Investigation report

C1/2009L

Helicopter collision with the ground at Pyhäselkä on 5 February 2009

Translation of the original Finnish report

OH-HWH

Hughes 369D

Onnettomuustutkintakeskus
Centralen för undersökning av olyckor
Accident Investigation Board

Osoite / Address:	Sörnäisten rantatie 33 C FIN-00500 HELSINKI	**Adress:**	Sörnäs strandväg 33 C 00500 HELSINGFORS
Puhelin / Telefon: **Telephone:**	(09) 1606 7643 +358 9 1606 7643		
Fax: **Fax:**	(09) 1606 7811 +358 9 1606 7811		

Sähköposti: onnettomuustutkinta@om.fi tai etunimi.sukunimi@om.fi
E-post: onnettomuustutkinta@om.fi eller förnamn.släktnamn@om.fi
Email: onnettomuustutkinta@om.fi or first name.last name@om.fi

Internet: www.onnettomuustutkinta.fi

Henkilöstö / Personal / Personnel:

Johtaja / Direktör / Director	Veli-Pekka Nurmi
Hallintopäällikkö / Förvaltningsdirektör / Administrative Director	Pirjo Valkama-Joutsen
Osastosihteeri / Avdelningssekreterare / Assistant	Sini Järvi
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Johtava tutkija / Ledande utredare / Chief Rail Accident Investigator	Esko Värttiö
Erikoistutkija / Utredare / Rail Accident Investigator	Reijo Mynttinen
Vesiliikenneonnettomuudet / Sjöfartsolyckor / Marine accidents	
Johtava tutkija / Ledande utredare / Chief Marine Accident Investigator	Martti Heikkilä
Erikoistutkija / Utredare / Marine Accident Investigator	Risto Repo
Muut onnettomuudet / Övriga olyckor / Other accidents	
Johtava tutkija / Ledande utredare / Chief Accident Investigator	Kai Valonen

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Translation R&J Language Service

SUMMARY

HELICOPTER COLLISION WITH THE GROUND AT PYHÄSELKÄ ON 5 FEBRUARY 2009

An accident occurred at Pyhäselkä on Thursday, 5 February 2009 at 12:46. A Hughes 369D helicopter, registration OH-HWH, collided with the ground on a power line sawing flight. The pilot, who was the sole occupant in the helicopter, sustained minor injuries. The helicopter was destroyed. On 16 February 2009 Accident Investigation Board of Finland appointed investigation commission C1/2009L for this incident. Investigator Juhani Hipeli was named Investigator-in-Charge, accompanied by Investigator Hans Tefke and Captain Juha Kepsu serving as members of the commission. Mr. Hannu Kokkonen, a teacher of aircraft maintenance, was designated as technical expert to the commission.

The helicopter was equipped with a topping saw (heli-saw) weighing 302 kg and hanging 17 metres below the helicopter. Following its previous flight the helicopter was refuelled while the engine was idling. At this time it was noticed that the N_1 idle RPM was 61%, whereas according to the flight manual the desired value is 64–65%. After an engine runup and pilot change it was decided that the aircraft could take off again. After ten minutes of treetop trimming in hover the engine suddenly lost power. In the sudden, unexpected circumstances the pilot's only option was to steer the helicopter into the woods. When the helicopter hit the ground it tipped over onto its left side. On the ground the pilot was unable to turn the engine off. The pilot reported the accident to the flight's supervisor by radio after which he managed to get out the helicopter on his own.

When the helicopter's engine was inspected, it was detected that the bearing of the Gas Producer Fuel Control Unit was broken. Laboratory tests concluded that the bearing failed due to insufficient lubrication of the spool bearing. Tests established that the grease that was used as the lubricant met the requirements and that the materials used in bearing components met their requirements. The investigation aimed at determining the factors that possibly contributed to the insufficient lubrication of the bearing. While four possible factors were determined, none of them could be definitively confirmed or eliminated. The investigation also called attention to the fact that the RFM's N_1 idle RPM requirement was not followed when the decision was made to take off again. The N_1 idle RPM that was lower than the desired value was possibly a symptom of a defect that was already present before the flight.

The accident was caused when the bearing of the Gas Producer Fuel Control Unit failed due to insufficient lubrication. The malfunction of the Fuel Control Unit caused a sudden loss of engine power that resulted in an emergency landing in which the helicopter was destroyed. Possible causes for degraded lubrication could be attributed to shelf life, a flaw or impact damage that prevented the bearing from retaining its lubrication, wear due to continuous fuel scheduling variations due to hovering operations, or a manufacturing flaw resulting from an insufficient amount of lubricant. None of the aforementioned factors could be definitively confirmed or eliminated.

The decision to take off again even though the N_1 idle RPM was not within the flight manual's limits was a contributing factor. It is highly likely that the N_1 idle RPM that was lower than the desired value was a symptom of a defect that was already present before the flight.

The investigation commission made no safety recommendations.

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ABBREVIATIONS

cl/dl	centilitre/decilitre
CPL (H)	Commercial Pilot Licence (Helicopter)
FAA	Federal Aviation Administration
FCU	Fuel Control Unit
GPS	Global Positioning System
HE	Honeywell Engineering
hPa	hectopascal
kg	kilogramme(s)
lb	pound
m	metre(s)
N_1 RPM	Gas producer speed
N_2 RPM	Power turbine speed
N_R RPM	Rotor speed
NTSB	National Transportation Safety Board
OTKES	Accident Investigation Board of Finland
Pc	Compressor discharge air pressure
PTG	Power Turbine Governor
Px	Acceleration bellows pressure
QNH	Altimeter sub-scale setting to obtain elevation when on the ground
RRC	Rolls-Royce Corporation
UTC	Coordinated universal time

SYNOPSIS

An accident occurred at Pyhäselkä on Thursday, 5 February 2009 at 12:46 (all times in this report are in Finnish time, UTC+2h). A Hughes 369D helicopter, registration OH-HWH, collided with the ground and was destroyed while trimming treetops with a topping saw along a power line. The helicopter was owned by the Swedish Malmskogens Aerocenter AB and operated by the Finnish Heliwest Oy. The pilot who was the sole occupant in the helicopter sustained minor injuries. Hughes Helicopters Inc. manufactured the helicopter in 1980.

On 16 February 2009 Accident Investigation Board of Finland appointed investigation commission C1/2009L for this incident. Investigator Juhani Hipeli was named Investigator-in-Charge, accompanied by Investigator Hans Tefke and Captain Juha Kepsu serving as members of the commission. Mr. Hannu Kokkonen, a teacher of aircraft maintenance, was designated as technical expert to the commission.

During the inspection of the helicopter's engine, it was established that the Fuel Control Unit bearing had failed. On 5 June 2009 the investigation commission sent both of the engine's control units for thorough inspection to the United States. This inspection was conducted through collaboration with Honeywell Engineering (HE), the manufacturer of the units, and the Rolls-Royce Corporation (RRC), representing the engine manufacturer. At the behest of the National Transportation Safety Board (NTSB) a representative of the Federal Aviation Administration (FAA) supervised the testing. The investigation report was completed on 2 September 2009. Following this, HE and RRC continued to pursue the root causes of the FCU's bearing failure. The associated Investigation Closure Summary was issued on 13 September 2009.

The investigation report was translated into English.

The investigation commission requested comments on the draft final report from TraFi Aviation, Finavia Oyj and from HE and RRC through the NTSB, as well as from concerned parties. The comments were received by 8 March 2011 and they did not change the draft.

The investigation was completed on 9 March 2011. The material used in the investigation is stored at Accident Investigation Board of Finland.

1 FACTUAL INFORMATION

1.1 History of the accident flight

1.1.1 Events before the flight

The pilot's first flight of the day with the helicopter was a ferry flight from Imatra to Pyhäselkä. This flight lasted 1 h 15 min and the landing at the temporary landing strip at the tree trimming site occurred at 09:50. The ground crew had already prepared the topping saw which they then attached to the helicopter. Power line clearance was beginning in the Pyhäselkä area. A topping saw is used to trim overly long branches along the edges of power lines. A topping saw is a petrol-powered circular saw that has two horizontally assembled blades, each of which is approximately one metre in diameter. The operating height of the saw, including the suspension bar, is approximately 17 m and its total weight is 302 kg. For the purpose of this aerial work the left cabin door was replaced with a door that was narrow at the bottom and bulbous at the top. The pilot is able to thus monitor the suspended saw through the bubble. In order to determine the height of the cutting line two video cameras were attached to the suspension bar of the topping saw. Their displays were attached to the canopy frame in front of the pilot. On line sawing flights the helicopter is flown from the left seat.

The pilot and the company's flight operations manager, who supervised and trained the pilot on line sawing flights, had lunch before starting the aerial work. The flight operations manager flew the first flight from 11:25 to 12:31. As part of his own training, the pilot observed the heli-sawing from the ground, together with the assistant quality controller.

Following this flight the helicopter was refuelled while the flight operations manager sat in the cockpit with the engine at idle. At this point in time the flight operations manager noticed that the N_1 idle RPM was 61%. According to his statement he took note of the nonstandard value because normally it was between 63-64%. He then tested the engine by raising the RPM to flying power. The RPM did not change when cockpit heating, engine anti-icing and the generator were switched off. Nor did the RPM change when the generator was switched back on. The flight operations manager and the pilot discussed the nonstandard idle RPM and noted that the N_1 idle RPM had been 63-64% on both of the previous flights that day. The abnormal RPM did not result in any action; following this the pilot took over.

1.1.2 Events on the flight

Takeoff occurred at 12:36. Soon after takeoff the pilot focused his attention on the slight fluctuation (*yawing*, according to the pilot) of the rotor speed indicator (N_R). The pilot radioed the flight operations manager who had flown the previous flight and asked him whether he had noticed any such oscillation. When he received an affirmative answer from the flight operations manager he flew on to the starting point of the line sawing op-

eration, approximately 5 km north-northwest of the temporary airstrip. The pilot had not noticed any fluctuation of the N_R RPM display on the first flight of the morning.

The pilot commenced the line sawing at 12:41 by trimming the treetops on the left side of a 110 kV power line in the approximate heading of 140°-160°. The flight operations manager, supervising the operation, and the quality controller arrived at the site by car in order to monitor the pilot's aerial work. From the ground it seemed that the work was proceeding without problems. Approximately five minutes into the line sawing the pilot heard the ENG OUT audio warning, indicating an engine flameout and low rotor speed. Immediately after this he noticed that the N_R RPM was dropping. According to his account he tried to increase engine RPM by lowering the collective lever a little and by opening up the throttle. The throttle, however, was already fully open. Due to the loss of engine power the helicopter lost altitude. The pilot managed to steer it into the woods on the left side of the power line.

As the helicopter made contact with the ground it turned to the right towards the power line and tipped over onto its left side. All of the main rotor blades broke off close to the hub when they hit the ground. The suspension bar was bent into an arc between the helicopter and the topping saw. When the helicopter tipped over the pilot's head was pinned between the ground and the helicopter's structures. However, he managed to get his head loose. Due to the attitude of the helicopter and an injury to his left hand he was unable to turn the engine off from the collective lever. He could not turn off the Fuel Shut-off Valve because of how tight it was and because his hands were slippery. The engine was left on and as the rotating mast kept turning the stubs of the main rotor the blades dug a hole into the ground. After the pilot unbuckled his safety harness he left the cockpit through the broken windshield.

The accident occurred at 12:46. There were no eyewitnesses. As the sawing operation was progressing forward the flight operations manager drove his car to a turnaround spot, from where he could not see the helicopter. When he returned within about a minute he could no longer see the helicopter. He called the helicopter by radio, to no avail. He also called the temporary airstrip so as to find out whether the helicopter had returned there. A moment later the pilot reported that an accident had occurred. At 12:49 the flight operations manager reported the accident to the Emergency Response Centre.

Figure 1. The helicopter following the accident.

1.2 Injuries to persons

The pilot sustained injuries to his head and his left hand.

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

1.3 Damage to aircraft

The helicopter was destroyed.

1.4 Other damage

A few small and medium-size trees were damaged when the helicopter collided with the ground. Additionally, trees had to be felled around the helicopter during the clearance operation.

1.5 Personnel information

Pilot: Age 51.

Licences: Commercial Pilot Licence Helicopter CPL (H), valid until 2 November 2012.

Medical certificate: Class 1, valid until 26 June 2009.

Ratings: All required ratings were valid.

Flying experience	Last 24 hours	Last 30 days	Last 90 days	Total hours and landings
All types	7 h 9 landings	7 h 9 landings	55 h 117 landings	5005 h 14193 landings
Type in question	7 h 9 landings	7 h 9 landings	40 h 101 landings	600 h 500 landings

The pilot's flying experience with external load encompassed 1100 hours. He had flown 32 hours of line sawing flights.

1.6 Aircraft information

1.6.1 Basic aircraft information

The Hughes 369D is a five-seater metal frame light utility helicopter fitted with a single Allison 250-C20B turboshaft engine.

Helicopter:

Type: Hughes 369D

Registration: OH-HWH

Registration number: 1761

Manufacturer: Hughes Helicopters Inc.

Serial number: 500702D

Year of manufacture: 1980

Maximum Take-off Mass: 3000 lb (1360 kg) w/o external load

3550 lb (1610 kg) with external load

Owner:	Malmskogens Aerocenter Aktiebolag, Linköping, Sweden
Operator:	Heliwest Oy
Total hours:	12380 hours

Engine:

Type:	Allison 250-C20B
Serial number:	CAE-831630
Manufacturer:	Allison
Total running time:	5839 hours
Fuel:	JET-A1

1.6.2 Airworthiness information

The Certificate of Registration was issued on 12 March 2002. Following an aircraft inspection on 25 September 2007 the helicopter's Certificate of Airworthiness was valid until 30 September 2009.

Journey logbook

There were two uncommented on remaining remarks on page 53 of the journey logbook's column XI, dated 30 December 2008: *Master power does not come on. Poor radio reception*. On the Remaining Remark List there were three items which were marked for completion no later than 11000 hours running time. These items were not marked as completed.

Rotorcraft Flight Manual

The Rotorcraft Flight Manual (RFM) was not compatible with the helicopter's automatic relight system. Regarding the engine relight system, the manual's instructions apply to a later modification. Since the helicopter did not have this particular modification, the RFM should have retained the instructions for the old system. A similar shortcoming was detected during the investigation (OTKES C8/2007L) of an accident that happened to another similar type helicopter of the company on 8 November 2007.

1.6.3 Weight and balance information

The helicopter was weighed on 27 September 2004 at which time its basic weight was 1489 lb (675 kg) and its centre-of-gravity (CG) point was 109.70 in. At takeoff the helicopter carried approximately 185 l (330 lb/150 kg) of fuel, depleting to approximately 165 l by the time of the accident. Including the external load (topping saw 666 lb/302 kg)

takeoff mass was calculated at 2683 lb. The maximum takeoff mass is 3550 lb (1610 kg). Throughout the flight the CG was within the permissible range, both longitudinally and laterally.

1.7 Meteorological information

The meteorological information was taken at Joensuu aerodrome, approximately 28 km northwest of the accident site. METAR 12:20: Wind from 40–100° at 10 kt, visibility 8 km, light snow, cloud base at 850 m, temperature -13 °C, dew point -14 °C and QNH 1008 hPa.

METAR 12:50: Wind from 70° at 10 kt, visibility 4.4 km, light snow, cloud base at 975 m, temperature -13 °C, dew point -14 °C and QNH 1008 hPa.

The forecast called for light snow with 3-8 km visibility, wind from 60° at 8 kt and cloud base at 900 m.

According to the people that participated in the line sawing operation the weather was suitable for the sawing. The wind was steady and the light snow did not affect the operation at all. From time to time the sun could be seen through the clouds.

1.8 Aids to navigation and radars

Aids to navigation and radars had no effect on the occurrence.

1.9 Communications

The helicopter pilot and the flight operations manager remained in radio contact. When the flight operations manager lost sight of the helicopter he called the helicopter by radio, with no response. Shortly after having crashed to the ground the pilot announced the accident by radio. Following this, the flight operations manager reported the accident to the Emergency Response Centre on his mobile phone and, later, to Accident Investigation Board Finland.

1.10 Aerodrome information

The helicopter's temporary airstrip was at Pyhäselkä, in the municipality of Joensuu, approximately 2 km northeast of the Hammaslahti population centre. The coordinates are: N 62°26.455' E 30°00.784'. The elevation of the site is 123 m MSL.

1.11 Flight recorders

The aircraft had no flight recorders.

1.12 Wreckage and impact information

1.12.1 Accident site information

The accident site is situated at N 62°28.636' E 29°59.621', at 90 m MSL. The location is approximately 5 km north-northeast of Hammaslahti's population centre in Pyhäselkä. The helicopter collided with the ground approximately 30 m east of the power line in dense mixed woodland, turned almost completely towards the direction from which it came and tipped over onto its left side.

1.12.2 Wreckage investigation

The helicopter lay on its left side in dense woods, almost facing the topping saw on the ground. The saw had not moved much from the place where it made contact with the ground. It lay between the power line and the helicopter. The suspension bar was in vertical position and was bent into the shape of an arc between the helicopter and the topping saw. The suspension bar had come loose from the external cargo hook.

The left landing gear skid was bent under the helicopter. The lower left front part of the helicopter frame and the top part of the left door frame were crushed inwards as a result of the collision with the ground. The windshield and the overhead window were broken. All of the main propeller blades had broken off close to the rotor hub and were heaped in a pile next to the rotor mast, but otherwise almost whole. The tail rotor had torn off of its gearbox when it hit the trees and broken loose. The tail rotor blades were intact. The tail boom was twisted counter-clockwise and bent downwards approximately one metre from the tip of the boom.

The helicopter's vertical/horizontal stabiliser had been disconnected to better facilitate transportation in the terrain. The helicopter engine was fitted with a snow baffle.

The connections to the engine controls of the throttle and the collective lever functioned properly. Fuel filters in the helicopter frame and in the engine were checked for cleanliness. The frame filter held approximately 0.3 dl of fuel and approximately 1 cl of water. The finger filter of the Fuel Control Unit (FCU) was clean. While the fuel nozzle looked like it was in proper functioning order, its filter contained minor quantities of, possibly, metallic particles. The Pc pneumatic air line filter was clean. The compressor bleed valve was in the open position. The engine's anti-icing valve was in the closed position and functioned properly through its control cable when tested. The anti-icing valve control in the cockpit was in the OFF position. Judging by visual inspection, all lines and hoses in the engine compartment were properly fastened. There was fuel in the fuel tank.

In the cockpit the trim circuit breaker was up (in the OFF position); the other circuit breakers were pressed into the ON position. The fuel shutoff valve was pulled into the closed position.

1.13 Medical and toxicological information

The pilot took a breathalyzer test, the results of which were zero blood alcohol.

1.14 Fire

There was no fire.

1.15 Rescue operations and survival aspects

At 12:49 the ERC of North Karelia in Joensuu received notification of an accident from the company's flight operations manager who was in the vicinity of the accident site. Two rescue units, two ambulances as well as a command unit and a light all terrain vehicle were dispatched to the site. The first units arrived within 15 minutes of the notification. Since the pilot managed to escape from the wreckage on his own, no actual rescue and evacuation operation was required. The quality controller, being the first one to approach the accident site, assisted the pilot to the yard of the closest house, where the rescue units arrived. The rescue personnel administered first aid, transported the pilot to the North Karelia Central Hospital in Joensuu and secured the wreckage with regard to fire and environmental hazards. According to the official who was in command of the rescue effort, the dispatched response was appropriate for the purpose at hand and the resources were sufficient.

Because the saw was attached to the helicopter to the very end of the flight, the helicopter came to the ground in a partly uncontrollable fashion. Thanks to his seat harness the pilot remained in his seat and escaped further injuries because the cockpit maintained its shape, for the most part. Owing to the soft soil the pilot sustained only minor head injuries even though his head was pinned between the ground and the airframe for a while after the helicopter tipped over. The pilot was not wearing a helmet.

In order to mitigate the danger of a fire the pilot switched off the master power before he left the cockpit.

1.16 Tests and research

1.16.1 Technical inspection of the helicopter

Cockpit and fuselage

The lower left corner of the front fuselage was crushed inwards as a result of the collision with the ground. As a consequence of the deformation the supporting structures of the pilot's tail rotor pedals were broken and bent. The battery, situated under the pilot's footwell, was jammed into the structures. This is why the battery cables were disconnected only when the helicopter was being transported. The upper part of the left door frame was crushed inwards. The bulbous "sawing door", used during sawing flights, was

torn at the top, yet maintained its shape. The left landing gear skid struts were broken at their attachments and the skid was broken loose from the struts.

The right side of the helicopter was intact. Engine access doors remained in place and were intact. As a result of a tree strike on the horizontal stabiliser the tail boom was bent approximately 30° counterclockwise and slightly downwards. The leading edges of the vertical and horizontal stabilisers bore marks of having hit trees.

Transmission and flight control systems

The transmission from the engine to the main rotor hub was intact. The overrunning clutch was in normal working order. The main transmission and the main rotor turned normally when they were turned by hand. The main rotor blades had broken off close to the rotor hub. The blades were in one piece, albeit deformed from the strikes.

The ascent/descent and other flight control systems were intact and the swashplate moved normally. The helicopter was fitted with dual flight controls on the right side; the right side tail rotor pedals were disengaged.

Regarding the tail rotor control system, there was a properly functioning connection from the pilot's tail rotor pedals all the way to the tip of the tail boom. The pedals' attachment brackets were broken and their interconnector was bent. The tail rotor driveshaft had broken at the spot where the tail boom was bent. The tail rotor gearbox was torn off and the tail rotor had broken loose. The tail rotor control system components inside the part of the gearbox that tore off remained intact.

Engine inspection

Preliminary inspection of the engine was conducted when it was still in its place in the airframe. All lines and hoses were fastened, the auxiliary components were in place and looked undamaged. Control rods were fastened and the range of movement and travel of control levers was as it should be. Apart from the rotor's RPM generator coupling that was loose, the engine's electrical wiring and components were also intact.

A Fuel Control System Pneumatic Leak Check was performed as per the engine manufacturer's maintenance manual. The check detected a considerable air leak in the FCU. The air leak became evident when the Pc pneumatic air line was pressurised. According to the maintenance manual, a leak is not allowed in the FCU at this time. The engine, including components, was removed for detailed inspection and for the purpose of establishing the cause of the leak.

The FCU was removed from the engine and the maintenance manual's air leak check was performed on the FCU alone. The leak came through the breather hole below the FCU. The purpose of this hole is to facilitate the venting of any possible fuel and oil deposits within the FCU. The breather hole uses the same space as the FCU's flyweights. Air also vents through this hole when the FCU is in operation.

The FCU was opened and partly disassembled. At this time it was detected that the spool bearing of the bushing at the end of the FCU's flyweight driveshaft was broken. Bearing balls were scattered inside the FCU and a disconnected, thin bearing shield was also found loose inside it. The bronze coating around the flyweights had peeled off. Metal chips were discovered in the FCU casing. Due to the mechanical failure the bushing had moved up and tilted to one side, which in turn jammed the Px line open. Since the pressure inside the line directly affects engine fuel control, the malfunction rendered the fuel control system inoperative and made it impossible for the pilot to control engine power.

Figure 2. The Fuel Control Unit opened.

History of the engine

The engine was new when it was taken into use on 16 January 1979. In recent years the following repairs had been performed: the compressor was replaced in April 2008, because of temperature problems; the bleed air valve was replaced in June 2008; the turbine was replaced in November 2008; and the engine transmission was replaced in September 2008, due to a warning about engine chips in the engine oil.

History of the engine fuel control unit

The total running time of the Fuel Control Unit is not known. The FCU was overhauled in 2004 and taken into use in 2005 at which point its running time was given as zero. There

are no documents with regard to the overhaul itself or any maintenance action before the overhaul.

Prior to its installation on another engine the FCU was repaired at the running time of 271 hours. According to the operator, the reason for the repair was a hot start of the engine. During this repair the FCU was properly tuned and tested. Documents on this repair are available. At that running time the FCU was installed on the engine that was being used in the helicopter then. Another engine, the one which was on the accident flight, was installed on the helicopter in 2007. At that time the FCU was removed from the old engine and mounted on the newly installed engine. At that point the running time of the FCU was 723 hours. The running time at the moment of the accident was 1572 hours. The FCU's time between overhauls is 2500 hours.

1.16.2 Inspection of the engine's control units

Both engine control units, the Fuel Control Unit and the Power Turbine Governor, were sent to the United States for inspection. This inspection was conducted in South Bend, Indiana, at the premises of Honeywell Engineering (HE), the manufacturer of the FCU, in collaboration with the Rolls-Royce Corporation (RRC), representing the engine manufacturer. Since the Power Turbine Governor was intact, its inspection is not explained any further.

The inspection of the FCU aimed at establishing the factors which resulted in the failure of the spool bearing. The investigation into the condition of the components of the bearing concluded that the bearing failed due to insufficient lubrication of the spool bearing. This conclusion was arrived at on the basis of surface wear, fragmentation, surface corrosion and thermal discoloration. The investigation was unable to identify the specific root cause or causes of the insufficient lubrication. It was concluded that the grease that was used as lubricant met its specific requirements (ES-1962). Energy Dispersive Spectroscopy was employed to establish that the materials used in bearing components met their requirements.

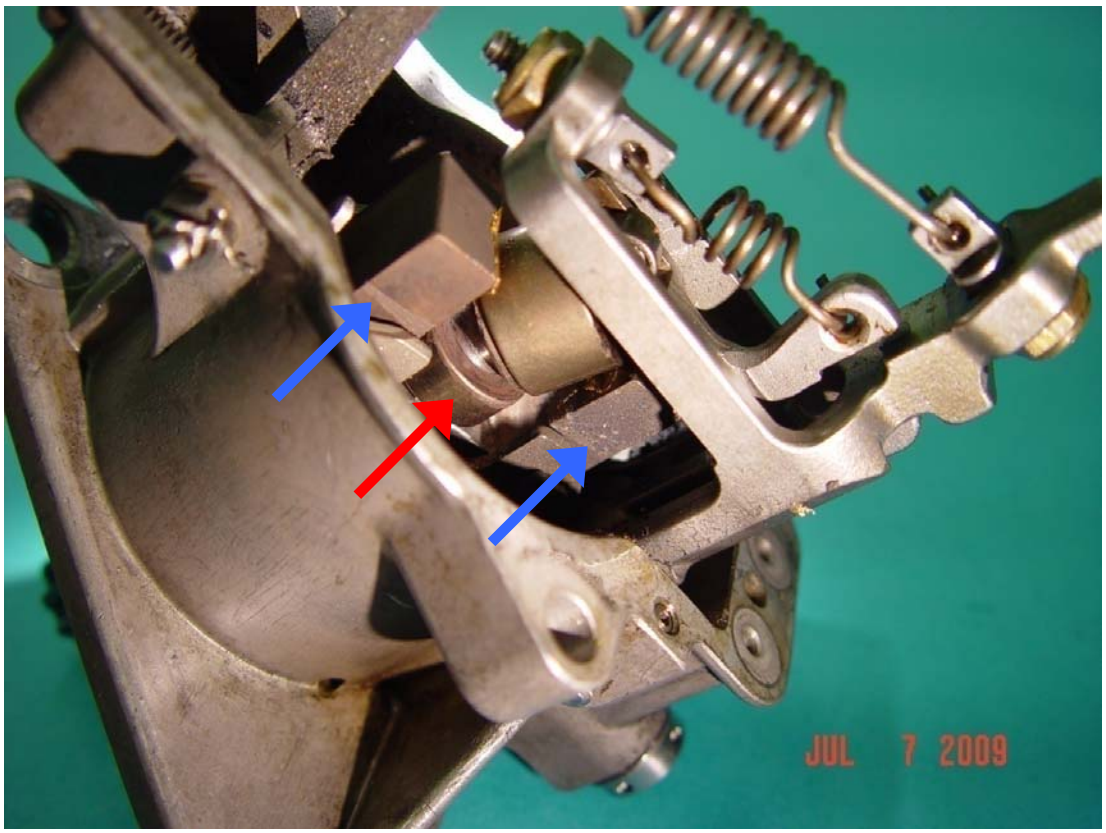

Figure 3. The Fuel Control Unit from the inside (photo: Honeywell). The flyweights are indicated by the blue arrows and the bushing as well as the broken spool bearing are indicated by the red arrow.

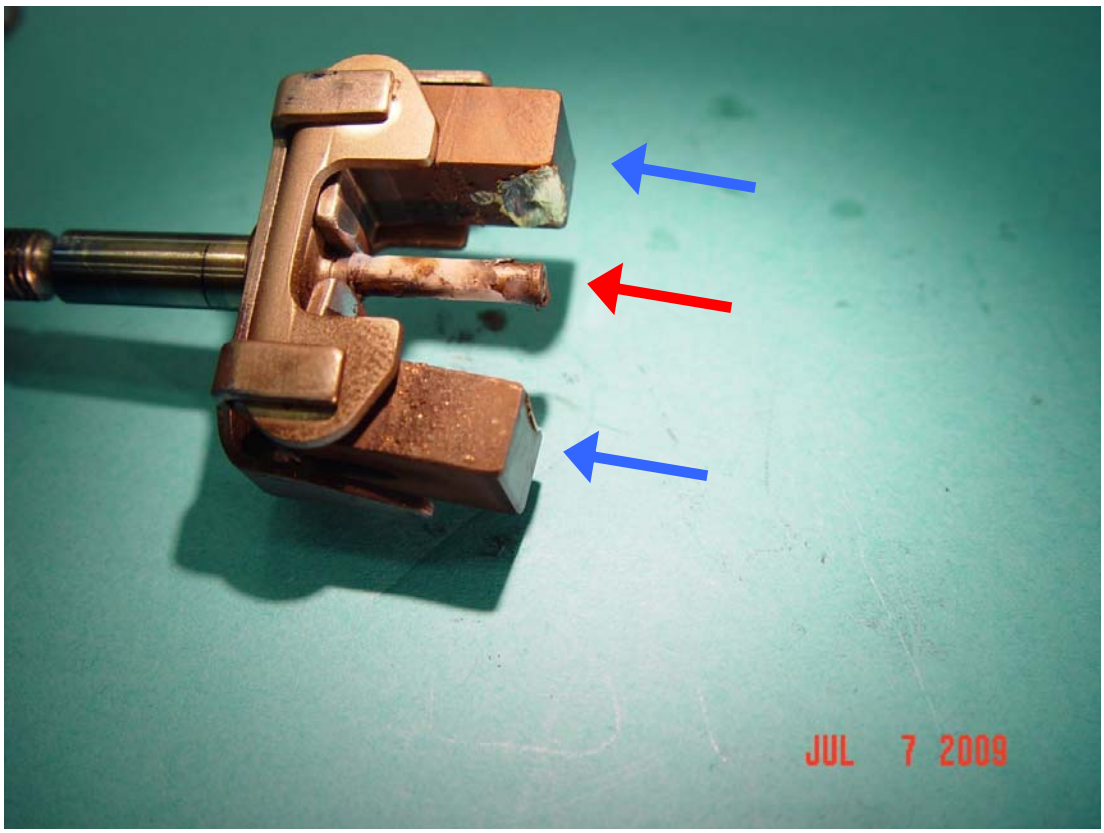

Figure 4. The FCU driveshaft and flyweights (photo: Honeywell). The damaged flyweights are indicated by the blue arrows and the melted Teflon coating by the red arrow.

Following laboratory testing RRC, in collaboration with HE, wanted to continue pursuing the root cause for the bearing's insufficient lubrication. The Investigation Closure Summary presented three possible root causes that could not be confirmed or eliminated. The root causes that were given were: *degradation of lubrication (attributed to shelf life), failure of the bearing shield (that retains the lubrication) due to a flaw or impact damage, and wear due to continuous fuel scheduling variations due to operations maneuvers* (sic).

The risk of degradation of lubrication through shelf life was judged to be minimal since the FCU was maintained at an HE Authorized Warranty Repair facility, which has an established maintenance history spanning almost 40 years. The risk associated with a material flaw in the bearing shield was considered low but could not be ruled out since only a small portion of the shield could be retrieved and inspected. Wear was considered unlikely since the hovering type maneuvers being conducted by the operator are common practice around the world. This is the only documented failure of a spool bearing in a GP FCU in 160 million flight hours, yielding a failure rate of 6.25×10^{-9} events/hour. In accordance with the bearing design 90% of bearings in corresponding use reach the life of 9178 hours. The spool bearing replacement interval is 2500 hours.

In view of the above, the Investigation Closure Summary concludes that no design, manufacturing, field containment or other mitigating actions are deemed necessary or warranted.

1.16.3 Inspection of the GPS device

The helicopter was fitted with Garmin GPSMAP 196 and GPSMAP 296 global positioning systems. The progress of the accident flight was analysed on the basis of information recorded in the memory of the GPSMAP 296 device.

1.17 Organisational and management information

1.17.1 General

The aerial work permit issued to Heliwest Oy was valid until 28 February 2013. This permit also covers line sawing flights. The Heliwest Oy Operations Manual (OM) for Aerial Work Operations describes the company's activities. The following persons report to the accountable manager: the flight operations manager, the maintenance manager, the ground operations manager and the training manager. The accountable manager also holds the post of quality manager and the flight operations manager doubles as the training manager. In addition to the accountable manager the company employs three helicopter pilots and four maintenance personnel.

The company's fleet includes two Hughes 369D, one MD-500D and two Robinson R44 helicopters. One of the Robinson R44 helicopters is owned by the company whereas the others are leased.

Branch and treetop trimming flights are the mainstay of Heliwest's aerial work. In its aerial work Heliwest Oy collaborates with Eltel Networks Oy which, in turn, provides power line clearance to Fingrid Oyj, the owner of the power grid. The instructions for line sawing operations are included in the Heliwest Oy OM as well as in Eltel Networks' handbook on helicopter line sawing clearance and are also in its safety plan.

1.17.2 Flight operations

Heliwest Oy has performed helicopter line sawing flights for more than a decade. This aerial work was the primary job of three pilots. As one of them left the company for other duties, the line sawing training of the pilot that flew the accident flight was commenced in November 2008. The pilot in question is an experienced helicopter pilot, possessing considerable experience with external load operations as well. The company's treetop trimming flight training syllabus encompasses 18 hours of theoretical knowledge instruction, 9 hours of flight training with an instructor pilot as well as 40 hours of supervised line sawing operations. The accident occurred during a supervised sawing flight.

1.17.3 Maintenance activities

With regard to Hughes and MD helicopters, Heliwest Oy had a valid maintenance contract with the Swedish Malmskogens Aerocenter Ab (MAC). The company also owns the helicopters. The helicopter was being maintained in accordance with MAC's Maintenance Organisation Exposition (MOE) at the line maintenance station in Urajärvi. MAC is a maintenance organisation that meets EASA Part-145 requirements.

2 ANALYSIS

2.1 The accident flight

2.1.1 Preparation for the flight

Prior to the accident flight the helicopter was refuelled with the engine idling. At that time it was noticed that the N_1 idle RPM was 61%. According to the Rotorcraft Flight Manual the N_1 RPM at idle should be 64-65%. The minimum permitted N_1 idle RPM in the limitations section of the flight manual is 64% (Rotorcraft Flight Manual MD500D [Model 369D] pp. 2-6, section 2-7 Powerplant Limitations Allison 250-C20B). In question is a limitation pertaining to a type of engine which, as per the flight manual's page F-i, must be followed. According to the company's flight operations manager, who had plenty of flying experience on the helicopter; the RPM in question with this particular helicopter was normally 63-64%. Since the preflight engine test did not reveal any other deviation, the decision was made to continue flying. Both the pilot and the flight operations manager agree that in order to tune the N_1 idle RPM maintenance personnel would have needed to come to the site , after which the aerial work and the line sawing would have continued just as it did on the accident flight.

The inspection of the fuel control unit established that the bearing failure resulted from insufficient lubrication, and that the failure could have occurred already before the accident flight, which the lower-than-normal N_1 idle RPM indicates happened. The investigation commission believes that the clear aberration of the N_1 idle RPM from the flight manual's desired value and from the minimum permissible value was a factor which should have been established before the next flight. The change in the N_1 idle RPM had occurred during the previous flight.

2.1.2 Events on the flight

Takeoff and the flight up until the onset of the engine failure progressed uneventfully. The flight operation manager considered the slight wobble in the N_R RPM indication at the beginning of the flight characteristic of the helicopter type. It evidently resulted from mechanical wear in the RPM generator or contact failure in wiring, appearing as minute indicator vibration.

The failure of the FCU's spool bearing resulted in a sudden loss of engine power. Since the helicopter was trimming treetops in hover, the only option for the pilot was to clear the power line by steering the helicopter into the woods. When the helicopter crashed into the ground the suspension bar was bent into the shape of an arc and the helicopter tipped over onto its side. The fact that the pilot did not release the sawing apparatus probably contributed to the helicopter tipping over. This was quite reasonable because the pilot had very little time to consider his options and to take action in an emergency situation that suddenly arose while sawing at a low height. According to the company's Operations Manual the saw must be immediately released if the engine fails. According

to the Rotorcraft Flight Manual, if the engine fails the external load should be released as soon as practicable while taking into account other flight safety considerations. The investigation commission believes that, notwithstanding the unfavourable circumstances, it would have been easier to steer and control the helicopter had the sawing apparatus been released.

2.1.3 Events after the flight

When the helicopter tipped over the pilot was unable to turn off the engine due to an injury to his left hand. Probably because of the combined effects of the tightness of the fuel shut-off valve, the slipperiness of his hands and the need to quickly get out of the cockpit the pilot could not shut off the valve. His hands were slippery from blood that was coming from the injury to his head. Since the pilot maintained that the tight space did not allow him to wear a helmet, he was not wearing one on the flight. The pilot left the cockpit and began walking towards the nearest house. The engine was left running.

After first aid was administered to the pilot the flight operations manager was the first one to arrive at the accident site. He turned off the engine approximately 21 minutes after the crash by closing the fuel shut-off valve. He, too, considered the valve to be tight. In this particular instance there was no fuel leak or fire, so the fact that the fuel shut-off valve remained open was irrelevant. If there is the possibility of a fuel leak, the risk of fire and its extent can be reduced by closing the valve. The investigation commission believes that the fuel shut-off valve functioned properly even after the accident.

2.2 Technical condition of the helicopter

Apart from the engine, the helicopter functioned properly in the beginning of the accident flight.

The helicopter engine's N_1 idle RPM at 61% did not comply with the flight manual's desired value of 64-65%, or the minimum permissible RPM of 64%. It is highly likely that the lower RPM was an indication of an incipient defect, which resulted in the loss of engine power after ten minutes of flying.

Technical investigations (HE and RRC) found that the cause of the defect was the failure of the FCU's spool bearing due to insufficient lubrication. Three possible root causes were given for the insufficient lubrication: degradation of lubrication (attributed to shelf life), failure of the bearing shield (that retains the lubrication) due to a flaw or impact damage, and wear due to continuous fuel scheduling variations due to operations maneuvers. The investigation commission also believes that a manufacturing fault could have been one of the causes, in which case the bearing would have received too little lubricant. None of the aforementioned root causes can definitively be confirmed or eliminated.

Investigations conducted by HE and RRC established that this is the only documented failure of a spool bearing in a GP FCU in 160 million flight hours. The occurrence, in other words, was extremely uncommon. The investigation commission concurs with the

Investigation Closure Summary regarding the fact that no design, manufacturing, field containment or other mitigating actions are deemed necessary or warranted. Since the minimum permissible N_1 idle RPM of 64% was not reached before the accident flight, the helicopter was not airworthy.

2.3 Airworthiness of the helicopter

The helicopter's journey logbook had two remaining open remarks and there were three items on the Remaining Remark List which were not marked as completed. The Rotorcraft Flight Manual was not compatible with the operation of the helicopter's automatic relight system. In the beginning of the accident flight the N_1 idle RPM did not comply with the flight manual's limitations. Owing to the abovementioned, the helicopter was not airworthy in the beginning of the accident flight.

2.4 Management of flight operations

During the investigation (OTKES C8/2007L) of an accident that happened to another similar type helicopter of the company on 8 November 2007, it was established that there were shortcomings in the company's Operations Manuals as well as in the Rotorcraft Flight Manual. The investigation's safety recommendations proposed that the company's AOMs (flight manuals) for each aircraft be updated and that staff procedures be amended so as to comply with the valid AOMs. The recommendation had not been implemented as regards the accident helicopter's Rotorcraft Flight Manual. Following the accident that resulted in the ongoing investigation the company's Operations Manual has been amended.

The investigation commission took notice of the fact that when the company's accountable manager, the flight operations manager and the pilot were interviewed their opinion was that the flight manual's N_1 idle RPM limitation was not absolute. The pilot's and the flight operation manager's decision to continue with flying can be regarded compatible with the company's organisational culture. An organisational culture that fails to update its instructions or ignores them cannot be considered safety conscious. Deliberate risks that entail unknown consequences are taken. The investigation commission states that up-to-date instructions, including compliance with said instructions, constitutes the cornerstone of correct and safe staff procedures.

3 CONCLUSIONS

3.1 Findings

1. Heliwest Oy had a valid aerial work permit for line sawing flights.

2. The helicopter's registration and airworthiness certificates were valid.

3. The helicopter was not airworthy in the beginning of the accident flight because its journey logbook had open items in its remaining remarks list, the Rotorcraft Flight Manual was not compatible with the helicopter's automatic relight system and the engine's N_1 idle RPM did not comply with the flight manual's limitations.

4. The pilot had the required licence and his ratings were valid.

5. The helicopter was fitted with a snow baffle and its external load was a 302 kg and 17 m long topping saw.

6. Following a flight that lasted one hour and six minutes the helicopter was refuelled on the ground while the engine was running at idle.

7. On the ground it was noticed that the N_1 idle RPM was 61%. According to the Rotorcraft Flight Manual the desired value is 64-65%. The minimum permitted N_1 idle RPM in the flight manual's limitations is 64%.

8. The engine was tested after which the decision was made to continue flying. When tested, all other engine parameters seemed normal.

9. After ten minutes of flying the helicopter engine suddenly lost power.

10. As a result of the engine failure when the helicopter was trimming treetops in hover, the only option for the pilot to clear the power line was by steering the helicopter into the woods.

11. The pilot chose not to release the sawing apparatus. According to the company's Operations Manual the saw must be immediately released if the engine fails. According to the Rotorcraft Flight Manual, if the engine fails the external load should be released as soon as practicable while taking into account other flight safety considerations.

12. The investigation commission believes that, in spite of the unfavourable circumstances, it would have been easier to steer and control the helicopter had the sawing apparatus been released.

13. Partly due to the sawing apparatus, the helicopter tipped over onto its left side as it made contact with the ground.

14. The pilot sustained minor injuries as a result of the helicopter tipping over. However, he managed to get out of the cockpit on his own through the broken windshield.

15. Due to the attitude of the helicopter and an injury to his left hand he was unable to turn the engine off when it was on the ground.

16. Probably because of the combined effects of the tightness of the fuel shut-off valve, the slipperiness of his hands and the need to quickly get out of the cockpit the pilot could not shut off the valve.

17. Being the first one to arrive at the accident site, the flight operations manager turned the engine off approximately 21 minutes after the crash.

18. Following first aid, the pilot was transported to the North Karelia Central Hospital in Joensuu.

19. Technical investigations found that the Fuel Control Unit's spool bearing failed due to insufficient lubrication.

20. Possible causes for degraded lubrication could be attributed to shelf life, a flaw or impact damage that prevented the bearing from retaining its lubrication, wear due to continuous fuel scheduling variations due to hovering operations, or a manufacturing flaw resulting from an insufficient amount of lubricant. None of the aforementioned factors could be definitively confirmed or eliminated.

21. A FCU spool bearing failure is an extremely uncommon occurrence. According to the FCU's manufacturer this is the only documented failure in 160 million flight hours.

22. The manufacturer of the bearing holds that no design, manufacturing, field containment or other mitigating actions are deemed necessary or warranted. The investigation commission concurs with this opinion.

23. The company's flight operations did not comply with the Rotorcraft Flight Manual's limitation regarding the N_1 idle RPM.

24. The investigation commission believes that the clear aberration of the N_1 idle RPM from the flight manual's desired value and from the minimum permissible value was a factor which should have been established before the next flight.

3.2 Probable cause

The accident was caused when the bearing of the Gas Producer Fuel Control Unit failed due to insufficient lubrication. The malfunction of the Fuel Control Unit caused a sudden loss of engine power that resulted in an emergency landing in which the helicopter was destroyed. Possible causes for degraded lubrication could be attributed to shelf life, a flaw or impact damage that prevented the bearing from retaining its lubrication, wear

due to continuous fuel scheduling variations due to hovering operations, or a manufacturing flaw resulting from an insufficient amount of lubricant. None of the aforementioned factors could be definitively confirmed or eliminated.

The decision to take off again even though the N1 idle RPM was not within the Rotorcraft Flight Manual's limits was a contributing factor. It is highly likely that the N1 idle RPM that was lower than the desired value was a symptom of a defect that was already present before the flight.

4 SAFETY RECOMMENDATIONS

4.1 Action taken during the investigation

In its letter, dated 22 September 2009, Heliwest Oy informed AIB Finland of the action taken with regard to implementing the safety recommendation the company received in investigation report C8/2007L. According to the letter the company's Operations Manual has been amended, among other things, with regard to weather limitations. Pilots have been instructed to comply with the Operations Manual and supervision of the pilots' procedures has been intensified. Flight manuals have been updated to comply with helicopter equipment.

4.2 Safety recommendations

The investigation commission makes no safety recommendations. A Fuel Control Unit spool bearing failure is an extremely uncommon occurrence. According to the FCU's manufacturer this is the only documented failure in 160 million flight hours.

Helsinki 9 March 2011

Juhani Hipeli Hans Tefke

Juha Kepsu