material transfer. The power turbine bearing support, the power turbine inner shaft, the power turbine rotating labyrinth seal, and the power turbine stage 3 wheel were sent to the Rolls-Royce materials laboratory for metallurgical evaluation.

Metallurgical examination of the gas producer stage 1 turbine wheel fracture surfaces using binocular and scanning electron microscopes (SEM) revealed dendritic and ductile dimple features consistent with overload. A cross section through the rim of the wheel and through one of the partial blades revealed a coarsened microstructure and partially solutioned gamma prime region in the airfoil section consistent with thermal distress while the rim section did not exhibit those signs of thermal distress. Semi-quantitative energy dispersive x-ray spectroscopy analysis confirmed that the gas producer stage 1 turbine wheel material composition was consistent with the manufacturing print.

The tie bolt fracture surfaces showed evidence of ductile dimples consistent with tensile and torsional overload; the material composition was consistent with the manufacturing print. During the last engine overhaul, the gas producer stage 1 turbine wheel and the tie bolt were installed as new, zero-time components.

Metallurgical examination of the remnants of the power turbine stage 3 turbine wheel blade airfoils revealed that one airfoil exhibited features consistent with a high cycle fatigue fracture with initiation on the trailing edge and progressing forward approximately a half inch before the blade ultimately failed in overload. SEM images and semi-quantitative energy dispersive x-ray spectroscopy (EDS) of the fracture surface revealed no chemical or material anomalies near the fatigue crack origin; oxidation was also present which is consistent with the crack being exposed to engine gas path operating temperatures. The material composition of the power turbine stage 3 wheel was consistent with the manufacturing print. Grit blasting and micro-etching confirmed that the material grain size was as specified, and no thermal distress or microstructural anomalies were observed.

The stage 3 turbine wheel is susceptible to high cycle fatigue blade fractures due to vibratory responses at certain power turbine operational speed ranges. The Federal Aviation Administration issued Airworthiness Directive 2006-20-07, to prevent loss of power, possible engine shutdown, or uncontained failure by requiring operators to track power turbine speed excursions in those speed ranges that induce a vibratory response that can cause the stage 3 turbine wheel blades to crack and fail. The stage 3 and stage 4 turbine wheels are allowed a maximum of six power turbine speed excursion events before they must be removed from service. These tracking requirements are also included in the Rolls-Royce 250-C47B operation and maintenance manual along with the speed ranges to avoid.

Review of the Viking Aviation engine inspection and components card for the accident helicopter revealed that as of May 2023, the last overhaul of the turbine, the stage 3 and stage

4 wheels had all 6 allowable power turbine speed excursions remaining. Furthermore, the power turbine stage 3 turbine wheel was visually inspected and fluorescent penetrant inspected at the last engine overhaul, 45.5 hours and 99 cycles, prior to the accident.

The engine electronic control unit stores engine operating data and fault data. The data was downloaded and examination of the engine operating and fault data showed that the first indications of an engine problem were a loss of torque with a corresponding decrease in power turbine rotational speed and helicopter rotor speed and an increase in gas turbine temperature; all this occurred at essentially the same time.

At this time, faults for power turbine speed and engine torque limit exceedances were also recorded coinciding with the engine parameter shifts noted above. The faults and initial engine operating parameter movements were all consistent with a failure with the power turbine section first. A few seconds later, gas producer speed and fuel flow started to drop, indicating an issue in the gas producer section. The engine control unit summary report is programmed to list the power turbine exceedances above the do not exceed speeds for the engine. The report contained no recorded exceedances for the gas producer or power turbine.

## Information

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| **Certificate:** | | **Age:** | |
| **Airplane Rating(s):** | | **Seat Occupied:** | |
| **Other Aircraft Rating(s):** | | **Restraint Used:** | |
| **Instrument Rating(s):** | | **Second Pilot Present:** | |
| **Instructor Rating(s):** | | **Toxicology Performed:** | |
| **Medical Certification:** | | **Last FAA Medical Exam:** | |
| **Occupational Pilot:** | | **Last Flight Review or Equivalent:** | |
| **Flight Time:** | | | |

## Aircraft and Owner/Operator Information

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| **Aircraft Make:** | Bell | **Registration:** | N793SF |
| **Model/Series:** | 407 | **Aircraft Category:** | Helicopter |
| **Year of Manufacture:** | 1999 | **Amateur Built:** | |
| **Airworthiness Certificate:** | Normal | **Serial Number:** | 53345 |
| **Landing Gear Type:** | High skid | **Seats:** | 7 |
| **Date/Type of Last Inspection:** | July 22, 2024 AAIP | **Certified Max Gross Wt.:** | |
| **Time Since Last Inspection:** | | **Engines:** | 1 Turbo shaft |
| **Airframe Total Time:** | 10398.8 Hrs as of last inspection | **Engine Manufacturer:** | ROLLS-ROYC |
| **ELT:** | C126 installed, not activated | **Engine Model/Series:** | 250-C47B |
| **Registered Owner:** | N179SF LLC | **Rated Power:** | 650 Horsepower |
| **Operator:** | Viking Aviation LLC | **Operating Certificate(s) Held:** | On-demand air taxi (135) |
| **Operator Does Business As:** | Survival Flight | **Operator Designator Code:** | 2VKA |

## Meteorological Information and Flight Plan

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| **Conditions at Accident Site:** | Unknown | **Condition of Light:** | Day |
| **Observation Facility, Elevation:** | | **Distance from Accident Site:** | |
| **Observation Time:** | | **Direction from Accident Site:** | |
| **Lowest Cloud Condition:** | | **Visibility** | |
| **Lowest Ceiling:** | | **Visibility (RVR):** | |
| **Wind Speed/Gusts:** | / | **Turbulence Type Forecast/Actual:** | / |
| **Wind Direction:** | | **Turbulence Severity Forecast/Actual:** | / |
| **Altimeter Setting:** | | **Temperature/Dew Point:** | |
| **Precipitation and Obscuration:** | | | |
| **Departure Point:** | Oklahoma City, OK | **Type of Flight Plan Filed:** | VFR |
| **Destination:** | Okmulgee, OK | **Type of Clearance:** | VFR |
| **Departure Time:** | | **Type of Airspace:** | Unknown |

## Wreckage and Impact Information

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| **Crew Injuries:** | 3 None | **Aircraft Damage:** | Minor |
| **Passenger Injuries:** | N/A | **Aircraft Fire:** | None |
| **Ground Injuries:** | | **Aircraft Explosion:** | None |
| **Total Injuries:** | 3 None | **Latitude, Longitude:** | 35.580768,-95.60749 |

## Administrative Information

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| **Investigator In Charge (IIC):** | Hunsberger, Robert |
| **Additional Participating Persons:** | Nick Shepler; Rolls-Royce; Indianapolis, IN<br>Dave Keenan; FAA Accident Investigations; Washington DC , DC<br>Douglas Wahl; Viking Aviation LLD – Director of Maintenance; Batesville, AR<br>David Guidry; Arrow Aviation; Broussard, LA<br>Cody Johnson; Arrow Aviation; Broussard, LA |
| **Original Publish Date:** | April 14, 2026 |
| **Last Revision Date:** | |
| **Investigation Class:** | Class 3 |
| **Note:** | The NTSB did not travel to the scene of this incident. |
| **Investigation Docket:** | https://data.ntsb.gov/Docket?ProjectID=194854 |