Transportation Safety Board of Canada

Bureau de la sécurité des transports du Canada

AVIATION INVESTIGATION REPORT
A07Q0085

IN-FLIGHT BREAK-UP

HELI-TRANSPORT SERVICES (CANADA) INC.
EUROCOPTER AS350 B1 ASTAR (HELICOPTER) C-GZCN
CHIBOUGAMAU, QUEBEC, 176 nm NE
27 MAY 2007

Canada

Aviation Investigation Report

In-flight Break-up

Heli-Transport Services (Canada) Inc.
Eurocopter AS350 B1 Astar (Helicopter) C-GZCN
Chibougamau, Quebec, 176 nm NE
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Report Number A07Q0085

Summary

The Heli-Transport Services Inc. Eurocopter AS350 B1 Astar helicopter (registration C-GZCN, serial number 2207) departed a mining camp 176 nm northeast of Chibougamau, at 0800 eastern daylight time en route to a drill site 20 nm to the southeast. Approximately four minutes after departure, the helicopter broke up in flight and descended rapidly to the ground. The pilot, the sole occupant, was fatally injured and the aircraft was destroyed.

Ce rapport est également disponible en français.

Other Factual Information

The helicopter C-GZCN was under contract to Melkior Resources Inc. (Melkior), which was engaged in the acquisition and exploration of Canadian mining properties, primarily in Ontario and Quebec. Melkior had positioned an exploration team in the Otish Mountains northeast of Chibougamau, Quebec, to explore for uranium. Heli-Transport Services (Canada) Inc. (Heli-Transport), based in Carp, Ontario, is a helicopter transport company operating under Sections 702 and 703 of the *Canadian Aviation Regulations* (CARs), and was contracted to support Melkior's drill site needs, such as crew shift changes, drill site supplies and drill moves. Heli-Transport operates a base in Trois-Rivières, Quebec, where the accident helicopter had undergone extensive maintenance to ready it for the summer season.

The helicopter was manufactured in 1989 and imported into Canada in 2004. It was operated and maintained by Heli-Transport in accordance with existing regulations and approved maintenance organization (AMO) procedures. All modifications, mandatory airworthiness directives, and required maintenance had been completed. The helicopter's weight and centre of gravity were within the prescribed limits during the flight. The helicopter was not equipped with a flight data recorder or a cockpit voice recorder, nor was either required by regulation.

The helicopter had flown approximately 9380 total hours, including 35 hours since the completion of the last scheduled major aircraft inspection, which took place between 15 March 2007 and 14 May 2007. The helicopter also underwent the 3500-hour inspection on the main gearbox (MGB) epicyclic reduction gear module, main rotor shaft corrosion inspection, and the modification of the rear fuselage structure attachment bulkhead. This work was completed, and the paperwork was signed on 14 May 2007.

During the 3500-hour inspection, the MGB epicyclic reduction gear module was removed from the MGB. This work involved removing the main rotor blades, disconnecting the flight controls, and separating the upper and lower rotor shaft casings of the MGB to gain access to the epicyclic reduction gear module. The epicyclic reduction gear and the rotor shaft casings were sent for overhaul to the Eurocopter Canada facility. They were returned to Heli-Transport on 20 April 2007, and the epicyclic reduction gear module was re-installed on the MGB.

Maintenance activities were completed on 15 May 2007. The aircraft was ground and flight tested to verify the proper installation of the various system components, to check for fluid leaks and to assess overall aircraft performance. The helicopter was flown for 1.5 hours. The main rotor system was checked with a tracking system to ensure the proper flight path and balancing of the rotor blades. During these ground and flight tests, it was noted that the main rotor rpm (Nr) indicated 10 revolutions per minute (rpm) lower than the normal 394 rpm setting. This lower rpm was still within limits. It was later confirmed through the tracking system that the actual main rotor rpm was not below normal, and that the anomaly was an indicator problem.

During one of the test flights, ground resonance[1] occurred after landing, while bringing the throttle from full power to idle. Power was immediately re-applied and the resonance disappeared. The aircraft was repositioned without further ground resonance. The maintenance personnel checked all dynamic components as per the maintenance manual and replaced the steel strip vibration absorbers located at the aft end of both skids. In addition, a humming noise was heard during some of the engine ground runs. An engine technical representative present during these engine ground runs indicated that a similar hum had occurred on other AS350 Bs. The hum subsequently stopped, and troubleshooting to find the source of the hum also stopped.

During another session of ground and flight testing, the main rotor gear box (MGB) chip warning light illuminated. The magnetic chip detector was inspected, and fine metal fuzz was observed. The Eurocopter technical representative was informed. He referred the aircraft maintenance engineers (AMEs) to Maintenance Manual (MM) 05.53.00.608[2] for special inspection procedures required after such an event. According to the Eurocopter technical representative and the special inspection procedure documents, the presence of metal fuzz or fine metal particles after replacing parts such as the MGB epicyclic reduction gear module is not abnormal. The special inspection procedure was performed, and no other MGB chip warning light appeared. Each of the above problems was addressed as per the manufacturer's maintenance manual. There were no further indications of problems, and the aircraft was released for flight.

The helicopter had been expected at the mining camp in the Otish Mountains on 15 May 2007. Due to the delay in maintenance, the pilot, along with an AME, departed with the helicopter late in the day on 16 May 2007 and arrived on site before noon on 17 May 2007.

The pilot was certified and qualified for the flight in accordance with existing regulations. She had approximately 1600 hours of total flying time, with 110 hours on the Eurocopter AS350. She had completed her training and pilot proficiency check in April 2007. The AME assigned to the Melkior contract was licensed in 2005, and had completed the technical Eurocopter AS350 helicopter course. He had worked for Heli-Transport as an independent contractor on many occasions during the previous three years.

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1 Eurocopter explains the ground resonance phenomenon as follows: "When the helicopter is on the ground with its rotor spinning, the vibrations have a support point via the landing gear; if the natural frequency of the landing gear coincides with the principal vibrational frequencies of the main rotor, the vibrations are augmented at every blade revolution as they receive a new "reflected" impulse. The vibration amplitude then increases very rapidly, the vibration becomes divergent and the resulting oscillations can destroy and overturn the helicopter."

2 Maintenance Manual MM 05.53.00.608 – Inspection following an incident – Gearbox oil is contaminated and Standard Practices Manual 20.08.01.601 – Periodical Monitoring of lubricating oil checking element.

Over the 10 days before the accident flight, the pilot inspected the aircraft before the first flight of each day, and the AME inspected it again at the end of the day. The AME continued to monitor the low Nr indication, and had attempted various corrective maintenance measures including many consultations by telephone with the maintenance base in Trois-Rivières in order to rectify the problem. None of the proposed solutions resolved the problem.

On 22 May 2007, the MGB chip warning light illuminated. The AME inspected the magnetic chip detector and observed fine metal fuzz. The oil and filter were replaced, and the maintenance manual special inspection procedures were performed before releasing the helicopter for flight. This event was reported to the maintenance base in Trois-Rivières.

On 25 May 2007, the pilot experienced ground resonance while landing on a log pad. The resonance immediately dissipated when the pilot reapplied engine power and repositioned the helicopter on the pad. The AME inspected the vibration absorbers and the relevant dynamic components for their condition and their attachments. No abnormalities were found. Other than the above seemingly unrelated problems, the pilot did not report any aircraft performance or other helicopter related problems during this period.

On 27 May 2007, the pilot inspected the helicopter for flight and departed at 0645 eastern daylight time[3] with a drill crew for the morning crew change. Weather conditions were appropriate for visual flight rules (VFR) flight. At the drill site, the pilot completed three sling moves, and then returned to camp with the exiting night-shift crew. During the return flight, the low rotor rpm warning horn sounded and the pilot reported hearing a low-frequency hum at idle power. A ground check was performed at idle power to attempt to identify the source of the noise. The AME could also hear the hum, but it would disappear as soon as power was increased to 100 per cent.

The aircraft then departed on the accident flight. It was observed after take-off to be en route to the drill site. A trail of what appeared to be smoke was coming from the helicopter, and the helicopter descended rapidly toward the ground. The camp manager and the AME were advised, and a search and rescue plan was initiated.

The helicopter was found at approximately 1000 in a swamp, 8 nm from the mining camp. The aircraft was partially inverted, and on its right side. The main rotor blades struck the cockpit while in flight, fatally injuring the pilot and severing the cabin roof, sidewalls, and doors. The wreckage debris was spread over a distance of approximately 700 feet in a northeast direction. The tail boom was separated from the helicopter and was found approximately 120 feet east of the main cabin. The wreckage was transported to the TSB Engineering Laboratory for further examination.

During the accident flight, the tailboom had separated from the fuselage at the rear fuselage bulkhead rivet line. The tailboom had recently been modified to fulfill the requirements for Airworthiness Directive (AD) F-2004-035, *Fuselage - Rear Structure Junction Frame*. The modification of the frame allowed compliance with Alert Service Bulletin 05.00.43. This modification consisted of removing the rivets and installing a reinforcement doubler at the rear fuselage bulkhead, along with new rivets.

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[3] All times are eastern daylight time (Coordinated Universal Time minus four hours).

The rear fuselage structure modification and the repair procedures were examined, and a metallurgical examination was completed. No deficiencies were found in the rivets, or in the quality of the riveting. During the in-flight break-up of the helicopter, the tailboom was subjected to a load in excess of its design limits, and the rivets failed in overstress.

The helicopter engine (Turbomeca model Arriel 1D, serial number 7023) was sent to Turbomeca Canada for examination. Under the supervision of a TSB investigator, the engine was disassembled. All damages found were consistent with an engine that was producing power at impact.

The main rotor components were examined at the TSB Engineering Laboratory. The main rotor system had impact marks along the Starflex arms and main rotor blades' attachment bushings. These impact marks indicate that the main rotor was rotating when it struck the forward fuselage.

During the post-accident examination, the MGB was split at the main rotor shaft lower casing assembly line. The six main rotor shaft retaining bolts and the self-locking centre bolt attaching the epicyclic reduction gear to the mast were found unscrewed in the bottom of the sun gear. All of the associated locking tabs and bolts were accounted for. Additionally, snap ring segments were found above the phonic wheel (spacer assembly) in the rotor shaft upper casing (see Figure 1).

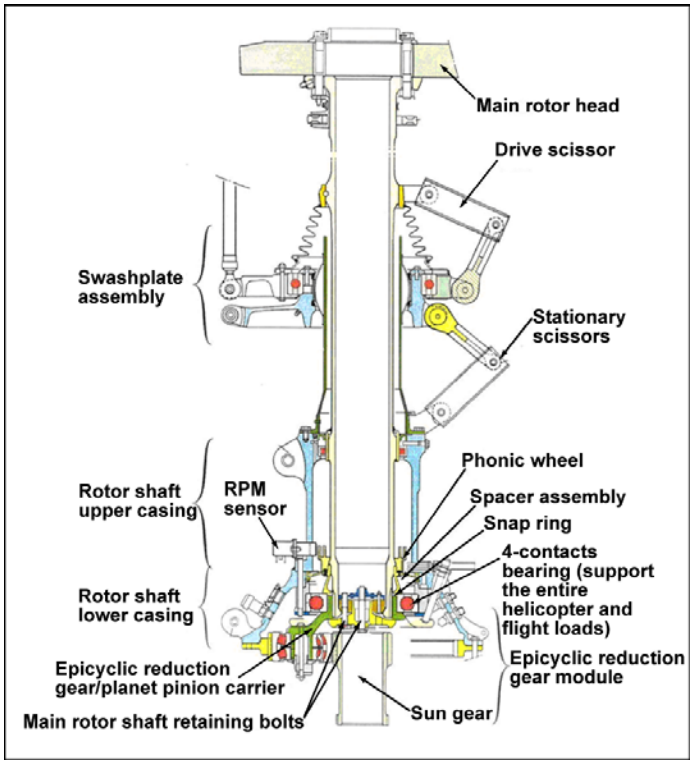

Figure 1. AS350 Main gearbox schematic

The 3500-hour maintenance tasks, including the reinstallation of the epicyclic reduction gear module, were completed using an electronic version of the Eurocopter Maintenance Manual MM 63.10.16.403[4] as the primary reference (see Appendix A).

To perform the reinstallation of the epicyclic reduction gear module, the electronic version of the Maintenance Repair Manual (MRM) work card (WC) 62.30.16.701[5] (see Appendix B) was referenced via a hyperlink within a caution note (see below) in the MM 63.10.16.403. The task headings within the 15 pages, including 9 diagrams, of the work card were not all applicable to this specific epicyclic

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4 MM 63.10.16.403 – Main rotor drive, main gear box (MGB) modules (post MOD 076120) removal and installation.

5 WC 62.30.16.701 – Rotor Mast, replacement of shaft casing bearings and seal post MOD 076120 and 077092 and main rotor shaft.

reduction gear module reinstallation because there was no need to replace the mast bearing, the main rotor shaft or the rotor mast seal. However, the reinstallation of the main rotor shaft was necessary and reinstallation steps were outlined in WC 62.30.16.701. Although several of the reinstallation steps were not necessary, some of the steps were crucial to ensure the proper reinstallation sequence. The AMEs who completed the reinstallation did not follow WC 62.30.16.701.

Section 3.2 (b) of MM 63.10.16.403, the primary reference, assures the snap ring is fitted, but does not specify the installation sequence. The maintenance manual states the following; "Coat the splines[6] with grease and install planet gear carrier on rotor shaft, after checking for presence of snap ring." This instruction is accompanied by the following caution note:

> CAUTION: CHECK THAT SNAP RING IS CORRECTLY FITTED, W.C. 62.30.16.701. DO NOT OMIT TO FIT THE LOCK PLATES (6), (9), AND WASHER (7). OBSERVE THE CORRECT POSITION OF LOCK PLATES (9) (DETAIL A).

These instructions do not specify the installation sequence of the snap ring. They simply state to ensure its presence.

However, MRM WC 62.30.16.701, section 4, subsection 4.1 e) (see Appendix B), does specify the snap ring installation sequence. It states, in part, to install the casings on the rotor shaft and to fit the snap ring, and includes the following caution note:

> CAUTION: OBSERVE THE PROCEDURE FOR INSTALLING SPACER ASSEMBLY (28), CASINGS AND HOUSINGS BEFORE POSITIONING SNAP RING (24).

During the final steps of the epicyclic reduction gear module installation, the AMEs used a borescope to visually inspect the interior of the main rotor shaft. To confirm proper installation of the mast retaining bolts, the AMEs confirmed an equal number of visible threads on the mast retaining bolts as per MM 63.10.16.403, section 3, subsection 3.2 d) and MRM WC 62.30.16.701, section 4, subsection 4.2 g), h), and i). The AMEs saw approximately 1 ½ threads showing on all the mast retaining bolts. The instructions do not specify a minimum number of visible threads required to ensure correct installation.

During the post-accident examination, the six mast retaining bolts and the self-locking centre bolt attaching the epicyclic reduction gear to the mast were found unscrewed in the bottom of the sun gear. In addition, segments of the snap ring were found above the spacer assembly as opposed to below the spacer assembly. The snap ring's sole function is to retain the spacer assembly, the casings and housings on the main rotor shaft while manipulating the MGB upper module before the epicyclic gear module is bolted on. It is not intended to take either the aircraft weight or dynamic loads experienced in flight.

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[6] A spline is a shaft with a series of longitudinal, straight projections that fit into slots in a mating part to transfer rotation to or from the shaft.

If the snap ring is installed in the wrong sequence, which was the case in this occurrence, it will move out of its groove due to overload forces. This will release the tension on the mast retaining bolts and locking tabs. The tabs will no longer function as locking devices. The direction in which the sun gear turns and rubs the bolt heads allows for the progressive loosening of the mast retaining bolts. When the bolts no longer secure the mast, the main rotor shaft will move vertically and cause the main rotor blades to fly down into the forward fuselage.

The AME in charge of the MGB epicyclic disassembly and reassembly project had been employed with Heli-Transport since 2002, and had been fully licensed since 2004. He completed his technical Eurocopter AS350 Astar type training in 2005, and had performed a reassembly of the MGB epicyclic reduction gear module only once before. Although he was present for the disassembly and reassembly of the MGB, he was not present during the ground-runs and flight tests.

The other licensed AME had been employed with Heli-Transport since June 2004, and had been fully licensed since January 2007. He completed his AS350 type training in October 2006. He had never performed a reassembly of the MGB epicyclic reduction gear module.

At different times during the maintenance work, these AMEs were assisted by an AME apprentice. All maintenance operations are overseen by the production manager. Human factors training was completed by all company AMEs in 2005. The work environment, equipment, workload, work and rest periods were examined during the investigation, and were not considered to have negatively affected the work carried out. The AMEs were trained and comfortable working with the English version of Eurocopter's reference documentation.

Of the 2832 Eurocopter AS350, AS355, and AC130 helicopters operating with the 4-contact bearing and MGB assembly, as was the case for the occurrence helicopter, 993 are operated in Canada and the United States.

A similar occurrence happened in Spain in February 1993. The helicopter had been in maintenance following a mast oil leak. The MGB was opened, the seal was changed, and the unit was re-assembled. The helicopter had flown approximately 17 hours after maintenance when a grinding noise was reported. The maintenance inspection did not find the cause of the noise. On a subsequent flight, the helicopter went into a dive before crashing and burning. Although the symptoms were similar to this occurrence, they were not linked to the snap ring installation sequence. Following the accident in Spain, Eurocopter issued Telex Service Letter 01-41, which addressed the troubleshooting of abnormal noise if maintenance of the mast epicyclic reduction gear assembly had been recently (100 hours) performed. Eurocopter also added the mast retaining bolts borescope inspection to the re-installation instructions to ensure the proper installation. Caution notes were added to MM 63.10.16.403, section 3, subsection 3.2 b) and MRM WC 62.30.16.701, section 4, subsection 4.1 e). Transport Canada (TC) issued Airworthiness Directive (AD) 93-030-065 (B) to ensure that Canadian operators comply with the Telex Service Letter issued by Eurocopter.

In Canada, a similar occurrence happened in June 2006.The snap ring had been installed in the wrong sequence with respect to the phonic wheel/spacer assembly. The helicopter had undergone maintenance at approximately 92.5 flying hours before the occurrence. Maintenance personnel had previously completed the 12-year inspection of the main rotor shaft, which

required that similar maintenance operations be performed on the MGB. The information gathered indicated that no ground resonance, Nr problems and/or hum were reported preceding the occurrence. While in flight, the pilot reported a sudden bang, and the MGB warning chip light came on. The pilot landed and had the helicopter inspected. The MGB was split and it was observed that six of the seven mast retaining bolts had loosened but were still holding the mast. The other bolt was found in the bottom of the sun gear. As with the above occurrences, Nr problems and/or hum and ground resonance were not present even though the snap ring installation sequence was incorrect.

Although information from the occurrence in Canada was unofficially disseminated to a few members of the helicopter community, no formal process was in place to identify and inform the community at large. The manufacturer was not made aware of the occurrence or the circumstances leading to it. No specific action or procedures were put in place to prevent a recurrence. TC's present definition[7] of a Reportable Service Difficulty found in CAR 591 includes human factors–related issues only if the Instructions for Continued Airworthiness (ICA) for the product are determined to be the cause of the error. In Advisory Circular (AC) 591-001, TC maintains that "An organization's Safety Management System should address these occurrences." TC provides a Service Difficulty Reporting Logic Chart (TP 14134B) to assist in the determination of defects, failures and malfunctions that require reporting to the Service Difficulty Report (SDR) program (see Appendix C). Heli-Transport's AMEs were aware of the June 2006 occurrence and double checked, as per the MM, that the snap ring was in place and, by using the borescope, that all bolts had the same number of threads visible. However, this operation did not guarantee a correct installation of the epicyclic reduction gear assembly.

Analysis

The TSB post-accident examination revealed that the snap ring within the MGB epicyclic reduction gear module was installed before installing the spacer assembly. The wrong installation sequence of the snap ring, relative to the spacer assembly, allowed the snap ring to slip from its groove on the mast, which in turn prevented the locking tabs from holding the mast retaining bolts. The bolts loosened by rubbing inside the sun gear, and eventually fell out, allowing the main rotor shaft to move vertically. The vertical movement of the main rotor shaft caused the rotor blades to strike the forward fuselage.

MM 63.10.16.403 was used as the primary reference for installing the snap ring. MRM WC 62.30.16.701 was not considered to be applicable information because most of the steps were not applicable to the task being performed. This was determined, at the time of the maintenance work, by visually scanning the headings within the 15 pages of MRM WC 62.30.16.701. None of the headings were considered pertinent and therefore further reading of the material was deemed unnecessary. This caused the AMEs to miss pertinent information concerning the proper installation sequence of the snap ring. The MM instructions imply that

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7 Present regulations require that a Service Difficulty Report (SDR) to Transport Canada be made when there is a defect or malfunction of an aircraft part. Defects, failures and malfunctions occurring directly as a result of human factors are not reportable to the SDR program unless the Instructions for Continued Airworthiness (ICA) for the product are determined to be the cause of the error.

the snap ring should already have been installed, but do not indicate exactly when to install it. The MM instructions lead the AMEs to WC 62.30.16.701 to check for correct fitting of the snap ring. They considered this redundant because the snap ring could only be fitted in one specific groove on the main rotor shaft.

Using the borescope to confirm a correct and complete installation by verifying an equal number of threads on the mast retaining bolts provided false confidence by implying that the assembly was done properly. The instructions fail to specify a minimum number of visible threads necessary to ensure the integrity of the assembly.

Before this occurrence, low Nr, magnetic chip fuzz, ground resonance, and a low-frequency hum were detected. Each of these symptoms was examined individually by qualified personnel according to the manufacturer's instructions. None of the symptoms were considered to be related, nor were they linked to the installation of the epicyclic reduction gear module. The troubleshooting references, including technical representative consultations, did not link these symptoms to the snap ring installation sequence likely because a previous relationship between these symptoms was not known. Even though these symptoms were present at various points in time over the 35 hours of flight conducted, the aircraft continued to operate within its normal parameters.

In addition, the information available from previous occurrences did not clearly link these symptoms to the snap ring installation sequence. It is now known that these symptoms may indicate a loss of integrity of the MGB epicyclic reduction gear assembly.

The following TSB Engineering Laboratory reports were completed:

LP054/2007 – In Flight Break Up Analysis
LP053/2007 – Site Survey & Altitude Determination

These reports are available from the Transportation Safety Board of Canada upon request.

Findings as to Causes and Contributing Factors

1. The aircraft maintenance engineers (AMEs) did not consult the applicable sections of the work card for the re-installation of the main rotor shaft and the main gearbox (MGB) epicyclic reduction gear module. This resulted in the snap ring being installed in the wrong sequence.

2. The wrong installation sequence of the snap ring ultimately allowed the mast retaining bolts to loosen and the mast to move vertically, causing the rotor blades to strike the forward fuselage.

Findings as to Risk

1. The symptoms experienced during ground-runs and flight tests, and noted during flights following the maintenance, demonstrated a previously undiscovered link to the incorrect assembly of the MGB epicyclic reduction gear module. Current maintenance manual troubleshooting instructions do not direct AMEs to a possible MGB epicyclic reduction gear module assembly problem.

2. Referring AMEs to lengthy instructions, not necessarily required in full, may result in a filtering process that causes important information to be missed.

3. The maintenance manual specifies that the same number of threads should be visible on the main rotor shaft retaining bolts during the borescope inspection, but it does not specify the actual number of threads that should be visible to confirm proper installation. Therefore, the installation could appear to be secure when it is not.

Safety Action

Subsequent to this occurrence, Eurocopter took the following actions:

- Issued a Telex Information Letter (T.F.S. No. 00000393 dated 15 June 2007) entitled *Main Rotor Mast Equipped with a 4-contact Bearing. Assembly of the spacer/phonic wheel with respect to the retaining ring*. This telex acts as an initial information letter to all operators prior to a final document amendment. The telex clarified compliant installation of the snap ring.

- Changed its documentation and added a new assembly diagram to WC 62.30.16.701 to ensure a better applicability of the assembly procedures.

- Modified WC 05-53-00-614 for related troubleshooting details.

- Deleted the borescope inspection within the MM 63.10.16.403 and the WC 62.30.16.701.

- Changed the material of the snap ring from steel to elastomeric, making the assembly tolerant to potential assembly error. The new elastomeric ring will shear if it is not installed in the proper order under the torquing loads of the mast retaining bolts. This will result in the assembly becoming secure by all the required contact points.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 04 June 2008.

*Visit the Transportation Safety Board's Web site (**www.tsb.gc.ca**) for information about the Transportation Safety Board and its products and services. There you will also find links to other safety organizations and related sites.*

Appendix A - Extract from Eurocopter Maintenance Manual MM 63.10.16.403

MAIN ROTOR DRIVE
main gear box (MGB) modules (post MOD 076120)
removal and installation

(...)
3 EPICYCLIC REDUCTION GEAR MODULE
(...)

3.2 Installation
(...)
b) Coat the splines with grease and install planet gear carrier (1) on rotor shaft, after checking for presence of snap ring (Fig. 3) .

CAUTION: CHECK THAT SNAP RING IS CORRECTLY FITTED, W.C. 62.30.16.701, THE LOCK PLATES (6), (9), AND WASHER (7) OBSERVE THE CORRECT POSITION OF LOCK PLATES (9) {DETAIL A).

NOTE: Position the slot of the bearing housing in front of the chip detector (14).

c) Install plates. (23) (24), screw on and tighten bolts (22) to the required torque value and lock (Fig. 4) .

d) Fit bolts (8) and (5) with lock washers (9) and (6) observing the sequence of operations specified below :
   1) Tighten bolts (8); screw them oil by hand until the contact of the bolt heads is obtained.
   2) Apply a torque load of 1 m.daN to ALL bolts, observing the sequence shown in DETAIL B-
   3) Repeat step 2), increasing the torque value to 1.5 m.daN (132,7 lbf.in.).
   4) Repeat step 2), increasing the torque value to 2.2 m.daN (194 .6 lbf.in.).
   5) The final torque load will be obtained when the bolt do not rotate any longer after tightening them several times to 2.2 m.daN (194.6 lbf.in) in the order prescribed above.
   6) Repeat operation 5) on all bolts, observing the sequence specified in DETAIL B.
   7) Screw on the centre bolt (5) and apply the- torque load, as shown in Fig. 3.
   8} Fold down lock plates *(6),* (9) (Fig. 3)

NOTE: To perform step 8, take care not to modify the position of the heads of bolts (8) and (5).

   9) Using a borescope through and down the top inner dia. of the vertical shaft, check that all the bolts (8) stand proud of the tapped flange inner face by the same number of threads.

Appendix B - Extract from Eurocopter Mechanical Repair Manual MRM WC 62.30.16.701

ROTOR MAST
Replacement of shaft casing bearings and seal
post MOD 076120 and 077092 and main rotor shaft

4. RE-INSTALLATION

4.1 Re-installation of the upper casing bearing and seal.

(...)

e) Install the casings on the rotor shaft (20) and fit snap ring (24).

CAUTION : OBSERVE THE PROCEDURE FOR INSTALLING SPACER ASSY (28), CASINGS AND HOUSINGS BEFORE POSITIONING SNAP RING (24).

(...)

4.2 Re-installation of the 4–contact point bearing

(...)

e) Fig. 1: Coat the splines with grease and install planet pinion carrier (30) on rotor shaft (20), after checking for presence of snap ring (24). Position the chip detector (7) slot.

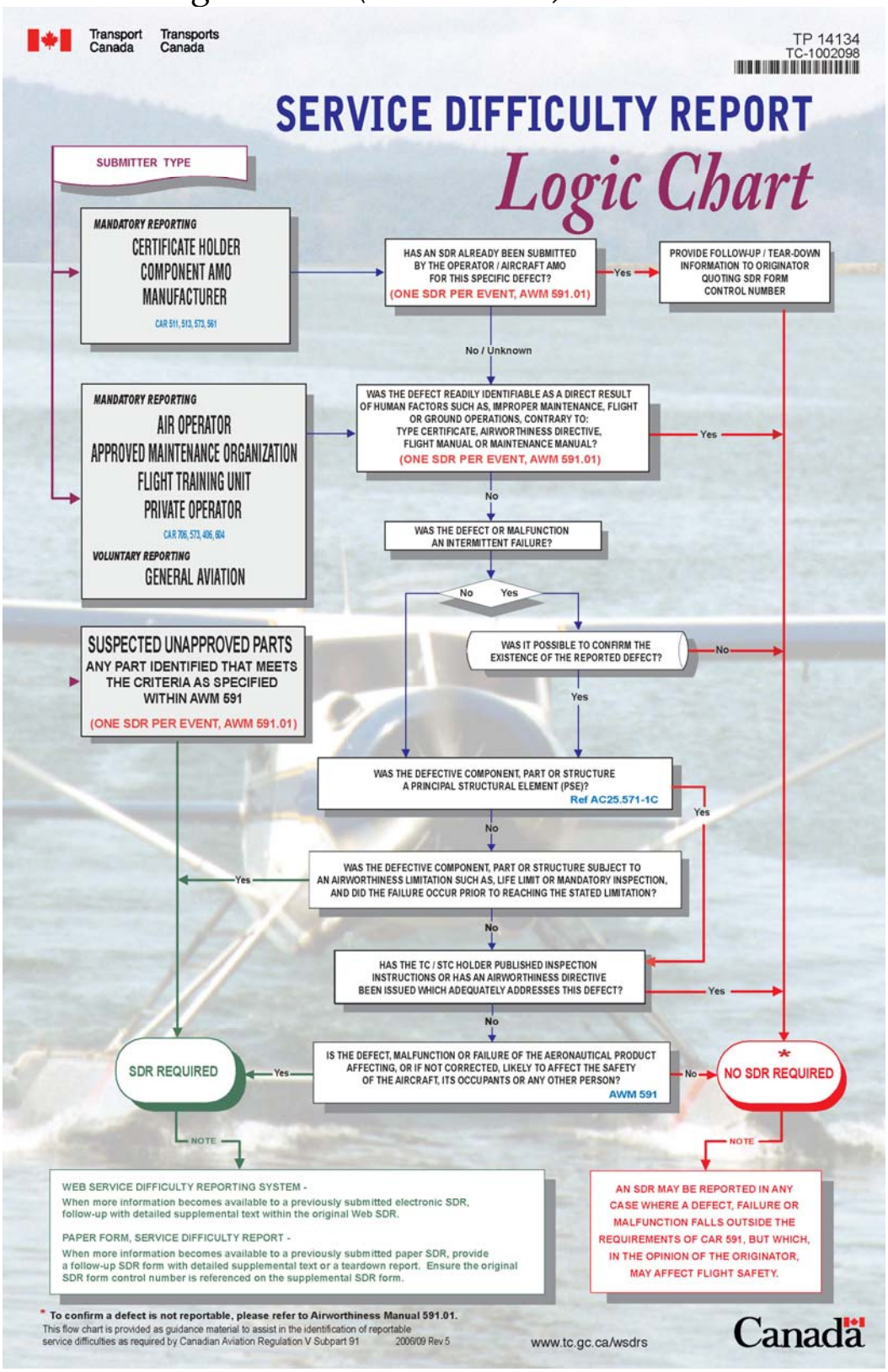
f) Fig. 2: Install plates (21) and (22) and sensor support (23 3 screw on and tighten bolts (8) to the required torque value and lock.

NOTE: When the shaft is replaced carry out the following operations: Fig. 9 install the flange assembly (20) with its new "0" ring seal (36) on the main rotor shaft (19).

g) Fig. 1: Fit clamping washer (6) and tab washers (4): screw on bolts (5) by hand until the underside of their heads touch, and tighten in the order A-B-C-D-E-F (as shown by arrow 4). Apply a torque load of 1 m.daN, then 1.5 m.daN and lastly 2.2 m.daN.
The final torque load will be obtained when the bolts do not rotate any longer after tightening them several times to 2.2 m.daN, in the order prescribed above. Lock bolts (5).

h) Using a borescope through and down the top inner dia. of the vertical shaft, check that all the bolts (5) stand proud of the tapped flange inner face by the same number of threads.

Appendix C – Transport Canada Service Difficulty Report Logic Chart (TP 14134B)



Appendix D – Comments from the Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile
(This document does not exist in English)

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BOARD CONSIDERATION
FEV FEB 28 2008
CONSIDÉRATION DU BUREAU

Le Bourget, 28 février 2008

Madame Wendy A. Tadros
Présidente du BST
a/s du Service des rapports du Bureau
Place du Centre
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4ème étage
GATINEAU (QUEBEC)
CANADA

Objet: Projet de rapport d'enquête A07Q0085 (A0739)
Accident survenu le 27 mai 2007 à l'AS 350 B1 Astar immatriculé C-GZCN
V/réf : Lettre du 8 janvier 2008
Courriel du 6 février 2008
P.J.: Commentaires du BEA
Documentation technique EUROCOPTER

Madame la Présidente,

Nous vous remercions de nous avoir consultés sur le projet de rapport relatif à l'accident survenu le 27 mai 2007 à l'AS 350 B1 Astar immatriculé C-GZCN à 176 NM au nord-est de Chibougamau.

Nous sommes d'accord sur de nombreux points du projet de rapport. Cependant, nous souhaiterions vous transmettre nos observations détaillées ci-jointes ainsi que les documents techniques modifiés par EUROCOPTER dont la diffusion devrait intervenir à court terme.

Nous voudrions également souligner la mise en place d'une nouvelle procédure de vérification par le trou du capteur NR à la place du contrôle endoscopique ainsi que le remplacement du jonc métallique par un jonc en élastomère qui permettra d'obtenir un montage correct même si le jonc n'était pas monté au bon moment.

Nous suggérons une recommandation qui devrait permettre un meilleur retour d'expérience concernant de graves erreurs de maintenance.

Nous apprécierions que nos observations soient prises en compte. Si cela n'était pas possible, nous vous remercions de bien vouloir les annexer au rapport.

Nous vous prions de croire, Madame la Présidente, à l'expression de notre parfaite considération.

Philippe MAUVIOT

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Commentaires du BEA
relatifs
au projet de rapport d'enquête sur l'accident de l'AS 350 B1 immatriculé C-GZCN
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1 – Page 6

- Au lieu de : « *Pour le remontage du réducteur épicycloïdal, on renvoyait à la version électronique de la carte de travail (CT) CT.62.30.16.701*[5] *(voir l'Annexe B) du manuel de réparation (MRR) au moyen d'un hyperlien se trouvant dans un avertissement du MET.63.10.16.403 (voir les notes en bas de page).* »

Le BEA propose : « *Pour le remontage du réducteur épicycloïdal, le MET.63.10.16.403 renvoyait à la version électronique de la carte de travail (CT) CT.62.30.16.701*[5] *(voir l'Annexe B) du manuel de réparation (MRR) au moyen d'un paragraphe « ATTENTION » qui demandait de vérifier la bonne installation du jonc. Cette CT.62.30.16.701 définissait de façon précise l'ordre de montage à respecter pour le positionnement du jonc».*

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- Au lieu de : « *Les différents titres de rubrique figurant dans les 15 pages de la carte de travail ne s'appliquaient pas directement au remontage de ce réducteur épicycloïdal en particulier, puisqu'il ne fallait pas remplacer les roulements du mât, l'arbre rotor principal ni le joint du mât rotor.*»

Le BEA propose : «*Les 16 pages de la carte de travail dont 9 pages de figures ne concernait pas directement le remontage de ce réducteur épicycloïdal en particulier, puisqu'il ne fallait pas remplacer les roulements du mât, l'arbre rotor principal ni le joint du mât rotor ».*

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- Au lieu de : « *Les TEA qui ont procédé au remontage n'ont pas suivi la CT.62.30.16.701 ».*

Le BEA propose : «*Les TEA qui ont procédé au remontage n'ont pas appliqué la CT.62.30.16.701 ».*

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- Le paragraphe 3.2 b) du MET.63.10.16.403 (la référence principale) permet de garantir que le jonc est en place mais il ne précise pas le moment où il faut poser le jonc. Le manuel d'entretien indique ce qui suit : « Enduire les cannelures[6] *de graisse et monter le porte-satellite sur l'arbre rotor en s'assurant de la présence du jonc ». Cette instruction est accompagnée de l'avertissement suivant : ».*

Si le MET.63.10.16.403 ne précise pas le moment où il faut poser le jonc, il n'est pas possible de voir le jonc si le montage n'est pas correct.
En conséquence, le BEA propose d'écrire : *«Le paragraphe 3.2 b) du MET.63.10.16.403 (la référence principale) permet de garantir que le jonc est en*

place mais il ne précise pas le moment où il faut poser le jonc. Le manuel d'entretien indique ce qui suit : « Enduire les cannelures[6] de graisse et monter le porte-satellite sur l'arbre rotor en s'assurant de la présence du jonc.». En cas de mauvais montage, comme celui opéré sur le C-GZCN, il n'est pas possible de voir le jonc à l'instant de cette opération. Les TEA qui ont procédé au remontage n'ont pas pu appliquer l'item de la MET.63.10.16.403 qui prévoit la vérification de la présence du jonc».

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- Au lieu de : « *Cette instruction est accompagnée de l'avertissement suivant : ATTENTION : VERIFIER LE MONTAGE DU JONC (MRR) CT.62.30.16.701. NE PAS OUBLIER .....DETAIL A. Ces instructions ne précisent pas le moment où il faut poser le jonc. Elle demandent simplement de s'assurer de la présence du jonc* ».

Le BEA propose d'écrire :
« Cette instruction est accompagnée de l'avertissement suivant : ATTENTION : VERIFIER QUE LE JONC EST CORRECTEMENT MONTE (MRR) CT.62.30.16.701. NE PAS OUBLIER .....DETAIL A. Cette instruction demande précisément à l'opérateur d'appliquer la CT.62.30.16.701.qui définit le moment où il faut poser le jonc».

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- Au lieu de : « *Toutefois, le paragraphe 4.1 e) de la CT.62.30.16.701. (Voir l'annexe B) précise le moment où il faut poser le jonc* ».

Le BEA propose d'écrire :
«Par ailleurs, le paragraphe 4.1 e) de la CT.62.30.16.701. (Voir l'annexe B) précise le moment où il faut poser le jonc. Ces instructions n'ont pas été respectées ».

7 – Page 8

- « *Les TEA étaient entrainés et ils se sentaient à l'aise de travailler avec la version anglaise de la documentation de référence d'Eurocopter* ».-

Serait-il possible de savoir pourquoi les TEA n'ont pas appliqué toutes les instructions du MET et de la CT, et, si la raison est connue, de le préciser? Une partie de la réponse semble apparaitre dans l'analyse (« redondant »).

8 – Page 9

- Au lieu de « *Comme dans les événements mentionnés précédemment, on ne savait pas que les problèmes de Nr et/ou le bourdonnement et la résonnance au sol étaient reliés au fait que le jonc n'avait pas été posé au bon moment* ».

Cette affirmation n'est pas logique dans la mesure où le cas de juin 2006 au Canada ne présentait ni problème de NR, ni problème de résonnance sol et ni problème de bourdonnement. Seul, le voyant d'alarme du détecteur de particules de la BTP s'était allumé.
Le BEA propose d'écrire :

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« on ne savait pas que les problèmes de Nr et/ou le bourdonnement et la résonnance au sol pouvaient être reliés au fait que le jonc n'avait pas été posé au bon moment ».

9 – Page 9

- *« La règlementation actuelle n'exige pas qu'un événement de ce genre soit signalé ».*

Il apparait que l'événement du Canada du mois de juin 2006 aurait pu déboucher sur un accident identique à celui du C-GZCN. Ce genre d'incident, lié à une erreur ou des erreurs de maintenance, revêt le caractère d'un incident grave de maintenance. Il est dommage que les opérateurs ne puissent pas être informés de ce retour d'expérience via l'autorité de régulation et/ou de surveillance ou via le constructeur.
Le BEA propose une recommandation dans ce sens.

10 – Page 9

- Au lieu de : *« Les TEA d'Heli-transport étaient au courant de cet événement et, conformément au MET, ils avaient contre-vérifié que le jonc était bien en place et ils avaient utilisé un endoscope pour s'assurer que tous les boulons laissaient voir un nombre de filets identique ».*

A la lecture du rapport et à notre connaissance, il apparait que les TEA n'ont pas contre-vérifié que le jonc était bien en place tant au niveau de sa présence conformément au MET.63.10.16.403 qu'au niveau du moment de sa mise en place conformément à la CT.62.30.16.701.
L'opération d'endoscopie permet de vérifier que le système n'est pas monté de travers mais ne permet pas de s'assurer d'un montage correct.
En conséquence, le BEA propose d'écrire :
« Les TEA d'Heli-transport étaient au courant de cet événement. Ils avaient utilisé un endoscope pour s'assurer que tous les boulons laissaient voir un nombre de filets identique. Cependant, cette opération ne permettait pas de garantir que le montage était correct ».

11 – Page 9

- *Au lieu de « Le MET.63.10.16.403 avait servi de référence principale au moment de la pose du jonc. La CT.62.30.16.701 du MRR avait été jugée comme source de renseignements secondaires car la plupart des étapes qui s'y trouvaient ne s'appliquaient pas aux travaux de maintenance en train d'être effectués. On en était arrivé à cette conclusion, au moment des travaux de maintenance, en parcourant visuellement les titres des rubriques des 15 pages de la CT.62.30.16.701 du MRR. Aucun des titres n'avait été jugé pertinent, si bien que la lecture des rubriques n'avait pas été jugée nécessaire. Résultat, les TEA ont manqué l'occasion de lire de l'information importante sur l'ordre de montage, dont le moment de poser le jonc. Les instructions du MET laissent entendre que le jonc devrait déjà avoir été posé, mais elles n'indiquent pas exactement quand il doit être posé. Les instructions du MET ont amené les TEA à consulter la CT.62.30.16.701 pour s'assurer que le jonc avait été mis en place correctement. Ils ont estimé que ce point était redondant, puisque le*

jonc ne pouvait être placé que dans la rainure bien précise sur l'arbre du rotor principal ».

Le BEA propose d'écrire :
« Les TEA se sont servi du MET.63.10.16.403 comme référence principale au moment de la pose du jonc. Le MET ne précise pas le moment où il faut poser le jonc mais il demande de s'assurer de la présence du jonc. L'ordre des opérations de montage n'ayant pas été respectées, le jonc ne pouvait pas être visible. La vérification visuelle de cette présence était donc impossible.
Les TEA ont jugé que la CT.62.30.16.701 du MRR constituait une source de renseignements secondaires car toutes les étapes qui s'y trouvaient ne s'appliquaient pas aux travaux de maintenance en train d'être effectués. Seuls, les titres de la CT.62.30.16.701 ont été parcourus visuellement et aucun n'a été jugé pertinent, si bien que la lecture des instructions de montage n'a pas été jugée nécessaire par les TEA.
Pourtant, le MET avertit, en lettre majuscule, l'opérateur et lui demande de vérifier que le jonc est correctement monté en se reportant sur la CT.62.30.16.701. Cette instruction n'a pas été appliquée.

Les TEA ont consulté la CT.62.30.16.701 et ont estimé que le point relatif au montage du jonc était redondant car le jonc ne pouvait être placé que dans la rainure bien précise sur l'arbre du rotor principal. Pourtant, la CT.62.30.16.701 détaille toutes les opérations et le moment où il faut poser le jonc. Par ailleurs, un avertissement, en lettre majuscule sur la CT.62.30.16.701, demande de respecter la procédure de montage avant de mettre le jonc. Les opérations de montage du jonc, définies dans la CT.62.30.16.701 n'ont pas été appliquées ».

12 – Page 10 « Faits établis quant aux causes et aux facteurs contributifs »

Au lieu de :
« *1. Au moment du remontage de l'arbre rotor principal et du réducteur épicycloïdal de la boîte de transmission principale (BTP), les techniciens d'entretien d'aéronef (TEA) n'ont pas consulté les rubriques pertinentes de la fiche de travail et le jonc a été posé au mauvais moment* ».

Le BEA propose d'écrire :
« 1. Au moment du remontage de l'arbre rotor principal et du réducteur épicycloïdal de la boîte de transmission principale (BTP), les techniciens d'entretien d'aéronef (TEA) n'ont pas appliqué l'instruction, figurant dans le MET.63.10.16.403 de vérification de la présence du jonc. Ils n'ont pas également appliqué les instructions de montage du jonc figurant dans la CT.62.30.16.701. Le jonc été posé au mauvais moment et, par conséquent, le montage de l'ensemble n'était pas correct. »

13 – Page 10 « Faits établis quant aux causes et aux facteurs contributifs »

Au lieu de :
« *2. Du fait que le jonc a été posé au mauvais moment, les boulons de fixation du mât se sont desserrés et le mât s'est déplacé verticalement au point où mes pales du rotor sont venues percuter le fuselage avant »*

Le BEA propose d'écrire :
« 2. Du fait que le jonc a été posé au mauvais moment, le montage de l'ensemble n'était donc pas correct, ceci a conduit au desserrement des boulons de fixation du mât. Ce dernier s'est déplacé verticalement au point où les pales du rotor sont venues percuter le fuselage avant.»

14 – Page 11 « Faits établis quant aux risques »

« 1. Les symptômes .....BTP. »

Le BEA propose de rajouter :
« Eurocopter a modifié la CT 05.53.00.614 relative à la recherche de panne en y intégrant ces phénomènes pour la détection d'un mauvais montage ».
Nota : cette CT 05.53.00.614 est jointe à ces commentaires

15 – Page 11 « Faits établis quant aux risques »

« 2. Demander à des TEA de consulter de longues instructions supplémentaires n'étant pas nécessairement pertinentes risque de se traduire par un processus de filtration faisant perdre des renseignements importants. »

A la lecture du MET.63.10.16.40 et de la CT.62.30.16.701 il n'apparait pas que les instructions soient longues et non pertinentes. Très souvent lors d'opérations de maintenance, une documentation générale du type MET renvoie à une documentation plus précise du type CT.
Par ailleurs, dans le cas du C-GZCN, les TEA n'ont pas appliqué la première instruction du MET.63.10.16.40 qui consistait à vérifier la présence du jonc.
Le risque réside toujours dans la non exécution d'une ou de plusieurs instructions par l'opérateur. Quelque soit l'instruction, le risque de sa non exécution est lié au facteur humain que représente tout opérateur.
Il est proposé de supprimer cette phrase.

16 – Page 11 « Faits établis quant aux risques »

« 3. Le manuel d'entretien indique que, pendant l'inspection endoscopique, le même nombre de filets devrait être visible sur tous les boulons de fixation de l'arbre rotor principal, mais il ne précise pas le nombre de filets qui doivent être visibles pour confirmer qu'ils ont été posés correctement. Résultat, le montage peut sembler avoir été fait correctement alors que ce n'est pas le cas ».

Le BEA est d'accord sur ce point.
Cependant, ce facteur de risque n'existe plus avec la mise en place par Eurocopter d'une nouvelle procédure de vérification par le trou du capteur NR.
Cette nouvelle procédure figure sur le MET.63.10.16.40 et la CT.62.30.16.701 modifiés, ci-joints. Ces documents ont été approuvés et doivent faire l'objet d'une diffusion prochaine.
Par ailleurs, en plus de cette nouvelle procédure et de la modification des documents, Eurocopter a décidé l'adoption d'un joint élastomère en lieu et place du jonc métallique. La modification a été adoptée. Les opérateurs le recevront lorsque l'approvisionnement sera opérationnel. Ce nouveau matériau permettra, en cas d'un

non respect des instructions de montage et de la nouvelle procédure de vérification, au jonc de se rompre sous les efforts de cisaillement qui seront introduits par le couple de serrage des vis de fixation. Il en résultera un montage correct des pièces avec tous les appuis nécessaires.

Compte tenu de ces éléments, le BEA propose soit de supprimer le facteur de risque « 3 » soit d'indiquer qu'il n'existe plus en précisant les éléments ci-dessus.

17 – Page 11 « Mesures de sécurité »

Au lieu de :
« *Eurocopter a l'intention de modifier son manuel d'entretien afin de tenir compte de ce point, le but étant d'offrir une meilleure solution face à ces symptômes.* ».

Le BEA propose d'écrire :
« Eurocopter a modifié le MET.63.10.16.40 et la CT.62.30.16.701 et établi une nouvelle procédure de vérification par le trou du capteur NR.
Ces documents ont été approuvés et doivent faire l'objet d'une diffusion prochaine.
Par ailleurs, en plus de cette nouvelle procédure et de la modification des documents, Eurocopter a décidé l'adoption d'un joint élastomère en lieu et place du jonc métallique. La modification a été adoptée. Les opérateurs le recevront lorsque l'approvisionnement sera opérationnel. Ce nouveau matériau permettra, en cas d'un non respect des instructions de montage et de la nouvelle procédure de vérification, au jonc de se rompre sous les efforts de cisaillement qui seront introduits par le couple de serrage des vis de fixation. Il en résultera un montage correct des pièces avec tous les appuis nécessaires ».

18 – Page 11 « Mesures de sécurité »

Il apparait que l'événement du Canada du mois de juin 2006 aurait pu déboucher sur un accident identique à celui du C-GZCN. Ce genre d'incident, lié à une erreur ou des erreurs de maintenance, revêt le caractère d'un incident grave de maintenance. Il est dommage que les opérateurs ne puissent pas être informés de ce retour d'expérience via l'autorité de régulation et/ou de surveillance ou via le constructeur.
Le BEA propose que tout incident grave de maintenance, survenu chez un opérateur au Canada, soit portée à la connaissance de l'autorité canadienne de surveillance ainsi qu'au constructeur.