Statens haverikommission
Swedish Accident Investigation Board

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Finalreport RL 2011:14

Aircraft accident to helicopter SE-JKF at Stockholm/Arlanda airport, Uppsala county, Sweden on 9 January 2009

Case L-01/09
2011-10-21

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The Swedish Accident Investigation Board has investigated an accident that occurred on 9 January 2009 at Arlanda airport, Uppsala county, to a helicopter registered SE-JKF.

In accordance with Regulation 996/2010 of the European Parliament and of the Council and SFS (the Swedish Statute Book) Section 14 of the Ordinance concerning the investigation of accidents (1990:717), the Swedish Accident Investigation Board herewith submits a report on the investigation.

The Board will be grateful to receive, by 21 january at the latest, particulars of how the recommendations included in this report are being followed up.

In case of discrepancies between the English and the Swedish texts, the Swedish text is to be considered the authoritative version

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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 exactly happened? Why did it happen? How can such 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 investigations of aviation accidents are 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

The Swedish Accident Investigation Board (SHK) was notified on 9 January 2009 that a helicopter with registration SE-JKF had an accident at 07:57 hours on that day near to Stockholm/Arlanda airport, Uppsala county.

The accident was investigated by SHK representatives Göran Rosvall, Chairperson, Agne Widholm, Investigator In Charge, Henrik Elinder, technical investigator until 31 december 2010, Staffan Jönsson thereafter, Gerd Svensson, MTO (Humans, Technology and Organization) investigator and Urban Kjellberg, rescue services investigator.

SHK was assisted by Liselotte Yregård as a medical expert, also Ingvar Johansson and Leif Åström as operations experts.

The investigation was followed by Swedish Transport Agency representative Ulrika Svensson until 8 November 2010, and by Ulrik Rönnbäck thereafter.

The accredited representative from the French Accident Investigation Bureau (BEA - Bureau d’Enquêtes et d’Analyses pour la sécurité de l’aviation civile) was Xavier De Gastines.

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Aircraft; registration and model	SE-JKF, Eurocopter AS350 B3
Class, airworthiness	Normal, valid Certificate of Airworthiness with ARC (Airworthiness Review Certificate)
Registered owner/Operator	Airlift Helicopter AS, c/o HTG AS, Strandveien 50, Blokk B, N-1366 LYSAKER, Norway/Airlift Helicopter Sweden AB Box 197, SE-824 24 HUDIKSVALL, Sweden
Time of occurrence	9 January 2009, at 07:57 Note: All times are given in Swedish standard time (UTC + 1 hour)
Place	Immediately south-west of Stockholm/Arlanda airport, Uppsala county (position 59° 37:9´ N, 017° 54,1′ E; about 40 m above sea level)
Type of flight	Aerial work
Weather	Arlanda airport at 07:55: Wind west to north-west 10-15 knots, visibility > 10 km, no cloud below 2000 feet, temperature/dew point +5/±0°C, QNH 1005 hPa
Persons on board: crew members passengers	 1 -
Injuries to persons	Minor
Damage to the aircraft	Substantially damaged
Other damage	Broken trees, fuel spillage
The pilot: Age, certification Total flying time Flying hours previous 90 days	 62 years, CPL(H) 11 007 hours, of which 4 000 hours on type 172 hours, all on type

Summary

The pilot intended to the land the helicopter on Stockholm/Arlanda airport in order to pick up passengers for a taxi flight. Shortly after the speed reduction before landing the chip warning system for the helicopter tail rotor gearbox was activated. The pilot noted that the helicopter tended to turn to the left. When the helicopter reached the airport he could not maintain the heading. The helicopter turned left though applying full deflection to the right pedal.

By increasing the speed through reducing the altitude and at the same time reducing the engine power the pilot managed to stop the turn but experienced big difficulties to control the helicopter’s route.

When the helicopter some minute later was located above a small wooded area and the pilot couldn’t see a suitable place for an emergency landing he decided to try to land the helicopter on a small glade in the terrain.

During this manoeuvre the helicopter entered an uncontrolled yaw. After collision with some small trees the helicopter impacted to the ground hard. On impact the helicopter tuned over. The pilot was able to get out of the helicopter by himself.

The investigation showed that the flight was performed with the tail rotor gearbox drained from oil why the gearbox broke because of lack of oil.

During exchange of oil before the actual flight it was forgotten to refill the gearbox with oil.

It is the opinion of SHK that there have been deficiencies in the management and quality assurance control of the technical maintenance and in the Transport Agency Aviation Department inspections of maintenance organizations.

It is the opinion of SHK that the emergency instructions for this type of helicopter give insufficient support to the pilot for the management of a chip warning or a TRDF[1] respectively. Generally the problems with TRF[2] and the difference between TRCF[3] and TRDF have not been enough paid attention to by helicopter manufacturers and supervising authorities.

The accident was caused by the helicopter not being restored to an airworthy condition after maintenance work had been carried out. A contributory factor was deficiencies in the quality assurance management by the maintenance organization.

The consequences of the maintenance error were aggravated by deficiencies in the emergency instructions for this type of helicopter in respect of the management of a chip warning or a TRDF respectively.

Recommendations

It is recommended that EASA:

- strives for a review of the emergency checklists for the affected models of helicopter so that landing is recommended, as soon as practically possible, when the chip warning system for the tail rotor gearbox is activated *(RL 2011:14 R1)* and to

- considers suitable measures to minimise the risk of misinterpretation of the oil level in the tail rotor gearbox on this particular model of helicopter, and on other helicopters with similar visual measuring systems *(RL 2011:14 R2)*

[1] TRDF – Tail Rotor Drive Failure
[2] TRF – Tail Rotor Failure
[3] TRCF – Tail Rotor Control Failure

1 FACTUAL INFORMATION

1.1 History of the sequence of events

The pilot and a colleague from the aircraft operating company intended to fly two helicopters from Hudiksvall airport to Stockholm/Arlanda airport, where they would collect ten passengers for a taxi flight.

The flight was performed as a "loose pair[4]" with the accident helicopter as "number two" in the pair i.e. the second aircraft in the unit. The flight took mostly place in darkness, and dawn occurred a little more than 10 minutes before the planned landing time for the pair.

Just after the beginning of reducing speed for landing, about 2 km from Stockholm/Arlanda airport, the chip warning system for the helicopter tail rotor gearbox was activated. The pilot decided that it would be best to continue the approach, on the basis of the flight manual instruction, "*Continue flight*" for this type of warning. Shortly thereafter he heard and felt strange noises and vibrations from the rear of the helicopter. At the same time he noted that the helicopter was tending to turn to the left.

To be able to maintain the heading the pilot was forced to apply more and more right pedal deflection. When the helicopter had passed over the airport boundary and crossed runway 01L, the helicopter turned to the left even though by now he was applying full deflection to the right pedal.

The pilot realised that a serious fault had developed in the tail rotor system of the helicopter, which he reported to Stockholm/Arlanda TWR[5] while at the same time requesting permission to land on the airport.

After the air traffic control had identified which helicopter in the pair had the problem, permission was granted for the helicopter to land from its present position. The difficulty to control the helicopter together with obstacles in the form of lighting masts, aircraft and buildings in the area beneath the helicopter contributed to the decision not to make an emergency landing immediately.

Initially the pilot did not succeed in stopping the left turn, which continued through a 360º turn west of runway 01L. Only by reducing altitude, increasing speed and at the same time reducing engine power did he manage to stop the turn. The helicopter than flew somewhat to the west of and in the opposite direction to the final approach to runway 01L.

The pilot experienced great difficulty in controlling the helicopter in yaw and reported to the air traffic control that he needed a large clear space in order to be able to land the helicopter at a good forward speed.

A little less than two minutes after the tail rotor problem had begun, the helicopter was located above a small undulating and sparsely wooded area about 600 m south-west of the threshold of runway 01L. The altitude and speed were by this time so low that the pilot realised that he would not be able to reach a suitable place for an emergency landing.

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[4] Pair – Two aircraft operating together as one unit
[5] TWR – "The Tower", air traffic control for the airport's control zone

The pilot then decided to reduce speed and try to put the helicopter down in a glade in the terrain below. When he lowered the collective pitch and reduced engine power the helicopter started to enter an uncontrolled yaw. The rotation was so powerful that he was unable to reach the engine shutdown control on the roof panel. As the helicopter approached the ground he raised the collective in order to reduce the descent rate.

After first colliding with some small trees the helicopter impacted the ground hard, the right way up but almost vertical, and at a high rate of descent. On impact, the helicopter turned over on its left side. The rotor blades slashed several small trees and struck the ground before the rotor stopped. The pilot was able to get out of the helicopter by himself.

The event was observed by several people on the ground.

The accident occurred at position 59°38′ N 017°54′ E; about 40 m above sea level. There was no fire.

1.2 Injuries to persons

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

1.3 Damage to the aircraft

Substantially damaged.

1.4 Other damage

Some small trees were chopped down. There was a minor leak of fuel from the helicopter.

1.5 The crew

1.5.1 Pilot

The pilot was 62 years old at the time and had a valid CPL (H) Licence.

Flying hours			
Latest	24 hours	90 days	Total
All types	2,3 hours	172,0 hours	11 007 hours
This type	2,3 hours	172,0 hours	Approx. 4 000 hours

Flight training on AS350 B1 was carried out in 1982.
Conversion training to the AS350 B3 was carried out on 14 May 2003.
Latest PC (Proficiency Check) was carried out on 8 January 2009.

The pilot had a valid instructor's authorization and had served 4 075 hours as a FI (Flight Instructor).

1.5.2 The pilot's duty schedule

The pilot had a Christmas holiday from 18 December 2008 to 7 January 2009.
On 8 January 2009 he was on duty between 08:00 – 12:00, and on 9 January his duty began at 06:00.

1.6 The aircraft

1.6.1 General

The aircraft	
Type certificate holder	Eurocopter, France
Model	AS350 B3
Serial number	4516
Year of manufacture	2008
Flight mass	Max. authorised take-off/landing mass 2 250 kg, actual 1 622 kg
Centre of mass	Within permitted limits
Total flying time	144,9 hours
Total number of cycles	563
Flying time since latest inspection	0,9 hours
Fuel loaded before event	JET A1
Engine	
Type certificate holder	Turbomeca S.A.
Model	Arriel 2B1
Number of engines	1
Total flying time	144,9 hours
Total number of cycles	70
Rotors	
Manufacturer	Eurocopter
Total running hours: Main rotor	144,9 hours
Total running hours: Tail rotor	14499 hours

The helicopter had a Certificate of Airworthiness with valid approval certificate (ARC – Airworthiness Review Certificate).

The helicopter type is a small, single-engined helicopter with seats for up to six people. The type is used, among other things, for passenger transport and various kinds of lifting tasks. The main rotor rotates clockwise seen from above.

Figure 1. AS350 B3 helicopter

1.6.2 Tail Rotor Gearbox

At the rear end of the tail boom there is a 90 degree tail rotor gearbox which connects the rotor drive shaft to the tail rotor. The gearbox shall hold a certain amount of oil for lubrication and cooling of the gearwheels and bearings. The oil is filled up through a filler hole on the top of the gearbox housing. The oil level can be checked visually through a sight glass on the left side of the housing.

In the lower part of the gearbox housing is installed a metal chip warning sensor, which is connected to the helicopter metal chip warning system. The sensor has two magnetic poles which attract any magnetic metal chips that may be present in the oil. If metal chips are gathered between the poles there will be a connection, the warning system is activated and a warning lamp is lit in the pilot's cabin. The hole in the gearbox housing for the sensor also acts as a drain hole for the gearbox oil.

The tail rotor gearbox has no system for measuring and indicating the oil level or oil temperature during flight.

During the first 100 hours from manufacturing or after overhaul of the tail rotor gearbox, a running-in oil with special lubrication characteristics must be used. This oil is then replaced by ordinary oil. Which type of oil that has been used to fill the gearbox must be indicated by a sign placed on the gearbox or on the gearbox cover close to the sight glass.

Concerning ordinary changing of oil in the tail rotor gearbox the helicopter manufacturer gives in MM[6], Chapter 3.1 and 4.1, work card No. 12.00.00.201 among other things the following recommendations:

- When draining the oil should be warm.
- After filling up oil, the rotor system shall be run on ground for about five minutes.
- After this running the oil level in the gearbox shall be checked and, if needed, be adjusted.

[6] MM – Maintenance Manual

1.7 Meteorological information

At the time of the accident a low pressure area was moving eastwards over Finland, and a weak high pressure ridge covered eastern Scandinavia.

The weather situation at Stockholm/Arlanda airport at 07:55: Wind west to north-west 10-15 knots, visibility > 10 km, no clouds below 2000 feet, temperature/dew point +5/±0 °C, QNH 1005 hPa.

1.8 Aids to navigation

Not applicable.

1.9 Radio communications

The helicopters flew as a pair during the flight. Up to the time that the accident helicopter, the second in the pair, had a tail rotor problem, the radio communications with the air traffic control were handled by the pilot in the lead helicopter.

When the problem arose, the pilot of the accident helicopter, SE-JKF, contacted Stockholm/Arlanda TWR directly, in accordance with the transcript below of the recorded radio traffic.

Time	Communication
07.56.02	**SE-JKF:** *I have problems here, I have some tail rotor fault, may I use the runway here in some way?*
07.56.14	**TWR:** *Juliet Foxtrot, is it you who are at Terminal 2 now and descending, or?*
07.56.20	**SE-JKF:** *Yes, I'm out on the runway here trying going off to the side somewhere, so I have no tail rotor control here now.*
07.56.34	**TWR:** *Yes, that is understood. Can you put the "kite" down where you are now, that is OK with me.*
07.56.37	**SE-JKF:** *Aah***,** *I'll need to have a bit longer area for eh can I come in on a kind of glide path.*
07.56.47	**TWR:** *OK, that is understood. Would it be enough with the taxiway which is 25 metres wide?*
07.56.54	**SE-JKF:** *Yes...in some way I have to try and to have a little higher speed on a longer track, so eh I keep flying out here on the side at a higher speed.*
07.57.08	**TWR:** *Kilo Foxtrot, you are cleared to land on 01 Left instead, and mm, are you declaring an emergency?*
07.56.16	**SE-JKF:** *I have problems here now, real...*

Radio communication then ceased without an emergency being declared.

1.10 Aerodrome information

Stockholm/Arlanda status was in accordance with AIP[7]-Sverige/Sweden.

1.11 Flight recorders and voice recorders

There was no Flight Data Recorder (FDR) or Cockpit Voice Recorder (CVR) on board, and no requirement for them.

The helicopter was equipped with two GPS units. One of these had a TRAC LOG feature, which however was not activated on the occasion.

1.12 Location of occurrence and aircraft wreckage

1.12.1 Occurrence site

It has been possible to reconstruct the approximate flight track of both the helicopters, using information from witnesses on the ground, testimony from the pilots of both helicopters, recorded radio communications and radar tracking. The flight tracks and accident site have been drawn on the satellite image below of the south-western part of the airport.

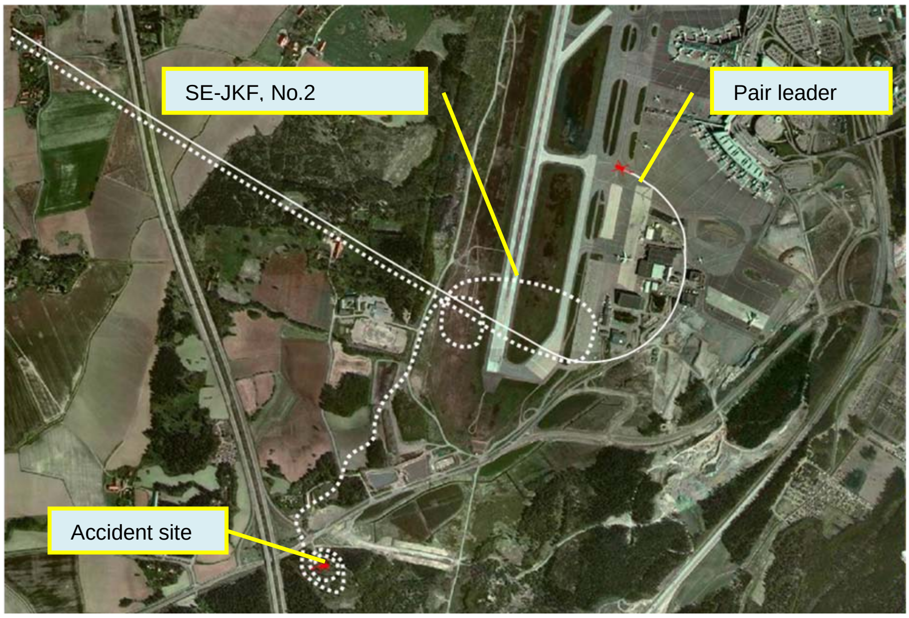

Figure 2. The approximate flight tracks of the helicopters.

The malfunction of the tail rotor system occurred just before the helicopter reached the western boundary of Stockholm/Arlanda airport. It then flew in an increasingly uncontrolled manner across the southern part of runway 01L and a little south-west of the runway threshold for over two minutes before it impacted with the ground.

1.12.2 The impact site

The helicopter came down in a small wooded area about 600 metres south-west of the southern threshold of runway 01L. The impact site was a glade in the woods that was covered by mixed saplings. The terrain at the site

[7] AIP – Aeronautical Information Publication

slopes to the north towards a dirt track, passing about ten metres away from the final position of the helicopter.

The damage to the trees and ground indicates that the impact was almost vertical, with low forward speed. On contacting the ground, the helicopter's direction of movement was approximately easterly.

1.12.3 The aircraft wreckage

On impact with the ground the right landing gear broke. The helicopter finally rolled over to the left, whereupon the rotor blades slashed the adjacent trees and ground. The main rotor blades bent and the transmission partly detached from its mountings. The helicopter structure and tail boom suffered substantial damage. The tail rotor blades were not damaged.

Figure 3. The helicopter wreckage as seen from the dirt road (from the north).

1.13 Medical information

The pilot had undergone the prescribed medical examinations with approved results, the most recent having been in the spring of 2008.

In December 2008, with a prescription from his company physician, the pilot began taking medication for high blood pressure. His aviation physician was not contacted in relation to this, and there was no follow-up of the medication before the accident.

During a check-up by an aviation physician one week after the accident, the pilot had such high blood pressure that a medical certificate for flying could not be issued. However a certificate was issued some weeks later, when his blood pressure became satisfactory after the medication had been adjusted.

According to JAR-FCL, the holder of an aviation medical certificate must not be taking any prescription medicine, unless they are completely certain that the medicine will not have a negative effect on their ability to perform their tasks safely. In the case of any uncertainty, advice must be sought from the Transport Agency, an aviation medicine centre or an aviation physician.

The holder of an aviation medical certificate must, in the case of regular use of a medication, without unreasonable delay seek advice from the Transport Agency, an aviation medicine centre or an aviation physician.

1.14 Fire

There was no fire.

1.15 Survival aspects

1.15.1 General

After the accident the pilot’s cabin was relatively intact. The helicopter was equipped with energy-absorbing pilot's seats, of Sicma Aero Seat 159-Series type, fitted with four-point seat belts. Damage to the right hand pilot’s seat (the one used by the pilot) showed that the vertical forces on impact were so great that the seat’s stressed components broke, whereupon the seat was deformed and compressed during energy absorption. See the illustrations below.

Figure 4. Compressed pilot’s seat (right)

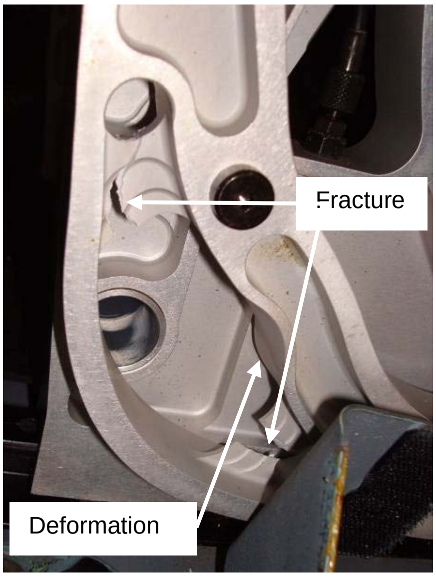

Figure 5. Fractures and deformation

The emergency locator transmitter, P/N S182250202, was activated by the impact, and deactivated by a technician called in from Stockholm/Arlanda airport.

1.15.2 Actions by the rescue services

The airport rescue services were called out at 07:57 by a crash alarm from the Stockholm/Arlanda airport air traffic control, TWR. Information was given that an AS350 helicopter with one person on board had come down south-west of runway 01L. At first it was not clear whether the crash had occurred inside or outside the airport perimeter fence.

The airport rescue services emergency unit from “Station West” reported, after checking at the runway 01L that the helicopter was not inside the fence.

The crew of an aircraft that was standing at the holding point for runway 01L had seen what happened and informed the airport rescue services commander that the helicopter had crashed just outside the airport, south-west of the runway 01L.

The airport rescue services vehicle then drove, via an opened crash gate in the airport’s southern fence, towards the accident site, which was then found to be 600 metres south-west of the runway threshold. The first rescue vehicle from the airport arrived at the accident site at 08:06.

In parallel with the air traffic control tower alarm, at 07:58 the alarm was raised concerning a helicopter crash at the SOS centre in Stockholm via the emergency telephone number 112. This call was forwarded a minute later to the Aeronautical Rescue Coordination Centre, ARCC[8]. At this time it was not clear whether the accident had occurred within or outside the airport area.

The SOS centre sent an alarm to the fire station at Märsta, which was near to that end of the runway concerned. The Märsta rescue services unit localised the accident site and arrived there less than a minute before the airport rescue services vehicle.

By the time the first rescue unit and ambulance arrived at the accident site, the pilot had got out of the helicopter. He was taken care of by the ambulance personnel and transported to the Karolinska University Hospital in Solna.

Fuel had leaked out from the helicopter and foam was laid down as a safeguard against fire. The police cordoned off the accident site.

1.16 Special tests and research

1.16.1 Technical investigation

At the accident site

A preliminary examination and documentation of the helicopter was performed at the accident site. It was then found that the helicopter was complete on impact and that extensive damage had occurred to the structure and the main rotor during the impact itself.

During the examination it was noted that the tail rotor gearbox showed signs of overheating at the input drive shaft, and that the input and output shafts could be turned independently of each other. The oil filler plug for the gearbox was in place and there were no signs of oil leakage, neither on the gearbox nor on the tail boom.

After recovery

After recovery of the helicopter to a hangar a supplementary technical examination was carried out in conjunction with representatives from, among others, the French accident investigation bureau (BEA), the

[8] ARCC - Aeronautical Rescue Coordination Centre, nowadays JRCC, Joint Rescue Coordination Centre

Transport Agency Aviation Department, the helicopter manufacturer, the operator and the maintenance organization. Apart from the tail rotor gearbox described below, no other fault or abnormality was discovered on the helicopter that was assessed to have had any effect on the accident.

A sign on the tail rotor gearbox cover stated that the gearbox had been filled with NYCOLUBE 3525 oil, which is a type of oil that is recommended by the manufacturer. A sign on the tail rotor gearbox housing stated however that the gearbox had been filled with OPTIGEAR 32VP453 oil, which is a type of running-in oil.

The tail rotor gearbox

The tail rotor gearbox and tail rotor were detached from the helicopter and inspected by an authorised helicopter workshop. On dismantling the gearbox it was found that there was virtually no oil in it, but there was a large amount of metal chips. The gear teeth on the input drive shaft gear (the smaller) were completely “lathed off” and the adjacent roller bearing had seized. The gear teeth on the output drive gear (the larger) were severely damaged. (See picture below.)

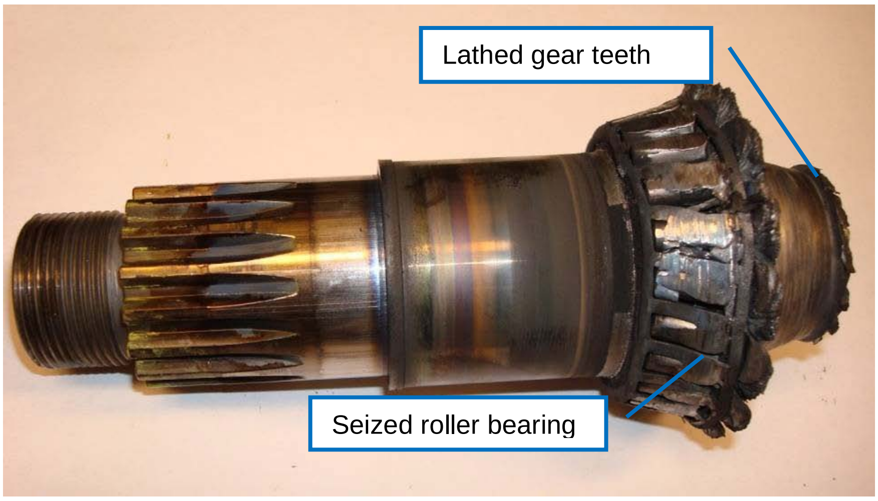

Figure 6. Input drive shaft

Oil and material analysis

Samples of the remaining oil and the metal chips that were found in the gearbox were examined in a materials laboratory. The analysis results showed the type of oil to be Castrol OPTIGEAR 32, which is a so-called running-in oil. The chemical composition of the metal chips met the applicable material specification for the drive gears of the gearbox.

1.16.2 The helicopter’s maintenance status

According to presented documentation the maintenance of the helicopter followed the valid regulations.

Four days before the accident flight, the helicopter had undergone a 100 hours inspection. The work was carried out at the air operator’s base at Hudiksvall airport by a licensed technician who had been approved by the technical manager of the maintenance organization.

As an additional action during the inspection it was planned that the running-in oil, Castrol OPTIGEAR 32, that filled the tail rotor gearbox would be replaced by oil recommended by the manufacturer, NYCOLUBE 3525.

According to the technician who performed the inspection, this oil change was done in accordance with the company's normal procedures, and the process is written into and signed for on the helicopter log sheet no. 3033.

After the maintenance the helicopter was parked in a locked hangar until the day of the accident.

1.16.3 *The technician's recollection of the oil change*

The licensed technician was interviewed on two occasions and provided the following information.

Before Christmas he had decided to work on 2 and 5 of January 2009 doing maintenance work on two helicopters. On this particular helicopter he would, among other things, complete a started 100 hour inspection in accordance with the helicopter's maintenance schedule, and perform certain follow-up checks associated with that inspection.

Changing the type of oil in the tail rotor gearbox was one of the tasks that were included in the follow-up checks. He added that earlier, on 17 November 2008, at about 50 hours flying time for that helicopter, he had changed to new running-in oil of OPTIGEAR 32 type, since the helicopter was going to operate in Finland for some time.

The two helicopters that he was working on were located in the same hangar. That was also where he parked his service vehicle with the tools, oil, and other items that were required for performing maintenance.

On the morning of 5 January he first completed the work on the other helicopter. Then he began to carry out the inspection procedures on this particular helicopter.

He said that he carried out the inspection procedures in blocks and worked his way round the helicopter anti-clockwise, starting by removing the cover at the extreme rear. He fetched a stepladder in order to inspect and change the oil in the tail rotor gearbox, and placed a bucket on the floor to collect the oil as it drained out. After removing the magnetic plug he drained out the old oil with the help of a mandrel, because he did not have a hose and adapter. The oil had about room temperature when draining.

While he was standing holding the mandrel in place he checked the colour, etc. of the oil and saw that it appeared to be normal. He remembered that some oil spilled on to the floor and he wiped it up.

He also remembered that afterwards he took away the refill can with the operating oil, NYCOLUBE 3525, and put it in the service vehicle. He thought that he recalled filling up with operating oil, but realised after the accident that he could not have. He could not remember that anything happened to distract him.

He then ate lunch and continued with the inspection procedures at the front of the helicopter.

He had a recollection, possibly in connection with a re-check that the covers were secured, of noting that he had forgotten to affix a label on the helicopter with information on which oil he had changed to. He therefore made a DYMO label and stuck it securely to the cover below the sight glass, which was the usual location for this information. He then wrote into the log book that he had changed the oil.

A ground running of the rotor system during five minutes with a final check of the oil level and if necessary filling up with oil in the tail rotor gearbox was not done after the oil shift.

When he had completed the 100 hour inspection he discovered that there was a component that was not operating correctly. He managed to order a replacement unit by contacting colleagues in Norway.

According to the log book he had not performed a daily inspection, and explained this by saying that it was better that someone else did it as an extra check, since he himself had just completed the 100 hour inspection.

The technician did not remark on anything of importance in respect of his work environment, such as for example the lighting, air quality, working posture, working time or stress. Nor in respect of the manuals and work orders that he used did he offer any remarks, but considered that the working conditions were satisfactory. He had, according to his own account, performed the same inspection procedures, and particularly the oil change, many times previously.

1.16.4 The pilot's recollection of checking the oil level during the daily inspection

The pilot performed the daily inspection of the helicopter before the flight, which he was authorised to do. It was the first flight after the 100 hours inspection. The daily inspection includes checking the tail rotor gearbox in respect of oil level and leakage. He checked the log book and saw that a 100 hour inspection recently had been carried out and that the oil in the tail rotor gearbox had been changed. He saw no signs of external leakage.

The pilot checked the oil level in the tail rotor gearbox while the helicopter was fitted with the marshalling wheels, which can affect the nose level, being about ± 5° from the horizontal. He thought that the oil level was a "little bit low", but enough for that particular flight. Before taking off he spoke to a colleague and asked him to tell the technician to top up the oil in the tail rotor gearbox at the return.

1.16.5 The technical manager's description of the work that had been done

SHK has also run through the oil change procedure with the technical manager. He explained that a mandrel was often used when emptying out the oil. Regardless of how the oil change was performed, he considered that it was good practice while emptying the oil to always remove the filling cap from the gearbox and put it on top of the gearbox, as a reminder, until the gearbox had been refilled.

1.16.6 Test of oil level

As stated in Sec 1.6.2, the level of oil in the tail rotor gearbox is checked visually through a sight glass. SHK has carried out practical tests on a helicopter of the same type as the accident helicopter, with the aim of getting an idea of how the oil level indication is affected by the helicopter being tilted, and an indication of how it appears when the gearbox has just been emptied of oil.

The sight glass on the gearbox is visible through a hole in the left side of the gearbox cover. There are markings on the sight glass that show the lowest and highest permitted oil levels for flight. The normal oil level indication when the helicopter is standing on a flat surface is shown in the following illustration.

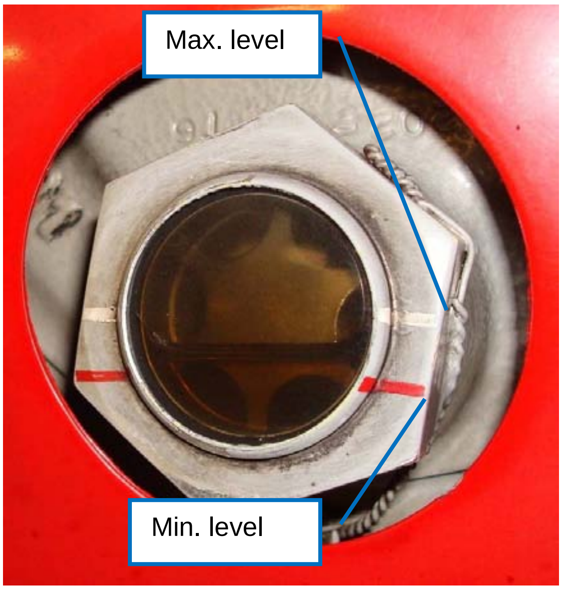

Figure 7. Oil level indication

The following illustrations show the sight glass with the same oil amount in the gearbox and the helicopter tilted in different ways.

Figure 8. Nose down approx. 5°

Figure 9. Nose up approx. 5°

Figure 10. Tilted right approx. 3°

Figure 11. Tilted left approx. 3°

The illustrations below show the sight glass with the helicopter standing on a flat surface after the room temperature oil in the gearbox, due to gravity, has drained out through the hole for the chip warning sensor. The oil that can still be seen in the sight glass is residual oil that is stuck, due to capillary action, on the inside of the sight glass.

Figure 12. Seen at an angle from the front.

Figure 13. Seen directly from the front.

1.17 The company's organization and management

At the time of the accident the following applied:

1.17.1 Organization

Airlift Helicopter Sweden AB is a wholly-owned subsidiary of Norwegian Airlift Helicopter AS with its main base at Hudiksvall airport and operates in all the Nordic countries, but mainly in Sweden and Finland.

The company operates four AS350 B3 type helicopters. The main business concerns using specially developed equipment to apply granulated limestone, fertilizer and ashes from the air over specified areas on the ground.

The company's Air Operator Certificate (AOC) was issued by Luftfartsstyrelsen, the Swedish Civil Aviation Authority, (now Transportstyrelsen, the Swedish Transport Agency) and covers commercial air transport of passengers and goods, along with Aerial Work, in accordance with the conditions in the terms of the licence. This authorisation applies only to flying in VFR[9] during daylight.

1.17.2 *Operations manual*

Operational procedures, including the applicable quality assurance system, are described in the company Operations Manual (OM), which was compiled by the aviation company and approved by the supervisory authority (the Swedish Transport Agency). According to the OM, the company belongs to the group of operators that are considered to be “small”, with a suitably adapted quality assurance system.

The company manager is, together with the subordinate managers, among other things responsible for that deviations from the normal procedures are being reported in accordance with the company's quality assurance system. He must also call all staff to meetings twice a year to review incoming reports and subsequent measures taken. Quality checks and inspections must in accordance with the OM take place at least every 12 months. These checks and inspections are to cover all areas of the business.

Among other things the OM contains descriptions of all the personnel’s powers, tasks and responsibilities, including those of aircraft commanders. The aircraft commanders are, according to these descriptions, responsible for ensuring that daily inspections (DIs) are carried out. This requires the commander to be approved for the particular type of helicopter by the technically responsible organization.

1.17.3 *Organization for technical maintenance*

The aircraft operator has contracted the technical maintenance for the business to an approved Part-145 organization, which also has authorisation to issue a continued airworthiness, a so-called Continuous Airworthiness Management Organization (CAMO). The maintenance organization has its main base at Umeå airport and a technical base at Säve airport. The organization has about five employees and is authorised to follow up and maintain small aircraft and helicopters, and to inspect certain components.

In connection with the aircraft operator expanding its fleet to four helicopters, it engaged in the spring of 2008 (about seven months before the accident) a certified technician to be located at the operator’s main base at Hudiksvall. As “Certifying Staff” this technician was authorised to perform inspection work on site but in accordance with directives and instructions from the maintenance organization and under its responsibility.

The operational business means that the operator’s helicopters are based “in the field” for certain periods, far away from the normal bases at Hudiksvall and Umeå. For practical reasons, therefore, sometimes certain types of periodic inspections, such as the 100 hour inspections and some component changes, are carried out on site by the operator’s technician.

1.17.4 *Governing documentation for the technical operations*

The work done by the CAMO is governed by an operations manual for continued airworthiness, called the Continuing Airworthiness Management Exposition (CAME).

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[9] VFR – Visual Flight Rules

Part-145 organizations are governed by an operations manual for the maintenance work called Maintenance Organization Exposition (MOE).

These documents, which must be made by the respective organizations and written in Swedish or English, must be approved by the supervisory authority and, among other things, describe working procedures and quality assurance systems.

1.17.5 *Quality assurance system within the organization for technical maintenance*

The quality assurance system for the technical maintenance is described in the organization's maintenance manual, MOE in Section 3, "Quality System Procedures".

This section describes, among other things, the following:

Deviation reporting
A system for deviation reporting (Occurrence Reporting) must be made and used.

Technical quality meetings
Every quarter of the year, the Quality Manager (QM) of the organization must hold a technical quality assurance meeting (Quarterly Quality Meetings) with the appropriate staff, to discuss procedures and quality standards. The following areas shall be dealt with:

- Occurrence Reports
- Deviations from quality standards
- How to improve maintenance quality
- How to improve maintenance procedures
- Feedback from operators/customers on quality and customer satisfaction/dissatisfaction
- Reports from operators on safety issues and recurring defects
- Staff training needed
- Facility and environmental improvements
- Quality of products from suppliers
- Subcontractor quality
- Tools and equipment – needs, reliability

The QM must keep the minutes of such meetings, and follow up that taken decisions will be accomplished within a prescribed time period.

Internal periodic quality assurance audits
A programme of periodic quality assurance audits (Quality Audit Program) must be made and in use. The results must be documented by the QM.

Internal annual quality assurance audits
A programme of internal annual quality assurance audits must be made and in use. Such audits must, among other things, deal with:

- Outcome of quality audits
- Outcome of SCAA audits
- Revised Part 145 requirements
- Input from staff, presented at quality meetings
- Incorporation of new operators

Approved personnel
An updated list of the pilots and technicians that have been approved by the technical organization to perform specified tasks on the aircraft must have been made. For each employee this list must include:

- Education
- Training
- Work experience
- Type approvals

1.17.6 *Practical application of the technical quality assurance system*

In order to assess how the technical quality assurance system is used in practice, SHK has read the technical documentation and talked to the personnel. During this assessment, the following was found:

Concerning reporting of deviations
Out of the five deviation reports that were presented (covering the period 24 October 2008 to 24 March 2009), one report was analysed from the flight safety viewpoint.

According to information from the pilots, technical mistakes had occurred that had not been reported. As an example, a case was mentioned where the technician at Hudiksvall in connection with changing a component (Epicyclic Reduction Assy) in the helicopters main rotor gearbox incorrectly refitted a component that always must be replaced at this action. This maintenance work is regarded rather complicated but is allowed to be fulfilled by an approved technician. This deviation was noted and could be corrected before the helicopter was in duty but was not documented for further handling according to the organization's MOE

Concerning the technical quality meetings
No minutes or other documentation from any of the technical quality meetings or systematic follow-up of decisions that had been taken have been presented.

Concerning the internal periodic quality assurance audits
The presented documentation indicates that the periodic quality assurance audits were held in accordance with the applicable regulations.

Concerning the internal annual quality assurance audits
No documentation concerning internal annual quality assurance audits has been presented.

Concerning the list of approved personnel
The list of approved personnel does not contain complete information of the employees' education, training or work experience.

1.17.7 *The work situation of the technician*

The technical manager stated that the technician at Hudiksvall had from the outset been allowed to work independently in accordance with the work orders and instructions from the Umeå base. He had been instructed to contact the technical manager in the least case of doubt, at any time of the day or night. The technical manager was aware that the technician, at the beginning of his engagement, had a limited experience of working completely on his own. The manager considered however that he had sufficient experience.

Before the accident the technical manager had not carried out any particular follow-up of the technician's work on site, nor had any regular meetings been held with him in respect of technical problems, working procedures, etc. at the . Except regular telephone contact concerning mainly production business, they had occasionally worked together, and the manager was satisfied with the work done by the technician at those times.

The technical manager stated that he had not received any formal deviation reported from the aircraft operator's pilots concerning the technician's work or concerning the technical maintenance during the previous year.

1.18 Other

1.18.1 CAA PAPER 2003/1 Helicopter Tail Rotor Failures

The British Civil Aviation Authority (CAA) published in November 2003 a report, CAA PAPER 2003/1, Helicopter Tail Rotor Failures, as the result of a comprehensive study that had been carried out in respect of the problems and risks associated with helicopter tail rotor failures.

The background to the study included the fact that it had been found that Tail Rotor Failures (TRF) of different types occurred at a considerably greater frequency than was acceptable in respect of the existing airworthiness requirements, both for civil and military types of helicopter. The failures occurred more often as the result of technical faults than by operational mistakes.

A sudden failure in the tail rotor system is always serious, from a flight safety viewpoint, since it generally requires almost immediate and correct action to be taken by the pilot, to prevent the helicopter from becoming uncontrollable.

The study aimed, among other things, to analyse and map out TRF problems, and to develop recommendations with the purpose of reducing the risks associated with TRF and also reducing their effects.

The report has 255 pages and can be accessed via the Internet at the address *http://www.caa.co.uk/docs/33/CAPAP2003_01.PDF*

Below follows a brief summary:

Types of TRF
TRF can be divided into two main types:

- Tail Rotor Control Failure (TRCF), which means that manoeuvring of the tail rotor blades stops working so that the blade angles will be uncontrolled. Examples of such failures are seizure in the control system or a broken control cable.

- Tail Rotor Drive Failure (TRDF), which means that there is a serious failure in the drive to the tail rotor which more or less ceases to rotate. Examples of such failures are a broken drive shaft or a gearbox failure.

Depending on which type of these tail rotor failures that has occurred, the pilot must control the helicopter to a certain extent in different ways. The pilot must therefore first identify that there is a tail rotor failure and then identify which type it is.

Actions in the case of TRF
The necessary management and control of a TRF can thereafter be divided into three phases:

1. *Transient:* Trouble as a result of the failure and recovery of control over the flight.
2. *Manoeuvring:* Possibilities to manoeuvre the helicopter with the remaining failure.
3. *Landing:* Possibilities to land the helicopter in the failed condition.

The first two of these phases must take place within a few seconds. The third phase also usually requires rapid decisions and actions. The correct management of a tail rotor fault therefore places very high demands on the pilot.

The effects of TRF
Depending on the phase of flight and the type of failure, a tail rotor fault can result in rapid and powerful movements in yaw. These can cause aerodynamic forces that may exceed the structural strength of the helicopter. This type of disturbance is commonly accompanied by pitch and roll movements which can lead to rapid loss of altitude. Powerful pitch and roll movements can also bring about an increased angle of attack of the main rotor disk and thereby the risk of over speeding.

Differences in the effects of TRCF and TRDF respectively depend, among other things, on the fact that a rotating tail rotor in the case of a TRCF may contribute to some extent to the helicopter’s yaw stability even if its blade angles cannot be controlled. If the helicopter has sufficient forward speed this effect can be created by the rail rotor disk with TRCF, together with the tail boom and fin by means of their “weathercock effect”.

In the case of a TRDF, when the tail rotor more or less stops, the tail rotor is assumed not to provide such a contribution that would be meaningful.

Practical tests in helicopter simulators have shown that a helicopter can momentarily yaw by up to 60° if a TRDF occurs while flying at cruising speed, even though the pilot within a few seconds has unloaded the main rotor by pushing the collective pitch down. Yaw disturbances of this magnitude may also result in roll rates of up to 60° and pitch transients. Some types can after TRDF has occurred continue to be flown stable if the helicopter has enough speed forward, while the pilot in other types, independent of speed, immediately must shut down the engine/engines and land with autorotation to avoid the helicopter to rotate and be uncontrollable.

The report contains general recommendations concerning how a TRCF or a TRDF should be managed during different phases of flight.

The development of emergency procedures
It is the responsibility of the type certificate holder to produce relevant emergency procedures for different types of technical failure for their respective types of helicopter. The development and validation of emergency procedures for tail rotor faults cannot, for safety reasons, always proceed with the aid of practical flight testing. The report defines three types of validation methods which are considered usable.

- Type 1: Validation of the method of recovery to safe flying conditions by a manned flight simulation.
- Type 2: Validation of the method of recovery to safe flying conditions by using the best available engineering calculations in combination with manned flight simulation.
- Type 3: Validation of the method of recovery to safe flying conditions based only on aerodynamic and aeronautical engineering calculations.

If the defined emergency procedures are not relevant, the consequences can be catastrophic. The study therefore considers that emergency procedures for TRCF must be produced and validated in accordance with Type 1, and for TRDF at least using the Type 2 method.

There is a large variation between the standards of emergency procedures among helicopter manufacturers and helicopter types. According to the report there are major deficiencies, both in respect of validation and the level of detail.

A total of 36 emergency instructions have been studied in detail. The table below, compiled from the report, shows the percentage of these which contain detailed instructions in various ways:

Detailed instructions	%
Prompt action required to stop rotation about yaw axis	69
Increasing vibration level indicates an impending failure	22
The helicopter's pitch attitude could change following the loss of tail components	14
Speed increase/decrease to improve/reduce fin efficiency	69
Use of main rotor speed to aid control	31
Use of cyclic to control flight path and reduce sideslip	56
Use of collective to control heading	69
Autorotation required	92
Engine(s) must be shut off	61
Possible power and speed combination in forward flight/no possible power and speed combination	53
Fail-safe pitch available	17
Benefits in different wind directions for landing	33
Run-on landing required	69

Training and practice

The study shows the need for pilots to receive training and practice, if possible in a simulator.

These disturbances can, particularly if the pilot reduces the main rotor pitch (*collective pitch*), result in the main rotor speed increasing up to 150 % of its nominal value and thereby expose the rotor blades and hub to high and abnormal loads.

The loss of altitude can exceed 600 feet. Such an event is dramatic and there is a risk that the pilot, even if immediate and correct action is taken, can suffer from spatial disorientation, meaning that he/she will be unable to correctly assess the flight situation.

The effects of a tail rotor fault vary between different types of helicopter. Correct handling on occurrence of a TRF depends to a large extent therefore on which helicopter type is being flown.

Reference is given to the US Federal Aviation Administration's (FAA) prescription Advisory Circular (AC) 120-63[10] in which among other things is recommended the use of training simulators that can be moved in six axes (length, side, altitude, roll, pitch and yaw)

In addition, simulators being used to instruct pilots on how to identify and manage TRF must embody correct and validated simulation models of the failures.

Health and Usage Monitoring Systems (HUMS)

HUMS is an established and within qualified aviation operations a commonly used method of preventing technical failures by continuously monitoring various parameters within systems. By identifying changes in the parameters, possible malfunctions can be revealed and prevented in good time.

Apart from the need to have the necessary knowledge to operationally manage tail rotor failures correctly, the report also points out the need to use HUMS to a greater extent, in order to use technical aids to avoid such failures.

The use of HUMS can prevent tail rotor failures by providing warnings so that a flight does not take place with an incipient fault, or to encourage a pilot to break off the flight before a failure has fully developed. Correctly used, HUMS can also support a pilot in the diagnosis of a fault and provide guidance to taking the correct actions.

The study concludes that 49% of TRDF that have occurred could have been avoided by better utilisation of existing HUMS technology, and a further 15% after further development of this technology.

Technical improvements

The study also points towards the possibility of reducing the risk and effects of tail rotor failures by using new technical solutions. An example of this is by duplicating certain critical components. The introduction of fail-safe

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[10] Web address:
http://rgl.faa.gov/Regulatory_and_Guidance_Library/rgAdvisoryCircular.nsf/0/b56f9f7d967affbb862569e000736080/$FILE/Contents.pdf

arrangements in connection with critical systems could have the effect of reducing the consequences of failures. An example of this is to have the tail rotor blades automatically move to a pre-determined neutral position if a serious fault occurs in the control system.

Recommendations

The report provides a total of ten recommendations, which are briefly listed below.

- Updating and supplementation of existing regulations for the certification of helicopters in respect of the problem of TRF.
- Supplementation of HUMS in respect of TRF.
- Increased use of the existing HUMS in respect of TRF.
- Development of technical solutions in order to reduce the effects of TRF.
- Introduction of automatic speed control for the main rotor in the case of TRCF during the hover.
- Development of deployable aerodynamic devices to provide some additional yaw stability on the case of TRF.
- Use of the Type 1 method to validate emergency procedures for TRCF, and at least Type 2 to validate emergency procedures for other types of TRF.
- Use of at least Level C simulators as defined in US Federal Aviation Administration Advisory Circular AC 120-63. 13, in the case of simulator training for TRF.
- Improvements in the dissemination of information to the affected parties in respect of TRF that have occurred and how these have been handled.
- Obligatory demonstration of TRCF in connection with the basic training of helicopter pilots.

Measures taken by supervising authorities concerning the TRF problems

As a result of the report CAA PAPER 2003/1, the British Air Accident Investigation Board (AAIB) has published the document UNKG -2003-038. In this document CAA is recommended to produce a draft to the affected helicopter manufacturers and authorities of how Flight Manuals for helicopter types with tail rotors shall include a description of TRDF, its effects and how the problem shall be handled.

The CAA PAPER 2003/1 was formally handed over to the European Aviation Safety Agency (EASA) on 21 June 2005 during a meeting in the

Advisory Group National Authorities (AGNA). EASA was at the same time requested to take action following the recommendations in the report.

As a result of this, the following actions have been taken by EASA:

Concerning information to pilots
On 21 October 2010 the bulletin Safety Information Bulletin (SIB) -2010-12R1, "Loss of tail rotor effectiveness (LTE) or unanticipated yaw in helicopters" was published. In the bulletin is discussed general loss of tail rotor effect and unexpected yaw and is also specified what demands should be made on pilots to be able to identify such disturbances. In the bulletin is referred to four other publications which handle these problems more in detail.

Concerning TRCF
With a preliminary start in 2013 a study will begin (Rulemaking Task 27&29.018) with the purpose to study if more regulation actions can be made concerning TRCF.

Concerning TRDF
A study has been initiated (Rulemaking Task 27&29.017 and Rulemaking Task OPS.074) concerning an eventual authority demand in the future to monitor the tail rotor function during operation by measuring vibrations (Vibration Health Monitoring, VHM) The result will be presented in the beginning of 2012.

The Swedish Transport Agency intends to handle the problem with TRF at both meetings with PC-controllers and Chief Pilots seminars and estimates that necessary information in this way will reach all involved organizations.

1.18.2 *Emergency instructions in the case of tail rotor failure in the AS-350 B3 Flight Manual*

Below can be seen the emergency instructions concerning tail rotor failure in the Flight Manual for the AS-350 B3 helicopter:

TRDF

3.3.1 COMPLETE LOSS OF TAIL ROTOR EFFECTIVENESS

Symptom : the helicopter will yaw to the left with a rotational speed depending on the amount of power and the forward speed set at the time of the failure.

WARNING

SAFE AUTOROTATIVE LANDING CAN NOT BE WARRANTED IN CASE OF A FAILURE IN HOGE BELOW THE TOP POINT OF THE HV DIAGRAM (REFER TO SECTION 5) OR IN CONFINED AREA.

3.3.1.1 HOVER-IGE (or OGE in HV diagram)

LAND IMMEDIATELY

1. **Twist Grip** .... **IDLE detent**
2. **Collective** .... **INCREASE** to cushion touch-down

3.3.1.2 HOVER-OGE (Clear area, out of HV diagram)

Simultaneously,

1. **Collective .... REDUCE** depending on available height
2. **Cyclic .... FORWARD** to gain speed
3. Cyclic .... ADJUST to set IAS to Vy and control yaw

LAND AS SOON AS POSSIBLE

If a go-around has been performed, carry out an autorotative landing on a suitable area for landing procedure.

3.3.1.3 IN CRUISE FLIGHT

1. Cyclic .... ADJUST to set IAS to Vy and control yaw
2. Collective...................... REDUCE to avoid sideslip

LAND AS SOON AS POSSIBLE

APPROACH AND LANDING

On a suitable area for autorotative landing :

1. Twist grip .... IDLE detent.
2. Carry out an autorotative landing as landing procedure.

TRCF

3.3.2 TAIL ROTOR CONTROL FAILURE

Symptom : jamming of pedals or pedals effectiveness loss. These conditions induce an inability to change tail rotor thrust with the pedals.

WARNING

LANDING IS MADE EASIER BY LANDING WITH A RH WIND COMPONENT.

WHEN AIRSPEED IS LOWER THAN 20 KT, GO-AROUND IS IMPOSSIBLE DUE TO LOSS OF VERTICAL FIN EFFICIENCY.

1. Cyclic and collective .... ADJUST to set IAS to 70 kt (130 km/h) in level flight.
2. [**HYDR TEST**] or [**ACCU TST**].................... DEPRESS, load compensator depressurizes.

After 5 sec. :

3. [**HYDR TEST**] or [**ACCU TST**].................... RESET in up position.

On a suitable area for a running landing procedure:

Make a shallow approach with a slight left sideslip. Perform a running landing, the sideslip will be reduced progressively as airspeed is reduced and collective is applied to cushion the landing.

TGB Chip Warning

Concerning the metal particle warning for the tail rotor gearbox, *TGB Chip Warning*, the following is stated:

TGB CHIP Metal particles in TGB oil circuit.	**Avoid prolonged hovering** **CONTINUE FLIGHT**

1.18.3 Management of TRF in connection with the basic CPL(H) training

TRCF
The training is usually based on the applicable emergency instructions in the Flight Manual for the helicopter type. Such practice is often only carried out by the instructor simulating various types of failure by "freezing" the pedal position during flight.

TRDF
The training is usually based on possible emergency instructions in the Flight Manual for the helicopter type. In practice the manoeuvring involved cannot be practised while in flight. At the present time, the requirement for simulator training is mainly only applicable to aircraft operators who are engaged in HOSP[11]and SAR[12] operations, and then only in cases where suitable simulators for their helicopter types are available.

1.18.4 Safety management in maintenance operations - general

According to Reason and Hobbs[13], the single greatest fault category in maintenance work is where part of the work has not been carried out. Most often this happens in respect of a procedure in assembly or installation work, such as a system not being locked or secured safely, work has not been documented, material is left over, equipment is not installed, hatches or covers not being closed, a service item not being performed, etc.

The factors which have often been found to give rise to such omissions include interruptions during the task, too much reliance on one's own memory, pressure of work, fatigue, unusual or even routine tasks, and the way the task, tools and procedures are arranged.

The authors provide detailed information on a number of measures at different levels that can reduce the risk of this type of error. It is a matter for example of going through the maintenance steps and procedures in order to identify those places where there is a risk of a step being missed, and rewriting the procedures and/or putting in place effective "reminders". It is also a matter of leadership and organizational measures, with functional routines for the reporting and analysis of mistakes that have not led to accidents, along with constructive use of the information so as to reduce the risks. This is a question of patient, continuous and systematic work.

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[11] HOSP - Ambulance service
[12] SAR - Search and Rescue
[13] Reason J. & Hobbs A. Managing Maintenance Error A Practical Guide. Ashgate Publishing Company 2003

The main message from the authors is that even though the risks of maintenance errors can never be completely eliminated, such risks can be dealt with more efficiently. Maintenance personnel and their managers need to understand why maintenance errors occur, and how the risks involved can be controlled. They say that the most important thing is to acquire a basic mindset.

The authors say that the meaning of such a mindset is as follows: Organizations in businesses with high safety concerns and with few accidents are always conscious of the risks of human, technical or organizational failings. They expect that faults can occur and train their staff to understand, intervene and catch them in time. They work hard to create a reporting culture and make the most of a limited amount of event data. They also “brainstorm” possible event scenarios and have plans for dealing with them.

1.18.5 The supervision by the Swedish Transport Agency

The supervisory authority for Part 145 organizations is the Transport Agency (previously the Swedish Civil Aviation Authority). Apart from authorisation checks this authority performs periodic activity checks on approved maintenance organizations. These mainly consist of checks on the organization’s MOE[14], site visits to inspect the premises and equipment, and meetings with the technical management. Both the review of the MOE and the site inspections take place in accordance with prescribed checklists and are documented. Time plans are determined for the action to be taken concerning any deviations that have been noted, and the authority must thereafter follow up to ensure that any such measures have been implemented in the defined time period.

The latest audit on this particular maintenance organization before the accident was performed in November 2008. A number of deviations in the MOE were discovered during this audit and are noted in the minutes LS-2008-5165. The deviations were corrected within the prescribed time frame. The standard was assessed by the authority as normal for the size of the organization.

At this audit was not noted the lack of documented quality meetings and documented annual quality assurance audits, which among other things are noted in Sec. 1.17.6.

During the interviews with the Swedish Transport Agency staff that was held to describe the Agency’s supervision work it was stated that there was an unbalance between goals and resources at the Airworthiness Department. The working condition for the inspectors was trying. In some case the unbalance was considered so big that supervision of certain operators was suffering and that the demand level in the regulations was not reached as desired, see Sec. 1.19, Measures taken.

[14] MOE- Quality manual (Maintenance, Organisation, Exposition)

1.18.6 The pilot's privileges

An extract from JAR-FCL 2.060 can be seen below:

JAR–FCL 2.060 Curtailment of privileges of licence holders aged 60 years or more

(a) Age 60–64. The holder of a pilot licence who has attained the age of 60 years shall not act as a pilot of an aircraft engaged in commercial air transport operations except:

(1) as a member of a multi-pilot crew and provided that

(2) such holder is the only pilot in the flight crew who has attained age 60

This means that he due to his age was not licensed to perform the planned passenger flight.

1.18.7 Environmental aspects

A certain amount of aviation fuel leaked out from the helicopter wreckage and was absorbed by the ground. This was dealt with by the local authorities.

1.18.8 Equal opportunities aspects

Not applicable.

1.19 Measures taken

1.19.1 Changes of the organization and activities of the Swedish Transport Agency Aviation Department

In the beginning of 2009 the Airworthiness Department's work at the Transport Agency's office in Sollentuna was reorganized. A larger section was divided into two sections with fewer areas of responsibility; one section became responsible for supervision concerning airworthiness and the other for certification concerning maintenance organizations. The purpose with the reorganization was to create better conditions for the new sections' work. Some tasks have been transformed to the main office in Norrköping and other parts of the organization. Furthermore the number of inspectors was increased in the beginning of 2010.

Also a new data based working system has been introduced and a project to coordinate and make the inspection activities more effective has been carried out.

2 ANALYSIS

2.1 History of the sequense of events

2.1.1 The flight

The purpose of the planned flight was to move the helicopter to Stockholm/Arlanda airport, where passengers were to be picked up for a commercial passenger flight. SHK has understood that this particular flight took place as part of that task. Since the air operating company was not authorised for night flying, the flight was performed outside the terms of the company's operational authorisation.

The planned passenger flight from Stockholm/Arlanda airport raises further questions concerning the pilot. As he was more than 60 years old he was not licensed to fly as a single pilot with passengers on a commercial flight.

Certainly these deviations from valid regulations were of no importance for the sequence of events but they can give an indication on a defective safety culture at the company.

In other respects the first part of the flight seems to have been performed in a routine manner and without problems.

2.1.2 The Tail Rotor Drive Failure

The serious tail rotor problem originated rapidly. After the tail rotor metal chip warning system had been activated, the tail rotor gearbox failed within some minute.

The technical examination showed that the tail rotor gearbox had been operating during the entire flight almost without any oil. Just before landing, the gearbox broke due to overheating and the tail rotor successively ceased to rotate. The pilot thereupon was affected by a TRDF, which according to Sec. 1. 18.1 is regarded as the most serious tail rotor failure from a flight safety viewpoint.

This helicopter type with a sprinkle lubricated tail rotor gearbox has, as certain other helicopter types of the same category, no system for measuring oil temperature or oil level in the tail rotor gearbox that during flight can be read by the pilot or activate a warning system.

Regarding the central function of the tail rotor gearbox in the helicopter's control system - and for flight safety reason – it should be some kind of system that could warn the pilot if any shortage of oil occurs.

The only warning system that was available in this case was the gearbox metal chip warning system which primarily is intended to warn of a relatively slow failure sequence, which in the design is extremely unlikely and it is not constructed to work in a situation like this when there is a lack of oil in the gearbox.

The advantage of the metal chip warning system was therefore marginal. When the system was activated the damage in the gearbox was already so severe that a TRDF occurred only some minute afterwards.

2.1.3 Dealing with a metal chip warning

Presence of metal chips in the tail rotor gearbox is normally an indication on a beginning failure that can lead to gearbox break-down if no action is taken in time. Even if it is rare it can, like in this case, also be caused by a sequence of damage that goes fast. It can in general be said that when the metal chip warning system is activated it is not possible to know for certain if it is a slow or a fast sequence of damage.

As mentioned above TRDF always has serious consequences for flight safety. It is therefore the opinion of SHK that it is inappropriate that the Flight Manual for this particular helicopter type when there is a metal chip warning recommends “Avoid prolonged hovering – CONTINUE FLIGHT” i.e. permits continued flight instead of recommending landing as soon as this is practically possible, for example with the text “LAND AS SOON AS PRACTIBLE”.

It is possible that the pilot in this case had been able to perform a safe emergency landing if it had commenced immediately when the metal chip warning was activated.

2.1.4 *The management of the situation by the pilot*

The clockwise (seen from above) rotation of the main rotor creates a yaw force to the left on the helicopter, which is normally balanced, among other things, by the thrust from the tail rotor. Both the pilot’s description of the sequence of events and the descriptions by the witnesses of the flight path of the helicopter show that the tail rotor function gradually diminished within the space of around one minute. The helicopter thus began to yaw in an increasingly uncontrolled manner to the left, despite the pilot finally applying full pedal deflection to the right.

The failure placed the pilot into a highly critical situation. He pushed the cyclic forward and lowered the collective somewhat in order to raise the forward speed of the helicopter and at the same time relieve the load on the main rotor.

Thanks to this manoeuvre the vane effect of the tail rotor/fin increased at the same time as the main rotor torque to the left reduced, which together sufficed to stop the left yaw and to some extent stabilise forward flight, maintaining the heading. By this time the helicopter had flown almost two complete turns to the left after the failure had occurred.

The consequence of this manoeuvre was however that the helicopter, while reducing altitude, left the airport area. Since the pilot adjudged that a possible emergency landing would require some forward speed, this at the same time reduced his freedom of action, since such a manoeuvre required a large landing area in order to succeed.

Finally the helicopter arrived over a wooded area beyond the airport runway system and other flat areas without obstacles. It was therefore relevant that the pilot at this stage abandoned all attempts at an emergency landing and instead concentrated on reducing speed, to put the helicopter down as gently as possible on the underlying terrain.

2.1.5 *The impact*

Even though the pilot, while trying to put the helicopter down, lowered the collective and reduced the engine power, the engine was still delivering power, which resulted in a certain amount of residual yaw moment to the left from the main rotor system.

As the speed reduced, this also reduced the tail boom/fin vane effect which had up to now balanced the yaw moment. As the tail rotor was no longer functioning, gradually the force that balanced the main rotor torque dissipated, which explains why the helicopter once again began to yaw to the left during the final manoeuvre.

As the speed slowed, the yaw rate increased, and the helicopter finally went into an uncontrolled yaw. This rotation became so powerful that the pilot was not able to reach the controls to shut down the engine.

As the helicopter approached the tree tops the pilot raised the collective in order to reduce the descent rate, which still more increased the rotational rate.

Even though the continued descent became uncontrolled, this movement contributed to a reduction in the sink rate, the vertical forces that were exerted on impact with the ground, and their effects.

2.2 Tail Rotor Failure - general

2.2.1 Fault categories

It is generally known in the helicopter branch that most types of faults in the tail rotor system are serious from a flight safety viewpoint. In connection with the investigation of this accident, the attention of SHK has been drawn in particular to the problems associated with TRF, their different characters and consequences.

This event also shows the difficulty for a pilot to quickly identify which type of TRF is involved, and the need to manage the situation promptly and correctly, along with the serious consequences that can otherwise result. In this case it was not possible for the pilot to identify what type of TRF it was and thereby take the correct action according to the Flight Manual´s emergency procedures.

Among other things this highlights deficiencies in the tail rotor system. In many types of helicopter this system is not guarded against failure so that a certain “emergency function” would come into use if a serious failure occurred (failsafe). Many types of helicopter do not have warning systems such as for oil temperature or oil level which could in good time warn the pilot of the onset of a tail rotor failure.

It is the opinion of SHK that the difference between TRCF and TRDF has not been given enough attention by helicopter manufacturers and supervisory authorities. Measures associated with the validation of emergency procedures and the productions of emergency instructions have been poorly managed by certain helicopter manufacturers.

SHK considers that the difference between TRCF and TRDF has not been clarified enough in the emergency checklist for this particular type of helicopter.

2.2.2 CAA study of Tail Rotor Failures

The CAA Paper 2003/1 Helicopter Tail Rotor Failures is the result of a comprehensive study of the problems and flight safety risks associated with TRF. SHK has found the report to be highly relevant, and agrees with all its recommendations.

There are also indications that many helicopter pilots don’t have enough knowledge of the difference between TRCF and TRDF, how they can be identified, their consequences and how they shall be handled.

However SHK can see that the problems with TRF have been paid attention to by EASA as well as by the Swedish Transport Agency as a consequence of both the CAA study and of experiences from this investigation.

It is the opinion of SHK that ongoing and planned activities by the supervising authorities to reduce the risk for TRF-related accidents are relevant and positive.

SHK takes it for granted that all the recommendations will be carefully considered and with high priority in the ongoing work by the authorities and therefore refrain from giving any special recommendation in this respect.

2.3 The Tail Rotor Gearbox

2.3.1 The damage sequence

The technical examinations of the helicopter's tail rotor gearbox, both at the accident site and in the workshop, showed that it had been in operation throughout the accident flight on the whole without oil. There is no indication that oil had leaked out during the flight.

The main purpose of the oil in a gearbox is to prevent metal-to-metal contact between cogs, to reduce friction and to lead away heat from the heat-generating parts. Lack of oil during operation therefore means greater friction, resulting in increased heat generation and poorer cooling.

The absence of oil in the tail rotor gearbox meant that the temperature in the smaller of the two gears in the gearbox, after some time in flight, became so high that its tempering was weakened. The damage to the gear wheel showed that the metal of the cogs finally were worn away under the load to which they were subjected, which led to the break-down of the gearbox.

Once the temperature had risen to a certain level the continued damage sequence probably took place very quickly. The metal chips that were produced, and that were later found in the gearbox, did not reach the chip warning sensor until a late stage. A contributory reason for this was that the chips were unable to reach the sensor in the usual way via the oil, which normally circulates inside the gearbox during operation.

2.3.2 Failsafe aspect

This particular type of fault is "treacherous", in that it does not make its presence known until the flight has been in progress for some time. During flight the gearbox functions in a completely normal manner until the moment when overheating occurs. After this the failure develops very quickly and the pilot has no way of preventing it.

The tail rotor gearbox does not have sensors for oil level and temperature which can be read by the pilot during flight, nor to activate a warning system. The operation of the gearbox is therefore based entirely on having sufficient oil before take-off, and that the oil does not leak out during operation. That the amount of oil is enough at take-off shall be checked by the pilot but during flight it is normally impossible to discover if the oil level becomes too low, for example as a result of leakage.

2.3.3 Oil level measurement

At this particular oil exchange and at the daily check before the accident flight there were deviations from the valid instructions which contributed to the helicopter taking off without filled up oil in the tail rotor gearbox. The determing factor was that the gearbox oil was cold (did not have operating temperature) when draining. Therefore the indication in the sight glass showed a bigger amount of oil due to the capillarity than if the oil had been warm.

Another contribution to the event is the wrong judgement of the oil level that the pilot made during the daily inspection. This was made possible by the current system for reading the amount of oil in the gearbox.

The practical tests carried out by SHK have shown that the oil level in the sight glass, which is supposed to show the amount of oil in the gearbox, is considerably affected by how the helicopter is standing parked.

Depending on whether the helicopter is leaning a few degrees to the left or to the right, the oil level with the same amount of oil may be read as being almost to the MAX limit or to the MIN limit for flight.

Maybe most seriously is that remaining oil after draining, by capillarity, may remain visible on the inside of the sight glass, even after the gearbox has been drained of oil. This can give an impression that the gearbox is filled with oil to some extent.

The importance of the amount of oil being correct before take-off has been described above and it is therefore unsatisfying that the system for checking the oil level can give a wrong visual indication.

Therefore it is the opinion of SHK that there is a good reason to take appropriate measures to minimise the risks that the tail rotor gearbox on this type of helicopter and other helicopters with a similar type of visual measuring system for the oil level are operated with too little oil due to misinterpretation of the level in the sight glass.

2.4 The maintenance organization

2.4.1 Structure:

The structure of the technical maintenance means that both the formal responsibility and the heavier maintenance are contracted to an external Part 145 organization.

On their own responsibility are carried out periodic maintenance and repairs by of the company authorised technicians. The work is performed both at the aviation company’s and the maintenance organization’s bases respectively and “in the field”.

Such a structure is in many cases necessary so that small operators can run their business economically. The geographically spread out maintenance work carries however an obvious risk that the responsible technical manager does not have full control of the work that is carried out in the field, neither of quality nor of quantity respectively of the work.

Such a structure is based on the continuous communication between the maintenance base and its technicians at outstations being very good, and that both parties are fully conscious of which actions may be taken outside the main technical base. The capacity of the maintenance organization is in detail regulated in a capacity list that is continuously reviewed.

2.4.2 Maintenance work

In this particular organization, for more than a half year before the accident, most of the simpler inspections and repairs at the operational base at Hudiksvall were performed by a licensed technician who had newly been engaged by the aviation company. He was relatively inexperienced to work totally alone but was given the responsibility of managing the technical maintenance at the base on his own.

Certainly there were instructions that all the maintenance work should be planned, prepared and ordered by the maintenance organization, but since the assistance from that external maintenance organization cost both time and money, it is close at hand that the technician's ambition was to manage himself as many of the arising tasks as possible.

One example of this is the complicated exchange of a component that the technician, although with the technical manager's blessing, performed on a main rotor gearbox at an earlier occasion, which resulted in incorrect assembly in vital moments. A maintenance structure as above therefore requires a very stringent management and control.

It is the opinion of SHK that the technician did not get the direction and the support that he needed in order to assure the quality of the work he did. It is not enough to refer to the company's written instructions and exhort the technician to "call me" if he came across a problem.

Contributory to this and to the fact that the technician was so soon left to work on his own could have been that he himself thought that he was competent enough to perform the various tasks.

It is always however incumbent on maintenance organizations to assure themselves that all externally working technicians have both the necessary competence and the tools they need to perform all the technical maintenance procedures that are involved. One of the conditions for this is a good working quality system which is well described in the organization's own MOE.

2.4.3 Quality control

Under the heading "Quality System Procedures", the maintenance organization's MOE contains procedures that are described in more detail for deviation reporting, quality meetings, internal quality audits, etc., which shall ensure that all affected personnel have the competence and equipment, and continuously receive the support they need in order to be able to perform maintenance work according to the maintenance documentation, regardless of where it is done.

After talking to the technical management staff and going through the documents that shall reflect the way the quality assurance work is practised, SHK has gained the impression that this is not done in accordance with the organization's own regulations:

- The number of deviation reports is so few that there is a suspicion that the “bar” for which deviations must be reported is set high.

- Periodic technical quality assurance meetings with the personnel involved, during which deviation reports, quality issues, training, equipment, etc. should be discussed have not taken place. That type of meeting seems only to have been held sporadically and without being documented.

- Annual quality audits had not been carried out.

- The list of the company’s authorised technicians was not complete.

SHK is aware that such regulations are difficult to follow in practice with a business that is so geographically dispersed. Adaptation to such procedures forms at the same time the basis for being able in the long term to operate this type of business at the quality and aviation safety levels that are required.

The documented deficiencies above reveal a method of working and a company culture that do not meet requirements that reasonably can be made upon a Part 145 organization and can, according to SHK, have contributed to a such routine moment as filling up oil in a tail rotor gearbox being forgotten.

As all technical deviations probably were not reported the maintenance organization and the detached technician had not satisfactory possibilities to understand and learn from the deviation report system and what actions were needed to avoid repetition.

It can also be questioned if there was a culture where people felt such trust that they dared to admit their own mistakes, which is a necessary condition for a deviation reporting system to work. Contributing to create such a culture is a main task for the organization.

Since enough technical meetings with involved personnel were not held, the organization also missed opportunities to better understand for example which more concrete support the technician needed in his work environment.

Correctly practiced such meetings could also contribute to everyone to build up a fundamental attitude to risk and safety as written above, i.e. to always be aware of human mistakes of different kinds, expect that mistakes can be made and train to understand, prevent and catch them in time and to study different scenarios of events and how to deal with them. (See Sec. 1.18.4)

2.4.4 *Supervision*

It is the responsibility of the Transport Agency to approve Part 145 organizations and to ensure that they live up to the applicable quality requirements.

During the periodic audits that were performed by the inspection authority on the affected Part 145 organizations, this standard has been adjudged as “normal”.

SHK has gained the impression that lack of time and resources at the Agency have meant that in its audits in certain cases the inspectors have only managed to go through the documentation and formal procedures without having enough time to follow up how the routine work was implemented in practice.

During the audit at the technical organization that the Transport Agency made in November 2008 was for example not noted all the defects that SHK found concerning regular and documented quality meetings and quality assurance audits. These are vital functions for the organizations capability to keep the regulated standards.

On the other hand there is a risk that maintenance organizations create documented instructions and procedures mainly to satisfy the authority but in practice operate with other routines. These routines might seem practical and economical but do not guarantee flight safety standards.

The reorganization at the Swedish Transport Agency's Aviation Department that is described in Sec 1.19.1 estimates to result in better conditions for an improved supervision.

2.5 The oil change

2.5.1 Implementation

The technician wrote in the helicopter log book that the running-in oil in the tail rotor gearbox should be changed to normal operating oil. He has related how he emptied the running-in oil out of the tail rotor gearbox and how, as far as he could remember, he replaced the running-in oil by normal operating oil. The technical investigation showed however that there was no filling with normal operating oil, which meant that after the inspection the helicopter had not been restored to an airworthy condition.

The most probable explanation for the fact that refilling did not take place is that the technician, after draining the oil out of the gearbox, intended to fill it with normal operating oil a little later, but forgot to do so. It has not been possible to say with any certainty why he forgot to fill up with oil. In his account of the maintenance work on the helicopter on that day, there were however some conceivable reasons, in the form of disruptions or interruptions to wipe up the oil spill, go for lunch or to telephone in order to find an exchange component for the helicopter.

Experience has shown that the so called prospective memory, "intention memory" of humans is particularly sensitive to interruptions and disruptions. Telephone conversations, interruptions while equipment is being fetched, or to perform a more important task are common reasons to forget to do something that one had intended to do. This applies also to maintenance work, and is one of the most common reasons for mistakes during maintenance (see Sec. 1.18.4).

One way to reduce the risk of this type of forgetfulness can be to provide some sort of "reminder". To, during an oil change as the technical manager practiced, have the habit always to put the oil filler cap in a special way on top of the gearbox, might work as a "reminder". This kind of procedure can be a valuable help.

That the technician as in this case didn't use a "reminder" may depend on his limited experience to work on his own. Having changed the oil before does not automatically mean understanding the risk to forgetting to fill up with new oil and creating a habit to get a reminder. It is something that you learn from your own and others experience and from the knowledge about human errors. It is also something that can be learnt from guidance from and discussions with more experienced colleagues.

The deficiencies that were found in the application of the maintenance organization's quality assurance system can, in SHK's opinion, have contributed to the fact that knowledge transfer of this kind had not taken place to a sufficient extent.

2.5.2 Control moments

After maintenance work has been completed, there is usually some type of checks and certifications. One reason for these procedures is to detect and correct any mistakes and incorrect operations in time.

Follow-up check
A ground running of the rotor system after the oil change was not executed and therefore nor a check of the oil level in the tail rotor gearbox after this moment. This was a deviation from the type holder's instruction and can as mentioned above have contributed to the mistake not being noticed.

Writing in and signing of the completed oil change in the helicopter log book
According to the statement made by the technician he wrote into the log book and signed for implementation of the oil change after he had checked that the cover was secure and placed a note next to the sight glass with information on which oil he had changed to. These two actions were consequently not done in immediate connection with the oil change but as part of the after-check that the covers had been secured.

The technician imagined that he had changed the oil in the tail rotor gearbox, why writing and signing executed oil change in the log book didn't work as a check. It can be discussed if a routine to sign the oil change in the log book and exchange the note with oil type immediately in the connection with the oil change had given better opportunities to discover that oil had not been refilled.

The later preparation and securing of the DYMO label with information on the type of oil also probably contributed to the fact that the existing label on the tail rotor gearbox itself was still present, with the information that it contained OPTIGEAR 32 running-in oil.

Check of the oil level in the tail rotor gearbox during the daily inspection
The fact that there was no oil in the tail rotor gearbox was not discovered during the daily inspection of the helicopter before flight. The technician did not carry out the daily inspection, since he thought that it would be better to have it done by another authorised person to secure the independence.

An independent check, i.e. a check carried out by another person and/or by another method, is generally considered to be more effective than self-checking after maintenance work (see for example previously presented work by Reason & Hobbs). It can be added that both an independent check and a self-check are considered to be less effective than checks in the form of functional testing and technical solutions (see for example Hobbs A. An Overview of Human Factors in Aviation Maintenance, Australian Transport Safety Bureau, December 2008).

The helicopter pilot, who was authorised to perform daily inspections on the helicopter, noted on his visual check in the sight glass that there was oil in the gearbox. The level appeared to be low but he judged that it was acceptable for that particular flight. The deficiency in the design of the sight glass, as described in Sec. 2.3.3, contributed to this assessment.

It is the opinion of SHK that many factors can have influenced the pilot's judgement. After draining the gearbox, remaining oil can have stuck to the inside of the glass giving the impression that there was oil. As the check was made with mounted marshalling wheels and the level indication is depending on the helicopter's inclination the pilot can have got the impression that the oil level was acceptable. His judgement was probably also influenced of the log book that stated that there had been an exchange to new oil, that the helicopter had not been flown since then and that there was no sign of leaking oil.

In spite of these circumstances there can be a sign of lack of safety culture by the pilot and the organization that the flight was commenced with a noticed oil level in the tail rotor gearbox that likely was very low or even below the minimum level.

2.6 Rescue services

SHK has found that the rescue services operated in accordance with the areas of responsibility and procedures that were applicable.

2.7 Medical information

2.7.1 The pilot

On impact with the ground the forward speed was low and the descent rate high. There are strong indications that the deformation of the cabin in combination with the energy-absorbing capability of the pilot's seat dampened the impact and contributed to the pilot survived the accident with minor personal injury.

In respect of the medical status of the pilot, it was found that he had begun medication for high blood pressure some weeks before the accident without an aviation physician or the Transport Agency Aviation Department being aware of this, which deviates from the regulations in JAR-FCL 2.040. During a check-up by an aviation physician one week after the accident occurred, the pilot's blood pressure was so unsettled that a medical certificate for flying could not be issued until several weeks later, when after adjustment of medication his blood pressure was under control.

Nothing however has arisen to indicate that the problem with the pilot's high blood pressure and the recently started treatment would have affected the way that he managed the event.

During the investigation of this accident it has come out that there is in general poor knowledge among personnel with a demand on a medical

certification for aviation work and physicians who do not have competence in aviation medicine of which rules apply in JAR-FCL concerning illness and the establishment of treatment.
There is therefore reason for EASA to in a suitable way inform these categories on valid regulations concerning illness and medical treatment in order to reduce the potential risk that accidents could occur for medical reasons.

3 CONCLUSIONS

3.1 Findings

a) The aircraft operator did not have authorisation to perform this particular flight.
b) The pilot was not authorised to perform the planned passenger flight.
c) The helicopter had a valid Certificate of Airworthiness.
d) In connection with a 100 hour inspection, performed in direct association with this particular flight, there were several deviations from the TC holder´s instruction concerning change of oil in the tail rotor gearbox.
e) The pilot wrongly read the oil level in the tail rotor gearbox at the daily inspection.
f) The flight was performed with the tail rotor gearbox drained of oil.
g) The tail rotor gearbox failed during flight due to the lack of oil.
h) There had been deficiencies in the management and quality assurance control of the technical maintenance.
i) There had been deficiencies in the Transport Agency's inspection of the maintenance organization.
j) This type of helicopter has no system for measuring oil level and temperature in the tail rotor gearbox that can be read by the pilot during flight or activate a warning system.
k) The visual indication of the oil level in the tail rotor gearbox is imprecise and can be misinterpreted.
l) The pilot did not declare an emergency to the air traffic control.
m) The emergency instructions for this type of helicopter give insufficient support to the pilot for the management of a chip warning or a TRDF respectively.
n) The problems of TRF and the difference between TRCF and TRDF have not been given enough attention by helicopter TC Holder and supervisory authorities.
o) The medical status of the pilot was not correctly reported in accordance with JAR-FCL 2.040.

3.2 Causes of the accident

The accident was caused by the helicopter not being restored to an airworthy condition after maintenance work had been carried out. A contributory factor was deficiencies in the quality assurance management by the maintenance organization.

The consequences of the maintenance error were aggravated by deficiencies in the emergency instructions for this type of helicopter in respect of the management of a chip warning or a TRDF respectively.

4 RECOMMENDATIONS

It is recommended that EASA:

- strives for a review of the emergency checklists for the affected types of helicopter so that landing is recommended as soon as practically possible when the chip warning system for the tail rotor gearbox is activated *(RL 2011:14 R1)* and to

- considers suitable measures to minimise the risk of misinterpretation of the oil level in the tail rotor gearbox on this particular type of helicopter, and on other helicopters with similar visual measuring systems *(RL 2011:14 R2)*