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REPORT ON THE AVIATION ACCIDENT AT GÅSVASSRYGGEN, STORE GÅSVATN, SKJERSTAD IN NORDLAND COUNTY, 2 SEPTEMBER 2003, WITH A HUGHES 369D SE-HSI OPERATED BY FJELLFLYGARNA AB

This report has been translated into English and published by the AIBN to facilitate access by international readers. As accurate as the translation might be, the original Norwegian text takes precedence as the report of reference.

SUBMITTED
May 2006

The Accident Investigation Board Norway
PO Box 213
NO-2001 LILLESTRØM
Telephone: +47 63 89 63 00
Telefax: +47 63 89 63 01
http://www.aibn.no
E-mail: post@aibn.no

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Designation of type:	Hughes 369D
Registration:	SE-HSI
Owner:	Fjellflygarna AB
Operator:	Same
Crew/Commander:	1
Passengers:	1
Accident site:	At Gåsvassryggen, Store Gåsvatn lake, Skjærstad in Nordland County, N 66 56.2 E 015 00.6
Accident time:	Tuesday 2 September 2003, at time 1930.

All times given in this report are local times (UTC+2 hours), unless otherwise stated.

NOTIFICATION

The duty accident inspector at the Accident Investigation Board[1] (AIBN) was notified of the accident by the Joint Rescue Co-ordination Centre for Northern Norway on Tuesday, 2 September 2003, at time 2020. AIBN sent two accident inspectors to the accident site on Wednesday, 3 September.

SUMMARY

SE-HSI, with its Commander and one passenger on board was flying on a reindeer-herding mission. While the helicopter was hovering into the wind, the yellow caution light for T/R XMSN CHIPS illuminated (warning of metal fragments in the tail rotor gear box), at the same time as an abnormal sound was heard from the rear of the helicopter. Approx. 2 seconds later the commander lost control

[1] The Accident Inspection Board Norway changed its Norwegian name from Havarikommisjonen for sivil luftfart og jernbane (HSLB) on 1. September 2005 to Statens havarikommisjon for transport (SHT), but in this English language version will be referred to by the acronym AIB/N.

of the tail rotor, and the helicopter began to rotate around the main rotor axle. The Commander used maximum pedal deflection to combat the rotation, without any effect being noted.
The pilot then shut off the power and landed the helicopter on the ground. The rotation stopped but the landing was hard. The main rotor blades cut the tail boom during touch down and impact with the sloping terrain and were destroyed.

The Commander shut down the helicopter and he and the passenger evacuated the helicopter uninjured. There was mobile phone coverage in the area and the pilot phoned his company in Adolfström in Sweden which in turn informed the Joint Rescue Co-ordination Centre for Northern Norway (HRS). A Sea King rescue helicopter was sent to pick up the pilot and passenger and flew them to Bodø airport.

Investigation carried out by the AIBN revealed that the input gear in the tail rotor gearbox/transmission had cracked due to fatigue. One tooth from the gear was broken off, the gear cracked and the gear box fractured into two pieces.

It has not been possible to establish the cause of the initiation of the fatigue crack by metallurgical examination alone. However, the investigations revealed that the tail rotor gearbox had been involved in a crash in 1998 when it was overhauled and reinstalled in another helicopter belonging to the same company. AIBN considers that the fatigue crack in the input gear was initiated by overload as a result of a sudden stoppage at the previous accident.

AIBN has made 2 safety recommendations.

1. FACTUAL INFORMATION

1.1 History of the flight

1.1.1 SE-HSI, with its Commander and one passenger (the customer) on board was flying on a reindeer-herding mission. The flight was carried out VFR and with no flight plan.

1.1.2 The mission for the day was nearing its end. The reindeer herd was to be left close to Store Gåsvatn lake before the helicopter was to return to its temporary base at Røkland, approx. 6 NM (around 3 min flight time) east of the accident site.

1.1.3 With the helicopter in hover at a low height, with its front in to the wind, which was blowing from a southern direction at about 15-20 kt, the yellow caution lamp for T/R XMSN CHIPS (warning of metal fragments in the tail rotor gear box) illuminated. At the same time, the pilot and passenger heard an unusual sound from the tail of the helicopter.

1.1.4 Approx. 2 seconds later the pilot lost tail rotor control and the helicopter started to rotate. The pilot attempted to use maximum pedal deflection without any effect.

1.1.5 The helicopter continued to rotate around the main rotor axle. The Commander throttled back and landed the helicopter in the terrain. The rotation stopped after approx. 200º rotation as a result of the loss of the rotor's torque, and the landing was relatively hard. The hard landing led to the main rotor blades impacting with the tail boom and cutting it off around half way along. The terrain sloped in such a way that the main rotor blades touched the ground to the right and front of the helicopter and further damage was caused to them.

1.1.6 The Commander and the passenger left the helicopter uninjured. There was mobile phone coverage in the area and the Commander called his company in Adolfström in Sweden to notify them of the accident. The company notified the Joint Rescue Co-ordination Centre for Northern Norway, which sent a Sea King search and rescue helicopter to the accident site and flew the Commander and the passenger to Bodø airport.

1.2 Injuries to persons

INJURIES	CREW	PASSENGERS	OTHERS
FATAL	0	0	0
SERIOUS	0	0	0
MINOR/NONE	1	1	0

1.3 Damage to aircraft

The helicopter was significantly damaged. Cf. 1.12.

1.4 Other damage

None.

1.5 Personnel information

1.5.1 Commander

The Commander, a 39 year-old male, qualified as a helicopter pilot at the Scandinavian Flight Centre (SFC) at Torp airport in 2000. Since then, he has worked for, among others, Flygtjenst, Vilhelmina, Sweden and Fjällflygarna AB, Arjeplog, Sweden.

He holds a CPL-H, checked out for HU 369 until 31 August 2004. His medical certificate was valid until 18 December 2003.

The Commander was relatively well experienced in reindeer herding and other domestic flights.

He had slept 8 hours and felt rested and in a good condition when he started the flight in the morning. The accident occurred at the end of a 12-hour working day.

FLYING HOURS	ALL TYPES	RELEVANT TYPE
LAST 24 HOURS	7	7
LAST 3 DAYS	7	7
LAST 30 DAYS	57	52
LAST 90 DAYS	160	155
TOTAL	927	Not stated

1.6 Aircraft information

1.6.1 General

1.6.1.1 SE-HSI, Hughes 369D with S/N 811041D, is a conventional single-engine helicopter with an Allison 250C20B turbine engine. The helicopter was built in 1981. It has room for one pilot and four passengers. Maximum take-off mass is 3,000 lbs (1,364 kg) with internal load and 3,550 lbs (1,614 kg) with external load.

1.6.1.2 The helicopter's take-off mass was approx. 2,600 lbs (1,182 kg) and the position of the Centre of Gravity, C.G. was 100.7 inches. At the time of the accident the mass was approx. 2,000 lbs (909 kg) and C. G. 101.7 inches. Hence, the mass and balance were within limits (C.G. limits were 99-104.2 inches at take-off and 99-106 inches at the time of the accident, respectively).

1.6.1.3 The helicopter took off with a total of approx. 400 litres of JET-A1 in the main and reserve tanks. At the time of the accident there were approx. 60 litres remaining in the main tank. This provides around 33 minutes flying time. Flying time to the fuel depot was around 3 minutes.

1.6.1.4 The helicopter’s airworthiness certificate was valid until 31 May 2004.

1.6.2 Aircraft history

1.6.2.1 Tail rotor gearbox

The AIBN sent the tail rotor gearbox to the Norwegian Defence Logistic Organisation/ Air Depot Kjeller (FLO/LHK), Analytical Laboratory. Based on a report from FLO/LHK (cf. appendix 3) AIB/N initiated investigation into the history of the tail rotor gearbox. This revealed that a Tail Rotor Gearbox with type no. 369D25400, S/N 2046, had been installed on the helicopter Hughes 369D, SE-HMP, owned by the same company, which was a total write-off in an accident at Sorsele in Sweden on 10 November 1998. The helicopter (SE-HMP) was on a reindeer-herding flight when the engine failed, with the commander and one passenger on board. The commander landed under autorotation at a low height in rough terrain. During the landing the tail boom with the tail rotor gearbox and tail rotor blades was torn off and the helicopter was a complete write-off. One of the tail rotor blades was damaged. Following the accident, the tail rotor gearbox was overhauled and installed on SE-HSI. The gearbox run satisfactorily for 700 hours before the accident with SE-HSI.

1.6.2.2 The tail rotor gearbox overhaul.

The tail rotor gearbox was overhauled by Walthers Flygservice AB in Umeå, Sweden.

The company writes in its report to the AIBN:

> *”We have received information about the accident with SE-HMP. The landing took place with Power Off, and as the damage to the tail rotor blade was restricted to a small dent on one of the blades, we decided that it would not be necessary to perform a magnetic particle inspection (MPI). There was no suspicion of any impact damage.*

> ***The Component Overhaul Manual states that such inspection should be made upon "parts suspected or with evidence of impact damage". (Heavy type by the AIBN).***
>
> *The usual visual inspection, as well as measurement was made in the investigation.*
>
> *The measurement of the Input Gearshaft Runout and the Output Gearshaft Runout gave the following results:*
>
> *The Input Gearshaft Runout was measured at 0.01 mm (max 0.051 mm).*
>
> *The Output Gearshaft was measured at 0.09 mm (max 0.0635 mm). The Output Shaft therefore showed a Runout that exceeded the permitted value, and therefore needed to be replaced, which it was.*
>
> *As the Output Gearshaft did not meet the required measurements, a new consideration should have been made concerning MPI of the Input Gearshaft. An MPI Inspection of the Input Gearshaft would have been desirable because the Output Gearshaft was replaced.*
>
> *It is not possible to state whether the Input Gearshaft at time of inspection had any hidden damage that could have been discovered during an MPI, as it has operated for a number of years, for approx. 700 hours, according to the information given .*
>
> *As a result of this incident, we are going to amend our inspection routines so that MPI, and FPI are performed on all components that are not normal time runout.*
>
> *We would also regard it as desirable that MD Helicopters had been more precise in their instructions concerning the requirement for performing FPI and MPI, instead of relying on the interpretation of the inspection workshop."*

The AIBN has established that when the tail rotor gearbox was sent to Walters Flygservice, an "unserviceable component tag" was attached with "accident" written in the "reason for removal" field. In parallel with this, Walters Flygservice received a handwritten letter from Fjällflygarna with the following content:

> *"Here is the tail rotor gearbox. We await a proposal from you as to what is to be done with it. It was on the HMP that crashed. The tail rotor part was relatively undamaged. One of the tail rotor blades was slightly bent. The other blade was undamaged."*

Metal particles were also found on the magnetic plug and in the gearbox, which led to all four bearings being replaced.

As can be seen from the workshop's report, the minor damage to the tail rotor of the crashed helicopter is cited as the reason for the lack of suspicion of impact damage and the reason for there being no requirement to perform a Magnetic Particle Inspection (MPI) of the parts of the gearbox. Following this overhaul, the gearbox was fitted to SE-HSI.

1.6.3 <u>Factory maintenance requirement after tail rotor strike</u>

1.6.3.1 MD Helicopters Maintenance Manual, CSP-HMI-2, Table 1. Conditional Inspections:

> *"AFTER TAIL ROTOR BLADE STRIKE*

WARNING: Any component, assembly or detailed part that is removed for overhaul must be identified as to the reason for removal. Components that require replacement must be scrapped.

After tail rotor blade strike, inspect the following:

369D/E/FF Tail rotor transmission for radial play and run-out of output shaft, cracks in mounting flanges, and chip detector for metal particles.

Remove for overhaul tail rotor transmission if damage is indicated"

1.6.3.2 MD Helicopters Component Overhaul Manual, 369D25400 Tail Rotor Transmission Inspection/Check:

"2 Process Inspection

After cleaning perform fluorescent penetrant inspection (FPI) or magnetic particle inspection (MPI) as applicable on all parts suspected of or evidence of impact damage. Complete inspection is required for units involved in crash damage (Cf. Table 504)."

Table 504 lists Input gearshaft under MPI.

1.7 Meteorological information

TAF

ENBO 021524 12015KT 9999 –RA FEW015 BKN030 TEMPO 1524 20015KT RA=

METAR

ENBO 021750Z 11009KT 9999 –RA FEW018 BKN030 09/07 Q1009 NOSIG=

General Wx in the area, approx. 40 km southeast of Bodø (reported by the commander)

Wind: 180º 15–20 kt. Somewhat strong turbulence in the shelter of the mountain peaks. Visibility: 6-8 km. Cloud cover: Clouds at 4,000 ft. Weather: Showers. Temperature: 8 ºC.

1.8 Aids to navigation

Not relevant.

1.9 Communication

There was not VHF radio coverage in the area, but there was mobile phone coverage.

1.10 Aerodrome information

Not relevant.

1.11 Flight recorders

Not installed and not mandatory.

1.12 Crash site and helicopter wreckage

1.12.1 Crash site

The accident occurred at Gåsvassryggen, Store Gåsvatnet in the municipality of Skjerstad in Nordland county, at an altitude of approx. 2 000 ft AMSL. Position N 66 56.2 E 015 00.6.

1.12.2 Wreckage

The helicopter wreck lay on a heather-covered slope on the western side of Gåsvassryggen. The right skid was broken. The front pointed north.

Fig. 1 Crash site seen from the east

The main part of the helicopter with the cabin, main gearbox and the forward part of the tail boom exhibited structural damage (cf. Fig.1).

The tail boom was cut off by the main rotor blades. The severed tail, with half of the tail rotor gearbox (Input section) still attached, lay a couple of metres behind the helicopter (cf. Fig. 1 and Appendix 2).

The tail rotor with the remainder of the tail rotor gearbox (Output section) lay 15 metres southeast of the severed tail (cf. Fig. 2 and Appendix 2).

The input gear in the split tail rotor gearbox (Input section) was missing a segment. This part, approx. 6 cm in length, was found in the heather 10 metres northeast of the main section of the helicopter (cf. Appendix 3, fig. 4).

Fig. 2 SE-HSI Tail rotor with Output section of gearbox

All five main rotor blades were partially severed and damaged. Four of the blades were still attached to the Rotor Hub, while the last (Yellow) blade was detached from the Hub, and lay 44 metres southeast of the main wreck.

All parts of the helicopter were found and accounted for. All parts were within an area with a radius of 44 metres, in a sector of around 200º from northwest to south southeast.

1.13 Medical and pathological information

Bodø police took a routine blood test of the Commander. No traces of intoxicants were found.

1.14 Fire

No fire occurred.

1.15 Survival aspects

The Commander carried out the emergency procedure for loss of tail rotor control in accordance with the emergency procedure described in the Flight Manual. The helicopter landed hard in a normal landing attitude, but the heather-covered, sloping terrain and failure of the right skid softened the landing. A lot of energy was absorbed when the right side landing gear was crushed. This meant that the fuselage was resting on its right side and left skid, which was relatively lightly damaged.

The helicopter was fitted with an ELT, type CIR-11-2. This was activated in the emergency landing. The Commander informed his company in Adolfström, Sweden about the accident on his mobile phone. The company rang the Joint Rescue Co-ordination Centre, who then called the Commander and requested him to turn off the emergency locater transmitter. The rescue centre had received notification of an active emergency transmitter from an aircraft that flew over the area.

The Commander was later called up by 330 squadron for an exact position for the rescue helicopter.

The cabin section was relatively undamaged, apart from broken window panels on the left hand side. The front seats were equipped with four-point seat belts and shoulder belts. These were intact and contributed to Commander and passenger being uninjured.

The Commander and his passenger were warmly dressed for the flight in the mountains. They were not wearing helmets, but their heads did not come into contact with the cabin during the accident.

1.16 Tests and research

1.16.1 Components from the tail rotor gearbox were examined more closely at the Norwegian Defence Logistic Organisation/Air Depot Kjeller (FLO/LHK), Analytic Laboratory. The parts were examined in a stereo microscope and in a Spectrographic Electronic Microscope (SEM). cf. Appendix 3.

1.16.2 The examination revealed that the input gear in the tail rotor gearbox split into two parts as a result of a fatigue crack. One part/segment of the gear was ejected from the gearbox when it split.

1.16.3 The report from FLO/LHK concluded:

> *"No wear or crack initiation has been observed that could have been caused by faulty interlocking between the gears or abnormal wear as a result of lack of lubrication. Nor were there observed any occlusions or other faults in the microstructure that could have been expected to initiate the observed damage. Nor has any sign of plastic deformation in the root of the tooth been observed in the optical microscope.*
>
> *Our conclusion is, therefore, that it must be clarified whether the component could have undergone a sudden stop. Such an event will give a local overload in a tooth root, with the attendant risk of initiation of local fatigue under continued use, as observed in the case investigated.*
>
> *As the gear in question has a carburised martensitic surface structure, it would be particularly difficult to prove that this has been exposed to a local overload. This is because the structure in itself can be regarded as a deformation structure and further deformation would be difficult to distinguish from the original structure.*
>
> *We would therefore recommend an examination of the history of the gearbox to see whether it is possible to find events that could be regarded as sudden stop.*

1.16.4 It was not possible to use the metallographic examinations to find the cause of the fatigue crack. For this reasons the history of the gearbox was investigated to see whether it had been involved in a sudden stop.

1.16.5 The investigations confirmed that this tail rotor gearbox had been involved in a sudden stop event at an earlier point in time. cf. 1.6.2.

1.17 Organizational and management information

The helicopter was owned and operated by Fjällflygarna AB, Arjeplog, with its registered office in Adolfström in Sweden, a company that operates domestically in Sweden and Norway. The company holds a Swedish AOC in regard to JAR-OPS 3, and had made many flights in connection with reindeer herding in both countries.

At the time of the accident, the company operated 2 helicopters, one a Hughes/MD Helicopters 369 and the other an EC-120B. The company had 4 employees.

Fjällflygarna did not have its own JAR 145 organisation, but had a maintenance contract with a JAR 145 approved aircraft repair service, Anderssons Flygservice, at Arjeplog, Sweden.

The commanders mainly worked independently and autonomously when they were out on flight work. They reported back to the Flight Operations Manager at the head office in Adolfström, Sweden, which is located approx. 75 km from Arjeplog.

1.18 Additional information

None.

1.19 Useful or effective investigation techniques

This investigation has not used methods that qualify for special discussion.

2. ANALYSIS

2.1 Emergency landing

2.1.1 Loss of tail rotor power is one of the most critical emergency situations a helicopter pilot can experience. The AIBN considers that the commander carried out the emergency procedure for loss of tail rotor power in a correct and professional manner, and in accordance with the emergency procedure in the Flight Manual. The helicopter continued a half rotation in a clockwise direction to a northerly heading, before the Commander made an emergency landing in sloping terrain.

2.2 The crash

2.2.1 The AIBN considers that the Commander limited the extent of damage with his determined and correctly performed emergency landing. The Commander could not have done more to limit the extent of the damage.

2.3 Survival aspects

2.3.1 The helicopter's ELT was triggered by the crash. An aircraft that flew over the area picked up the signals from the ELT and reported this to Bodø control. Then the Joint Rescue Co-ordination Centre was notified about the crash. After the crash, the Commander reported it to his employer in Sweden by mobile phone. This notification was sent on the Joint Rescue Co-ordination Centre for Northern Norway. The Commander was then contacted by mobile phone and requested to turn off the ELT.

2.3.2 The Commander and passenger (customer) were well dressed for a flight in the mountains. The AIBN considers the survival aspects as good.

2.4 Technical findings

2.4.1 The opinion of the AIBN is that a tooth on the Input Gear was overloaded as a result of sudden stoppage during the crash of SE-HMP. The overload caused damage/microfracture in the metal structure of the root of the tooth. The damage was not discovered when the gearbox was overhauled, but initiated a fatigue crack that developed over several hundred flying hours.

2.4.2 Based on the technical examinations at FLO/LHK and the time until the failure, the AIBN considers it doubtful to discover the damage caused by the sudden stoppage, both with visual inspection and with MPI/FPI (cf. Appendix 3). For this reason, the AIBN considers that components in a helicopter's drive train that have been subjected to sudden stoppage, in addition to MPI/FPI should be evaluated with regard to shorter inspection interval or scrapping.

2.4.3 The workshop that overhauled the gearbox has interpreted the overhauling regulations in such a way that a visual inspection was sufficient, in addition to a check measurement of runout, which was within acceptable limits. Subsequently the workshop has introduced mandatory MPI/FPI on all components that are not normal time runout. The AIBN considers that this initiative is not sufficient alone, as overload damage caused by sudden stoppage would not necessarily be revealed by such inspection.

2.4.4 Investigation revealed that it took around 700 flying hours from the crack initiation (sudden stoppage as a result of the accident with SE-HMP) to residual fracture. It is natural that the residual fracture would take place during hover, as this is when the load on the tail rotor is greatest.

2.4.5 When the Input Gear fractured and a tooth and piece of the gear detached, the gearbox was split in two. Immediately before the residual fracture, metal particles detached from the gears, and metal particles on the magnetic plug triggered the caution light (T/R XMSN CHIPS) in the cockpit (cf. Appendix 1).

2.5 MD Helicopters Maintenance Manual and Component Overhaul Manual

2.5.1 The AIBN is in agreement with Walters Flygservice AB that the factory's maintenance requirements for components are too vague with respect to components in the helicopter's rotor system that have been involved in crash damage, rotor blade strike or sudden stoppage.

2.5.2 The Maintenance Manual describes the inspection following a tail rotor blade strike. The inspection procedure can be interpreted as follows: if radial play and runout of output shaft are within limits and a component passes a visual inspection, the component can be reused. If the tolerances are outside the limits, and the relevant parts are replaced, the gearbox can be reused.

2.5.3 The Component Overhaul Manual states that FPI/MPI shall be performed

> *"on all parts suspected of or evidence of impact damage. Complete inspection is required for units involved in crash damage*

2.5.4 The overhaul workshop has stated to the AIBN that, based on the damage to the tail rotor blades, it did not consider that there was any suspicion of impact damage and therefore no requirement for FPI/MPI. In hindsight, it would seem that the inspection requirement should be adequate, but this is an example of an overhaul workshop possibly misinterpreting the text. In the opinion of the AIBN, if one workshop has misinterpreted the text of the Maintenance Manual and Component Overhaul Manual, other workshops will make the same mistake in the future, unless the inspection requirements are clarified. It is, therefore, the opinion of the AIBN that the Maintenance Manual and Component Overhaul Manual should be revised to specify treatment of components that have been involved in rotor blade strike, sudden stoppage and potential crash damage.

2.5.5 Subsequently, the workshop has come to the conclusion that FPI/MPI should be carried out when overhauling damaged components and this should be made clear in the Component Overhaul Manual. The workshop has subsequently introduced this practice. However, the AIBN considers that overload damage in this structure that results from sudden stoppage is difficult to prove with FPI/MPI. In this case, the Input Gear operated for 700 flying hours before failing catastrophically. This is an indication that it is highly improbable that an FPI/MPI inspection would have revealed overload damage/micro fracture (cf. 2.4.2 and Appendix 3).

2.5.6 The AIBN is aware of several similar occurrences where components that have been overhauled in accordance with the manufacturer's overhaul procedures, after being involved in a helicopter accident, have failed after a certain amount of time in another helicopter.

2.6 Safety barriers

2.6.1 To sum up the cause factors/failed safety barriers that led to this accident, the AIBN would like to refer to James Reason's model for accidents and incidents:

- MD Helicopters' Maintenance Manual and Component Overhaul Manual allow misinterpretation concerning maintenance requirements for components that have been involved in accidents (latent fault, weak safety barrier).

- The personnel of Walthers Flygservice have, because of the unclear maintenance instructions, possibly misinterpreted the Maintenance and Overhaul Manual with respect to the requirements laid down concerning overhaul of a tail rotor gearbox that has been involved in an accident (latent fault, weak safety barrier).

- The gearbox's CHIPS warning system (a magnetic plug for metal particles and associated warning light) does not detect a developing fatigue fracture (latent fault, lack of safety barrier).

- The fatigue fracture developed over 700 flying hours. This is well within the inspection interval for the gearbox, and excludes the possibility of discovering a fatigue crack in the tail rotor's Input Gear (latent fault, lack of safety barrier).

2.6.2 Investigation has shown that possibly damaged components airworthiness, and therefore the continued airworthiness of an aircraft, depends on a technician's qualified assessment. This accident shows that a technician assessed/interpreted the maintenance requirements to a certain meaning. Seen in the context of the circumstances, AIBN considers this to indicate the possibility for others to interpret the maintenance requirements in a similar way. This is an indication that the last safety barrier is too weak to prevent an accident.

2.6.3 It is the opinion of the AIBN that the weak safety barriers could be strengthened if MD Helicopters include specific overhaul, inspection and scrapping requirements for components that have been involved in an accident.

3. CONCLUSIONS

3.1 Results of the investigation

3.1.1 The Commander was certified and qualified for the flight.

3.1.2 The helicopter's airworthiness certificate was valid.

3.1.3 The helicopters mass and balance were within the applicable limits.

3.1.4 The tail rotor gearbox failed as a result of a fatigue fracture in the Input Gear.

3.1.5 The commander acted quickly and carried out a correct and controlled emergency landing in accordance with the emergency procedure in the Flight Manual. This resulted in limited damage to the aircraft.

3.1.6 The tail rotor gearbox had been involved in a crash in which SE-HMP was written off on 10 November 1998. Following replacement of the Output Gear Shaft and visual inspection, the tail rotor gearbox was fitted in SE-HSI.

3.1.7 The workshop that overhauled the tail rotor gearbox following SE-HMP's accident, has possibly misinterpreted the Maintenance and Overhaul Manual with respect to the requirements when overhauling tail rotor gearboxes that have been involved in an accident.

3.2 Significant results of the investigation

3.2.1 The Input Gear was most probably weakened as a result of undiscovered overload damage in the structure following a previous accident.

3.2.2 Investigations have shown that there are reasons to doubt whether it would be possible to prove overload damage in this structure resulting from sudden stoppage, using FPI/MPI.

3.2.3 The text of MD Helicopters' Maintenance Manual and Component Overhaul Manual allows misinterpretation of the inspection requirements in connection with tail rotor strike, sudden stoppage and impact damage.

4. SAFETY RECOMMENDATIONS

The text in the helicopter type's maintenance documentation may allow misinterpretation. The Swedish Civil Aviation Authority (Luftfartsstyrelsen), in agreement with FAA and MD Helicopters, is advised to consider whether the maintenance requirement for the helicopter's drive train related to sudden stoppage, tail rotor blade strike and impact damage should be clarified in the helicopter type's Maintenance Manual and Component Overhaul Manual.
(SL recommendation no. 17/2006).

Components that have been involved in an accident may have suffered overload damage that may be difficult to prove using FPI/MPI. The Swedish Civil Aviation Authority (Luftfartsstyrelsen), in agreement with FAA and MD Helicopters, is advised to consider whether more detailed guidelines for demands relating to continued airworthiness/scrapping of components in a helicopter's drive train that have been involved in an accident should be specified.
(SL recommendation no.18/2006).

REFERENCE

Reason, J.: Managing the Risks of Organisational Accidents, Ashgate1997, London.

APPENDECIES

1. SE-HSI Magnetic plug and the Output section of the tail rotor gearbox.
2. SE-HSI Tail rotor gearbox, Input section with cracked gear and Output section.
3. SE-HSI Report from FLO/LHK.
4. SE-HMP Accident leading to write-off and the tail rotor.
5. MD Helicopters Maintenance Manual Conditional Inspection Tail Rotor Blade Strike.

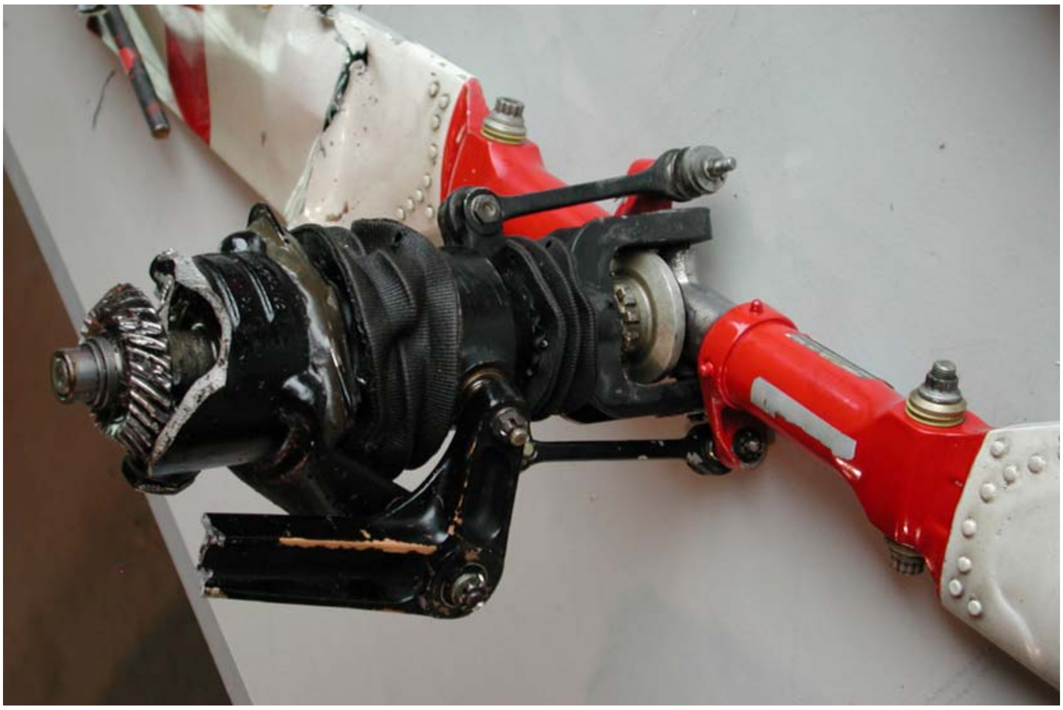
ABBREVIATIONS

AIBN	Accident Investigation Board Norway
C.G.	Centre of Gravity
CPL-H	Commercial Pilot Licence Helicopters
FLO/LHK	Norwegian Defence Logistic Organisation/ Air Depot Kjeller
FPI	Fluorescent Particle Inspection
AIB/N	The Accident Investigation Board Norway
METAR	Meteorological Aerodrome Report
MPI	Magnetic Particle Inspection
P/N	Part Number
SEM	Spectrographic Electronic Microscope
AIB/N	The Accident Investigation Board Norway
S/N	Serial number
TAF	Terminal Aerodrome Forecast
T/R	Tail Rotor
XMSN	Transmission

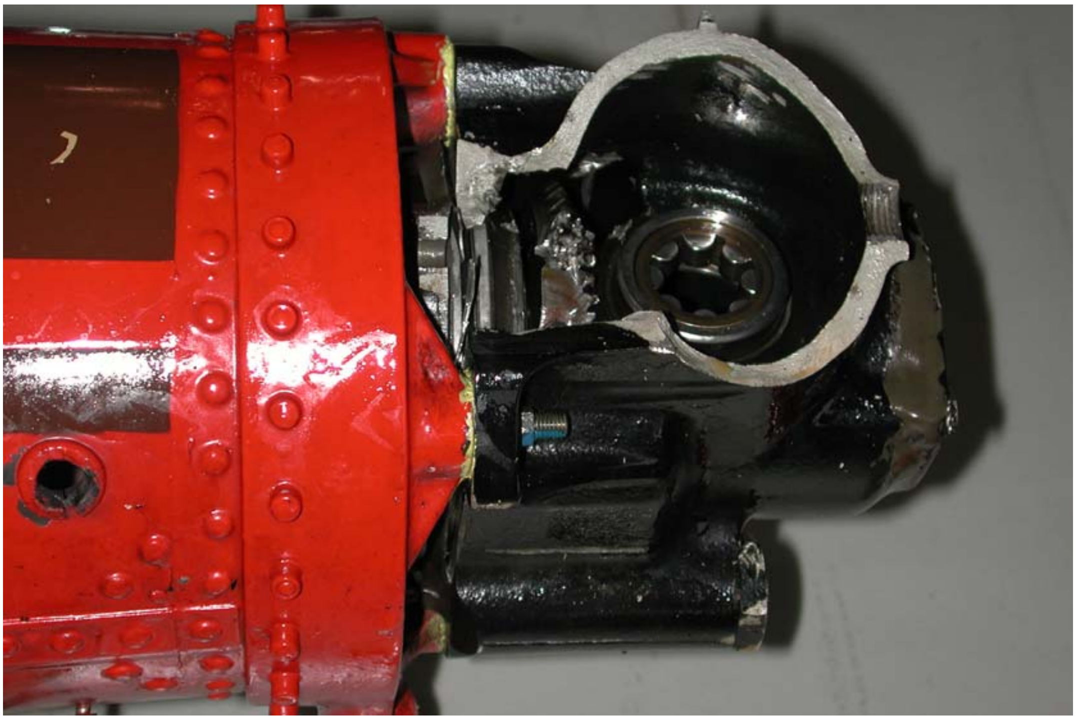
The Accident Investigation Board Norway

Lillestrøm, 29 May 2006

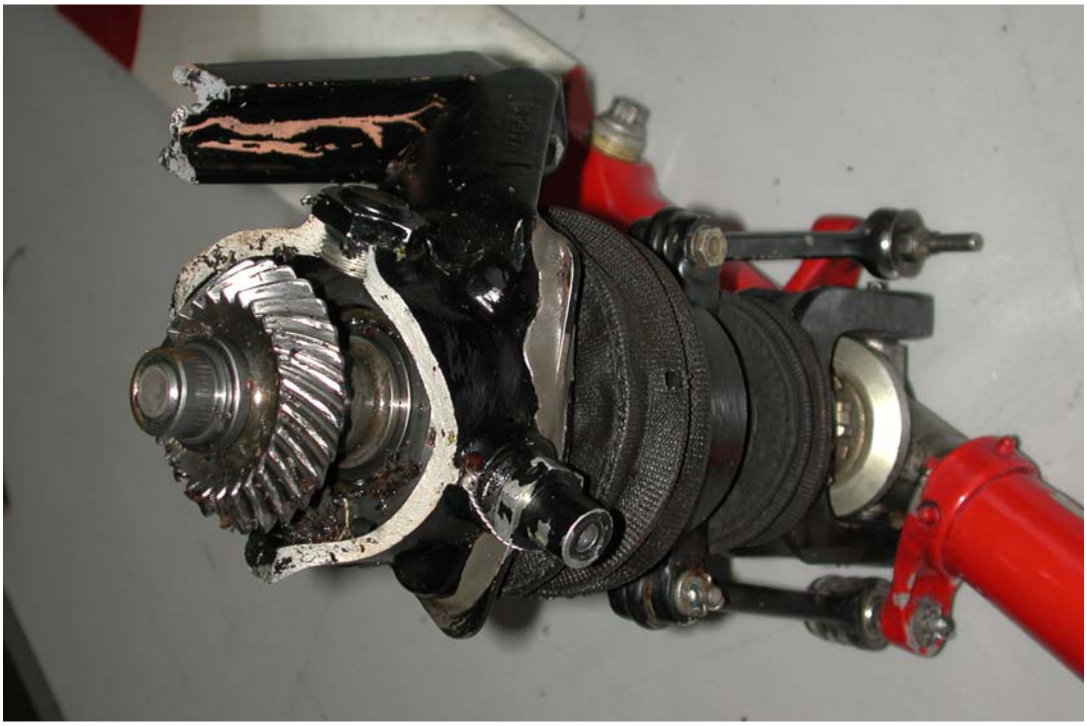
Tail rotor gearbox magnetic plug



Tail rotor with Output section of the gearbox



Tail rotor gearbox Input section with fractured gear



Tail rotor gearbox Output section

Norwegian Defence Research Establishment
Analytic Laboratory
Chemistry and materials technology

Technical report

Client	Client's reference
AIB/N attn. T. Nørstegård	SE-HSI Model No: 369D25400 S/N: 2046
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Title
Gearbox Failure, Helicopter SE-HSI

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Written by		**Head VLA**
Senior engineer I.M. Kulbotten Senior eng. Ø. Frigaard		Senior eng. T A Gustavsen

Summary

FOLAT, chemistry and materials technology, received a damaged helicopter tail rotor gearbox. The gearbox had detached and a fracture could be seen in one of the gears on the power input side of the gearbox. The client wanted an assessment of possible root causes.

Conclusions

No wear or crack initiation has been observed that could have been caused by faulty interlocking between the gears or abnormal wear as a result of lack of lubrication. Nor were there observed any occlusions or other faults in the microstructure that could have been expected to initiate the observed damage. Nor has any sign of plastic deformation in the root of the tooth been observed in the optical microscope.

Our conclusion is, therefore, that it must be clarified whether the component could have undergone a sudden stop. Such an event will give a local overload in a tooth root, with the attendant risk of initiation of local fatigue under continued use, as observed in the case investigated.

As the gear in question has a carburised martensitic surface structure, it would be particularly difficult to prove that this has been exposed to a local overload. This is because the structure in itself can be regarded as a deformation structure and further deformation would be difficult to distinguish from the original structure.

We would therefore recommend an examination of the history of the gearbox to see whether it is possible to find events which could be regarded as sudden stop.

Address :
FLO/LHK/VLA
PO Box 10
NO-2027 KJELLER

Telephone :
+47 63 80 80 00
Mil: 505 8000

Telefax :
+ 47 63 80 87 58
Mil: 505 8758

1 Introduction

FOLAT, chemistry and materials technology, received a damaged helicopter tail rotor gearbox. The gearbox had detached, Figure 1, and a fracture could be seen in one of the gears on the power input side of the gearbox, Figure 2. The client wanted an assessment of possible root causes.

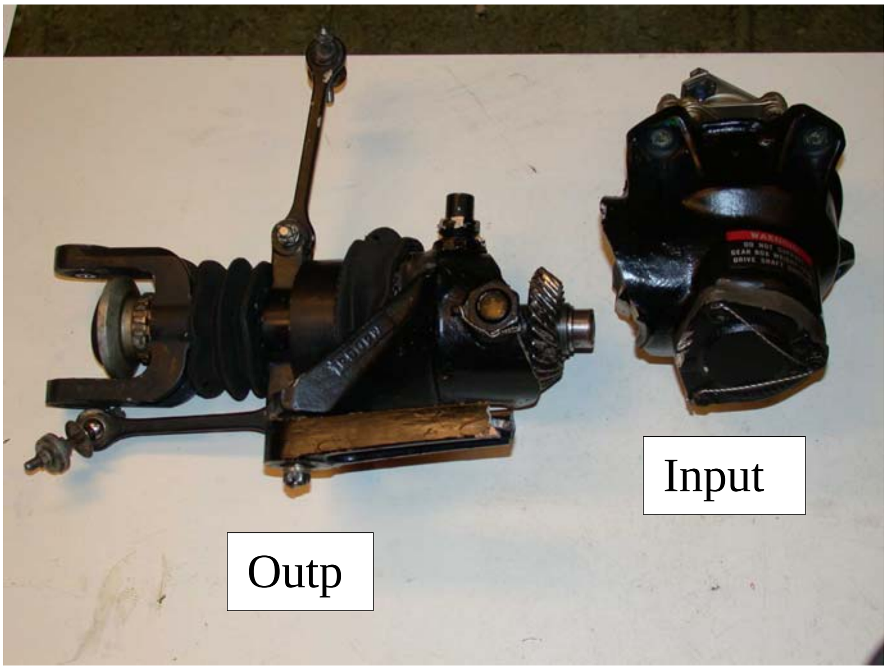

Figure 1 Photograph of the damaged gearbox.

Figure 2 Photograph of fractured gear as observed in input side of the gearbox ref. Figure 1.

2 Preliminary examination

Preliminary examination was conducted with the stereo microscope. No abnormal wear could be observed on the gear on the output side of the gearbox. The damage observed showed clear indication of being secondary damage that was caused when fragments from the gear have been trapped, Figure 3 and 4

Figure 3 Photograph of output section gear. Examination using the stereo microscope concluded that the damage observed was secondary damage.

The gear on the input side was separated as shown in Figure 4. No indication of abnormal wear could be observed apart from the secondary damage that occurred when the gear detached. It can be seen when the separated part is fitted (integrated in Figure 4) into the gear in Figure 5, that a tooth is missing.

Observation through the stereo microscope reveals clear static lines in the fracture surface, which indicates fatigue. In order to confirm the fracture mechanism, a fractography was carried out in SEM. Further examination was concentrated around the crack initiation area, marked in Figure 4.

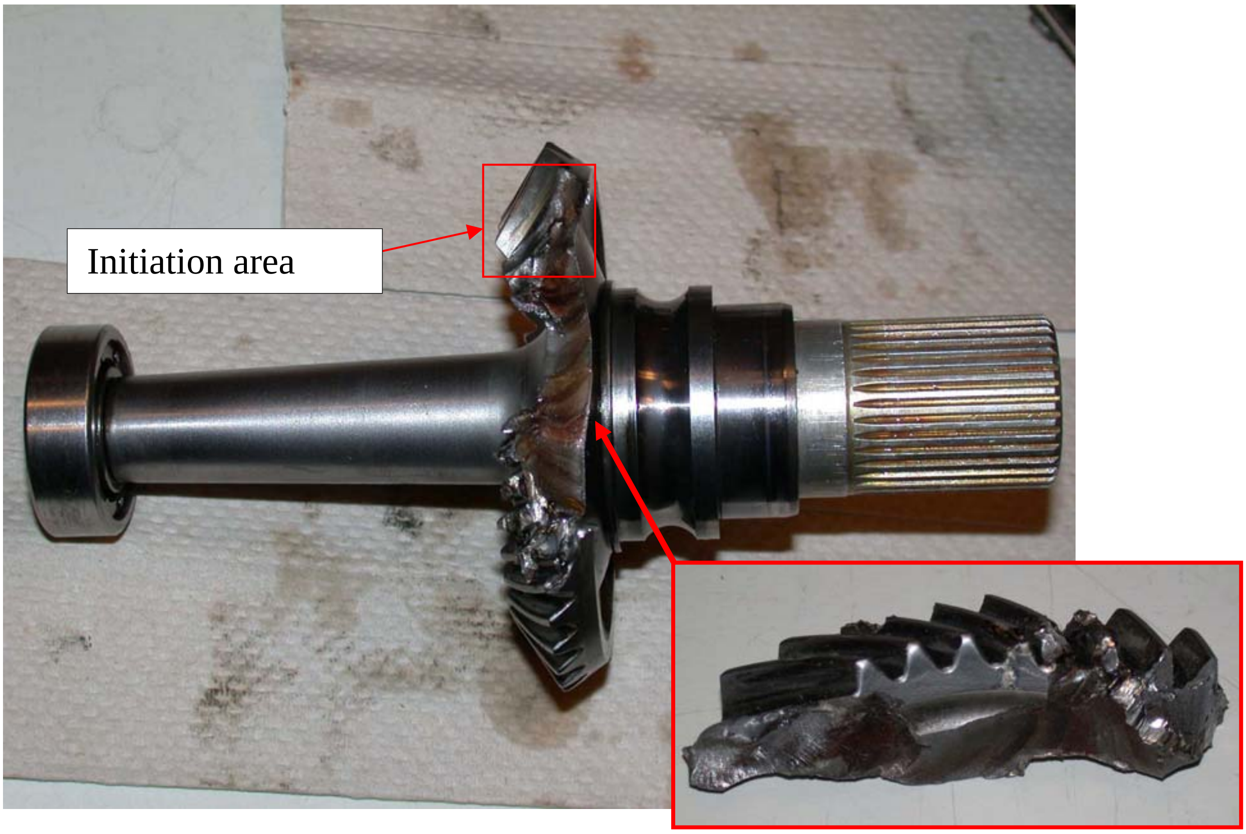

Figure 4 Photograph of fractured gear. The probable crack initiation area is shown at the top if the photograph. The separated part (ref. red arrow) has been integrated in the photograph.

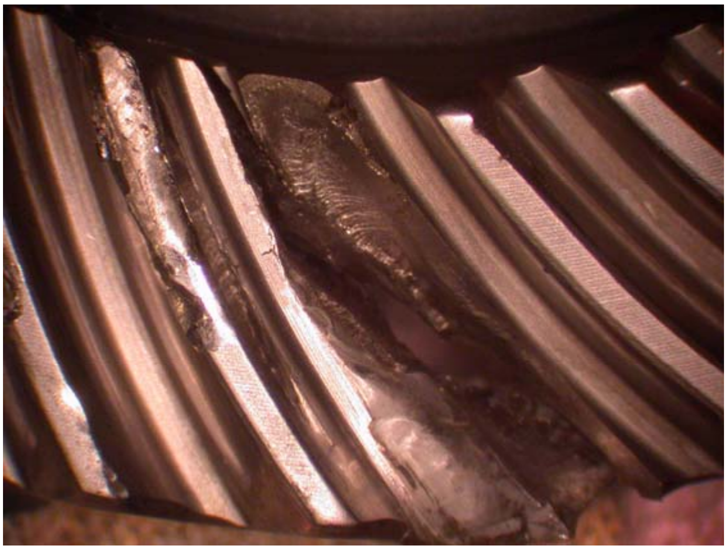

Figure 5 Photograph of the separated part sat into the gear. Shows that a tooth is missing.

3 Fractography in SEM

Fracture surface shown in Figure 4 was examined in SEM. Characteristic photographs of the fracture surface are shown in Figure 6, and it can be seen from the photographs that the fracture growth has taken place as a result of fatigue. It was not possible to conclude what the mechanisms in the initiation area were, as the area was oxidised and spread/secondary damage as shown in Figure 7.

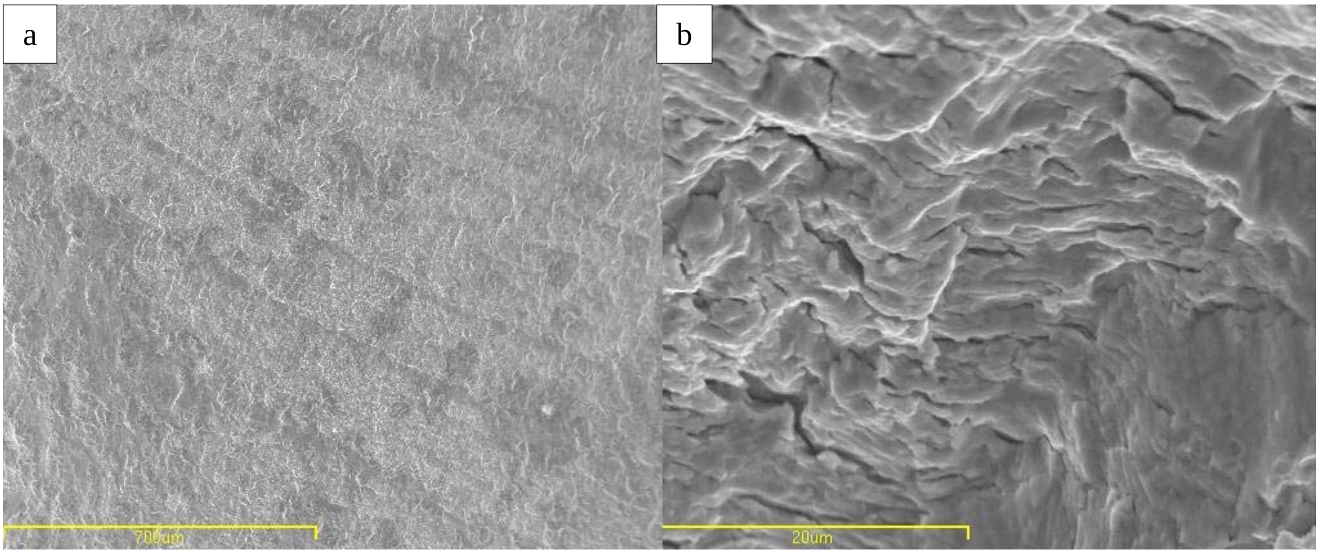

Figure 6 Characteristic photograph of the fracture surface in two enlargements. a: Shows clear static lines in the fracture surface, b: Shows microfractures consistent with fatigue.

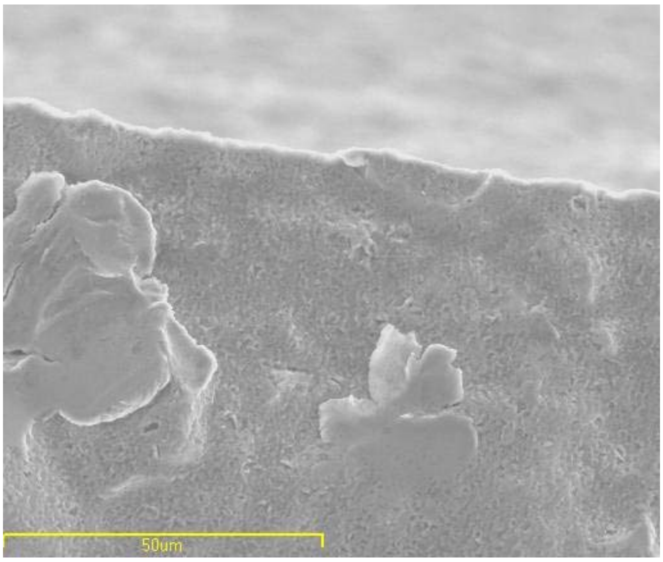

Figure 7 SEM image of the initiation area. Shows oxidised surface with indication of spread/secondary damage.

4 Microstructure examination

A section through the fracture initiation area (see Figure 4) was extracted for metallographic examination. Figure 8 shows a photograph of the test following etching in Nital, and it can be seen from the photograph that the gear has a carburisation layer. Representative photographs of the microstructure are shown in Figure 9 a and b for the carburisation layer and base material respectively.

A series of grinds and repolishes were carried out in order to reveal potential microstructure deviations in fracture initiation area, but it was not possible to reveal deviations as occlusions or visible plastic deformation, Figure 10.

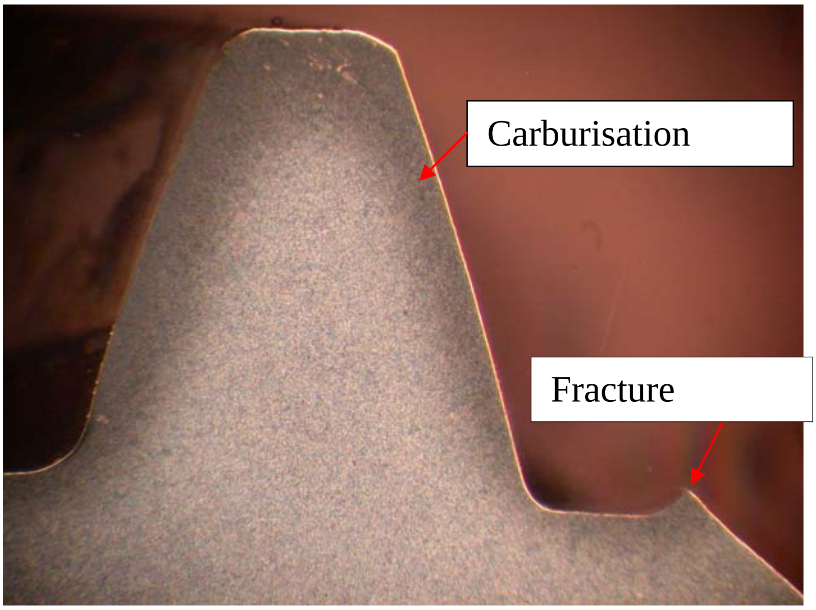

Figure 8 Photograph of the section grind following etching in Nital show that the gear has a carburisation layer.

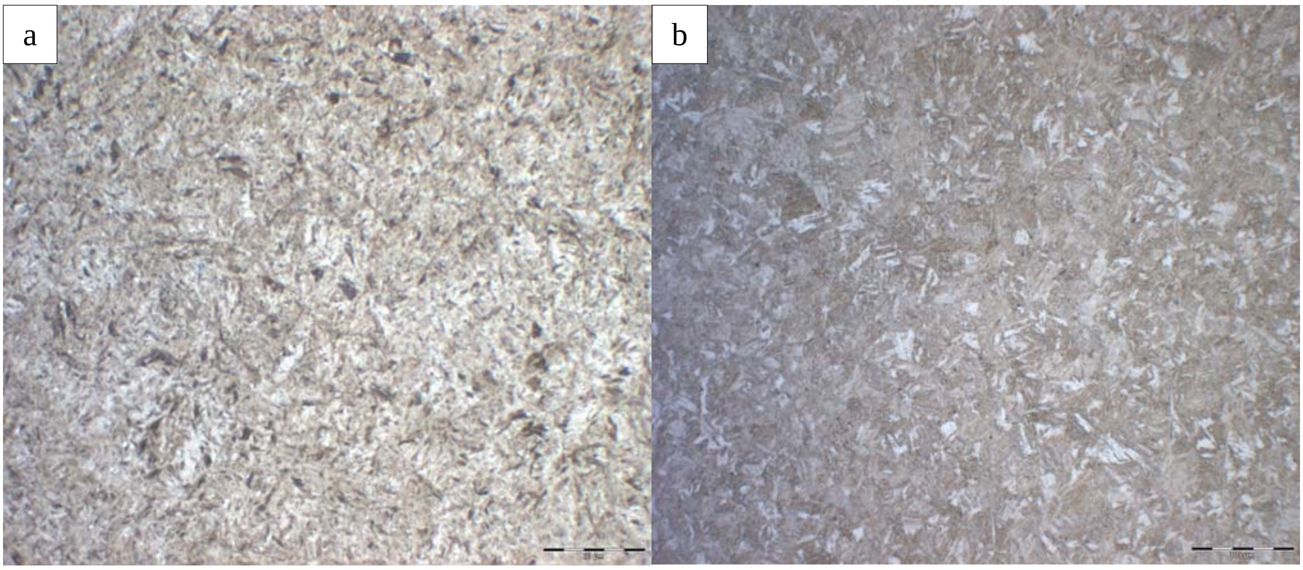

Figure 9 a: Microstructure photograph shows a carbonised annealed martensitic structure. b: Microstructure photograph from the base material shows an annealed martensitic structure.

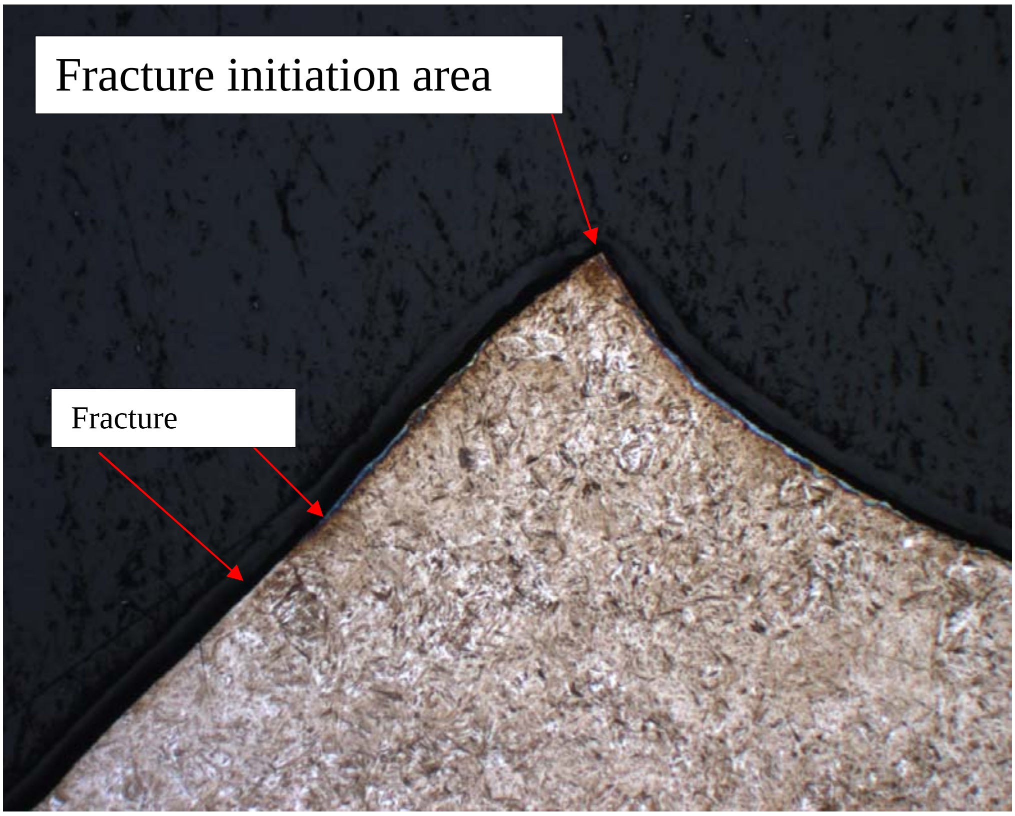

Figure 10 Representative photograph of section grind in fracture initiation area.

5 Conclusions

On the basis of the examinations that have been carried out, we conclude the following:

No wear or crack initiation has been observed that could have been caused by faulty interlocking between the gears or abnormal wear as a result of lack of lubrication.

Nor were there observed any occlusions or other faults in the microstructure that could have been expected to initiate the observed damage. Nor has any sign of plastic deformation in the root of the tooth been observed in the optical microscope.

<u>Our conclusion is, therefore, that it must be clarified whether the component</u> could have undergone a sudden stop. Such an event will give a local overload in a tooth root, with the attendant risk of initiation of local fatigue under continued use, as observed in the case investigated.

As the gear in question has a carburised martensitic surface structure, it would be particularly difficult to prove that this has been exposed to a local overload. This is because the structure in itself can be regarded as a deformation structure and further deformation would be difficult to distinguish from the original structure.

We would therefore recommend an examination of the history of the gearbox to see whether it is possible to find events that could be regarded as sudden stop.

Crash leading to write-off SE-HMP 10. November 1998

Tail rotor SE-HMP

Table 1. Conditional Inspections (Cont.)

Model	Requirement	Chap/Sect
ALL	Remove and scrap main rotor drive shaft.	63
ALL	Overhaul main transmission assembly (Ref. COM).	63
ALL	Remove and scrap engine-to-transmission drive shaft.	63
ALL	Overhaul overrunning clutch assembly (Ref. COM).	63
	AFTER TAIL ROTOR BLADE STRIKE	
	<u>WARNING</u>: Any component, assembly or detailed part that is removed for overhaul must be identified as to the reason for removal. Components that require replacement must be scrapped.	
	After tail rotor blade strike, inspect the following:	
369D/E/FF	If equipped with Bendix couplings, remove and scrap couplings.	63
369D/E/FF	Tail rotor blades for dents, nicks, scratches or separation of skin.	64
369D/E/FF	Tail rotor flapping hinge bolt for damage.	64
369D/E/FF	Tail rotor transmission for radial play and run-out of output shaft, cracks in mounting flanges, and chip detector for metal particles. Remove for overhaul tail rotor transmission if damage is indicated.	63
369D/E/FF	If equipped with Kamatics couplings: Perform Tail Rotor Drive Shaft Twist Inspection. Misaligned or missing stripes require removal and scrapping of drive shaft and Kamatics couplings, and an overhaul inspection of tail rotor transmission (Ref. COM).	63-15-10 63-25-10 63-25-20
369D/E/FF	Remove tail rotor drive shaft and inspect couplings for distortion and cracks; damper, damper bracket and bulkheads for damage.	63
	<u>NOTE</u>: If damage in excess of allowable limits due to blade strike is noted in above areas, continue with following inspections:	
369D/E/FF	Tail rotor drive fork, pitch links, swashplate, hub and pitch control bearing housing for obvious damage.	64
369D/E/FF	Upper fuselage and boom tail rotor control linkage. If tail rotor control rod is damaged, ensure that all rod bulkhead grommets are in place.	67
369D/E/FF	Aft frame of tailboom for cracks and boom skin for loosened or popped rivets.	53
369D/E/FF	Main transmission chip detectors and transmission lube pump oil filter for metal particles.	63
369D/E/FF	Main rotor hub assembly and strap pack assembly for evidence of damage.	62
	AFTER TAILBOOM STRIKE	
	<u>WARNING</u>: Any component, assembly or detailed part that is removed for overhaul must be identified as to the reason for removal. Components that require replacement must be scrapped.	
	If one or more main rotor blades strike tailboom while blades are rotating, inspect following:	
ALL	Perform Main Rotor Blade Inspection.	62-10-00
ALL	If excessive damage requires replacement of main rotor blade(s), inspect complete main rotor and scissors assembly, including droop stop mechanism and strap packs, for evidence of damage.	62

MD Helicopters' inspection procedure after Tail Rotor Blade Strike (AIB/N considers this procedure to be incomplete)