Statens haverikommission
Swedish Accident Investigation Board

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Report RL 2011:02e

Accident to helicopter SE-JME in Flatruet Härjedalen, Z County, on 28 October 2009

Case L-18/09

The report is also available on our website: www.havkom.se

Statens haverikommission (SHK) Swedish Accident Investigation Board

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Statens haverikommission
Swedish Accident Investigation Board

2011-05-23

L-18/09

European Aviation Safety Agency
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Report RL 2011:02e

The Swedish Accident Investigation Board (Statens haverikommission, SHK) has investigated an accident that occurred on 28 October 2009 at Flatruet Härjedalen, Z county, involving a helicopter with registration SE-JME.

The Board hereby submits a report on the investigation under the Regulation EU, no: 996/2010 on the investigation and prevention of accidents and incidents in civil aviation.

The Board will be grateful to receive, by 22 August 2011 at the latest, particulars of how the recommendations included in this report are being followed up.

Carin Hellner   Sakari Havbrandt

Duplicate to the Swedish Transport Agency

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General

The Swedish Accident Investigation Board (Statens haverikommission – SHK) is a state authority with the task of investigating accidents and incidents with the aim of improving safety. SHK accident investigations are intended so far as possible to determine both the sequence of events and the cause of the events, along with the damage and effects in general. An investigation shall provide the basis for decisions which are aimed at preventing similar events from happening again, or to limit the effects of such an event. At the same time the investigation provides a basis for an assessment of the operations performed by the public emergency services in respect of the event and, if there is a need for them, improvements to the emergency services.

SHK accident investigations try to come to conclusions in respect of three questions: *What happened? Why did it happen? How can a similar event be avoided in future?*

SHK does not have any inspection remit, nor is it any part of its task to apportion blame or liability concerning damages. This means that issues concerning liability are neither investigated nor described in association with its investigations. Issues concerning blame, responsibility and damages are dealt with by the judicial system or, for example, by insurance companies.

The task of SHK does not either include as a side issue of the investigation that concerns emergency actions an investigation into how people transported to hospital have been treated there. Nor are included public actions in the form of social care or crisis management after the event.

The investigation of this aviation incident is taking place in accordance with Regulation (EU) No. 996/2010 concerning the investigation and prevention of accidents and incidents in civil aviation. The application and procedures in respect of the performance of such investigations are also in accordance with Annex 13 of the Chicago convention.

The investigation

SHK was informed on 29 October 2009 that the accident had occurred with a helicopter (registration SE-JME) at Flatruet, Z County, on 28 October 2009 at 9.40 a.m.

The accident was investigated by SHK, represented by Carin Hellner, chairperson, Sakari Havbrandt, Investigator in charge, and Staffan Jönsson, technical investigator.

The investigation has been monitored by Transportstyrelsen (The Swedish Transport Agency) by Ulrika Svensson.

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L-18/09
Report finalised 23 May 2011

Aircraft: registration and type	SE-JME, Eurocopter France EC120 B
Class/Airworthiness	Normal, Certificate of Airworthiness with Airworthiness Review Certificate[1] valid until 30-04-2010
Owner/Operator	AB Jämtlands Aero, Osterman Helicopter AB Göteborg
Time of occurrence	28-10-2009 at 9:40 in daylight Note: All times refer to Swedish standard time (UTC + 1 hour)
Place	Flatruet, Z County, (pos. N 62°41' 60 E 012°41' 46; 801 m above sea level)
Type of flight	Commercial air transport
Weather	According to SMHI's analysis: NW wind 7-12 knots, visibility>10 km, isolated snow showers 4-7/8 with base 1500-4000 feet, temperature/dew point -2/-3 °C, QNH 1019 hPa
Persons on board;	
crew members	1
Passengers	2
Injuries to persons	None
Damage to aircraft	Significant
Other damage	None
Pilot in command	
Age, licence	33 years, CPL(H)
Total flying time	1,253 hours, of which 843 hours on aircraft type
Flying hours previous 90 days	100 hours, of which 96 hours on aircraft type
Number of landings previous 90 days	304, of which 249 on aircraft type

Summary

The pilot took off from the company's base in Östersund for a commercial air transport with several planned stops in the mountain districts west and southwest of the starting location. After a first stop on Helags mountain station, the pilot flew south towards Funäsdalen. After passing Flatruet's highest point after approximately 1 km into the flight the pilot heard a loud bang and very strong low-frequency vibrations were felt in the helicopter. It was not possible to read the instruments and parts of the interior fittings had become detached. The altitude was 500-700 feet above the ground and the pilot realized that the vibrations were linked to the main rotor speed. He decided to conduct an autorotation and turned 180° right towards a snow-covered moor and adjusted altitude to 20 foot and hovering. Touchdown was calm and soft on the intended landing area. The time from the loud bang to the landing on the moor was less than 30 seconds. After examination of the helicopter, a large open crack in the main rotor hub was discovered along with several cracks in the tail section and the tail boom. The ELT[2] was not activated during the landing.

[1] ARC: Airworthiness Review Certificate
[2] ELT: Emergency Locator Transmitter

The accident was caused by the fact that the maintenance system for the helicopter model did not detect this type of defect because the time from initiation of the crack to final fracture is shorter than the inspection interval.

Recommendations

It is recommended that EASA:

works towards a more sensitive method aimed at detecting any defects in the main rotor hub at an earlier stage than those described in EASA AD No. 2010-0026-E proposed measures *(RL 2011:02e R1)*.

1 FACTUAL INFORMATION

1.1 History of flight

The pilot took off at 8.25 a.m. from Osterman Helicopter AB's base in Östersund for a commercial transport flight with two passengers. The purpose of the flight was to inspect a number of antennas in the mountains. The flight was carried out initially over rough terrain at an altitude of 6,000 feet (above sea level) through snow squalls. A landing was then made at Helags' mountain station before the flight to Funäsdalen began.

Around a kilometre after passing Flatruet's highest point and at a speed of 100 kt IAS[3], the pilot heard a loud bang and very strong low-frequency vibrations were felt in the helicopter. The instruments could not be read, and parts of the interior fittings detached from the fuselage, the altitude was 500-700 ft above the ground. The pilot understood that the vibrations were linked to the main rotor speed and decided to lower the collective pitch and carry out an autorotation[4]. Above and to the right, the pilot saw a moor that he could land on and turned into the wind (NNO). During the turn he heard the audio warning for high rotor speed i.e. > 420 revolutions per minute and the level of vibrations increased further. During the final in connection with raising the nose and deceleration, the audio warning signal ceased and the level of vibrations decreased slightly.

At about an altitude of 20 feet, the pilot began to hover and he carried out a calm and gentle touchdown on a snow-covered moor. Ground resonance[5] was feared because of the powerful vibrations. The pilot decided to set the engine to idle, and the vibrations then decreased. He cut the engine, applied the rotor brake and braced himself, expecting the helicopter to roll over. The rotor revolutions and the vibrations reduced, the helicopter stood firmly on its skids. After that, the pilot and the passengers could open the door and leave the helicopter. The time from the loud bang to the landing on the moor was less than 30 seconds.

After examination of the helicopter, a large open crack in the main rotor hub was discovered along with several cracks in the tail section and the tail boom.The accident occurred during daylight and the helicopter landed at position N 62°41' 60 E 012°41' 46, 801 m above sea level.

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[3] IAS: Indicated Air Speed

[4] Autorotation: the main rotor is driven by the inflowing air from underneath without driving via the motor, often with a controlled landing

[5] Ground resonance: oscillation that can occur for certain types of rotor systems, the rotor blades oscillating when the helicopter is on the ground, so that rotor disk's centre of gravity does not to lie exactly over the rotor mast.

Fig. 1 Landing site, the helicopter's nose is facing north.

1.2 Injuries to persons

	Crew members	Passengers	Others	Total
Fatal	–	–	–	–
Serious	–	–	–	–
Minor	–	–	–	–
None	1	2	–	3
Total	1	2	–	3

1.3 Damage to the aircraft

Significant.

1.4 Other damage

None.

1.5 Crew members

1.5.1 The pilot

At the time of the incident, the pilot was 33 years old and possessed a CPL(H) certificate.

Flying hours			
Latest	24 hours	90 days	Total
All types	1.1	100.8	1253.4
This type	1.1	96.3	842.6

Number of landings this type over the previous 90 days: 304.

Training for type rating on ECF EC120 B was carried out on 14 Jan 2008 and ECF AS350 a few days before the accident 23 Oct 2009.
Last OPC (Operator Proficiency Check) was carried out 10 Jul 2009 on EC120 B and the previous OPC was also carried out on 31 Dec 2008 on EC120 B. The medical certificate for JAR-FCL 3 Class 1 medical certificate was valid.

1.5.2 The pilot's service

Before the accident, the pilot had had been working approximately 2.7 hours and had flown 1.1 hours. The previous night he had had about eight hours sleep. The pilot had not flown the four days proceeding the day of the accident.

1.6 Aircraft information

1.6.1 General

Fig. 2 ECF EC120 B SE-JME.

Aircraft	
TC holder[6]	Eurocopter France
Type	EC120 B
Serial number	1184
Year of manufacture	2000
Gross mass	Maximum permissible flight mass 1,715 kg, actual 1,556 kg
Centre of gravity	3.958 m, within allowable limits
Total flying time	2,722.7 hours
Number of cycles (VMD[7])	2088
Operating time since inspection (100 Fh inspection)	1,0 hours
Fuel added before incident	Jet A1

[6] TC holder: type certificate holder, the owner of the rights to develop and manage the design
[7] VMD: Vehicle and Maintenance Display

Engine	
TC holder	Turbomeca S. A.
Model	Arrius 2F
Number of engines	1
Engine	
Total flying time, *hours*	2722.7
Running time after inspection, *hours*	*195.9*
Cycles since new	Ng[8] 3150 Nf[9] 2372
Rotor	
Rotor make	Eurocopter
Main rotor, *hours*	2,722.7
Tail rotor, *hours*	2,722.7
Both main rotor and tail rotor gear box have 3,750 Fh/24 years to inspection	

The aircraft had a certificate of airworthiness and a valid Airworthiness Review Certificate (ARC) through to 30 Apr 2010.

1.6.2 *Statutory inspections*

At every 500 Fh inspection the helicopter hub is inspected in accordance with EC120 B AMM[10].

The 100 Fh inspection consists mainly of the lubrication and greasing of components on the main rotor hub. Detailed inspection/control of the areas where the cracks initiated are not included in the 100 Fh inspection.

According to AMM, during a daily inspection, which can be performed by a pilot, the following controls can be carried out in the area in question:

- Rotor hub (drag absorber zone) – Condition, absence of cracks.

1.6.3 *Main rotor hub - history*

The component was fitted to the helicopter when it was manufactured in 2000. During an inspection on 20 Feb 2004, it was discovered that the conical part of the main rotor hub was corroded (where the mast comes up through the hub, see figure 3) and it was dismantled and sent to a component workshop to be repaired. The running time of the helicopter and the component at this point in time was 961 Fh[11]. The problems were rectified under guarantee by Eurocopter.

[8] Ng: Number of cycles in the gas generator (compressor turbine)
[9] Nf: Number of cycles on the free turbine
[10] AMM Aircraft Maintenance Manual
[11] Fh: Flight hour

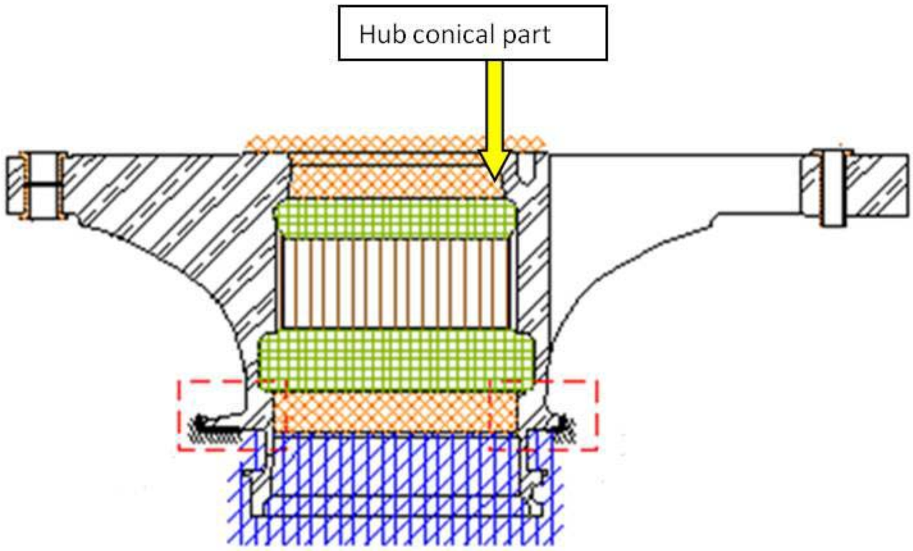

Fig. 3 The main rotor hub in cross section.

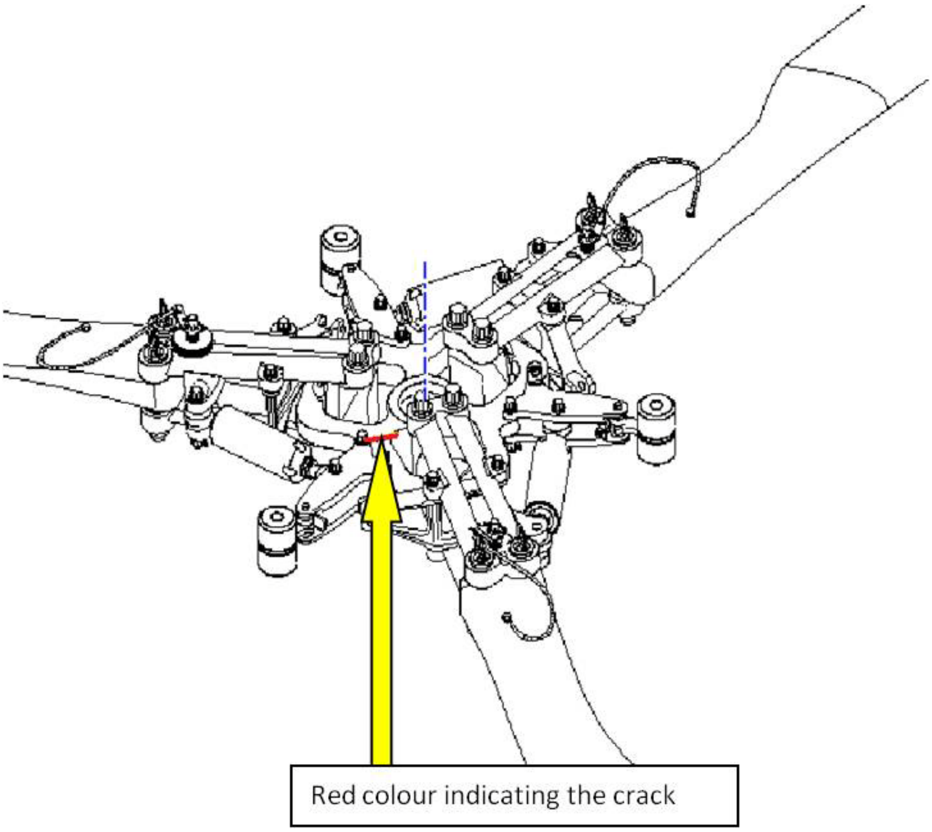

Fig. 4 Complete main rotor hub with blades.

100 h inspections have been carried out several times without abnormal findings on that part of the hub where the vibration damper (Eurocopter nomenclature Treble Adaptor Frequency) and the mass balances are fitted.

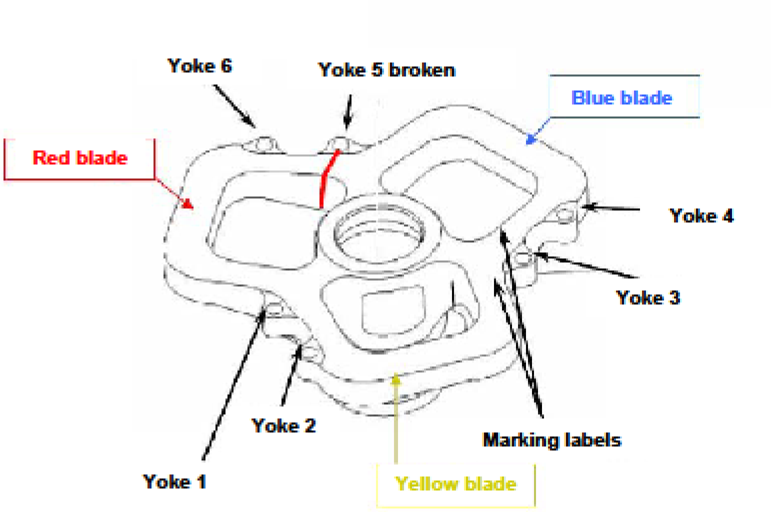

Fig. 5 The main rotor hub with a marked crack (broken) on the ear (yoke).

Main rotor hub P/N C622A1002103, S/N M165		
Date /2009	TSN[12](Fh)	Action/Event
11 March	2526.8	100/500 Fh inspection WO[13]: JME-15 AMM 62-21-00, 6-2 to 6-20 completed without visual observation
23 June	2624.3	M /R hub inspected after contact with the engine hatch during flight WS[14]: 228
1 August	2624.3	M /R blades replaced, see details 23 June
14 August	2635.5	100 Fh inspection WO: JME-22
22 October	2721.7	100 Fh inspection WO: JME-23
28 October	2722.7	Accident Flatruet

Fig. 6 Main rotor hub measures/events 2009.

1.6.4 Main rotor hub

After the accident, the crack in the main rotor hub was discovered and was easily visible from the underside, when the observer stands on the helicopter foot step assembly, see fig. 7.

When not under load, the crack was open approximately 5 mm. The discoloration (brown) shows the area where the crack started under the blue-coloured bracket for the vibration damper, see Fig 8.

[12] TSN: Time Since New
[13] WO: Work Order, work order system of traceability of the work done
[14] WS: Work Sheet, ancillary documents in WO

Fig. 7 The main rotor hub with a visible crack.

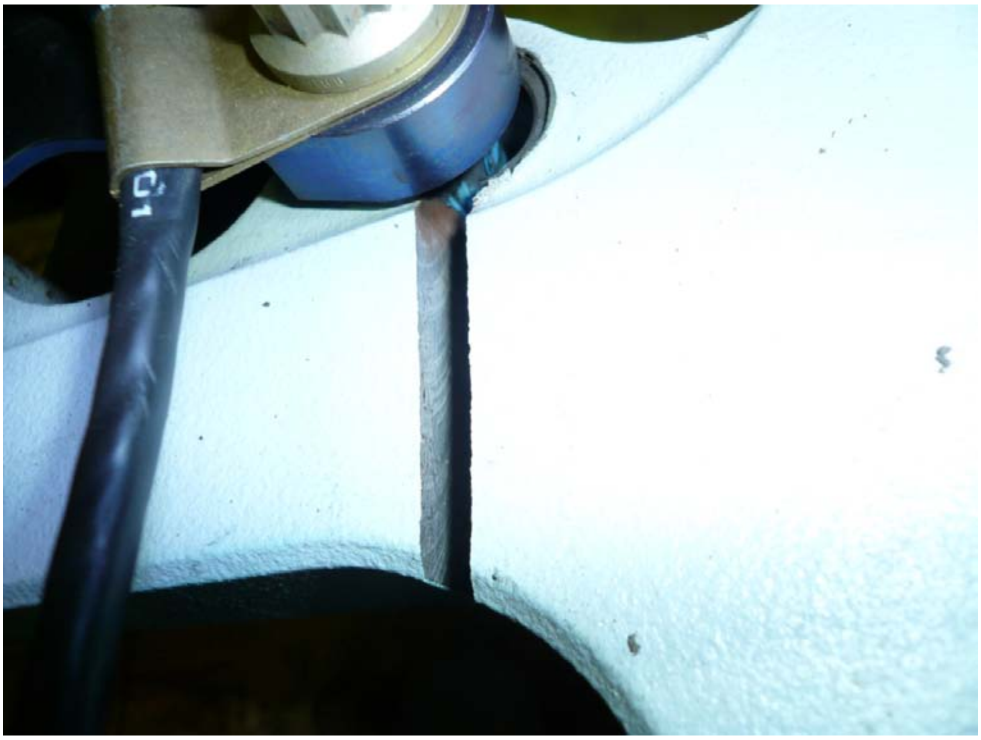

Fig. 8 Main rotor hub with fatigue crack, as seen from above.

1.7 Meteorological information

The weather at Flatruet was, according to SMHI's analysis:

NW wind 7-12 knots, visibility >10 km, 4-7/8 with base 1500-4000 feet, temperature/dew point -2/-3 °C, QNH 1019 hPa

1.8 Navigation aids

Not applicable.

1.9 Radio communications

Not applicable.

1.10 Airfield information

Not applicable.

1.11 Flight recorders

Not available, were not required.

1.12 Accident site and aircraft

1.12.1 The accident site

The landing site was a snow-covered moor in which there was no frost in the ground. The ground was therefore quite soft. The helicopter's landing gear sank several inches into the ground during the time it was standing on the landing area before it was recovered the day after the accident.

1.12.2 Aircraft

Primary damage was localized to the main rotor hub, which consisted of a titanium forging. One of the yokes in the hub where one of the main rotor blades was attached had a through-crack. The helicopter's tail section and tail boom with Fenestron[15] had incidental damage in the form of permanent dents and several cracks. There were also fatigue cracks on the longitudinal stiffeners in the tail section, above the rear fuselage bulkhead. Additional secondary damage was localized to the tail section's hard points on the fuselage (the reinforcements for the transference of forces) where there were several cracks in the paint and the sealant. Incidental damage had occurred when the rear section of the fuselage oscillated (swinging from side to side) in the horizontal plane.

1.13 Medical information

Nothing has emerged to suggest that the pilot's mental or physical condition was impaired before or during the flight.

1.14 Fire

There was no fire.

[15] Fenestron, ECF term for a ducted multi-blade tail rotor

1.15 Survival aspects

1.15.1 General

The landing was controlled by hovering before touchdown and the emergency transmitter, manufactured by Kannad, model 406 AF-H, and was not activated.

1.15. 2 The rescue operation

No rescue operation was initiated because the pilot himself contacted the home base. Subsequently, all people on board were picked up and transported back to Östersund.

1.16 Tests and research

With the assistance of BEA[16], SHK has examined the main rotor hub. BEA has overseen the investigation Eurocopter France made. The study concluded the following: see paragraph 1.16.1.1 and 1.16.1.3. The report Eurocopter Material quality laboratory test report EQTTL No. 2010-3017, dated 28 May 2010 which is available on SHK's website.

1.16.1 General examination of the main rotor hub

Eurocopter verified compliance with the production documentation by undertaking: hardness measurement, control of the chemical composition of the hub, geometric control of dimensions, radii and surface finish. In no instances were there any differences noted that were outside of acceptable tolerances.

1.16.1.1 Main rotor hub - crack initiation

A stationary main rotor transfers forces as a result of the blade's own weight primarily via the spherical bearings to the rotor hub. The stress gives rise to tension load on the top of the yoke in the hub and a pressure load on the underside of the area concerned. The attachment to the vibration damper is housed in the rotor hub's yoke and transfers forces from the main rotor blade in a horizontal plane perpendicular to the mast. At the far end of the attachment to the vibration damper, balance weights are fitted, see figure 4. The torque which the balance weights generate when the rotor is standing still due to gravity, is insignificant; however, the load increases significantly when the rotor rotates at normal speed and the blades turn in the plane of rotation. This load is directed in a radial direction and is transferred to the FTI bushings that are stored in the main rotor hub. Crack initiation occurred when the "Blue Coat" surface coating (antifriction coating) on the FTI bushings in the main rotor hub degraded due to micro-mechanical movements which in turn were caused by the tensions and stresses that arise during flight. Once a crack is established, it continues as a result of the stress concentration at the tip of the crack.

All the six ears where the oscillation dampers are fitted, have been more or less severely damaged at the contact surface between the FTI bushing and the main rotor hub. The underside of the main rotor hub exhibits identical damage. When manufactured, the ear where the crack occurred had been fitted with over-dimensioned FTI bushings - R1 (Ø=15.2 mm) which was permitted according to the production specifications.

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[16] BEA: Bureau d'enquête et d'Analyses pour la sécurité de l'Aviation Civile, the French Air Accident Investigation Commission

1.16.1.2 The main rotor hub's fractographical analysis

The fractured areas can be clearly seen from figure 9. Crack initiation first occurred in the red (inner) and then in the blue (outer) area of the ear, number 5 (yoke). The final fracture is highlighted in yellow and is the area under the yellow line out to the free boundary curve. The fractured surface area relative to the entire area of fracture is on the inside (red area= area 1) 70%/ 25%/ 5%; the first figure applies to the area with a pure fatigue crack. On the outer (blue area= area 2) the corresponding figures are 40%/ 60%. Area 2 has no zones with mixed fatigue failure and final failure. It can clearly be seen how little of the fracture area that remains once the final fracture occurred.

The striations (Macro Marks MM) are clearly visible on the images of the fracture surface, both primary MM1 and secondary MM2 can be identified.

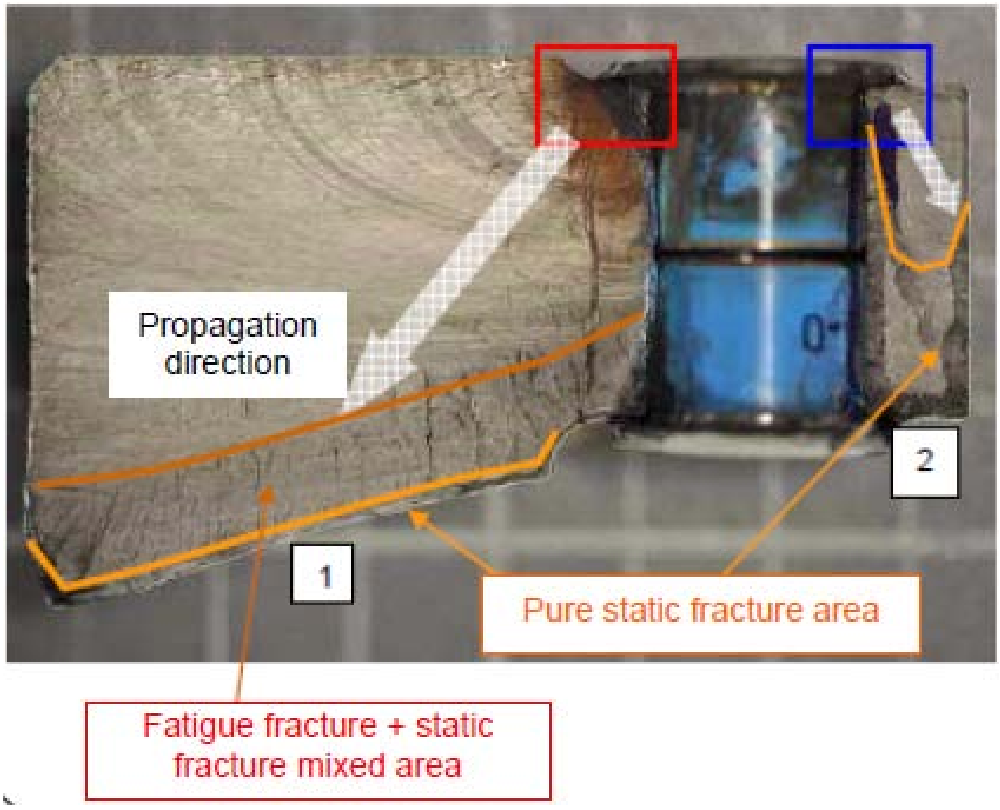

Fig. 9 A cross-section through the main rotor hub ear (yoke) number 5 with marked fatigue zone, mixed zone and the zone final fracture (static fracture zone).

The design department at ECF has not been able to explain how the damage could have arisen during normal flight. As the forces that caused the damage could not have arisen during operating conditions that have been reported or in connection with the stresses that occurred when the engine hatches were in contact with the main rotor blades during the summer 2009.

1.16.2 Comparison with previous similar incidents that have occurred on ECF EC120 B

According to ECF, damage has occurred on the FTI bushing's "Blue Coat" surface coating on at least two previous occasions for the helicopter model in question. Both cases relate to the same helicopter and the crack initiation has, in all probability taken place on the ground in connection with parking. The main rotor blades have been locked with a blade lock, but high winds combined with gusty winds occurred when the helicopter was on the ground. The surface coating of "Blue Coat" has in both cases, been compromised and contact has been made between the steel in the FTI bushing and the rotor hub.

The time between crack initiation and visual detection was relatively short. The cracks were located in the same area of the main rotor hub, toward the outside of the ear on the hub and they were therefore relatively easy to detect, see fig. 10.

Fig. 10 Ear on the damaged rotor hub with exposed crack, item S/N 1070.

Helicopter S/N:	1070
Total flying hours rotor hub (Fh):	5031
Time since installation (Fh):	866

1.16.3 *Compensatory measures Eurocopter and EASA*

The type certificate holder ECF published information about the current incident through established information channels. On 5 November 2009 ECF issued a Safety Information Notice (SIN) No. 2110-S-62 on the Internet entitled Eurocopter Technical Information Publication (TIPI) to provide information about the need for an augmented inspection of the rotor hub on the helicopter in question. The information in the SIN is optional to implement. In addition, in ECF Emergency ASB No. 05A012. Rev. B dated 19 February 2010, there is a description of the visual inspection of the rotor hub every 15 Fh. The instructions for implementing inspection are as follows:

- Visually inspect the inspection areas (A1) and (A2) on the hub (a), and make sure that there is no crack.

The selected length of the inspection interval derives from a technical assessment as to when a possible crack is visually detectable with consideration taken to the crack propagation speed. EASA[17] published AD No. 2010-0026-E, 19 Feb 2010. The reference in AD[18] to ECF Emergency ASB[19] No. 05A012. Rev. B makes inspection mandatory under aviation law.

[17] EASA: European Aviation Safety Authority
[18] AD: Airworthiness Directive
[19] ASB: Alert Service Bulletin

1.17 The company's maintenance organization

The maintenance of the helicopter was contracted to Walters Flygservice (Walter's Air Service) with maintenance permit SE.145.0038. The approved organization for continuing airworthiness CAMO, SE.MG.0074 develops a maintenance programme that reflects the operation the individual helicopter carries out based on known facts. This reflects sling load transports, power line inspection, passenger services, flight training, etc. If the essential elements of the operation of the individual helicopter change this must be reflected in a review of the maintenance programme.

1.18 Miscellaneous

1.18.1 Gender equality

Not applicable.

1.18.2 Environmental aspects

No known environmental effects.

2 ANALYSIS

2.1 The accident flight

2.1.1 Flights before the incident

Information on helicopter operations before the accident, shows no deviation from the operational profile that is normally applied by the operator and which should have been able to initiate the actual damage.

2.1.2 The flight and the incident

The flight was carried out on a day when a zero-degree isotherm was at ground level, indicating little risk of icing at the prevailing height intervals operated in by the helicopter.

The flight was completely normal until the muffled bang was heard and the extremely strong vibrations were noted by the pilot. His quick response and the fact that the helicopter was at a relatively low altitude, at the same time as landable terrain was available, meant that a successful emergency landing was possible.

The exceptionally strong vibrations originated in the yoke which the red blade was fitted onto (the marking is there to identify the blades for balancing and tracking); this had shifted more than 10 mm in a radial direction when the rotor hub fractured. The main rotor's centre of rotation and centre of gravity did not coincide with the centre of the rotor mast and resulted in extreme vibrations in the horizontal plane.

2.2 Main rotor hub

2.2.1 Maintenance

The helicopter had undergone all the maintenance procedures required by the Type Certificate holder within the times stipulated. The approved maintenance programme reflected the specific helicopter's operational profiles in a reasonable manner.

SHK is of the opinion that the general inspection during a daily supervision cannot be considered adequate to detect this type of initial cracks.

2.2.2 The initiation of fatigue crack

The damage to the “Blue Coat” surface connected to the FTI bushings occurs on both the top and bottom of the main rotor hub. The bushings, which were mounted at ear number 5 lacked a considerable amount of the “Blue Coat” coating and had more extensive damage than the rest of the hub-mounted bushings. Since the load on the main rotor hub is symmetrical for each blade, it is reasonable [to assume] that initialization takes place where most of the “fretting” occurs, i.e. where the “Blue Coat” coating is damaged the most.

Once the crack initiation occurred, the crack growth is developed further due to stress concentration at the tip of the crack which is oriented perpendicular to the dominant direction of load during flight. Of the parameters investigated, the number of engine starts correlates to the number of striations (MM1). Both the crack initiation of the red and blue areas (see 1.16.1.3) took place from the top of the rotor hub where the tensile stress is greatest when the rotor is stationary. The discoloration (brown colour) indicates that the crack had been there a long time and where the crack was initiated.

Of the two known cases that ECF describes, the crack initiation occurred in the same way from the top of the main rotor hub, but the crack has propagated towards the hub’s outer surface and at a much higher speed.

2.2.3 Final fracture

The pilot had flown the helicopter during much of the time when the crack had propagated in the main rotor hub, without sensing anything abnormal during flight or noting anything slightly different about the helicopter. A one hundred hours inspection was carried out one flying hour before the accident, without the technician noticing anything abnormal that affects the area where the damage was localized.

During normal flight, the main rotor hub is under low stress, as evidenced by the fact that the surface which remains at the final fracture area (static rupture zone) in the red area (see 1.16.1.2) forms a small part of the total fracture surface. The blue area (see 1.16.1.2) has a larger share of the final fracture which can be explained by the fact that crack initiation on this side occurred later than in the blue area. This means that the time until the fracture occurs is shorter.

2.2.4 Reason for the crack initiation

It has not been possible despite the completed investigation to determine why the crack developed in the main rotor hub.

2.2.5 Inspection in accordance with ECF Emergency ASB No. 05A012, Rev. B

In ECF Emergency ASB No. 05A012, Rev. B a visual inspection is recommended. SHK’s assessment is that the tools required would at least have to be in the form of a magnifying glass and a mirror in order to detect cracks of such a critical size, which means that the inspection does not ensure airworthiness.

2.2.6 Survival aspects

The pilot’s quick analysis of the situation and resolute action, presented a situation of bringing the helicopter down shortly after the main rotor hub had fractured and the vibrations started. Both the pilot and passengers avoided any injury in this way.

The main rotor hub's yoke where the fracture occurred would not have been able to bear the load for a longer period of time, had the vibrations continued. The red blade in this situation would have separated from the helicopter with serious consequences.

3 STATEMENT OF OPINION

3.1 Findings

a) The pilot was qualified to perform the flight.
b) The helicopter had a valid ARC, and was formally airworthy.
c) The flight was conducted within the permissible performance limits.
d) One of blade mounts on the main rotor hub was exposed to a final fracture following crack initiation with slow steady development of fatigue cracks.
e) The red main rotor blade was shifted radially and high vibration levels were felt in the helicopter.
f) The pilot carried out a controlled emergency landing on a moor.
g) It has not been possible to determine why fatigue cracks in the hub started.

3.2 Causes of the accident

The maintenance system for this model of helicopter did not detect the current type of defects because the time from the initiation of the crack to final fracture is shorter than the inspection interval.

4 RECOMMENDATIONS

It is recommended that EASA:

works towards a more sensitive method aimed at detecting any defects in the main rotor hub at an earlier stage than those described in EASA AD No. 2010-0026-E proposed measures *(RL 2011:02e R1).*

APPENDIX

1. Eurocopter Material quality laboratory test report EQTTL No. 2010-3017, issued 28 May 2010.
2. Note from the French investigation authority, the Bureau d'enquête et d'Analyses pour la sécurité de l'Aviation Civile (BEA).

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TECHNICAL QUALITY ASSURANCE

Materials Laboratory

MATERIAL QUALITY LABORATORY TEST REPORT

EQTTL No. 2010-3017

FILE IDENTIFICATION

DESCRIPTION:	**TEST REPORT TESTS CARRIED OUT FOLLOWING FAILURE OF EC120 ROTOR HUB**
FILE NUMBER:	**2009-1665**
ENCLOSED NOTE No.:	
ISSUE DATE:	28/05/2010
IN CHARGE OF FILE:	D. DUPRIEZ

CUSTOMER IDENTIFICATION

REQUESTED BY:	**E. CORNILLE, C. SALBASHIAN**
REFERENCE DOCUMENT	**RIU CO 199-09 – BEM 41488**

IDENTIFICATION OF THE TESTED ITEM

Aircraft:	**EC 120 B S/N 1184**	Part Number:	**C622A1002 103**
Owner/Operator:	**Jämtland Fly AB**	Part Description:	**Hub body**
Operating hours:	**2,720 flying hours**	Supplier:	**Marignane**

ADDRESSEES

EDDLM: O.RAYMOND
ETMCR: C. SALBASTHIAN
ETMR: E. CORNILLE
ESEEM: F. ANTOINE
EQTTI: E. DE MATOS

Keywords: **FLEET FOLLOW-UP – INCIDENT – OPERATION – FATIGUE – Ti 10.2.3**

EQTTL	EQTTL	EQTT
SIGNED	**SIGNED**	**SIGNED**
O. MOLINAS	**O.MOLINAS**	**M. PIERANTONI**

This report is composed of 27 pages (including this page).
This Test Report only concerns the tested items. Duplication of this report is authorized only in its entirety.

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1 CONTEXT

During the flight of aircraft EC120 B S/N 1184 belonging to Customer Jämtland Fly AB, the crew (1 pilot and 2 passengers) felt very strong vibrations. The pilot tried to make an autorotation emergency landing. He made a hard landing instead. After landing, the pilot noticed the failure of the hub body and damage to the structure in the engine cowling area.

For information:
<u>*Analysis of the Manufacturing File*</u>*: When new, all the bushes of this hub were removed and replaced:*

- *The two bushes of the yoke of the cracked bore were replaced (after re-bore) with 2 bushes 7050A3622046 (repair R1, dia. 15.2 mm for dia. 15 mm when new) in accordance with IFMA 572.*

- *All the other bushes were replaced with bushes of the same diameter (dia. 15) without re-boring the hub.*

<u>*Event prior to the incident*</u>*: Five months before the incident (June 2009), following an impact on the blades, the Customer applied WC 05-50-00, 6-3 (Steps to be taken after impact on main rotor blades). The MRH was not replaced.*

<u>*Maintenance*</u>*: Two months before the incident (14/08/2009), the 100-hour inspection was carried out. (Actions carried out: Lubrication of the vibration damper, the droop restrainer ring, the swashplate and the stationary and rotating scissors). No cracks found.*

This is the first case of total failure of the hub strap.

Target of the expert analysis and of the tests:
After removal of the parts, the hub was shipped to the EQTTL material laboratory in order to determine:

- The nature and root cause of the crack,
- The conformity of the hub material.

2 CONCLUSION

- ➢ As regards damage:

The crack found on "yoke 5" located between the red blade and the blue blade of hub body S/N M282 resulted from the initiation then growth of a gradual fatigue cracking phenomenon. The initiation area is located on the upper face of the titanium hub, under the shoulder of the FTi bush, in an area which resulted heavily damaged by fretting corrosion. As a matter of fact, under the shoulder, we noticed that the Blue Coat varnish was missing. The observations made under the FTI bushes of the other yokes revealed similar deteriorations, however in a less advanced stage. The number of main macroscopic marks was estimated to approximately 210 over the entire fracture surface. The examination with a field-emission scanning electron microscope revealed a striation whose Da/Dn varies from $2.63\text{-}10^{-5}$ mm/cycle in the initiation area to $5.88\text{-}10^{-5}$ mm/cycle at the end of the fatigue growth.

- ➢ As regards conformity:

The hardness characteristics of the EC120 hub body comply with the definition.
The chemical composition of the EC120 hub is acceptable with respect to the definition.

Opinion and interpretation: (In agreement with the Design Office)

- We found approximately 210 main macroscopic marks over the entire fracture surface. Considering the assumption that one macroscopic mark corresponds to one engine start, as the Customer carried out 196 engine starts in 104.4 flying hours, the crack growth time from initiation to total failure is approximately 112 hours (Calculation Memo ETMC 1009-10).
- It is not possible to relate the damage (fretting / wear) to the bush removal/installation operations, to the blade impact or to the flight loads.
- In order to know the effect of the removal/installation of the bushes and the number of possible repairs on titanium parts, tests in accordance with DEL No. 0236 have been initiated.

Damage process:

- The deterioration scenario is as follows:
  - Wear/creep of the Blue Coat under the shoulders of the bushes.
  - Significant fretting between the bearing face of the hub and the shoulder of the bush marked No. 5.
  - Initiation of the hub failure under the shoulder of the bush marked No. 5.
  - Total failure of the hub.
  - The root cause of the wear could not be identified.

Recommendation: (Refer to FST 199/09)

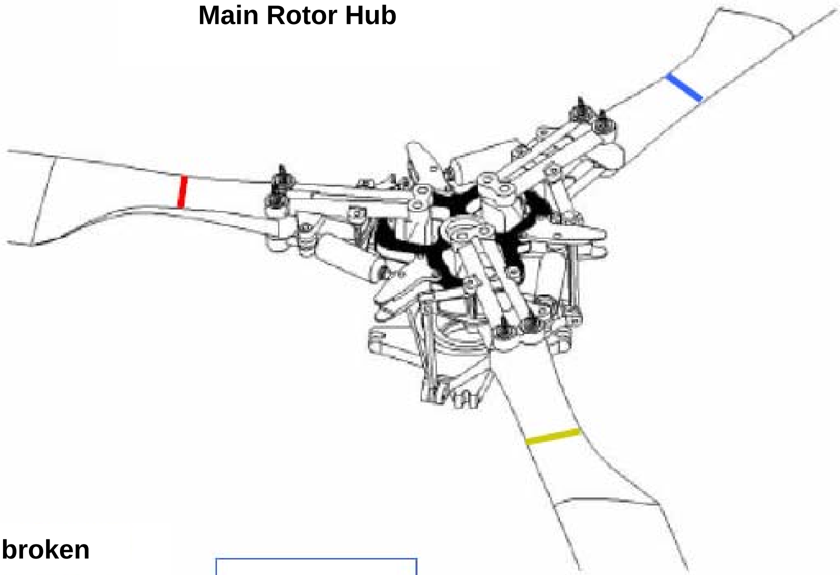
3 IDENTIFICATION OF THE TESTED ITEMS

Customer	**Jämtland Fly AB**		
Aircraft	**EC120**	Operating hours	**2,720 flying hours**

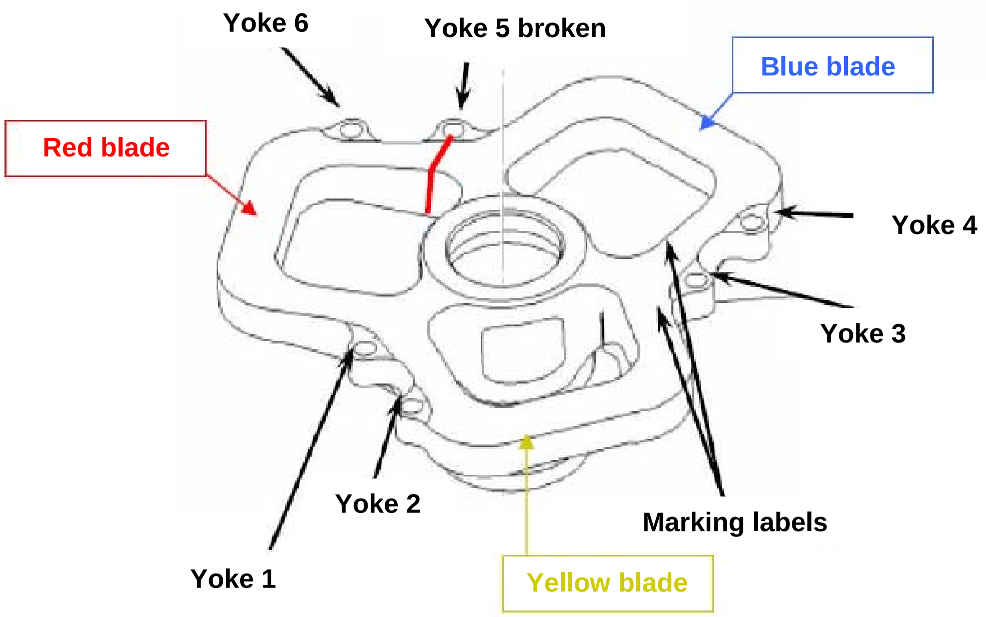
Laboratory identification	Part description	Flying hours	Part number	Material	Marking
2009-1665	**Hub**	**2,720**	**C622A1002 103**	**TI 10.2.3**	M282

4 LOCATION OF THE TESTED ITEMS ON THE AIRCRAFT AND/OR ON THE PART

Main Rotor Hub



Hub body



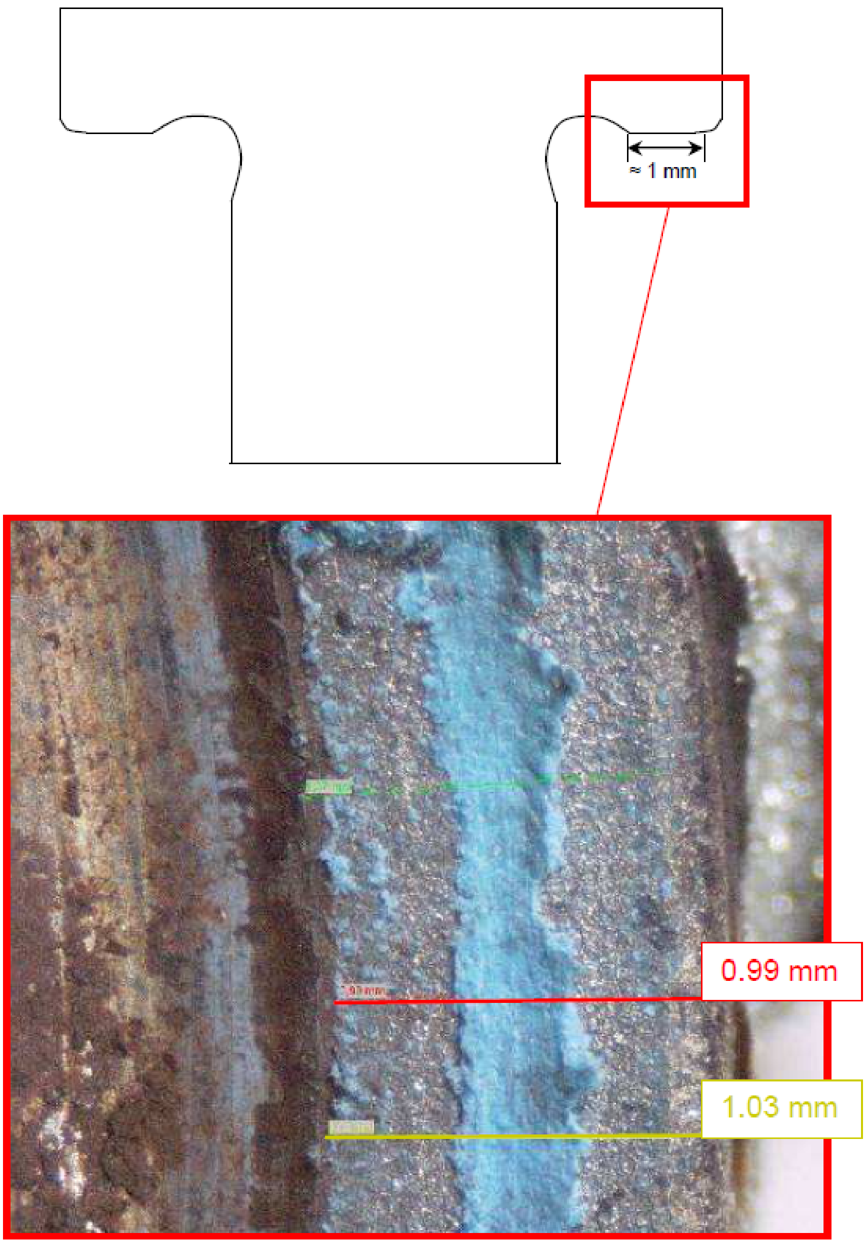
5 DIMENSIONAL CHECK

5.1 Measurement carried out by the Material Laboratory

Operator	D. DUPRIEZ	Supervisor: Not applicable
Date of the test	24/03/2010	Ambient conditions: Not applicable

Equipment
Description: Binocular magnifier
Identification: 61270001

The dimensional measurements carried out in the Laboratory on a slightly damaged bush revealed that the measurement of the seating face of the FTi bush in contact with the hub was approximately 1 mm.



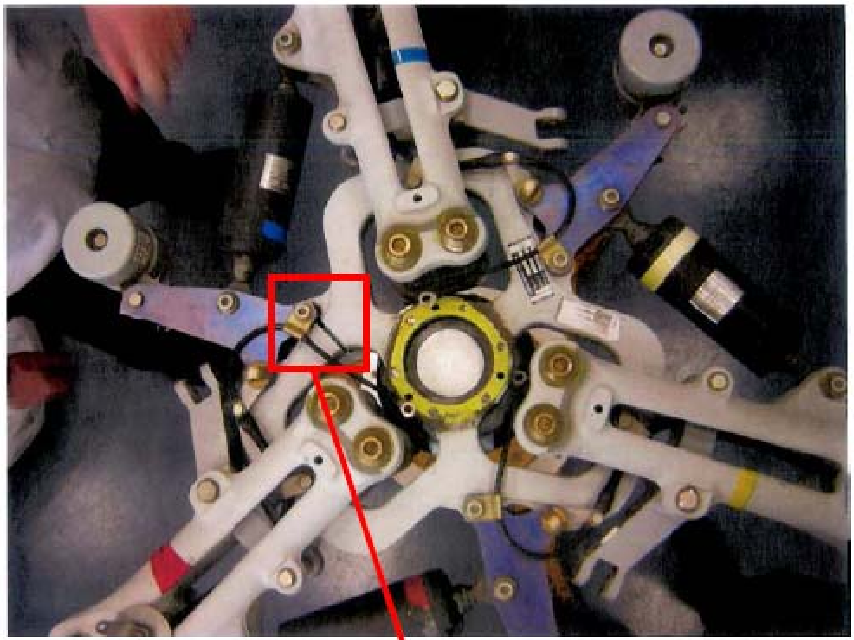
Estimation of uncertainty	Not calculated
Opinion and Interpretation	This value changes depending on the bushes, but remains approx. 1 mm.
Observation	Not applicable.

6 LABORATORY EXAMINATION

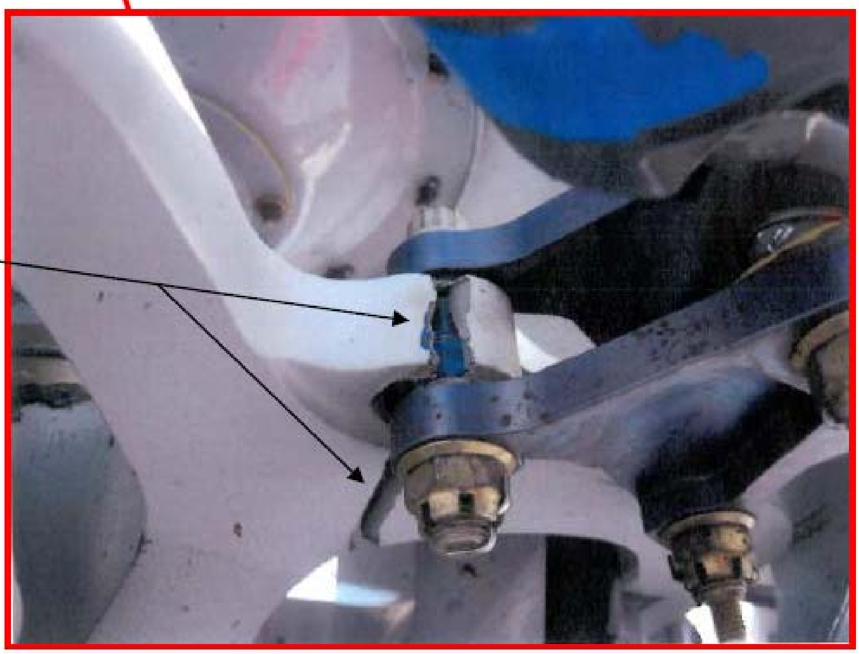
6.1 Overall examination

EI or standard	EI072T0073 – Characterisation of damage on metallic and non-metallic parts.		
Operator	D. DUPRIEZ	Supervisor:	Not applicable
Date of the test	23/03/2010	Ambient conditions:	Not applicable

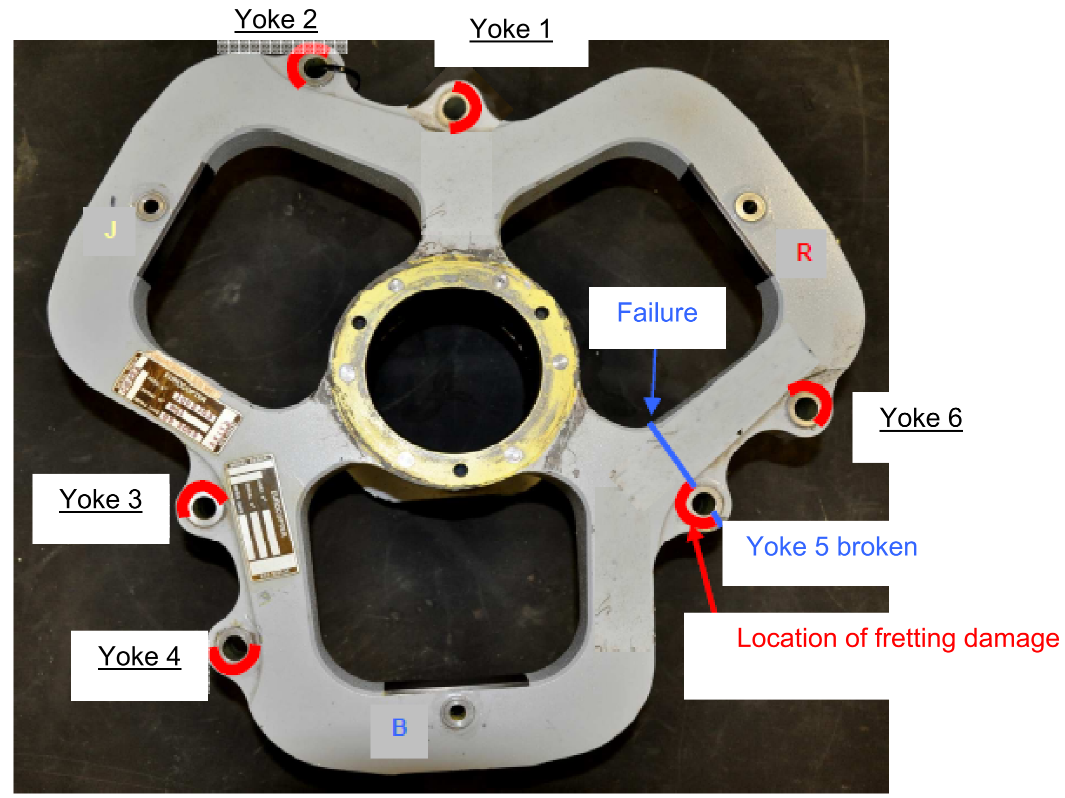
Before removal, the fracture could be observed at one of the yokes used for attachment of the drag dampers.



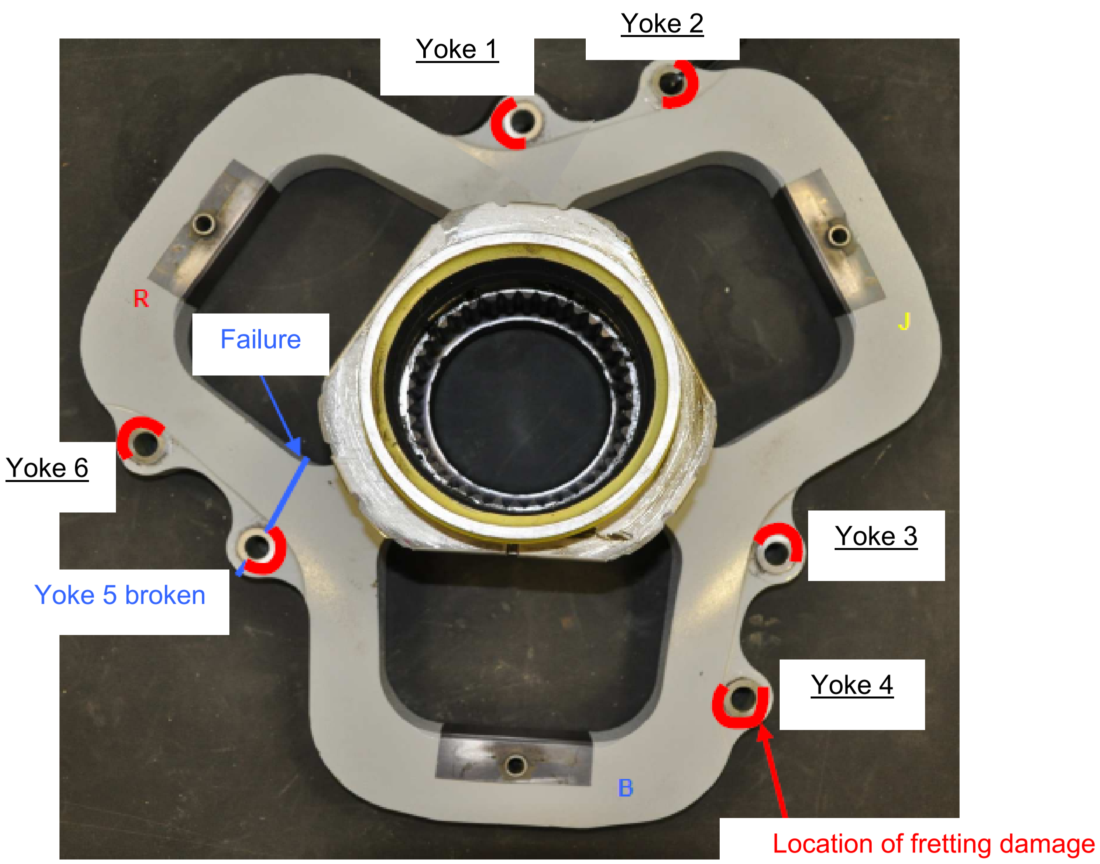
Detail of the total failure of the hub strap



➤ **Location of fretting damage under the shoulder of FTi bushes on the upper face of the hub (rotor side)**

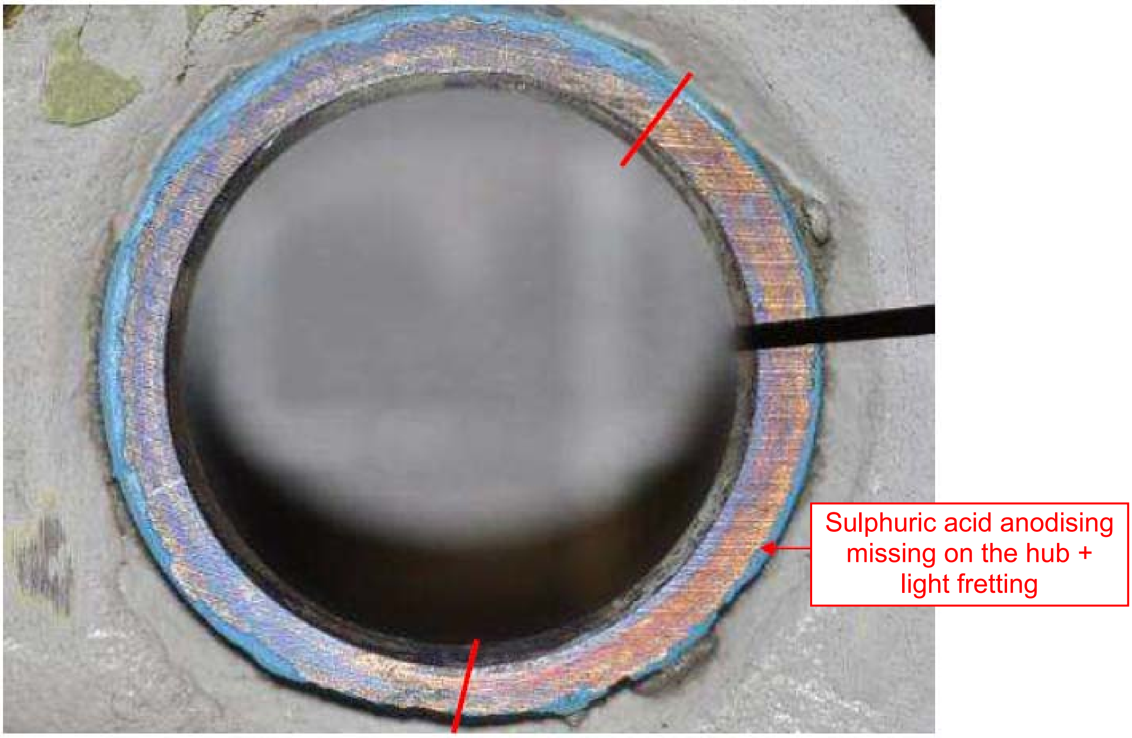


➤ **Location of fretting damage under the shoulder of FTi bushes on the lower face of the hub (MGB side)**

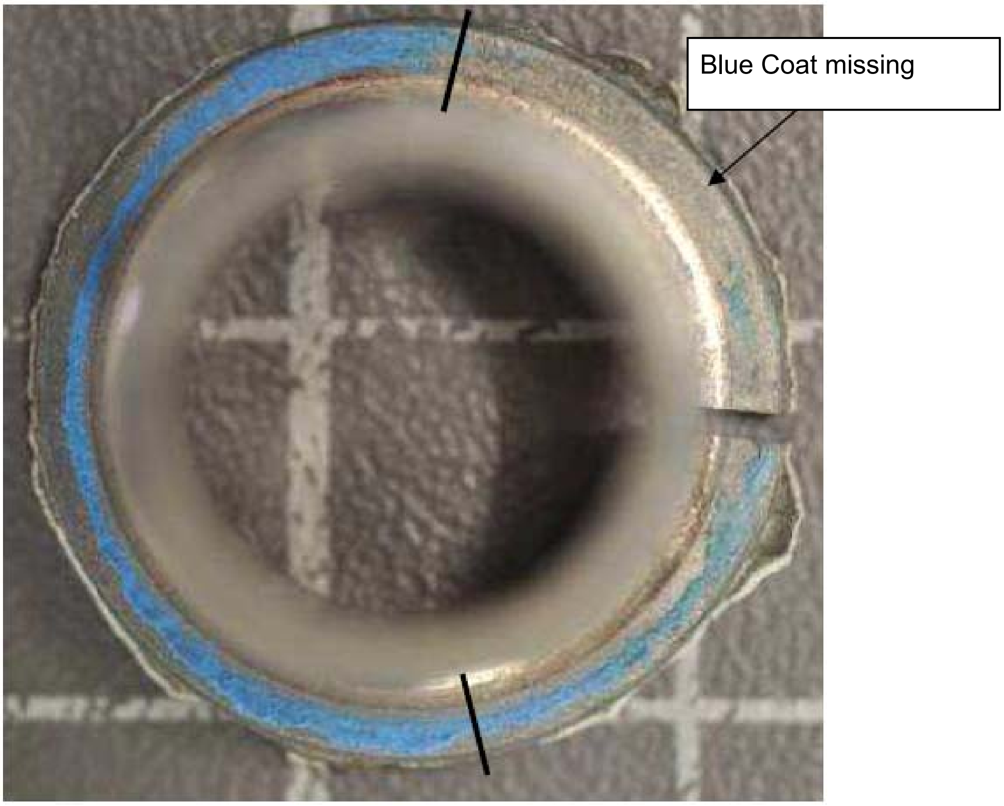


➢ **Detail of fretting damage on the upper face of the hub and on the shoulder of the FTi bush**

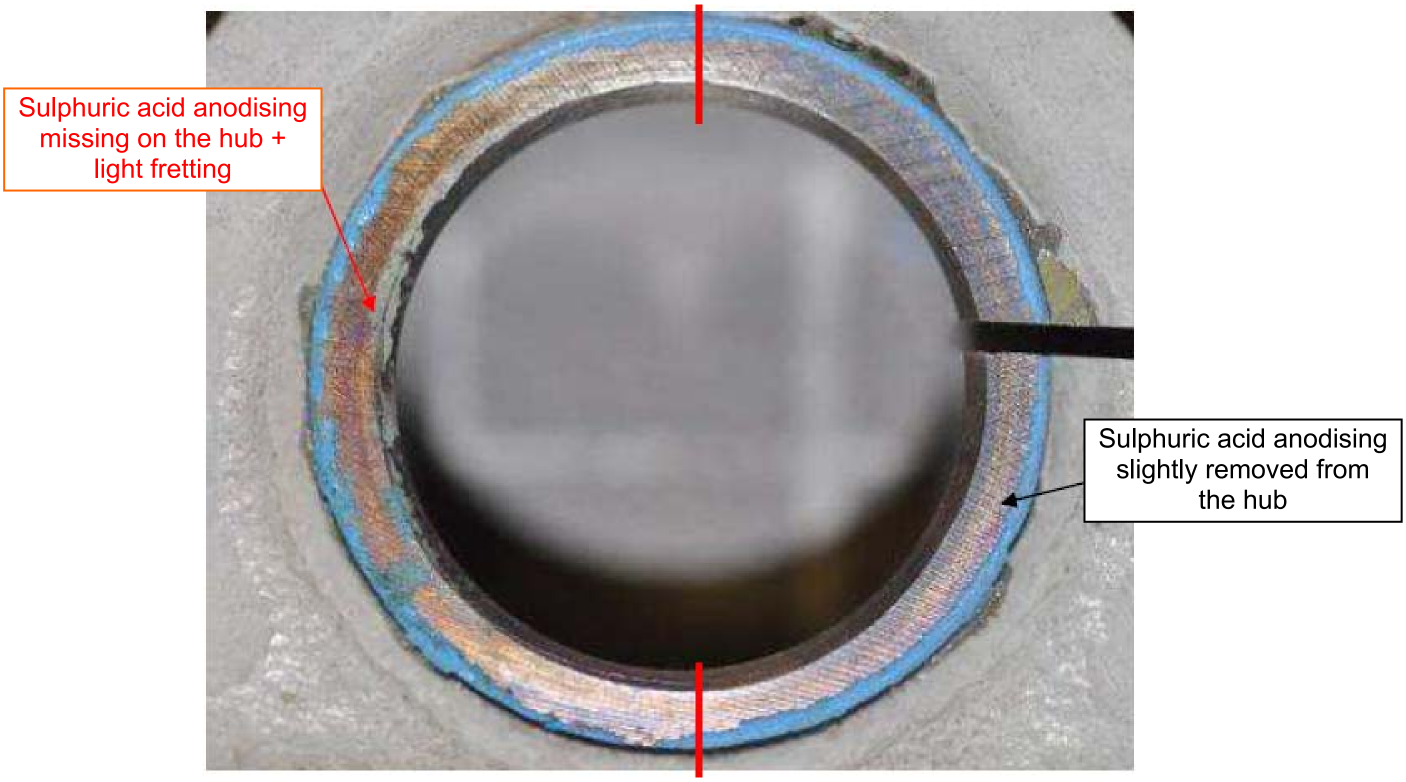
- Yoke No. 1



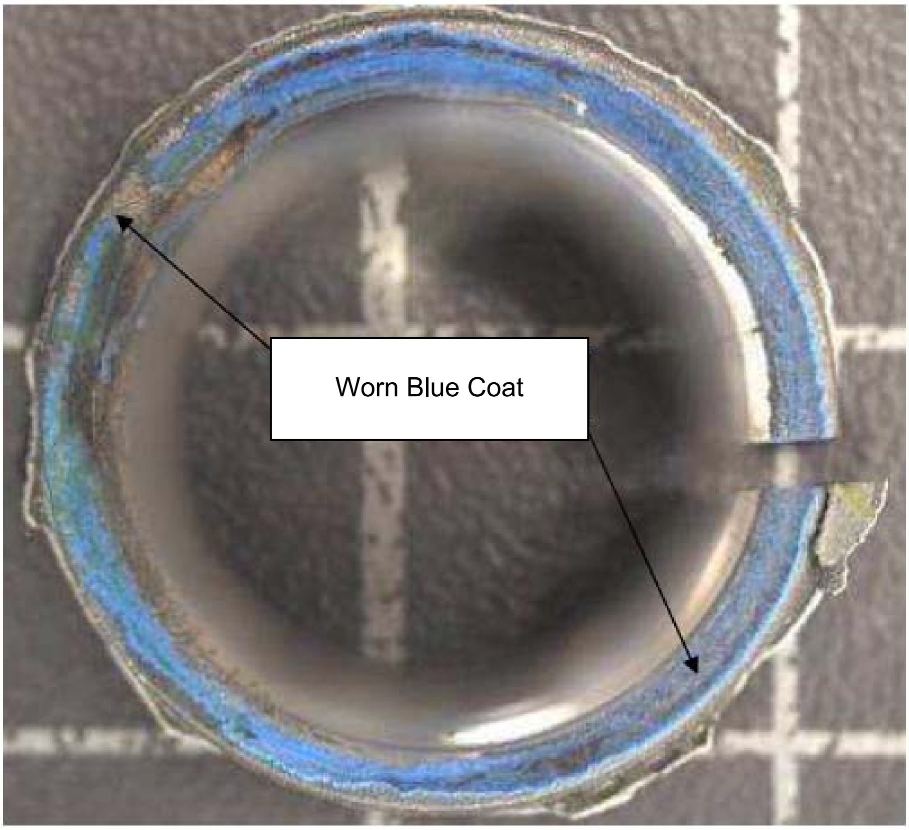
- FTi bush No. 1



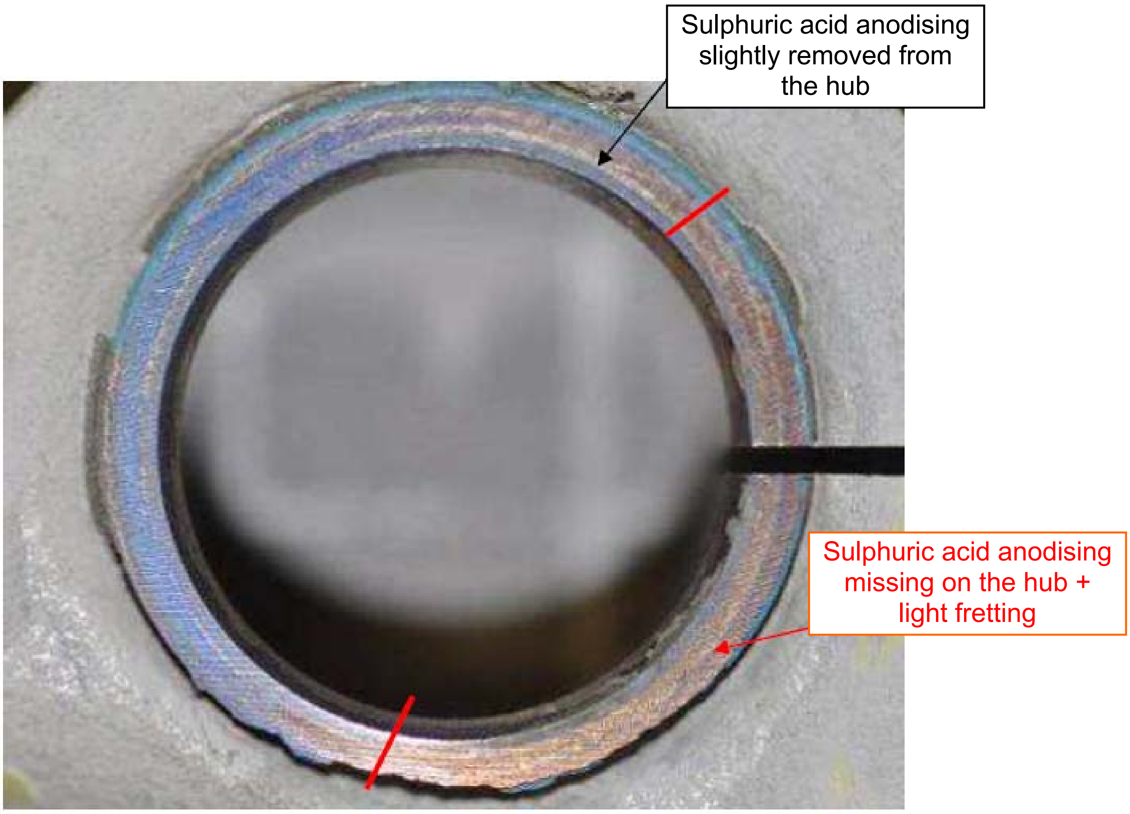
- Yoke No. 2



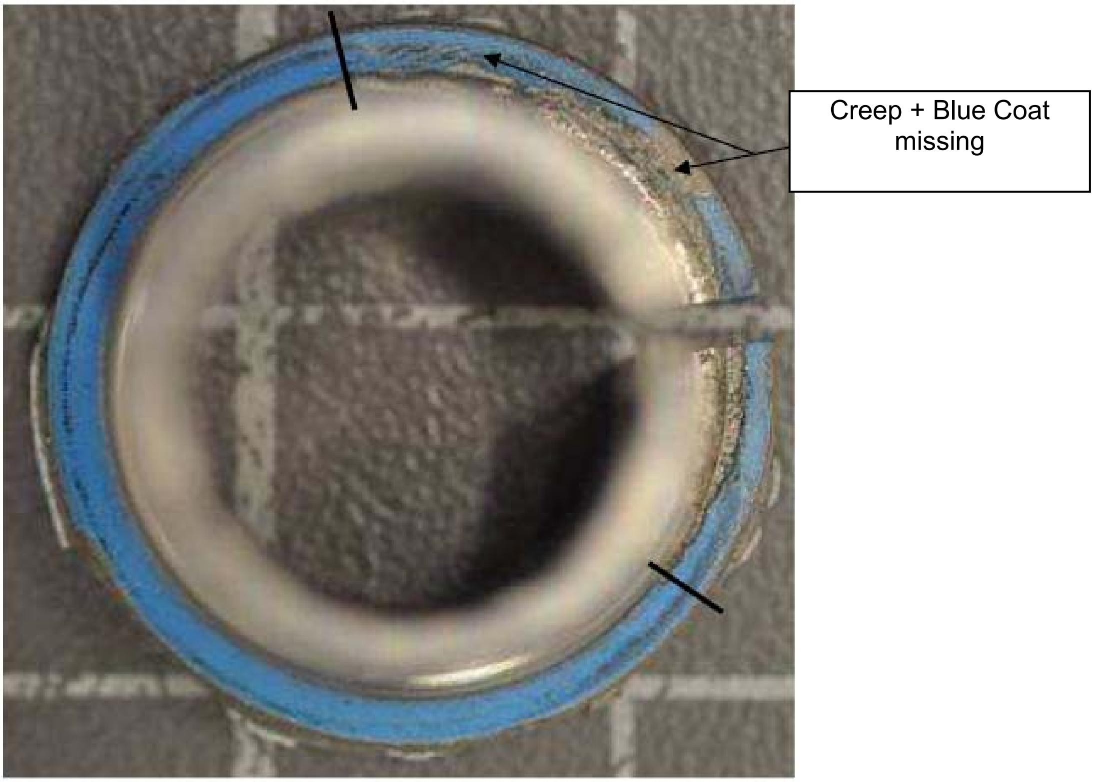
- FTi bush No. 2



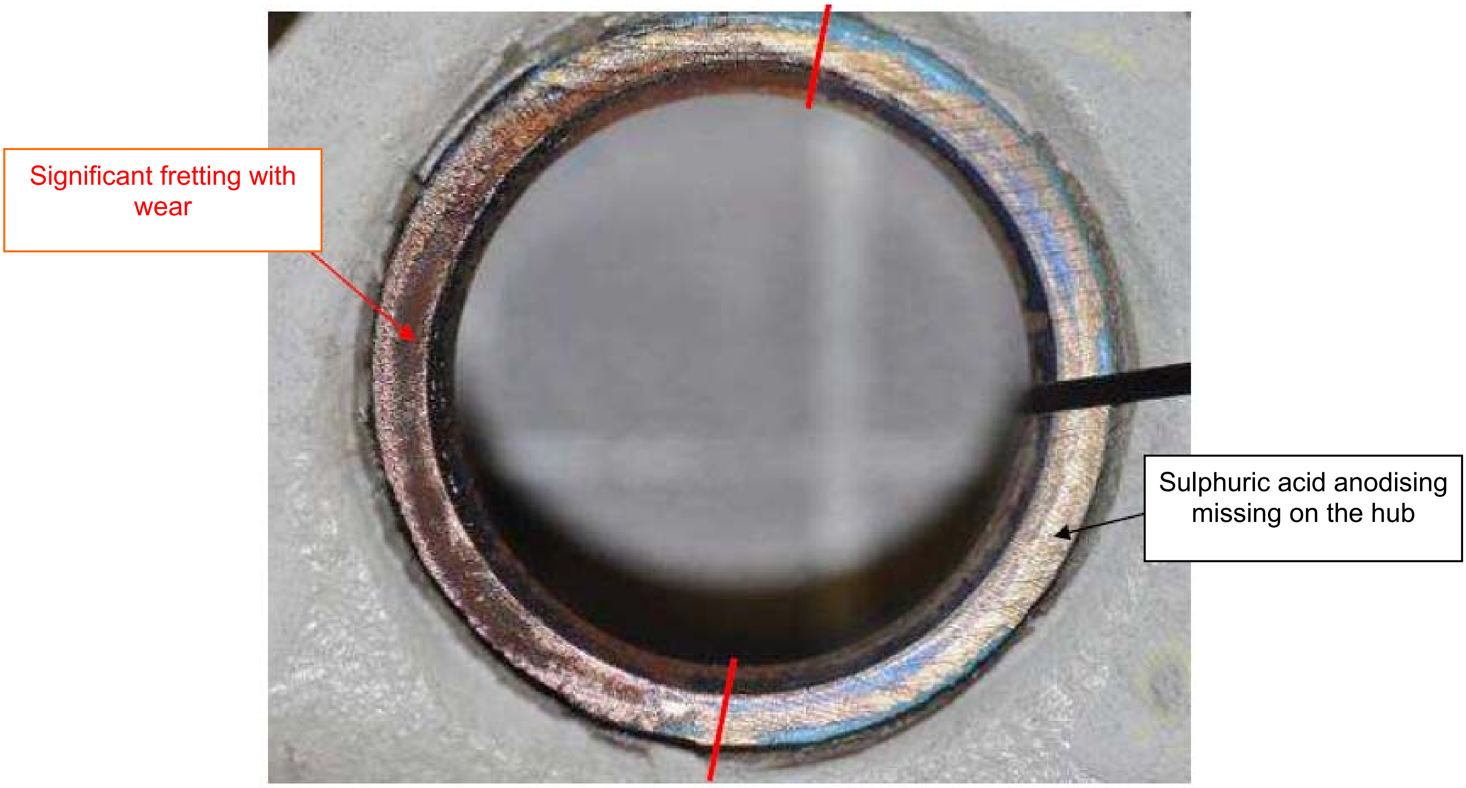
<u>- Yoke No. 3</u>



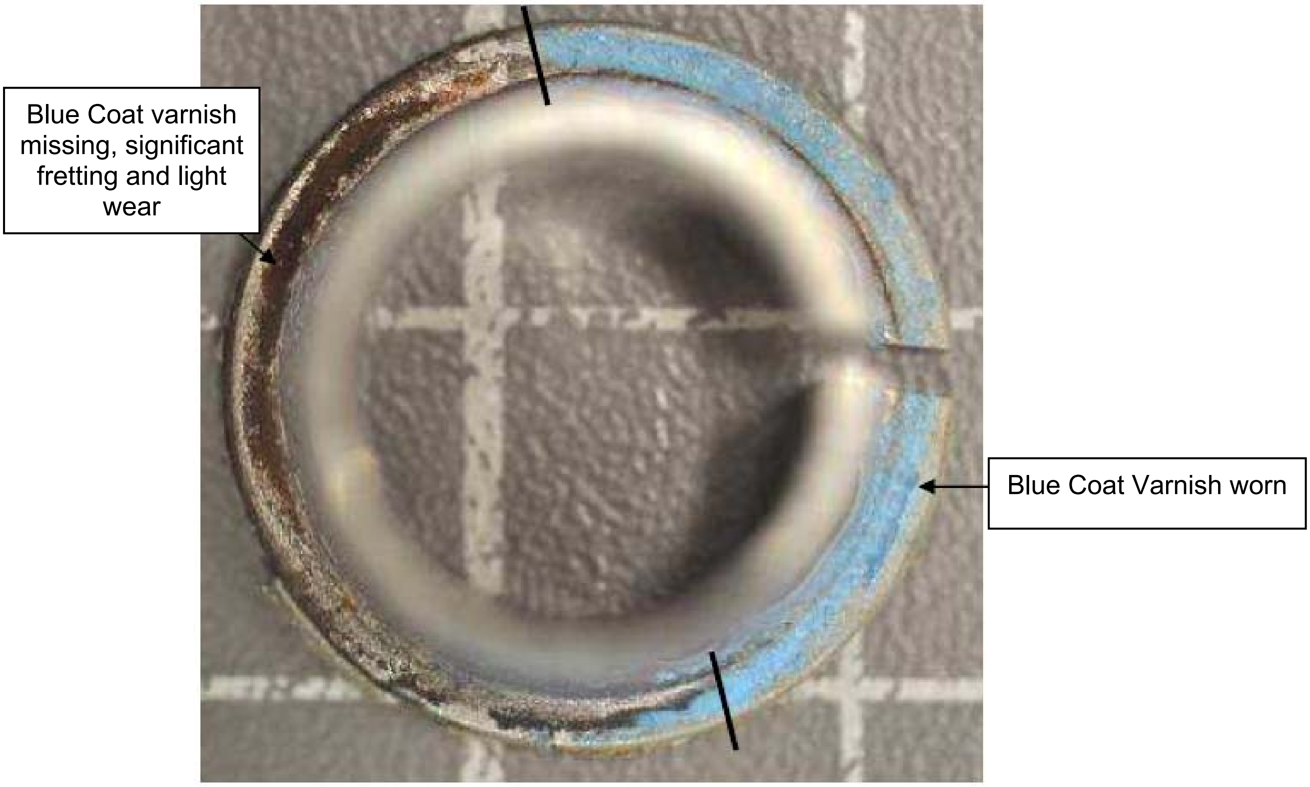
<u>- FTi bush No. 3</u>



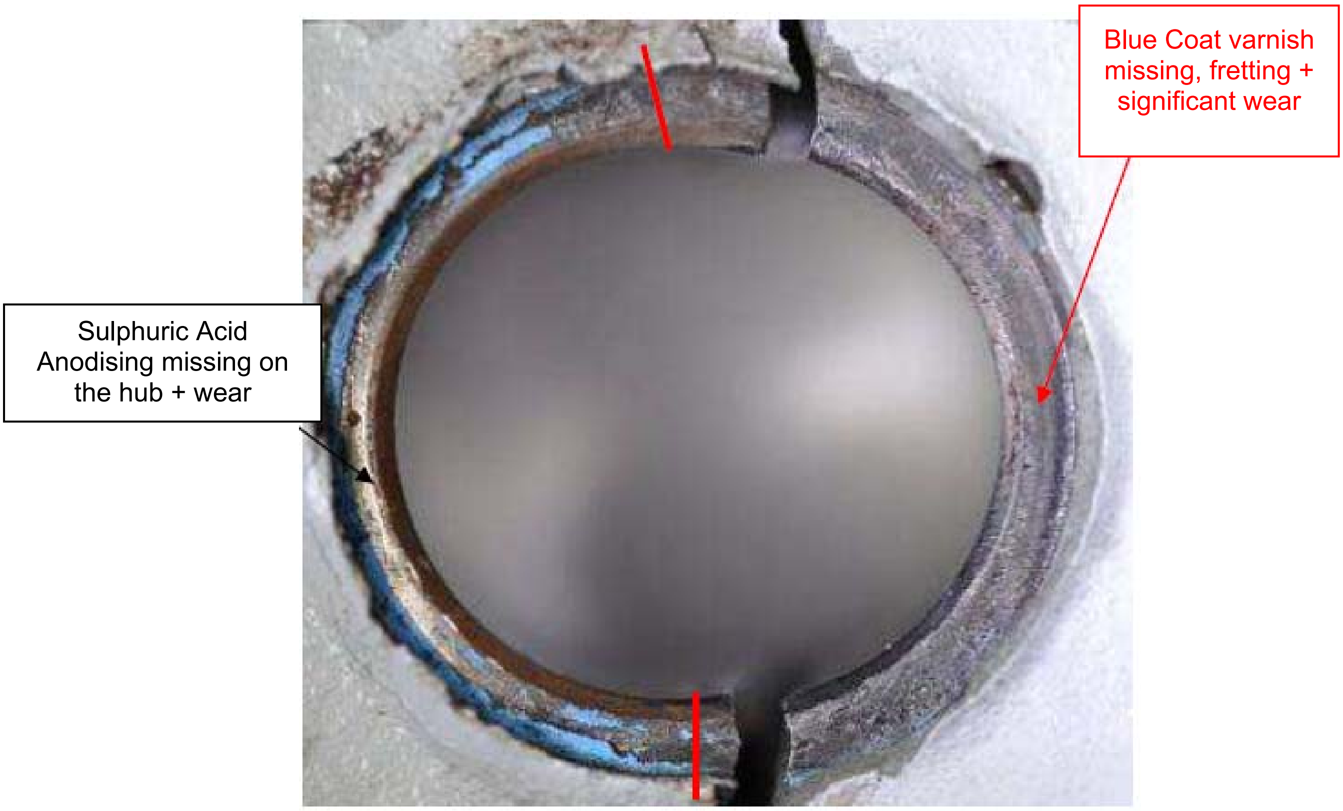
- Yoke No. 4



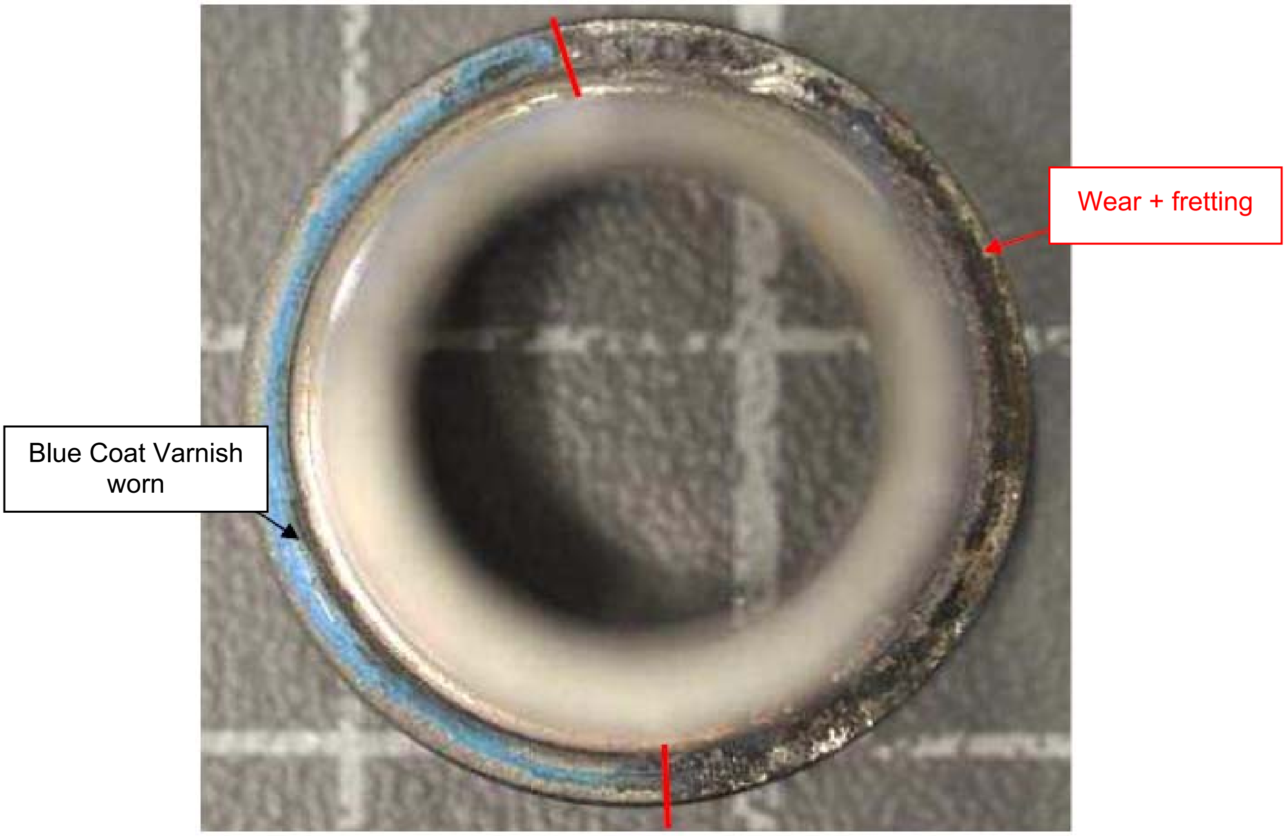
- FTi bush No. 4



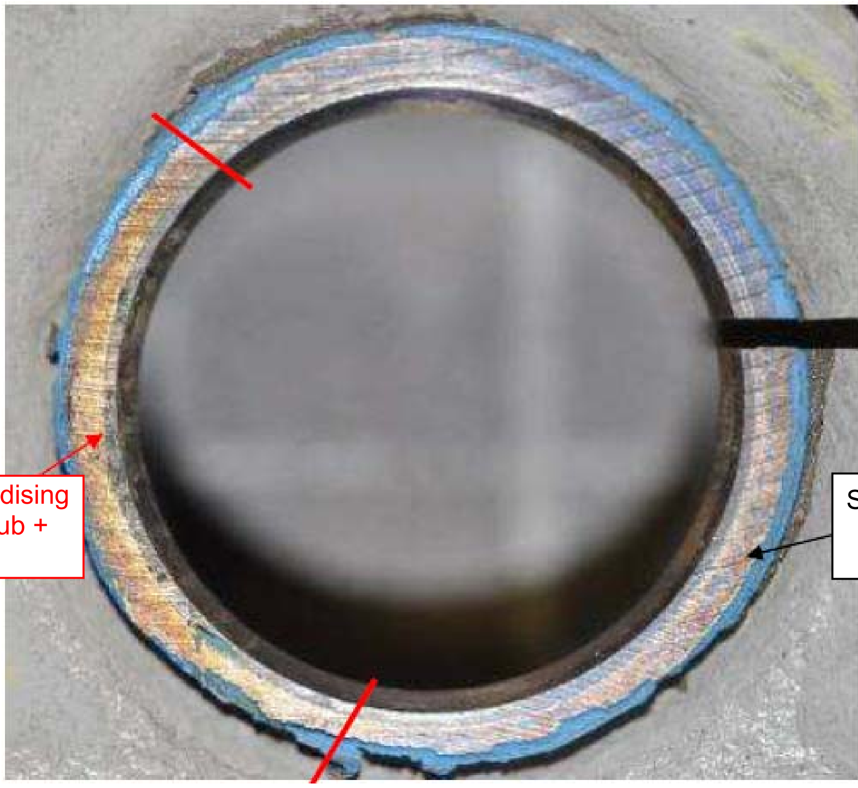
- Broken yoke No. 5



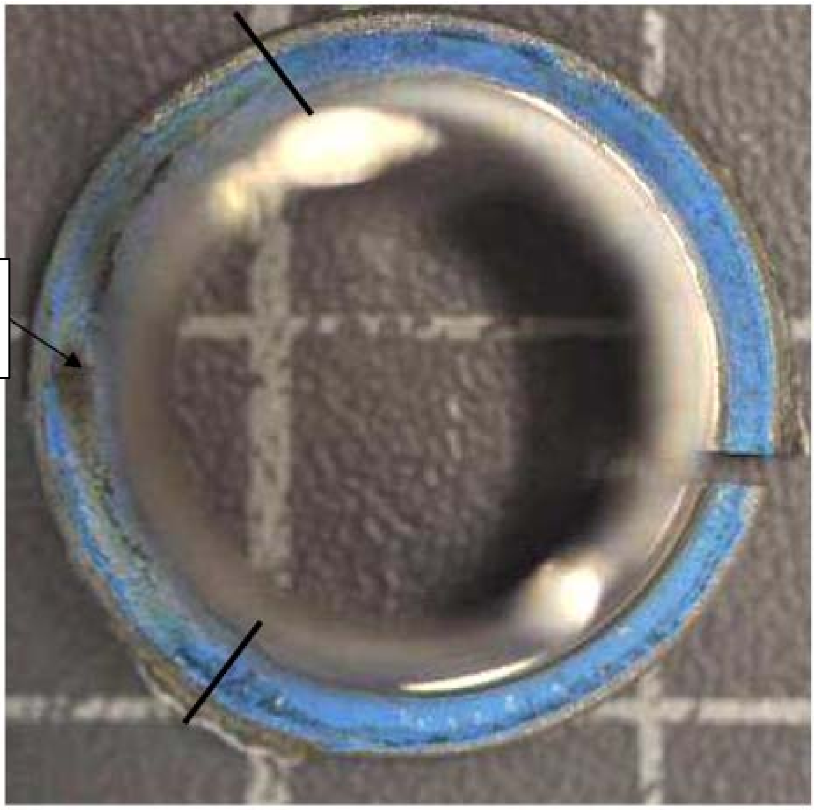
- FTi bush No. 5



<u>- Yoke No. 6</u>

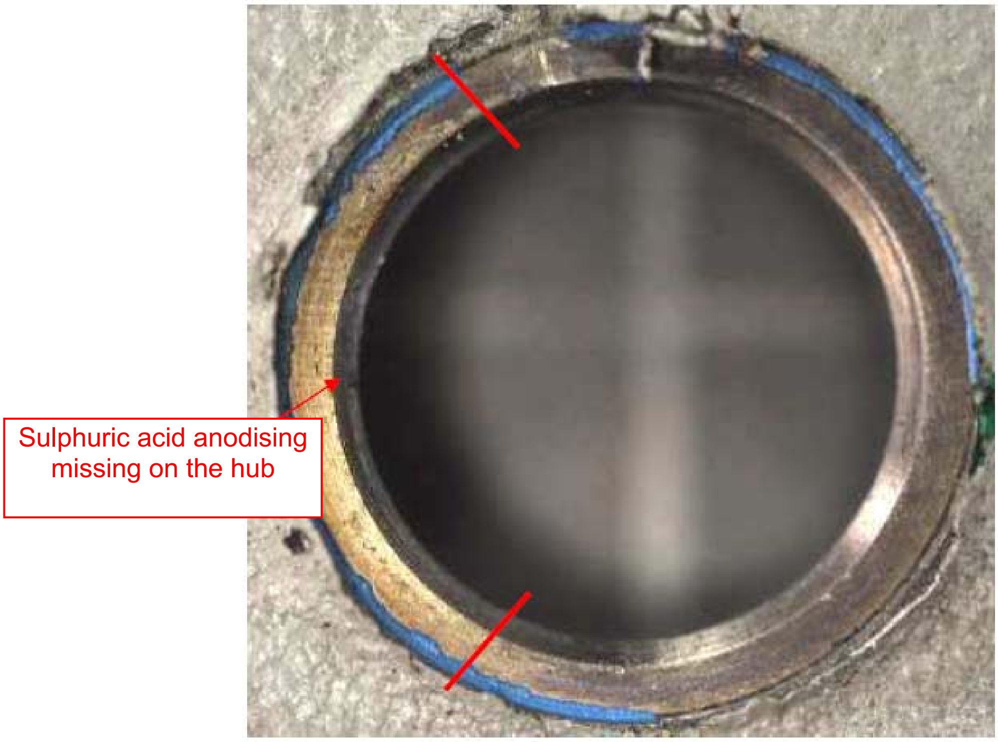


<u>- FTi bush No. 6</u>

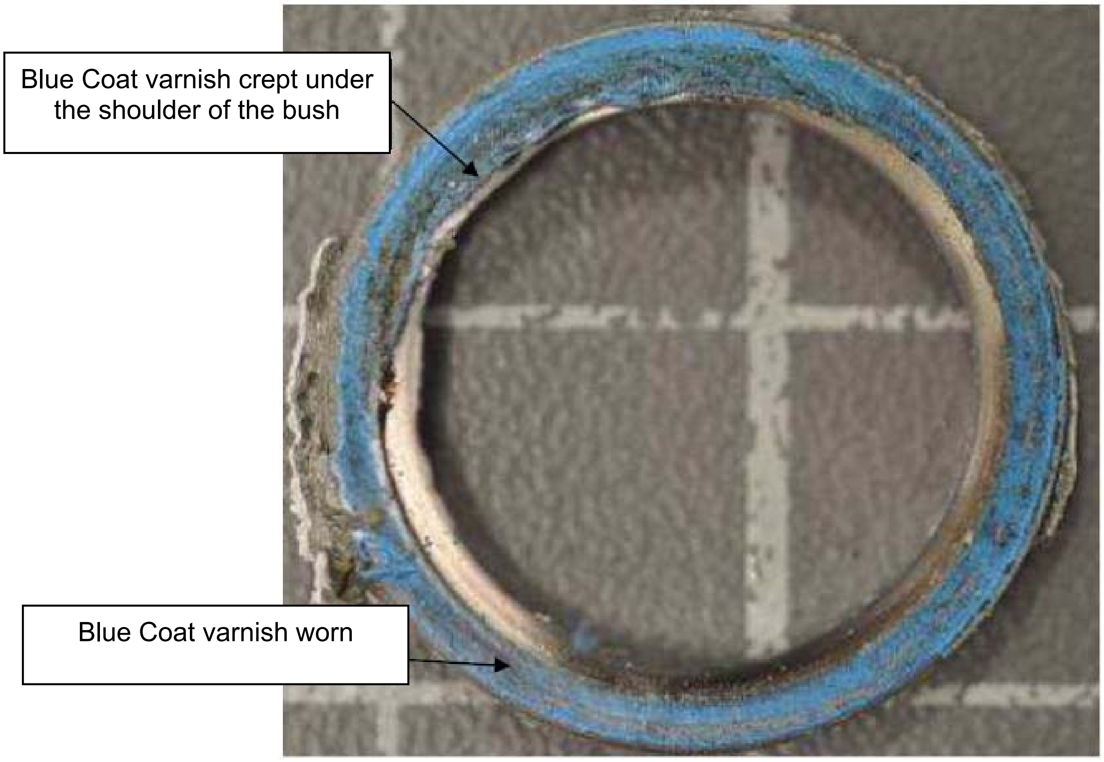


➢ **Detail of fretting damage on the lower face of the hub and on the shoulder of the FTi bush**

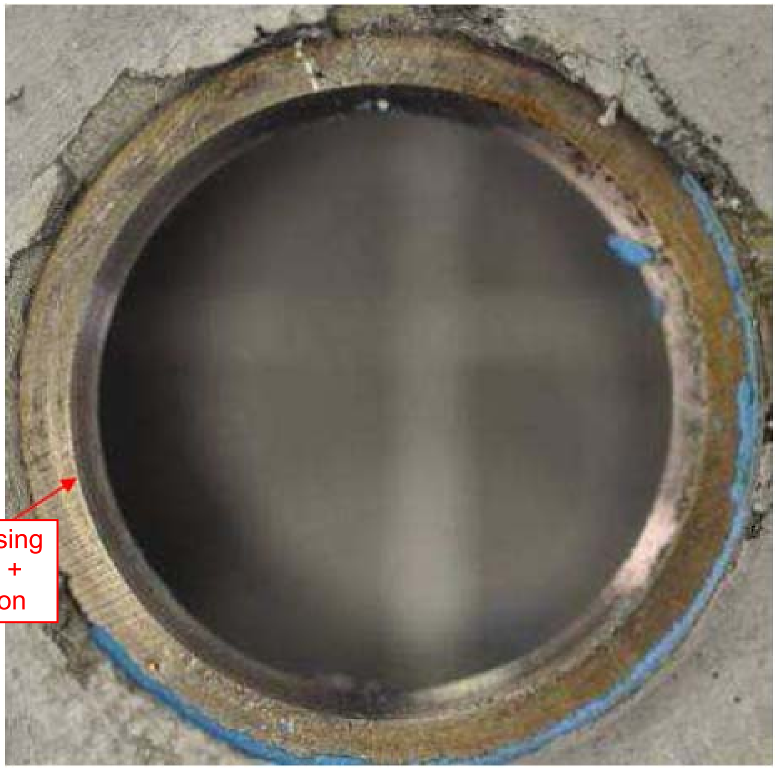
- Yoke No. 1



- FTi bush No. 1



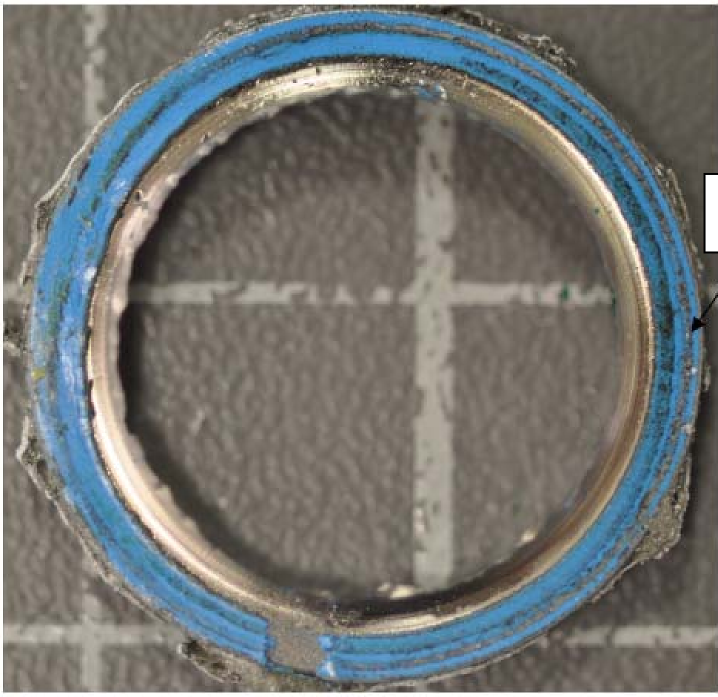
- Yoke No. 2



- FTi bush No. 2

- Yoke No. 3

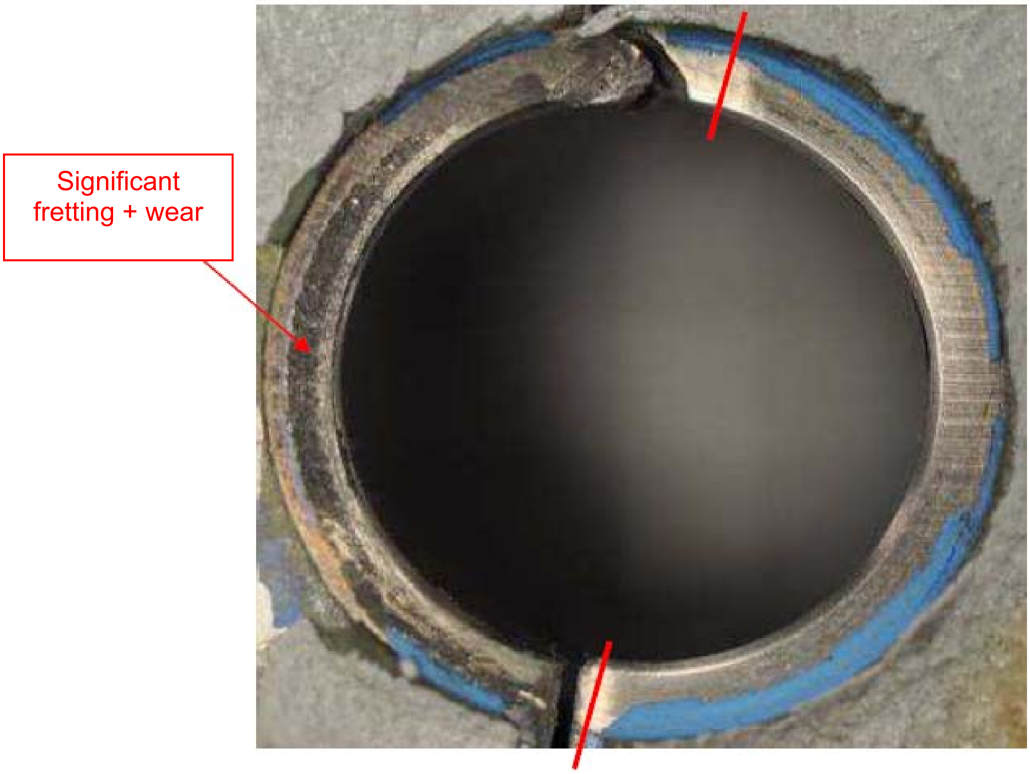
- FTi bush No. 3



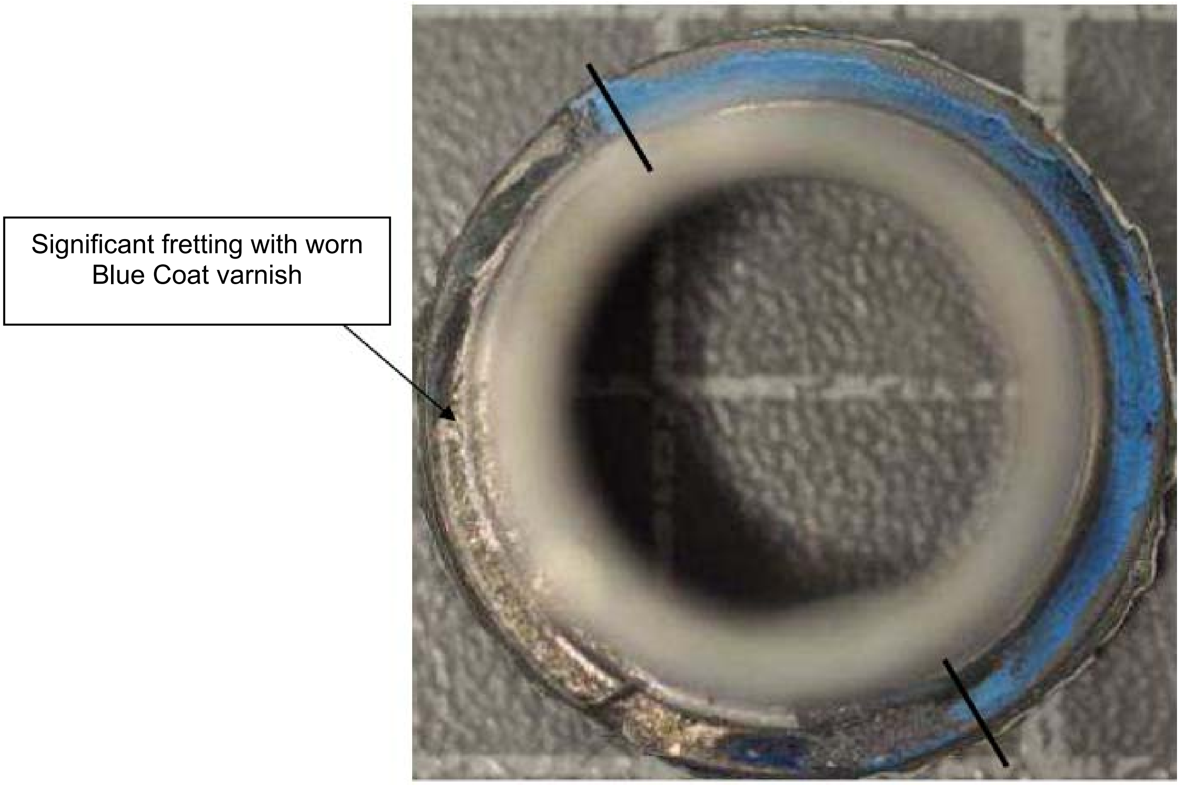
<u>- Yoke No. 4</u>

<u>- FTi bush No. 4</u>

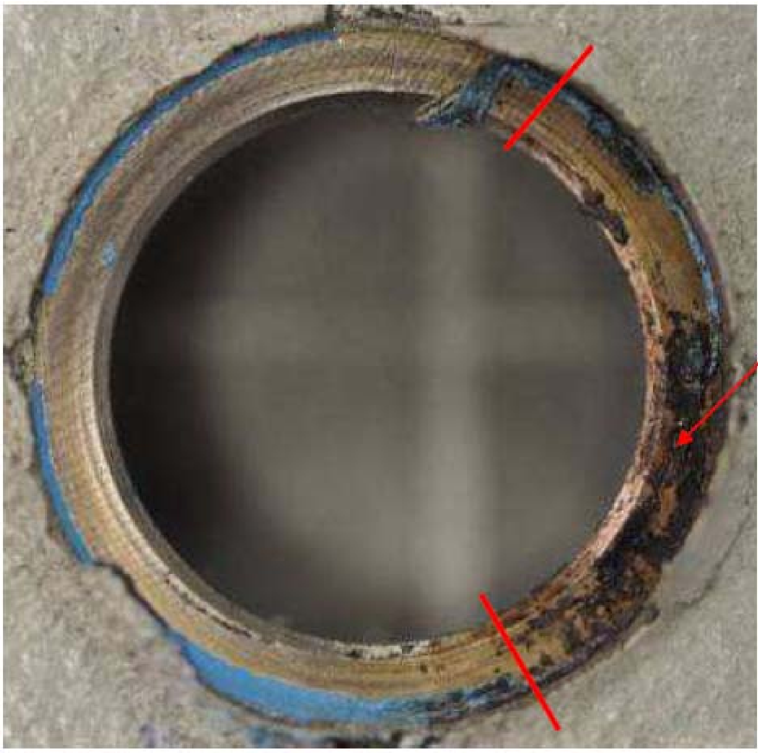
- Yoke No. 5



- FTi bush No. 5



- Yoke No. 6



- FTi bush No. 6

- **Synthesis of the observations made on hub M 277**

- Upper face side

		Fretting damage level	
		Hub M282	Upper bush
Red blade	Yoke 1	Low	Average
	Yoke 2	Low	Average
Yellow blade	Yoke 3	Low	Average
	Yoke 4	Significant	Significant
Blue blade	Yoke 5	Significant	Significant
	Yoke 6	Average	Average

- Lower face side

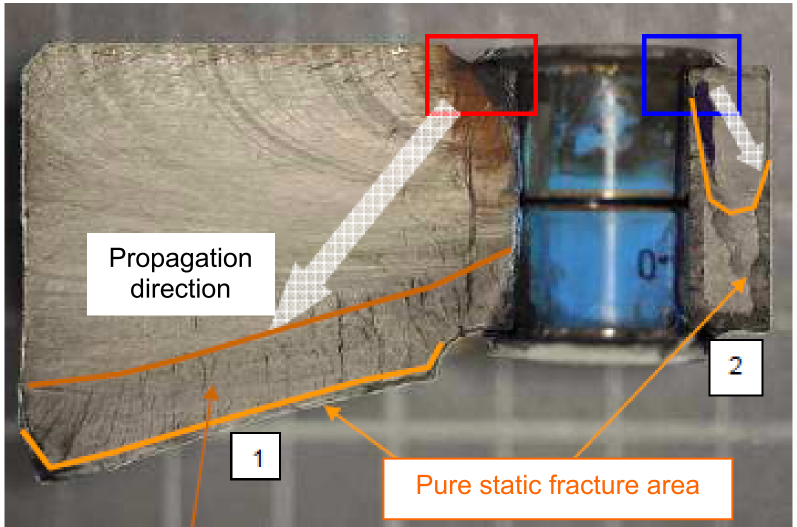
		Fretting damage level	
		Hub M282	Upper bush
Red blade	Yoke 1	Average	Average
	Yoke 2	Low	Average
Yellow blade	Yoke 3	Average	Low
	Yoke 4	Low	Average
Blue blade	Yoke 5	Significant	Significant
	Yoke 6	Significant	Significant

Decision on conformity	Not applicable
Estimation of uncertainty	Not applicable
Opinion and Interpretation	Using the synthesis tables above, one can notice that: - The location of the damage is identical on both the upper and lower faces; - Yokes 3, 4, 5 and 6 of the yellow and blue blades exhibit the most significant damage. In agreement with the Design Office, we cannot relate this damage to the flight loads or to the impact on the rotor blades.

6.2 Macrofractographic examination

EI or standard	EI072 T 0077 – Fractography characterisation of fractures.		
Operator	D. DUPRIEZ	Supervisor:	Not applicable
Date of the test	16/02/2010	Ambient conditions:	Not applicable

The failure of the hub initiated and propagated due to fatigue, under the bush shoulder on both sides of the FTi bush, in an area with significant fretting corrosion. The fatigue / mixed zone / static fracture proportion is approximately 70% / 25% / 5% for the crack which propagated towards the inside (1), and 40% / 60% for the crack which propagated towards the outside (2).

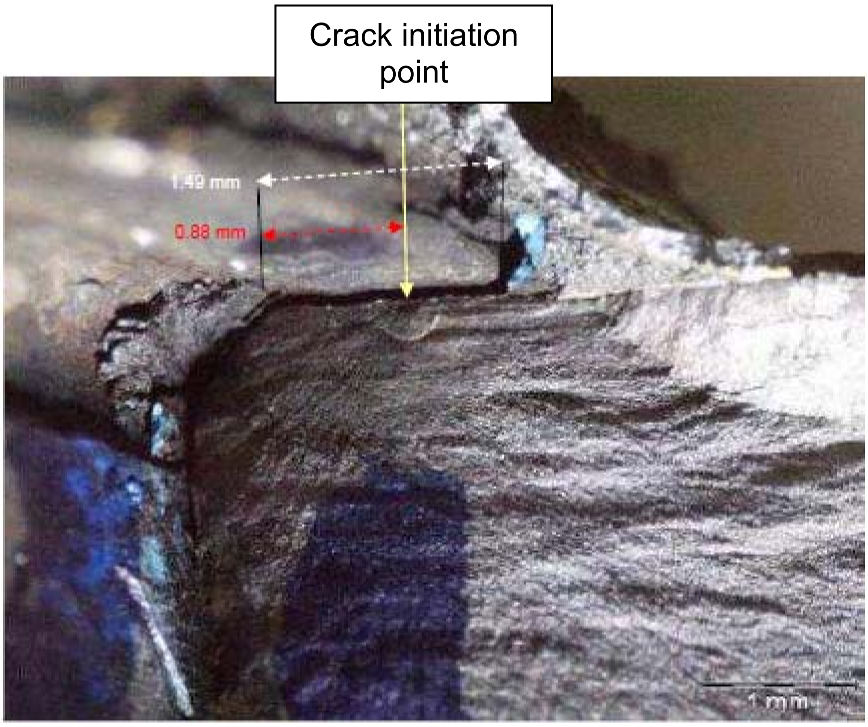


Fatigue fracture + static fracture mixed area

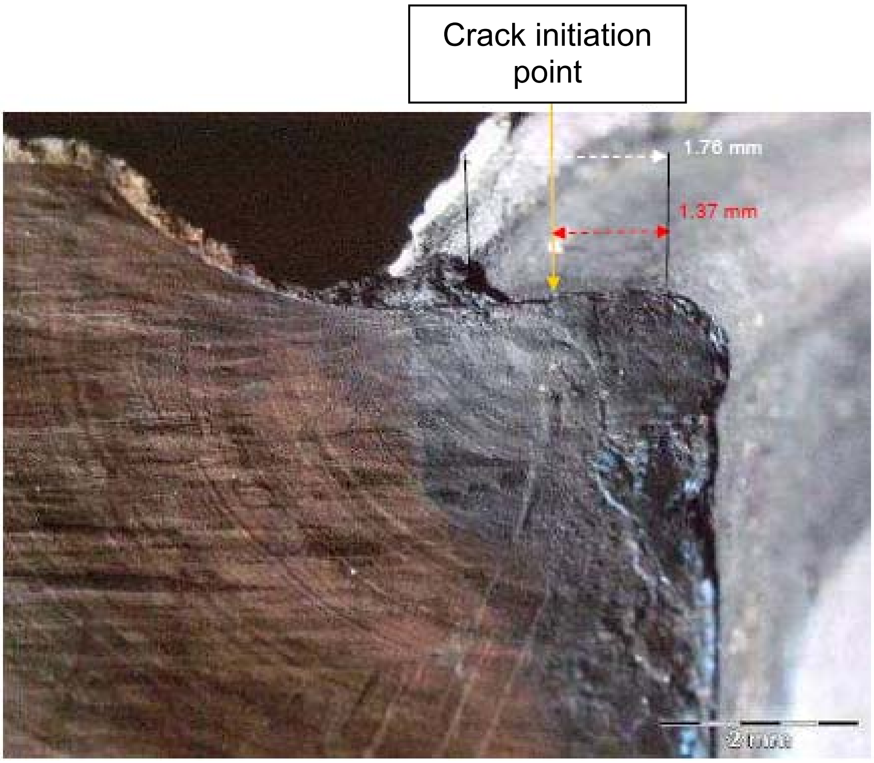
The crack initiated on both sides of the FTi bush, under the shoulder.

Distance from the crack initiation point to the chamfer

- Outer side



- Inner side



Decision on conformity	Not applicable
Estimation of uncertainty	Not applicable
Opinion and Interpretation	Not applicable
Observation	The crack initiation zone is centred over the hub / bush shoulder contact area.

7 MATERIAL CHARACTERISATION

7.1 Hardness measurements

EI or standard	EI 072 T 0007 – Hardness measurements.		
Operator	D. DUPRIEZ	Supervisor:	Not applicable
Date of the test	12/02/2010	Ambient conditions:	23.7°C

Table of results:

Sample identification	Unit = $HBW_{2.5/187.5}$			Decision on conformity
	Criteria	Results	Average	
2009-1665-1	> 320	**371.8**	365.7	Conforming
		371.8		
		361.1		
		368.6		
		355.5		

Estimation of uncertainty	2.9%
Opinion and Interpretation	The values measured exceed the criterion of minimum hardness. Therefore, the hardness of the hub is conforming.
Observation	Not applicable.

8 DETERMINATION OF THE CHEMICAL COMPOSITION

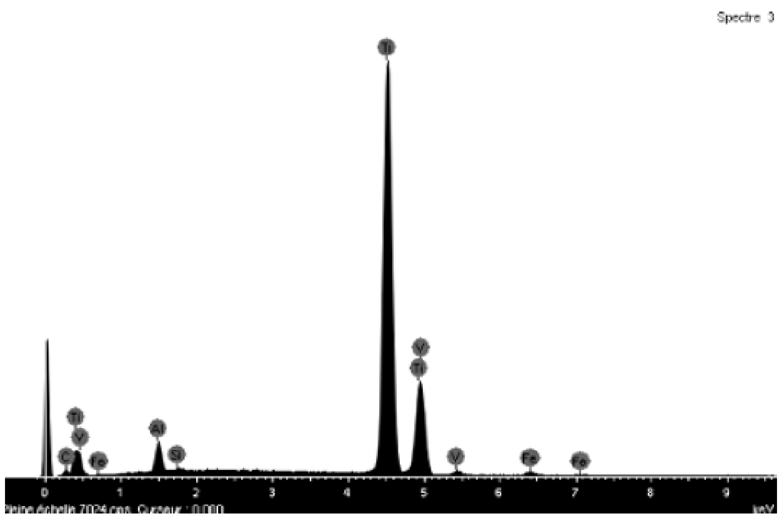
8.1 Microanalysis by Energy Dispersion X-ray Spectrometry (EDS)

EI or standard	IGC 04 24 173 – Carry out X-ray diffraction microanalyses		
Operator	D. DUPRIEZ	Supervisor:	Not applicable
Date of the test	15/02/2010	Ambient conditions:	Not applicable

DEFINITION

TI10.2.3

RESULTS



Decision on conformity	The chemical composition of the hub complies with the definition (TI 10.2.3)
Estimation of uncertainty	Not applicable
Opinion and Interpretation	Not applicable

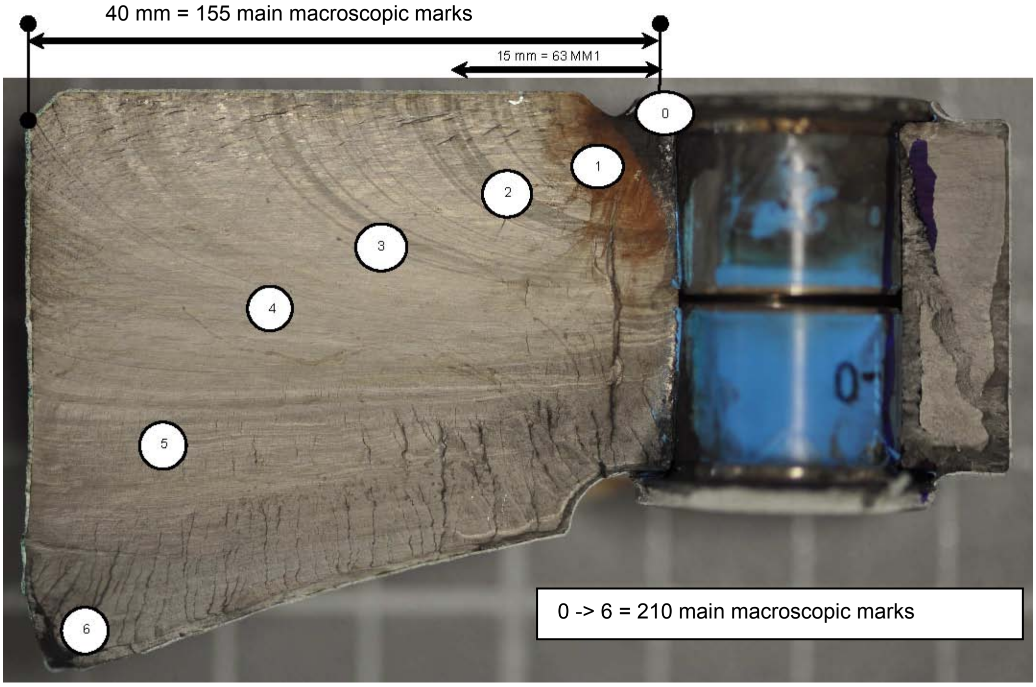
9 COUNTING OF MACROGRAPHIC MARKS

EI or standard	EI 072 T 0079 – Counting of macrographic marks.		
Operator	D. DUPRIEZ / T. CAPARROS	Supervisor:	Not applicable
Date of the test	19/12/2009	Ambient conditions:	Not applicable

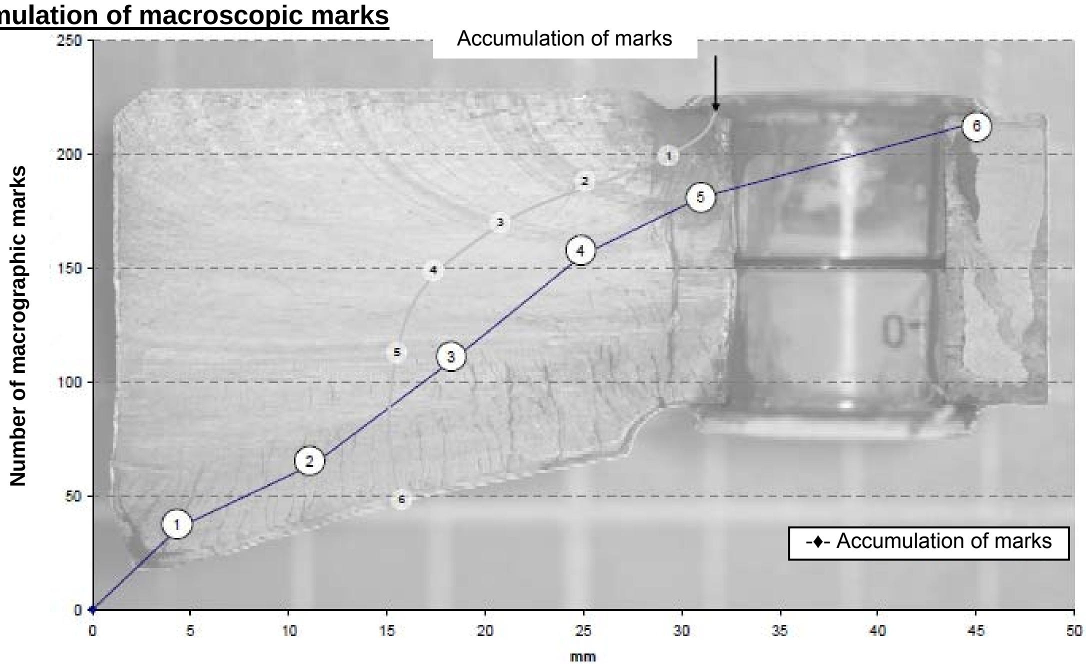
Parameter:

Type of marks	Main
Counting method	Direct, with binocular magnifier

Zone	Distance from initiation point	Quantity of main macroscopic marks
0-0	Crack initiation	0
0-2	15 mm	63
0-4	40 mm	155
0-6	Total failure	210



➢ **Accumulation of macroscopic marks**



- Aircraft flight spectrum

Day	Duration of the flight with a rotor start and stop	Number of engine starts	Number of landing during the flight	Number of sling/lift	Ng cycles	Nf cycles	Operation type (% of flight hrs.)	A/C tot. Hours including this flight
2009-06-16	4,6	8	16	12	5,85	7,65	Sling 30% and taxi 70%	2622,9
2009-06-17	1,4	4	5	0	2,35	3,40	Taxi	2624,3
2009-08-01	0,1	1	1	0	0,80	0,75	Technical	2624,4
2009-08-06	0,4	1	1	0	0,65	0,75	Taxi	2624,8
2009-08-07	1,5	2	2	0	1,40	1,60	Taxi	2626,3
2009-08-09	0,6	3	5	0	2,05	2,30	Taxi	2626,9
2009-08-11	3,6	8	14	0	5,80	6,60	Taxi	2630,5
2009-08-12	1,3	5	8	0	4,15	4,90	Taxi	2631,8
2009-08-13	2,8	6	7	0	4,10	5,85	Taxi	2634,6
2009-08-14	0,9	2	3	0	1,30	1,65	Taxi	2635,5
2009-08-15	3,5	4	40	0	2,90	3,55	Taxi	2639,0
2009-08-16	0,9	2	3	0	1,20	1,60	Taxi	2639,9
2009-08-17	4,4	6	13	0	4,50	5,25	Taxi	2644,3
2009-08-19	7,5	7	19	25	4,60	6,55	Taxi 45% and lift 55%	2651,8
2009-08-20	1,6	2	4	0	1,40	1,55	Taxi	2653,4
2009-08-21	1,6	5	6	0	4,35	4,80	Taxi	2655,0
2009-08-22	5,4	7	18	0	5,35	6,20	Taxi	2660,4
2009-08-23	0,4	1	1	0	0,70	0,80	Ferry	2660,8
2009-08-24	3,3	6	25	2	4,65	4,85	Taxi 90% and lift 10%	2664,1
2009-08-25	4,0	5	20	0	4,00	4,10	Taxi	2668,1
2009-08-26	2,1	3	6	0	2,10	2,35	Taxi	2670,1
2009-08-28	3,1	3	8	0	2,20	2,55	Taxi	2673,3
2009-08-29	2,2	3	7	0	2,30	2,60	Taxi	2675,5
2009-08-30	2,6	6	6	0	4,40	4,85	Taxi	2678,1
2009-08-31	1,1	2	7	0	1,50	1,60	Taxi	2679,2
2009-09-01	1,5	6	7	0	5,05	4,95	Taxi	2680,7
2009-09-02	4,2	9	18	7	7,35	8,50	Taxi 75% and lift 25%	2684,9
2009-09-03	3,3	7	12	0	4,60	5,15	Taxi	2688,2
2009-09-04	3,1	6	13	0	4,40	5,05	Taxi	2691,3
2009-09-06	2,1	4	6	0	2,60	3,30	Taxi	2693,4
2009-09-07	1,0	3	6	5	1,75	2,40	Lift	2694,4
2009-09-10	2,1	8	11	0	5,15	6,50	Taxi	2696,5
2009-09-12	2,9	4	12	0	2,65	3,40	Taxi	2699,4
2009-09-15	0,6	2	3	0	1,30	1,55	Taxi	2700,0
2009-09-18	0,7	3	4	0	1,70	2,40	Taxi	2700,7
2009-09-21	3,9	7	35	0	4,20	5,25	Taxi	2704,6
2009-09-22	2,4	3	6	0	2,05	2,45	Taxi	2707,0
2009-09-23	2,2	3	10	6	2,10	2,65	Taxi 50% Lift 50%	2709,2
2009-10-06	2,1	6	8	0	3,20	5,15	Taxi	2711,3
2009-10-08	1,4	2	2	0	0,95	1,65	Taxi	2712,7
2009-10-10	0,9	1	1	0	0,50	0,85	Ferry	2713,6
2009-10-11	0,3	1	1	0	0,50	0,80	Ferry	2713,9
2009-10-12	3,1	5	13	1	2,80	4,25	Taxi 90% lift 10%	2717,0
2009-10-13	0,8	3	5	1	1,70	2,60	Taxi 60% lift 40%	2717,8
2009-10-14	2,5	5	7	0	2,30	4,25	Taxi	2720,3
2009-10-15	0,1	1	1	0	0,45	0,80	Ferry	2720,4
2009-10-20	0,9	2	2	0	1,10	1,65	Taxi	2721,3
2009-10-22	0,4	1	1	0	0,65	0,80	Ferry	2721,7
2009-10-28	1,0	2	2	0	1,30	2,10	Taxi	2722,7
	104,4	**196**	**431**	**59**	**134,95**	**167,10**		

Produced by SUN 2009-11-10

OSTERMAN HELICOPTER, Östersund

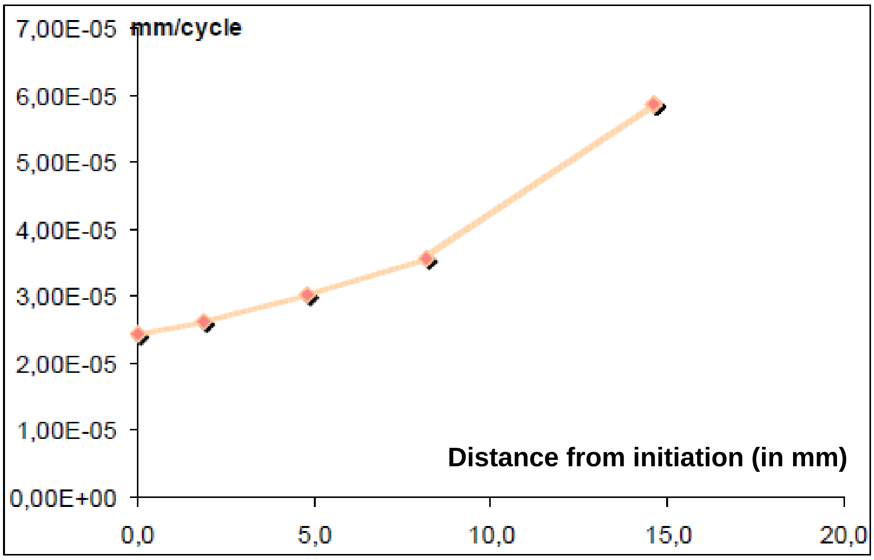
Estimation of uncertainty	20%.
Opinion and Interpretation	We counted approximately 210 main macroscopic marks over the entire fracture surface (1). In agreement with the ETMC Design Office, we determined that one macroscopic mark corresponded to one engine start. As the Customer carried out 196 engine starts in 104.4 flying hours, the propagation time from initiation to total failure is approximately 112 hours (Calculation Memo ETMC 1009-10).

10 COUNTING OF FATIGUE STRIATIONS

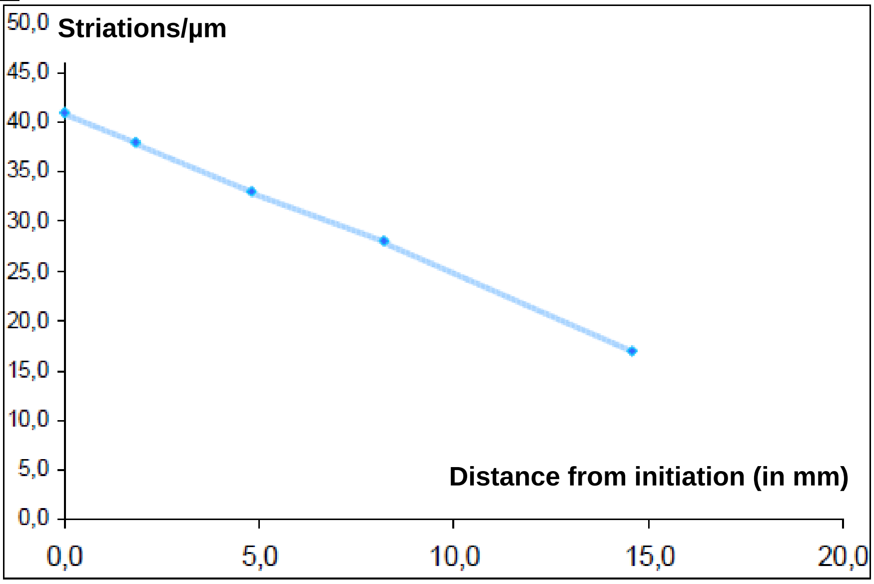
EI or standard	EI 072T 0035 – Counting of fatigue striations.	
Operator	D. DUPRIEZ	Supervisor: Not applicable
Date of the test	16/02/2010	Ambient conditions: Not applicable

Distance from initiation point	Number of striations / µ	Da/Dn
0.0	41.0	0.0
1.9	38.0	2.63E-05
4.8	33.0	3.03E-05
8.2	28.0	3.57E-05
14.6	17.0	5.88E-05

- Propagation rate



- Density of striations



Estimation of uncertainty	Not applicable
Opinion and Interpretation	Even if the Da / Dn increases slightly at the end of the propagation, the crack propagation rate increases linearly due to flight loads.
Observation	Not applicable.

The French investigation authority, the Bureau d'enquête et d'Analyses pour la sécurité de l'Aviation Civile (BEA) has made the following comments about the report.

For chapter 1.6.2 the final report doesn't mention the Flight Related Checks of the day (VLV). We asked that this chapter be modified as:

The EC 120 B's Aircraft Maintenance Manual and Flight Manual describe Flight Related Checks of the day (VLV). It specifies that "They must be carried out by a person qualified for maintenance or by a pilot having received appropriate training when authorized by the local aviation authority".

The BEA would have appreciated to get information about the individuals (maintenance or pilot) who performed the Daily VLV checks and his training.

For chapter 2.2.3 we asked for the following modifications:

The one hundred hour inspection is dedicated to the hub greasing and not to the detection for cracks which is performed during the Daily VLV checks.