



AVIATION INVESTIGATION REPORT

A07A0056



REDUCTION GEARBOX FAILURE

UNIVERSAL HELICOPTERS NEWFOUNDLAND LIMITED

BELL 407 HELICOPTER C-GOFL

POSTVILLE, NEWFOUNDLAND AND LABRADOR, 7 nm S

03 JUNE 2007

The Transportation Safety Board of Canada (TSB) investigated this occurrence for the purpose of advancing transportation safety. It is not the function of the Board to assign fault or determine civil or criminal liability.

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Summary

The Universal Helicopters Newfoundland Limited Bell 407 helicopter (registration C-GOFL, serial number 53130) was en route to Postville, Newfoundland and Labrador, from the Jacques Lake drilling site, with the pilot as the sole occupant and an empty fuel tank weighing approximately 450 pounds on a 75-foot long line. At 500 feet above ground, the engine chip light illuminated along with audible indications of an engine failure. Immediately after, there were two indications on the full authority digital engine control (FADEC): FADEC Fail and FADEC Degrade, followed by the audible engine-failure horn. Engine power output degraded and the pilot entered autorotation. At approximately 200 feet above ground, the pilot released the long line, landed in a bog, and exited the helicopter uninjured. The aircraft was undamaged, and there was minimal environmental impact. The incident occurred at 0900 Atlantic daylight time.

Ce rapport est également disponible en français.

Other Factual Information

The operator's maintenance personnel travelled to the incident site and removed the engine, the power and accessory gearbox (gearbox), and associated hardware from the helicopter. These components were transported to the operator's base at Goose Bay, Newfoundland and Labrador, for examination. When the gearbox cover was removed, it was noted that one of the gears had fractured. The cover was reinstalled and the gearbox was sent to the manufacturer for further examination. The gearbox was disassembled at the manufacturer's facility in the presence of a TSB investigator.

Examination of the gearbox revealed that a section of the helical torquemeter gearshaft (hereinafter referred to as the torquemeter gear), part number 6893673-W, serial number NN144767, had separated and was found detached inside the gearbox.

Records indicate that the aircraft was certified, equipped, and maintained in accordance with existing regulations and approved procedures. The helicopter was equipped with a Rolls-Royce 250-C47B turboshaft engine (serial number CAE847124). The engine supplies power to the helicopter's transmission via a gearbox. The gearbox (serial number CAG47124) had accumulated 6076.9 hours of total time since new, and 4096.8 hours since repair on 08 November 2000 by a Rolls-Royce approved overhaul facility.

Torquemeter Gear

The torquemeter gear (see Photo 1) exhibited significant gear tooth damage (the double-headed arrow marks a 90-degree arc). Microscopic examination of the fractured section of the torquemeter gear identified a fatigue crack originating on the driven surface of a tooth near the forward end (circle marks the location of a fatigue crack), at approximately the centre of the active profile. Damage to the fracture surface precluded detailed fractographic and metallurgical examination of the origin region. The tooth wear was measured and found to be 0.004 inch and, with the exception of damage done after the torquemeter gear failed, there was no spalling¹ or pitting noted. Material analysis determined that the torquemeter gear met the requirements of the engineering drawing.

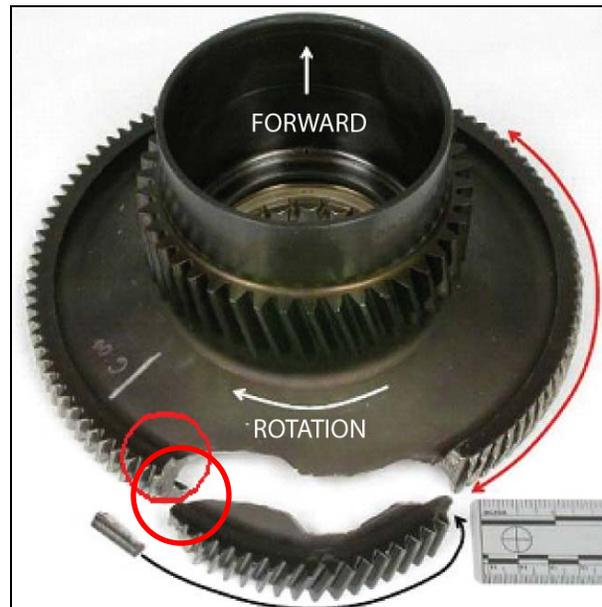


Photo 1. Broken torquemeter gear

¹ The cracking and flaking of particles out of a surface.

The torque-meter gear is maintained on-condition so there is no requirement to record the time-in-service in either the certification documents or the engine log books. Even though the certification document provided by the overhaul facility did not record the torque-meter gear's time-in-service, it was possible to determine its time-in-service from information obtained from Rolls-Royce, the overhaul facility, and the helicopter operator. The occurrence torque-meter gear had been in use a total of 4576 hours since new. It was originally installed in another gearbox (serial number CAG47247), and, at 479 hours since new, it was removed from that gearbox and returned to Rolls-Royce where it was re-worked and certified as serviceable. The torque-meter gear was installed in the occurrence helicopter gearbox during the gearbox repair on 08 November 2000.

The engine log book shows that *Commercial Engine Bulletin* (CEB) 72-6028R1, dated 03 December 1999, was complied with during the gearbox repair. During the gearbox examination after the accident, it was noted that the torque-meter gear had not been re-identified, as required by the CEB.

Torque-meter Gear Service History

Rolls-Royce indicated that, for some operators of its 250-C47 series engines, the mean time between removals (MTBR) for the torque-meter gear is about 650 hours. A search of the Federal Aviation Administration (FAA) Service Difficulty Reporting (SDR) database for torque-meter gear-related entries submitted between 01 January 1998 and 28 August 2007 revealed a total of 46 unique SDRs: 45 were specific to the C47 gearbox, and 1 was specific to the C30 gearbox. The description of the problem included spalling, galling, and possible misalignment between the torque-meter gear and the helical pinion (pinion) gear. Some torque-meter gears were reported to have been removed from service with as few as 154 hours.

On 13 October 2004, Rolls-Royce issued CEB 72-6049, which advised customers of the 250-C30 and 250-C47 series engines that the pinion and torque-meter gears had been redesigned to eliminate premature wear. The CEB indicated that the new gears should be installed when the affected parts are directly available for removal and have been deemed unserviceable for any reason.

On 17 August 2007, Rolls-Royce issued CEB 72-6061, which advised customers of the 250-C30 and 250-C47 series engines that the power gears (pinion gear, torque-meter gear, and power take-off gear) had been redesigned to improve the reliability of the new gears. The CEB states that compliance is a customer option.

Rolls-Royce indicated that it will no longer manufacture the part number 6893673 torque-meter gear. However, this torque-meter gear is still approved for use as long as it is serviceable and is installed in accordance with CEB 72-6061.

On 02 February 2007, a Bell Helicopter Company model 407 medical helicopter departed Tamworth, New South Wales, Australia, en route to a car accident. The pilot reported that the engine chip detector advisory illuminated on the master caution panel. Approximately five seconds later, he heard a frequency vibration with a complete loss of engine power. Preliminary examination showed that the torque meter gear had fractured due to fatigue cracking from an origin at the root region of a rim gear tooth (see Photo 2). Magnetic particle inspection showed evidence of cracking at the roots of several other gear teeth adjacent to the location of the fracture. Localized gear tooth spalling and uneven surface contact patterns were also observed.



Photo 2. Broken Australian gear

Instructions for Continued Airworthiness

The gearbox is maintained on-condition, and Rolls-Royce relies on the closed oil system and two indicating type magnetic drain plugs (chip detectors) to monitor the condition of the internal gears and bearings. The chip detectors are designed to capture steel particles and provide a visual warning, via a chip light, of potential failure. For the occurrence helicopter, there was no report of a chip light warning except for immediately before the loss of power that precipitated this occurrence.

The Rolls-Royce 250-C47B Operation and Maintenance Manual (MM) does not require that the gearbox be opened at any specific time-in-service. However, it does state that, whenever the gearbox is opened for any reason, a general inspection of the assembly should be made, paying particular attention to the condition of the accessory gearshaft drive splines and the gears. The following is an excerpt from the MM:

A visual check for wear on the drive splines and gear teeth should be performed. If there is any doubt that there is excessive wear on the drive splines or wear other than polishing of the gear teeth at their contact surface is present, the wear should be checked using a 0.020 inch radius scribe. Chipping, or localized pitting, spalling, or step wear which may be felt with the scribe is reason for rejecting and replacing the gearshaft or gear. If the records indicate that more than 3500 hours have elapsed since the gears were new or were last magnafluxed, all gears are to be magnetically inspected (magnetic particle inspection [MPI]).

Rolls-Royce indicated that the 0.020-inch radius scribe will typically detect wear steps of 0.001 to 0.002 inch, which is sufficient to reject the gears. It also indicated that the gearbox may never be opened because it is an on-condition module without a specific overhaul requirement (hours or cycles). Therefore, the gears could far exceed the 3500-hour MPI requirement.

Analysis

The engine MM states that wear felt with the radius scribe is reason for rejecting and replacing the torque-meter gear, and Rolls-Royce indicated that the radius scribe will typically detect wear of 0.001 to 0.002 inch. Therefore, it could be concluded that the in-service wear limit would be 0.001 to 0.002 inch. Rolls-Royce has also indicated that, because the gearbox is maintained on-condition, the gears could far exceed the 3500-hour MPI requirement. The occurrence torque-meter gear had 0.004 inch wear, at least twice the in-service wear limit, and had failed at 4576 hours, 1076 hours beyond the MPI inspection requirement.

The torque-meter gear failed as a result of an undetected crack that progressed in fatigue. MPI is a method of non-destructive testing used to visually identify cracks originating at the surface in steel components. If an MPI had been carried out on the torque-meter gear before its failure then it is likely that the crack would have been detected. However, the requirement to perform the MPI is based specifically on the time-in-service of the torque-meter gear, and then only if the gearbox is already opened. There is no requirement to track the time-in-service for the torque-meter gear, or for any of the other gears in the gearbox. Therefore, if a serviceable gear is installed during gearbox maintenance, it is possible that the gear's time-in-service may not be determined.

Rolls-Royce has reported that, for some operators, the MTBR of the torque-meter gear is 650 hours, and SDR data indicate that torque-meter gears have been rejected with as few as 154 hours. The longer a gear remains in service without being inspected, the greater the risk of failure, such as the occurrence torque-meter gear.

In October 2004, Rolls-Royce introduced a redesigned torque-meter gear to eliminate premature wear. In August 2007, Rolls-Royce introduced another redesigned torque-meter gear to improve the reliability. Because the gears identified in CEB 72-6061 are not considered as mandatory replacements, operators can continue to use and install serviceable part number 6893673 torque-meter gears, although it is possible that the gear's time-in-service may not be determined.

Finding as to Causes and Contributing Factors

1. The helical torque-meter gear failed as a result of an undetected crack that progressed in fatigue. The failure of the torque-meter gear resulted in the loss of engine power to the helicopter's transmission.

Findings as to Risk

1. In-service wear may cause torque-meter gear part number 6893673 to wear prematurely.
2. Because it is not mandatory to replace torque-meter gear part number 6893673 with the newly released torque-meter gear, it is possible that torque-meter gear part number 6893673 will experience premature wear and failure.

3. The Rolls-Royce 250-C47B Operation and Maintenance Manual inspection requirements allow the torque-meter gear and other gears installed in the gearbox to potentially exceed 3500 hours in service before a magnetic particle inspection (MPI) is carried out.
4. The current visual and radius scribe inspections may be inadequate to detect cracks in the gear teeth.
5. The Rolls-Royce Operations and Maintenance Manual identifies the requirement for an MPI on the torque-meter gear and other gears in the gearbox based on their time-in-service. However, there is no requirement to track the time-in-service for any of these parts.

Safety Action Taken

On 17 August 2007, Rolls-Royce issued *Commercial Engine Bulletin* (CEB) 72-6061, which advised customers of the 250-C30 and 250-C47 series engines that the power gears (pinion gear, torque-meter gear, and power take-off gear) had been redesigned to improve the reliability of the new gears. The CEB states that compliance is a customer option.

On 26 March 2008, Rolls-Royce advised that it is developing a visual inspection to be placed into the 2000-hour inspection section in the Operation and Maintenance Manual. Implementation is targeted for the third quarter of 2008.

On 23 May 2008, Transport Canada advised that a Service Difficulty Alert regarding this issue has been approved and will be published by the end of July 2008.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 23 May 2008.

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