Statens haverikommission
Swedish Accident Investigation Authority





Final report RL 2022:02e

Accident at Skeberg, Dalarna County, on 16 March 2021 involving the helicopter SE-JVF of the model Robinson R44, operated by a private individual

File no. L-15/21

6 May 2022

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 16 mars 2021 that an accident involving a helicopter with the registration SE-JVF had occurred in Skeberg, Dalarna County, the same day at 11:13 hrs.

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

SHK has been assisted by Jim Lindqvist and No1 Flightengineering AB as technical experts, MSAB as an expert in forensic examination of mobile devices, and Element Materials Technology AB as an expert in the examination of materials. Support for certain technical examinations of an iPad has been provided by the French accident investigation authority Le Bureau d'enquêtes et d'analyses pour la sécurité de l'aviation civile (BEA).

Shaun Williams has participated as an accredited representative of the United States' accident investigation authority, the National Transportation Safety Board (NTSB).

Thom Webster from Robinson Helicopter Company has participated as an adviser on behalf of the NTSB. Susanne Schramm has participated as an advisor on behalf of the European Union Aviation Safety Agency (EASA). Ulf Sterner has participated as an adviser on behalf of the Swedish Transport Agency until 12 January 2022, when he was replaced by Magnus Axelsson.

The following organisations have been notified: the NTSB, the EASA, the European Commission and the Swedish Transport Agency.

Investigation material

Interviews have been conducted with the pilot, the passenger, two witnesses to the occurrence and personnel responsible for aircraft maintenance. The accident site and the helicopter have been examined. Technical examinations of relevant systems and components have been conducted by SHK and in cooperation with the NTSB. Data from mobile devices has been obtained and analysed.

Meetings with the interested parties were held on 31 January and 4 February 2022. At the meetings, SHK presented the facts discovered during the investigation, available at the time of the meetings.

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Aircraft:	
Registration, type	SE-JVF
Model	Robinson R44 Astro
Class, airworthiness	Normal, Certificate of Airworthiness and valid Airworthiness Review Certificate (ARC)[1]
Serial number	0315
Owner	Elvanq AB
Time of occurrence	2021-03-16 at 11:13 in daylight Note: All times are given in Swedish daylight saving time (UTC[2] + 1 hour)
Location	Skeberg, Dalarna County, (position 60°38' N 14°52' E, 225 metres above mean sea level)
Type of flight	Private
Weather	According to SMHI’s analysis: Fair weather, wind NW-N 10 knots, visibility over 10 km, cloud: broken cloud cover with a base of 4,900 feet, temperature/-dew point +4/-3°C, QNH[3] 1015 hPa
Persons on board:	3
Crew members including cabin crew	1
Passengers	2
Injuries to persons	1 fatality 2 seriously injured
Damage to the aircraft	Hull loss
Other damage	Minor forest damage
The pilot in command:	
Age, licence	49 years, PPL(H)[4]
Total flying hours	63 hours, of which all on type
Flying hours previous 90 days	1.9 hours
Number of landings previous 90 days	3, all on 16 March 2021

[1] ARC – Airworthiness Review Certificate.
[2] UTC – Coordinated Universal Time.
[3] QNH – altimeter set so that the altitude above mean sea level is obtained when on the ground.
[4] PPL – Private Pilot License.

SUMMARY

On March 16 2021, a pilot would fly a helicopter from Skavsta to Grene, which is north of Gothenburg. The pilot planned the route via Skeberg in Dalarna County. There he picked up two passengers and made a fifteen-minute round trip in the area.

In connection with the approach for landing the speed was reduced. The helicopter suffered an unanticipated yaw which turned into a rotation around the yaw axis. The pilot tried to make an emergency landing in an opening in the forest, but the forest was too dense and the helicopter collided with the treetops. The tail rotor with its attachment was broken off and the main rotor cut a number of treetops before the helicopter finally fell to the ground from a height of 10–15 metres. The helicopter hit the ground with the left front of the cabin first and the emergency transmitter was activated A witness alerted the rescue services. Several flying rescue resources were activated to locate the accident site. The rescue service arrived at the scene after 19 minutes.

The helicopter suffered extensive damage in the crash. The passenger in front was fataly injured. The pilot and the passenger who was sitting in the right rear seat suffered extensive injuries.

No technical defects that may have contributed to the course of events has been established.

The accident was caused by a number of factors. In the final phase of the flight the speed was reduced and the helicopter transitioned to a hovering position where the tail rotor probably was disturbed by the air from the main rotor. This resulted in that the helicopter unexpectedly yawed to the right. The measures taken to counteract the yaw were not sufficient and therefore the yaw rate increased. An underlying cause of the accident was that the pilot had low total flying hours in combination with little recent flight experience which has reduced the possibility of anticipating the consequences of the speed reduction and the possibility of taking adequate measures.

Safety recommendations

None.

1. FACTUAL INFORMATION

1.1 History of the flight

1.1.1 Circumstances

The pilot was to fly the helicopter from Skavsta Airport to Grene, north of Gothenburg. The flight was a private flight. The pilot planned to fly via Leksand, where two passengers would embark for a short tour of the area where they lived. The pilot had then planned to refuel at Dala-Järna Airport before the remaining flight to Grene.

The helicopter had undergone a 100-hour inspection immediately before the flight. When the pilot collected the helicopter from the inspection workshop in Skavsta, no flight check had been performed because there had been no pilot for this purpose. Staff at the workshop asked the pilot to hover the helicopter to check for leaks before take-off. A hover was performed. Thereafter, the helicopter had been fully refuelled.

The pilot has stated that he made two landings in Mockfjärd to check the wind conditions before he picked up the two passengers in Skeberg. One passenger sat in the front left and the other in the right rear seat.

1.1.2 Sequence of events

After completing the round trip with the passengers, the helicopter was approaching to land in the field where the passengers had previously been picked up. In connection with the approach, the speed was reduced. The helicopter suffered an unanticipated yaw which turned into a rotation around the yaw axis. The pilot could not control the yaw and the speed of rotation increased around the yaw axis. He tried to make an emergency landing in a small opening between the trees in the forest. The opening was not large enough and the main rotor blades hit the treetops, after which the helicopter fell an estimated 10-15 metres. The rotor blades broke off. The left front part of the cabin hit the ground first and the impact was hard.

The accident occurred at 11:13 hrs at position 60°38' N 14°52' E, 225 metres above mean sea level, in daylight. The time of the accident was confirmed on the basis of recorded image data from a mobile phone.

The course of events from the pilot's perspective

The pilot has stated that, when he came in for landing after the short tour, there were no indications of anything abnormal and that the approach felt normal in terms of speed and approach path. During the approach, the pilot noted a brief drop in main rotor RPM (NR). The NR recovered quickly and became normal. He also noticed a sound that sounded like something "snapped" or "slammed". The helicopter was over a patch of forest when it started to yaw to the right. The pilot tried to correct the right yaw with a pedal displacement to the left but did not get the intended response.

Part of the flight that has been visualised by means of recorded image data from a mobile phone

With the help of the company MSAB, SHK has extracted underlying data from the pictures that the passenger in the front seat took using a mobile phone during the flight, see also section 1.19 Special methods of investigation. Data from the four images taken during the last 26 seconds are illustrated in Figure 1 and 2.

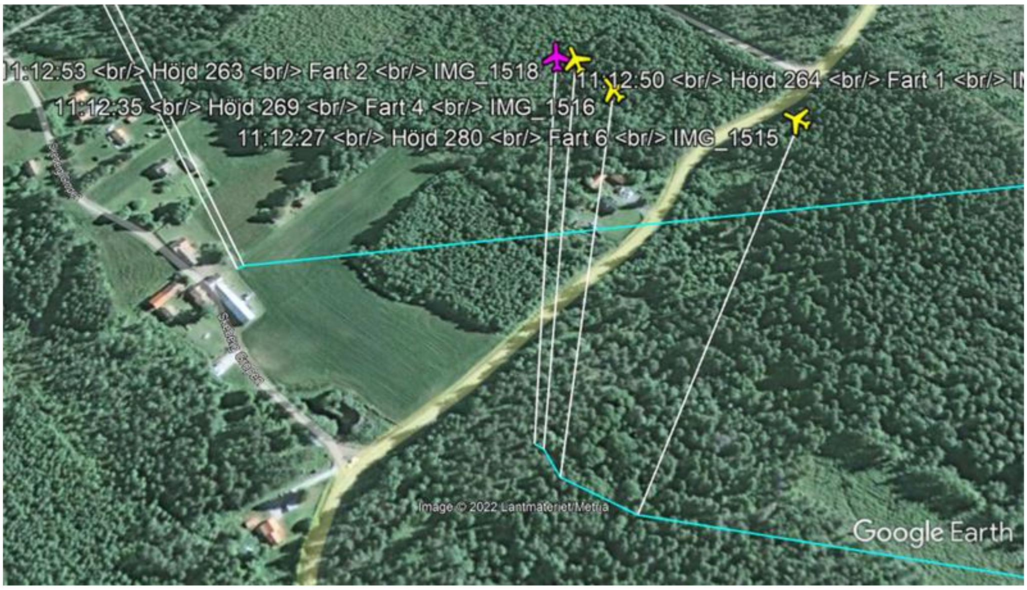

Figure 1. Last part of the flight. Source: Mobile phone data, Google Earth and © Lantmäteriet.

The image positions are marked with airplane symbols. The green line connects the positions and does not show the exact flight path. The text in white in figure 1 shows the current speed and altitude at the time when the picture was taken. (Ground speed in km/h and altitude in metres above mean sea level.) The ground level at the accident site is about 225 metres above mean sea level and the trees are around 18 metres high.

Figure 2 shows the image positions directly from above in yellow text and the estimated wind direction.

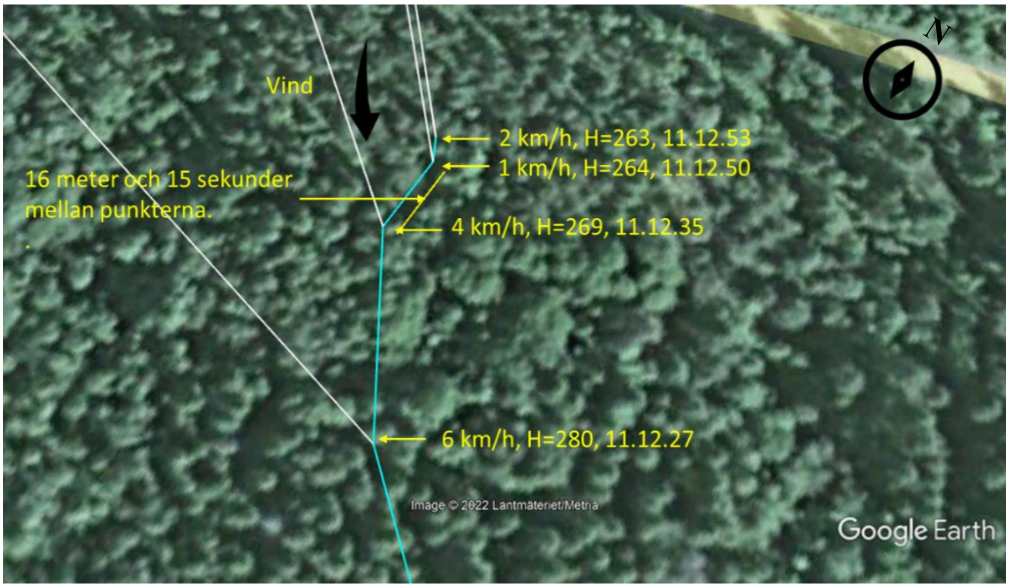

Figure 2. Time, speeds and altitudes during the last part of the flight. Source: Mobile phone data, Google Earth and © Lantmäteriet.

Mobile data shows the following regarding the helicopter's speed at the time each photo was taken:

- Time 11.12.27 the speed was 6 km/h
- Time 11.12.35 the speed was 4 km/h
- Time 11.12.50 the speed was 1 km/h
- Time 11.12.53 the speed was 2 km/h

During the sequence, the helicopter changed direction to the right and the height was about 20 metres above the trees.

Photos taken by the passenger in the back seat

SHK has also reviewed photos taken during the flight with a mobile phone by the passenger in the back seat. Two of these images are shown in Figure 3.

Figure 3. Indicated air speed (blue marking). Altitude (barometric height above sea level in feet, yellow marking) is the same on both occasions. The clock on the instrument panel (green mark) was not set to the correct time. The pictures are cropped by SHK. Photo: Private.

The pictures were taken during the last part of the approach to the field. The second hand on the clock on the instrument panel shows that the right image was taken 50 seconds after the left. The position and altitude were about the same on both occasions. In the left picture the indicated speed was 23 knots and in the right picture the speed was 0 knots and the uncontrolled right yaw had started.

1.1.3 Additional information

Information from witnesses

One witness saw the helicopter head-on at a distance of around 600 metres. The witness has stated that the helicopter looked like it was standing still above the forest and that it was turning a little in one direction before then turning in the other direction in an accelerating rotation. The helicopter then disappeared from view.

Figure 4. The witnesses' view towards the helicopter at the time of the accident. The helicopter silhouette shows the approximate location of the helicopter during the rotation prior to the crash, as perceived by the witness.

1.2 Injuries to persons

	Crew members	Passengers	Total on board	Others
Fatal	-	1	1	-
Serious	1	1	2	-
Minor	-	-	0	Not applicable
None	-	-	0	Not applicable
Total	1	2	3	-

1.3 Damage to the aircraft

Hull loss.

1.4 Other damage

1.4.1 Environmental impact

In conjunction with the accident, damage occurred to the trees that were hit by the helicopter. A number of trees were also felled prior to recovery of the wreckage. A small fuel leak also occurred.

1.5 Personnel information

1.5.1 Qualifications and duty time of the pilot

The pilot in command

The pilot in command was 49 years old and had a valid PPL(H) with flight operational and medical eligibility.

Flying hours				
Latest	24 hours	7 days	90 days	Total
All types	1.9	1.9	1.9	64
Actual type	1.9	1.9	1.9	64

Number of landings actual type previous 90 days: 3, all on 16 March 2021. Type rating concluded on 13 June 2019.
Latest PC[5] was conducted on 6 mars 2020 on type.

The pilot underwent PPL(H) training at a flight school in Säve, Gothenburg. The licence was issued on 27 March 2020. The Swedish Transport Agency informed the pilot on 9 July 2020 that the licence was not valid because there was a lack of training in accordance with the requirements for solo long-distance flying. The pilot completed fight training and the Swedish Transport Agency announced on 30 September 2020 that the pilot's licence was valid.

In September 2020, the total flying time was 62 hours. This was followed by a break due to long periods of weather restrictions until 14 December 2020, when the pilot flew 0.7 hours. On 16 March 2021, the pilot flew about 20 minutes during a hover check for any leaks following an inspection.

1.6 Aircraft information

The Robinson R44 is a four-seated, piston-engine powered helicopter constructed primary of metal. The pilot and passenger doors are constructed of fiberglass and thermoplastic. The main and tail rotors have two blades and the blades are made of metal. The landing gear consists of skids. The fuel tanks are crash protected (known as bladder tanks). The helicopter in question was modified with a hydraulic flight control system for main rotor control and equipped with inflatable floats.

[5] PC – Proficiency Check.

Figure 5. Helicopter SE-JVF. People anonymised by SHK. Photo: Kjell Nilsson.

1.6.1 *Helicopter*

TC-holder	Robinson Helicopter Company
Model	R44
Serial number	0315
Year of manufacture	1997
Gross mass (kg)	Max. take-off/landing mass 1,089 Actual 987
Centre of gravity	Within limits
Total flying time, hours	3 195
Flying time since latest periodic inspection, hours	2
Type of fuel uplifted before the occurrence	176 litres AVGAS 100 LL
Engine	
TC-holder	Lycoming Engines
Type	Lycoming O-540-F1B5
Number of engines	1
Serial number	L-25026-0A
Total operating time, hours	3 195
Operating time since latest periodic inspection, hours	2
Operating time since latest overhaul, hours	488
Deferred remarks	
None	

The aircraft had a Certificate of Airworthiness and a valid ARC.

1.6.2 Maintenance

Latest inspection

The helicopter had undergone a 100-hour inspection with additional tasks before the flight. The tasks at the inspection also included the implementation of a service bulletin concerning the making of an inspection access hole in the fuselage, in the area below the pedals, and an 18-month inspection of the floats. In addition, deferred remarks were rectified and, among other things, a small dent in the horizontal stabiliser was repaired. The inspection included a routine inspection of the tail rotor drive shaft and checking the straightness (runout) of the drive shaft. No abnormalities with the drive shaft were noted.

According to the helicopter's maintenance programme and the type certificate holder's maintenance instructions, a flight check shall be performed in conjunction with a 100-hour inspection. During the flight check, certain functions should be checked during hover and level flight (for example autorotation RPM, vibrations and pedal positions). The maintenance organisation did not have a pilot available for the flight check and it was therefore not performed. Instead, the pilot in question who would be flying the helicopter from the airport was asked to perform a hover to check for any leaks. A hover lasting about 20 minutes was performed and the maintenance organisation then checked for any leaks.

Maintenance history

This model of helicopter requires a total overhaul every twelve years or after 2,200 flight hours, whichever comes first. For the helicopter in question, this overhaul took place in July 2010 at 1,968 flight hours.

A modification with a hydraulic flight control system and installation of new main rotor blades was performed in April 2019 at 2,808 flight hours.

An inspection after a hard landing was performed on 27 February 2020 at 3,069 flight hours.

1.6.3 Description of parts or systems related to the occurrence

Engine and transmission

The helicopter is powered by a six cylinder carbureted engine. A V-belt sheave is mounted to the engine output shaft. Four V-belts transmit power to an upper sheave. There is a forward drive shaft on the upper sheave that powers the main rotor gearbox, which in turn drives the main rotor. Rearwards of the sheave is a long drive shaft to the tail rotor gearbox. During engine start, the V-belts are not taut. The clutch switch in the cockpit operates an actuator which tensions the V-belts by raising the upper sheave. The upper sheave has a free-wheel function that allows the main and tail rotors to rotate in case the engine fails.

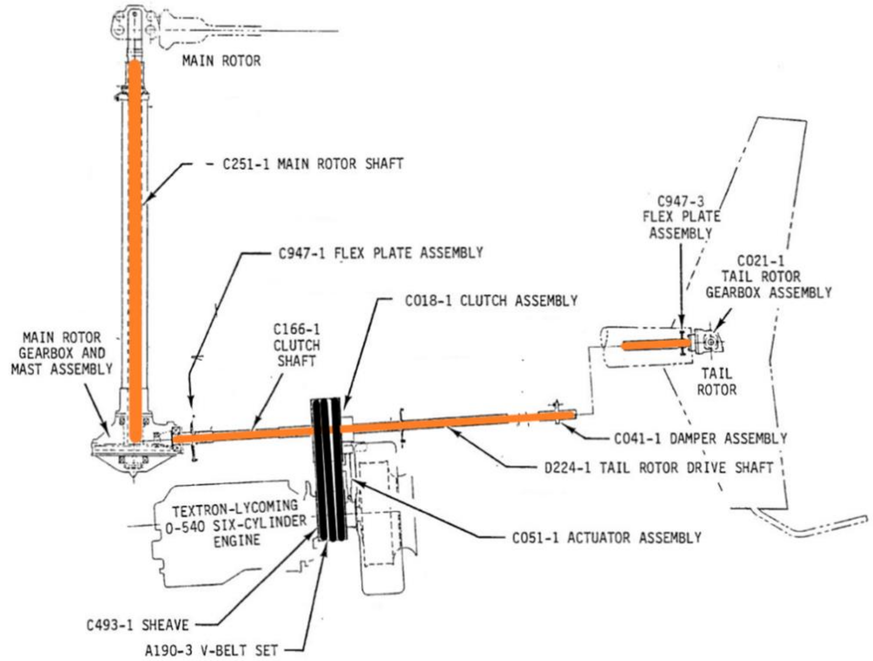

Figure 6. Principle illustration of the transmission system on the R44. Markings by SHK. Image: Robinson Helicopter Company.

Control system for yaw control

The helicopter is controlled about the yaw axis using pedals that control the blade pitch on the tail rotor via push-pull tubes and bell cranks. The tail rotor counteracts the torque from the main rotor.

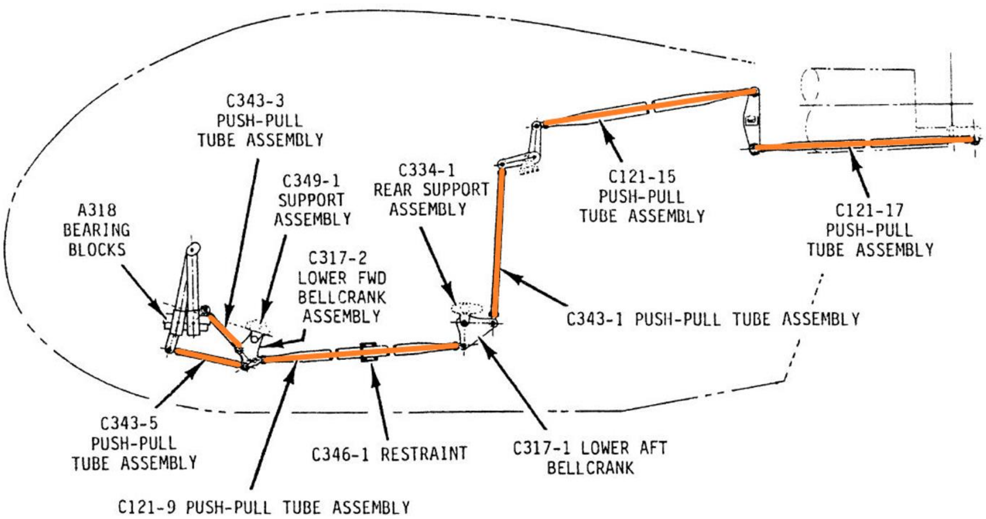

Figure 7. Flight control system for yaw control. The connection of the pedals to the tail rotor. Markings by SHK. Image: Robinson Helicopter Company.

Tail rotor drive shaft

The tail rotor drive shaft is mounted aft of the upper sheave and to the tail rotor gearbox with flex couplings. Located about one third of its length is a damper bearing.

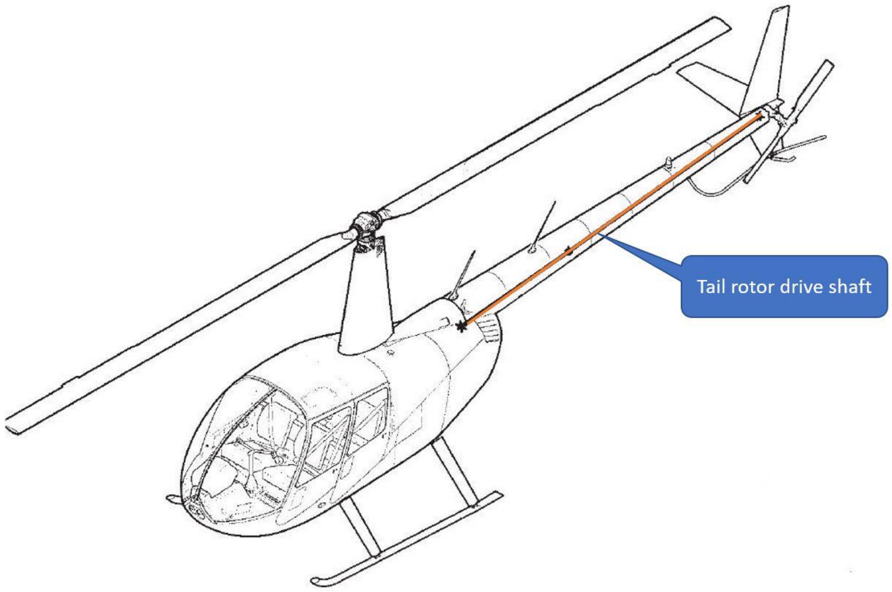

Figure 8. Tail rotor drive shaft. Markings by SHK. Image: Robinson Helicopter Company.

Tail section/Empennage

The empennage is mounted on the aft bulkhead of the tail boom and consists of three stabilizers. Also attached to this bulkhead is the tail rotor gearbox with the two-bladed tail rotor. There is a tail skid on the lower fin and there is a tail rotor guard on the rear part of the tail boom.

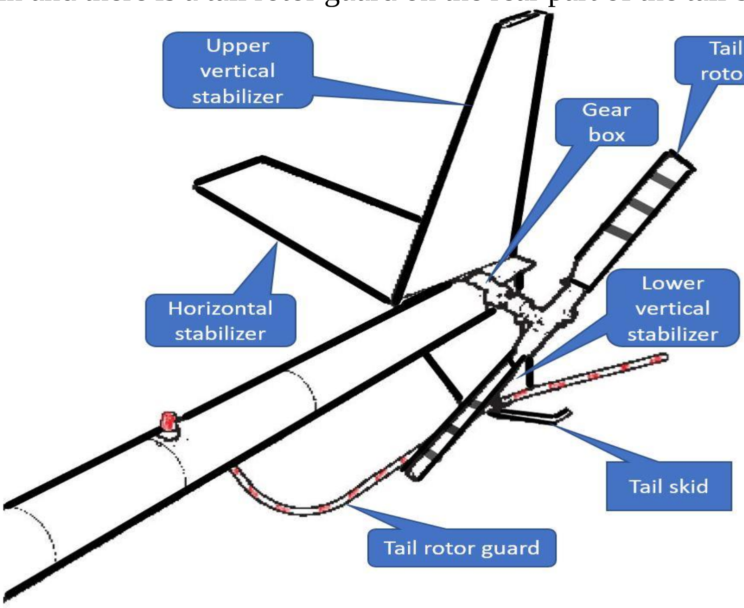

Figure 9. Various parts of the empennage.

1.6.4 Certification of strength requirements in the event of a crash

The Robinson R44 is certified in accordance with specifications in the American airworthiness standard 14 CFR[6] Part 27, Normal Category Rotorcraft, dated 1 February 1965, with revisions up to and including July 1992.

These specifications include requirements concerning the protective capacity of a helicopter in the event of a crash. The structure must be designed to give each occupant every reasonable chance of escaping serious injury in the event of a crash. The following limitations applies in respect of ultimate inertial load factors:

- Upward – 1.5g
- Forward – 4.0g
- Sideward – 2.0g
- Downward – 4.0g

1.7 Meteorological information

According to SMH's analysis: Fair weather. Wind NW-N knots, visibility over 10 km, cloud: broken cloud cover with a base of 4,900 feet, temperature/dew point +4/-3°C, QNH 1015 hPa.

The location of the crash site may result in local variations in wind direction and speed. The general wind flow is not deemed to give rise to any low-altitude turbulence in the area at the time of the crash.

1.8 Aids to navigation

The pilot was using an iPad with the application SkyDemon as a navigational aid.

1.9 Communications

Not pertinent.

1.10 Aerodrome information

Not pertinent.

1.11 Flight recorders

The helicopter was not equipped with a flight data recorder or cockpit voice recorder and nor was there any requirement for such equipment on this type of aircraft. However, SHK has retrieved data from the passengers' mobile phones that were on board during the flight and attempted to retrieve data from the iPad that was used as a navigational aid.

[6] CFR – Code of Federal Regulations.

1.12 Accident site and aircraft wreckage

1.12.1 Accident site

Figure 10. The approximate location of the accident site marked with a yellow pin by SHK. The field for take-off and landing was located 100 metres NW of the accident site. Source: Google Earth and © Lantmäteriet.

The accident site was located in an area with rolling terrain and a high proportion of coniferous forest. The accident took place in a patch of forest with tall, dense conifers, around 100 metres from the nearest road (see Figure 10).

1.12.2 Aircraft wreckage

During the crash, the helicopter initially collided with trees that were 15–18 metres tall. At that time, the helicopter did not have any forward speed. The main rotor cut off the tops of several trees at a length of 30 centimetres and a diameter of 13 cm. In conjunction with the rotation, the empennage has hit the trees, at which point the tail rotor and its attachment separated from the helicopter. Finally, the helicopter has fallen freely towards the ground for the last 10–15 metres. The helicopter collided with the ground with its left side first, and in a nose-down attitude.

The wreckage was located in one place. One main rotor blade was, however found 32 metres from the wreckage. The tail rotor, with stabilizer and the bulk of the tail rotor drive shaft was two metres behind the wreckage. The tail rotor drive shaft was twisted and had broken. The tail rotor blades did not have any damage caused by rotational forces. The tail rotor hub and stabilizer were damaged on the left side.

The cabin was substantially deformed on the left front part and the helicopter was resting on its front left side.

The emergency floats were deployed and the cable to the release mechanism had been stretched in conjunction with the deformation that arose during the crash.

Figure 11. The aircraft wreckage.

Figure 12. Tail rotor with drive shaft and stabilizer. Damage to the left side of the stabilizer and tail rotor hub.

Figure 13. One of the tree trunks that was cut off by the main rotor blades. The diameter of the tree is 13 cm.

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

A rescue operation can be divided up into rescue services in accordance with the Civil Protection Act (2003:778) and other rescue operations. In the Civil Protection Act, the term "rescue services" denotes the rescue operations for which central government or municipalities shall be responsible in the event of accidents in order to prevent and limit injuries to people and damage to property or the environment. Other rescue operations include pre-hospital medical care and the actions of the police and others.

During the rescue operation in question, national search and rescue and municipal rescue services were initiated. The resources that took part came from organisations including the Swedish Maritime Administration, the Swedish Armed Forces, Northern Dalarna Fire Brigade and medical resources from the regions Dalarna and Värmland. Northern Dalarna Fire Brigade, which is responsible for rescue services in

Leksand, is a municipal federation involving five municipalities: Leksand, Mora, Orsa, Vansbro and Älvdalen.

A call about the accident was received by SOS Alarm at 11:15 hrs. The caller had seen a helicopter go down a few hundred metres south of the village of Gropen in Dalarna. The JRCC[7] was connected to the call because it was an air accident. SOS Alarm called out rescue resources from the fire stations in Mora and Leksand two minutes later. An ambulance and Dalarna's air ambulance helicopter in Mora were also called out at the same time, and the police were informed. The air ambulance in Mora was not available. However, it was possible to call Värmland's air ambulance from Karlstad out to the site.

SOS Alarm was able to obtain a GPS location for the caller's mobile phone through AML (Advanced Mobile Location) but the location of the crash site was still unknown. The JRCC led the operation until the wreckage was found and the rescue resources were being guided towards the location of the caller.

The Emergency Transmitter (ELT[8]) type Kannad 406 AF was activated at the event. Just after the alarm call was received, the JRCC had also received an emergency signal from the Cospas-Sarsat system[9]. A location that later proved to be 1.9 km south-east of the crash site was stated but this also provided further confirmation that the helicopter had crashed in the area. The JRCC began searching for and calling out airborne resources in order to search for the crashed aircraft. This included searching for radar images from the area and calling out SAR helicopters from Stavanger, Stockholm and Gothenburg. The Swedish Armed Forces was able to contribute by sending two JAS fighter aircraft from F7 in Skaraborg towards the location. The JAS aircraft flew over the area but were not able to locate the crash site. It was not necessary to use the SAR helicopters because it was possible to locate the crash site before they had arrived.

An ambulance and a part-time force from the fire station in Leksand were the first to arrive in the area at 11:32 hrs, other resources arrived gradually after this. It had not yet been possible to locate the accident site and the rescue force began flying drones over the area. However, the forest was very dense, which made it difficult to make out the ground in the images from the drones. At the same time, a private individual had walked into the forest and succeeded in locating the wrecked aircraft 100 metres from the road. The pilot had freed himself from the wreckage.

Once the crash site had been located, the JRCC terminated the national rescue service, the time was then 11:50 hrs.

[7] JRCC– The Swedish Maritime Administration's Joint Rescue Coordination Centre.
[8] ELT – Emergency Locator Transmitter.
[9] Cospas-Sarsat is an emergency alarm system that consists of satellites and ground stations.

The rescue personnel on site were able to establish that one person had died and that one person was trapped. The helicopter was in a stable position between some trees, but there was a minor leak from the fuel system. The rescue personnel prepared to both free the passengers from the wreckage and deal with a potential fire. Aside from the fact that the process of freeing the casualty could itself start a fire, the battery was not accessible and thus impossible to disconnect. However, no fire broke out and it was possible to free the trapped person using hydraulic tools and take them to the air ambulance.

The municipal rescue service operation was terminated at 13:08 hrs and the accident site was handed over to the police and the Swedish Accident Investigation Authority. The rescue service informed POSOM[10] in Leksand for support to those affected and conducted a debriefing of its own personnel.

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

The pilot sat in the right pilot seat. The passenger who was fatally injured sat in the left front seat and the other passenger was in the right passenger seat in the rear. All had used the seatbelts. Both the pilot and the passenger in the right passenger seat suffered injuries including fractures.

1.16 Tests and research

1.16.1 Tail rotor drive shaft

The broken tail rotor drive shaft has been examined for the purpose of measuring its distortions, and to make a fractographical survey of the fracture surfaces.

Measurement of the drive shaft gave the following results:

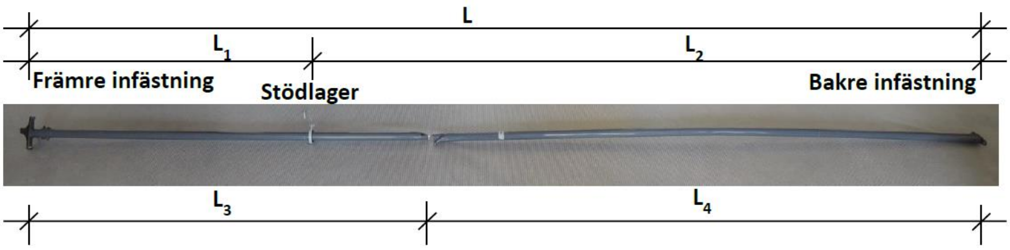

Figure 14. Measured lengths of the drive shaft.

Mått	L	L_1	L_2	L_3	L_4
Längd [mm]	4458	1300	3158	1850	2608

Figure 15. Table of length measurements.

[10] Municipal function for psychological and social care.

Measurements showed that the drive shaft has a torsional deformation of about 40 degrees and a deflection of 125 mm. The torsional residual deformation of the drive shaft has resulted in wavelike pattern (buckling phenomenon) along the shaft. The damage indicates that the load that caused the fracture has been distributed along the drive shaft. This is also an indication that there has not been any weak materials areas, or extensive load concentration at the fracture location at the time of the fracture.

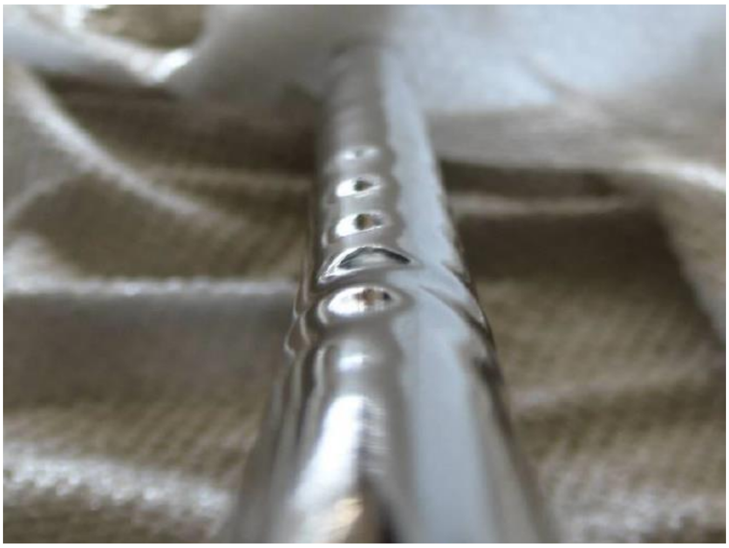

Figure 16. Waveform buckling as a result of torsion.

The load direction is in the direction of the engine torque. The damage corresponds with an overload fracture resulting from a torsional overload that has occurred on one single occasion (see Figure 17).

Figure 17. The fracture with load direction.

1.16.2 Examination of the empennage

The stabilizers had sustained extensive damage. The upper vertical stabilizer had impact damage to its leading edge and at the tip of its trailing edge. The lower vertical stabilizer had severe impact damage to its leading edge. The horizontal stabilizer had impact damage to its leading edge and at the tip of the trailing edge.

Figure 18. Damage to the horizontal stabilizer.

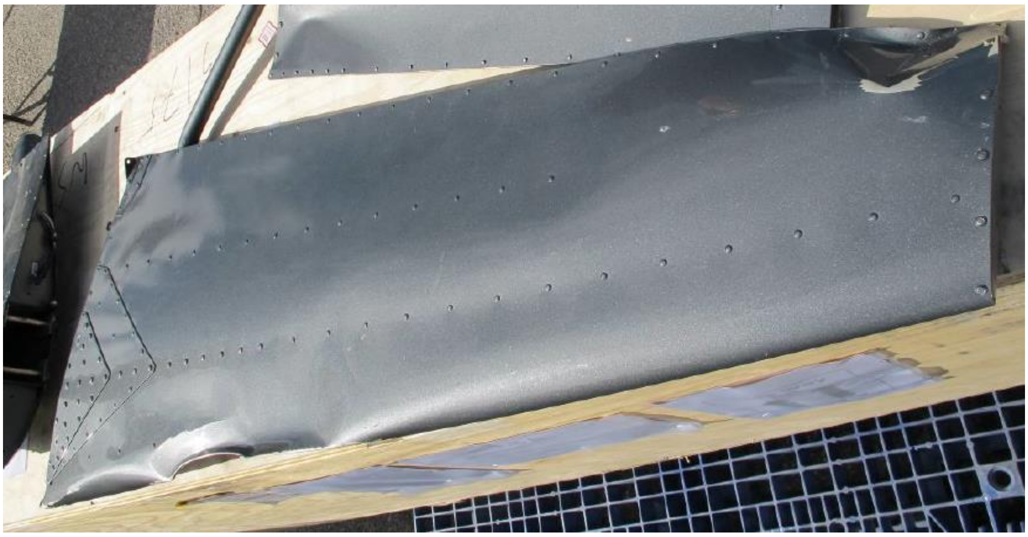

Figure 19. Upper vertical stabilizer.

Figure 20. Lower vertical stabilizer.

The attachment for the tail rotor gearbox in the tail boom was broken, with sheared rivets (see Figure 21). A small broken part of the boom's skin panel was remaining to the attachment. The rivets of the attachment were sheared in a direction that indicates the attachment has been broken off in a backwards direction in relation to the skin panel on the boom.

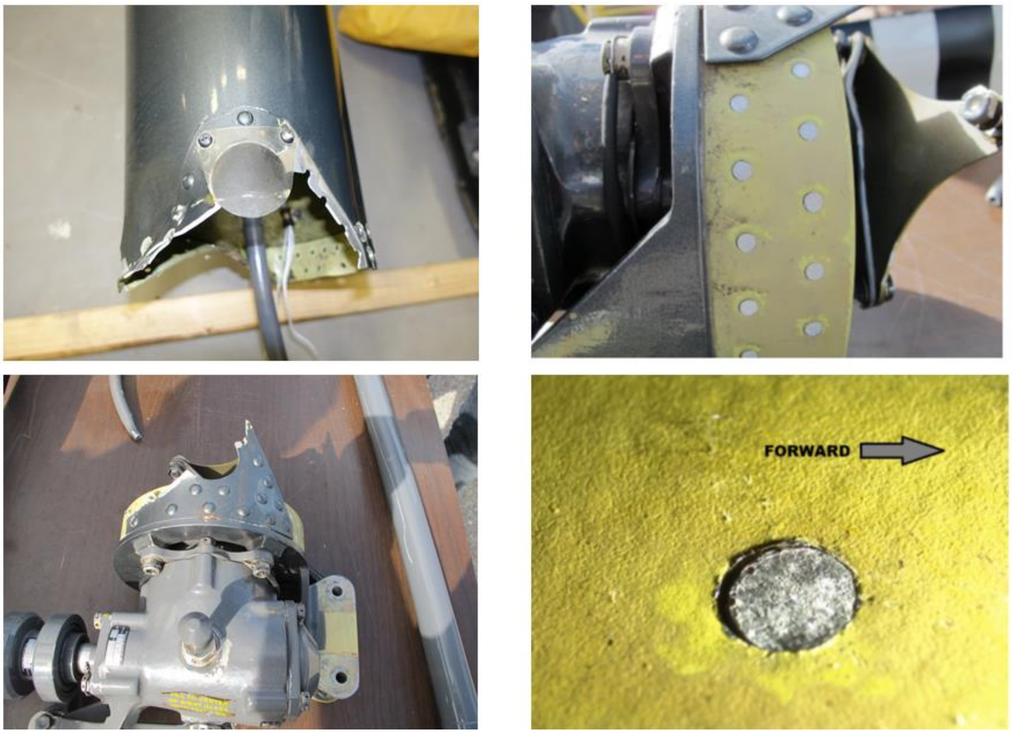

Figure 21. The tail rotor gearbox was broken off the tail boom.

1.16.3 *Examination of the tail rotor gearbox*

A disassembly of the tail rotor gear box did not show any anomalies. There was no damage to the gears. The roller bearings for the input and output shaft rotated smoothly and freely. The magnetic chip detector was free of any debris. Analysis of the oil did not show a high level of wear metals or external contaminants. The viscosity of the oil was consistent with the manufacturer's specifications.

Figure 22. Tail rotor gearbox with components.

Examination of the engine and drive system

The following examinations of the engine and drive system have been conducted.

- The engine could be rotated without abnormal resistance or abnormal noises and with the valves moving normally.
- The engine’s compression has been tested by measuring the static leak rate. All cylinders had good values.
- The engine oil and oil filter did not contain any visible metal particles or contaminants.
- The spark plugs had normal appearance and were mounted with torque.
- The function of the magnetos has been tested. There were no remarks of relevance to the occurrence.
- The ignition key was broken off in the “Both” position. This position means that the ignition system was able to function on both of the magnetos.
- The fuel filter contained no contaminants and the fuel had no abnormalities.
- The carburetor and intake showed no abnormalities of relevance to the occurrence.

- The V-belts for the clutch were in tension and nothing abnormal could be noted. The free-wheel function “sprag clutch” in the upper sheave functioned normally and rotated easily. The oil in the free-wheel assembly contained no contaminants.

- The main rotor rotated easily and without abnormal noises from the gearbox. There were no remarks concerning the oil in the gearbox. An examination with an inspection camera showed no visible damage to the gears in the gearbox.

Examination of warning lights in the cockpit

There are a number of warning lights on the instrument panels in the cockpit (see Figure 23). All the warning lights have been examined.

Figure 23. The location of the warning light on the instrument panels. Picture from the start of the flight. Markings by SHK. Photo: Private.

When a lit light bulb is subjected to g-forces, as is the case during a crash, the glowing filament is stretched. Inspection of the filaments from the warning lights under a microscope shows that it is highly probable that the warning light for low voltage from the alternator was illuminated (see Figure 24). This indicates that the engine had either stalled or had low RPM before the impact with the ground.

Figure 24. The warning light for low voltage with a stretched filament.

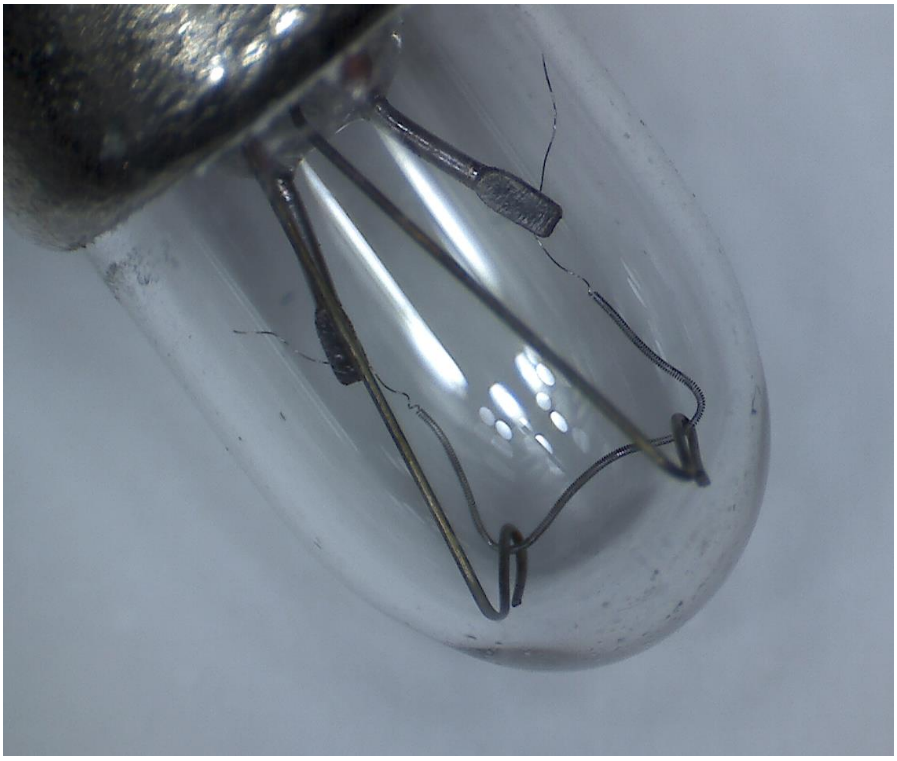

Figure 25. Filament with a normal appearance for comparison. In this case, the warning light for low engine oil pressure.

There is also a certain probability that the filament in the warning light indicating that the engine RPM governor is switched off was illuminated at the time of impact. This warning light indicates that the switch for the engine RPM governor was in the off position. However, the switch, which is located on the collective, was broken off in the helicopter wreckage.

The assessment was made that the other warning lights were not illuminated at the time of impact. These include warnings for metal chips and high oil temperature in the main rotor and tail rotor gearboxes, low rotor RPM and low engine oil pressure.

Examination regarding carburetor icing

The relationship between the air temperature and the dew point was such that there was a risk of carburetor icing. The helicopter was equipped with a carburetor heat assist device. The control knob for carburetor heat was in the unlatched position, which means that the heat assist was functional.

There was an instrument in the cockpit that shows the temperature in the carburetor. The temperature has to be kept outside of the marked area (see Figure 26).

Figure 26. Instrument showing the temperature in the carburetor (Carb Temp).

An analysis of pictures and videos taken during the flight showed carburetor temperatures between +10°C and +20°C on the instrument. These values indicate that the carburetor heat was working during the flight and probably prevented any problems with carburetor icing.

The visual images showed that the instruments in the cockpit indicated normal values and that no warning lights were illuminated during the flight.

Flight control system for yaw control

The system for tail rotor control was damaged in the area under the pedals, with broken push-pull tubes (see Figure 27). This area sustained major structural damage in the accident. The push-pull tube at the tail rotor was also broken (see Figure 28). All fracture surfaces have been examined and these showed that the fractures have occurred due to overload. There was connection in the remaining part of the yaw control system.

Figure 27. Broken push-pull tubes for the flight control system for yaw control in the area under the pedals.

Figure 28. The broken push-pull tube at the tail rotor.

1.17 Organisational and management information

Not pertinent.

1.18 Additional information

1.18.1 Unanticipated yaw

If the tail rotor suffers interference, unanticipated yaw can arise. This sort of interference can have both technical and operational causes. Aviation authorities and manufacturers have identified and advised about a risk of unanticipated yaw, which can be caused by, among other things, interference to the tail rotor, which in turn is caused by the air that is being used by the tail rotor being affected by the main rotor (downwash).

This phenomenon has led to many accidents involving helicopters. A common cause is the helicopter being hit by a side wind when it is standing still in the air or being manoeuvred at low speed (at speeds below the speed that provides translational lift[11]). On this type of helicopter, with a main rotor that rotates anticlockwise, this phenomenon can arise when the wind is blowing obliquely from the front left. In a situation in which the tail rotor ends up in disturbed air from the main rotor, it is vital to recognise the situation when it occurs and that the pilot may need to be more active with the controls than they are used to. This is especially the case at low speed, during high-power manoeuvres such as entering a hover without ground effect[12] or during a slow approach to a limited area.

1.18.2 Published safety documents concerning unanticipated yaw

FAA AC 12/26/95

The US Federal Aviation Administration (FAA) has published an advisory circular as a result of several accidents in which the phenomenon of unanticipated yaw has been implicated in the cause of the accident. (*FAA AC 12/26/95*).

EASA SIB No.: 2010-12R1 Issued: 21 October 2010

The EASA has published a safety document regarding the risk of unanticipated yaw. EASA Safety Information Bulletin SIB No.: 2010-12R1 Issued: 21 October 2010 Subject: Loss of tail rotor effectiveness (LTE) or unanticipated yaw in helicopters.

[11] Translational lift: Translational lift is increased lift from the rotor disc that arises during horizontal movement relative to the air mass; in practice, at forward speeds of around >20–25 knots.

[12] Ground effect: The helicopter needs less lift close to the ground due to the formation of a “cushion of air”.
Ground effect decreases with increased height above the ground and vanishes completely at a height equivalent to the diameter of the rotor. Hovering without ground effect requires supplying more lift or engine power than hovering with ground effect.

Robinson SN-42 Unanticipated Yaw, 2017

The type certificate holder Robinson Helicopters Inc. has published a safety document in which they point out the risk of unanticipated yaw in, for example, wind from the left or low rotor RPM (*Robinson SN-42 Unanticipated yaw, 2017*).

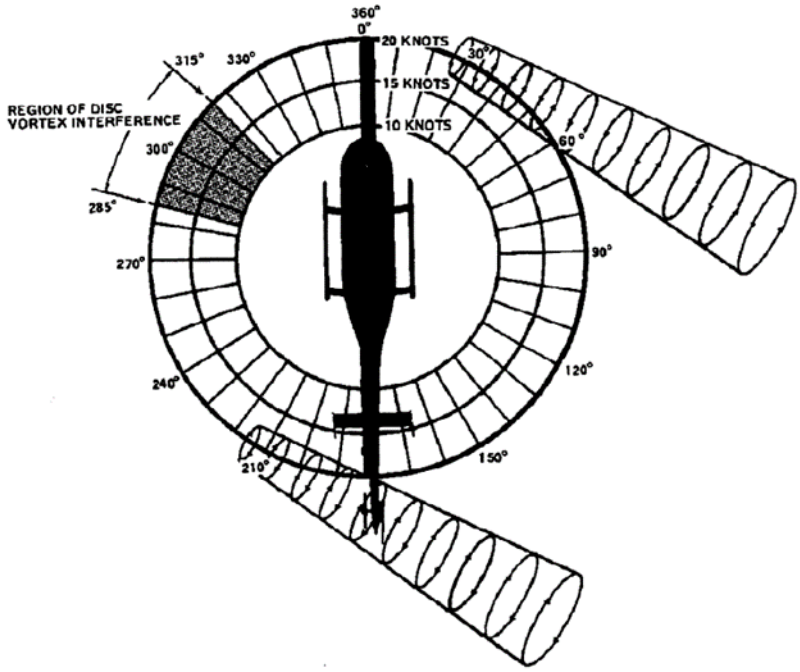

FIGURE 1. MAIN ROTOR DISC VORTEX INTERFERENCE

Figure 29. Shows how the downwash from the main rotor can interfere with the function of the tail rotor. Source: FAA AC 12/26/95.

1.18.3 Requirements for flying with passengers

With a private pilot certificate, a pilot is authorized to fly for one year after the last test for an examiner. A pilot must perform three take-offs, approaches and landings in the last 90 days in order to carry passengers (Commission Regulation (EU) No 1178/2011, FCL.060 and FCL.740).

1.18.4 Helicopter configuration requirements

The helicopter was equipped with a deviating configuration where double command for collective stick was installed but not for pedals and cyclic stick. According to safety information from Robinson, the double command must always be dismantled when you have non-pilot rated passengers in the front seat.

1.19 Special methods of investigation

Retrieval of data from an iPad with the navigation application Sky-Demon

With the support of the BEA, SHK has attempted to retrieve data from the iPad that was being used by the pilot. The memory units were removed from the severely damaged iPad and were put into an equivalent, undamaged iPad. Due to the damage to the memory units, it was not possible to retrieve the desired information.

Retrieval of data from the passenger's mobile phone

With the help of the company MSAB, SHK has extracted underlying data from the pictures that the front passenger took with his mobile phone during the flight. The passenger took several pictures during the flight. The data for each image shows the time (hour, minute and second), speed, altitude, position and the direction in which the image was taken. They have thus contributed to the reconstruction of the flight and provided support for the analysis of the final phase of the flight and the circumstances that led to the accident.

2. ANALYSIS

2.1 Results of the technical examinations

No technical fault on the helicopter that could have contributed to the sequence of events have been identified. All the damage to the helicopter is deemed to have occurred during the impact.

The examination of the broken tail rotor drive shaft showed that the fracture on the shaft was an overload fracture caused by torsional overload. The examination of the tail rotor gearbox did not show any abnormalities that may have caused the gearbox to have had high resistance or to have prevented free movement. The drive shaft has probably fractured in conjunction with the empennage breaking off the tail boom when the helicopter hit the trees.

The warning light for low voltage was illuminated at the time of impact. This was probably because the engine RPM fell below the idle speed during the final phase of the sequence of events when the main rotor blades cut off several tree trunks. The fact that the warning light for low oil pressure did not illuminate in this context can be explained by the fact that the oil pump is being powered as long as the engine is turning, albeit slowly, and by the fact that it takes a certain amount of time for the oil pressure to fall once the engine has stopped. The fact that the warning light for low rotor RPM was not illuminated at the time of the impact is explained by the fact that this warning is inhibited when the collective is in its lowest position.

The most probable explanation for the warning light for the engine RPM governor probably being illuminated at the time of impact is that the switch, which is located on the collective stick for the right-hand pilot seat, was inadvertently set to the off position during the sequence of events. No explanation for the snapping sound that the pilot stated that he heard in the final phase of the flight has been identified.

2.2 Why was the control lost?

The speed was low in the final phase of the flight and devolved into hovering. The wind direction was from the front. When the helicopter turned slightly to the right, the wind instead came to act on the left front part of the main rotor. The helicopter has thus been hovering at low speed, without translational lift and without ground effect. The power output was relatively high in relation to descend flight with forward speed. These circumstances, combined with the relative wind from the left, resulted in an increased risk of interference to the tail rotor. This has led to an unanticipated yaw, which resulted in a loss of directional control about the yaw axis. The actions taken initially were not sufficient and the low height above the forest has limited the potential to regain control.

The pilot must be deemed to have had relatively limited flying experience, with 64 total flying hours at the time of the accident. The pilot's recency is estimated to have been affected by the fact that he had only flown 40 minutes in the last 6 months before the day of the incident. The relatively limited pilot experience in combination with the current recency has reduced the chances of detecting the risk of an uncontrolled yaw and of taking the necessary action to get out of the critical situation.

2.3 Survival aspects

After the treetops slowed the fall, the helicopter fell freely from a height of 10–15 metres before hitting the ground with the front part of the left side of the cabin. That part is not crash-protected in the same way as the lower part of the helicopter is. The forces to which the cabin and passenger compartment were exposed did exceed by far the requirements for crash resistance set for helicopter type certification.

2.4 The rescue operation

The rescue operation went relatively quickly despite the fact that the accident site could not be located immediately. The rescue resources could be directed near the accident site because the position of the mobile phone used in the 112 call could be obtained. The caller was only a few hundred metres from the accident site. Sufficient search and rescue resources were alerted to the accident and no delays occurred during the operation. The Accident Investigation Authority has therefore chosen not to analyze the rescue operation further.

2.5 Requirements for flying with passengers

A private pilot's certificate has an unlimited validity period and the pilot can carry out what applies to the certificate as long as it has a valid license and medical certificate. A pilot is authorized to fly alone for one year after a PC[13] or skill test has been completed with an examiner. A PC can also be replaced with an instructed flight if certain time requirements in the past year are met. No actual flight time needs to be generated during this period to maintain the rating.

To be allowed to fly with passengers, however, a pilot must have completed three takeoffs, approaches and landings in the last 90 days.

The requirements in the regulations are only formal minimum requirements to be considered competent. They do not guarantee that a pilot will be able to complete the flight safely. Before each flight, a pilot must assess his ability to complete the flight. This assessment can be difficult to make by a pilot who has low total flying hours or limited recent flying experience.

[13] PC – Proficiency Check.

3. CONCLUSIONS

3.1 Findings

a) The pilot was qualified to perform the flight.

b) The pilot had low recency and had low total flying experience.

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

d) The helicopter had undergone a 100-hour inspection before the flight. No maintenance flight check in accordance with the helicopter's maintenance programme was performed in conjunction with the inspection.

e) The helicopter was equipped with a deviating configuration where double command for collective stick was installed but not for pedals and cyclic stick.

f) No technical fault with the helicopter that could have contributed to the occurrence has been identified.

g) During the final part of the flight the helicopter had a low speed without translational lift, and a relatively high power output.

h) The helicopter came to hover without ground effect and with a relative wind from the left.

i) The helicopter ended up in an uncontrolled rotation about the yaw axis.

j) A controlled emergency landing was not possible.

k) After colliding with the treetops, the helicopter fell from a height of 10–15 metres.

l) The forces to which the cabin were subjected to far exceed the crash-resistance requirements for certification of this type of helicopter.

m) Sufficient search and rescue resources were alerted to the accident and no delays occurred during the operation.

3.2 Causes/contributing factors

The accident was caused by a number of factors. In the final phase of the flight the speed was reduced and the helicopter transitioned to a hovering position where the tail rotor probably was disturbed by the air from the main rotor. This resulted in that the helicopter unexpectedly yawed to the right. The measures taken to counteract the yaw were not sufficient and therefore the yaw rate increased. An underlying cause of the accident was that the pilot had low total flying hours in combination with little recent flight experience, which has reduced the possibility of anticipating the consequences of the speed reduction and the possibility of taking adequate measures.

4. SAFETY RECOMMENDATIONS

None.

On behalf of the Swedish Accident Investigation Authority,

Kristina Börjevik Kovaniemi Stefan Carneros