

Investigation Report

Identification

Type of Occurrence:	Accident
Date:	5 December 2012
Location:	Neustädter Bucht
Aircraft:	Helicopter
Manufacturer / Model:	Eurocopter / AS 350BA
Injuries to Persons:	Pilot and system operator fatally injured
Damage:	Aircraft severely damaged
Other Damage:	None
Information Source:	Investigation by BFU
State File Number:	BFU CX024-12

Factual Information

During a ferry flight with an AS 350BA helicopter from Germany to Sweden radar and radio contacts were lost in the area of the Lübecker Bucht (Lübeck Bay). After a search lasting for several days the helicopter and the bodies of the crew were found in the area of the Neustädter Bucht (Neustädt Bay) and subsequently recovered.

History of the Flight

Since February 2012, the Norwegian operator conducted laser scanning measuring flights with AS 350 helicopters in Norway, Sweden, Denmark and Germany for a Swedish contractor. On 16 November 2012 the measuring flights in Germany began. Due to several flight cancellations caused by the weather, the measuring flights in Germany should be stopped for 2012 and the helicopter was to be flown back to Norway.

On the day of the accident at about 1345 hrs¹ the pilot took off from Lübeck Airport (EDHL) for a ferry flight to Halmstad (ESMT), Sweden. He was accompanied by a system operator. In Halmstad the additional mission equipment was to be removed and periodic maintenance work on the helicopter was to be conducted before continuing the ferry flight to Norway.

For the flight to Sweden the pilot had filed a flight plan. It stated a cruising speed of 100 kt and Visual Flight Rules (VFR) as altitude without any explicit route. Flight time to Halmstad (ESMT) was given as two hours. The flight time to the border to Denmark was given as 10 minutes and to Sweden as one hour and 40 minutes. The flight plan listed three hours as maximum endurance.

After he had left the control zone the helicopter flew with a northern heading toward the western coast of the Neustädter Bucht. According to the radio transcript the pilot established radio contact with Bremen Information (125.10 MHz) at 1352 hrs. His attention was called to a temporary restricted area in the area of Sierksdorf Special Airfield (EDXT) straight ahead. The flight information service recommended passing it either to the right or left. The pilot suggested flying east toward Fehmarn. At that time a transponder signal of the helicopter was no longer recorded and the flight information service called the pilot's attention to the fact that only a primary signal could be seen on the radar screen. The pilot said he would switch the transponder off and on again. He once again asked for the extent of the restricted area and how far east he would have to travel to fly round it. The flight information service recommended flying across the Lübecker Bucht toward the town Grömitz. The pilot acknowledged it and turned east after he had once again received the information that the restricted area was directly ahead of him. At 1357 hrs the flight information service informed the pilot that now not even a primary signal was visible on the radar screen and traffic information could no longer be provided. At 1357:30 hrs the pilot

¹ All times local, unless otherwise stated.

transmitted an unintelligible sentence with an excited voice and then radio contact ceased.

Radar equipment of the Bundeswehr (German Armed Forces) recorded the last primary signal of the helicopter at 1357:47 hrs coming from approximately the middle of the Neustädter Bucht (N54°02'44" E010°50'45") with a heading of 084°.

After radio contact had ceased the flight information service tried several times to re-establish contact either directly or by asking other aircraft to serve as relay stations. Once it became clear that these attempts were futile and it was suspected that an accident had occurred, the search and rescue service was notified at about 1431 hrs. The search for the helicopter and the two occupants began.

On 13 December 2012 the helicopter and the crew were found in a depth of about 20 m on the seabed of the Neustädter Bucht. The two deceased were found on the seabed about 50 m and 67 m, respectively, away from the helicopter.

On 14 and 15 December 2012 the pilot and the system operator as well as the helicopter were recovered, after the site under water had been documented.

Personnel Information

The 27-year-old pilot held a Norwegian Commercial Helicopter Pilot's License issued in accordance with JAR-FCL 2. It was initially issued on 27 May 2007 and valid until 2 February 2016. The license contained the type rating as Pilot in Command (PIC) for AS350/B3/EC130B4. He held a class 1 medical certificate issued in accordance with JAR-FCL 3, with the restriction to wear glasses (VDL and RXO); it was valid until 1 December 2013.

He had become an employee of the Norwegian operator in April 2008. Initially he worked as load master during fire-fighting missions with helicopters. In addition, he flew as PIC Under Supervision (PICUS) for about 390 hours. Since February 2012 the operator deployed him as PIC.

The Norwegian operator stated his total flying experience was about 530 hours; since May 2007 most of them on AS 350 helicopters.

The system operator was 32 years old. He was an employee of the Swedish contractor. During the entire time of the measuring flights in Germany he had been deployed together with the pilot.

Aircraft Information

The single-engine helicopter AS 350B manufactured by Eurocopter (formerly Aerospatiale) is a lightweight multi-purpose helicopter for up to six occupants. It was certified according to FAR/JAR Part 27 in 1977. The model AS 350BA was certified in 1991. It is equipped with a Turbomeca Arriel 1B engine, a Star Flex three-blade main rotor, landing skids and a tail rotor for anti-torque. The tank has a volume of 540 litres. Maximum take-off mass of the model AS 350BA is 2,100 kg. When transporting a jettisonable external load on a cargo hook it is 2,250 kg. The manufacturer stated that until the end of 2011 3,931 AS 350 helicopters were produced. Together they had a total operating time of about 18,880,000 hours.

In normal operation (394 rpm of the main rotor) the tail rotor has about 2,086 revolutions per minute (rpm). It is powered by a two-part tail rotor drive shaft. The drive shaft consists of a forward, short steel shaft and a rear longer multiple mounted aluminium alloy shaft. The two drive shafts are connected to each other by means of flexible couplings and a splined shaft for length compensation. In normal operation and during autorotation the drive shaft rotates with about 6,125 rpm. The tail rotor drive shaft runs above the tail boom to the tail rotor gear box. It is covered by a fairing consisting of several segments.

The rate of descent for the AS 350BA in case of an autorotation is approximately 1,800 ft/min at an airspeed (minimum rate of descent) of about 65 kt.

Since 2011, a simplified flight data and image recorder is part of the standard equipment of AS 350 delivered helicopters in the USA. Since 2013, this equipment is also part of the standard equipment of AS350 helicopters in France assembly lines. For the retrofit of all AS 350 delivered before these dates, a certified (FAA, EASA) STC is available.

The accident helicopter was built in 1978 and had the manufacturer's serial number 1017. It was delivered as a B-Version and in 1995 it was converted into a BA-Version. The empty weight was about 1,275 kg. The last airworthiness inspection was conducted on 20 September 2012. On 8 November 2012 at a total of 12,941 operating hours the last release to service was issued after a maintenance check (W.O. 9) including a prescribed periodic visual inspection of the engine. At the time of the accident, the helicopter had a total of approximately 12,970 operating

hours. The helicopter was registered in Norway and operated by a Norwegian operator.

The helicopter was equipped with a so-called Saab TopEye™. This consisted of a cargo container below the fuselage between the skids and a computer rack in the rear cabin. The Swedish Modification Certificate No. *M1/95, Rev.5* existed for the additional mission equipment. According to the owner of the additional equipment it weighed about 220 kg. The flight manual supplement for flights with installed TopEye™ (Supplement for TopEye™, No. 8081 001-102 and -103) stated the weight of the equipment with about 336 kg. The supplement stipulated a maximum airspeed (VNE) of 105 KIAS. The airspeed in normal cruise is reduced by about 30 KIAS due to the higher aerodynamic drag. The rate of descent during an autorotation is therefore approximately 150 ft/min higher. With the TopEye™ electrically connected, operation with emergency floats is not possible

The following items were found aboard the helicopter: Personal effects of the pilot and the system operator (estimate 30 kg), different documents (5 kg), a crate filled with oil cans and a can of 1 litre anti-ice fuel additive (15 kg), a battery charger (6 kg), an external power cable (3 kg), a portable external power battery (26 kg), transport wheels attachable to the skids (44 kg), rotor blade socks and engine cover (3 kg), a toolbox (5 kg), a bag with ropes for external loads (9 kg), an external drum fuel pump (26 kg), several cases for memory mediums and other additional equipment for the mission (11 kg). Further, the helicopter was equipped with a set of mirrors for external load transport and the skids were fitted with so-called bear paws. The total mass of the helicopter with all the mentioned items, the TopEye™ equipment and a filled fuel tank without the crew was about 2,110 kg.

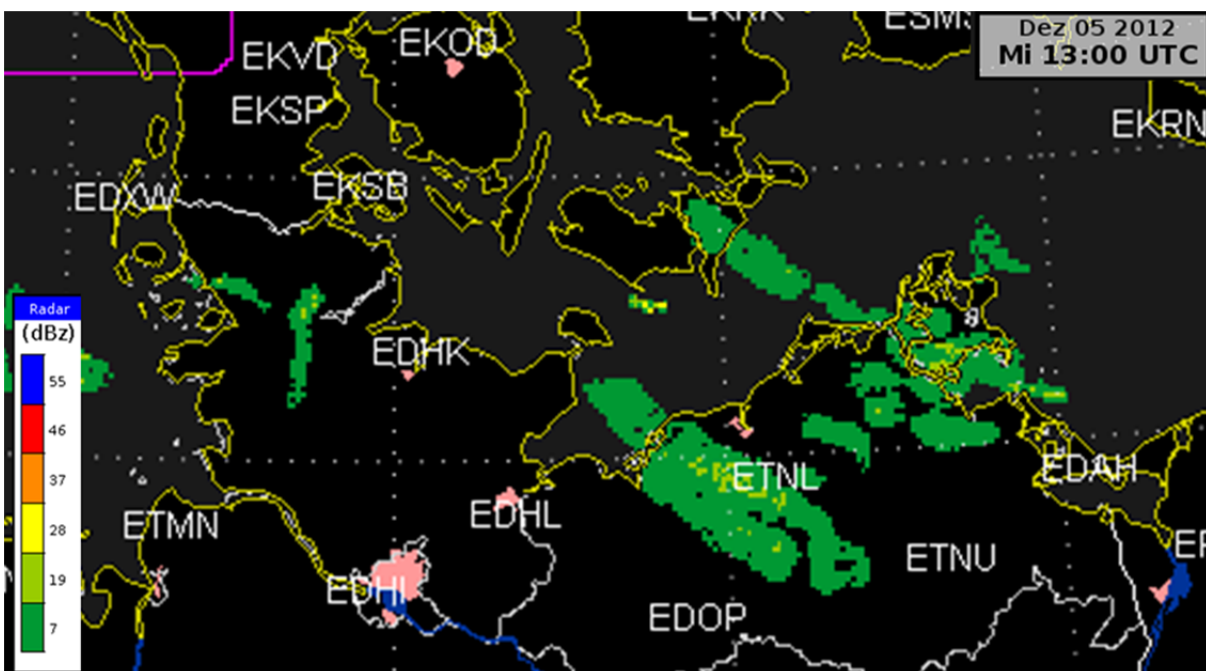
According to the aircraft logbook the helicopter was completely filled with fuel on 3 December 2012 for the flight from Braunschweig to Lübeck. The flight time was one hour. On the day of the accident the helicopter was refuelled at Lübeck Airport with 191 litres Jet A-1 fuel and prior to take-off the rotor blades had been de-iced with 63 litres de-icing fluid.

The helicopter was not equipped with emergency floats. Life vests were not found in the helicopter.

Meteorological Information

According to the Meteorological Aviation Report (METAR) of Lübeck Airport (EDHL), at the time of the accident visibility was more than 10 km, no clouds below 5,000 ft (CAVOK), wind from 280° at 8 kt, temperature was -2°C and dewpoint -6°C. Air pressure (QNH) was 1,001 hPa.

The radar precipitation pattern of the Deutsche Wetterdienst (German meteorological service provider, DWD) did not show any precipitation in the area of the Neustädter Bucht. The precipitation east of the Lübecker Bucht moved toward the south-east.



Radar image at the time of the accident

Image: DWD

The Bundesamt für Seeschifffahrt und Hydrographie (BSH) (Federal Maritime and Hydrographic Agency) stated the water temperature at the day of the accident was about 4°C.

In Neustadt, Holstein, sunset was at about 1555 hrs. In Halmstad, Sweden, the destination airport, it was at about 1532 hrs.

Aids to Navigation

The operator had provided an iPad including mounting for pre-flight preparation and navigational support which was aboard the helicopter.

Communication

Radio communications between pilot and Lübeck Tower on 3 December 2012 and on 5 December 2012 and with Bremen Information on 5 December 2012 have been made available to the BFU for evaluation purposes as transcripts and recording, respectively.

According to the transcript of Lübeck Tower (128.70 MHz) there was no transponder signal from the helicopter between take-off and leaving the control zone. At 1351:32 hrs, after the pilot had passed reporting point November in 500 ft and requested to leave the frequency a transponder signal was received for a short time. The tower informed the pilot accordingly.

The Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile (French civil aviation safety investigation authority, BEA) as well as the BFU conducted a spectral analysis of the background noise recorded during radio communications between the pilot and Bremen Information. BFU and BEA conclusion was that the spectral analysis was not conclusive regarding the operation of the propulsion system. BEA analysed that the main rotor rpm was normal during the three first messages (Bewel Gear frequency). There was no significant frequency relative to the power train in the last message (the previous frequency was missing).

Several people tried to interpret the last radio communication of the pilot. Contradictory interpretations were the result. Subsequently the BFU asked the Institut für Nachrichtentechnik (Institute for Communications Technology) of the Technische Universität Braunschweig for support. Their analysis of the last radio communication did not offer an unambiguous result either. The following analyses / interpretations were heard or a technical result: „*hope we have a great xxx*, or *xxx xxx we are going stuck*, or *xxx xxx we are going south*“. The investigator in charge heard: "*I hope we have a break shaft*", investigators of the French and Norwegian air accident investigation authorities heard: "*We are going down*".

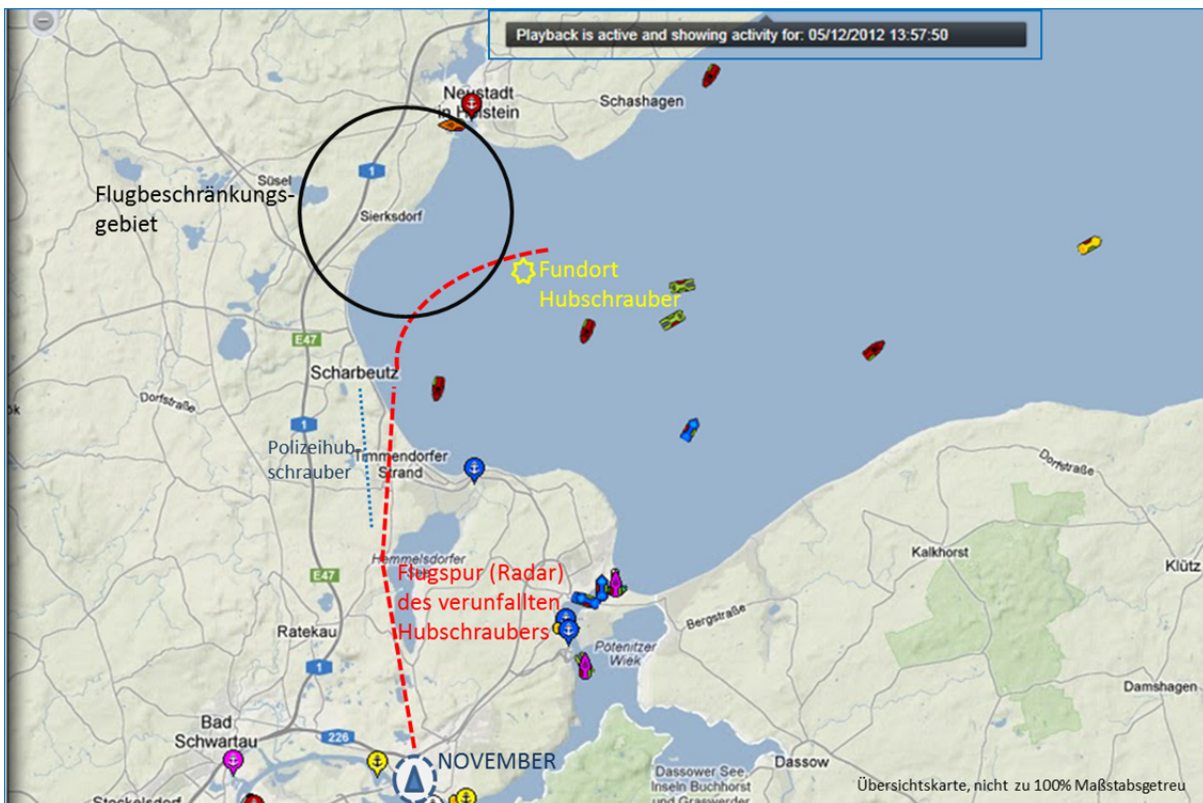
Information on the Aerodrome of Departure, the Temporary Restricted Area and the Location of the Wreckage

According to the statements of the operator and the analysis of the radio communications, the helicopter landed at Lübeck Airport (EDHL) on 3 December 2012 due to worsening weather conditions along the flight path for the ferry flight. Until 5 December 2012 the helicopter was parked on the apron in front of

hangar B. Lübeck Airport has a control zone with exit point November in northern direction.

The Aeronautical Information Publication (AIP) SUB VFR 18 (ENR) of 29 November 2012 stated that in the area around Sierksdorf a temporary restricted area will be established between 4 December 2012 and 6 December 2012 (NFL I-294-12). It had a radius of two Nautical Miles (NM) around the coordinates N 54°04'25" E 010°46'40" and extended from the ground up to Flight Level (FL) 100.

The so-called Neustädter Bucht is the north-west part of the Lübecker Bucht. This area of the Baltic Sea is often used by the Bundesmarine (German Navy) for military training. The water is up to 20 m deep. The distance to cross the Neustädter Bucht from the town Niendorf in the south to the Lighthouse Neustadt in the north is about 6.5 NM. Here the maximum distance to shore is about 3.6 NM.



Overview of the Neustädter Bucht including the positions of the ships and a police helicopter at the time of the accident
 Image: Google Maps™ / Shipfinder / BFU

Flight Recorders

The helicopter was not equipped with a Flight Data Recorder (FDR) or a Cockpit Voice Recorder (CVR). There were no legal aeronautical requirements for such equipment to be fitted.

Several video cameras at Lübeck Airport have recorded the loading, refuelling, de-icing and the engine start-up until lift-off of the helicopter. The video data was made available to the BFU for evaluation. The recordings show that the helicopter had been covered with a layer of frozen and crusted snow which could not simply be brushed off. The pockets of the rotor blade socks were frozen to the blades. The pilot needed several minutes to free each rotor blade from its blade sock. After the luggage had been stored the upper surface of each rotor blade was brushed off by hand and afterwards de-iced. Prior to engine start-up the pilot walked around the helicopter and also removed the cover of the engine air intake. Additional opening of maintenance compartment doors and the engine cowling could not be identified. During refuelling no anti-ice fuel additive was added by the pilot.

The iPad found in the helicopter was made available to the BFU. It was not possible to read out the data possibly stored in the iPad.

Wreckage and Impact Information

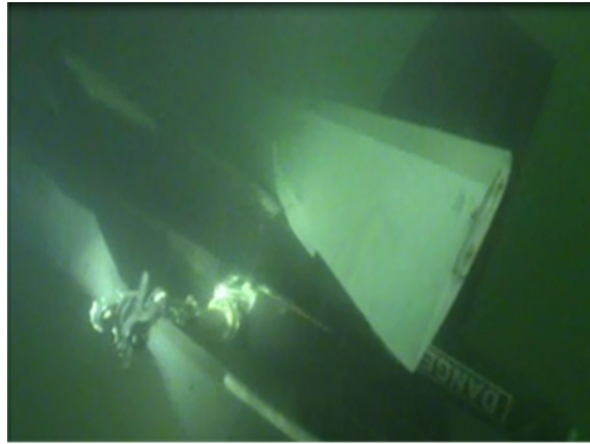
The accident occurred in the area of the Neustädter Bucht. The helicopter was found at N 54°02'39" E 010°50'33"; approximately 253 m south-west of the last radar recording and more than 4,600 m from the nearest coast. The two dead people were found about 50 m and about 67 m, respectively, east of the helicopter.

The helicopter was lying on the seabed of the Neustädter Bucht on its main rotor hub, tilted right toward the left fuselage side. The tail boom had been severed and was found next to the fuselage beneath the skid cross beam opposite to the fuselage direction with the horizontal stabiliser horizontally on the ground and the tail skid pointing upward. One of the main rotor blades jutted out and pressed down on the tail boom prior to the vertical fin with its trailing edge. In this area the trim edge of the rotor blade was damaged. The right cabin door, the safety belts on the seats front right and rear right were open. On the left front seat one of the two transport wheels attachable to the skids was fastened with the seat belt.

Fuselage and tail boom were recovered individually of each other.



Fuselage lying on its side with open cabin door and tail boom



Photos (2): Navy / Police

Investigation on the Recovery Ship

After the fuselage had been recovered it was determined that all maintenance compartment doors and fairings were closed and secured. The cabin's front windows and the window panes on the right side and the door were intact. The window panes of the left side were pushed inside the fuselage. The left bottom window pane was missing. The left lower fuselage side and the area of the front skid cross tube were pushed in. The front part of the TopEye™ cargo container was pushed in and torn open.



Fuselage after recovery



Photos (2): BFU

The main gear box, the engine, the control units and the hydraulic system did not show any apparent damages after the mud had been washed off. The fuel control lever was locked in position "flight". Of the three main rotor blades only the "yellow" showed slight damages in the area of the trim edge and the "red" blade had a bent tip at the end of the blade. On the rotor head the Star Flex to all three blade grips was

torn off. The power transmission from the turbine to the drive shaft, main gear box and main rotor shaft was connected. The free-wheeling unit opened and locked as designed. The sheet metal of the fracture area on the aft fuselage section where the tail boom had been torn off was dented on the underside, the right side was warped and the left stretched. The forward tail rotor drive shaft protruded from the aft fuselage section.



Damages on the aft fuselage section and the Star Flex rotor head

Photos (2): BFU

The forward flexible coupling of the tail rotor drive shaft on the engine's backside was torn. The fairing in this area and the two half shells surrounding the forward end of the drive shaft showed rotation tracks, were torn out of their mountings and damaged.



Damages on the forward coupling of the tail rotor drive shaft

Photos (2): BFU

On the rear end of the tail rotor drive shaft the flexible coupling was pushed in, the flanks of the flanges were bent and one flange was torn off. On the outer side of the

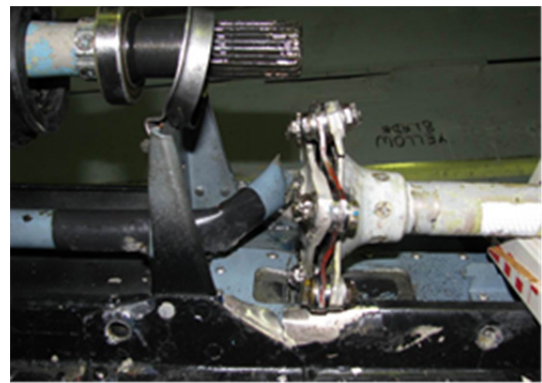
splined flange rotation tracks were found. The securing nuts were deformed and the washers were partially jaggedly pushed in.



Damages on the rear coupling

Photos (3): BFU

After the tail boom was recovered it was determined that the tail rotor was undamaged. Soot and combustion residue had not been washed off the tail rotor. One of the two pitch links was slightly bent. Except for the most forward tail rotor drive shaft fairing all segments of the fairing were intact. The rear tail rotor drive shaft could be turned soundlessly and without resistance. The tail rotor gear box transmitted the rotation and the tail rotor turned. The chip detector of the tail rotor gear box was free of chips. The tail rotor gear box was filled with water. The foremost segment of the tail rotor shaft fairing was milled from the inside out in the area of the flexible coupling. The foremost three quick release fasteners on the left side were torn out. The inside of the fairing showed straight scratch marks stretching from the milling groove to the forward fairing opening. The tail rotor drive shaft was sent to France to the manufacturer for further investigation under BEA supervision.



Damages on the forward tail rotor drive shaft fairing and coupling

Photos (3): BFU

Additional Investigation on Land

After the helicopter was recovered it was taken to Neustadt, Holstein. The BFU examination of the helicopter was supported by representatives of the French civil aviation safety investigation authority (BEA), the helicopter manufacturer Eurocopter, and the engine manufacturer Turbomeca. Among other things, the engine was examined by borescopy and the Fuel Control Unit (FCU) removed for further examination at facilities of the manufacturer. During disassembly of the FCU a contaminated inlet fuel filter was found (particles and a kind of jelly). The engine was examined on site and no indications for mechanical damage or an operations failure were found.

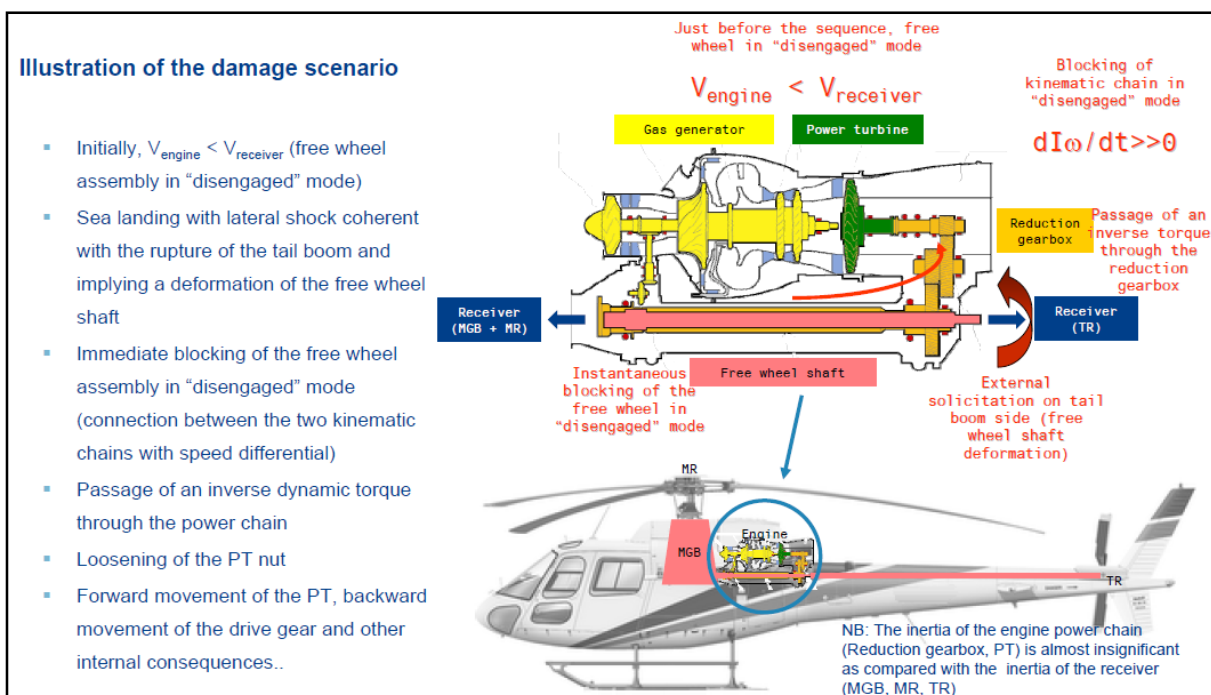
The helicopter was transported to Braunschweig and there the airframe fuel filter was examined. It was determined that no filter element had been installed in the fuel filter housing. The last documented maintenance and check of the fuel filter occurred in February 2012; about 227 operating hours ago. A visual inspection of the fuel sump of the helicopter did not show any indication of contamination. Approximately a third of the tank was filled with sea water.

On 8 January 2013 the FCU was examined at Turbomeca facilities in the presence of BEA representatives. It was determined that the contaminated fuel filter (particles still there but the jelly much less present, almost dry) did not impair fuel regulation when

compared with a new fuel filter. The FCU functioned in accordance with the manufacturer specifications. The FCU was subject to a maximum life cycle of 10 years (calendrical) from the first date of entry into service. The last overhaul of the FCU had occurred on 13 May 2002 and the first date of entry into service was 26 June 2002, as had been documented in the respective log card.

On 12/13 February 2013 the helicopter, the control system, the gear box, the engine and the fuel system were once again examined in the presence of representatives of the helicopter and engine manufacturers and the BEA. No indications for a mechanical failure of the fuel system or other technical failures were determined. Subsequently, the engine was dismantled for further investigation at facilities of the engine manufacturer.

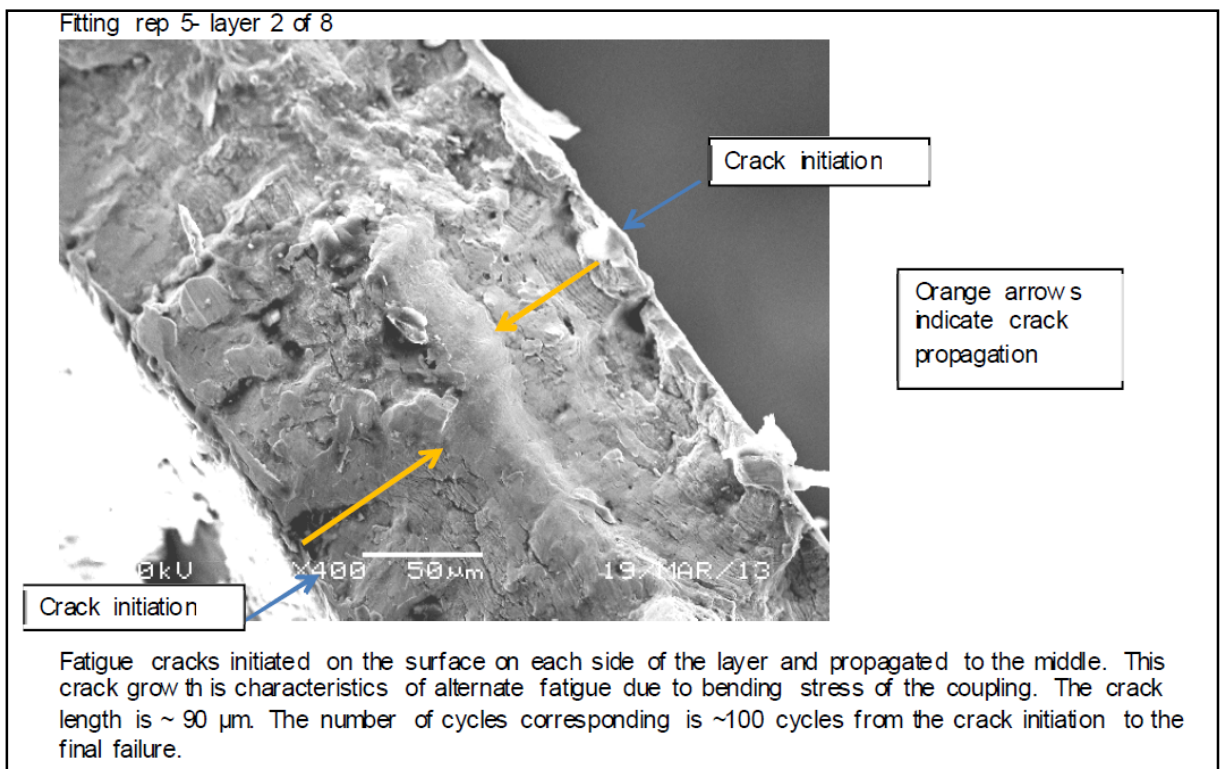
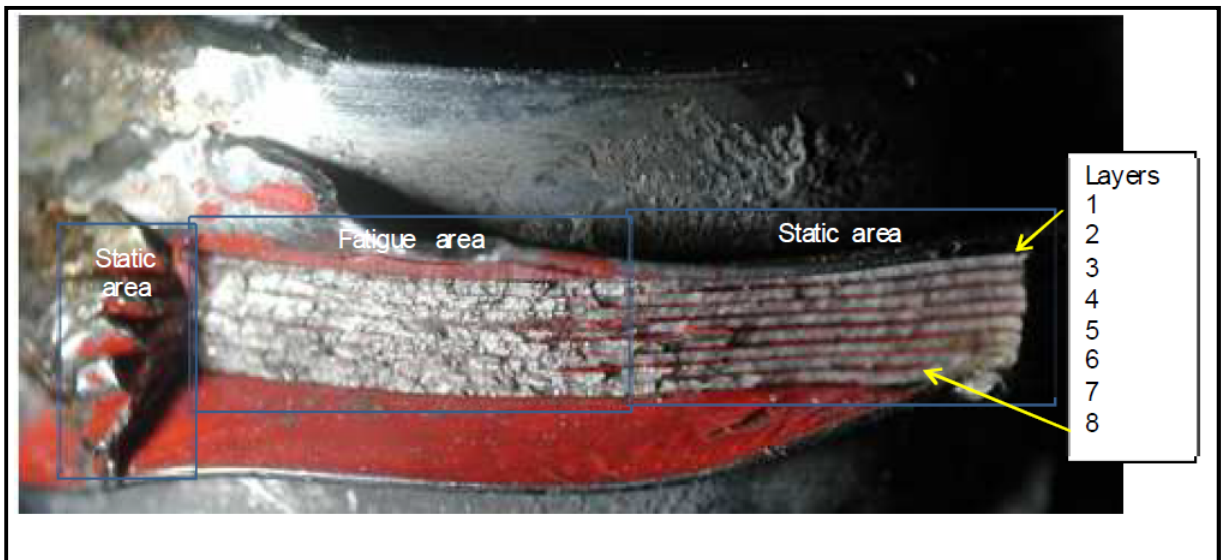
In the presence of BEA representatives the engine was fully disassembled and examined at Turbomeca facilities. The result was a 44-page investigation report detailing the damages found on the engine component. They were assessed to be consequences of the accident. The findings were: the free wheel sprags showed severe damage in the disengaged state, the aft part of the free wheel assembly was deformed, the power turbine (N2) splined nut was loose, and the power turbine showed light contact marks in the 8 - 11 o'clock position. Two teeth on the non-working flank of the reduction gearbox show contact marks. These findings allow the following conclusions:



Excerpt engine investigation report

Source: Turbomeca

The tail rotor drive shaft with the splined shaft was examined at Eurocopter facilities under BEA supervision and a 24-page report prepared. The results were that the flexible coupling discs partially showed fatigue and forced fractures. Due to the size and dimension of the fatigue fracture striations the final fracture occurred after about 100 cycles.



Excerpts (2) from report of the examination of the tail rotor drive shaft

Source: Eurocopter

The damages on the flexible coupling and the flanges of the aft part of the front tail rotor drive shaft can be traced back to the separation of the splined shaft due to elongation (the tail boom was bent downward during ditching) with the shaft still rotating until the front part of the coupling failed.

The Bundeswehr Research Institute for Materials, Explosives, Fuels and Lubricants (WIWEB) examined fuel samples taken from the fuel tank and the airframe fuel filter. The result was that both samples were Jet A1 fuel. In both samples diethylene glycol monoethyl ether (anti-icing agent) was found. The sample taken from the tank which was clearly contaminated with sea water, showed 0.006 % VA whereas the sample from the closed airframe fuel filter showed 0.694 % VA. An additive portion of 0.10 - 0.15 % VA is normal. A jelly-like substance could not be found in the samples. In 2010, Eurocopter issued the Information Notice IN 2145-I-28 to inform customers of the risk to exceed the recommended anti-icing concentration: *You must avoid exceeding the dose of anti-icing additive. The recommended concentration is sufficient to prevent fuel icing phenomena from occurring on a helicopter. An excessive concentration of additive can rapidly cause helicopter fuel filter clogging [...].* Anti-ice additive manufacturer point out the importance of careful mixing the fuel with the icing inhibitors. *Just pouring the product in the tanks will result in insufficient mixing and separation of the inhibitor and the fuel.* Anti-ice additives have nearly the same specific gravity than water. As water, after a while they will settle on the bottom of the fuel tank.

The filaments of the caution panel were examined. An elongation of the filaments in individual lamps which would have indicated illumination of warning lights during ditching could not be proven.

Medical and Pathological Information

The two bodies were subject to post mortem examinations. It was determined that the cause of death was hypothermia in combination with drowning. There were no injuries due to the emergency landing on the water.

Fire

There was no fire.

Survival Aspects

Search and Rescue

About 34 minutes after radio contact with the helicopter was lost the Search and Rescue Centre Glückstadt (SAR) was notified. The SAR Glückstadt requested the filed flight plan and called each airport along the suspected flight route asking for the missing helicopter. An emergency locator transmitter signal of the helicopter was not intercepted. At 1455 hrs it was confirmed that RCC Copenhagen did not have any contact with the helicopter. At 1647 hrs the SAR helicopter in Warnemünde was notified. At 1735 hrs two helicopters (Bundeswehr (German Armed Forces) and Bundespolizei (German Federal Police)) reached the search area. At about 2115 hrs the search was aborted due to worsening weather conditions.

In the following days several ships and aircraft participated in the search for survivors and wreckage parts. On 6 December 2012 a backpack was found on the beach of the northern shore of the Neustädter Bucht. It could be clearly related to one of the occupants of the helicopter. Other pieces of luggage or parts of the helicopter were not found. On 7 December 2012 the search was interrupted to discuss other options. On 10 December 2012 the Bundesmarine (German Navy) made available for the underwater search: the minesweeper "Passau" equipped with sonar and one autonomous submarine of the REMUS family with side scan sonar and mine divers. From 11 December 2012 on two BFU staff members were aboard the "Passau" supporting the crew in the interpretation of the information regarding the course of the flight and the determination of the search area. In addition, the crew received extended information regarding the helicopter to support the interpretation of the sonar images.

After the helicopter had been located, an area of 500 x 500 m surrounding the site was searched with the autonomous submarine. The two occupants were found about 50 m and 67 m, respectively, away from the wreckage on the seabed. The BFU staff members switched to the multi-purpose vessel "Scharhörn". On 14 December 2012 and 15 December 2012 they supported the "Scharhörn" crew and the police divers in the preparation and execution of the recovery of the two people and the helicopter. Immediately after the recovery of the helicopter it was cleaned with fresh water. Subsequently, the BFU staff members conducted an initial examination of the helicopter. On the evening of 15 December 2012 recovery work was completed.

Survival in Cold Water

A study of the United States Search and Rescue Task Force states that depending on the physical condition and without protective clothing one has approximately 15 to 30 minutes until exhaustion or loss of consciousness occur with water temperatures of 0 - 4°C. Overall survival time is given with 30 - 90 minutes.

The study of the Institute of Naval Medicine, University Portsmouth (Golden and Henry 1981), states that there are different stages during a plunge into cold water with a temperature of less than 15°C. Stage 1 is the plunge reflex and cold shock. Within the first 3 - 5 minutes danger of drowning is imminent due to reflexive breathing under water, reduced ability to hold one's breath and uncontrolled quick breathing. Stage 2 is the incapability to swim due to hypothermia of the muscles and nerves close to the skin. Within 3 - 30 minutes drowning due to failure of the muscular power and skill is possible. Stage 3 is hypothermia. Hypothermia of the body results in drowning due to loss of consciousness or cardiovascular failure.

Protective clothing or life vests were neither found aboard the helicopter nor were the two recovered people wearing any.

The operator stated that three life vests should have been aboard the helicopter.

Tests and Research

The manufacturer Eurocopter conducted tests on a fuel test bench due to the missing filter element in the helicopter's fuel filter. By comparing the two scenarios of missing and present filter element, it was to be determined whether a missing filter element has any negative effect on the operation of the turbine due to the presence of potential residual air which could lead to bubble formation in specific conditions. The test determined no indications for adverse effects on the fuel supply for the engine except that there was the contamination hazard of the FCU, the hoses and nozzles because the fuel is not filtered.

Organisations and their Procedures

The operator of the helicopter was certified in Norway in accordance with JAR OPS 3 for commercial air transport and had an operation permit for Aerial Work in accordance with the national regulations BSL D 2-2. The company was one of the largest inland helicopter operators in Norway. Its main office was located in Trondheim, Norway. The company had additional offices in Norway. A total of 23

helicopters were operated, including several AS 350. The company had its own maintenance organization certified in accordance with EASA, Part 145 and in general it conducted all maintenance work in its own facilities.

The flights in Germany including all ferry flights were aerial work operations.

The Luftfahrt-Bundesamt (German civil aviation authority, LBA) issued an entry permit valid from 5 November 2012 to 31 December 2012 for the flights in Germany.

According to statements of the operator, the deceased pilot was briefed to fly back via Denmark by crossing the Little and Great Belts as they had done on the incoming flight to Germany. From the perspective of the operator the planned flight was not a flight over water and therefore no additional equipment was needed or even possible due to the limitation of the TopEye™ equipment.

The operator's Flight Operations Manual Part A Chapter 8 contained all aeronautical regulations (JAR-OPS 3 and BSL D 2-2) for flights over water with helicopters of the performance class 3 and category B procedures. In addition, the Flight Operations Manual Part A Chapter 8.1.13.2 stipulated that all crew members should not just have a life vest at hand but wear it during all flights over water.

Additional Information

On a direct flight from Lübeck to Halmstad the Fehmarnbelt would have had to be crossed. At the narrowest part the Fehmarnbelt is about 11 NM wide. A flight altitude of approximately 9,000 ft AGL would be necessary for an autorotation over a distance of 5.5 NM. On this route additional short flights over water, between Denmark and Sweden, would have been necessary to reach Halmstad.

Aeronautical Regulations regarding Helicopter Flights over Water

The Norwegian civil aviation authority published the Aeronautical Information Circular (AIC-N) 30/10 on 2 November 2010 regarding "Flights with helicopters over water". It included all aviation regulations valid in Norway at the time of the accident (JAR OPS 3 for commercial air transport and BSL D 2-2 for aerial work) for flights with helicopters over water.

JAR-OPS 3.540 ff stipulated for single-engine helicopters (flight performance class 3) that the conduct of the flight was to be planned and conducted in a way that an emergency landing in case of engine failure is possible at all times. According to

JAR-OPS 3.825: *An operator shall not operate a helicopter for any operations on water or on a flight over water:*

(1) When operating in Performance Class 3 beyond autorotational distance from land. According to JAR-OPS 3.825: (2) ... is equipped with life jackets equipped with a survivor locator light, for each person on board, ... According to JAR-OPS 3.827: (b) An operator shall not operate a helicopter in Performance Class 3 on a flight over water beyond autorotational or safe forced landing distance from land when the weather report or forecasts available to the commander indicate that the sea temperature will be less than plus 10°C during the flight, unless each member of the crew is wearing a survival suit. According to JAR-OPS 3.830: (1) In the case of a helicopter carrying less than 12 persons, a minimum of one liferaft with a rated capacity of not less than the maximum number of persons on board; JAR-OPS 3.843 states: (d) An operator shall not operate a helicopter in Performance Class 3 on a flight over water beyond safe forced landing distance from land unless that helicopter is; so designed for landing on water; or is certificated in accordance with ditching provisions; or is fitted with emergency flotation equipment.

BSL D 2-2 item 9.2 reads (approximate translation by the CAA-NO): *To the extent possible, flights in single engine helicopters over water should be avoided. Except from this are helicopters equipped with floatation gear, when the sea conditions are such that a safe forced landing can be performed.* These regulations also require life vests with lights to be carried. Flight over water in this context, means flight over each open water area, which is of such size, that the distance to land exceeds a safe forced landing on land dependent on the flight altitude and glide ratio.

In Germany there are similar regulations in the Third Executive Order for the Regulation on Operation of Aircraft (3. DV LuftBO) para 22 and para 23 also for so-called aerial work and non-commercially operated helicopters over water.

Analysis

Helicopter Pilot

The pilot was properly licensed. His flying experience was still relatively low. He was at the beginning of his flying career. It is highly likely that the task to conduct measuring flights over an extended period of time alone in Germany including the respective ferry flights through different countries was still a challenge for the pilot. It is to be assumed that the relatively inexperienced pilot was under supervision of more experienced colleagues or the head of operations and had been in contact with either by telephone. It is certain that the company knew about the planned flight path.

Planning and Conduct of the Flight

The distance between Lübeck and the destination Halmstad was approximately 190 NM. In the flight plan the pilot gave a flight time of two hours for this distance. It is highly likely that a direct flight without significant deviations was planned because of the speed limitations due to the installed TopEye™ (VNE 105 KIAS). Landing in Halmstad before sundown (sun set at 1532 hrs) was no longer possible because of the delayed take-off (1345 hrs) due to the de-icing procedure. A more or less direct flight path would have taken them over water several times.

The pilot contacted Lübeck Tower and reported passing reporting point November of the control zone in 500 ft. It is likely that the helicopter remained in this low altitude. This would explain why the air traffic service organisation lost radar contact with the helicopter south of the Neustädter Bucht. The Bundeswehr stated that in the area of the Neustädter Bucht the military radar extended down to about 30 m AGL. At the day of the accident the flight information service did not have this radar data available.

Technical Aspects

The examination of the accident helicopter allowed drawing several conclusions. Due to the intact fuselage a controlled ditching with little forward motion has to be assumed. The almost undamaged main and tail rotor blades imply reduced rpm at the time of contact with water. The undamaged drive shaft and flexible coupling between engine and main gear box and the fracture surface of the Star Flex on the rotor head indicate either a severely reduced or entirely missing engine thrust. The manufacturer documented a total of 31 ditching incidents of the same helicopter type with or without engine thrust and some of them showed considerably more damages.

In general, whenever engine thrust was present, the drive shaft and the rotor blades were either severely damaged or destroyed.

The engine test conducted by the manufacturer indicated that at the time of ditching and bending of the tail boom the free-wheeling unit was disengaged. This would mean that the engine had failed or its rpm was less than that of the power transmission between main and tail rotor. The missing damages on the engine compressor and the N1 and N2 turbine blades support the assumption that during ditching the engine did not produce full thrust or high rpm.

Damages and deformations on the fracture surface of the tail boom prove that during ditching the tail was bent downward before it separated probably on contact with the sea bed in the Neustädter Bucht. Because the tail was bent downward the short tail rotor drive shaft slipped off the splined coupling and because it was still powered by the main gear box it caused the damages in the area of the coupling. The helicopter manufacturer had various photos of damage scenarios available for comparison purposes.

The examination of the tail rotor drive shaft and the flexible coupling determined that the front flexible coupling discs showed fatigue fractures after about 100 cycles due to excessive deformation before the coupling failed. This matched the probable course of the accident after ditching.

By comparing possible technical problems with contingent effects on the course of the flight, the conclusion was drawn that a power problem must have caused an inevitable ditching. There was neither a fire, nor were there metal chips in the main gear box, nor did turning of the gear box indicate any technical malfunction. With all other possible problems there would have been sufficient time to at least try to reach the coast about 5 km away; provided that the pilot had reacted correctly. If engine failure is assumed at approximately 500 ft AGL, the pilot would have had only a few seconds until contact with the water because of the autorotation rate of descent of about 1,800 ft/min, the mass of the helicopter and the increased drag due to the TopEye™ equipment below the fuselage.

The recorded radio contact proves that the pilot was confronted with a drastic technical problem. He was able to conduct a controlled ditching by adhering to an emergency procedure. Both individuals were able to leave the helicopter uninjured.

Survival Aspects

The two persons on board suffered death due to hypothermia and drowning. Contributing factors were lack of adequate survival equipment in combination with the late notification and arrival of rescue organisations.

The valid aeronautical regulations - in Germany and Norway - stipulated the following for single-engine helicopters and flights over water outside the autorotation distance to shore and a water temperature of less than 10°C: life vests, survival suits, life rafts and emergency flotation equipment. The operator's flight operations manual included all valid aeronautical regulations in regard to the survival equipment.

Since the flight information service had received an unclear radio communication from the pilot and was therefore left uncertain as to what had happened possible rescue actions were delayed. The defective transponder and the subsequently missing radar target even before radio contact ceased left flight information service and the search and rescue service in the dark as to what had happened to the helicopter. Initially it was not clear whether the helicopter had crashed or ditched or if it was simply a loss of contact with a low-flying helicopter. Valuable time was wasted. A clear emergency call or Mayday call would have informed flight information service. It would have been possible to inform SAR right away and conduct a search at the correct location, in the area of the Neustädter Bucht. Even though a police helicopter, a naval vessel and fishing and police boats were in the vicinity, no one noticed or reported the accident and therefore no help could be provided.

Flight Operations Aspects

It is highly likely that the weather had not influenced the course of the flight. It was a clear winter day; visibilities were good, there was no precipitation in the area of the accident site. At the time the technical problem occurred the wind came from behind. Since the helicopter was found south-west of the last recorded radar target it can be concluded that the pilot tried to turn into the wind.

The weighing of the on-board equipment showed that in addition to the installed Topeye™ equipment, the helicopter had been overloaded during take-off, the first part of the ferry flights and probably also during the local measuring flights until the fuel burn had reduced the weight. According to the aircraft log book take-off always occurred with a full fuel tank. The helicopter was neither weighted nor was the Centre of Gravity (CG) re-calculated after the Topeye™ equipment had been installed. A weighing would have been important because the weight of the actual Topeye™

equipment did not comply with the data provided in the Supplement. The BFU is of the opinion that a useful flight planning concerning the actual aircraft weight and the CG in regard to the very limited additional loading capacity with a full fuel tank was not possible. The installed cargo container below the fuselage cannot be compared to a jettisonable external load on the cargo hook in the centre of gravity of the helicopter. The BFU is of the opinion that the maximum take-off mass was therefore not increased to 2,250 kg.

The investigation further determined that the helicopter was formally not airworthy because the filter element in the airframe fuel filter unit was missing and the life span of the engine fuel control unit had expired.

The portion of anti-ice agent in the fuel sample of the airframe fuel filter unit was considerably higher than normal. The source of the anti-ice agent could not be identified. The video of the refuelling process prior to take-off in Lübeck showed that no additive was added. The laboratory conducting the test and the helicopter manufacturer had examples where an excessive concentration of additive may cause jelly-like deposits which then cause problems with the filters. While dismantling the engine fuel control unit a jelly-like substance was found. During the FCU bench test with the contaminated inlet fuel filter no anomalies were detected. The amount of jelly and its consistence were less than at the time the FCU was removed from the wreckage.

The helicopter and engine manufacturers and the BEA are of the opinion that it is highly likely the loss of engine thrust was due to engine fuel starvation. The fuel starvation was caused by the missing fuel filter element, excess of anti-ice additive which created a jelly-like substance. The increased fuel viscosity reduced the fuel flow at the FCU inlet strainer.

The investigation of this accident was very complex since there were no witness statements, no technical findings which could unambiguously be determined and no objective recorded data. It was not possible to read out the data which might be stored in the pilot's iPad. With helicopters who remain below the requirement for flight data recorders due to weight or number of seats, the accident investigation is missing objective data for analysis. The BFU is of the opinion that all helicopters should be equipped or refitted with simple flight data recorders. Equipment and technical solutions are available and certified.

Conclusions

The air accident was caused by reduced engine thrust which did not allow holding the altitude and because of the flight route and altitude the shore could not be reached. The cause for the engine failure could not be determined with absolute clarity.

Contributory factors regarding the severity of the accident were the missing survival equipment, the winterly weather conditions and delayed rescue operations.

Safety Recommendation

Recommendation No 09/2014

The Norwegian civil aviation authority (Luftfartstilsynet) should, in its role as supervisory body of the operator involved, ensure that the flight organisation in regard to planning and conduct of flight as well as the maintenance organisation adhere to the relevant aeronautical regulations and the operational and maintenance procedures stipulated by the manufacturer and maintenance work is carried out correctly.

Investigator in charge:	Axel Rokohl
Field investigation:	Thomas Kostrzewa, Axel Rokohl
Assistance:	Philipp Lampert, Thomas Karge, Dietmar Nehmsch, Uwe Berndt
Braunschweig:	14 August 2014

This investigation was conducted in accordance with the regulation (EU) No. 996/2010 of the European Parliament and of the Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation and the Federal German Law relating to the investigation of accidents and incidents associated with the operation of civil aircraft (*Flugunfall-Untersuchungs-Gesetz - FIUUG*) of 26 August 1998.

The sole objective of the investigation is to prevent future accidents and incidents. The investigation does not seek to ascertain blame or apportion legal liability for any claims that may arise.

This document is a translation of the German Investigation Report. Although every effort was made for the translation to be accurate, in the event of any discrepancies the original German document is the authentic version.

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Bundesstelle für
Flugunfalluntersuchung
Hermann-Blenk-Str. 16
38108 Braunschweig

Phone +49 531 35 48 - 0
Fax +49 531 35 48 - 246

Mail box@bfu-web.de
Internet www.bfu-web.de