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Swiss Transportation Safety Investigation Board STSB

Aviation Division

Final Report No. 2265 by the Swiss Transportation Safety Investigation Board STSB

concerning the accident
involving the AS350 B3e helicopter,
registration HB-ZMO,

on 1 July 2013

'Mändliteifi' area

430 m south-west of Kröntenhütte

Municipality of Erstfeld/UR

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Ursachen

Der Unfall ist mit hoher Wahrscheinlichkeit darauf zurückzuführen, dass der Pilot nach dem Auftreten von *servo transparency* in einer Rechtskurve und nahe dem Gelände die Kontrolle über den Helikopter verlor und dieser in der Folge mit dem Gelände kollidierte.

Die risikobehaftete Flugtaktik des Piloten hat zur Entstehung des Unfalls beigetragen.

General information on this report

This report contains the Swiss Transportation Safety Investigation Board's (STSB) conclusions on the circumstances and causes of the accident which is the subject of the investigation.

In accordance with Art 3.1 of the 10th edition, effective from 18 November 2010, of Annex 13 to the Convention on International Civil Aviation of 7 December 1944 and Article 24 of the Federal Air Navigation Act, the sole purpose of the investigation of an aircraft accident or serious incident is to prevent further accidents or serious incidents. The legal assessment of accident/incident causes and circumstances is expressly no concern of the investigation. It is therefore not the purpose of this investigation to determine blame or clarify questions of liability.

If this report is used for purposes other than accident/incident prevention, due consideration shall be given to this circumstance.

The German version of this report constitutes the original and is definite.

All information, unless otherwise indicated, relates to the time of the accident.

All times in this report, unless otherwise indicated, are stated in local time (LT). At the time of the accident, Central European Summer Time (CEST) applied as local time in Switzerland. The relation between LT, CEST and coordinated universal time (UTC) is:
LT = CEST = UTC + 2 hours.

Final report

Aircraft type	Eurocopter AS350 B3e 'Ecureuil'	HB-ZMO
Operator	Swiss Helicopter AG, Hartbertstrasse 11, 7000 Chur	
Owner	Swiss Helicopter AG, Hartbertstrasse 11, 7000 Chur	

Pilot	Swiss citizen, born 1980
Licence	Commercial pilot licence helicopter (CPL(H)) in accordance with joint aviation requirements (JAR), issued by the Federal Office of Civil Aviation (FOCA)
Ratings	AS350 B3, valid until 30 November 2013 Mountain landings (MOU(H))
Medical certificate	Class 1 (commercial single pilot with pax), shall wear corrective lenses (VDL), issued on 25 October 2012, valid until 8 November 2013

Flying hours	**Total**	1443 h	**During the last 90 days**	129:20 h
	On the type involved in the accident	1197 h	**During the last 90 days**	127:12 h

Location	'Mändliteifi' area, municipality of Erstfeld/UR		
Coordinates	686 449 / 183 489	**Elevation**	1950 m AMSL
Date and time	1 July 2013, 09:15		

Type of operation	VFR, commercial
Flight phase	Landing approach
Type of accident	Collision with ground

Injuries to persons

Injuries	Crew	Passengers	Total no. of occupants	Third parties
Fatal	1	3	4	0
Serious	0	0	0	0
Minor	0	0	0	0
None	0	0	0	n/a
Total	1	3	4	0

Damage to aircraft	Destroyed
Third-party damage	Damage to the ground

1 Factual Information

1.1 Pre-fligh history and history of the flight

1.1.1 General

For the following description of the background and the history of the flight, statements and information from various respondents were used as well as documents from the pilot and the air transport operator. The navigation computer on board the helicopter was also analysed.

The flight was carried out under visual flight rules (VFR). It was a flight to perform aerial work.

1.1.2 Pre-flight history

From the beginning of June 2013, the pilot had been transporting goods two to three times per week to the Swiss Alpine Club's (SAC) mountain hut 'Kröntenhütte' which was being renovated. At the end of the previous week, the flight operations management had drawn up an operation programme for the following Monday. The evening prior to the accident flight, the manager of the air transport operator discussed the following day's programme with the pilot over the telephone. In the course of the conversation, the flight operations manager who also flew for the company offered to take over the following day's flight programme. The pilot declined because he was looking forward to the interesting programme the next day. After two days away from work and flying duty, the pilot was well rested and recouped.

On the morning of 1 July 2013 at 7:05, the pilot took off from Erstfeld with two flight assistants and a fitter as passengers on board of HB-ZMO.

The first landing took place at the mountain hut 'Leutschachhütte', where the fitter disembarked. Subsequently, the flight continued to Göscheneralp, where approx. six return trips were made to transport material with the aid of the two flight assistants. The next assignment took place in Andermatt, where approx. 25 loads of concrete were transported. A company fuel vehicle was located in the car park Nätschen, where the helicopter was refuelled to a quantity of approx. 240 litres.

1.1.3 History of the flight

On 1 July 2013 at around 9:00 am, the pilot took off with the helicopter HB-ZMO in Andermatt for the transfer flight to Erstfeld. Both of his flight assistants were also on board.

During the flight, the operations management informed the pilot by radio that the fitter who was dropped off earlier in the day at the Leutschachhütte was ready to be picked up. Therefore, the pilot decided to fly directly to the Leutschachhütte, where the fitter boarded the helicopter at the landing site adjacent to the hut whilst the engine remained running. In the flight from the Leutschachhütte back to the base, prior to returning to the base, the pilot intended to drop off one of his flight assistants at the Kröntenhütte in preparation for the next assignment.

Shortly afterwards, HB-ZMO took off with four people on board. During the helicopter's climb, the pilot headed north-west, in order to first cross the east ridge of the Mäntliser mountain at approx. 2600 m AMSL (approx. 8530 ft) and later the north ridge at the Päuggenfurggi mountain at approx. 2450 m AMSL (approx. 8040 ft). The ground speed was 116 kt (approx. 215 km/h). At a height of approx. 550 m above the planned landing site, HB-ZMO flew into the basin south of the Kröntenhütte.

Descending with a high forward speed, the helicopter crossed the Steinchelen area. According to the last recording of the satellite-based navigation computer, the ground speed was about 135 kt (approx. 250 km/h).

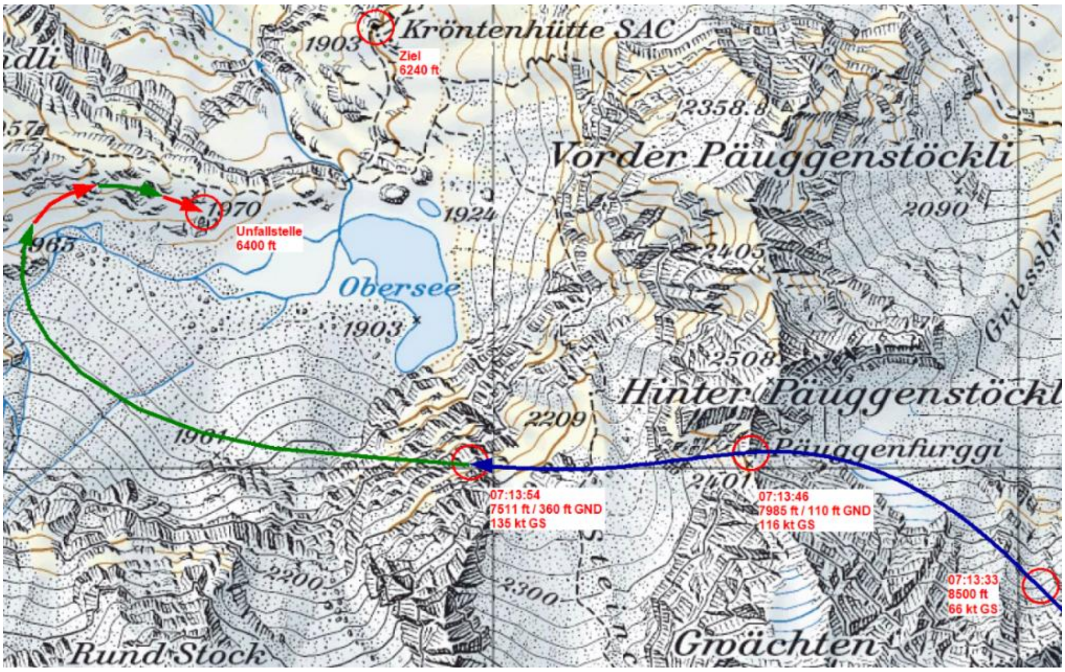


Figure 1: Flight path of HB-ZMO: the flight path as recorded by the navigation computer (blue), flight path observed by witnesses (green) and the not-observed flight path (red); base map 1:25 000, reproduced by permission of the Federal Office of Topography Swisstopo (JA150149).

At this time, the manager of the hut, the warden with his staff and various workers, approximately 10 people in total, were spending their 9 o'clock break on the south-east side of the hut. That morning, some of them had been flown directly to the Kröntenhütte in two groups by another helicopter from the same air transport operator. They had completed an inspection of the sewage plant and the foreman was ready for the upcoming concrete work. They were expecting the arrival of the transport helicopter.

All these people were able to watch the helicopter flying into the basin because from the hut they had an excellent view of the basin above. Flying into the basin, the helicopter crossed the Päuggenfurggi, a passage at 2401 m AMSL which is one kilometre from the Kröntenhütte.

People with many years of experience working with helicopters described the speed of the helicopter as very high. The first stretch of the flight observed in front of the rocky background conformed to a descending straight flight path. The helicopter then turned more and more to the right along the terrain in the basin. The helicopter seemed to follow the sloping ridge that confines the mountain basin in the north towards the lake at the basin mouth (see appendix 1).

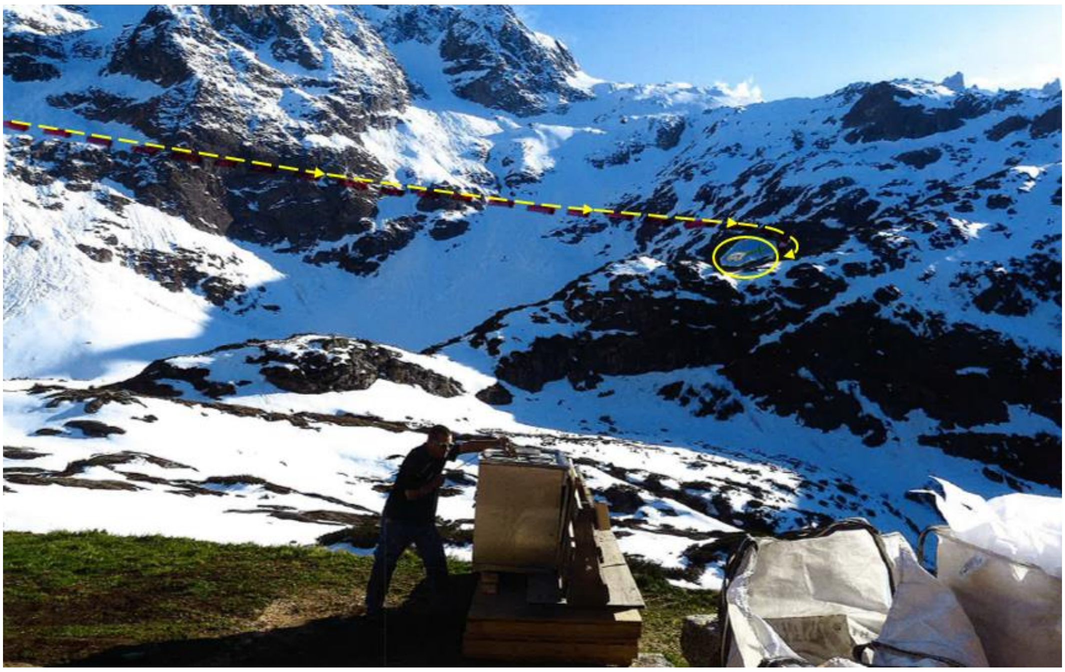


Figure 2: Flight path of HB-ZMO flying into the basin according to an observer's flight reconstruction viewed from the Kröntenhütte. The picture was not taken on the day of the accident. The underside of the photoshopped helicopter, circled in yellow, is visible. This photo montage illustrates the position and location of the helicopter immediately prior to the accident behind the crest.

This surprised some observers who were expecting the helicopter to follow a path towards the Kröntenhütte in a direction out of the basin after turning above the sloping ridge.

One observer made the following statement: "*I was thinking that he was flying rather fast and low […] It looked as if he could not get over the crest. After that he 'swayed'. It looked as if he wanted to slow down. Then he disappeared behind this crest […]*"

Only briefly and just above the crest, the position of the helicopter was clearly visible. The bank angle was judged to be very steep because only the underside of the helicopter was visible. The helicopter then disappeared behind the crest. A moment later, smoke rose from behind the crest. No abnormal noises were noticed.

Three of the observers immediately ran towards the rising smoke and after a few minutes, reached the accident site of the helicopter. The hut warden alerted the emergency services.

The wreckage burned generating a lot of heat. The smell of fuel was in the air. There was nothing that the helpers could do for the occupants who had received fatal injuries on impact.

1.2 Information on the wreckage, the impact and the accident site

1.2.1 Accident site

The accident site is on a ridge that is sloping from the peak of the Oberseemandli mountain towards the east, between the so-called 'Mändliteifi' area and the Obersee lake. The distinctive ridge confines a 500-m-wide mountain basin west of the Obersee lake to the north. The Obersee lake at the basin mouth is 350 m from the Kröntenhütte. The Kröntenhütte and the Obersee lake are both at an altitude of 1903 m AMSL.

Figure 3: Position 1 shows the first impact marks of the helicopter and position 2 the final position of the wreckage on the ridge below the Oberseemandli mountain, between the Mändliteifi area and Obersee lake.

1.2.2 Impact

The impact marks on the terrain indicate that the helicopter had a considerable forward speed with a descending flight path roughly parallel to the ridge. At the accident site, the ridge is sloping approximately 20° to the east and has an approximate 25° incline towards the inside of the basin.

Three main areas of impact could be identified:

In the first area there were clear impact marks such as displacements of soil and snapped pine shrubs. The first longitudinal marks of the impact came from the landing skids. The initial and most westerly longitudinal marks were line-like marks in a direction of 090° and pointing towards the main wreckage. Pieces of the landing skids and various pieces of the cowling were found in this first location.

The second location was 25 m east from the first marks. This is where the completely destroyed and burnt-out helicopter cabin was found together with the engine, pieces of the main rotor blades and the transmission, with transport equipment spread around the site.

The tail boom with the comparatively less damaged tail rotor was in the third location which was south of the second location and bordering on the terrain sloping towards the basin.

The four occupants who were fatally injured on impact were all found in the second location and its surroundings.

1.2.3 Wreckage

The main wreckage was on a flat area on the ridge. The helicopter was destroyed by the impact and the subsequent fire. The engine as well as remnants of the main transmission, swashplate and main rotor head lay in the middle of the main wreckage. All the main rotor blades were connected to the rotor head. Two blades were severely damaged by the impact; the third one was destroyed to a large extent by the fire. The damaged instrument panel of the cockpit was found outside of the fire-affected area. The tail boom including tail rotor, the left-hand side cockpit and sliding door, the left-hand side luggage hold cover, the right-hand side cockpit door including door pillar together with the small rear door and a cowling cover were a couple of metres away from the main wreckage. These parts were damaged by the impact but not affected by the fire. In the area between the first impact and the main wreckage, pieces of the landing skids were found.

The body of the pilot was still strapped into his seat. The bodies of the three passengers were in the area of the fire and its immediate surroundings.

Figure 4: Final position of the HB-ZMO wreckage.

1.3 Fire

The impact caused an explosion-like fire that destroyed most of the helicopter.

1.4 Survival aspects

1.4.1 General

The accident was not survivable.

1.4.2 Search and rescue

The helicopter was equipped with an emergency location transmitter (ELT) type Kannad 406 AF-H. The device was activated by the impact and began sending signals.

1.5 Meteorological information

1.5.1 General weather conditions

On the ground, a shallow ridge of a high pressure area over the Azores extended to Eastern Europe. At altitude, the Westerlies extended from Newfoundland to Belarus.

1.5.2 Weather at the time and location of the accident

The weather was sunny with southerly winds across the Alps crest and with a westerly wind in exposed mountain areas.

Weather/clouds	no clouds
Visibility	70 km and more
Wind	low
Temperature/dew point	8 °C / 1 °C
Atmospheric pressure QNH	1021 hPa (pressure reduced to sea level, calculated with the values of the ICAO standard atmosphere)
Dangers	Southerly Foehn tendency at the Alps crest

1.5.3 Astronomical information

Position of the sun	Azimuth: 92°	Elevation: 34°
Lighting conditions	Daylight	

1.5.4 Visual obstruction of the pilot by glare

The possibility of a visual obstruction of the pilot by sun glare was assessed at the accident site by a different helicopter taking the attitude and position of HB-ZMO with a similar position of the sun. As the elevation of the sun was already high at the time of the accident, it is unlikely that sun glare affected the course of the accident.

1.6 Information on the aircraft

1.6.1 General

Registration	HB-ZMO
Aircraft type	Eurocopter AS350 B3e ‘Ecureuil’
Specification	Single-engine multipurpose helicopter with landing skids and six seats. Main rotor with three blades, exposed tail rotor for torque compensation.
Manufacturer	Eurocopter, France
Year of manufacture	2011
Serial number	7281
Engine	Turbomeca Arriel 2D Serial number: 50003
Fuel quantity	The helicopter had approx. 240 litres on board at take-off in Andermatt and approx. 200 litres at the time of the accident.

Max. permissible mass	2250 kg with internal load
Mass and centre of gravity	During the entire flight, mass and centre of gravity were within the permissible limits as stated by the manufacturer. The total mass of the helicopter at the time of the accident was approx. 1900 kg to 1950 kg.
Operating hours	Airframe: 554:44 h TSN[1] Engine: 554:44 h TSN
Technical limitations	None
Certificate of registration	Issued by FOCA on 1 July 2012, valid until deletion from the aircraft register.
Certificate of airworthiness	Issued by FOCA on 6 March 2012, valid until revoked.
Airworthiness review certificate	Date of issue: 20 November 2012 Date of expiry: 25 November 2013
Types of operation	In commercial operation: VFR by day

1.6.2 Maintenance

The last scheduled maintenance work on the HB-ZMO was carried out on 29 June 2013 at 552:32 TSN and included a 50-hour inspection. The inspections were performed by the company's own maintenance organisation.

In the period between 24 May and 7 June 2013, a 500-hour/24-month inspection of the airframe and a 100-hour inspection of the engine at 500:42 TSN were certified for the same helicopter.

Furthermore, repair work on the flexible connection of the driveshaft was carried out during this period because of a loose bolt connection. This included the following tasks:

- Removal and installation of the main transmission
- Replacing of the driveshaft and the flexible connections
- Removal and installation of the engine
- Measuring the vibration of the tail rotor driveshaft
- Measuring the vibration of the engine
- Measuring the engine oil pressure

These tasks were carried out in cooperation with experts from an external engine maintenance organisation.

1.6.3 Information on the hydraulic system

1.6.3.1 General

The helicopter is equipped with a conventional flight control system. This means the cyclic and collective stick are connected to the main rotor with rods and the swashplate. The pedals are connected to the tail rotor in a similar way. The aerodynamic forces acting on the main rotor blades must be overcome with these three controls. In order to reduce the effort required by the pilot to operate the controls,

[1] TSN: time since new

the helicopter was equipped with a hydraulic system. Via rods the flight controls actuate the hydraulic servos which transmit the control movement to the rotor blades and thereby control the angles of the blades.

The helicopter is equipped with three servos for the main rotor and one servo for the tail rotor. The three servos controlling the blade angle of the main rotor are fitted between the main rotor transmission and the swashplate (see figure 6). The servo fitted at the front left controls the pitch, the front right servo and the rear left servo control the roll. All three servos together control changes from the collective. The three servos connected to the main rotor are in principle identical.

A hydraulic pump provides a system pressure of 600 psi (40 bar) to the servos. In case of complete loss of hydraulic pressure, the control effort required by the pilot would considerably increase. Each servo is therefore fitted with an accumulator which maintains the pressure for up to 30 seconds after a complete loss of pressure in the hydraulic system. This provides the pilot with sufficient time to land from a hover flight or to reach the recommended speed for the continuation of the flight. When the pressure falls under a certain minimum, a red HYD warning light illuminates on the warning light panel in the cockpit and the corresponding aural warning sounds.

In order to prevent overload of the main rotor system, the servos are designed for a maximum force of 185 daN (Dekanewton). If this value is exceeded, the hydraulic system reaches its operational limits. The required additional effort must be provided by the pilot via the flight controls. The required effort increases significantly which can be perceived as stiffening of the controls. This phenomenon called ‘servo transparency’ is explained in more detail in the following.

The manufacturer offers a version of this helicopter type with a duplicated hydraulic system, which increases the maximum take-off mass by 100 kg and is mandatory e.g. when flying the helicopter under IFR because of system redundancies. Two independent hydraulic pumps deliver the pressure to the servo cylinders which are attached in parallel. There is a possibility that the main rotor is excessively loaded. For this reason the servos are equipped with integrated load sensors which will activate the LIMIT warning light on the warning light panel when the pre-determined limit is exceeded.

HB-ZMO was fitted with a single hydraulic system and did not have the respective warning light.

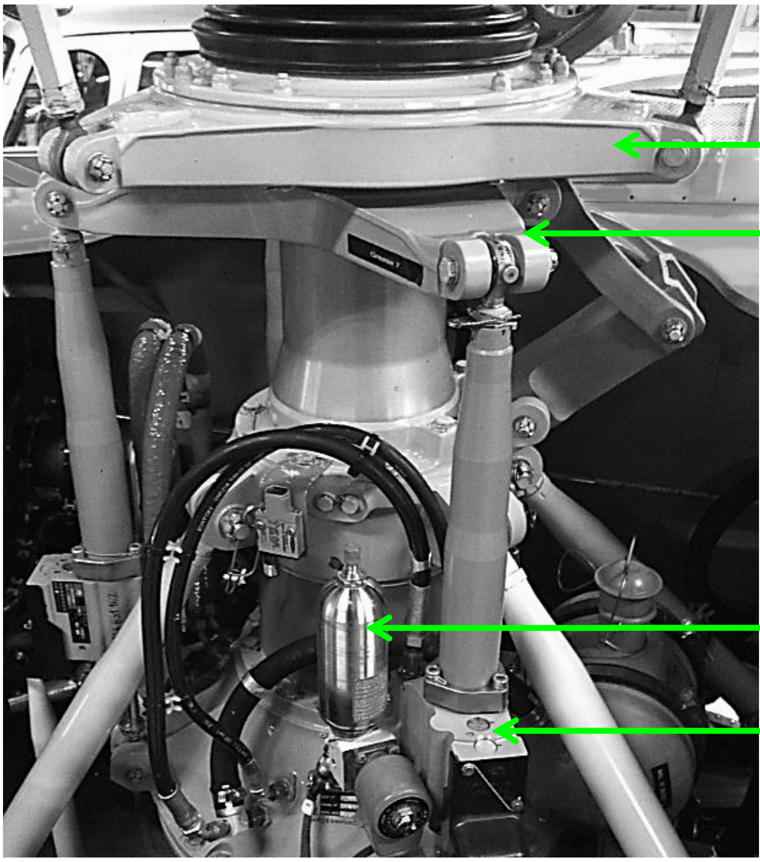


Figure 5: Hydraulic servos with accumulators and control rods to the swashplate.

1.6.3.2 Excerpt from the aircraft flight manual

The aircraft flight manual (AFM) of the helicopter AS350 B3e describes the handling of the possible occurrence of servo transparency in the limitations section:

"2.3.6 MANOEUVERING LIMITATIONS

Continued operation in servo transparency (where load feedback is felt in the controls) is prohibited.

Maximum load factor is a combination of TAS[2], Hσ [3] and gross weight.

Avoid such combinations at high values associated with high collective pitch.

Transparency may be reached during manoeuvres, steep turns, hard pull-up or when manoeuvring near VNE. Self-correcting, the phenomenon will induce an uncommanded right cyclic load and an associated collective down reaction. However, even if the transparency feedback loads are fully controllable, immediate action is required to relieve the feedback loads: reduce the severity of the manoeuvre, follow the aircraft's natural reaction, let the collective pitch decrease naturally (avoid low pitch) and smoothly counteract the right cyclic motion. Transparency will disappear as soon as excessive loads are relieved.

In maximum power configuration, decrease collective pitch slightly before initiating a turn, as for this manoeuvre, the power requirement is increased.

In hover, avoid rotation faster than 6 sec. per full rotation."

[2] TAS: true air speed

[3] Hσ: density altitude

1.6.3.3 Description of servo transparency

The following description is based on the accident report LN-OXC of the Accident Investigation Board Norway.

As mentioned above, hydraulic servos in the flight controls can be subjected to overloads so that servo transparency occurs, also called ‘jack stall’. In forward flights, on helicopters with a main rotor that rotates clockwise as seen from above, the blades have the highest blade angle when they pass aft on the right-hand side of the helicopter. The high blade angle is required to compensate for the lower resultant speed over the blade when it moves aft while the helicopter is flying forward. The general load on the main rotor increases under the following conditions:

- High speed
- High power, high torque (high collective pitch)
- High mass
- High g-load
- Increasing density altitude, i.e.: increasing flying altitude, increasing temperature, increasing humidity

Some factors have clear limitations, for example maximum permissible take-off mass and maximum speed VNE (never exceed). However, servo transparency can occur through a combination of factors even if the limitations for individual parameters are not exceeded. In addition, the load on the right-hand side of the rotor increases also when the helicopter banks to the left, is held in a left turn or when the helicopter is quickly rolled out of a right bank to the left.

One factor that always increases the margins before the onset of servo transparency is lowering the collective before or during the initiation of a steep turn.

There is no indication or warning for the pilot of the helicopter before the onset of servo transparency. The flight manual AFM/RFM does not provide any information on the values from which servo transparency should be expected. The fact that the total sum of individual load factors for the main rotor has exceeded the maximum capacity of the servo only becomes apparent when the phenomenon actually occurs.

The graph below shows schematically that servo transparency occurs for as long as the 185 daN maximum force of the servos is exceeded. If the load factors on the main rotor momentarily add up to for example 195 daN, the pilot has to provide the required additional effort manually. This steering input builds up instantaneously. As only small efforts are normally required to control the cyclic stick of a AS350, the surprised pilot perceives the additional and suddenly required effort of 10 daN as if the controls were jammed.

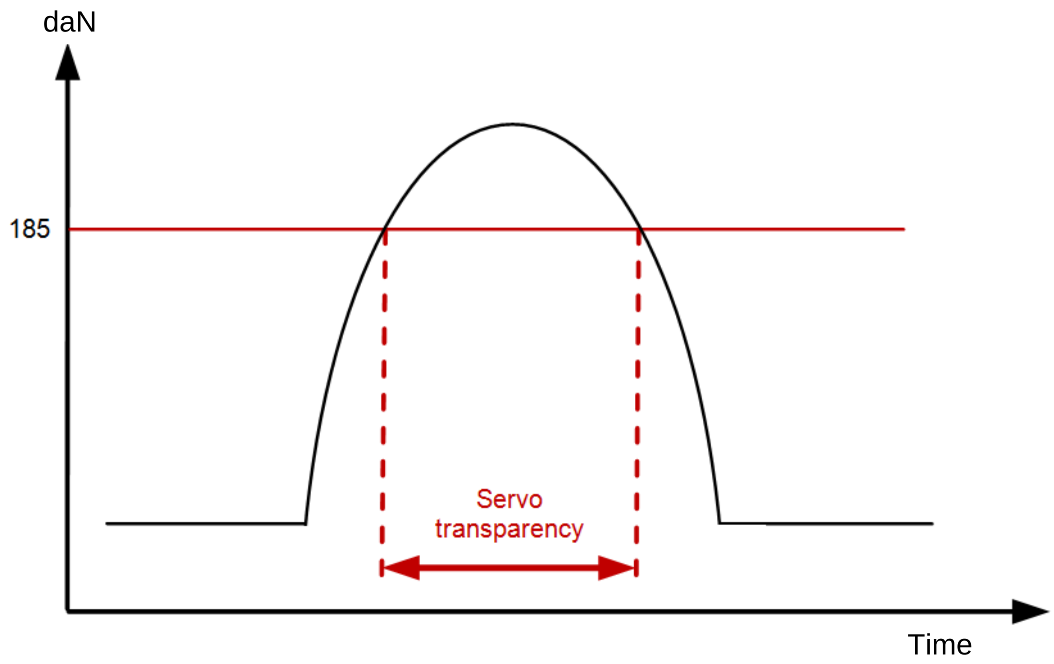


Figure 6: Servo transparency – the required output exceeds the servo's capacity in the period between the dotted red lines. The servo can output a maximum force of 185 daN.

A pilot that is prepared can provide the required additional control force, however in doing so he may overload the rotor system. If the pilot is surprised by the phenomenon, the helicopter's flight path, i.e. altitude and track may change. As mentioned above, the lift from the rotor blade passing through the aft right-hand sector will become insufficient. This creates a rolling movement to the right. Due to the gyroscopic effect on the rotor, this will also cause the helicopter's tail to drop and the nose to pitch up. Under normal circumstances, this pitch-up causes the flying speed to decrease. This results in a decrease of the load factor which reduces the likelihood of the servo transparency persisting. According to the manufacturer, servo transparency normally does not last longer than 2-3 seconds.

1.7 Recording devices

1.7.1 Vehicle and engine multifunction display

The primary function of the vehicle and engine multifunction display (VEMD) is to provide the pilot with information on various systems during the flight but it also records certain parameters. This is, however, no continuous recording system. Only when a failure occurs, different numbers of parameters are recorded depending on the type of failure. In addition, the time of the failure occurring is recorded. 'Over limit' events are also captured, however, without recording the time of the event. Only the parameter and the extent of the exceedance are recorded.

The investigation of the VEMD did not show any 'over limit' events and no relevant defect before the accident. The recorded flight time until the accident was 2:12 hours, including the time on the ground with the rotor turning.

1.8 Examination of the wreckage

1.8.1 General

The helicopter HB-ZMO showed a high degree of damage because of the impact and the subsequent fire. During the examination of the wreckage, the following findings were established as described here in the following sub-chapters:

1.8.2 Engine

The damage to the engine could be attributed to the fire, to overspeed and to the severe impact. The rotating components of the individual engine modules were not seized and did not show any anomalies. The magnetic plugs of modules 1 (driveshaft) and 5 (reduction gearbox) were free of swarf.

It was established from the engine and from other dynamic components that the engine was delivering power at the time of the impact.

1.8.3 Landing skids

The landing skids showed some longitudinal tube failures at the connection points with the cross tubes. A forward cross tube failure was found in the area of the right-hand airframe connection.

The left-hand landing skid showed clear longitudinal tube bending upwards, which is more likely to be attributed to displacement or deformation during the disintegration sequence than to a vertical impact.

The tube connections and the structural components were connected to the landing skids.

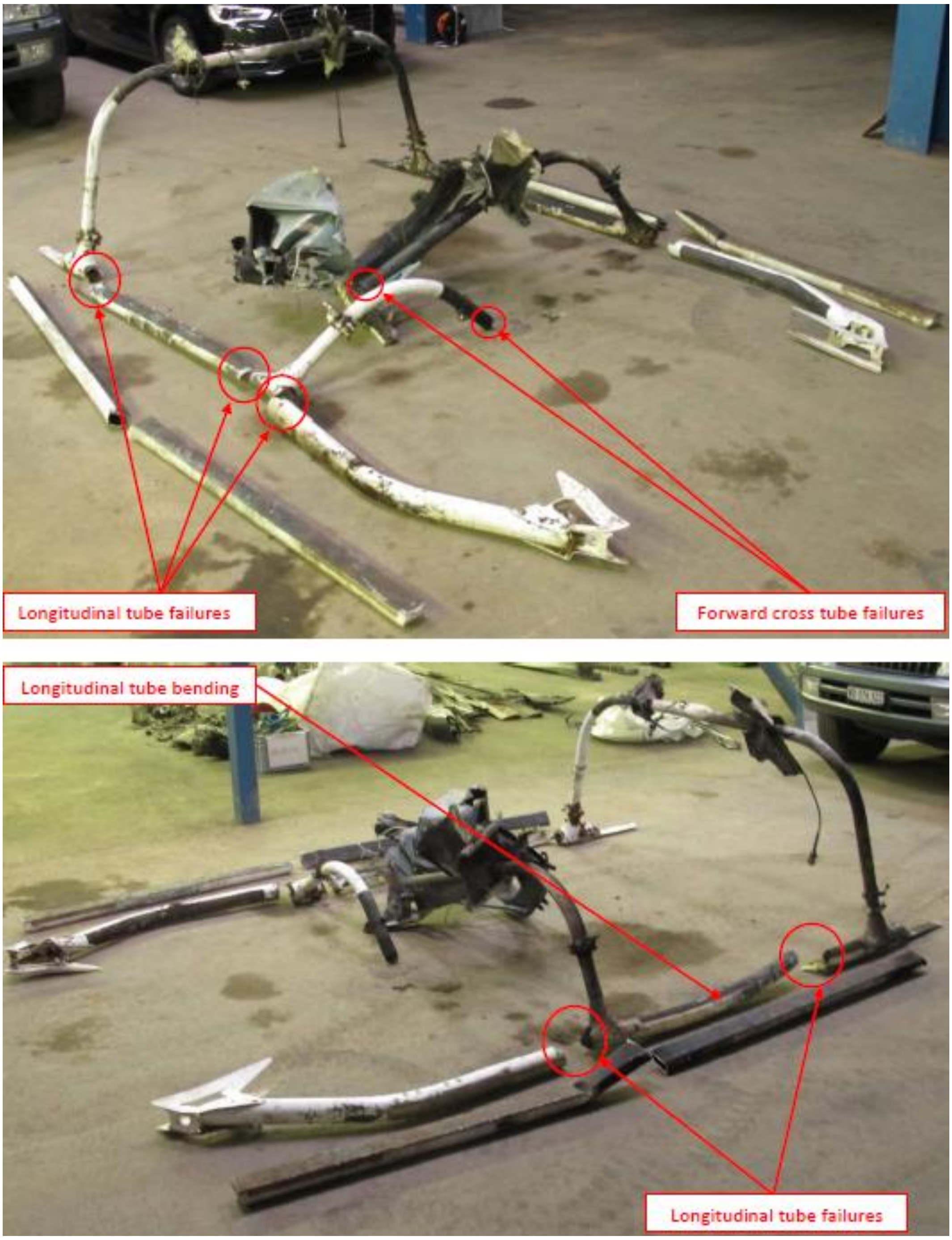


Figure 7: The pieces of the landing skids were set up to their original position. Significant fractures are marked in red.

The findings on the landing skids indicate the main direction of movement and the flight attitude of the helicopter at the time of the accident:

- Low vertical speed
- Considerable forward speed
- Nose down attitude
- Right roll attitude

1.8.4 Airframe

Apart from the complete tail boom and a part of the cockpit, the helicopter airframe was completely destroyed by the impact and the subsequent fire.

The instrument panel was separated from the airframe by the impact and thrown forward.

Due to overload, the tail boom was separated from the airframe at the mounting points and showed deformations in this area.

The tail skid was bent upwards and the lower tail fin was bent to the right. The end of the tail boom aft of the tail rotor transmission was twisted.

The tail boom showed a left-to-right failure at the first bearing of the tail rotor driveshaft, which matches the twisted tail cone, the bent tail skid and the bent tail side fin.

The findings on the tail structure showed that the tail boom was separated from the connection point to the fuselage which led to the tail skid's contact with the ground and resulted in deformation of the tail boom and the tail fin.

The separation of the driveshaft led to damage to the engine cowling and to the control rods of the swashplate near the rear splined driveshaft coupling.

1.8.5 Pilot's seat

The pilot's seat suffered considerable damage from the fire and showed major deformation due to the impact.

The findings regarding the damage and the deformation of the pilot's seat indicate the following:

- Overload of the pilot's seat to the front right, little vertical load
- High-energy impact
- Low vertical speed
- Considerable forward speed
- Nose down attitude
- Right roll attitude

1.8.6 Main rotor blades

The rotor blades were severely damaged by the impact and the fire. In addition, the blades showed clear damage from the contact with the ground whilst they were powered.

1.8.7 Main rotor head

The main rotor head showed considerable damage which can be attributed to the impact and the fire.

All components on the main rotor head were mechanically connected correctly and showed damage that had been caused by the blades' contact with the ground whilst they were powered.

1.8.8 Main transmission

The casing of the main transmission was destroyed by the fire. As the main components of the casing are made from an aluminium-magnesium alloy, the high heat generated led to melting. The planetary gear and the bevel gear as well as the lubrication module did not show signs of mechanical damage.

1.8.8.1 Transmission suspension

The suspension struts that are connected to the underside of the main transmission were largely non-existent as they had been melted as a result of the high temperatures generated by the fire. The fact that the mounting points of these struts were still present is evidence that the struts had been there at the time of the accident.

1.8.9 Clutch between engine and main transmission

The clutch connecting the engine and main transmission was damaged by overload and no longer had a frictional connection.

The flexible connection on the engine side showed signs of contact with the splined flange. The connection also showed signs of deformation which can be attributed to a misalignment of the shaft under torque due to the deformation of the airframe.

The flexible connection on the main transmission side was severely damaged by the fire. It also showed signs of deformation.

The findings show that the damage resulted from contact of the powered main rotor blades with the ground, and that the helicopter had significant forward speed.

1.8.10 Tail rotor driveshaft

The forward tail rotor driveshaft made of steel was deformed near the engine flange.

The bearings of the aft driveshaft made of light metal were pulled forwards out of their supports.

The flange on the engine-side of the forward driveshaft and the flange of the engine driveshaft were severely deformed.

The flexible connection between the forward and aft tail rotor driveshafts was completely destroyed. The splined flange was still attached to the flexible connection.

The splines and the connection piece of the splined flange showed no signs of damage.

It can be concluded from the findings that the tail rotor driveshaft was separated in the area of the flexible connection immediately after the tail boom had been separated from the airframe.

1.8.11 Tail rotor transmission and tail rotor hub

The tail rotor transmission could drive the tail rotor hub faultlessly. The hub was neither damaged nor deformed.

There was no metal swarf on the magnetic plug.

The condition of the components indicated that the connection of the driveshaft had been separated before the main and tail rotor contacted the ground.

1.8.12 Tail rotor blades

Damage was visible on the collars of the tail rotor blades, which could be attributed to contact with the ground at low speed and without power after the tail rotor driveshaft had been severed.

1.8.13 Flight controls and hydraulic system

Because of the high degree of destruction the fire had caused to the wreckage, a complete examination of the flight control and hydraulic system could not be carried out. Nevertheless, it could be established from the wreckage that the hydraulic servos for the control of the main rotor were connected between the main transmission and the swashplate.

There was no damage to the hydraulic servo for the control of the tail rotor. The connections of the hydraulic oil pipes on the servo were broken off and the control rod was severely bent by the impact. Apart from the bent control rod, all components were correctly connected and thus provided control of the tail rotor blades.

1.8.14 Detailed examination of flight instruments

The detailed examination of instruments that had remained mainly intact showed that the indications had to be attributed to the destruction process, and did not allow conclusions to be drawn regarding the helicopter's initial impact.

1.8.15 Conclusion from the examination of the dynamic components

The technical examination of the wreckage's dynamic components showed the following:

- Contact of the main rotor blades under power with the ground
- Considerable forward speed
- When the tail boom was separated from the airframe, the tail rotor driveshaft was immediately severed in the area of the flexible connection
- The tail rotor driveshaft had been severed before the main and tail rotor blades contacted the ground
- The tail rotor blades had contact with the ground at low speed and unpowered

1.9 Information on the pilot

1.9.1 General

As a result of a requirement in the medical certificate, the pilot had to wear corrective visual aids. According to the statement from the air transport operator's manager, he complied with this by wearing contact lenses. The manager also said that the pilot had only been absent because of illness once or twice during his employment, and once or twice had been unable to carry out flying duties because of headaches. The last time this had happened was about eight months before the accident. The pilot had a healthily lifestyle, exercised regularly and was a non-smoker.

The pilot always wore a helmet on helicopter flying duty and he did so when the accident occured.

1.9.2 Training and experience of the pilot

The pilot completed the private pilot training in July 2005 on a Hughes H269 helicopter with a total of 48 flying hours.

In December 2006, he completed his commercial pilot licence on the helicopter type Eurocopter EC120 with a total of 110 flying hours.

The basic flight training included steep turns and approaches without hydraulic support (HYD OFF).

After that, the pilot started the mountain flight training in January 2007 and completed this in the summer of 2007 with a total of 140 flying hours. During that time, the pilot often took passengers with the EC120 on scenic flights through the mountains.

In November 2008, the pilot received conversion training to fly the helicopter type AS350 B3. His total flying time was 222 hours. Together with his flight instructor, the pilot practised the standard flight operation range of the AS350 B3 helicopter in accordance with the type rating. Approaches without hydraulics from approx. 70 kt were practised in particular. The issue of possible hydraulic servo transparency outside the normal flight envelope was touched on in theory. According to the flight instructor, this conversion training did not pose any particular difficulty to the pilot with his EC120 experience.

In 2009, the pilot was hired by the air transport organisation in Erstfeld that was involved in this accident. In addition, the pilot was an aircraft mechanic for helicopters. When the new helicopter HB-ZMO (AS350 B3e) was introduced, he had concentrated particularly on the rotorcraft flight manual (RFM) and familiarised his colleagues with the differences to the earlier version AS350 B3.

The pilot was described by his flight instructor and flight operations manager as calm, loyal and well integrated into the team.

His passenger transport and transfer flights were often in the surrounding mountains of his operation bases.

In May 2010, when his total flying time was 410 hours, the pilot started his external cargo sling (ECS) training under the instruction and supervision of the flight operations manager.

During this time, the pilot was mainly assigned to ECS jobs in the mountains from the Erstfeld base. Towards the end of 2011, the pilot had performed a total of 880 flying hours and 1500 ECS operations.

Towards the end of 2012, the total flying time was 1265 hours with 3900 ECS operations.

On 28 June 2013, shortly before the accident, the pilot had a total of 1420 flying hours and completed 5079 ECS operations. He carried out the ESC flights using the 'mirror and vertical reference' technique. As the pilot was not a flight instructor, his flying experience with regards to flight controls without hydraulic support was limited to the compulsory annual proficiency checks.

According to his ECS instructor, the servo transparency phenomenon was mentioned because in certain situations during the ECS flights, knocks had been noticeable in the controls.

As the Kröntenhütte is located near the Erstfeld helicopter base, the pilot had flown to this hut many times as part of his work as commercial helicopter pilot. He had approached the hut from various directions including from the basin above the hut and in different wind and weather conditions. Because of the hut renovation, the pilot had been flying there two to three times a week from the beginning of June 2013.

1.10 Medical and pathological findings

Autopsies were performed on the occupants of the helicopter HB-ZMO. The report states that the occupants died immediately on impact because of serious multiple trauma. The autopsy did not find any evidence of acute or pre-existing illnesses which could have caused sudden incapacity to fly.

According to the pilot’s family doctor and FOCA’s independent aeronautical medical examiner, the pilot was in good health prior to the accident. The pilot was required to wear corrective visual aids on flying duty.

The pharmacology/toxicology report showed a blood alcohol concentration of 0.00 per mille in the pilot’s blood. There was no evidence of the presence of foreign substances.

Acting on information received, the examination was extended to include additional substances. No corresponding traces were found.

1.11 Reconstruction of the flight path

1.11.1 Calculations regarding the flight profile

Flight path from Päuggenfurggi to the last recorded tracking point:

500 m distance, 150 m difference in altitude, 16° angle, 3700 ft/min rate of descent (ROD) at an average ground speed (GS) of 125 kt.

Estimated flight path between the last recorded tracking point and the accident site based on the eyewitnesses’ information:

1.4 km distance, 335 m difference in altitude, 13.5° angle, 3300 ft/min ROD, at an average GS of 135 kt.

The calculated angle of bank is 60°, and the load factor 2.0 g at constant radius, horizontal flight profile and constant GS.

1.11.2 Reconstruction of the flight profile

The recorded and, in the final phase, observed flight profile was reconstructed in open terrain and at the same density altitude (DA) with the same helicopter type AS350 B3e, a corresponding flight mass of 1900 to 1950 kg and similar central c.g. position.

During the reconstruction flight, the following values were established:

The flight profile during the first straight stretch before the turn required a collective pitch of less than 40 % torque (TQ).

At the initiation of the turn, roll attitude and collective pitch were increased progressively. Because of the slower increase at the beginning, the roll attitude had to be increased accordingly at the end of the turn in order to achieve the given geometry. The indicated speed before initiating the turn was 110-120 kt. Two trials were carried out in constant descent, two in descent down to the imaginary terrain followed by rapid reduction of the sink rate and two with horizontal profile.

	Collective pitch power	Load factor	Bank angle	Servo transparency
Constant descent	70 % TQ	1.7 - 2.0 g	60° - 70°	Yes, complete
Descent with reduction of the sink rate	70 - 80 % TQ	1.9 - 2.1 g	65° - 75°	Yes, complete
Horizontal	80 - 90 % TQ	1.9 - 2.2 g	70° - 80°	Yes, complete

Table 1: Results of the reconstruction flights

The controls of the helicopter could only be operated with great effort when servo transparency occurred. In addition, with the occurrence of servo transparency, the roll rate to the right and the pitch-up increased rapidly. Guiding the helicopter out of this situation was quick and simple by easing or reducing the collective that was already pulling with great force downwards, followed by rolling out to the left. In doing so, the original accelerated flight path of the turn was of course exited towards the outside.

1.11.3 Calculations by the manufacturer

Calculations were performed by the manufacturer Airbus Helicopter, formerly Eurocopter, for the helicopter AS350 B3 with a flight mass of 1850 to 1950 kg and the atmospheric conditions present at the time of the accident. The occurrence of servo transparency was determined with theoretical constant bank and speed for a defined radius in accelerated horizontal flight.

Limit radius in function of speed to entry in servo-transparency (Level flight)						
Altitude=	1950 m		QNH=		1021 mbars	
Temperature=	8 °C		Dew point=		1 °C	
Air density=	0,806					
M=	1850 kg			M=	1950 kg	
Vp (kts)	n (g)	**radius (m)**		**Vp (kts)**	n (g)	**radius (m)**
100	2,10	**129**		**100**	1,99	**136**
110	1,97	**166**		**110**	1,87	**174**
120	1,85	**210**		**120**	1,75	**221**
130	1,73	**264**		**130**	1,64	**278**
135	1,67	**295**		**135**	1,58	**311**
140	1,60	**330**		**140**	1,52	**347**
150	1,48	**410**		**150**	1,41	**432**
155	1,42	**456**		**155**	1,35	**481**
VNE=155kt at Hp=0 (less 3kts / 1000ft)				VNE=155kt at Hp=0 (less 3kts / 1000ft)		

Figure 8: Results of the manufacturer's calculations

General statement of the manufacturer on the occurrence of servo transparency with regards to the required power setting and flight speed:

"The manufacturer demonstrated that:

- *with a torque lower than 50 %, servo transparency cannot occur*
- *with a speed lower than 100 kt, servo transparency can hardly occur*

Several test flights were performed in the past and demonstrated that the onset of servo transparency is progressive. The phenomenon is non-violent and transitory, and normally lasts for a period of two to three seconds.

The pilot feels the progressive increase of the aerodynamic load beyond the servo control capability. As the difference starts from "zero" the pilot gradually feels that he has to increase effort on the cyclic stick."

1.12 Additional information

1.12.1 Accidents and serious incidents

Accidents and serious incidents related to servo transparency of the helicopter type Airbus Helicopter AS350:

- Accident on 4 July 2011 Dalamot Norway, AS 350 B3, report SL2012/13 from AIBN:
  "An Airlift Eurocopter AS 350 making a passenger charter flight to a mountain cabin in day VMC appeared to suddenly depart controlled flight whilst making a tight right turn during positioning to land at the destination landing site and

impacted terrain soon afterwards. The helicopter was destroyed by the impact and by the ensuing fire; all five occupants were fatally injured. The subsequent investigation came to the conclusion that the apparently abrupt manoeuvring may have led to an encounter with 'servo transparency' at a height from which the pilot was unable to recover before impact occurred."

- Incident on 15 January 2001 Hunderfossen, Oppland County, Norway, AS350 B3, LN-OAK, report SL2001/42 from AIBN.
- Accident on 11 October 1994, Eurocopter AS350 B3 ZK-HZP, report 94-022, from Transport Accident Investigation Commission of New Zealand.
- Accident on 10 August 2001, Eurocopter AS350 B2, N169PA, report NTSB/AAB-04/02 from NTSB USA.
- Accident on 19 October 2001, Eurocopter AS350 B2, N111DT, report FTW02FA017 from NTSB USA.
- Accident on 11 May 2005, Kolsas in Baerum, Eurocopter AS350 B2, LN-OPY, report SL2010/01 from AIBN.
- Accident on 23 July 2007, Eurocopter AS 350 BA, C-FHLF, report A07W0138 from Transportation Safety Board of Canada.
- Accident on 15 September 2007, Scotland, Eurocopter AS 350 B2, G-CBHL, report EW/C2007/09/06 from Air Accidents Investigation Branch UK:

The helicopter flew at low altitude and high speed in a right turn and collided with trees shortly afterwards. There were indications that the pilot tried to manoeuvre out of the difficult flight situation. However, there was too little distance to the obstacles. All four occupants perished.

Extract from the AAIB UK accident report:

"According to Eurocopter, servo transparency is a transitory phenomenon which, because of the helicopter's natural response, tends to be self-correcting. However, this may not be so for a helicopter in a turn to the right. In this case, the helicopter's natural reaction will cause the angle of bank to increase which, together with a possible pitch-up, will cause an increased rate of turn. The effect, if any, on airspeed would be much less.

Although the helicopter will recover from the servo transparency of its own accord, the potential exists for a significant flight path deviation. The onset of this could be rapid and could conceivably lead to a helicopter in a right turn exceeding 90° of bank before the pilot was able to recognize what was happening and react accordingly. The associated transition from light and responsive controls to heavy controls that require considerable force to counter the un-commanded manoeuvre could cause an unsuspecting pilot to believe that he was experiencing a malfunction, rather than a known characteristic of the helicopter when manoeuvred at the published limits. As Eurocopter have advised, a servo transparency encounter may give a pilot who is not aware of this phenomenon an impression that the controls are jammed."

1.12.2 Safety Awareness Notification Data

FOCA SAND AS350 Types: Hydraulic Transparency – Information and Training Recommendation

“FOCA SAND-2014-001

Description

Following their investigation of a helicopter accident involving a Eurocopter AS350B3 Ecureuil, the Accident Investigation Board Norway (AABN) recommends that owners and operators of similar helicopters be reminded of the phenomenon of ‘Hydraulic Transparency’ (Safety Recommendations SL 2012/08T/09T).

The purpose of this SAND is to draw the attention to ‘Hydraulic Transparency’, also known as ‘Servo Transparency/Reversibility’ or ‘Jack Stall’. A full description of this feature is provided below through the information issued by Eurocopter in their Service Letter 1648-29-03, dated 14 December 2003. The Operational Evaluation Board (OEB) report for the Ecureuil family, published by EASA, defines additional awareness training to prevent the phenomenon.

The content of this SAND is based on the Eurocopter Service Letter (No. 1648-29-03), the accident report of AABN (SL 2012/13) and of the UK AIC (P 043/2009):

What happens?

On single-hydraulic-system-equipped helicopters, the Hydraulic Transparency phenomenon can occur when the general load of the main rotor increases excessively during immoderate manoeuvring. The general load on the main rotor increases under the following conditions:

High speed, High torque (high collective pitch)

High mass, High g-load

Increasing density altitude, i.e.: Increasing flying altitude

Increasing temperature, Increasing humidity

On this helicopter type, there is no indicator or warning which alerts the pilot that the helicopter is about to enter Hydraulic Transparency. It occurs in combination of the factors referred to above. If the load of the main rotor increases smoothly, the phenomenon could begin with vibrations of the “cyclic” control. If the load increases quickly, Hydraulic Transparency may occur instantly (equates HYD OFF on “collective”). The pilot may experience that the stick force increases from almost zero to 10 daN (equivalent to about 10 kg) over a short period of time, and may perceive that the controls are jammed.

Why avoid Hydraulic Transparency?

If the pilot is prepared and adds this extra force, she/he may keep the helicopter on intended flight path. If the pilot is surprised by the phenomenon, the helicopter’s flight path (altitude and track) may change: a sudden rolling movement to the right (may exceed 90º of bank) and the helicopter’s nose pitch-up (speed drop). If this phenomenon is encountered in close proximity to terrain or obstacles, especially in a right turn, it could be hazardous.

How to avoid Hydraulic Transparency?

Basic airmanship should prevent encountering this phenomenon by avoiding excessive manoeuvres leading to high rotor loads (>1.5g): Therefore avoid combinations of high speed, high gross weight, high bank and pitch angles, especially at high density altitude.

How to react if Hydraulic Transparency occurs?

The pilot's reaction to the first indication of control forces feedback should be to IMMEDIATELY counteract the unintended roll to the right, reduce the severity of the manoeuvre (to reduce the load) and to allow the collective pitch to decrease (of course, monitor main rotor rpm speed at very low pitch). Further smoothly counteract the right cyclic tendency to prevent an abrupt left cyclic movement as hydraulic assistance is restored.

Recommendations

1. Information to all pilots and awareness training

FOCA recommends to inform all pilots about the phenomenon and especially to highlight how to prevent and how to recover from Hydraulic Transparency. If possible, pilots should be trained by a flight instructor as described in the Operational Evaluation Board (OEB) report for the Ecureuil family (except for EC 130 B4 and AS 350 B3 Arriel 2B1 & AS 350 B3e when fitted with dual hydraulic system).

Hydraulic Transparency training with a flight instructor could be performed as follows:

Complete procedure should be performed above 1000 ft (AGL[4]),

Achieve airspeed between 130 and VNE (with a rate of descend),

Perform a 30° left turn,

Slowly increase the load factor by a backwards cyclic action,

When Hydraulic Transparency is achieved, the tendency of the aircraft is to pitch up and turn to the right,

As soon as the load decreases, Servo Transparency disappears,

The phenomenon occurs earlier (easier) with high All Up Weight and/or at high density altitude.

Pay attention to the following:

Due to control loads linked to Servo Transparency, the collective pitch tendency is to decrease,

The collective pitch decrease and the pitch-up may lead to rpm increase,

The procedure should neither be done too aggressively nor close to obstacles.

2. Operational restrictions

FOCA recommends, in addition to the AFM, to obligate pilots not to manoeuvre excessively, especially at low height."

[4] AGL: above ground level

2 Analysis

2.1 Technical aspects

There is no evidence of pre-existing technical faults that could have caused or influenced the accident.

The examination of the wreckage allows the following conclusions on the accident sequence:

- Contact of the powered main rotor with the ground.
- Considerable forward speed, rather low vertical speed.
- On impact, the helicopter had a nose down and right roll attitude.
- On impact, the tail boom was bent upwards and separated from the airframe.
- Considerable impact of the tail boom with the ground after separation from the airframe.
- The separation of the tail boom from the airframe immediately led to the separation of the main driveshaft in the area of the flexible connections.
- The driveshaft of the tail rotor had been severed before the main and tail rotor made contact with the ground.
- The tail rotor blades were not powered and were turning at low speed when they made contact with the ground.

There were signs on the wreckage and on the engine indicating that on impact the engine was connected to the main transmission and was delivering power.

2.2 Human and operational aspects

2.2.1 Background

At the end of the previous week, the flight operations management had drawn up an operation programme for the following Monday. On Sunday, this was again discussed by the flight operations manager and the pilot. These additional consultations are standard in the helicopter industry where new arrangements have to be made frequently because of new circumstances. These brief oral confirmations are important and sensible because they are an opportunity to exchange information on the readiness of personnel, machinery and customers as well as special conditions such as the weather or location.

The operation programme for the helicopter HB-ZMO was varied and attractive for an experienced transport pilot and it is therefore understandable that the flight operations manager would have liked to stand in for the pilot. However, according to the flight operations manager, the pilot was looking forward to the missions at the beginning of the week. With this informal discussion, the pilot's flight planning had already started on the day before the accident and the planning was formally completed on the morning of the accident. The pilot was appropriately prepared and rested for flying duty.

There is no indication that the two flight assistants or the passenger could have influenced the accident in the phase before it occurred.

2.2.2 History of the flight

With more than 1300 flying hours and slightly more than 5000 ESC operations, the pilot could be described as relatively experienced. He knew the operation area very well and was familiar with all the locations he approached on this Monday morning. In particular, he had flown to the two SAC huts, the Leutschachhütte and the

Kröntenhütte, many times and in various conditions. It was therefore quite understandable why the pilot chose this flight path after the unscheduled detour via the Leutschachhütte.

The pilot intended to fly the fastest route to the Kröntenhütte. This led him and his powerful helicopter over the topographically lowest passages east of the summit of the Gwächten peak. This route was different from the usual approaches to the Kröntenhütte from the open lower valley.

The Päuggenfurggi passage is 1 km from the Kröntenhütte landing site and 550 m higher. It was therefore normal to make use of the topography and to extend the flight path in a way that finally allowed for an optimum approach angle to the Kröntenhütte without any obstacles (see figure 1). After flying through the trough-like basin, however, this approach would have led the helicopter in a second phase over the sloping ridge that confines the basin to the north. Eyewitnesses have observed this occasionally.

The data recorded by the navigation computer are evidence of the pilot's decision to descend in the basin along the terrain. However, the data up to the last recorded point also indicate that the helicopter flew much faster than would have been optimal with regards to the altitude that had to be lost. The eyewitnesses at the hut confirmed this. They observed the straight flight path deep into the basin. Since the basin is confined by the ridge and the pilot did not fly out of the basin over the ridge, he must have continued the right turn and followed the shape of the terrain. The observers made consistent statements: the last and brief view was that of the complete underside of the helicopter at a large bank angle low above the ridge. This fact is very important for the reconstruction of the last seconds of the flight, as the helicopter collided with the ground only seconds after this last observation.

The information in chapter 1.11 shows that it is very likely that when he controlled the helicopter the pilot was faced with the occurrence of servo transparency because of the following facts:

- the geographical space available inside the basin up to the sloping ridge;
- the recorded and observed flight speed;
- the flight mass;
- the density altitude.

Because of the flight profile in the available space and the high bank angle that was last observed, it has to be assumed that the pilot had set high power or high collective pitch during the second part of the turn.

When servo transparency occurs in an accelerated right turn, the natural tendency of the helicopter is to roll to the right into even higher bank and to further decrease the turn radius with even more pitch-up. Reducing the power is the only option the pilot has to regain control of the helicopter. He will yield to the strong downward pull of the collective in the direction of less power and as the servo transparency eases off, he will almost simultaneously be able to roll back to the left to a normal flight attitude. However, in doing so, the helicopter deviates from its original flight path.

In the present case, flight altitude and distance to the ridge were not sufficient to do this. The helicopter must have collided with the ground during the rolling-out phase.

The first impact marks on the ground as documented in chapter 1.2.2 and the analysis of the wreckage (chapter 1.8) are evidence of the helicopter's position as well as its direction of movement and speed at the first impact.

Despite a tendency for light southerly Foehn, the local wind did not have any influence on the course of the accident. Visibility was very good. Due to the position and location of the helicopter, it was unlikely that the pilot had been affected by sun glare because of the already high position of the sun.

2.2.3 Decisions and flight tactics of the pilot

Making decisions was part of the pilot's everyday life. The detailed flight planning before that day's flight included choosing the flight route to complete the flight programme. If the pilot decides to accept a change of programme during the operation, then a situational adaptation with regards to the choice of flight path arises. In the present case, the decision for the first flight segment up to the Leutschachhütte was made during the flight to base. The decision regarding the flight path from the Leutschachhütte to the Kröntenhütte was also made during the flight or during the stop at the Leutschachhütte. By choosing to climb directly and to fly over the nearest passes below the summit of the Gwächten mountain, the pilot chose the most direct flight path. This choice is understandable with regards to the task and the helicopter's capabilities with its actual load and the weather conditions.

It remains an unanswered question as to when during the flight the pilot decided to fly the helicopter close to the terrain. The decision may have been made because of a spontaneous idea, previous experience or other unknown considerations. However, there was no time pressure that would have prevented a conscious decision-making process including an analysis of the hazards. The flight tactic that was finally chosen entailed great risks, because of the proximity to the terrain.

In the past, the pilot had discussed the possible occurrence of servo transparency with his flight instructor and his ESC trainer, at least in theory. It remains an unanswered question whether the pilot knew the controls-related consequences of a short overload of the hydraulic servo during a respective manoeuvre in normal flight operations.

Based on the available facts, it has to be concluded that it is very likely the pilot was taken by surprise by the servo transparency's intensity. His decision to continue to follow the terrain in low-level flight and in an accelerated right turn shows that he did not realise the danger of servo transparency particularly during a right turn and close to the terrain. He virtually let himself become trapped by the topography.

3 Conclusions

3.1 Findings

3.1.1 Crew

- The pilot held the required licence for the flight.
- The pilot was required to wear corrective visual aids when flying.
- There were no indications from the autopsy with regards to acute or pre-existing illnesses which could have caused sudden incapacity to fly.
- The pharmacology/toxicology report showed a blood alcohol concentration of 0.00 per mille in the pilot's blood. There was no evidence of the presence of foreign substances.
- According to the pilot's family doctor and FOCA's independent aeronautical medical examiner, the pilot was in good health prior to the accident.

3.1.2 Technical aspects

- There is no evidence of pre-existing technical faults that could have caused or influenced the accident.
- The evaluation of the VEMD did not show any 'over limit' events before the accident.
- There were signs on the wreckage and on the engine, indicating that on impact the engine was connected to the main transmission and was delivering power.
- On impact the helicopter had a nose down and right roll attitude.
- The first impact marks on the ground and the analysis of the wreckage are evidence of the helicopter's position as well as its direction of movement and speed at the first impact.
- Mass and centre of gravity were within the permissible limits as stated by the manufacturer.
- An emergency location transmitter was fitted. It was activated by the impact and began sending signals.

3.1.3 History of the flight

- At around 9:00 a.m., the pilot took off from Andermatt with the helicopter HB-ZMO with two flight assistants on board for a flight to Erstfeld.
- During the flight, the pilot decided to fly directly to the Leutschachhütte in order to let a passenger board whilst the engine was running.
- After that, the pilot intended to make a stop during his flight to base to let one of his flight assistants disembark at the Kröntenhütte.
- HB-ZMO took off from the Leutschachhütte with four occupants on board and flew climbing in north-westerly direction. Then, the helicopter crossed the east ridge of the Mäntliser mountain and after that the north ridge near the Päuggenfurggi mountain.
- At an altitude of 500 m above the intended landing site, HB-ZMO flew into the basin south of the Kröntenhütte.
- In fast descent, the helicopter crossed the Steinchelen area and subsequently turned more and more to the right along the terrain in the basin.

- The helicopter seemed to follow the sloping ridge that confines the mountain basin to the north, in the direction of the lake at the basin mouth.
- Shortly afterwards, the helicopter disappeared behind the ridge.
- In the present case, the flight altitude and the distance to the ridge were not sufficient to establish a normal flight position.
- At around 9:15 a.m., the helicopter collided with the terrain, very likely during the rolling-out phase.
- An impact fire developed.
- All four occupants suffered fatal injuries.
- The helicopter was destroyed.

3.1.4 Operational aspects

- The pilot had been hired by the air transport operator in Erstfeld in 2009.
- The flight was to perform aerial work.
- The pilot completed his flight training with the said air transport operator.
- In the past, the pilot had discussed the possible occurrence of servo transparency with his flight instructor and his ESC trainer, at least in theory.
- The pilot flew often to the Kröntenhütte as part of his work. He had approached the hut from various directions including from the basin above the hut and in various wind and weather conditions.

3.1.5 General conditions

- Despite a tendency for light southerly Foehn, the local wind did not have any influence on the course of the accident. Visibility was very good.
- Due to the already high position of the sun at the time of the accident, it is unlikely that possible sun glare influenced the course of the accident.

3.2 Causes

The accident is attributable, with a high likelihood, to a loss of control by the pilot after the onset of servo transparency during a right turn in close proximity to the terrain, and the subsequent collision of the helicopter with the ground.

The risky flight tactic of the pilot contributed to the development of the accident.

4 Safety recommendations, safety advices and measures taken since the accident

4.1 Safety recommendations

None

4.2 Safety advices

None

4.3 Measures taken since the accident

None

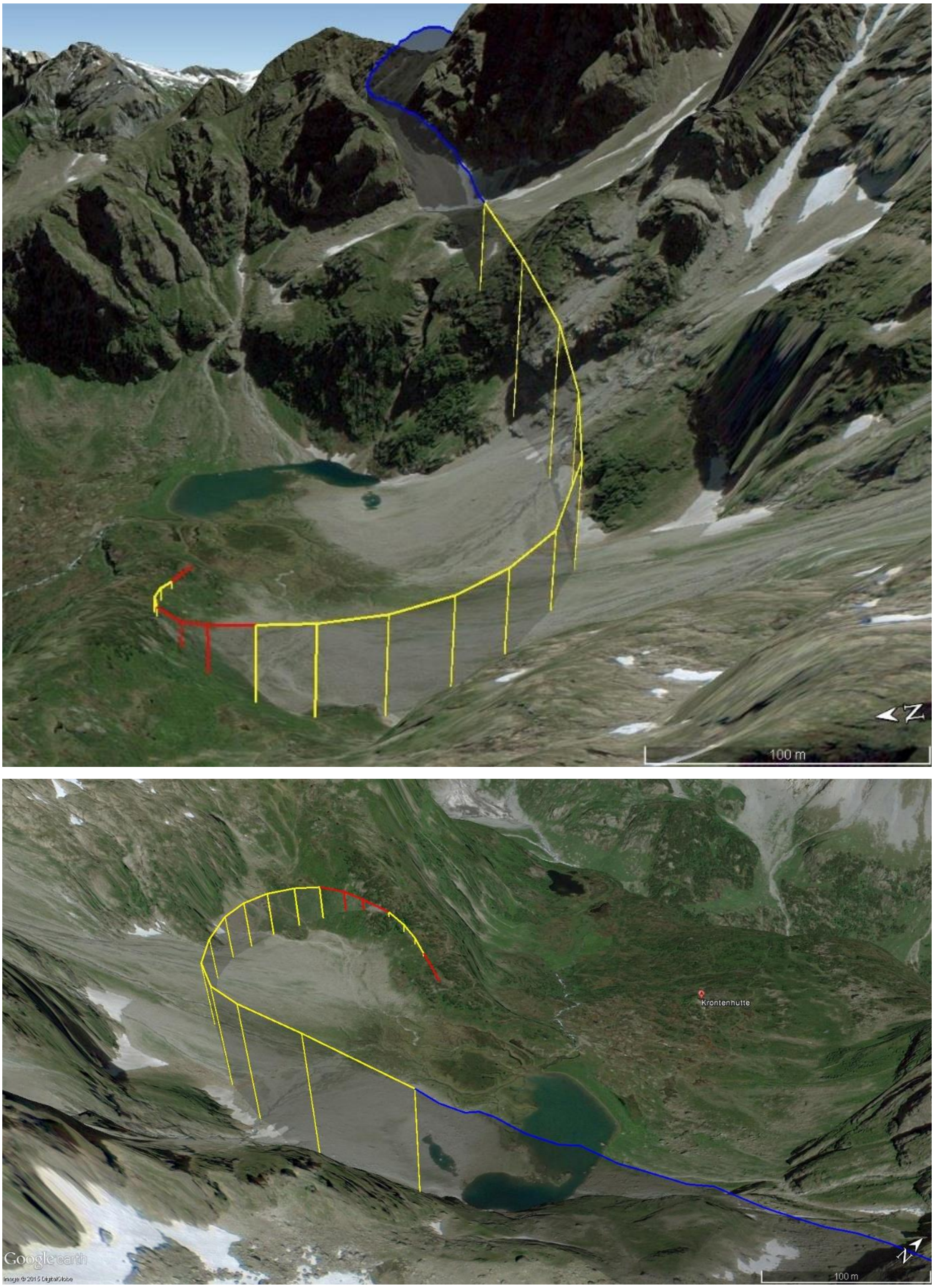
Payerne, 5 December 2016 Investigation Bureau STSB

This final report was approved by the Board of the Swiss Transportation Safety Investigation Board STSB (Art. 10 lit. h of the Ordinance on the Safety Investigation of Transportation Incidents of 17 December 2014).

Berne, 1st December 2016

Appendices

Appendix 1: Flight path of HB-ZMO marked on Google Earth



Flight path of HB-ZMO: the flight path as recorded by the navigation computer (blue), flight path observed by witnesses (yellow) and the not-observed flight path (red).