

The EC 225 LP accident near Turøy in Norway

The Second Loss of a Helicopter Main Rotor - Need for a Change in Certification and Continued Airworthiness of Large Rotorcraft?

By Kåre Halvorsen and Tor Nørstegård (AAIB)

On 29 April 2016, the Main Rotor suddenly detached from a helicopter with registration LN-OJF, an Airbus Helicopters EC 225 LP Super Puma, operated by CHC Helikopter Service AS. The helicopter transported oil workers for Statoil and was enroute from the Gullfaks B platform in the North Sea to Bergen Airport Flesland. The flight was normal and the crew received no warnings before the Main Rotor separated. All 13 persons on board perished instantly when the helicopter hit a small island and continued into the sea. Losing a Main Rotor is unacceptable. This was the second rotor loss for this helicopter type.

This presentation will focus on the following topics:

- The accident site
- Building a robust investigation team
- Challenges faced during the investigation
- The metallurgical investigation
- Certification and Continued airworthiness

The accident site

Wreckage parts were spread over a large area both at land and in the sea. The Main Rotor landed on an island about 550 meters north of the crash site (See Figure 1). The impact forces destroyed the helicopter, before most of the wreckage continued into the sea. Fuel from the helicopter ignited and caused a fire onshore.



Figure 1: The accident site.

There were many witnesses to the accident. Further, the Combined Voice and Flight Data Recorder (CVFDR) was picked up from the seabed and successfully downloaded. Additionally, with information from the Vibration Health Monitoring system, the accident sequence could be reconstructed.

However, it was necessary to find as many pieces as possible to find out why the Main Rotor separated, and parts from the Main Gearbox and its attachments had special focus. On the second day, the main wreckage was lifted from the sea (See Figure 2) and the Main Rotor was recovered (See Figure 3). A number of key parts from the main gearbox were also found at this time, including two segments of a fractured second stage planet gear that later became of vital importance.



Figure 2: Main wreckage being lifted from the sea.



Figure 3: The main rotor gear.

A large search operation was initiated which included members of the Norwegian Civil Defence who searched onshore using metal detectors. Divers from the Norwegian Armed Forces and the Bergen Fire Department performed in total 354 dives, a Remotely Operated Vehicle (ROV) was used in areas not covered by kelp forest and a purpose built magnet sledge was used to search for steel parts on the seabed. The Navy divers have since the accident used the area for training purposes and the last major part, the second stage planet carrier was found and recovered as late as February 2017.

Building a robust investigation team

Building a robust investigation team is of vital importance. In accordance with International Civil Aviation Organisation (ICAO) Annex 13, the French accident investigation organisation (BEA) was notified as the State of design and the State of manufacture. The BEA appointed an Accredited Representative to lead a team of investigators from the BEA and advisors from Airbus Helicopters, Safran Helicopter Engines and later the French bearing manufacturer. In accordance with Regulation (EU) No 996/2010, the European Aviation Safety Agency (EASA), the Regulator responsible for the certification and continued airworthiness of the helicopter, was notified of the accident and participated as advisor to the AIBN. The Norwegian Civil Aviation Authority (CAA-N), the operator CHC Helikopter Service AS and the Norwegian Defence Laboratories (NDL) were also advisors and part of the team.

The Air Accidents Investigation Branch in the UK (AAIB) together with the metallurgical laboratory at QinetiQ, Farnborough in UK had relevant experience from the investigation of a similar fatal helicopter accident off the coast of Scotland in 2009 with an Airbus Helicopters AS 332 L2, registered G-REDL. For that reason, they were asked to assist during the investigation. The AAIB appointed an Accredited Representative and advisors

from QinetiQ as part of the team. Later advisors with expertise in tribology and certification of helicopters joined the team.

The German accident investigation organisation (BFU) was later notified as the State of manufacture of the fractured gear bearing.

The transparent cooperation between these team members turned out to be a success. Documents were shared via controlled access to a secure file cloud.

Challenges faced during the investigation

Shortly after the accident, the EC 225 LP helicopter was grounded by the CAA-Norway and CAA-UK. Early June 2016 the AIBN gave a safety recommendation asking EASA to take immediate action to ensure the safety of the Main Gear Box. EASA issued a flight prohibition for both helicopter types, AS 332 L2 and EC 225 LP. The flight ban was lifted by EASA five months later, based on an agreed corrective actions package for return to service (RTS) between EASA and Airbus Helicopters. In this situation, EASA had at least two different roles. One as being responsible for the continuing airworthiness, the other as an advisor for the Norwegian Accident Investigation Board. This pressure was high on all parties involved, and influenced to some degree the sharing of information. From the Norwegian Accident Investigation Board perspective, it sometimes seemed that lifting the flight prohibition was first priority.

The Norwegian Accident Investigation Board also experienced that patience is necessary when asking for certification and design information. The AIBN understands EASA's obligation to follow its procedures as a public administrative body. However, the AIBN had to wait for two to six months before receiving some of the documents from EASA. Further, it is understandable that design information is sensitive proprietary information, but to study requested documentation at Airbus Helicopter's premises it is not an effective way of reviewing such information. Additionally, legal issues drew resources away from the investigation. The AIBN notes that Regulation (EU) No 996/2010 states 'free access to any relevant information or records', whereas ICAO Annex 13 states 'unhampered access to wreckage and all relevant material'. Safety recommendations SL No. 2018/10T and SL No. 2018/11T are issued based on this experience.

The metallurgical investigation

Two recovered segments of the fractured second stage planet gear, that make up approximately half of a gear, got special attention (See Figure 4).

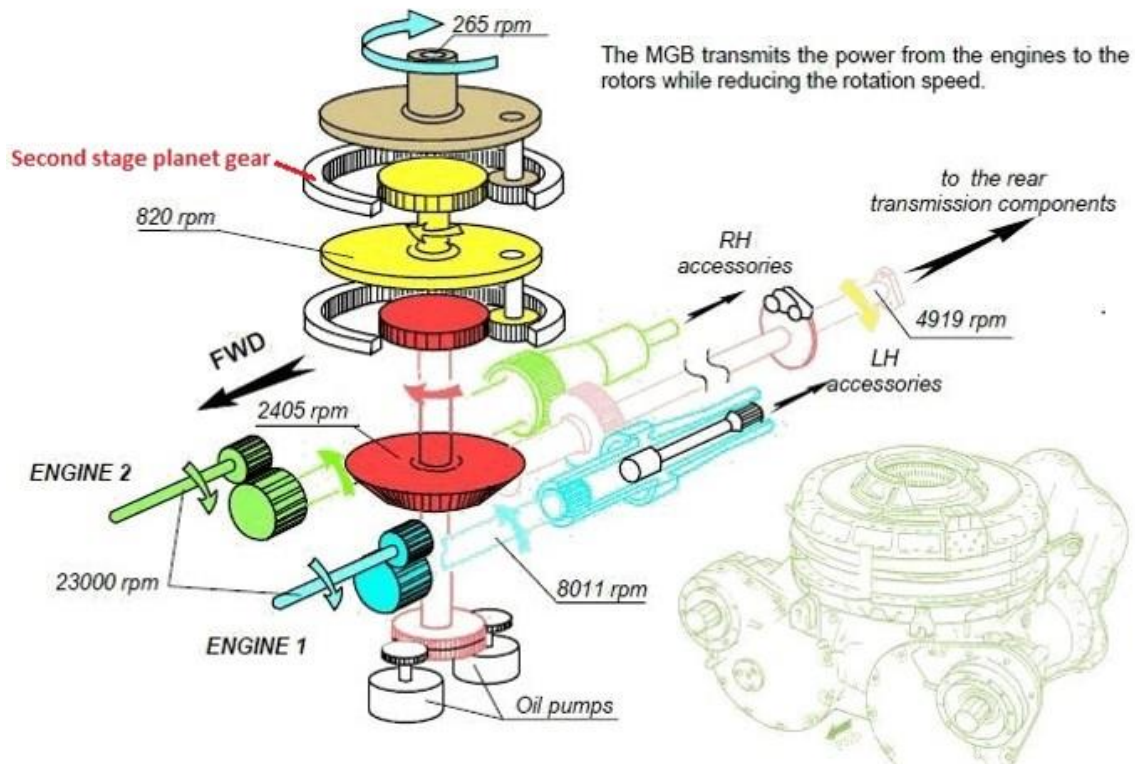


Figure 4: The rotor gear assembly showing the second stage planet gear.

Detailed metallurgical examinations carried out at QinetiQ, Farnborough in UK, confirmed that the gear had fractured due to fatigue. The different examinations revealed the sequence of break-up of the gearbox (See Figure 5).

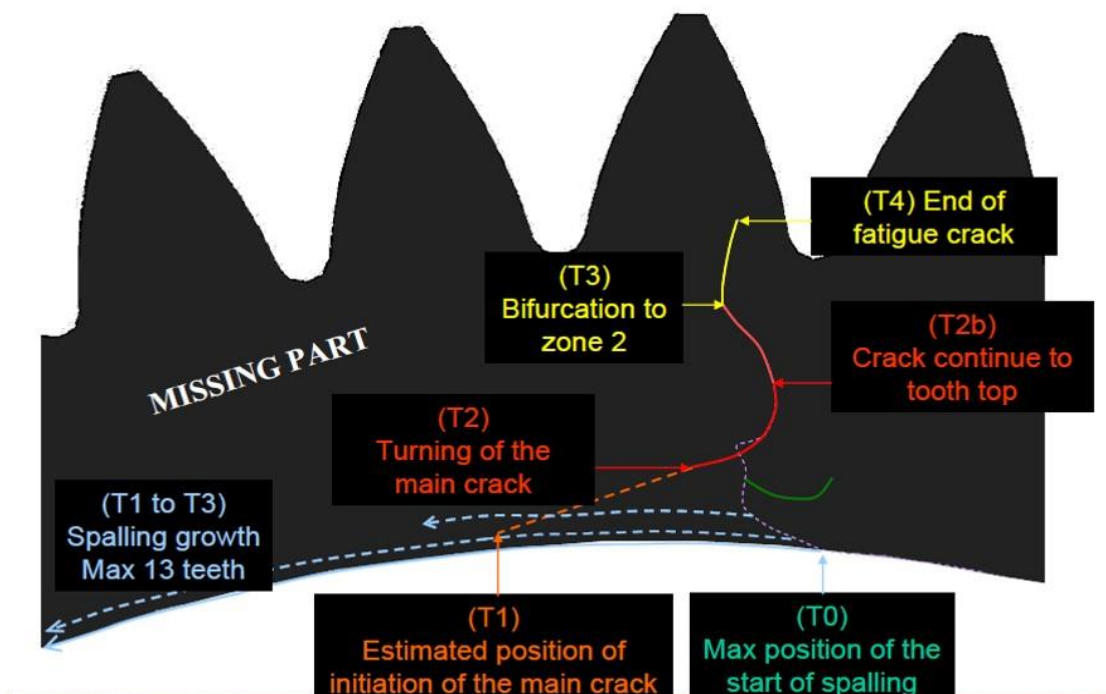


Figure 5: An estimate of the fracture sequence.

The fractured gear clashed teeth with other gears and caused an abrupt seizure and rupture of the gearbox, which lost its structural integrity.

The fatigue fracture initiated from a surface micro-pit in the upper outer race of the bearing (inside the second stage planet gear), propagating subsurface while producing a limited quantity of particles from spalling, before turning towards the gear teeth and fracturing the rim of the gear. Four spalls were observed centred along the line with maximum contact pressure (See Figure 6).

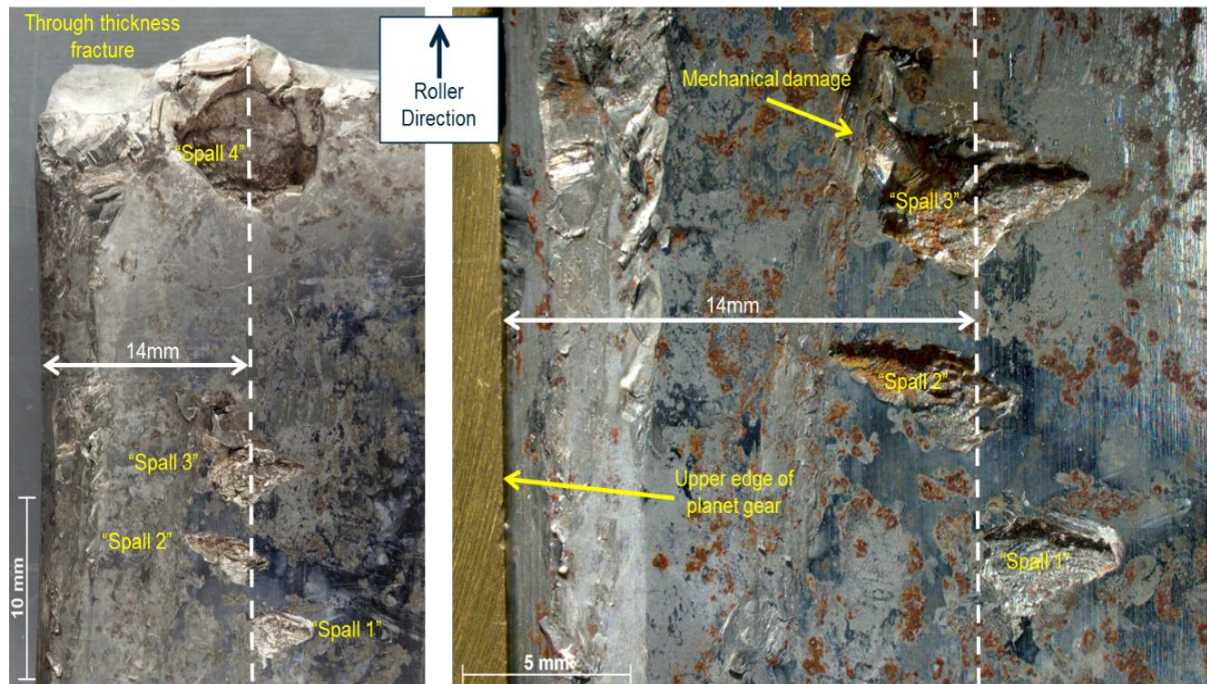


Figure 6: Investigators found spalling inside the second stage planet gear.

It is probable that the failure was initiated by debris caught within the bearing and scratching one or more rollers. This probably caused a band of local work hardening and associated micro-pitting at the outer race. The AIBN concludes that the fatigue fracture were neither a consequence of a mechanical failure or misalignment of another component, nor due to material unconformity. More research is needed in order to understand the fatigue behaviour for the material. It has not been possible to determine a conclusive crack propagation rate, but it must have developed within a maximum of 260 flight hours since the gearbox was inspected and repaired at Airbus Helicopters. The repair was done following a road transport incident.

Certification and Continued airworthiness

The helicopter Main Gearbox is both a mechanical drive train and a structural element without any redundancy. Any structural failure during flight will be catastrophic. The helicopter Main Gearbox must be regarded as one of the most safety critical components in the aviation industry.

The EC 225 LP is latest member of the Super Puma family that started with the SA 330 in 1970. The EC 225 LP is derived from the earlier AS 332 L2. The 2004 certification of the EC 225 LP is based on JAR 29 Change 1. The second stage planet gears were certified against FAR 29.571 Fatigue Evaluation of Flight Structure paragraph c) replacement time evaluation: *'It must be shown that the probability of catastrophic fatigue failure is extremely remote within a replacement time furnished under section A29.4 of Appendix A'*.

Crack initiation and propagation with limited spalling, was not expected or foreseen during design and type certification in 2004. It was assumed that if rolling contact fatigue occurred, spalling would result and be detected prior to gear failure. The AIBN believe that more could have been learned from the AS 332 L2 accident in 2009. The AS 332 L2 and EC 225 LP have near identical gearboxes. Using all information and hypothesis might have challenged the design basis. Even though small changes were made to the MGB following the 2009 accident, the certification aspects were not adequately reviewed.

Less than 10 % of all second stage planet gears in the EC 225 LP and AS 332 L2 helicopters ever reached their intended operational time before being rejected during overhaul inspections or non-scheduled MGB removals due to signs of degradation. Airbus Helicopters did not perform systematic examination and analyses of unserviceable and rejected second stage planet gears in order to understand the full nature of any damage and its effect on continued airworthiness.

Two catastrophic events (G-REDL and LN-OJF) and the service experience with many planet gears removed from service after relatively short service exposure, may suggest that the operational loading environment, on both AS 332 L2 and EC 225 LP, is close to the limit of endurance for the design.

The EC 225 LP satisfied the requirements in place at the time of certification. However, the AIBN has found weaknesses in the current EASA Certification Specifications for Large Rotorcraft (CS-29) and the Accident Investigation Board Norway AIBN have issued nine safety recommendations addressing these shortcomings. The following safety recommendations are made in order to enhance Certification Specifications and Continued Airworthiness of Large Rotorcraft:

SL No. 2018/01T

The Accident Investigation Board Norway recommends that the European Aviation Safety Agency (EASA) research into crack development in high-loaded case-hardened bearings in aircraft applications. An aim of the research should be the prediction of the reduction in service-life and fatigue strength as a consequence of small surface damage such as micro-pits, wear marks and roughness.

SL No. 2018/02T

The Accident Investigation Board Norway recommends that the European Aviation Safety Agency (EASA) assess the need to amend the regulatory requirements with regard to procedures or Instructions for Continued Airworthiness (ICA) for critical parts on helicopters to maintain the design integrity after being subjected to any unusual event.

SL No. 2018/03T

The Accident Investigation Board Norway recommends that European Aviation Safety Agency (EASA) amend the Acceptable Means of Compliance (AMC) to the Certification Specifications for Large Rotorcraft (CS-29) in order to highlight the importance of different modes of component structural degradation and how these can affect crack initiation and propagation and hence fatigue life.

SL No. 2018/04T

The Accident Investigation Board Norway recommends that the European Aviation Safety Agency (EASA) revise the Certification Specifications for Large Rotorcraft (CS-29) to introduce requirements for MGB chip detection system performance.

SL No. 2018/05T

The Accident Investigation Board Norway recommends that the European Aviation Safety Agency (EASA) develop MGB certification specifications for large rotorcraft to introduce a design requirement that no failure of internal MGB components should lead to a catastrophic failure.

SL No. 2018/06T

The Accident Investigation Board Norway recommends that the European Aviation Safety Agency (EASA) develop regulations for engine and helicopter operational reliability systems, which could be applied to helicopters which carry out offshore and similar operations to improve safety outcomes.

SL No. 2018/07T

The Accident Investigation Board Norway recommends that European Aviation Safety Agency (EASA) make sure that helicopter manufacturers review their Continuing Airworthiness Programme to ensure that critical components, which are found to be beyond serviceable limits, are examined so that the full nature of any damage and its effect on continued airworthiness is understood, either resulting in changes to the maintenance programme, or design as necessary, or driving a mitigation plan to prevent or minimise such damage in the future.

SL No. 2018/08T

The Accident Investigation Board Norway recommends that the European Aviation Safety Agency (EASA) review and improve the existing provisions and procedures applicable to critical parts on helicopters in order to ensure design assumptions are correct throughout its service life.

SL No. 2018/09T

The Accident Investigation Board Norway recommends that the European Aviation Safety Agency (EASA) research methods for improving the detection of component degradation in helicopter epicyclic planet gear bearings.

Thank you for listening.