Aircraft Accident Report No: 2/2011

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REPORT ON THE ACCIDENT TO AEROSPATIALE (EUROCOPTER) AS332 L2 SUPER PUMA, G-REDL 11 NM NE OF PETERHEAD, SCOTLAND ON 1 APRIL 2009

Registered Owner and Operator	Bond Offshore Helicopters Ltd
Aircraft Type	AS332 L2
Nationality	British
Registration	G-REDL
Place of Accident	11 nm NE of Peterhead, Scotland
Date and Time	1 April 2009 at 1255 hrs

Synopsis

The Air Accidents Investigation Branch (AAIB) was notified of the accident by Aeronautical Rescue Co-ordination Centre (ARCC) Kinloss at 1326 hrs on 1 April 2009 and the investigation began the same day. In accordance with established international arrangements the Bureau d'Enquetes et d'Analyses Pour la Securité de l'Aviation Civile (BEA), representing the State of Manufacture of the helicopter, and the European Aviation Safety Agency (EASA), the Regulator responsible for the certification and continued airworthiness of the helicopter, were informed of the accident. The BEA appointed an Accredited Representative to lead a team of investigators from the BEA, Eurocopter (the helicopter manufacturer) and Turbomeca (the engine manufacturer). The EASA, the helicopter operator and the UK Civil Aviation Authority (CAA) also provided assistance to the AAIB team.

The accident occurred whilst the helicopter was operating a scheduled passenger flight from the Miller Platform in the North Sea, to Aberdeen. Whilst cruising at 2,000 ft amsl, and some 50 minutes into the flight, there was a catastrophic failure of the helicopter's Main Rotor Gearbox (MGB). The helicopter departed from cruise flight and shortly after this the main rotor and part of the epicyclic module separated from the fuselage. The helicopter then struck the surface of the sea with a high vertical speed.

An extensive and complex investigation revealed that the failure of the MGB initiated in one of the eight second stage planet gears in the epicyclic module. The planet gear had fractured as a result of a fatigue crack, the precise origin of which could not be determined. However, analysis indicated that this is likely to have occurred in the loaded area of the planet gear bearing outer race.

A metallic particle had been discovered on the epicyclic chip detector during maintenance on 25 March 2009, some 36 flying hours prior to the accident. This was the only indication of the impending failure of the second stage planet gear. The lack of damage on the recovered areas of the bearing outer race indicated that the initiation was not entirely consistent with the understood characteristics of spalling (see 1.6.5.7). The possibility of a material defect in the planet gear or damage due to the presence of foreign object debris could not be discounted.

The investigation identified the following causal factor:

1. The catastrophic failure of the Main Rotor Gearbox was a result of a fatigue fracture of a second stage planet gear in the epicyclic module.

In addition the investigation identified the following contributory factors:

1. The actions taken following the discovery of a magnetic particle on the epicyclic module chip detector on 25 March 2009, 36 flying hours prior to the accident, resulted in the particle not being recognised as an indication of degradation of the second stage planet gear, which subsequently failed.
2. After 25 March 2009, the existing detection methods did not provide any further indication of the degradation of the second stage planet gear.
3. The ring of magnets installed on the AS332 L2 and EC225 main rotor gearboxes reduced the probability of detecting released debris from the epicyclic module.

Seventeen Safety Recommendations are made.

Findings

1. The flight crew were properly licensed and qualified to conduct the flight and were well rested. Their training was in accordance with the operators requirements.
2. The helicopter was certified, equipped and maintained in accordance with the existing regulations.
3. The helicopter was in cruising flight at 2,000 ft in daylight when the accident occurred. Neither weather nor the crew's actions were factors in the accident.
4. The first indication to the crew of a problem with the helicopter was the loss of MGB oil pressure and triggering of the master warning. Two and a half seconds prior to this indication, the co-pilot had made a radio transmission stating that the helicopter was serviceable.
5. Immediately after the loss of MGB oil pressure the helicopter began to descend and failed to respond to control inputs.
6. The main rotor system separated from the helicopter approximately 20 seconds after the loss of MGB oil pressure.
7. Separation of the main rotor occurred after the conical housing had become separated from the remainder of the MGB, thus forcing the lift struts to react engine torque. They were not designed for this and their attachments failed as a consequence.

8. During separation, the main rotor blades struck the helicopter's tail boom in several locations, severing it from the fuselage.

9. The fuselage fell into the sea at a high vertical speed and the impact was non-survivable for all occupants.

10. The loss of MGB oil pressure and subsequent separation of the main rotor system were the result of a rupture of the MGB epicyclic module case, which is integral with the epicyclic ring gear.

11. A section of a failed second stage epicyclic planet gear become entrained between the remaining second stage planet gears and the ring gear overloading the ring gear and module case, causing them to rupture.

12. The second stage planet gear failed due to the presence of a crack in the outer race of the gear bearing which propagated in fatigue until the gear failed. It then broke into several sections, three of which were recovered.

13. The morphology of the fatigue crack in the second stage planet gear, suggested that it had initiated from a point at or close to the surface of a highly loaded section of the bearing outer race, approximately 14 mm from the edge of the raceway.

14. The origin of the crack was in a section of the failed gear which was not recovered.

15. Production records for the failed gear showed that it met the quality control standards applicable during manufacture.

16. During the investigation, the use of advanced computational techniques, confirmed that the design of the second stage planet gear met the requirements applicable at the time of certification.

17. Stress analysis identified the possibility of crack propagation, in a manner similar to that observed on the failed gear, should a crack of sufficient depth, originating at or close to the race surface, exceed the depth of the carburised layer.

18. Two planet gears removed from other MGBs, due to extensive spalling, were found to exhibit cracks associated with the spalled area and within the carburised layer which showed a radial growth component. These cracks had grown beyond the carburised layer.

19. Computer modelling showed that the radial growth of spalling cracks could be explained by the bearing rollers sliding.

20. A metallic particle was discovered on G-REDL's epicyclic module magnetic chip detector on 25 March 2009, 36 flying hours prior to the accident.

21. The particle had been released from a position approximately 14 mm from the edge of the outer race of the failed gear. It had been released from a section of the failed gear which was not recovered.

22. Two indentations in the particle suggested that other debris was present in the epicyclic module.

23. No material or manufacturing process anomalies were found on the recovered pieces of the failed gear.

24. Spalling may have contributed to the failure of the second stage gear, however, the spalled area must have been less than is typically observed in such cases and have been confined to a maximum of 25.5% of the gear, which was not recovered.

25. The reason for the initiation of the crack in the failed second stage gear could not be established fully and the possibility of a material defect within the gear or foreign object debris could not be discounted.

26. The helicopter manufacturer operated a Continue Airworthiness programme in which components rejected in operation or during overhaul were inspected.

27. When the Continued Airworthiness programme for the AS332 L2 was initiated, it was determined that damage to planet gear outer races would not adversely affect the continued airworthiness of the helicopter.

28. Not all planet gears which had been rejected for spalling were sent to a laboratory for additional investigation.

29. The AS332 L2 does not provide an alert to the flight crew when the epicyclic module magnetic chip detector detects a particle.

30. An accident to a SA 330J Puma helicopter in 1980 bore many similarities to the G-REDL accident and also resulted from a stage 2 planet gear failure. In the former accident, large quantities of metallic debris had been collected over a number of weeks before failure and the inner race had typical evidence of severe spalling.

31. The use of oil analysis may have assisted in the identification of the deterioration of the MGB components.

32. The ring of magnets, introduced on the AS332 L2 and EC225 MGBs, reduced the possibility of detection of metallic debris, generated in the epicyclic module, by the main module magnetic chip detector or by inspection of the oil filter.

33. The discovery of a magnetic particle on the epicyclic module chip detector, during the initial stages of the 25 hour check on 25 March 2009, was the only indication of the degradation of the second stage planet gear.

34. The identification of a potential HUMS trend on the MGB combiner / bevel gear at the time the magnetic particle had been discovered, together with multiple epicyclic magnetic chip detection alerts, indicated to the operator's engineers that they were dealing with a complex MGB problem for which they sought the assistance of the manufacturer.

35. The EDR procedure was not used.

36. The use of verbal and email communication between the operator and manufacturer on 25 March 2009 led to a misunderstanding or miscommunication of the issue.

37. The maintenance recommendations provided by the helicopter manufacturer were based on their belief that small particles had been found on the main module chip detector and that the maintenance actions contained in AMM task 60.00.00.212 had already been completed.

38. The maintenance task to remove the epicyclic module and examine the ring of magnets on the oil separator plates, contained in AMM task 60.00.00.212.001, was not carried out.

39. The standard practices procedure used to identify the origin of metallic particles within the MGB was generic and open to interpretation.

40. The particle discovered on 25 March 2009, from visual examination, was identified as 'scale', but the material was misidentified as being silver or cadmium plating.

HUMS and recorded flight data

41. HUMS recorded 667 epicyclic magnetic chip detection warnings on 24 March 2009. These were not investigated due to the absence of an alert generated by the HUMS ground station.

42. Alerts will not be displayed on the HUMS ground station summary screens,if the HUMS data card is not closed down correctly.

43. HUMS recorded 76 chip detection warnings for the first operation from Aberdeen on 25 March 2009, and 94 for the second operation, also from Aberdeen. For both operations, the first recorded detection was during engine start.

44. The CVFDR was fitted in accordance with regulatory requirements.

45. CVFDR audio analysis revealed that three minutes and 24 seconds prior to the first warning to the flight crew, frequencies were identified which were consistent with the presence of second stage ring gear defect and a possible increasing misalignment of the left accessory gearbox oil cooler drive shaft.

46. Three minutes and three seconds prior to the loss of MGB oil pressure, HUMS recorded an epicyclic chip detection warning. Three further detections were recorded over the next minute and 43 seconds.

47. HOMP ceased recording 34 seconds prior to the CVFDR due to the presence of a memory buffer.

48. After the loss of MGB oil pressure, atmospheric pressure data recorded by radar and CVFDR became inaccurate.

49. The CVFDR ceased recording prior to other onboard systems, probably due to the activation of the g-switch.

50. Review of HUMS vibration data available at the time of the accident revealed no unusual trends related to the epicyclic module.

51. HUMS vibration monitoring capability of detecting degradation in epicyclic stage planet gear bearings is limited.

52. There is currently no formal requirement or process for component strip reports to be provided after components are removed from service due to HUMS alerts.

Safety Recommendations

The following Safety Recommendations were made during the course of this investigation.

Safety Recommendation 2009-048

It is Recommended that Eurocopter issue an Alert Service Bulletin to require all operators of AS332 L2 helicopters to implement a regime of additional inspections and enhanced monitoring to ensure the continued airworthiness of the main rotor gearbox epicyclic module.

Safety Recommendation 2009-049

It is Recommended that the European Aviation Safety Agency (EASA) evaluate the efficacy of the Eurocopter programme of additional inspections and enhanced monitoring and, when satisfied, make the Eurocopter Alert Service Bulletin mandatory by issuing an Airworthiness Directive with immediate effect.

Safety Recommendation 2009-050

It is Recommended that Eurocopter improve the gearbox monitoring and warning systems on the AS332 L2 helicopter so as to identify degradation and provide adequate alerts.

Safety Recommendation 2009-051

It is recommended that Eurocopter, with the European Aviation Safety Agency (EASA), develop and implement an inspection of the internal components of the main rotor gearbox epicyclic module for all AS332 L2 and EC225LP helicopters as a matter of urgency to ensure the continued airworthiness of the main rotor gearbox. This inspection is in addition to that specified in EASA Emergency Airworthiness Directive 2009-0087-E, and should be made mandatory with immediate effect by an additional EASA Emergency Airworthiness Directive.

Safety Recommendation 2009-074

It is recommended that the European Aviation Safety Agency, in conjunction with Eurocopter, review the instructions and procedures contained in the Standard Practices Procedure MTC 20.08.08.601 section of the EC225LP and AS332 L2 helicopters Aircraft Maintenance Manual, to ensure that correct identification of the type of magnetic particles found within the oil system of the power transmission system is maximised.

Safety Recommendation 2009-075

It is recommended that the European Aviation Safety Agency, in conjunction with Eurocopter, urgently review the design, operational life and inspection processes of the planet gears used in the epicyclic module of the Main Rotor Gearbox installed in AS332 L2 and EC225LP helicopters, with the intention of minimising the potential of any cracks progressing to failure during the service life of the gears.

The following additional Safety Recommendation are made.

Safety Recommendation 2011-032

It is recommended that, in addition to the current methods of gearbox condition monitoring on the AS332 L2 and EC225, Eurocopter should introduce further means of identifying in-service gearbox component degradation, such as debris analysis of the main gearbox oil.

Safety Recommendation 2011-033

It is recommended that Eurocopter review their Continued Airworthiness programme to ensure that components critical to the integrity of the AS332 L2 and EC225 helicopter transmission, which are found to be beyond serviceable limits are examined so that the full nature of any defect is understood.

Safety Recommendation 2011-034

It is recommended that the European Aviation Safety Agency (EASA) review helicopter Type Certificate Holder's procedures for evaluating defective parts to ensure that they satisfy the continued airworthiness requirements of EASA Part 21.A.3.

Safety Recommendation 2011-035

It is recommended that the Federal Aviation Administration review helicopter Type Certificate Holder's procedures for evaluating defective parts to ensure that they satisfy the continued airworthiness requirements of Federal Aviation Regulation Part 21.3.0.

Safety Recommendation 2011-036

It is recommended that the European Aviation Safety Agency (EASA) re-evaluate the continued airworthiness of the main rotor gearbox fitted to the AS332 L2 and EC225 helicopters to ensure that it satisfies the requirements of Certification Specification (CS) 29.571 and EASA Notice of Proposed Amendment 2010-06.

Safety Recommendation 2011-041

It is recommended that the European Aviation Safety Agency research methods for improving the detection of component degradation in helicopter epicyclic planet gear bearings.

Safety Recommendation 2011-042

It is recommended that the Civil Aviation Authority update CAP 753 to include a process where operators receive detailed component condition reports in a timely manner to allow effective feedback as to the operation of the Vibration Health Monitoring system.

Safety Recommendation 2011-043

It is recommended that Eurocopter introduce a means of warning the flight crew, of the AS332 L2 helicopter, in the event of an epicyclic magnetic chip detector activation.

Safety Recommendation 2011-045

It is recommended that the European Aviation Safety Agency require the 'crash sensor' in helicopters, fitted to stop a Cockpit Voice Recorder in the event of an accident, to comply with EUROCAE ED62A.

Safety Recommendation 2011-046

It is recommended that the Federal Aviation Administration require the 'crash sensor' in helicopters, fitted to stop a Cockpit Voice Recorder in the event of an accident, to comply with RTCA DO204A.

Safety Recommendation 2011-047

It is recommended that the Civil Aviation Authority update CAP 739, and include in any future Helicopter Flight Data Monitoring advisory material, guidance to minimise the use of memory buffers in recording hardware, to reduce the possibility of data loss.