ERF2010 048

„Safe in the Sky“
Continuing Airworthiness Process at Eurocopter Deutschland

Martin Lawall
martin.lawall@eurocopter.com
Stefan Emmerling
stefan.emmerling@eurocopter.com
Bernd Schwarze
bernhard.schwarze@eurocopter.com

Eurocopter Deutschland GmbH, 81663 Munich, Germany

Abstract

During the operation of aircrafts discrepancies due to failures or malfunctions of systems may occur. In the frame of the continuing airworthiness process, the design organisation of the Type Certificate Holder (TCH) and Original Equipment Manufacturer (OEM) is responsible to define the necessary actions to recover the specified and certified condition, thus ensuring flight safety. This correlation is described in general by a basic regulation overview and in particular on the procedures and processes in place within Eurocopter Deutschland GmbH to deal with airworthiness issues caused by major incidents in the fleet.

By means of a practical example, describing the rupture of a balance weight of a flight control lever of the tail rotor on an EC145 helicopter, the different process steps are shown and explained in detail. These steps start with the incident, along the occurrence reporting by the operator to the OEM, further to the different analysis and investigation steps which are subsequently leading to the definition of protective and corrective measures and finally to an information to all operators in order to accomplish actions for the affected helicopter fleet.

The safe, in case of need also restricted continuation of the flight operation of the existing helicopter fleet is ensured by the introduction of short term protective measures. The design organisation of the TCH defines in the following corrective measures which will be accepted and certified by the accountable aviation authority. The unrestricted operation of the helicopter will be established by accomplishment of these measures by the aircraft operator.

In the frame of the definition of the protective and corrective measures the main focus will be given on the practical and analytical investigation of damaged parts, which are a key element of the process chain in continuing airworthiness.

It is pointed out that the process of continuing airworthiness can only be upheld by close cooperation and interaction of many different services like customer support, quality, technical publication, design and airworthiness department, but also the aviation authorities. They all are key players for the continuing airworthiness and allow also further product improvement for future aircraft systems in terms of design robustness and reliability.

CONTENT

1. INTRODUCTION

1.1. In-Service Incidents

During operation of aircrafts, incidents may occur due to failure or malfunction of specific systems.

To collect, to analyse and to classify these occurrences and to define in case of need protective and corrective measures are key factors for the safe operation of aircrafts. Also the treatment of less significant incidents has a high priority and is contributing to the general flight safety like the failure pyramid (Figure 1) is indicating.

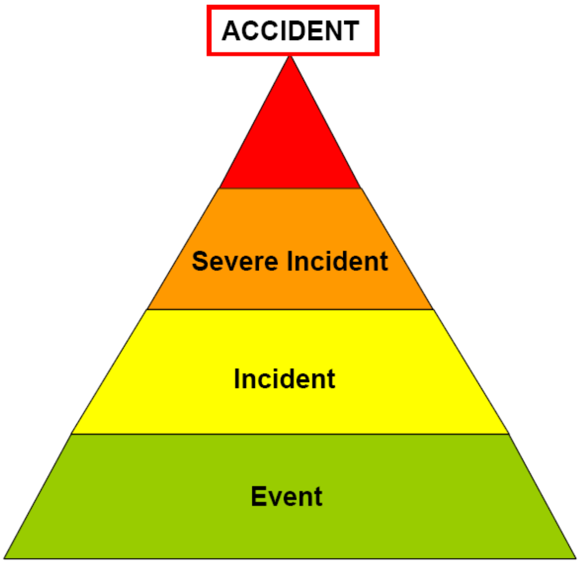


Figure 1. The failure pyramid in order to indicate the relationship between incidents and accidents

It can be seen that various incidents of lower severity, of which a few result in major incidents, of which also a small amount may come to an end in an accident.

In the commercial aviation an amount of approximately 300 to 400 minor incidents correlate with one accident. Subsequently it can be easily shown that the treatment and processing of in-service incidents is an important contributor for the improvement of the general flight safety.

1.2. Aviation Regulation

For the certification as design organisation (DO) or production organisation (PO) the compliance to the regulatory basics according to "Regulation (EC) No 216/2008 of the European Parliament and of the Council" [1] has to be demonstrated.

In part 21.A.3 (....) the duties of the type certificate (TC) holder and other groups are defined. These orders request to establish a system for collection, verification and analysis of occurrence reports beginning with the information about failures, functional failures, defects and other events which have or might have an influence on the airworthiness of the aircraft.

Furthermore the concerned organisations are required to establish an occurrence reporting system to the aviation authority.

1.3. Occurrence Reporting

The occurrence reporting of in-service incidents is defined within AMC 20-8 [3]. This document indicates several reporting paths and also different responsibilities of the reporting organisation like shown in Figure 2.

The information from the operator of the aircraft can of course not have the same technical detail depth as the ones of the concerned design organisation. It has to be ensured that the aviation authority as well as the design organisation receives the necessary data to analyse in-service events and to define afterwards in case of need the appropriate measures.

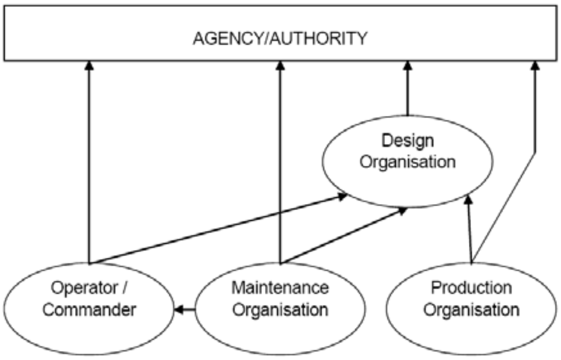


Figure 2. Occurrence reporting of in-service incidents of different organisations towards aviation authority and design organisation

1.4. Abbreviations

AD	Airworthiness Directive
AMC	Acceptable Means of Compliance
ASB	Alert Service Bulletin
CAB	Corrective Action Board
EAD	Emergency Airworthiness Directive
EASA	European Aviation Safety Agency
ECD	Eurocopter Deutschland GmbH
EDX	Energy Dispersive X-ray Spectroscopy
FH	Flight Hours
GM	Guidance Material
ISIR	In Service Incident Report
LBA	Luftfahrtbundesamt (German NAA)
MITB	Major Incident Technical Board
NAA	National Aviation Authority
S/N	Serial Number

2. CONTINUING AIRWORTHINESS PROCESS AT EUROCOPTER DEUTSCHLAND

First step in the process chain of flight incident treatment is the collection of the relevant data and the distribution of this content to the involved departments. Beside the treatment of incidents coming from the operator, also quality notifications within the production and assembly line can trigger this process. Furthermore root causes determined in the frame of an accident investigation are examined for their possible influence on the in-service fleet. Figure 3 shows in a schematic way how the process is initiated, followed and terminated.

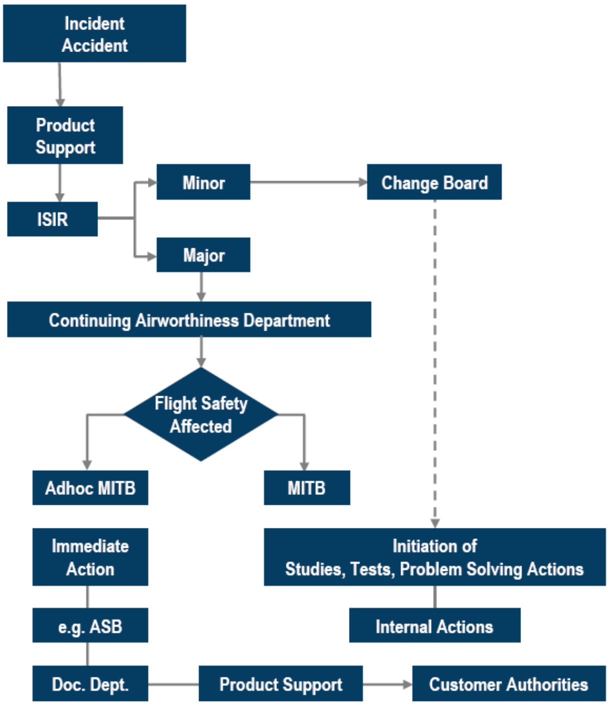


Figure 3. Simplified scheme for the continuing airworthiness process at Eurocopter Deutschland

Based on a first basic classification of an incident, the further treatment will be followed in the frame of product improvement or in case of a "major incident" classification in the continuing airworthiness process. The safety classification also determines the time frame of the incident treatment. In case an "Unsafe Condition" is declared in accordance to the defined criteria within "AMC and GM to Part 21" [4], the duty of the design organisation to report to the aviation authority within 72 hours is given. Beside first information on the event also first actions mainly focussing on protective measures should be proposed.

In the assigned Major Incident Technical Board (MITB) – in former times handled at ECD under the title Corrective Action Board (CAB) - representatives of different organisations like flight safety, design and system responsible, stress calculation, customer support, quality management, chief engineering and program management decide about all necessary actions, assign the right persons to the corresponding actions and define the associated time frame.

These actions can be categorized into basic actions, protective and corrective measures. Basic actions are defined to guide the process that means to launch laboratory investigation or any kind of basic investigations to determine the possible root cause of the incident. In this context also a more detailed safety analysis is established to discover other potential incident scenarios and determine the overall classification of the incident and its potential for safety degradation.

Protective measures ensure the further safe continuation of the aircraft operation by means of additional measures like new inspections, new inspection intervals, new life times or operational limitations.

Corrective measures are in most cases design changes that enable to re-establish the initially certified configuration of the aircraft and therefore are very often terminating actions for protective measures.

Protective as well as corrective actions are distributed to the operator by Service Bulletins or by Alert Service Bulletin depending on their classification. Upon the safe / unsafe classification of the incident also the need for an Airworthiness Directive (AD) by the aviation authority is determined. The AD application by the operator is then mandatory to comply with the airworthiness standards.

Information about incidents can be shared with all operators of the same model by means of "Safety Information Notices" or "Information Notices" and are mainly of use as a proactive and preventive tool to avoid further events by forwarding information or giving further explanations. This can help to avoid incidents that are more linked to human factors or the wrong or misinterpreted application of already existing procedures. Possible recipients of this information can be flight crews but also maintenance personnel.

3. THE HELICOPTER EC145

3.1. Development of the EC145

Target in the development of the EC145 was to take over the robust and reliable design of the BK117 and to combine it with new technologies like cockpit design, avionics, autopilot and flight control system from the EC135 [5].

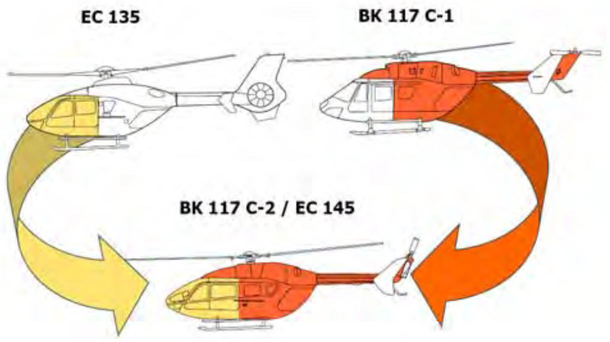


Figure 4. Development scheme of the EC145

The result is the BK117 C-2, offered under the Eurocopter brand name EC145, which combines in a good way the advantages of both concepts.

The EC145 is a twin engine multipurpose helicopter with up to 11 seats and a maximum takeoff weight of 3585 kg. Since its maiden flight on 19. June 1999 more than 313 helicopters have been delivered, which have accumulated more than 370.000 flight hours since.

Figure 5. EC145 on a rescue mission

Due to its modern design with two powerful and reliable engines and a very spacious cabin, a large variety of missions like air rescue service, police flights, VIP transport, offshore services in the oil and gas industry as well as military applications are possible.

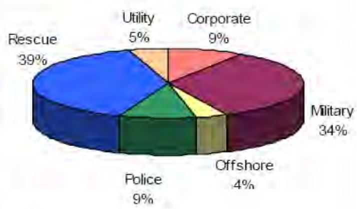
	EC145 fleet worldwide
Helicopters in service	313 helicopters
Flight hours total period	370.390 FH
Flight hours last 12 months	112.220 FH
Flight hours last quarter	29.960 FH
Mission distribution	

Table 1. Fleet statistics and distribution of the EC145 (status for 31.03.2010) on the different missions

Table 1 summarizes the most important data of the current fleet and mission distribution of the EC145.

3.2. Design of Tail Rotor and Tail Rotor Head

The tail rotor enables the helicopter to compensate the moment applied by the main rotor and allows control of the helicopter around the yaw axis. The tail rotor of the EC145 has two tail rotor blades with a central flapping hinge. Figure 6 shows the main components of the EC145 tail rotor system, which are also mounted with the same basic design on the helicopter models BO105 and BK117.

These main components are as follows:

- tail rotor shaft
- tail rotor head
- tail rotor control
- tail rotor blades
- tail rotor gearbox

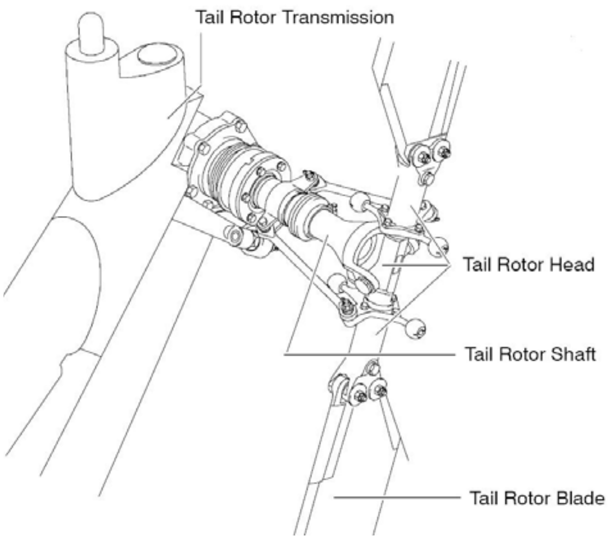


Figure 6. Overview on main components of the EC145 tail rotor

The following Figure 7 shows the detail composition of the tail rotor head and its single components.

The control input of angular changes for the tail rotor blades is accomplished by control rods, so called "pitch links". By means of a control lever the control inputs are transferred to both tail rotor blades.

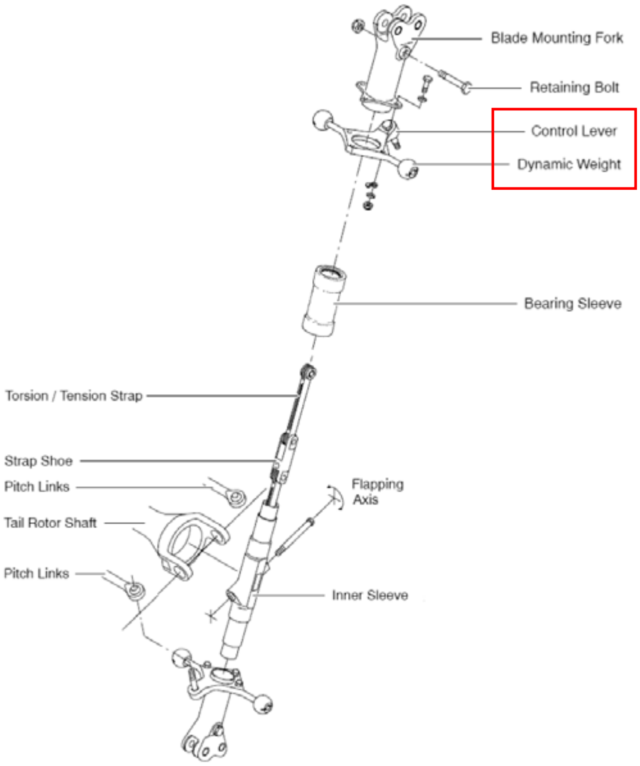


Figure 7. Explosion view of major components of the EC145 tail rotor head

Each control lever is equipped with two propeller moment weights, the so called “dynamic” or "chinese" weights (see Figure 7). These weights counteract the propeller moment of the blade which is acting against the control input.

Through these weights the control forces are reduced, which is necessary in case of an emergency, like the loss of the hydraulic amplification of the tail rotor control. The propeller moment weights are also designed in a way that the tail rotor will equilibrate the main rotor moment without applying additional pedal forces during flight.

3.3. Modification History of Tail Rotor Control Lever

The basic design of the BK117 control lever was taken over, but modified in a way for the EC145 to further improve the pedal force characteristic. To achieve this target, the resulting lever arm for the propeller moment weights on the control lever was increased by re-design of its outer shape. Figure 8 shows both design variants. With the new design the propeller moment weight is mounted on a more outboard position which enlarges the moment of inertia. The modified propeller moment weight has now no feed-through hole, but a blind bore. To reduce the degree of modification in terms of manufacturing, the basic design of the control lever was kept. Only the borehole for the split pin was moved to the inboard position. Subsequently the production of both control lever variants was possible with the same forged blank. In Figure 9 the details of both control lever arm designs are shown.

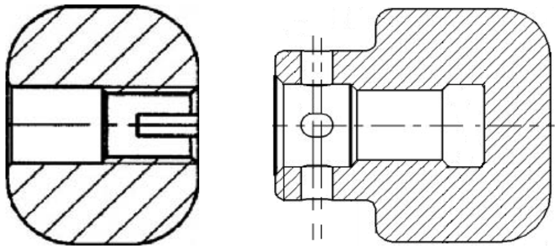


Figure 8. Initial (left-hand) and modified (right-hand) propeller moment weight design (material: tungsten)

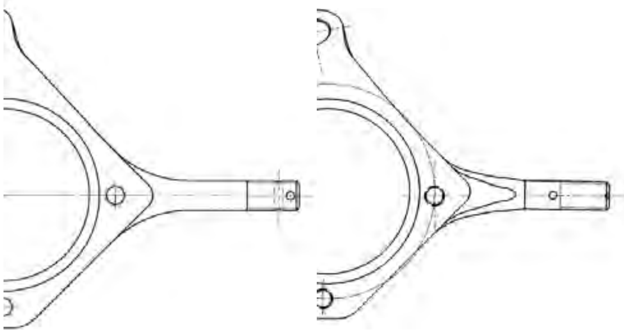


Figure 9. Initial (left-hand) and modified (right-hand) control lever design (material: titanium)

4. INCIDENT TREATMENT BY THE EXAMPLE OF A RUPTURED PROPELLER MOMENT WEIGHT FIXATION ON THE TAIL ROTOR HEAD

4.1. Report of a ruptured Propeller Moment Weight Fixation

Eurocopter Deutschland was informed by its customer support about an incident the 18.12.2006 on an EC145 helicopter operated in the United States of America.

During cruise flight severe vibrations in the area of the tail rotor were recognized. Subsequently the pilot initiated a safety landing which was successfully finished without further events. A visual inspection of the tail rotor after landing revealed a rupture of one arm of the control lever and the loss of the attached propeller moment weight. In consequence, the rupture resulted in the reported vibrations.

Figure 10 shows the affected control lever which was immediately sent to the laboratory for further root cause investigation.

Figure 10. Rupture of the attachment arm of the propeller moment weight

Due to the fact that this was the first case of control lever rupture of this kind, an ad-hoc action board between flight safety, design, stress calculation, quality management and customer support representatives was called in, to establish a first classification of the situation.

4.2. Definition of Protective Measures

First aim and priority after a verification of the event was to determine possible protective measures, which ensure a safe operation of the fleet, possibly by means of e.g. repetitive inspections, limitations of the flight envelope or similar measures. In the present case it was very soon recognized that the rupture of the control lever was closely linked to its design, which was previously modified as described in chapter 3.3. Similar occurrences of this kind of control lever rupture were never reported on the helicopters BO105 and BK117 in more than 9 million flight hours.

In the following course of events an Alert Service Bulletin (ASB) was decided and prepared, which should define the necessary protective measures for the fleet. This ASB was issued on 21.12.2006, three days after the first occurrence report to ECD.

The ASB contained the visual inspection of the control lever for possible mechanical damages in the area of the cotter pin and the contact area of the propeller moment weight. For this action, the removal of the propeller moment weight was necessary.

The first inspection was requested before the next flight, a further inspection 10 Flight Hours (FH) later and then in repetitive inspection intervals of 25 FH. Figure 11 shows an excerpt of the ASB which describes the actions to be performed.

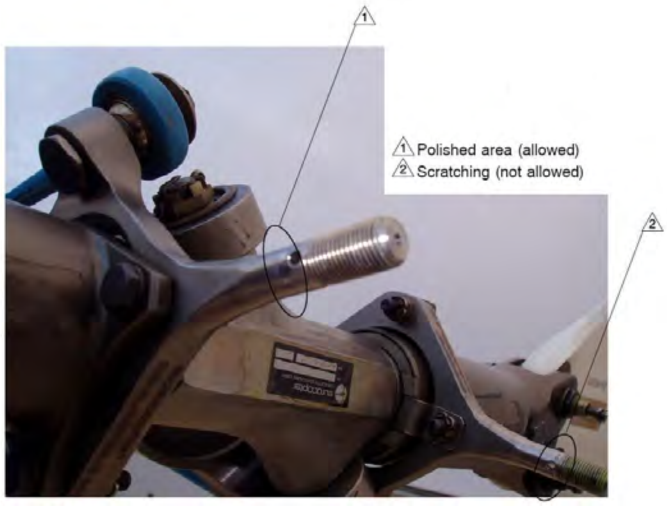


Figure 11. Visual Inspection of the control lever for mechanical damages

Based on a preliminary incident classification as "MAJOR", the national aviation authority, the Luftfahrtbundesamt (LBA) was informed by ECD about the current status of investigation. The Alert Service Bulletin issued by Eurocopter Deutschland was covered by an EASA Airworthiness Directive (AD) on 22.12.2006 and was herewith declared as mandatory for all operators within EASA field of applicability.

Herewith criteria were defined, which under introduction of repetitive inspections have enabled the continued and safe operation of the EC145 helicopters.

4.3. Analytical Investigation

After the first occurrence report a review of the stress substantiation documents was launched to determine possible influencing factors on the root cause of the rupture. The stress analysis performed at the time of the certification of the new control lever could not explain the failure despite

- the stress increase by the enlarged lever arm of the propeller moment weight
- the increase of the weight mass
- the stress concentration due to the cotter pin borehole

4.4. Laboratory Investigation of Damaged Parts

After removal of the second propeller moment weight of the damaged control lever, markings were found on the inner circumference of the close tolerance fit borehole which were caused by the thread manufacturing in the blind hole (Figure 12).

Figure 12. Markings on the inner side of the propeller moment weight

These markings could have imprinted on the control lever arm and have caused an additional stress concentration increase. The concerned components were analysed in detail at the EADS Innovation Works (IW) laboratory. Thereby the following results were achieved: the rupture was caused by at least two fatigue cracks (marked with red arrows) as shown in Figure 13.

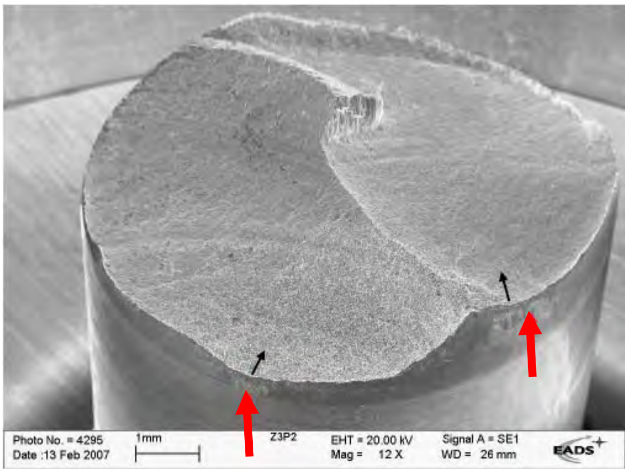


Figure 13. Rupture surface with two crack initiation points (red arrows)

In the vicinity of the two corresponding crack initiation points are zones with significant fretting corrosion (Figure 14) which show various surface cracking indications (Figure 15).

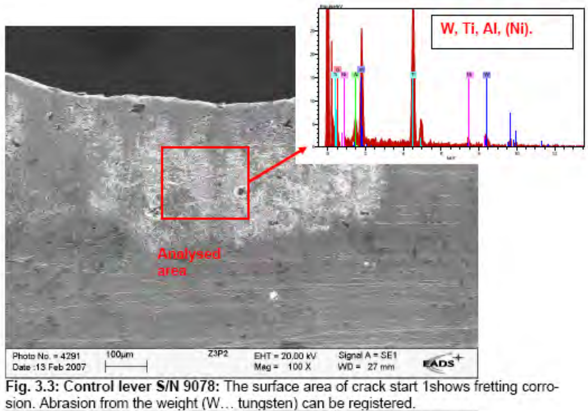


Figure 14. Zone with fretting corrosion

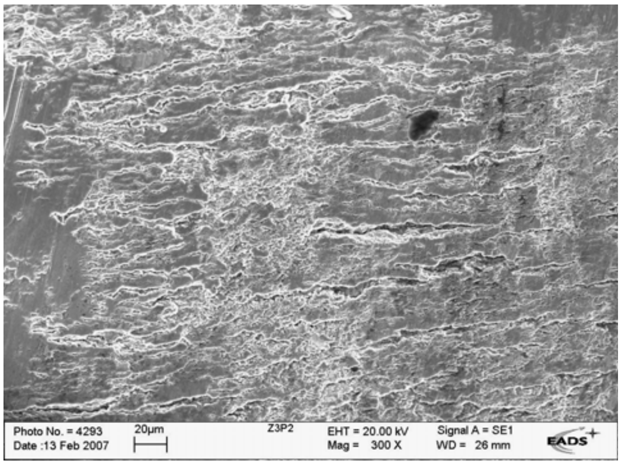


Figure 15. Surface cracks in the area with fretting corrosion

The EDX (Energy Dispersive X-Ray Spectroscopy) analysis conducted for the surface provided evidence of tungsten particles (coming from the propeller moment weight) attached to the surface of the titanium control lever. In addition the markings on the inner side of the propeller moment weight could be located and confirmed on the control lever arm (Figure 16).

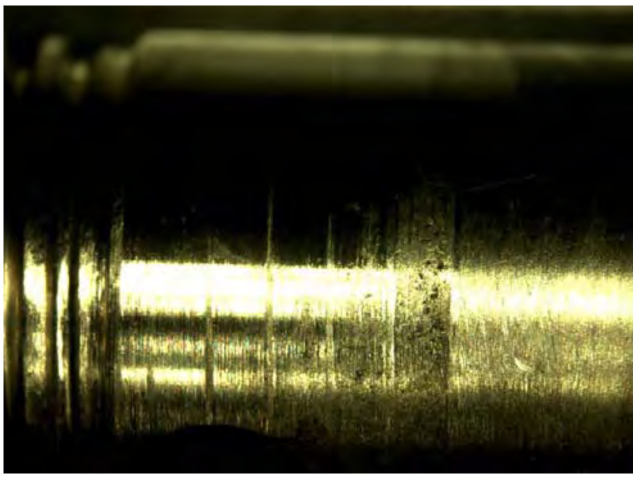


Figure 16. Markings on the surface of the control lever

The metallurgic investigation findings caused implications on the assessment of the existing design. The close tolerance fit between propeller moment weight and control lever arm which is in addition interrupted by the cotter pin borehole has a rather short length. Together with the eccentricity of the propeller moment weight centre of gravity, in relation to the close tolerance fit, the centering and fixing against tilting of the weight is not sufficient. The herewith allowed small tilting motions have caused fretting corrosion. At least one of the various surface cracks has subsequently grown under the dynamic bending stress and has finally led to the rupture of the control lever arm.

4.5. Influence of Fleet Feedback on the Airworthiness Process

By release of the Alert Service Bulletin (ASB), measures were in place which ensured the safe operation of the fleet under additional inspection effort for the operator. During the progress for the definition and substantiation of a future modified design a new event was reported.

During landing approach of an helicopter onto a platform a rupture of a control lever arm occurred. This was recognized by the pilot through an increased vibration level, whereas the helicopter still remained fully controllable. After the successful landing, the broken arm of the control lever with the still attached propeller moment weight was found. The rupture appeared 23 flight hours after the last inspection that means within the allowed limit of 25 flight hours as described in the ASB.

In coordination with the national aviation authorities (NAA) of the affected operator and the national authority of the design organisation of the helicopter, the inspection interval for the control lever was reduced by the factor of 3, to allow also in case of an imperfectly conducted inspection the detection of mechanical damages before it could lead to an in-flight separation of the propeller moment weight.

Figure 17. Broken control lever arm in the area of the cotter pin borehole

The re-defined inspection interval of 8 flight hours was published with revision 1 of the ASB on 09.07.2007, followed by EASA AD 2007-0189-E on 12.07.2007.

4.6. Design Modifications

After finalising the analytical investigations and the availability of the laboratory report, the results and conclusions were used to incorporate them into a modification of the design, which has to be implemented in the fleet as a necessary corrective action to re-establish the certified configuration and to terminate the repetitive inspections.

Figure 18 compares the modifications individually. Row one shows the initial design (affected by the ASB). Row two shows the improved control lever and propeller moment weight.

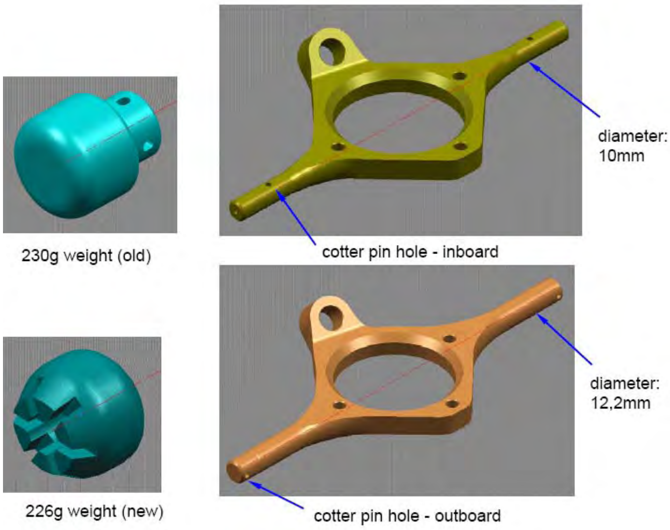


Figure 18. Comparison of the initial design (row above) and the improved design (row below)

The following design modifications were introduced:

- The diameter of the control lever arm was increased from 10 mm to 12,2 mm.
- The borehole for the cotter pin was moved outboard. To achieve this, the length of the arm was increased from 100 mm to 108 mm.
- The geometry of the propeller moment weight was improved and the close tolerance area to the control lever was increased by 55%.
- The contact surface between weight and control lever is treated with corrosion preventive paste prior to assembly.

4.7. Serial Implementation of Design Modifications

After finalisation and release of the modified drawing set by the design organisation, the modification was also reviewed and certified by the responsible aviation authority. After preparation of the necessary material, a retrofit kit was defined to enable the operators the installation by means of a revised ASB.

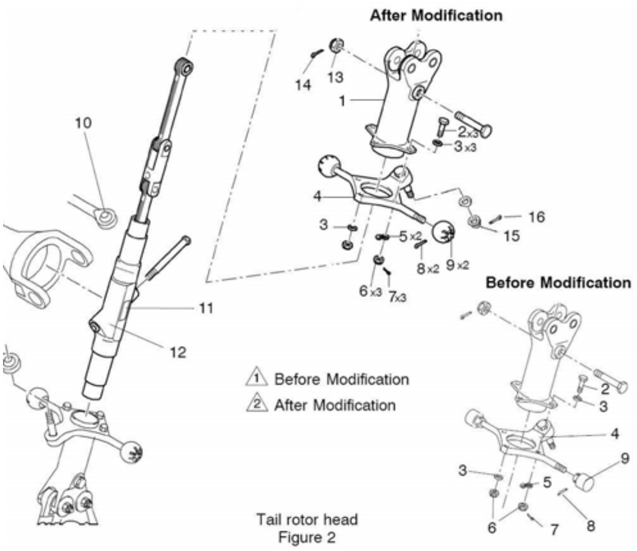


Figure 19. Introduction of the design modification by Alert Service Bulletin (ASB)

Figure 19 shows an excerpt of the retrofit documentation. To allow and describe the operators the necessary modifications, a new revision of the ASB was created, which requests the further continuation of the repetitive inspections until the implementation of the retrofit.

The 31.10.2007 was defined as due date until the retrofit has to be performed at the latest. From this date on no control lever is any more allowed in service which is listed under the inspection criteria of the ASB. The definition of such a concluding action is in general called "terminating action". To have these actions been conducted as mandatory actions by the operators, the revised ASB was also covered by EASA Airworthiness Directive AD 2007-0237 on 31.08.2007.

After this due date all affected control levers have been replaced by ones with the improved design and are herewith no more affected by the ASB and the corresponding AD.

The modified control levers and propeller moment weights are in service since that date and no further feedback was reported from the fleet.

5. CONCLUSION

The link and interaction between various directorates is necessary to analyse major flight incidents, to determine the root causes and in consequence to define appropriate counter measures. These measures are a significant key factor in the continuing airworthiness process and in the improvement of the general flight safety. For this reason it is also important to return the gained results into the development of new products.

By learning from discrepancies and detected flaws, future products will have from the beginning a higher degree of maturity. As examples improved material choices, material heat treatment or even complete design principles and systematics can be given.

Herewith the loop can be closed and any re-occurrence of a similar incident can be prevented.

6. REFERENCES

[1] REGULATION (EC) No 216/2008 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 20 February 2008 on common rules in the field of civil aviation and establishing a European Aviation Safety Agency, and repealing Council Directive 91/670/EEC, Regulation (EC) No 1592/2002 and Directive 2004/36/EC

[2] COMMISSION REGULATION (EC) No 1702/2003 of 24 September 2003 laying down implementing rules for the airworthiness and environmental certification of aircraft and related products, parts and appliances, as well as for the certification of design and production organisations

[3] AMC-20, GENERAL ACCEPTABLE MEANS OF COMPLIANCE FOR AIRWORTHINESS OF PRODUCTS, PARTS AND APPLIANCES, AMC 20-8, Occurrence Reporting

[4] DECISION NO. 2003/1/RM OF THE EXECUTIVE DIRECTOR OF THE AGENCY of 17 October 2003 on acceptable means of compliance and guidance material for the airworthiness and environmental certification of aircraft and related products, parts and appliances, as well as for the certification of design and production organisations (“AMC and GM to Part 21”)

[5] A. Humpert, Design of the Eurocopter Medium Twin Helicopter EC145, AHS Forum, USA, 05.2003