Appendix I: Airbus Helicopters Annex to AIBN Final Report

This annex is not State of Design and State of Manufacture comments by the Bureau d'Enquêtes et d'Analyses pur la Sécurité de l'Aviation Civile (BEA), cf. ICAO Annex 13, 6.3. These comments represents the views of the BEA's technical adviser, Airbus Helicopters. Nevertheless, the BEA has accepted that the comments are appended to the Final Report.

COMMENTS OF AIRBUS HELICOPTERS ON THE INVESTIGATION OF THE AIR ACCIDENT OF 29 APRIL 2016 NEAR TUROY, NORWAY CONCERNING AN AIRBUS HELICOPTERS EC 225 LP, REGISTRATION LN-OJF ANNEXED TO THE AIBN'S FINAL REPORT AT THE COURTESY OF THE AIBN.

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1. INTRODUCTION

1.1 Airbus Helicopters would like to take the opportunity presented by this document to express again its heartfelt condolences to all those who lost loved ones as a result of the accident.

1.2 In accordance with the provisions of Annex 13 to the Convention on International Civil Aviation, Airbus Helicopters participated in the Accident Investigation Board Norway's (AIBN) investigation of the accident as technical advisor to the Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile, the accredited representative of the State of Design and the State of Manufacture of the accident aircraft.

1.3 Airbus Helicopters is fully committed to learning as much as possible from the accident as part of its strong safety culture and unerring commitment to product safety and continuing airworthiness assurance.

1.4 This document does not cover all areas of the investigation where Airbus Helicopters has comments.

1.5 Airbus Helicopters agrees with the overall analysis and conclusions set out in the Report in relation to the root cause of the accident as well as the AIBN's proposed Safety Recommendations. The comments presented below focus on certain aspects of the Report which, in the interests of aviation safety, Airbus Helicopters consider important to be noted.

2. THE NATURE OF THE LN-OJF CRACK MODE WAS UNKNOWN AND UNEXPECTED

2.1 With the benefit of analytical support from bearing manufacturers and third party specialist experts (supported by multiple testing programmes), accident investigation team position is that the initiation of the crack was most probably based:

(a) on a particle becoming embedded in the cage and then generating a scratch on a roller;

(b) which, in turn, caused a micro pitted line on the bearing inner and outer races due to local overloading; and

(c) in consequence, progressively damaged the outer race (which, importantly, had similar contact pressure on the outer and inner races).

This occurred with very limited spalling during propagation of the crack to gear failure.

2.2 Based on the state of scientific and technical information known by AH before the LN-OJF accident, the phenomenon of unusually low particle liberation resulting from the above sequence was neither foreseen nor foreseeable by the bearing manufacturers or Airbus Helicopters and the industry more generally.

2.3 The theory about sub-surface cracks developing undetected is dependent on the existence of a material defect acting as an initiator. No such defect was found in the LN-OJF planet gear. The crack which led to the failure of the gear has not been found to have started sub-surface.

2.4 The possibility postulated in the G-REDL report that a crack could initiate sub-surface propagating to gear failure, has never been encountered because of the state of art standard 16NCD13 material used for planet gears. In any case, in the highly improbable likelihood of that phenomenon occurring, initiation would occur close to surface, due to stress tensor gradient.

2.5 In this last context, Airbus Helicopters (as part of its on-going post LN-OJF work) has performed a test in which a subsurface crack was artificially introduced in the 16NCD13 material close to the raceway, the crack propagated under simulated fatigue to the raceway surface and not to the rim.

3. RETURN TO SERVICE (RTS) OF AS 332 L2 AND EC 225LP FLEET

3.1 A set of safety measures has been implemented in the frame of the return to service (RTS) of the AS 332 L2 and EC 225 LP. The risk of outer race spalling has been considerably reduced and, should such spalling occur, chip detection means have been significantly enhanced. Overall, the risk of failure without adequate advance warning has been fully addressed.

Risk of outer race spalling reduction

3.2 Key to the RTS were the measures taken by Airbus Helicopters to reduce the risk of outer race spalling by replacing planet gears equipped with FAG bearings with planet gears equipped with SNR bearings while, at the same time, reducing the life limit of those bearings.

(a) *Fuse effect* and reduced outer race bearing contact pressure – though the loading on the outer and inner races of planet gear with FAG bearings is similar (see paragraph 2.1 above), there is a pronounced loading difference between the inner and outer races on planet gears equipped with SNR bearings.

That difference leads to a *fuse effect:* should spalling arise (for example, as a result of roller scratching), it will invariably start on the inner race, thus enabling planet gear spalling to be detected before it starts on the outer race area of the planet gear. Undetected spalling on the inner race is less critical than on the outer race because inner race cracking will not lead to opening of the inner ring.

In addition, lower contact pressure between rollers and the outer race in SNR bearings (when compared to FAG bearings) means that, in practice, the likelihood of possible spalling arising in SNR bearings is materially lower than in relation to FAG bearings.

(b) Bearing (SNR) life limit reduction - potential rolling contact fatigue degradation leading to potential spalling has been reduced by means of reducing the life limit of SNR bearings by a factor of four.

Improved capture of particles

3.3 Full flow magnetic plug (FFMP) - this has been developed by Airbus Helicopters in collaboration with a major manufacturer of chip detectors to maximize particle collection in the oil circuit without impacting the MGB lubrication system. Efficient performance has been demonstrated by tests carried out by the supplier and by Airbus Helicopters (laboratory testing, MGB bench testing, and helicopter flight testing). This has the effect of increasing the overall capture rate for particles from 12% to 50%.

Particle criteria reduction

3.4 The criteria for epicyclic module removal from service has been reduced to a defined surface of 3mm², established in view of the limited nature of LN-OJF spalling (28mm²). Criteria applicable to the size of individual particles that have been detected has also been reduced. Any of the five 16NCD13 spalling particles found in the oil cooler of LN-OJF after the accident would have led to MGB removal according to the newly introduced criteria. It will be recalled that the FFMP device was introduced upstream of the oil cooler (thus eliminating the need to inspect the oil cooler).

Reduction of inspection interval - justified by crack propagation determination

3.5 Inspection interval is based on crack propagation time plus a safety margin. Crack propagation time on an SNR planet gear bearing has been established by:

(a) analysis of beach marks observed on the LN-OJF part in comparison with LN-OJF's flight spectrum - this led to determination of a crack propagation timeline in excess of 73 flight hours;

(b) performing nine crack propagation tests on the MGB bench to determine crack surface function over operating time (with planet gear equipped with FAG and SNR bearings), thus validating the >73 flight hours determination;

(c) crack propagation calculation supporting conservative approach of 73 flight hours - this is based on the FAG planet gear even though those gears are no longer in service and there is technical evidence that a crack would take longer to propagate to failure in an SNR gear.

Human factors risk minimisation

3.6 Airbus Helicopters has established a Human Factor Safety case related to post LN-OJF additional maintenance with HeliOffshore and some North Sea operators to support operators as and when they decide to return aircraft to operations.

Airworthiness demonstration

3.7 The probability of outer ring spalling in an epicyclic module equipped with SNR second stage planet gears not being detected before any possible failure has been demonstrated by Airbus Helicopters to the satisfaction of all relevant airworthiness regulation authorities in accordance with all applicable airworthiness rules to be less than 4.3×10^{-9} / flight hours. This includes the Norwegian Civil Aviation Authority and the UK Civil Aviation Authority.

3.8 The measures implemented are not yet final measures (demonstrating a 10-9 probability). This is clearly stated in the relevant EASA Airworthiness Directive and taken into account in the Continuing Airworthiness Review Item (CARI) agreed with EASA. Airbus Helicopters

continues to work hard on additional measures which will demonstrate the final required probability (see further paragraphs 4.4-4.5 below).

4. AIRBUS HELICOPTERS' COMMITMENT TO SAFETY

4.1 Airbus Helicopters has invested considerable time and resources in the safety of the design, production and maintenance of AS 332 L2s and EC 225 LPs since the LN-OJF accident in the context of lessons learnt. Some of the technology has been developed for the first time in the helicopter industry, including the following initiatives:

(a) introduction of a new packaging for main gearbox transportation which monitors what happens between two confirmed secure locations: this monitoring system is made visible in order to raise awareness among the transportation staff;

(b) installation of the FFMP in the oil system with a significantly improved detection rate; and

(c) development and introduction of specific training for maintenance personnel for the purpose of minimising any risk of poor identification of the characteristics of particles found by the detection system.

4.2 Airbus Helicopters has also launched a proactive quality and safety enhancement project for the dynamic components of the future. This project is aimed at internally challenging everything that Airbus Helicopters is currently doing in relation to design, production, and maintenance repair organisations (MRO) by way of defining future standards, and includes application of enhanced digital-based technologies.

4.3 While maintenance was not identified as a contributing factor of the LN-OJF accident, Airbus Helicopters' proactive approach to safety has led it to look at how it can decrease risk of an accident due to human error in maintenance (including identifying where 'error proofing' features are most needed in order to support maintenance engineers during the most critical tasks). Recently completed trials organised by HeliOffshore with some North Sea operators and Airbus Helicopters have demonstrated already the potential for improving safety for offshore operations by taking this new approach to maintenance tasks.

4.4 Work on a number of potential improvements to the EC 225 LP MGB is in progress. It is meticulous, painstaking and ambitious in nature and has yet to reach a sufficient level of maturity for final decisions to be made and announced to the industry. Potential improvements under consideration which can be shared now include a research project launched by Airbus Helicopters to explore the potential for widening the scope and capability of its future Health and Usage Monitoring Systems (HUMS) to provide earlier detection of potential problems within the moving components inside transmissions.

4.5 In the frame of this research project, Airbus Helicopters needs to monitor and record several healthy main gearboxes operating in different environments. Airbus Helicopters has equipped its own prototype aircraft and by implementing such stand-alone recorder on several customer aircraft, it will be able to record data from healthy aircraft operating in different environments. A considerable amount of analysis and testing has been undertaken, including increasing the number of sensors combined with new algorithms and data processing. This ground breaking and complex work is not yet completed.