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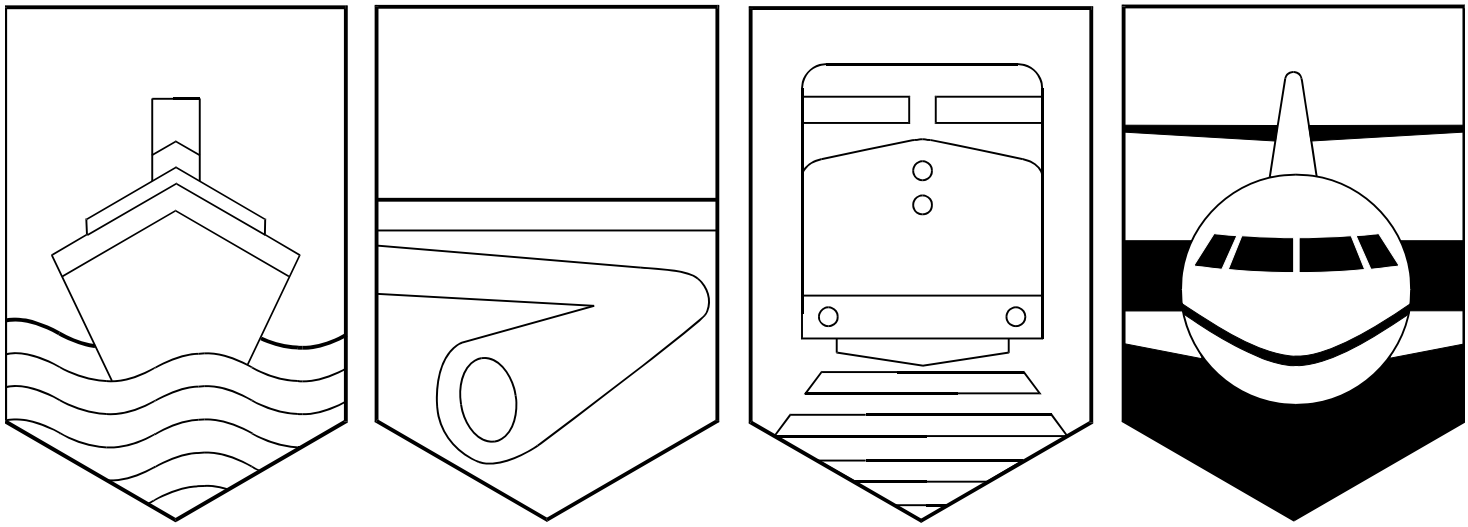

AVIATION OCCURRENCE REPORT

LOSS OF CONTROL DUE TO MAIN ROTOR COMPONENT PROGRESSIVE FAILURE

LES HÉLICOPTÈRES ABITIBI LTÉE AEROSPATIALE AS350BA ASTAR (HELICOPTER) C-FHAG SMOKY TOWER, ALBERTA 12 nm SE 14 AUGUST 1994

REPORT NUMBER A94W0144

Canada

MANDATE OF THE TSB

The Canadian Transportation Accident Investigation and Safety Board Act provides the legal framework governing the TSB's activities. Basically, the TSB has a mandate to advance safety in the marine, pipeline, rail, and aviation modes of transportation by:

- conducting independent investigations and, if necessary, public inquiries into transportation occurrences in order to make findings as to their causes and contributing factors;
- reporting publicly on its investigations and public inquiries and on the related findings;
- identifying safety deficiencies as evidenced by transportation occurrences;
- making recommendations designed to eliminate or reduce any such safety deficiencies; and
- conducting special studies and special investigations on transportation safety matters.

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Aviation Occurrence Report

Loss of Control due to Main Rotor Component Progressive Failure

Les Hélicoptères Abitibi Ltée
Aerospatiale AS350BA Astar (Helicopter)
C-FHAG
Smoky Tower, Alberta 12 nm SE
14 August 1994

Report Number A94W0144

Synopsis

The pilot of the Aerospatiale AS350BA helicopter was on a ferry flight from Tumbler Ridge, British Columbia, to Springbank, Alberta. While in cruise flight, the pilot experienced a vibration, increasing in magnitude, from the main rotor. The pilot reduced the airspeed to carry out a precautionary landing. When the helicopter was flared for the landing, control was lost. The helicopter struck the ground, and came to a stop resting on its right side. The pilot received minor injuries. The helicopter was substantially damaged.

The Board determined that the main rotor vibration levels increased and control of the helicopter was lost when one of three spherical thrust bearings (STBs) on the main rotor head failed in fatigue. Although it had been noted that an STB was blistered, the manufacturer's inspection/rejection criteria were not followed, and the helicopter was allowed to remain in service.

Ce rapport est également disponible en français.

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1.0 Factual Information

1.1 History of the Flight

The pilot of C-FHAG, an Aerospatiale (Eurocopter) AS350BA Astar helicopter, was on a ferry flight from Tumbler Ridge, British Columbia, to Springbank, Alberta, with a planned fuel stop at Edson, Alberta. Approximately 30 to 40 minutes after take-off, while in cruise flight at 5,500 feet above sea level (asl)[1] and at an airspeed of 125 knots, the pilot experienced a vibration, increasing in magnitude, from the main rotor. About 10 minutes later, upon sighting an abandoned well site in the heavily wooded area, the pilot reduced the airspeed to carry out a precautionary landing. When the helicopter was flared for the landing, control was lost. The helicopter struck the ground, and came to a stop resting on its right side. The pilot received minor injuries. The helicopter was substantially damaged.

The accident occurred at 1900 hours mountain daylight saving time (MDT)[2], during the hours of daylight, at an elevation of 3,890 feet asl[3]. The crash coordinates were 54°20'N latitude and 118°45'W longitude.

1.2 Injuries to Persons

	Crew	Passengers	Others	Total
Fatal	-	-	-	-
Serious	-	-	-	-
Minor/None	1	-	-	1
Total	1	-	-	1

1.3 Damage to Aircraft

The helicopter was substantially damaged.

1.4 Other Damage

There was no other damage.

1.5 Personnel Information

[1] See Glossary for all abbreviations and acronyms.

[2] All times are MDT (Coordinated Universal Time [UTC] minus six hours) unless otherwise stated.

[3] Units are consistent with official manuals, documents, reports, and instructions used by or issued to the crew.

	Pilot
Age	34
Pilot Licence	CPL
Medical Expiry Date	01 Oct 94
Total Flying Hours	3,586
Hours on Type	578
Hours Last 90 Days	249
Hours on Type Last 90 Days	249
Hours on Duty Prior to Occurrence	4
Hours Off Duty Prior to Work Period	72

1.5.1 Additional Pilot Information

The pilot was certified and qualified for the flight in accordance with the existing regulations. Although experienced on the AS350BA helicopter, he was unable to describe the vibrations in detail, but he observed that one blade was operating abnormally and felt that the main rotor required tracking.

1.6 Aircraft Information

Manufacturer	Aerospatiale SNI
Type	AS350BA
Year of Manufacture	1982

Serial Number	1546
Certificate of Airworthiness (Flight Permit)	Valid
Total Airframe Time	4,401.2 hr
Engine Type (number of)	Turbomeca Arriel 1B (1)
Propeller/Rotor Type (number of)	Aerospatiale SNI (1)
Maximum Allowable Take-off Weight	4,630 lb
Recommended Fuel Type(s)	Jet B, Jet A, Jet A-1
Fuel Type Used	Jet B

1.6.1 Additional Aircraft Information

The helicopter was being ferried to Springbank for maintenance and repair, because the engine had not been producing its maximum rated power.

The weight and balance were estimated to be within the prescribed limits. A total of 600 pounds of cargo was secured by a net in the rear of the cabin. The rest of the cargo was carried in the baggage compartments.

1.6.2 Other Helicopter Information

After the pilot took off with C-FHAG for the ferry flight to Springbank, he noted that the helicopter was not flying as smoothly as the other AS350 helicopter he had just flown to Tumbler Ridge. There was more vibration in flight, and he felt that the main rotor blades would have to be tracked while the helicopter was in Springbank for maintenance.

The pilot who had been flying C-FHAG prior to this ferry flight to Springbank had noted during pre-flight inspections that the spherical thrust bearings (STBs) were showing wear and checking (cracking) of the rubber, but he had not noticed any bulging or blistering. When the aircraft maintenance engineer (AME) took over the maintenance of the aircraft, approximately 81 flight hours prior to the occurrence, he inspected all the STBs, and noticed that one STB, he can't remember which, was checked and bulged (blistered). The AME released the helicopter for service as the bearing would be replaced at the next 500-hour inspection scheduled at 4,580.8 hours (179.6 hours after the occurrence). The AME last inspected the helicopter, including the STBs, on the morning of the occurrence, prior to the day's work. The helicopter was flown 4.7 hours after that inspection.

1.6.3 The Helicopter Conversion

This helicopter (C-FHAG) had been converted from an AS350D model to an AS350B model in May 1992 at 2,552.2 airframe hours, and to an AS350BA model in June 1992 at 2,691.7 hours. The conversions, in part, involved replacing the AS350D (Astar) main rotor blades (Part No. 350A11-0010-01) with AS355 (Twin Star) main rotor blades (Part No. 355A11-0020-11). The conversions retained the original AS350 STBs (Part No. 704-A-33-633-156). The total time since new (TTSN) for the STBs was approximately 162.7 hours at the time of the conversion, and 1,876 hours at the time of the occurrence.

1.6.4 Main Rotor Head Spherical Thrust Bearings

An STB consists of several steel cups laminated between thin rubber sheets, forming an elastomer. The elastomer is bonded between two aluminum frames forming the STB. These bearings carry the main rotor blade centrifugal loads when the rotor is turning. They are flexible in torsion, flapping, and drag, but rigid in compression. STBs are important components of the main rotor hub, as all motions and loads pass through them.

When an STB starts to fail, the rubber progressively squeezes out from between the metal plates, forming blisters on the exterior and an extrusion "tail" on the interior. The squeezed-out rubber causes the bearing to become shorter. Because of the bearing's location in the main rotor head, the rotor blade progressively shifts away from the centre of rotation; the centre of gravity (C of G) of the blade moves farther outboard than the other two blades, and causes a one-per-revolution vibration which increases as more rubber is squeezed out and the bearing grows smaller. When the rubber debonds from the frames, and the centre elastomeric section suddenly pops out, the affected rotor blade suddenly shifts outwards a distance equal to the thickness of the missing bearing section. The one-per-revolution vibration will suddenly become very intense, and control of the helicopter may be lost.

1.6.5 Description of STBs with Different Part Numbers

There are five STB part numbers listed in the AS350/355 part, service, and maintenance publications. STB Part Nos. 704A33-633-27, -28, and -30 are no longer available. STB Part No. 704A33 633-109 was introduced in 1987 as a replacement for the -27, -29 and -30 STBs as per Service Bulletin (SB) 62.09. The temperature limits for the -109 STBs are minus 25 degrees Celsius to plus 40 degrees Celsius.

The STBs, Part No. 704A33-633-156, as found installed on C-FHAG, were introduced in 1989 as per SB 01.24:

a) to withstand very low temperatures down to -40°C, with no upper temperature limit specified,

b) the elastomer has been made more supple, and when these STBs are used in positive temperatures, the MTBF (mean time between failures) is reduced (ref. SL 122-62-92). Therefore, Eurocopters recommends that these STBs be installed when operating in temperatures below -25°C, and

c) the recommended service life limit of these STBs had originally been stated as 6,400 hours in SB 01.24. However, the latest revision of the *Master Servicing Recommendations (MSR) 05.99.00*, Note (2), states: "Service life limit for metallic parts only", while the rubber portions remain "on condition."

Service Letter (SL) 1122-62-92 (25/09/92) recommends the -109 STBs for the majority of operations, instead of the -156 STBs, to increase the mean time between failures (MTBF). However, most Canadian operators surveyed stated that they used the -156 STBs year-round because of the cost of having two sets of STBs available for each machine.

There seems to be a misconception among AS350 helicopter operators that the 6,400-hour life of an STB, as originally stated by the manufacturer, is for the whole bearing. The applicable MSR revision states that the 6,400-hour life is only for the metal portion of the bearing, while the rubber portions are "on condition." These bearings are to be inspected daily, usually during the "after last flight of the day" (ALF) inspection.

1.6.6 The AS350BA Maintenance Manual/Bulletins/Directives

The MSR, Section 05.21.00, states that the check after the last flight of the day (ALF) is conducted to determine whether the aircraft can be scheduled for the next day of flying. The ALF check can be conducted either by a pilot or an AME. If this check is carried out by a pilot, and any abnormalities are found, he/she must report this to the AME qualified on the aircraft type. A decision is then made to determine whether the flight should be continued while monitoring the condition, or the aircraft should be grounded until the defects have been rectified.

MSR Section 62.20.00.601 item (4) specifies the limits to be used when determining if the STB and frequency dampers are in an airworthy condition.

On 20 March 1992, Aerospatiale Helicopter Corporation issued an *Urgent Fleet Telex* to all AS350 & AS355 operators. The telex was a re-issue of *Telex No. 10039*, dated 20 March 1991, issued by Eurocopters, France. The heading of the telex is "Inspection of Main Rotor Head Spherical Thrust Bearings on AS350 and AS355 Helicopters." Paragraph (2) states:

> Since the checks in the Flight Manual (section 4.3) do not contain inspection rejection criteria, if the pilot detects damage, a mechanic (or qualified personnel) must mandatorily inspect the rotor head prior to further flight using criteria found in the maintenance work cards.

Paragraph (3) states:

> We draw your particular attention to sudden abnormal vibration levels which can be caused by degradation of spherical thrust bearings (ref. SBs and AWDs).

The extent to which the urgent fleet telex sent to the operator was circulated to company employees other than maintenance personnel was not determined.

1.6.7 The AS350BA Flight Manual

The approved AS350BA Flight Manual was on board the helicopter at the time of the accident.

Section 4.3 of this flight manual describes the following three daily operating checks to be carried out:

(1) checks before the first flight of the day (BFF),

(2) turnaround check (TA), and

(3) check after the last flight of the day (ALF).

These checks may be carried out by qualified maintenance personnel, or by a qualified pilot. Although inspection of the STBs is not required by the BFF and TA checks, it is required by the ALF check. The flight manual states that no elastomer faults, unbonding, scratches, blisters extrusion, or cracks are permissible on the STBs. Therefore, pilots must report any damage to STBs, however minor, and a mechanic (or qualified personnel) must inspect the rotor head prior to further flight, using criteria found in the maintenance work cards.

There is no warning in the flight manual to alert pilots to the severity of the risks resulting from STB degradation, nor to the actions to be taken should sudden abnormal vibration levels, indicative of progressive failure of STBs, occur in flight.

1.7 Meteorological Information

Environment Canada reported that a weak ridge of high pressure was apparent over the eastern and central portions of Alberta, while an upper cold front approached the western side of the province from central British Columbia. The actual en route weather as described by the pilot was: "a temperature of +24°C, sunny skies and calm winds. The visibility was greater than 15 miles, and no precipitation was encountered during the flight." The weather was not a factor in the occurrence.

1.8 Wreckage and Impact Information

The pilot approached the centre of the clearing and abandoned well site on a heading of 095 degrees magnetic. The clearing was more or less level, at an elevation of about 3,900 feet asl, and between 400 and 500 feet square. A logging road on a heading of 228 degrees magnetic ran parallel to the eastern side.

The heading of the helicopter at rest was 008 degrees magnetic. The helicopter was lying on its right side with the main rotor head in contact with the ground. On the ground, on a bearing of 335 degrees magnetic, at 34, 36, and 39 feet from the helicopter, were three deep slash marks from main rotor blade strikes. The deepest strike had an impact angle of 25 degrees and was about one foot deep.

All the components of the three-bladed, main rotor head were located around the fuselage, except for the elastomeric centre section of the red blade STB, which was found 162 feet from the helicopter on a bearing of 355 degrees magnetic. The damage to the red blade STB indicated that the rubber portion had debonded from the inner and outer frames, and the frames (with sleeve segments) had detached from the Starflex main rotor head. Preliminary examination indicates that the STB failed in fatigue. The blue blade STB had debonded from the inner frame, and the elastomer and outboard frame had remained in the Star. The yellow blade STB was intact and in position, although the elastomeric section was checked and bulged. Pieces of the fibreglass main rotor blades were scattered over several hundred feet.

There was evidence of rotation of the rotor head after the fuselage came to rest, as a deep gouge had been dug into the ground. The grass had been burned immediately behind the engine's exhaust, suggesting that the engine had been running for some time after impact. The tail boom had failed at a production break immediately behind the fuselage, and was lying in front of the helicopter. The pilot's fibreglass seat had failed, and had detached from the attach structure.

1.9 Research on Previous STB Service Difficulties

The Transport Canada (TC) Service Difficulty Reporting Program has identified over 25 main rotor STB/elastomer premature failures.

1.10 Survival Aspects

This was a survivable accident. The pilot received only minor injuries. The pilot was wearing a flight helmet, but he did not have the chin strap fastened. The helmet came off during the crash sequence and was found cracked in three places.

The pilot's seat had became completely detached from the helicopter's structure, and the pilot was held in place only by the lap seat-belt, which was still attached to the cabin floor structure. The helicopter was also equipped with a retractable/lockable shoulder harness with an inertia reel attached to the back of the seat; after the seat had separated from the structure, the shoulder harness lost its effectiveness.

The 600 pounds of cargo carried in the rear of the cabin remained secured by the net.

2.0 Analysis

2.1 Introduction

The pilot was experienced and qualified for the flight, in accordance with the existing regulations. The weather was not a contributing factor in the occurrence. The helicopter systems were examined to the degree possible, and no evidence of a malfunction contributing to the occurrence was found, except for the failed STB in the main rotor head. Therefore, the investigation will focus on the bearing failure, the loss of control, and why the helicopter was considered to be airworthy despite the fact that the blisters found on the STBs were beyond the manufacturer's specifications.

2.2 The Spherical Thrust Bearing Debonding Failure

There may be a misconception among some AS350 helicopter operators that the 6,400-hour life of an STB, as originally stated by the manufacturer, is for the whole bearing. However, the applicable MSR revision states that the rubber portions of the STBs are "on condition" and are to be inspected daily, usually during the ALF inspection. Although the AME had noted that one STB was blistered, he did not follow the STB inspection/rejection criteria specified by the manufacturer, and he released the helicopter for service. Because the blisters were not measured, it is not known whether the condition of the STB exceeded the manufacturer's rejection criteria.

STBs fail in a progressive manner, as rubber gradually squeezes out from between the metal plates and blisters grow. The dimensions of the blisters prior to the ferry flight are not known; however, since the STB failed 4.7 flight hours after it was last inspected on the morning of the occurrence, prior to the day's flights, the condition of the STB at the time of the inspection must have exceeded the manufacturer's inspection/rejection criteria. Moreover, the blisters would have grown since the time that they were first noted by the AME, 81 flight hours prior to the occurrence, and they may have exceeded the manufacturer's inspection/rejection criteria during that period. Nonetheless, the helicopter was released for service until the STB could be changed at the next 500-hour maintenance inspection, which was scheduled at 4,580.8 hours, 179.6 flight hours after the occurrence.

Although the manufacturer had sent an urgent fleet telex on the subject of STB inspections to all AS350 and AS355 operators, the content of the telex was not included in the flight manual. Furthermore, the circulation of the telex within the company to employees other than maintenance personnel was not determined. Pilots may not have been alerted to the consequences of STB degradation and the accompanying sudden increase in main rotor vibrations.

The pilot was not aware that sudden, abnormal main rotor vibration levels are indicative of an impending STB failure. As a result, when the vibration level increased during the ferry flight, the pilot believed that the main rotor was out-of-track, rather than suspecting that he was experiencing an STB failure, and he continued the flight.

As the flight progressed, the STB failed in fatigue; the vibrations increased as the rubber squeezed out and, finally, the elastomeric section debonded and departed the rotor head. The balance of the whole main rotor head was now upset to the extent that the pilot was unable to control the helicopter.

3.0 Conclusions

3.1 Findings

1. There may be a misconception shared by some AS350 operators that the 6,400-hour service life for the metal portion of the bearing also applies to the rubber portion.

2. The rubber portion of the bearing is not a "life" item, but rather an "on condition" item.

3. Although the AME had noted that one STB was blistered, he did not follow the STB inspection/rejection criteria specified by the manufacturer, and he released the helicopter for service.

4. The condition of the STB was beyond the manufacturer's specifications when the aircraft was dispatched on the maintenance ferry flight.

5. An STB failure results in a C of G shift of the main rotor head, and results in a severe one-per-revolution vibration.

6. There is no warning or corrective action listed in the flight manual regarding sudden increases in vibration levels and addressing the fact that they could be caused by the failure of an STB.

7. The manufacturer advised the AS350 and AS355 operators of this bearing problem in 1991 and again in 1992.

8. As the circulation of the telex within the company to employees other than maintenance personnel was not determined and as the information in the telex is not in the flight manual, pilots may not have been alerted to the consequences of deteriorating STBs and the accompanying increase in main rotor vibrations.

9. The pilot was unaware of the significance of increasing vibration levels and, believing that there was a main rotor blade out-of-track condition, he continued the flight.

10. The red blade STB on the main rotor head failed and caused a loss of control.

11. The pilot's seat broke free from the helicopter at impact.

12. The shoulder harness and inertia reel, which were attached to the back of the seat, became ineffective when the seat broke free.

13. The pilot's helmet was cracked in three places; it came off the pilot's head during the crash sequence because the chin strap was not fastened.

3.2 Causes

The main rotor vibration levels increased and control of the helicopter was lost when one of three spherical thrust bearings (STB) on the main rotor head failed in fatigue. Although it had been noted

that an STB was blistered, the manufacturer's inspection/rejection criteria were not followed, and the helicopter was allowed to remain in service.

4.0 Safety Action

4.1 Action Taken

Transport Canada (TC) featured this occurrence in the *Aviation Safety Vortex*, issue 6/94, and also in the *Aviation Safety Maintainer*, issue 4/94. These TC publications are sent to all licensed personnel in the helicopter community. The articles highlighted the requirement to ensure the serviceability of the spherical thrust bearings (STBs). In addition, a TSB Aviation Safety Advisory was forwarded to TC indicating that the aircraft flight manual should include a warning or caution that abnormal vibration levels can be caused by degradation of STBs.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson John W. Stants, and members Zita Brunet and Hugh MacNeil, authorized the release of this report on 21 August 1995.

Appendix A - List of Supporting Reports

The following TSB Engineering Branch report was completed:

LP 133/94 - Hingeless Rotor Examination.

This report is available upon request from the Transportation Safety Board of Canada.

Appendix B - Glossary

ALF	after last flight
AME	aircraft maintenance engineer
AWD	airworthiness directive(s)
asl	above sea level
BFF	before first flight
C	celsius
C of G	centre of gravity
CPL	Commercial Pilot Licence
hr	hour(s)
lb	pound(s)
MDT	mountain daylight saving time
MSR	master service recommendation(s)
MTBF	mean time between failure(s)
SB	service bulletin
SL	service letter
STB	spherical thrust bearing(s)
TA	turnaround
TC	Transport Canada
TSB	Transportation Safety Board of Canada
TTSN	total time since new
UTC	Coordinated Universal Time
'	minute(s)
°	degree(s)
N	north
W	west

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