Statens haverikommission
Swedish Accident Investigation Authority





Final report SHK 2023:10e

Unanticipated yaw – Accident near Härnösand, Västernorrland County on 26 June 2022 involving the helicopter SE-JER of the model Bell 206B.

File no. L-58/22

25 August 2023

SHK investigates accidents and incidents from a safety perspective. Its investigations are aimed at preventing a similar event from occurring in the future, or limiting the effects of such an event. The investigations do not deal with issues of guilt, blame or liability for damages.

The report is also available on SHK´s web site: www.havkom.se

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This document is a translation of the original Swedish report. In case of discrepancies between this translation and the Swedish original text, the Swedish text shall prevail in the interpretation of the report.

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Content

General observations

The Swedish Accident Investigation Authority (Statens haverikommission – SHK) is a state authority with the task of investigating accidents and incidents with the aim of improving safety. SHK accident investigations are intended to clarify, as far as possible, the sequence of events and their causes, as well as damages and other consequences. The results of an investigation shall provide the basis for decisions aiming at preventing a similar event from occurring in the future, or limiting the effects of such an event. The investigation shall also provide a basis for assessment of the performance of rescue services and, when appropriate, for improvements to these rescue services.

SHK accident investigations thus aim at answering three questions: *What happened? Why did it happen? How can a similar event be avoided in the future?*

SHK does not have any supervisory role and its investigations do not deal with issues of guilt, blame or liability for damages. Therefore, accidents and incidents are neither investigated nor described in the report from any such perspective. These issues are, when appropriate, dealt with by judicial authorities or e.g. by insurance companies.

The task of SHK also does not include investigating how persons affected by an accident or incident have been cared for by hospital services, once an emergency operation has been concluded. Measures in support of such individuals by the social services, for example in the form of post crisis management, also are not the subject of the investigation.

Investigations of aviation incidents are governed mainly by Regulation (EU) No 996/2010 on the investigation and prevention of accidents and incidents in civil aviation and by the Accident Investigation Act (1990:712). The investigation is carried out in accordance with Annex 13 of the Chicago Convention.

The investigation

SHK was informed on 26 June 2022 that an accident involving a helicopter with the registration SE-JER had occurred at Skogsfånget, Härnösand Municipality, Västernorrland County, the same day at 20:10 hrs.

The accident has been investigated by SHK represented by Kristina Börjevik Kovaniemi, Chairperson, Ola Olsson, Investigator in Charge, and Stefan Carneros, Operations Investigator.

SHK has been assisted by Magnic AB as an expert in audiovisual analysis, Element Materials Technology AB as an expert in fuel and oil analysis and Roslagens Helikopterflyg AB as an expert in aeronautical engineering.

Nora Vallée from the Transportation Safety Board of Canada (TSB Canada) has participated as an accredited representative of Canada. She has been assisted by advisers from Bell Textron Canada Ltd.

Gabriel Ivan has participated as an adviser for the European Union Aviation Safety Agency (EASA).

Magnus Axelsson has participated as an adviser for the Swedish Transport Agency.

The following organisations have been notified: The EASA, the European Commission, the Swedish Transport Agency and the accident investigation authorities in the USA (NTSB) and Canada (TSB Canada), respectively.

Investigation material

Interviews have been conducted with the pilot, the passengers and a number of witnesses who saw the accident.

The accident site and the helicopter have been examined.

Flight data from a tablet with a navigation program has been obtained and analysed.

Images and audio from a video from a mobile phone that captured the accident have been analysed.

Wind data from nearby wind turbines have been obtained.

A fact finding presentation meeting with the interested parties was held on 25 January 2023 in Härnösand and a digital meeting was held in English on 1 February 2023. At these meetings, SHK presented the facts discovered during the investigation, available at the time.

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Aircraft:	
Registration, type	SE-JER, Bell 206
Model	206B
Airworthiness	Certificate of Airworthiness and valid Airworthiness Review Certificate (ARC)[1]
Serial number	2491
Operator	Private
Time of occurrence	2022-06-26, at 20:10 hrs in daylight Note: All times are given in Swedish daylight saving time (UTC[2] + 2 hours)
Location	Skogsfånget, Härnösand Municipality, Västernorrland County, (position 62°36'3 N 017°46'4 E, 84 metres above mean sea level)
Type of flight	Private
Weather	According to SMHI's analysis: Wind, south to south-east 7–9 knots, visibility more than 10 km, sky clear, temperature/dew point 21–23/13–15°C, QNH[3] 1017 hPa.
Persons on board:	5
Crew members	1
Passengers	4
Injuries to persons	None
Damage to the aircraft	Substantially damaged
Other damage	Leakage of fuel and oil. Minor damage to vegetation and a fence.
The pilot:	
Age, licence	44 years, PPL(H)[4]
Total flying hours	179 hours, of which 32 hours on type
Flying hours previous 90 days	72 hours, of which 32 hours on type
Number of landings previous 90 days	112

[1] ARC – Airworthiness Review Certificate.
[2] UTC – Coordinated Universal Time.
[3] QNH – Barometric pressure at mean sea level.
[4] PPL(H) – Private Pilot Licence Helicopter.

SUMMARY

The pilot had earlier during the day made a number of flights in the local area. During the evening, the pilot was to perform cost-shared flights with other private individuals. These flights started from a cultivated field at Skogsfånget near Härnösand. The accident occurred during the second flight from the location.

After about 15 minutes of flight, an approach was made towards the take-off and landing site. After a landing attempt in which the pilot experienced disturbances from the wind, the pilot performed a go-around in order to land in a different direction on a plot next to a house. This location had limited obstacle clearance, which meant that the pilot had to do a final with a steep descent. During the end of the final, the helicopter had low speed and high power output. The relative wind came from the front left. The helicopter unanticipatedly began to yaw to the right and the pilot experienced that the control actions were not sufficient to counteract the yaw, which turned into an uncontrolled rotation to the right. The pilot turned the throttle to idle, which stopped the rotation, but it also caused the helicopter to descend. The helicopter collided with trees and hit the ground hard.

No serious injuries occurred, but the damage to the helicopter was substantial.

No technical fault that could have contributed to the occurrence has been found.

The investigation has shown that a factor in the occurrence was a phenomenon known as unanticipated yaw, also known as loss of tail rotor effectiveness (LTE).

Causes/Contributing factors

During the approach, the helicopter was flown at low airspeed, high power output, without ground effect and with the relative wind from the left side. This contributed to a reduction in tail rotor effectiveness resulting in an unanticipated right yaw that transitioned into an uncontrolled rotation.

Contributing factors have been that:

- the pilot had insufficient knowledge of the risk of unanticipated yaw,
- the intended landing site had limited obstacle clearance and a high degree of difficulty.

Safety recommendations

The Swedish Transport Agency is recommended to:

- inform concerned parties about the risks of unanticipated yaw in an appropriate way. *(SHK 2023:10e R1)*

The EASA is recommended to:

- inform concerned parties about the risks of unanticipated yaw in an appropriate way. *(SHK 2023:10e R2)*

1. FACTUAL INFORMATION

1.1 History of the flight

1.1.1 Circumstances

The pilot had performed a number of flights in the local area earlier in the day. In the evening, the pilot was to perform further flights with other individuals on a cost-share basis. These flights departed from a cultivated field at Skogsfånget close to Härnösand. The accident occurred during the second flight from the location.

When the pilot was to land after the first flight, the pilot felt a yaw disturbance to the right, but was able to land on the field. When the passengers from the first flight had disembarked, four new passengers boarded the helicopter. One person on the ground assisted the passengers with safety belts and handling of the doors.

According to information the flights were paid for on what is known as a cost-share basis, which means that the pilot and the passengers share the direct costs incurred in connection with a flight.

1.1.2 Sequence of events

The flight was performed locally, including over the town of Härnösand (see Figure 1). After flying for just over 15 minutes, an approach to the take-off and landing site was made from the north.

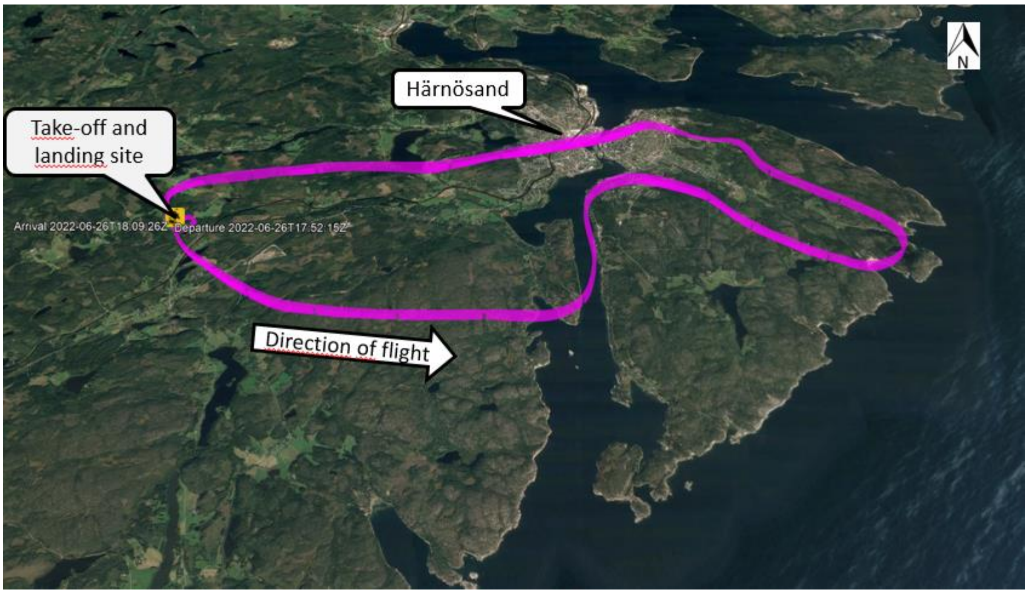

Figure 1. Image with flight data that shows the entire flight. Markings inserted by SHK. Map image: Google Earth. © Lantmäteriet File no. R61749_190001.

The pilot made an attempt to land in an east-north-easterly direction on the cultivated field. Due to an indication that the engine's torque was too high, the pilot was not able to manoeuvre the helicopter in yaw to the desired heading. Consequently, the pilot performed a go-around by turning left in order to land in a different direction on a plot at a nearby house. This was a site the pilot had used before. The plot was confined and a small tree had been removed to increase obstacle clearance.

Figure 2 shows the outbound direction at take-off, the approach direction, the take-off and landing site in the cultivated field, the go-around with a left turn and the accident site.

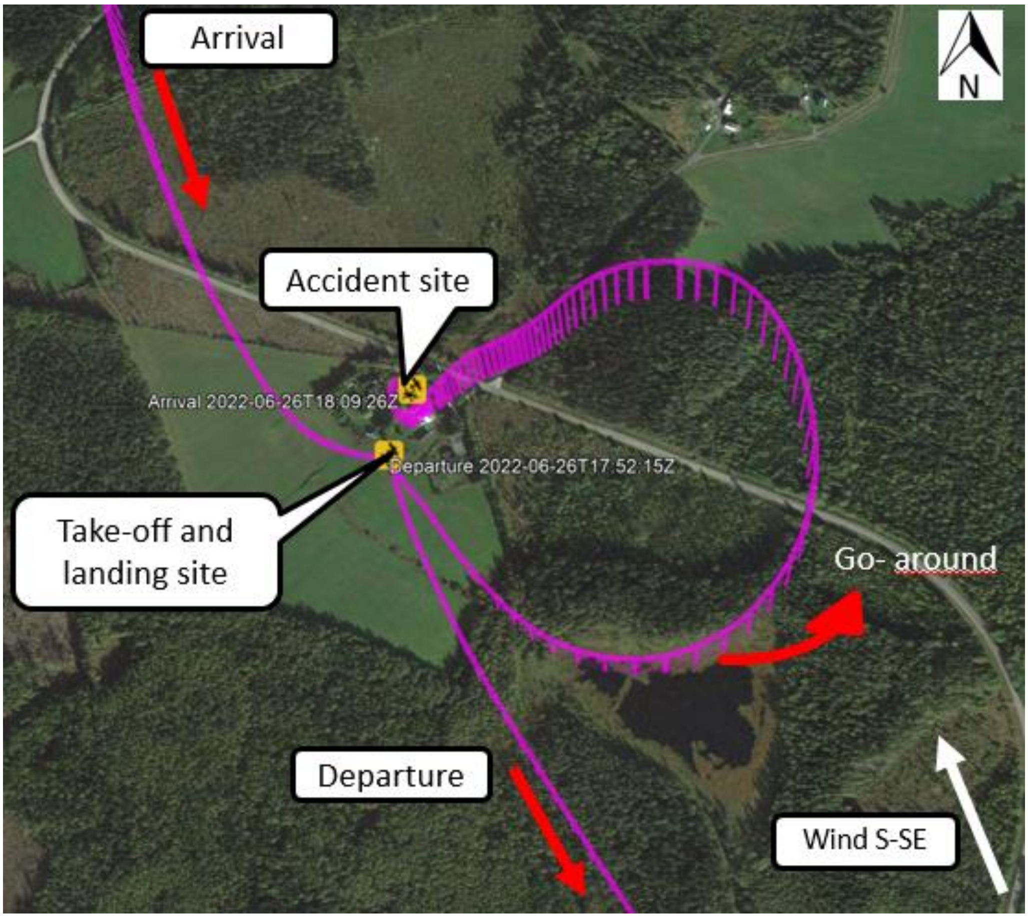

Figure 2. Image with flight data that, among other things, shows the area of the take-off and landing site, the go-around and the final approach towards the accident site. Markings inserted by SHK. Map image: Google Earth. © Lantmäteriet File no. R6174919_0001.

A final approach was made on a south-westerly heading in order to make a steep descent towards the new landing site. At the end of the final approach, the helicopter passed over a residential building in which there were a number of people. The helicopter's ground speed at that time was approximately 5 knots and decreasing, both the track and heading was around 220° and the height above the ground was approximately 30 metres (see Figure 3).

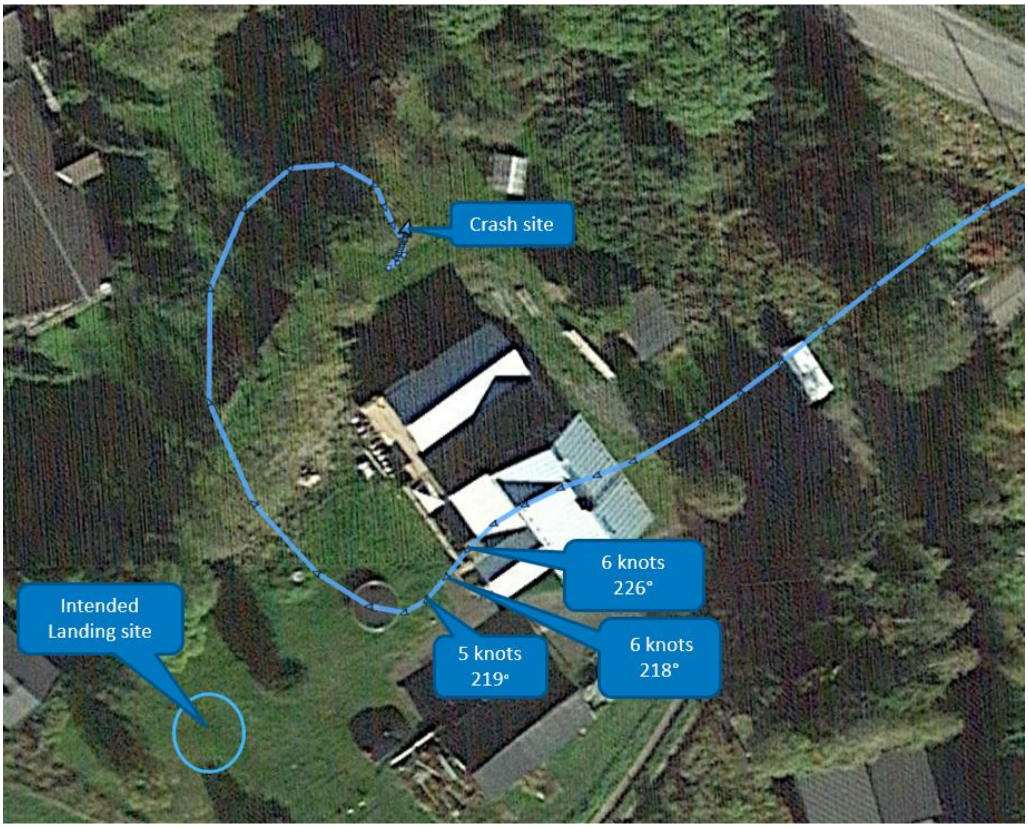

Figure 3. Image with flight data that shows the flightpath during the final approach. The ground speed and track in the last three seconds before the helicopter began to yaw to the right are marked, as is the intended landing site on the house plot and the site of the accident. Please note that the satellite image from Google Earth does not show the actual conditions at the time of the accident. Markings inserted by SHK. Map image: Google Earth. © Lantmäteriet File no. R6174919_0001.

Shortly after this, the helicopter began to yaw to the right. The pilot gradually increased left pedal displacement but felt that this was not sufficient to counteract the yaw.

To manage the yaw, the pilot lowered the collective and pushed the cyclic forward, but the yaw continued and developed into an uncontrolled rotation to the right (see Figure 4).

Figure 4. Series of images showing the helicopter in the uncontrolled rotation to the right. Markings by SHK that show frame rate and time code. Photo: Private.

The pilot turned the throttle handle to idle in order to reduce the rotation. The rotation stopped, but the reduction in engine power simultaneously caused the helicopter to descend towards the ground. The helicopter collided with a number of trees and hit the ground hard (see Figure 5).

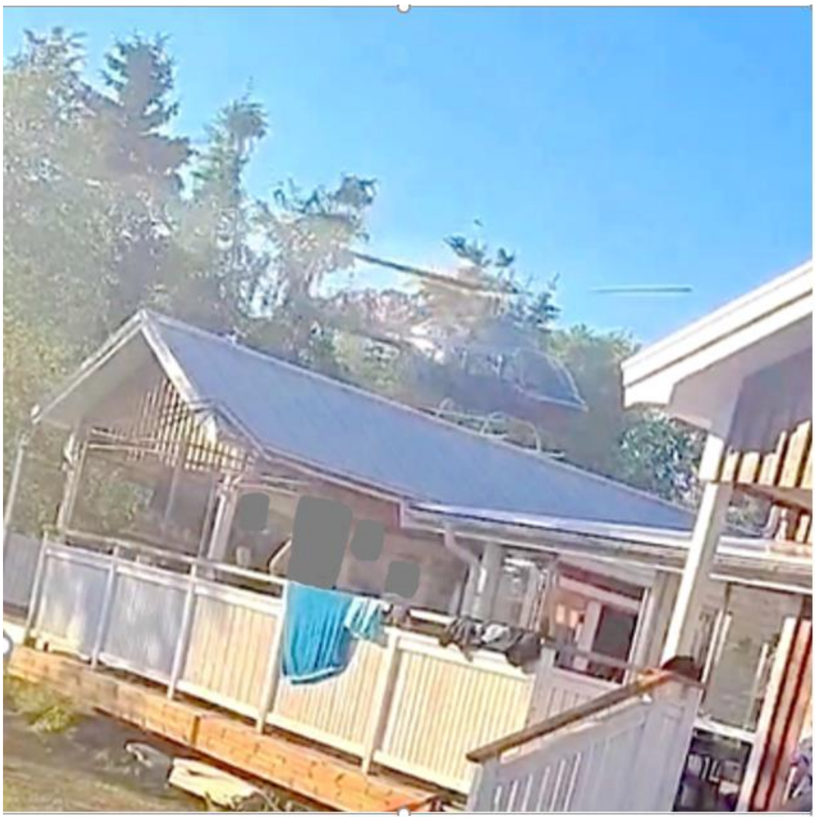

Figure 5. Position of the helicopter immediately prior to the impact. Photo: Private.

After the impact, the pilot shut down the engine.

A witness on the ground ran towards the helicopter, opened the passenger door on the right side and helped with the evacuation.

1.2 Injuries to persons

No serious injuries. However, two of the passengers experienced neck and back pain.

1.3 Damage to the aircraft

Substantially damaged.

1.4 Environmental impact and other damage

A leak of an estimated 170 litres of fuel and a smaller quantity of hydraulic fluid occurred at the accident. This resulted in an environmental decontamination by removal of 16 tonnes of soil from the accident site. Otherwise, there was minor damage to trees, bushes and a fence at the crash site.

1.5 Qualifications of the pilot

The pilot was 44 years old, had a PPL(H) with a valid rating on type and a valid medical certificate. The licence was issued on 21 December 2021 on the helicopter type Robinson R44.

Latest	24 hours	90 days	Total
All types	4	72	179
Actual type	4	32	32

Number of landings actual type previous 90 days: 112.
Type rating concluded on 31 May 2022.

1.6 Aircraft information

The Bell 206B is a single-engined, gas turbine-powered helicopter with a two-bladed main rotor that has a diameter of 10 metres. The helicopter is approved for one pilot and four passengers.

Figure 6. The helicopter SE-JER earlier the same day. Photo: Private

1.6.1 Helicopter

TC-holder	Bell Textron Canada Ltd, Canada
Model	Bell 206B
Serial number	2491
Year of manufacture	1978
Gross mass (kg)	Max. take-off/landing mass 1,451 Actual 1,332
Centre of gravity	Within limits
Total operating time, hours	10,468
Operating time since latest periodic inspection, hours	19
Number of cycles	14,208
Type of fuel uplifted before the occurrence	Jet A-1

Engine	
TC-holder	Rolls-Royce Corporation
Type	250-C20B
Number of engines	1
Serial number	CAE-840563
Total operating time, hours	4,578
Operating time since latest inspection, hours	19

The helicopter had a Certificate of Airworthiness and a valid Airworthiness Review Certificate (ARC). There were no deferred remarks. There were also no remarks during the last three-month period.

The latest inspection was performed on 14 June 2022 at an operating time of 10,449 flight hours and was a combined annual/100-hours inspection. During the inspection, i.a. a routine power check of the engine was performed without remark.

1.6.2 Rotor system

The main rotor has a speed of 395 RPM at the indication of 100 %. The approved operating range is 97–100 %. If the RPM falls below 90 %, a warning light illuminates on the instrument panel accompanied by an audible warning.

The main rotor on this type of helicopter rotates anticlockwise when viewed from above. Due to this rotation, the helicopter experiences a torque reaction in the opposite direction, which is to the right with this helicopter type. The torque reaction is most significant at high power in combination with low airspeed.

The purpose of the tail rotor is to provide opposing thrust that compensates for the torque generated by the main rotor (see Figure 7). The thrust from the tail rotor is controlled through pedal displacement, which changes the angles of the rotor blades. The tail rotor has a gear ratio of 6.472:1 to the main rotor. The speed of the tail rotor is 2,556 RPM at an indication of 100 %.

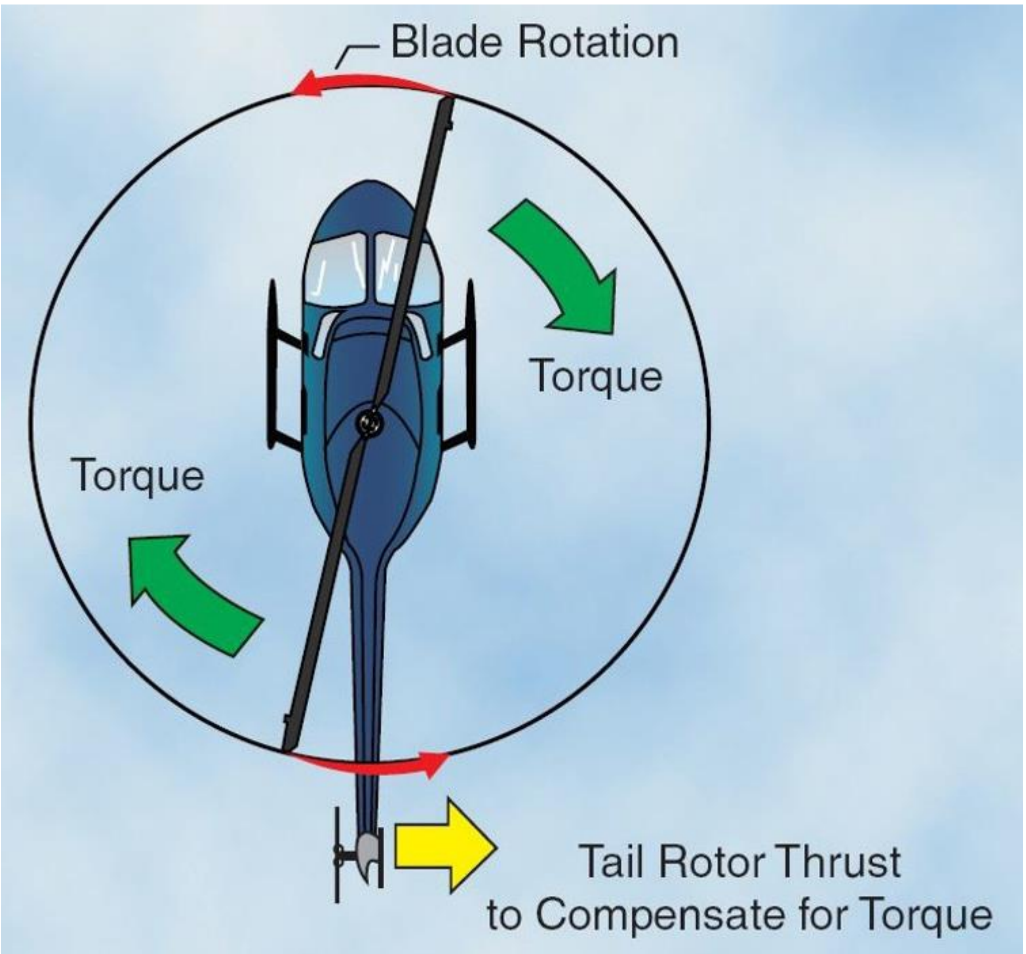

Figure 7. Schematic showing the direction of rotation of the main rotor blades and the torque generated, as well as the opposing thrust from the tail rotor. Source: Federal Aviation Administration (FAA).

1.6.3 Engine instruments

The helicopter was equipped with digital engine instrument that displays the turbine outlet temperature (ToT). This temperature is an important parameter of gas turbine engines and is an indication of the function of the engine. The instrument had a memory function that registers the temperature values during engine start and flight. A read-out off the instrument showed that no values had been exceeded.

1.6.4 Performance

Calculations made from the flight manual shows that the helicopter's performance was not limited by the actual conditions prevailing at the time.

However, the flight manual states that the tail rotor control margin and/or engine parameters (ToT and torque) may preclude operation if hovering with a relative wind coming from a sector of 050–210°.

1.7 Meteorological information

According to SMHI's analysis:

At the accident site 20:10 local time: Wind south to south-east 7–9 knots, visibility more than 10 km, sky clear, temperature/dew point 21–23/13–15°C, QNH 1017 hPa.

About the wind conditions

The accident site is 84 metres above mean sea level (MSL) and the nearest topographic landmarks are Hällenylandsberget 119 metres above MSL, located 1 km east of the site, Spjutåsberget 196 metres above MSL, located 3.7 km to the southeast and Lilltjärnsberget 143 metres above MSL, 3 km southwest of the accident site.

In the low level forecast for the area, the expected wind speed at the time was 1–10 knots, with gusts of up to 16 knots. This is deemed to be relatively light winds and should not have caused any mechanical turbulence and no moderate turbulence was forecast in the area either. However, it is not possible to rule out the terrain having caused variations in wind direction and speed, but it has not been possible to verify this through observations.

Information from nearby wind turbines

There are two wind turbines 3.6 km south-west of the accident site at Spjutåsberget. The location of the wind turbines is at approximately 170 metres above MSL and the tower height is 114 metres AGL. The towers are equipped with anemometers that record the wind direction and wind speed with min., max. and average wind speed over a ten-minute period.

According to data from the anemometers, the wind was southerly, between 169–188 degrees, with a speed of 7.4 m/s (max. 9.6 and min. 4.1 m/s) at the time of the accident.

1.8 Aids to navigation

Not pertinent.

1.9 Communications

Not pertinent.

1.10 Aerodrome data

Not pertinent.

1.11 Flight recorders

No flight data recorder or cockpit voice recorder was installed. Nor was such equipment required for this type of aircraft.

The pilot was using a tablet with the navigation application SkyDemon during the flight. SHK has gained access to the recorded flight data from the application. This data has been presented in section 1.1.2.

A witness on the ground filmed the accident using a mobile phone. SHK has analysed the video (see section 1.16.2).

1.12 Accident site and aircraft wreckage

1.12.1 Accident site

The helicopter hit the ground vertically by a group of trees in a garden. The crash site was about 10 metres from the closest residential building and just over 70 metres north of the take-off site (see Figure 8).

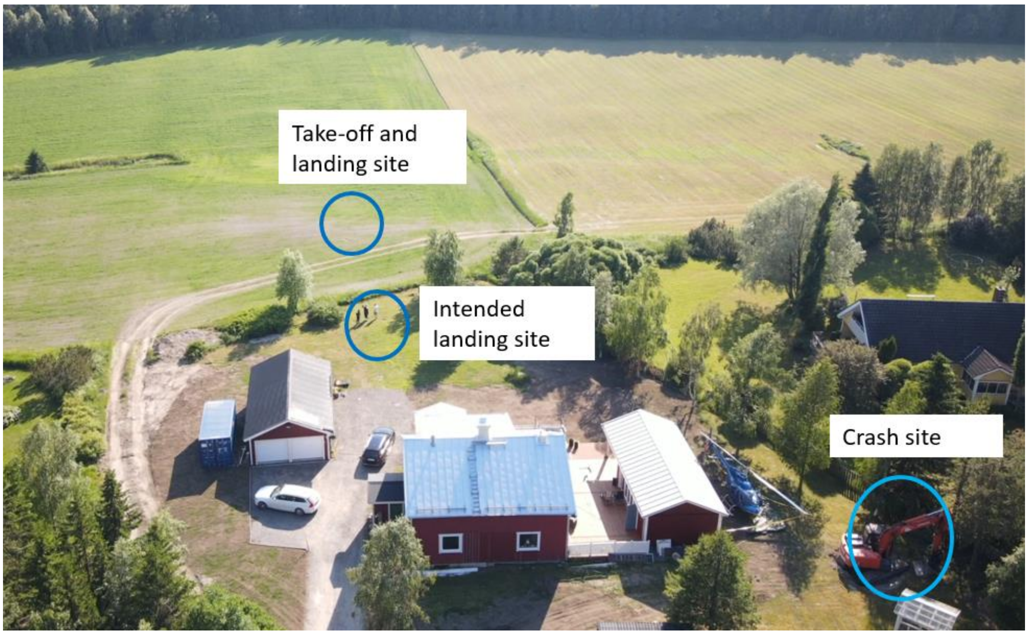

Figure 8. Picture of the accident area seen from the direction of the final approach. The take-off site in the field, the intended landing site on the house plot and the crash site are marked.

Parts of trunks and branches from birch and pine trees were cut off by the rotor blades. The aft portion of the tail boom had hit a fence that formed the boundary of the house plot and that of a nearby residential building (see Figure 9).

Figure 9. The helicopter at the crash site. Photo: Medelpads Rescue Service Association.

1.12.2 Aircraft wreckage

The left landing skid was broken and had ruptured the fuel tank. The aft portion of the tail boom suffered damage that was caused, among other things, by the tail rotor blades and the collision.

The outer part of one of the main rotor blades was broken off during the collision with the trees. It was found 185 metres from the accident site.

1.13 Medical and pathological information

There is nothing to indicate that the mental and physical condition of the pilot was impaired before or during the flight.

1.14 Fire

No fire broke out.

1.15 Survival aspects

1.15.1 Rescue operation

The ELT[5] of the type Kannad 406 AF- H was activated during the accident.

The signal from the ELT was received by the JRCC[6] at 20:11 hrs, at which point the rescue coordinator there began searching for information about the accident. The Swedish Maritime Administration search and rescue helicopter was also called out in order to begin a search for a potential accident site. It became clear at 20:26 hrs, after having made contact with the owner of the helicopter, that an accident had taken place but that no one was seriously injured. The owner had talked to the helicopter pilot and was able to pass on information about the occurrence, the position and that people on site had called 112 to raise the alarm.

The rescue coordinator called SOS Alarm at 20:29 using a special number in order to raise the alarm about the accident but hung up after two minutes and 40 seconds without anyone having answered. The public number 112 was also tried without getting an answer. At the same time, the JRCC also called the helicopter pilot who told what had happened, where they were and that all five people on board had escaped without serious injuries. The pilot also announced that he had tried to call 112 but that no one had answered.

At 20:33 hrs, the JRCC called SOS Alarm again and the call was answered after 17 seconds. After asking about the previous failure to answer, the emergency operator at SOS Alarm said that there was an unbelievably high volume of calls at the moment with a response time of up to four minutes. At close to 20:35 hrs, alarm calls from people at the accident site were also answered, the waiting time then was approximately three and a half minutes.

At 20:36, SOS Alarm called out the Höga Kusten-Ådalen Fire and Rescue Service and two ambulances and informed the police. The first ambulance arrived and the first fire and rescue service unit arrived around ten minutes later. The police did not send any resources to the site. The people who had been on board the helicopter were taken care of. Two of the passengers felt pain and were taken to hospital by ambulance to be checked over. The others who were on board later went to hospital themselves in order to be checked over.

[5] ELT – Emergency Locator Transmitter.
[6] JRCC – Joint Rescue Coordination Centre.

A large amount of fuel had leaked out of the helicopter. The majority had drained into the soil and the fire and rescue service was only able to collect a small quantity of fuel. Work to decontaminate the soil began shortly after the fire and rescue service operation was concluded at 22:13 hrs.

Response time for the emergency number 112

The alarm company SOS Alarm Sverige AB's responsibilities include the emergency number 112 and calling out fire and rescue services and prehospital healthcare. SOS Alarm is owned by the Swedish central government and Sweden's municipalities and regions. Its assignment is governed by an agreement (the alarm agreement) with the Swedish central government. The alarm agreement governs, among other things, response times when someone calls 112. Under this agreement, the average response time for emergency calls shall be no more than eight seconds and no one who calls 112 shall normally need to wait more than 30 seconds.

1.15.2 Position of crew and passengers and the use of seat belts

The pilot was sitting in the right pilot's seat. One passenger was sitting in the left front seat. The other three passengers were sitting in the rear passenger seat. All were using the installed seat belts.

The evacuation was conducted through the doors on the right side of the helicopter because the broken landing skid was blocking both of the doors on the left side.

1.16 Tests and research

1.16.1 Technical examination of the helicopter

A technical examination showed that the main rotor gearbox was broken in its attachments at the top of the fuselage. The chip detector in the bottom of the gearbox had broken loose, which meant that oil had leaked out of the gearbox.

The main drive shaft coupling between the engine and the main rotor gearbox was broken and the gear teeth of the inner spherical coupling had under rotation made contact with the surrounding structure, which had caused a large quantity of metal chips in the area for the engine and the gearbox.

A fuel sample was taken from the engine's fuel filter. This was within the required limits for Jet A-1 and no water or other contaminants were visible in the sample.

Other results from the examination:

- The tail rotor flight control system has been checked with respect to function, rigging and the installation of the correct components. No discrepancies were found.

- The oil in the tail rotor gearbox was within the approved level and analysis of the oil showed no abnormalities.
- The tail rotor drive shaft was broken at the aft portion of the tail boom. It was possible to turn both the forward and aft parts of the drive shaft without abnormal sounds or resistance.
- It was possible to turn the tail rotor without abnormal sounds or resistance.
- The leading edges of the tail rotor blades were clean and were not contaminated by insects. However, the surfaces of the blades were coated to some extent by soot from the engine exhaust. According to information from Bell Textron, the soot coating that was on the surfaces of the rotor blades has no performance degradation on their function.
- An analysis of the engine oil was without remarks.
- The collective and cyclic controls showed full ranges of movement.
- The magnetic chip detectors for the main rotor gearbox and tail rotor gearbox did not showed any notable quantities of chips or particles.
- The hydraulic filter for the servo control had no contaminants.

A technical examination of the engine including the turbine, compressor and gearbox did not reveal any technical faults that could have affected the event. There was no damage to fuel or air tubes. The power turbine fuel governor, fuel pump, fuel nozzles and air bleed valve have been functionally tested on another engine with no remarks.

1.16.2 Calculation of main rotor speed

The video that captured the sequence of events has been analysed in order to calculate the speed of the helicopter's main rotor. The analysis has involved the following steps:

- calculation of the number of rotations of the main rotor blades per unit time in the video,
- calculation of the number of audio impulses from the main rotor per unit time in the graphic wave form of the sound file,
- spectrum analysis of the sound from the tail rotor. As the main rotor and tail rotor are linked mechanically with one another, it has been possible to calculate the speed of the main rotor from the speed of the tail rotor.

The main rotor speed was relatively constant (app. 98 %) up until the right yaw occurred. The RPM then fell by a few percentage points during the sequence involving the uncontrolled rotation about the yaw axis. Upon making contact with the trees, the main rotor RPM was approximately 83 %, after which it fell rapidly.

1.16.3 Affect on yaw control at an RPM lower than 100 %

SHK has investigated whether the RPM of 98 % may have affected the sequence of events. Because the tail rotor has thrust margins for handling RPM changes within the permitted operating range (97–100 %), the reduction in the RPM is not deemed to have resulted in a noticable difference in performance.

1.17 Organisational and management information

Not pertinent.

1.18 Additional information

1.18.1 Loss of tail rotor effectiveness – Unanticipated yaw

Loss of tail rotor effectiveness (LTE) or unanticipated yaw is a known risk in connection with flight at low speed and high-power output.

Unanticipated yaw can be described as a rapid yaw in the opposite direction to the rotation of the main rotor that takes place without any control input by the pilot. The phenomenon is aerodynamic and is not caused by any technical failure, and is instead the result of the tail rotor not being able to provide sufficient thrust to maintain directional control. The phenomenon occurs when the airflow through the tail rotor is disturbed and only happens at airspeeds under 30 knots.

An unanticipated yaw can, if it is not corrected promptly, rapidly turn into uncontrolled rotation that can lead to an accident. Data from flight tests has shown that the tail rotor blades do not stall during an unanticipated yaw. Avoiding unanticipated yaw requires knowledge about the flight conditions that can lead to this phenomenon.

1.18.2 Flight conditions with a risk of unanticipated yaw

For helicopters with a main rotor that rotates anticlockwise (viewed from above)[7] there is a risk of unanticipated yaw when flying at low speed in connection with, i.a., relative wind from the following regions:

- With the wind from the left front, 285° to 315°, relative to the helicopter, the downward airflow and tip vortices from the main rotor can be blown into the tail rotor and cause so-called Main Rotor Disc Vortex Interference, which reduces the effectiveness of the tail rotor and an unexpected yaw can occur (see Figure 10).

[7] For helicopters with a main rotor that rotates clockwise (viewed from above), e.g. some helicopters manufactured in Europe, the conditions are the opposite.

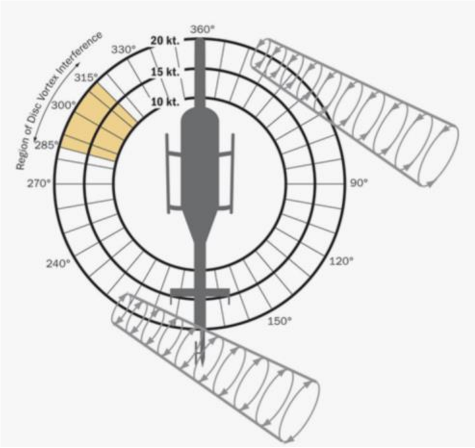

Figure 10. Region of Main rotor disc vortex interference. Source: FAA.

- With wind from the side, 210° to 330°, the airflow through the tail rotor can be pushed back and cause recirculation of the air through the tail rotor, known as Tail rotor vortex ring state, which reduces the effectiveness of the tail (see Figure 11).

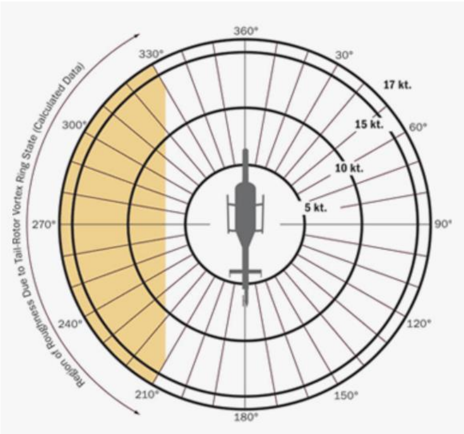

Figure 11. Region of tail rotor vortex ring state. Source: FAA.

- With wind from the tail region, 120° to 240, the helicopter's tail section and tail fin acts as a weathercock and tries to turn the helicopter into the wind (weathercock stability) (see Figure 12). An unanticipated yaw or increase of yaw rate can then occur.

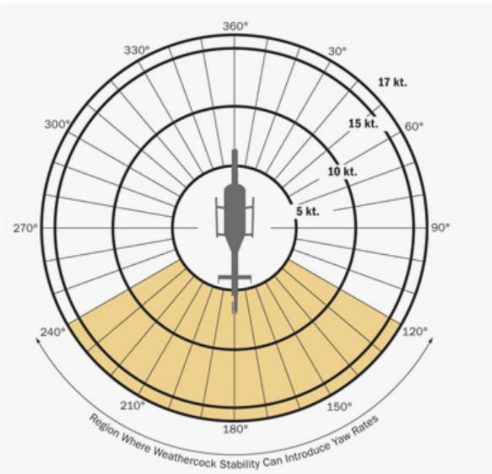

Figure 12. Weathercock stability. Source: FAA.

Although specific wind directions are identified for each region, a pilot should be aware that the regions may shift depending on the ambient conditions. The regions do overlap. The greatest losses of tail rotor effectiveness can occur in these overlapping regions.

Loss of lift can also result in unanticipated yaw. If the airspeed decreases, the translational lift[8] caused by the incoming airflow also decreases (loss of translational lift). An increase in power output in order to compensate for the loss of translational lift can result in unexpected yaw.

1.18.3 Documents containing information about unanticipated yaw

Unanticipated yaw has been drawn to attention by both regulators and helicopter manufacturers. Information about the phenomenon and how it should be dealt with has been published. For example, FAA has published information about unanticipated yaw in the *Helicopter Flying Handbook*. Due to a large number of accidents were unanticipated yaw has been a cause, the FAA has also published *Advisory Circular FAA AC 90-95*.

Bell Textron has published *Information Letter 206-84-41, 206L-84-27, Low speed flight characteristics which can result in unanticipated right yaw*.

The EASA has identified unanticipated yaw as a safety issue in the risk register for helicopter flying in the European Plan for Aviation Safety for 2023 (EPAS). The safety issue is described as being related to the inability to detect, control and recover from an unanticipated yaw or loss of tail rotor effectiveness (LTE) during low-speed phases of flight, leading to the helicopter loss of control.

In 2010 the EASA published a safety document regarding the risk of unanticipated yaw, SIB 2010-12R1.

1.18.4 Regulations relating to flight training for PPL(H)

Commission Regulation (EU) No 1178/2011[9] contains regulations concerning the training required for a PPL(H).

The syllabus for the theoretical training is set out in AMC1 FCL.210; FCL.215. Aerodynamics regarding tail rotors is included in part 5.2, which describes the basic principles of flying helicopters. There is no direct description of the unanticipated yaw phenomenon. The parts that can be deemed relevant are the points:

(a) Induced airflow and tail rotor thrust.

(c) Effect of tail rotor failure and vortex ring.

[8] Translational lift – an increase in lift from the rotor disc caused by horizontal speed.

[9] Commission Regulation (EU) No 1178/2011 of 3 November 2011 laying down technical requirements and administrative procedures related to civil aviation aircrew pursuant to Regulation (EC) No 216/2008 of the European Parliament and of the Council.

The practical part of the training is described in AMC2 FCL.210 PPL(H). The syllabus specifies several exercises in which the effect of the influence of the wind shall be included in flying exercises. Exercise 18 includes hovering out of ground effect[10] (OGE) and loss of tail rotor effectiveness.

1.18.5 Practical training – unanticipated yaw

The practical flight training includes the student having to learn the influence of the wind from different directions when hovering. For safety reasons, this part is practiced when hovering in ground effect. A practical exercise in which the student gets to practise this at a higher altitude, out of ground effect, is associated with a high risk and is therefore not conducted.

The phenomenon can be simulated in certain flight simulators. These simulators are available for larger helicopters but are largely lacking for smaller helicopters that are affected by accidents involving unanticipated yaw.

1.18.6 The pilot's flight training

The pilot's training adhered to the syllabus during the practical portion of the flight training. This included demonstration of and flying in conditions with vortex (recirculation of the air in the main rotor) and with recovery from this situation at high altitude. The influence of the wind when hovering in various directions and at various speeds was also demonstrated and practised.

The pilot has stated that information about the risk of unanticipated yaw was not included in the theoretical training for the private pilot licence. The pilot has also stated that the risk of unanticipated yaw was also not covered during type rating on the helicopter type in question.

1.18.7 Similar accidents

Several similar accidents have been investigated by SHK, see RL 2022:02, RL 2005:05, RL 2001:31 and RL 2001:19.

A number of similar accidents have also occurred abroad. Among others, TSB Canada has published the following reports: A13W0070, A16P0069, A20A0027 and A22W0005.

1.19 Special methods of investigation

Wind data have been obtained from nearby wind turbines (see section 1.7).

[10] Ground effect – an increase in lift that takes place when a helicopter flies close to the ground and occurs at a height corresponding to about one rotor diameter from the ground and below. Hovering without ground effect requires more lift than hovering with ground effect.

2. ANALYSIS

2.1 Technical examinations

No technical fault that could have contributed to the occurrence has been found. The damage to the helicopter is deemed to have occurred during the impact.

An analysis of the audiovisual recording shows that the main rotor RPM was within the permitted range (97–100 %) up until the point at which the pilot reduced the throttle with the aim to stop the uncontrolled yaw.

2.2 Wind conditions

According to data from the anemometers installed on the nearby wind turbines at Spjutåsberget, the wind was southerly, 169–188°, and had an average speed of 7.4 m/s at the time of the accident.

The wind is affected by friction forces from the ground surface. According to a meteorological rule of thumb, the wind turns 30° towards a higher gradient, at the same time as its speed increases by 50 % from ground level up to an altitude of 300 metres.

The difference in altitude from ground level at the accident site to the anemometers is around 230 metres. If local phenomena such as land and sea breeze changes are ignored, this means that the wind direction at the accident site was around 20° lower than that registered by the anemometers, i.e. somewhere around 149–168°, and the wind speed was around 5 m/s (10 knots).

Data from the anemometers therefore supports SMHI's analysis in which the wind was assessed to be south-easterly with a speed of 7 to 9 knots at the accident site.

2.3 The first attempt to land

During the landing attempt on the cultivated field, the pilot was unable to correct the heading as a result of the torque indication was approaching the maximum permitted value.

The high power requirement was probably due to the relative wind was acting from the sector where the tail rotor control margins and engine parameters can limit flight (see 1.6.4), and that the maneuver was performed without the helicopter being stabilized in hover.

A go-around was therefore made towards another site on a plot at a nearby house.

2.4 The chosen landing site

The landing site on the house plot was an area that the pilot had landed on before which may have contributed to the decision to land there. It was surrounded by buildings and vegetation and had limited obstacle clearance. It may be regarded as a confined area for a landing, compared with the surrounding field. The limited obstacle clearance meant that the pilot had to reduce the speed in order to initiate a steep descent towards the planned landing site. The reduction in speed resulted in the helicopter ending up in a hover out of ground effect. The degree of difficulty of the planned landing may be regarded as high for a private pilot with limited flying experience.

2.5 Why was control lost?

During the end of the final approach, the helicopter was hovering with high-power output and out of ground effect. The height above the ground was about 30 metres and the ground speed about 5 knots. Based on the prevailing wind speed of 7–9 knots, the flight speed has been calculated at just over 10 knots. GPS data and information from the video footage analysed show that both the track and heading was about 220° and that the relative wind hit the left sector of the main rotor.

The low speed of the helicopter, together with the prevailing wind conditions, has likely led to the tail rotor's effectiveness being initially affected by main rotor disk vortex interference. This resulted in an unanticipated yaw to the right. The helicopter then received the wind from the tail which increased the yaw rate. Once the yaw developed into a rotation, the tail rotor was struck by the airstream from the side, further reducing its effectiveness. The pilot's action to reduce engine power caused the rotation to cease, but simultaneously caused the helicopter to descend towards the ground since the rotor RPM decreased.

2.5.1 The pilot's experience of inadequate yaw control

Hovering without ground effect requires a high-power output. If the effectiveness of the tail rotor is disturbed under such conditions, the yaw control is affected. Full pedal travel may then be insufficient to counter the yaw moment that arises. This is likely the reason why the pilot felt that the steering inputs had no effect at this stage.

2.6 Survival Aspects

On impact, the helicopter struck the ground in a horizontal position. Thus, a large part of the impact energy was absorbed by the landing skids and the structure of the cabin remained almost intact. This contributed to the fact that those on board could escape without injuries.

2.7 Knowledge of unanticipated yaw should be increased

The pilot had insufficient knowledge about the phenomenon of unanticipated yaw and which flight conditions entail a risk of this. Consequently, the pilot was probably not able to identify the initial signs that the helicopter was entering an unanticipated yaw and to take sufficient action in time to prevent the sequence of events from developing.

Information about unanticipated yaw is included only to a limited extent in the basic helicopter training for a PPL(H). It is also included in the documents for flight training on single-rotor helicopter types. In spite of this, there have been several accidents where the pilots have not had sufficient knowledge of the phenomenon (see section 1.18.7).

Increased knowledge among pilots about unanticipated yaw and which flight conditions lead to this phenomenon is considered to be able to reduce the risk of similar accidents. Actions should therefore be taken by EASA and the Swedish Transport Agency to, in an appropriate way inform pilots and other concerned parties such as training organizations.

2.8 Rescue operation

According to information from witnesses and SOS Alarm, people at the accident site began calling 112 at around 20:15 hrs, just under five minutes after the crash. Those who called reached an answering service, waited approximately half a minute then hung up when there was no answer. One person who called at 20:31 hrs got through after waiting just over three minutes. The response time was therefore longer than the average response time of 8 seconds and the longest waiting time of 30 seconds specified under the Swedish state’s agreement with SOS Alarm.

Not being able to make contact via the emergency number 112 is of course very serious in an emergency situation. In the occurrence in question, no one was seriously injured but seconds can be decisive in a life-threatening situation. According to SOS Alarm, there had been problems during the summer of 2022 with maintaining the response times and there were more healthcare and rescue cases than normal at the time of the occurrence in question. Nevertheless, SOS Alarm has implemented and is implementing several measures to reduce response times. These include recruiting more operators and measures to improve the working environment.

The actions of the rescue resources on site were conducted without delays or other problems.

Consequently, SHK is not issuing any recommendations for safety actions with respect to the rescue operation.

3. CONCLUSIONS

3.1 Findings

a) The pilot was qualified to perform the flight but had limited flying experience.

b) The helicopter had a valid Certificate of Airworthiness and a valid ARC.

c) No technical faults that could have contributed to the occurrence have been identified during the technical examinations.

d) The flight was the second of the planned flights in which passengers were able to follow on a local flight.

e) It is stated that the flights were performed on a cost-share basis, with the pilot and the passengers sharing the direct costs.

f) The flights departed from a temporary take-off and landing site on a cultivated field.

g) After one attempt to land in the cultivated field, the landing site was changed to a plot by a house that had limited obstacle clearance.

h) The approach to the intended landing on the house plot had a high degree of difficulty.

i) During the final approach, the helicopter had a low speed and was out of ground effect. The power output was high and the relative wind was from the front left in relation to the helicopter.

j) The helicopter made an unanticipated yaw to the right.

k) The helicopter entered into an uncontrolled rotation about the yaw axis.

l) The pilot reduced the throttle in order to stop the rotation and the helicopter descended towards the ground.

m) The helicopter collided with trees and hit the ground hard.

n) There were no personal injuries.

o) There was a delay in the alarm process with SOS Alarm due to long response times.

3.2 Causes/contributing factors

During the approach, the helicopter was flown at low speed, high power output, without ground effect and with the relative wind from the left side. This contributed to a reduction in tail rotor effectiveness resulting in an unanticipated right yaw that transitioned into an uncontrolled rotation.

Contributing factors have been that:

- the pilot had insufficient knowledge of the risk of unanticipated yaw,
- the intended landing site had limited obstacle clearance and a high degree of difficulty.

4. SAFETY RECOMMENDATIONS

The Swedish Transport Agency is recommended to:

- inform concerned parties about the risks of unanticipated yaw in an appropriate way. *(SHK 2023:10e R1)*

The EASA is recommended to:

- inform concerned parties about the risks of unanticipated yaw in an appropriate way. *(SHK 2023:10e R2)*

The Swedish Accident Investigation Authority respectfully requests to receive, **by 27 November 2023 at the latest,** information regarding measures taken in response to the safety recommendations included in this report.

On behalf of the Swedish Accident Investigation Authority,

Kristina Börjevik Kovaniemi Ola Olsson