Norwegian Safety Investigation Authority

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REPORT SL 2020/17

REPORT CONCERNING AIR ACCIDENT ON STAVNES, KRAGERØ, NORWAY ON 23 MARCH 2019 INVOLVING A ROBINSON HELICOPTER R44, LN-OGF

The Norwegian Safety Investigation Authority (NSIA) has compiled this report for the sole purpose of improving flight safety. The object of any investigation is to identify faults or discrepancies which may endanger flight safety, whether or not these are causal factors in the accident, and to make safety recommendations. It is not the NSIA's task to apportion blame or liability. Use of this report for any other purpose than for flight safety shall be avoided.

This report has been translated into English and published by the NSIA to facilitate access by international readers. As accurate as the translation might be, the original Norwegian text takes precedence as the report of reference.

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AIR ACCIDENT REPORT

Type of aircraft:	Robinson Helicopter Company R44
Nationality and registration:	Norwegian, LN-OGF
Owner:	Savicon AS, Skien, Norway
Operator:	Private
Commander:	1
Passengers:	1
Accident site:	In the forest on Stavnes, Kragerø, in Telemark County, Norway (N 58,929° E 009,487°)
Accident time:	Saturday 23 March 2019 at approx. 1805 hours

All times given in this report are local time (UTC + 1 hour) unless otherwise stated.

NOTIFICATION

On Saturday 23 March 2019 at approx. 1840 hours, the Norwegian Safety Investigation Authority (NSIA) became aware through media reports of a helicopter accident that had taken place near Kragerø. The information was later confirmed by Air Navigation Services provider Avinor. It emerged that the helicopter involved was an R44, LN-OGF, and that two people had been injured. Two accident inspectors arrived at the accident site at approx. 0930 hours the next day

In accordance with ICAO Annex 13, Aircraft Accident and Incident Investigation, the US National Transportation Safety Board (NTSB) was notified of the accident as a representative of the manufacturing country. The NTSB appointed an accredited representative who assisted in the investigation.

SUMMARY

On Saturday 23 March 2019, the commander had hired LN-OGF, a Robinson R44 helicopter, to fly from Skien to Langøy, east of Kragerø. The commander found that the intended landing site on Langøy was unsuitable and decided to return to Skien. On his way back to Skien, the commander noticed that he was losing engine power. An attempt to autorotate from an altitude of about 800 ft failed. The rotor stopped completely, and the helicopter dropped vertically along the trunk of a 30-meter fir tree. The branches cushioned the impact somewhat, but both people on board were severely injured and the helicopter destroyed.

The examination of the helicopter wreckage showed that a spark plug on cylinder no. 5 was loose. This caused an air leakage, increased temperature in the cylinder and damage to an intake valve. The NSIA believes that the high temperature gradually may have caused pre-ignition in the cylinder and a significant loss of power. Most likely, the spark plug loosened because isufficient torque was applied during installation in connection with a 100-hour inspection conducted in November 2018.

A pilot who had rented the helicopter earlier that day, felt two thuds during flight. He consequently aborted the flight and landed in a field. The commander who subsequently rented the helicopter

continued his flight as planned, before the reasons for the aborted flight had been clarified. Most likely, problems with cylinder no. 5 also caused the aborted flight earlier in the day. The NSIA is of the opinion that the helicopter, after having landed in the field earlier in the day, should not have been operated until the cause of the aborted flight had been determined.

1. FACTUAL INFORMATION

1.1 History of the flight

1.1.1 The helicopter belonged to a company but was mainly flown and operated by a private person (hereinafter referred to as the owner). The owner also rented the helicopter out to other private people. On the Saturday in question, two different people had agreed to rent the helicopter (subsequently referred to as the first pilot and the commander). The first pilot had flown LN-OGF on the Wednesday of the same week, during a Proficiency Check with an instructor. He then conducted a familiarization flight with the owner of the helicopter to be allowed to operate the helicopter on his own.

1.1.2 Early on Saturday afternoon, the first pilot arrived on a farm north of Skien, where the helicopter was parked. He took the helicopter out of the building and conducted a daily inspection. The first pilot has explained to the NSIA that he did not sign for the inspection in the helicopter flight log because he could not find the log (see section 1.6.4). After the inspection, he took off with three passengers on board and flew to Lifjell, where he had a short ground stop of 30 minutes. He then returned to the farm and picked up three other passengers.

1.1.3 The departure for the second flight to Lifjell took place around 1555 hours. The first pilot has explained that he felt a thud in the helicopter during a slight climb, 3–4 minutes after take-off. He compared it to someone slapping the helicopter body with a flat hand. In retrospect, the first pilot could not say whether this affected the helicopter because he instinctively lowered the collective control lever and immediately started to turn the helicopter back 180°. All instruments showed normal values after the thud.

1.1.4 During a slight descent on his way back to the farm, he felt another thud from the helicopter. It was weaker this time and he did still not register any instrument changes. Below was a suitable field for landing and he decided to go into autorotation and land the helicopter in the field[1]. Having reached an altitude of about two meters, he aborted autorotation and hovered to the outskirts of the field where he landed without further problems. He then called the owner of the helicopter and explained the situation.

1.1.5 Based on the various explanations, it is somewhat unclear to the NSIA what was said and understood by the various parties after this. The first pilot agreed with the owner of the helicopter that he would check the helicopter. If nothing obvious was detected, he would call the aircraft technician who performed maintenance on the helicopter.

1.1.6 At the time, there was also telephone contact between the first pilot and the next pilot (the commander) who was to operate the helicopter later the same day. When the commander heard about the precautionary landing, he drove to the field. Together they checked the helicopter fairly thoroughly. According to the two, the following was checked:

[1] Mælagata 108, Skien

- External signs of damage, loose covers, etc.
- The oil level in the main gearbox, tail rotor gearbox and engine.
- The main rotor including the pitch links, swash plate and visible parts of the flight controls.
- The drive train to the tail rotor including the temperature indicators on the freewheel and the tail rotor gearbox.
- The tail rotor including the pitch links.
- They operated the clutch and checked that the indicator lights worked as normal.
- All indicator light bulbs in the cockpit.

Nothing unusual was detected.

1.1.7 The first pilot contacted the aircraft technician at 1615 hours. According to the aircraft technician, the first pilot had explained that he had experienced a drop in rpm[2]. The technician was busy and could not inspect the helicopter until the following day. He has explained to the NSIA that he "placed a flight ban on the helicopter." He indicated that there might have been a problem with the freewheel, but other than that could not help establish what might have been wrong with the helicopter. He asked to be informed if the first pilot found anything serious, and if it was obvious that the helicopter had to be transported to the workshop by truck.

1.1.8 It was quite a windy day and the wind is estimated to have reached 35 kt at an altitude of 2,500 ft at Lifjell. However, the first pilot found the wind stable and with no significant turbulence. Consequently, he did not think turbulence could be the cause.

1.1.9 The commander did not perceive that the aircraft technician or the owner had banned operation of the helicopter. He started the helicopter and lifted it into hover, while the first pilot was observing. The commander did not notice anything abnormal and after a few minutes he flew the helicopter back to the farm. There, he conducted several landings, including an autorotation, before completing a final landing following a 18 minutes flight. At 1703 hours, the first pilot called the aircraft technician and told him that the commander had taken off with the helicopter.

1.1.10 When the first pilot arrived at the farm a bit later, he understood that the commander intended to carry out the planned flight. In retrospect, the first pilot explained to the NSIA that he also did not have the impression that the aircraft technician had grounded the helicopter. He was in doubt as to what had happened to the helicopter, but did not think it was right to stop the commander from proceeding with the flight. The first pilot did not have access to the flight log and thus did not make any comments in the log. A comment in the flight log would have formaly meant that the helicopter would have had to stay grounded until competent personnel had released it for flight.

1.1.11 The commander was to hire the helicopter for a few days for, among other things, a work assignment at Langøy, east of Kragerø. On the afternoon in question, the commander and

[2] The first pilot does not recognize this statement.

a friend were flying to the island to look for a potential landing site. They loaded the helicopter with various equipment that they were going to use during the assignment. The NSIA later weighed the equipment and found that it was 162.1 kg. Earlier that day, the commander had called the Aeronautical Meteorological Services which reported that the wind would be 15 kt, with gusts of 27 kt in the area. He therefore thought it would be an advantage that the helicopter was heavily loaded. Neither did the commander make any comments in the flight log.

1.1.12 The commander took off from the farm at approx. 1740 hours, heading south toward Langøy. He did not submit a flight plan to Norway Control. However, he contacted Farris Approach at frequency 134.05 MHz and informed them that he was heading south toward Langøy. The helicopter transponder was set at the standard VRF code 7000 for flight in uncontrolled airspace. When above his destination near Garnvik in Langøy (see Figure 1), the commander realized that there was no suitable place he could land. He then decided to return to the farm north of Skien.

1.1.13 Heading north, during a slight climb at an altitude of 800 ft and a speed of 80 kt, the commander noticed something happening to the helicopter. He has explained to the NSIA that it felt like the engine suddenly had to work harder. Glancing at the carburetor temperature, the commander saw that it was in the green range. He noticed that the manifold pressure was increasing toward 18 in.Hg, that the rotor speed was dropping and that the low rotor RPM warning sounded.[3] The commander described the experience as driving a car uphill in third gear and then by accident putting it into fifth gear. The engine did not provide sufficient power.

1.1.14 The commander has explained that he lowered the collective control lever and pulled the cyclic control lever toward him to put the helicopter into autorotation. He realized that the rotor RPM was dropping despite his attempt to put the helicopter into autorotation. At the time, the helicopter was flying over the Stavnes peninsula, approximately one kilometer north of Langøy. He then noticed that the helicopter started rocking as the main rotor was about to stop. He saw that the best option would be a tall fir tree forest on the peninsula and decided to make an emergency landing there, almost straight ahead. He thought that the fall would be higher if he attempted to land in a field to his left, or on the sea to his right. As he approached the trees, he pulled the cyclic toward him to raise the nose of the helicopter.

1.1.15 The helicopter first hit some small branches before coming to a sudden stop. It then started to fall toward the forest floor. The commander was surprised that the impact with the ground was not harder. After the helicopter had come to a stop, it was quiet. The only sound was some beeping from the emergency locator transmitter, which had activated.

1.1.16 The commander's friend in the left seat was injured and unconscious. The commander managed to get his friend out of the wreckage and cleared his airways. He then called the emergency number 113. The Norwegian Air Ambulance app was used, but according to the commander there was an initial misunderstanding as to where the crash had taken place.

1.1.17 A Norwegian Air Ambulance helicopter with a medical doctor on board did not arrive at the scene until 1843. Due to the dense forest it was unable to land. At 1848 hours, one of

[3] A warning will sound when the rotor RPM is 97% or lower.

the Norwegian Armed Forces' Sea King rescue helicopters arrived and a rescuer was hoisted down. Almost simultaneously rescue crews arrived on foot through the forest. The two injured people were taken to Oslo Ullevål University Hospital in the rescue helicopter.

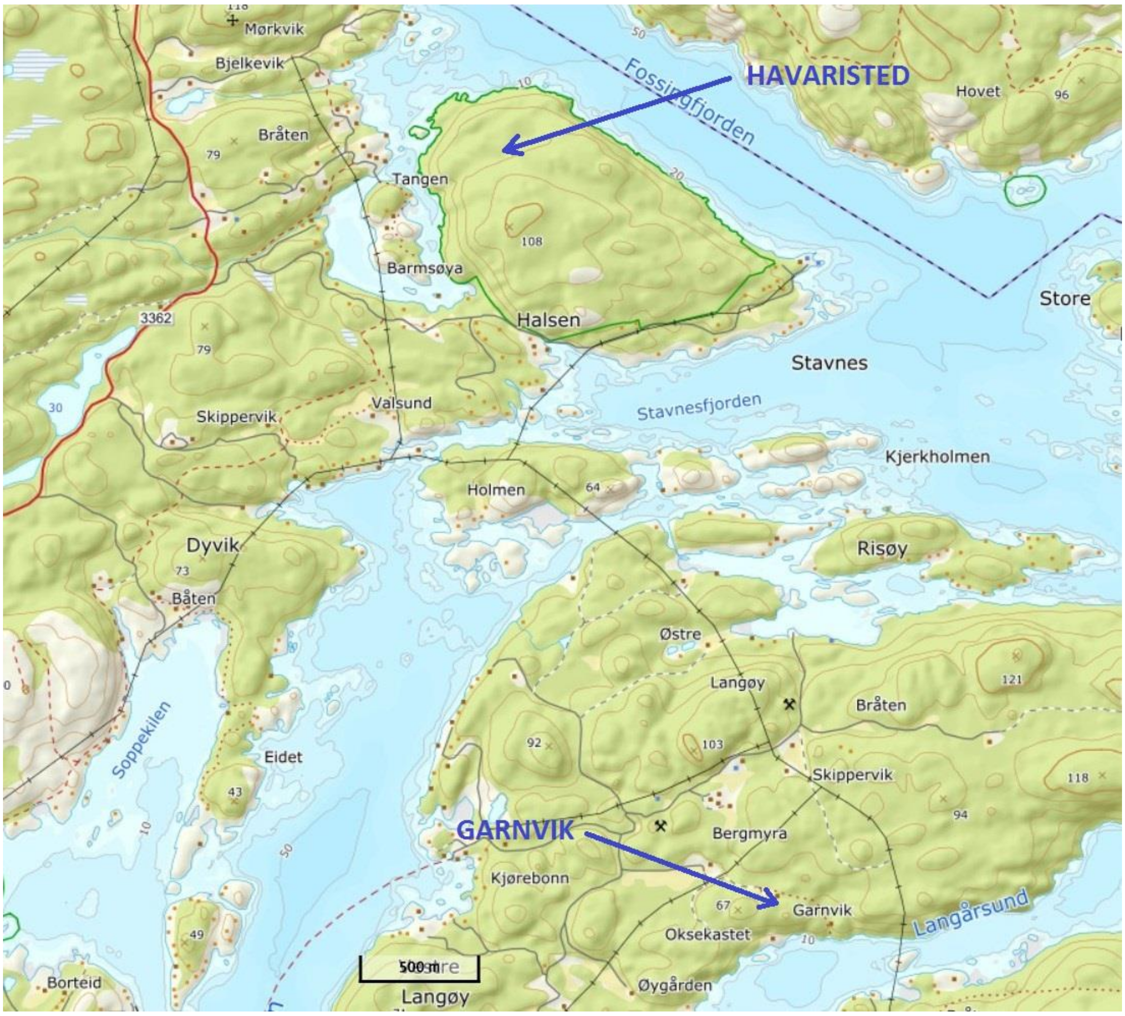

Figure 1: The accident site. Havaristed means accident site. Map: @ The Norwegian Mapping Authority

1.2 Injuries to persons

Table 1: Injuries to persons

Injuries	Crew	Passengers	Other
Fatal			
Serious	1	1	
Minor/none			

1.3 Damage to aircraft

The aircraft was totally destroyed, see Chapter 1.12.2 for a more detailed description.

1.4 Other damage

Damage to some trees. In order to retrieve the helicopter wreckage, it was necessary to cut down a number of trees.

1.5 Personnel information

1.5.1 The commander

1.5.1.1 The commander, 54, started flying in 1996. He started flying helicopters in 2015, after about 600 hours on airplanes. The commander had a private pilot license for helicopters (PPL(H)), issued on 19 April 2016. The type rating for operating an R44 aircraft was last extended on 14 April 2018 and was valid until 30 April 2019. The commander also held a valid Light Aircraft Pilot License (LAPL). In addition, he had worked as a loadmaster for a helicopter company for some time.

1.5.1.2 The commander held a class 2 medical certificate valid until 12 March 2020, with the following limitation: VNL "*Shall have available corrective spectacles for near vision and carry a spare set of spectacles*".

Table 2: Flying experience commander

Flying experience	All types	On type
Last 24 hours	1	1
Last 3 days	1	1
Last 30 days	1	1
Last 90 days	1	1
Total	Approx. 700	85

1.5.2 The aircraft maintenance technician

The aircraft maintenance technician working on LN-OGF had a valid EASA Part 66 aircraft maintenance license for the categories A1, A2, A3, A4, B1.1, B1.2, B1.3, B1.4, B2, and C, as well as national type ratings. His previous experience includes a number of senior technical positions for an airline and he had extensive experience with Robinson helicopters. At the time of the accident, he worked as an independent aircraft technician. Furthermore, the aircraft technician was connected to the Finnish CAMO organization Joen Service OY and was certified to perform *Airworthiness Reviews* of aircraft on behalf of this company.

1.6 Aircraft information

1.6.1 General Information

Robinson R44 is a light piston engine helicopter with four seats, two in the front and two in the back. The minimum crew is one pilot, seated in the front right-hand seat. The prototype first flew in 1990. The helicopter has a two-bladed main rotor which rotates anticlockwise, seen from above, and hydraulically assisted flight controls. The helicopter has become very popular and has in recent years been the most manufactured helicopter in the world.

1.6.2 General data

Manufacturer and model: Robinson Helicopter Company R44 I

Serial no.: 1449

Manufacturing year: 2005

Total flight time: 2,376.8 hours

1.6.3 Rotor RPM

1.6.3.1 The R44 pilot's Operating Handbook, Chapter 2 "Limitations" states the following RPM limitations:

Power On: maximum 102%, minimum 99%

Power Off: maximum 108%, minimum 90%

A low RPM warning horn will sound at 97%.

1.6.3.2 The operating handbook gives a number of safety recommendations and warnings, called Safety Notices. Below follows an excerpt from relevant Safety Notices:

Safety Notice SN-10

FATAL ACCIDENTS CAUSED BY LOW RPM ROTOR STALL

The primary cause of fatal accidents in light helicopters is a failure to maintain rotor RPM. To avoid this, every pilot must have his reflexes conditioned so he will instantly add throttle and lower collective to maintain RPM in any emergency.

(...)

Safety Notice SN-24

LOW RPM ROTOR STALL CAN BE FATAL

(...)

Rotor stall is very similar to the stall of an airplane wing at low airspeeds. As the airspeed of an airplane gets lower, the nose-up angle, or angle-of-attack, of the wing must be higher for the wing to produce the lift required to support the weight of the airplane. At a critical angle (about 15 degrees), the airflow over the wing will separate and stall, causing a sudden loss of lift and a very large increase in drag. The airplane pilot recovers by lowering the nose of the airplane to reduce the wing angle-of-attack below stall and adds power to recover the lost airspeed.

The same happens during rotor stall with a helicopter except it occurs due to low rotor RPM instead of low airspeed.

(...)

Safety Notice SN-29

AIRPLANE PILOTS HIGH RISK WHEN FLYING HELICOPTERS

There have been a number of fatal accidents involving experienced pilots who have many hours in airplanes but with only limited experience flying helicopters.

(...)

For example, in an airplane his reaction to a warning horn (stall) would be to immediately go forward with the stick and add power. In a helicopter, application of forward stick when the pilot hears a horn (low RPM) would drive the RPM even lower and could result in rotor stall, especially if he also "adds power" (up *collective). In less than one second the pilot could stall his rotor, causing the helicopter to fall out of the sky.*

(…)

Safety Notice SN-32

HIGH WINDS OR TURBULENCE

(…)

The helicopter is more susceptible to turbulence at light weight. Reduce speed and use caution when flying solo or lightly loaded.

1.6.4 Aircraft Flight Log

For all aircraft, there shall be a system for following up flight hours, inspections, remarks and maintenance actions. Unless otherwise approved by the Civil Aviation Authority Norway, an aircraft flight log must be available on board all private aircraft. This flight log was not found or used by the two pilots involved. The LN-OGF owner also used an electronic solution where the owner, aircraft technician and renter could book the helicopter and communicate about flight hours. The three people involved on the day of the accident had varying understandings of how this should be done in relation to the helicopter's aircraft flight log.

1.6.5 Maintenance history

1.6.5.1 Extensive maintenance was performed on LN-OGF in the summer of 2017. Such maintenance must take place after 2,200 flight hours, or every 12 years. The work entails a complete dismantling of the helicopter and overhaul or replacement of a number of key components. A great number of the components involved are overhauled or supplied new by Robinson Helicopter Company. The dismantling and re-assembly took place locally. In this connection, the engine was removed and overhauled by Norrønafly Rakkestad (see Chapter 1.6.6). An independent licensed aircraft technician signed off all the work on the helicopter (Certificate of Release to Service – CRS) (see Chapter 1.5.2) on 7 October 2017. The helicopter's total flight time was 2,129 hours. At the same time as the above maintenance was performed, the aircraft technician conducted and signed off a combined annual inspection / 100-hour inspection.

1.6.5.2 The same licensed aircraft technician subsequently performed[4]:

- 50-hour inspection on 12 March 2018 at 2,178 flight hours
- 100-hour inspection on 27 July 2018 at 2,235 flight hours
- 50-hour inspection on 20 August 2018 at 2,290 flight hours
- 100-hour inspection on 14 November 2018 at 2,335.7 flight hours[5].

1.6.5.3 The 100-hour inspection included the item *"Remove spark plugs. Test, clean and regap. Replace if necessary"*. However, during the inspection, all 12 spark plugs were replaced with new ones. The checklist that was used on 14 November 2018 contained a box which

[4] The stated times are the helicopter flight hours.
[5] 41.1 hours before the accident occurred.

must be signed after the task has been completed. However, there was no box for signing off for independent inspection. A leak check of the cylinders was also carried out[6]. The following results were documented:

1:76, 2:77, 3:76, 4:77, 5:78, 6:77

1.6.5.4 The aircraft technician has explained to the NSIA that the 100-hour inspection was conducted with assistance from an external person. He consequently put particular emphasis on performing the work in a systematic and controlled manner. He has stated to the NSIA that he was 100 percent sure that the spark plugs and ignition harness were correctly installed when the helicopter left the hangar in November 2018. Thus the technician suggested that somebody else must have worked on the spark plugs later on if anything was not installed properly.

1.6.5.5 On 28 February 2019, at 2,372.5 flight hours and about four flight hours before the accident, the aircraft technician worked on the helicopter. Among other work, he installed a system for preheating of the cylinders for start in cold weather. The system was supplied by Tanis Aircraft Products and had part number TSP6CYK-2927-230. It was not necessary to loosen the spark plugs or the ignition harness nuts during the installation or maintenance work that was performed. The aircraft technician has explained that as part of the work, the engine was thoroughly inspected and cleaned.

1.6.5.6 On board LN-OGF was the *Airworthiness Review Certificate* (ARC) issued on 11 October 2018 by Joen Service OY and valid until 11 October 2019. The certificate was signed by the same aircraft technician who had performed maintenance on the helicopter. When asked on 16 October 2019, the Civil Aviation Authority Norway had still not received a copy of this document as required. Consequently, the Civil Aviation Authority only had a copy of an ARC which was valid until 9 October 2018.

1.6.6 Engine

The helicopter is equipped with a six-cylinder carburetor engine of the Lycoming O-540-F1B5 type with serial number L-26381-40A. When the engine was overhauled by Norrønafly Rakkestad on 31 August 2017, it had a total flight time of 1,845 hours.

1.6.7 Fuel

In March 2018, LN-OGF was approved for automotive fuels through the issue of Supplemental Type Certificate (STC), no. SE00663WI. The certificate was valid for both the helicopter and the engine. The certificate was issued on the condition that no ethanol-containing fuels was to be used and that the Research Octane Number (RON) was minimum 91. In addition, the engine had to have fuel with sufficient lead content. A mixture of 30% Avgas 100LL and 70% unleaded gasoline would cover this need. The owner of the helicopter has explained that they covered the need for lead by sometimes filling up the helicopter tank with Avgas 100 LL. Furthermore, the owner has explained that they regularly took samples of the fuel to ensure that it did not contain alcohol.

[6] Tested against a pressure of 80 psi. A completely tight cylinder will have the result 80. Values below 60 indicate a significant leakage in the cylinder and there might be a cylinder defect.

1.6.8 Mass and center of gravity (CG)

	Arm (in)	Mass (lb)	Moment (inlb)
The helicopter's empty mass	105.1	1531.7	160,981.67
Commander and passenger	49.5	390	19,305
Fuel (115 liters)[7]	104	180	18,720
Cargo	79.5	357.4	28,413.3
Total	92.48	2,459.1	227,419.97

Maximum permitted mass 2,400 lb

Permitted center of gravity range at 2,400 lb mass: 93–98 in

The calculation shows that the helicopter's mass at the time of the accident was 59.1 lb (26.8 kg) above the permitted maximum, and that the center of gravity location was somewhat in front of the forward limitation.

1.7 Meteorological information

1.7.1 Information from the Norwegian Meteorological Institute

1.7.1.1 The NSIA has obtained a weather report from the Norwegian Meteorological Institute[8] for the area where the accident took place. The general weather situation is described as follows:

> *There was a strong low pressure area off Lofoten producing a strong wind field from the low pressure center in Nordland and all the way south to Lindesnes. This resulted in westerly winds in large areas of Southern Norway, a strong upper wind and a relatively strong wind at ground level with heavy gusts. The situation was the same for most of the day, with the wind abating somewhat in the evening. There were few clouds in Eastern Norway on the day of the accident. The 0-isotherm was at 2000-3000FT.*
>
> *(...)*
>
> *Observations from the area near the accident site show a predominantly westerly wind direction, with varying wind speeds. Several weather stations registered wind gusts. No precipitation was observed and there were few clouds in the area. CAVOK at Torp and FEW050 at Notodden (1550 UTC). The air was unstable,*

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[7] NSIA estimates. In his report, the commander estimated that there were 77 liters of fuel (55 kg) on board the helicopter at the time of the accident. 110 liters were drained from the tanks after the accident. A small quantity of fuel had leaked out before the tanks were drained.

[8] For an explanation of meteorological abbreviations, see: https://www.ippc.no/ippc/index.jsp

with showers in Western Norway and some showers heading slightly east of the mountains.

1.7.1.2 As regards ground wind, the Norwegian Meteorological Institute wrote as follows:

There are no recordings from near the accident area, so we have to use data from surrounding stations during the period before and just after the accident. These vary, as expected when the weather situation is dominated by unstable wind conditions with wind gusts. Torp registered wind gusts of 30 kt at 1750 hours local time and 27 kt at 1820 hours local time, but had registered 36 kt earlier in the day.

(…)

In the hour between 1700 and 1800, there was a declining trend in the wind gusts, but most stations in the surrounding area reported a slight increase again between 1800 and 1900 hours. We are unable to establish the exact time of the wind gusts registrations within the last hour.

Observations show wind gusts of 20-30 kt. The strongest gust was registered at Torp. Weather model estimates indicate a downward trend in turbulence after 1700 hours local time, which corresponds with the observation.

1.7.1.3 The Norwegian Meteorological Institute also provided an overview of the strongest wind gusts that were measured during the last hour at various locations. The overview shows that the strongest wind gusts of 59 kt were measured in Lifjell 1,102 meters above sea level during the period 1400-1500 hours. In Jomfruland, wind gusts of 35 kt were registered in the period 1700-1800 hours.

1.7.2 <u>TAF and METAR for Sandefjord Airport Torp (ENTO)</u>

1.7.2.1 The following TAF (Terminal Aerodrome Forecast) was issued for Torp at 1800 hours for the period 23 March, 1900 hours to 24 March, 1900 hours:

(Times in UTC)

ENTO 231700Z 2318/2418 24012KT CAVOK TEMPO 2318/2319 26018G30KT TEMPO 2409/2416 22015G25KT=

1.7.2.2 The following METAR (Meteorological Terminal Air Report) was issued for Torp:

(Times in UTC)

ENTO 231520Z 25015KT 220V290 CAVOC 09/M04 Q1015 TEMPO 260 26018G30KT=

ENTO 231550Z 26019G36KT 230V290 CAVOC 08/M04 Q1015 NOSIG=

ENTO 231620Z 26016G31KT 230V330 CAVOK 08/M04 Q1016 NOSIG=

1.8 Aids to navigation

Navigation took place through visual references. The commander also used an iPad with a GPS and the Air Navigation Pro software.

1.9 Communications

Shortly before the accident, the commander contacted Farris Approach on frequency 134.05 MHz and informed them that he was heading south toward Langøy. At that time, LN-OGF was north of Kragerø. The commander had no contact with any other units from the air traffic services.

1.10 Aerodrome information

Not applicable.

1.11 Flight recorders

Flight recorders are not mandatory for this type of aircraft and were not installed.

1.12 Wreckage and impact information

1.12.1 The accident site

1.12.1.1 The accident site is located approx. 300 meters from the sea, northwest on the Stavnes peninsula (see Figure 1). Much of the peninsula consists of undulating terrain and is covered by tall and dense fir tree forest. The accident site is situated approx. 65 meters above sea level. The nearest road, Stavnesveien, runs approx. 700 meters south of the accident site. Alternatively, it is possible to travel by boat and walk the 300 meters or so to the accident site.

1.12.1.2 No tree trunks or branches showing clear signs of having been cut by the rotor were observed near the accident site. An approximately 30-meter tall fir tree approx. 15 meters south of the accident site was leaning sideways as a result of an impact (see Figure 2). The top of the tree and another two-meter piece of trunk from the same tree, were lying on the ground between the tree and the helicopter wreckage.

1.12.2 The helicopter wreckage

1.12.2.1 The helicopter wreckage lay by the root of a 30-meter tall fir tree. A 2.8-meter-long main rotor blade section was discovered on the ground, 38 meters northeast of the wreckage. There was also a lot of broken plexiglass from the cockpit/cabin and fir tree branches in the area south of the wreckage. The helicopter was lying with the fuselage pointing north in the direction of flight.

1.12.2.2 The helicopter wreckage was lying partly on its belly, slanting to the right. The right-hand landing gear had been knocked off and the entire fuselage was to a varying degree deformed and crushed. When the NSIA arrived at the accident site, the entire cabin was open, the doors were either missing or partly missing and the cabin roof was squashed. The seat back attachment points for both front seats had yielded, resulting in the seat backs being folded far back (see Figure 4). The entire instrument panel had come loose and was hanging partly in front of, and outside the cockpit. The tail boom was dented at the forward end, but there was otherwise little damage, including to the tail surfaces.

1.12.2.3 Both of the main rotor blades were bent and pointing upward. The pitch link to the intact blade had snapped allowing the blade to turn so that the trailing edge was pointing straight up. (see Figure 3). The broken blade showed clear signs of having been bent upward at the place of failure. There was no damage to any of the main rotor blades' leading edges, nor were there any signs that they had cut trees or branches.

1.12.2.4 Except for a bend in one of the two rotor blades, there was no apparent damage to the tail rotor (see Figure 3).

1.12.2.5 LN-OGF was equipped with inflatable floats for emergency landing at sea. These had inflated during the crash.

Figure 2: The accident site seen toward the southwest. The 30-meter tree that was knocked sideways is shown to the left in the picture. Photo: NSIA

Figure 3: The accident site seen toward the northwest. The red arrows show a crack in one of the tail rotor blades and the bend in one of the main rotor blades. Photo: NSIA

Figure 4: Damage to the cockpit/cabin. Photo: NSIA

1.13 Medical and pathological information

The police did not suspect that the commander was intoxicated. Thus, no breath or blood samples were taken. A routine rapid drug test showed that the commander was not under the influence of any drugs.

1.14 Fire

No fire occurred.

1.15 Survival aspects

1.15.1 The two people on board did not wear helmets.

1.15.2 The helicopter was equipped with three-point seat belts, which both on board used.

1.15.3 The commander called the emergency number 113 himself and reported the accident.

1.15.4 LN-OGF was equipped with an emergency locator transmitter of the Kannad 406 AF-H type. It activated as intended during the crash and transmitted emergency signals via satellite. The signals were received by the Joint Rescue Coordination Centre.

1.15.5 The R44 helicopter type does not have certified impact-absorbing seat cushions or energy-absorbing mechanisms in the seat structure.

1.16 Tests and research

1.16.1 Introduction

The day after the accident, the helicopter wreckage was transported to the NSIA's hangar in Lillestrøm for further examination. Based on the statements that the commander gave to the NSIA, the helicopter transmission and engine were thoroughly examined. An experienced R44 technician assisted the NSIA in this work.

1.16.2 The helicopter's transmission

1.16.2.1 All components related to the main rotor and the tail rotor drive line were examined in detail. Initially, it was concluded that no components, neither in the drive line nor in the engine, showed any signs of having rotated when the helicopter crashed. For example, the underside of the cooling fan was flattened and had struck other parts during the crash. However, none of these damages showed any traces of rotation (see Figure 5).

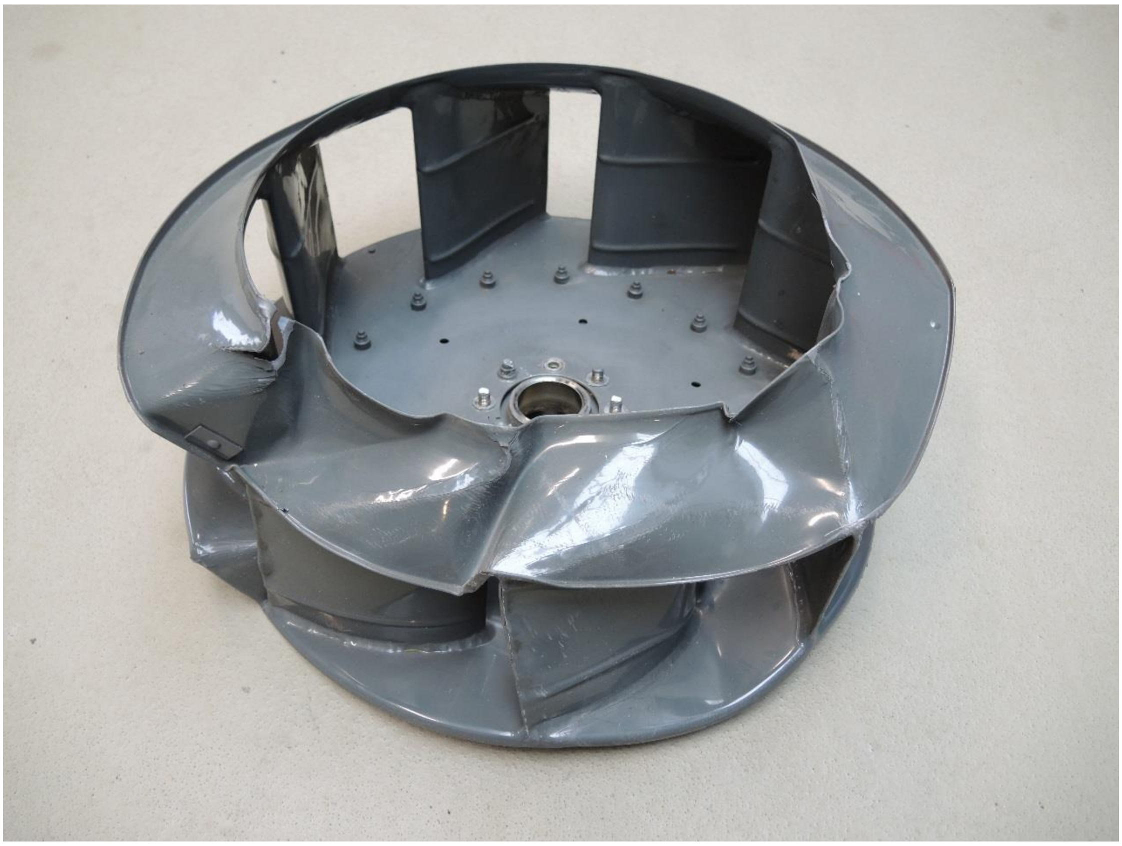

Figure 5: The underside of the engine's cooling fan was flattened. There was no visible sign that it had been rotating when it was damaged. Photo: NSIA

1.16.2.2 The examination of the drive line showed the following:

- All the Vee belts were in place and undamaged.
- The Vee belt clutch mechanism was found in an expected, normal position for flight.
- The freewheel was undamaged and functioned as intended. The temperature indicator on the freewheel showed no signs of overheating.
- The main gearbox rotated freely without any abnormal sounds, and the oil level was correct. There was no contamination in the gearbox's magnetic plug. The rotor brake was intact and showed no signs of overheating.
- The tail rotor drive shaft was intact and showed no signs of abnormal wear. There was some damage to the flexible coupling in the transition between the fuselage and the tail boom. This damage occurred in connection with the accident and the subsequent transport to Lillestrøm.
- The tail rotor gearbox rotated freely without any abnormal sounds, and the oil level was correct. The temperature indicator on the tail rotor gearbox showed no signs of overheating.

1.16.3 The engine

1.16.3.1 The engine was first examined externally without any abnormalities being discovered. The following was then examined:

- A leak test of the cylinders showed the following results (psi)[9]:
  1:70, 2:74, 3:76, 4:75, 5:15, 6:70

- The helicopter's fuel filter/water separator contained fuel without water. The filter was clean.

- The oil filter was opened up. No significant contamination was discovered.

- The ignition timing was at 25° BTDC (which is in line with the specifications).

- The valve covers were removed, and it was established that all valves moved freely when the engine was rotated.

1.16.3.2 Due to the extensive leakage, it was decided to remove cylinder no. 5 (see the first indent in the paragraph above). When the top spark plug was about to be unscrewed, it was found to be rotating when the spark plug nut was about to be loosened. It was discovered that the spark plug was completely loose so that it was possible to turn it by hand clockwise 180° from a position where the spark plug harness was in normal position. Consequently, it was necessary to hold the spark plug with a pair of pliers in order to loosen the spark plug nut (see Figure 6). It was established that the spark plug could be turned 190–200° from the position it was in when it was found, until it had the correct torque. Other than that, both spark plugs in cylinder no. 5 were in good condition and had a normal light brown color.

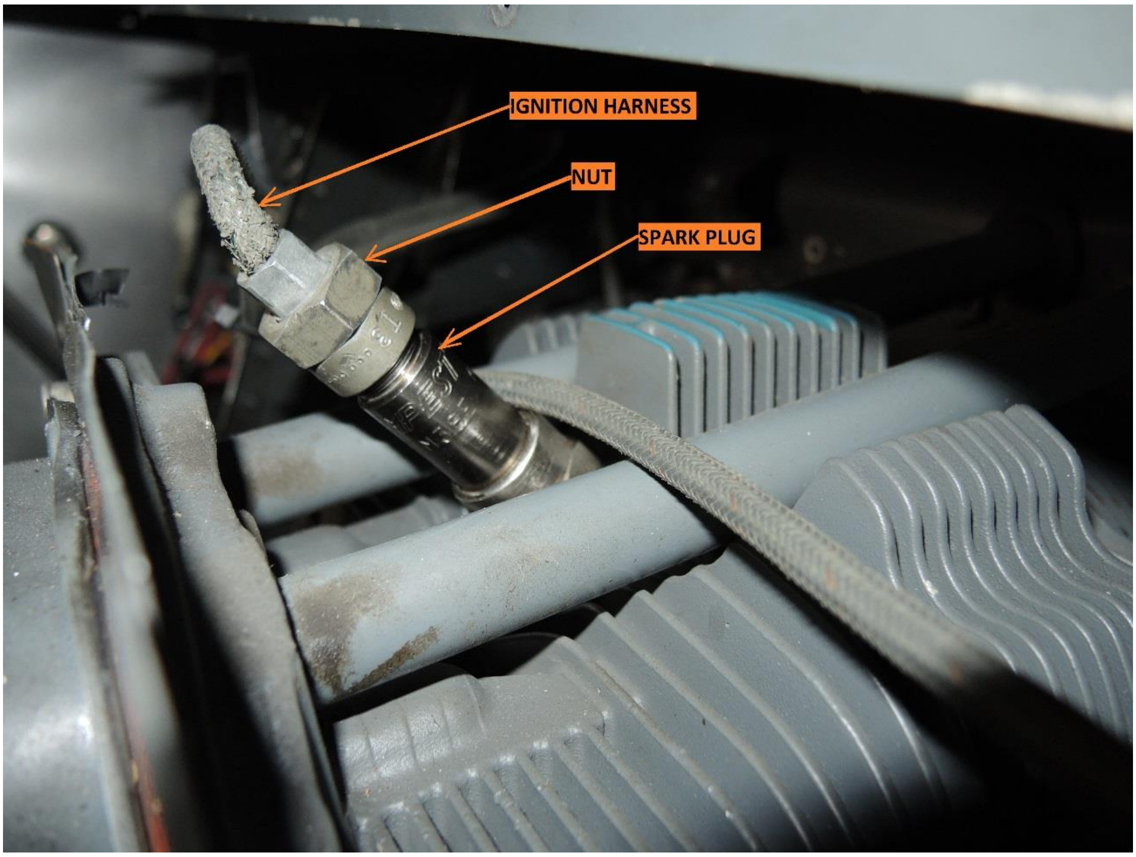

Figure 6: Photo of a correctly installed spark plug with wire. Photo: NSIA

[9] Measured against an inlet pressure of 80 psi

1.16.3.3 There were clear signs of an exhaust leakage (see Figure 7) around the loose spark plug and a new leak test was performed with the spark plug properly tightened. The new test gave only a negligibly improved result of 20 psi. When checking the other spark plugs on the engine's left side, it was found that the spark plug nuts on cylinders 1 and 3 were loose. It was also established that the lower rear (right) cylinder nut (9/16″) attaching cylinder no. 5 to the crankcase, was loose. The torque of the other seven nuts was as intended.

1.16.3.4 The piston in cylinder no. 5 was in good condition, with free moving piston rings and a clean piston head. There was no discoloration on the outside surface and no significant wear on the cylinder walls. Inside, the cylinder head was clean with little deposits and a normal light brown color (see Figure 8). After the cylinder was removed, valve leakage was checked with spirit. It was established that the exhaust valve was almost tight, whereas there was a leakage in the intake valve.

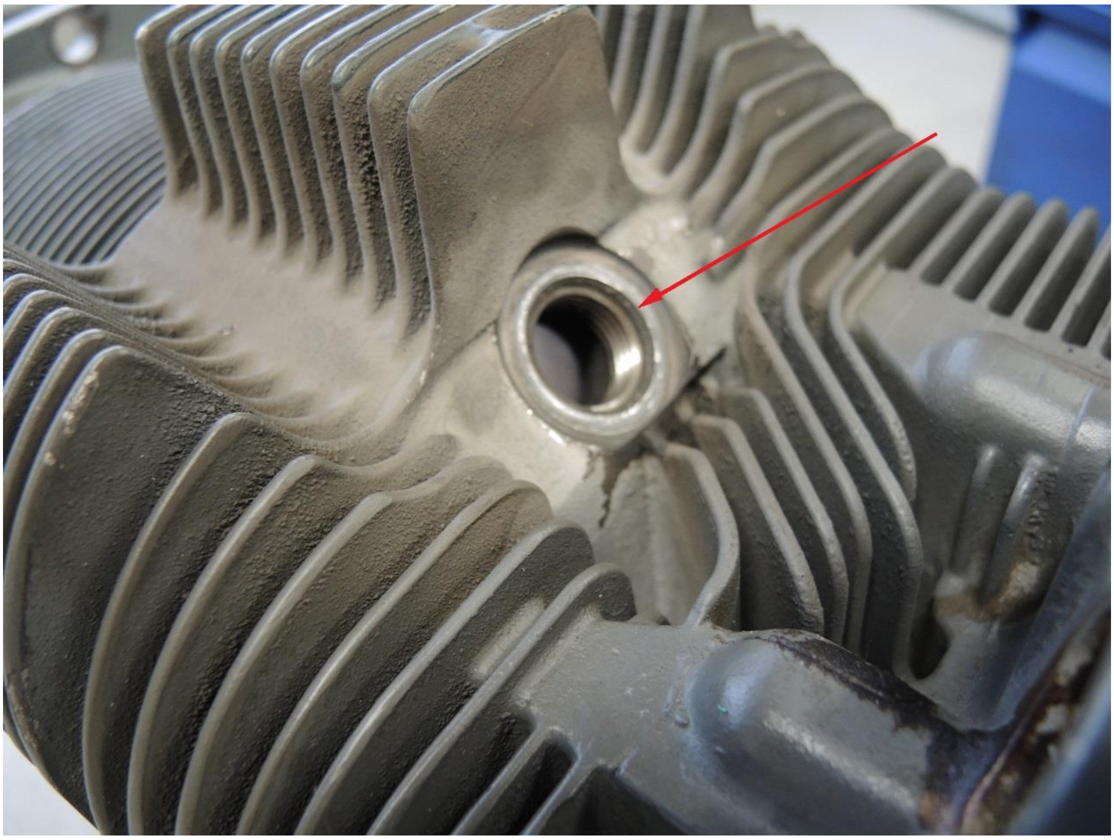

Figure 7: Cylinder no. 5 after it was removed. The arrow points to the upper spark plug hole surrounded by exhaust leakage. Photo: NSIA

1.16.3.5 The valves in cylinder no. 5 were removed. The following was observed:

- The exhaust valve had uneven "steps" on the valve head face. (see Figure 9). Otherwise, the valve had kept its geometrical shape. Similar damage was discovered on the exhaust valve seat. The valve was light brown in places with some green patches. Such green patches indicate that the valve has been exposed to high temperatures.

- There was only minor damage to the intake valve. The damage consisted in a step on about half the circumference on the valve head face and the surface was matt. However, the intake valve seat had a damaged surface on 60% of the area (see Figure

8). A closer inspection of the valve showed that the valve head had retained its geometrical shape, although the concentricity (run-out) was 0.3 mm.

Figure 8: Inside of cylinder no. 5 after the valves had been removed. The undamaged part of the intake valve seat is marked with a red line. The damaged part is darker/brown. Otherwise, it can be noted that the cylinder is clean and has a light color. Photo: NSIA

Figure 9: The exhaust valve from cylinder no. 5. The arrow points to the damage at the head face. The color of the valve is light brown with some green patches. Photo: NSIA

1.16.4 General examination of the helicopter

Except for the findings on the engine, no defects or deficiencies were observed in the helicopter's other systems that can explain why the helicopter engine lost power. Nor were any other findings observed that can explain the thuds that the first pilot experienced.

1.16.5 The fuel system

1.16.5.1 Upon arrival at the NSIA's premises in Lillestrøm, 110 liters of fuel were drained from the helicopter's two tanks. A small amount of fuel had already leaked out.

1.16.5.2 The NSIA submitted a fuel sample from LN-OGF to the Norwegian Defence Laboratories for analysis. The fuel was found to contain a combination of 95 octane and 98 octane gasoline with a RON value of 97.2. The fuel contained 0.88% ethanol and 0.02% isopropyl alcohol (see Chapter 1.6.7).

1.16.5.3 No ethanol damage was detected in hoses or other parts of the fuel system.

1.16.6 Information from the engine manufacturer Lycoming Engines

1.16.6.1 The NSIA has submitted photos and other information about the findings in the engine to the engine manufacturer Lycoming Engines. They replied as follows:

> *The loose spark plug clearly would provide a leak path for combustion pressures when the cylinder fires on the power stroke but of greater concern is the introduction of un-scheduled air into the cylinder during the intake stroke resulting in an excessive lean fuel air mixture to occur and accelerated temperatures for the #5 cylinder.*

1.16.6.2 Moreover, they believed that cylinder no. 5 showed clear signs of having operated at accelerated temperatures. The damage observed on the valves is to be expected with high temperatures. Lycoming goes on to say that:

> *Although it appears this is a relatively small leakage it can have significant operational issues with the engine. As noted on report: pilot experienced a change in engine noise and saw a reduction in rotor rpm and an* ***increase in manifold pressure.*** *The increase in manifold pressure would mostly likely occur during the combustion cycle for the #5 cylinder as the gases have a leakage path past the intake valve into the induction system affecting all the remaining cylinders. This condition can have a significant reduction of power loss for noted engine.*

1.16.6.3 Lycoming thought it unlikely that the engine problem was due to detonation or pre-ignition, as this would normally have resulted in visible damage to the piston or combustion chamber, or such damage to the valves that they would be shaped like a tulip.

1.17 Organizational and management information

1.17.1 The flight in question is defined as a private flight. The helicopter was provided by a private person, and the commander rented the helicopter with the intention of flying it privately.

1.17.2 According to the joint European aviation regulations EASA Part M, item M.A.201(a), the owner is responsible for ensuring the continuing airworthiness of an aircraft.

1.17.3 Responsibility for pre-flight inspection of the aircraft is regulated by Part M, item M.A.201(d) of the EASA regulations:

The pilot-in-command or, in the case of air carriers licenced in accordance with Regulation (EC) No 1008/2008, the operator shall be responsible for the satisfactory accomplishment of the pre-flight inspection. This inspection must be carried out by the pilot or another qualified person but need not be carried out by an approved maintenance organisation or by Part-66 certifying staff.

1.17.4 Part M, item M.A.402 of the EASA regulations stipulates that organizations or persons who conduct maintenance must: " *(h) ensure that the error capturing method is implemented after the performance of any critical task: …*"

1.18 Additional information

None

1.19 Useful or effective investigation techniques

No methods qualifying for special mention have been used in this investigation.

2. ANALYSIS

2.1 Introduction

The helicopter did not have equipment for data recording. Consequently, the analysis is based on statements from the persons involved, findings at the accident site and technical investigations. In Chapter 2.2, the description of the course of events is largely based on the commander's statement. His statement corresponds well with the other findings in the investigation. Chapter 2.3 describes the likely cause of the loss of engine power, and in Chapter 2.4 the accident is linked to the incident that took place earlier in the day. The last two chapters of the analysis discuss the helicopter maintenance as well as survival aspects.

2.2 History of the flight

2.2.1 The NSIA bases its analysis on the commander's statement, in which he explains that he first became aware of a change in engine noise and then registered that the manifold pressure increased, that the rotor RPM dropped and that the warning horn for low RPM sounded.

2.2.2 The NSIA believes this situation was the result of a significant loss of engine power. At the time, the helicopter was climbing at low altitude over the terrain in relatively strong wind. Furthermore, the helicopter was approx. 26 kg above the permitted maximum mass.

2.2.3 The commander's explanation that the helicopter started rocking is consistent with a main rotor about to stop. A number of findings on the accident site as well as detailed investigations of the helicopter wreckage indicate that the main rotor had come to a complete halt when the helicopter fell down along the trunk of the 30-meter fir tree. If the main rotor had been rotating, one would expect to find contact damage from the impact with tree trunks and branches. There were no such indications, neither on the rotor blades nor in the forest. Furthermore, the damage pattern on the engine’s cooling fan in particular showed that the engine was more or less inoperative when the helicopter struck the ground.

2.2.4 The NSIA can consequently conclude that the engine lost significant engine power at some point, and that this resulted in both the main rotor and the tail rotor stopping in a matter of seconds.

2.2.5 The importance of maintaining sufficient rotor RPM is a focus point in all helicopter flight training. It is clearly described how a low rotor RPM can cause fatal accidents, a fact that is also emphasized by the helicopter manufacturer Robinson Helicopters. How long it takes a rotor to lose RPM depends on a number of factors, such as the helicopter's mass, the kinetic energy stored in the rotor system, the degree of engine power loss, the effect from wind and how quickly the pilot reacts by lowering the collective.

2.2.6 The commander only had a few seconds to act after the engine started to lose power. When noises in the helicopter change, it will normally take some time before the pilot understands what is happening. The low RPM warning horn may have been what made the commander aware of what was about to happen. At that time, the RPM had most likely dropped to below 97%. An attempt to increase engine power by adding more throttle would not have helped as long as the engine was already delivering insufficient power. The only action that could have limited the loss of rotor speed was a rapid lowering of the collective, or moving the cyclic back. If the RPM drops below a certain value, around 80%, it will be impossible to increase the RPM again, even with engine power. The fact that the rotor stopped completely may indicate that the commander did not managed to take the necessary action in time.

2.2.7 The R44 has a rotor system with relatively limited kinetic energy, which means it is particularly important to react quickly. The helicopter was loaded beyond the maximum permitted limit. This may have contributed to the speedy drop in rotor RPM. The strong wind in the area may also have caused mechanical turbulence over the peninsula, which may have made the situation worse.

2.3 Likely technical cause

2.3.1 The NSIA assumes that the upper spark plug on cylinder no. 5 became loose, and that over time this caused an air leakage (see section 1.16.3.2). The air leakage is not likely to have reduced the engine power significantly, but would have supplied extra air to the cylinder during the intake stroke. This in turn would have resulted in the air/fuel mixture becoming leaner, making it lean of peak. Normally, the mixture in aircraft engines is richer (excessive fuel) than peak. The excessive fuel helps to cool the engine. If the mixture ratio becomes leaner than peak, the combustion temperature will increase until the temperature drops again when the excess of air is too high.

2.3.2 Soot in the area around the spark plug indicates a leakage past the spark plug. Over time, such a leakage and a resulting high temperature, can damage the valves and the valve seats. Findings during this investigation indicate that such damage has caused a significant leakage past the intake valve. A leakage past the intake valve will have a negative effect on the engine in a number of ways:

- During the compression stroke, some of the air/fuel mixture will be pressed back into the induction system and form a back pressure, which could affect the other cylinders.

- During the combustion cycle, the pressure will increase in the cylinder and more gas will be forced back into the induction system. This will cause significant disruption to the other cylinders and fill the induction system with a mixture of burned and unburned gasses.

- During the exhaust stroke, the pressure in the cylinder will decrease, but burned gasses will nevertheless leak into the induction system and affect the intake stroke.

- During the intake stroke, the cylinder will receive a mixture of burned and unburned gasses and air/fuel mixture.

2.3.3 Consequently, the NSIA believes that, in isolation, the leakage past the spark plug had little effect on the engine power. The damage to the intake valves would have had the greatest impact on the engine. The green color on the exhaust valve indicates that the cylinder in a period must have been abnormally warm.

2.3.4 It is difficult to say for certain why the loss of power only became significant during the climb north from Langøy. One possible reason may be that the engine was warm at the time and was operating at relatively high output during the climb. Some parts of the cylinder may have become so hot that they caused pre-ignition. The pre-ignition period could have been so short that there was insufficient time for the typical damage mentioned by Lycoming Engines to occur before the helicopter crashed (see Chapter 1.16.6).

2.3.5 The NSIA has noted that Lycoming Engines believes the increase in manifold pressure was caused by gasses being pushed past the bent valve and back into the induction system during the combustion cycle. An equally probable explanation is that the engine's governor noticed the drop in RPM tried to increase it by increasing the manifold pressure. As the engine's RPM dropped, there would be less need for air to the engine. The fact that the manifold pressure increased to a magnitude of 28 in.Hg is more likely to indicate that the engine was about to come to a complete stop. The manifold pressure for a stationary engine will equal the air pressure at the location, i.e. in this case approximately 29.7 in.Hg.

2.3.6 The NSIA cannot see a connection between the engine problems that arose and the two loose spark plug nuts on cylinders 1 and 3 (see section 1.16.3.3). Even though the nut was loose, the wires were still connected to the spark plug, which means that the high voltage would have reached spark plug.

2.3.7 The NSIA has not been able to establish why the nut which kept cylinder no 5 in place, was loose (see section 1.16.3.3). It may be that the nut had not been sufficiently tightened when the engine was overhauled (see Chapter 1.6.6). However, it could also be because the engine had been exposed to high loads during a brief period (pre-ignition).

2.3.8 The NSIA cannot see any connection between the accident and the use of automotive fuels. The alcohol content in the fuel was very low (see Chapter 1.16.5) and no nonconformities was discovered in the fuel system related to alcohol. Furthermore, the RON number was well within the limits stated on the issued Supplemental Type Certificate. However, if automotive fuels are used, samples are required at each filling to verify that there is no ethanol in the fuel. Alternatively, this has to be verified by the fuel supplier.

2.4 The incident earlier in the day

2.4.1 It cannot be determined for certain that the incident earlier in the day is connected with the accident, but the NSIA find it likely. The bangs or thuds that the first pilot experienced may have been caused by a short moment of pre-ignition, which did not show up on the instruments. A contributing factor to the phenomenon's sudden stop may be that the first pilot instinctively lowered the collective, thus reducing the load on the engine and stopping a potential pre-ignition.

2.4.2 Following this incident, the helicopter should not have been operated again before competent personnel had released it for flight. When a pilot experiences a situation serious enough to warrant aborting the flight and landing the aircraft in a field, there must be a high threshold for continuing to operate the same aircraft before the cause has been sufficiently determined.

2.4.3 During the situation in question, it may seem as if communication was inadequate and that responsibilities were vague. Generally, all incidents that can affect airworthiness, as well as any suspected technical faults, should be documented in the aircraft flight log. An entry in the flight log's section for remarks and actions would have formalized the incident and raised the threshold for continued operation of the aircraft.

2.4.4 The formal responsibility for ensuring that an aircraft is airworthy rests with the owner (see section 1.17.2). However, before each flight the commander must ascertain that the aircraft is in an airworthy condition (see section 1.17.3). In this case, there was uncertainty relating to what had taken place during the flight. The commander chose to fly despite this uncertainty. Good airmanship would have been to postpone the flight until competent personnel had released the helicopter for flight.

2.5 Technical maintenance

2.5.1 The NSIA does not find it likely that someone had loosened the spark plug after the helicopter had undergone the 100-hour inspection in November 2018. During the period before the accident, the helicopter had been in operation for about 41 hours and none of the persons involved reported any problems with the engine during this period.

2.5.2 Since no documented maintenance of the upper spark plugs had been carried out during this period, and since the spark plugs are not easily accessible, the NSIA finds it likely that the upper spark plug on cylinder no. 5 had not been properly tightened when all the spark plugs were replaced on 14 November 2018 (see section 1.6.5.3).

2.5.3 The NSIA believes that the damage to the valves in cylinder no. 5 has occurred after the spark plugs were replaced on 14 November 2018. This is substantiated by the fact that the leak test of the cylinders showed acceptable values (see section 1.6.5.3).

2.5.4 The spark plug nut for the upper spark plug on cylinder no. 5 was found tightened. It seems nearly impossible to tighten the spark plug nut correctly when a spark plug is completely loose and rotating freely, without also causing the spark plug to tighten. However, the nut torque should be lower than for the spark plug itself. The spark plug may therefore have been partly tightened in connection with the installation of the nut. It is most likely that the spark plug subsequently came loose and continued to loosen until the harness stopped it from rotating further.

2.5.5 The NSIA believes that the loose spark plug on LN-OGF's engine illustrates the importance of conducting all aircraft maintenance very thoroughly. Although double control of spark plugs and spark plug nuts is not specified, it is important to control each step in the work process. When installing spark plugs, all spark plugs should be checked (tightened again) a final time before attaching the spark plug harness and tightening the nut. All spark plug nuts should then be re-tightened. The fact that the work was conducted with assistance from another person, may have contributed to a moment of forgetfulness.

2.5.6 The aircraft technician failed to submit a copy of the updated *Airworthiness Review Certificate* (ARC) to the Civil Aviation Authority as one would expect. This may also have been a lapse (see section 1.6.5.6).

2.6 Survival aspects

2.6.1 To the extent that the commander had an actual choice, the NSIA believes that the emergency landing in the forest was decisive for the survival of the two people on board. In rough terrain, it may be an advantage to make an emergency landing in dense forest.

2.6.2 The helicopter hit a few meters down on the trunk of a 30-meter tall fir tree, and the impact was hard enough to break the tree in two places and knock it sideways. The tree slowed down the horizontal speed before the helicopter hit the next 30-meter tall fir tree and slide along this to the ground. The velocity was significantly reduced by branches as it fell toward the ground along the tree trunk. The relatively low fall velocity was the direct reason it was possible to survive the accident. A free fall from approx. 30 meters altitude would most likely have been fatal.

2.6.3 The two people on board did not wear helmets. In this case, it does not seem to be of much importance that the two on board did not wear helmets. Generally, wearing a helmet could provide vital protection in accidents like this.

2.6.4 In accidents involving strong vertical forces, impact-absorbing seats may be effective in preventing damage, particularly to the spine. The lack of certified impact-absorbing seats should be considered a disadvantage with this helicopter model.

2.6.5 The NSIA finds that the rescue operation in the main was efficient, despite the poorly accessible accident site.

3. CONCLUSIONS

3.1 Primary conclusion

A demanding situation arose when the engine lost significant power during flight. The commander did not manage to enter autorotation before the rotor RPM dropped too low. High mass and strong winds might have been contributing factors.

As the rotor RPM dropped, the commander tried to make an emergency landing, but the rotors stopped completely before the helicopter hit two fir trees and fell to the ground. The examination of the helicopter wreckage showed that a spark plug on cylinder no. 5 was loose. This most likely caused an air leakage, increased temperature in the cylinder and damage to an intake valve. The NSIA believes that the high temperature gradually caused pre-ignition in the cylinder and a significant loss of power.

3.2 Investigation results

a) Earlier on the same day, another pilot had aborted a flight with the same helicopter and landed in a field after he felt two thuds in the helicopter.

b) It is not entirely clear what was said and what was understood during the communication between the commander, the aircraft technician, the owner and the first pilot in connection with the landing in the field and the subsequent decision to fly.

c) The reason for the aborted flight had not been determined before the commander set off on the accident flight.

d) Most likely, problems with cylinder no. 5 also caused the aborted flight earlier in the day.

e) The preflight inspection was not signed off in the helicopter flight log, nor was any information about the aborted flight recorded in the log. That would have formalized the incident and raised the threshold for continued operation of the helicopter.

f) It was quite windy on the day of the accident. However, it is not possible to determine to what degree the wind affected the situation.

g) At the time of the accident, the helicopter's mass was approx. 26 kg above the permitted mass, and the center of gravity was somewhat in front of the forward limitation. It is, however, not possible to quantify to what extend this affected the situation negatively.

h) When the engine power dropped, at an altitude of 800 ft AGL and a speed of approx. 80 kt, the commander failed to establish autorotation in time. Consequently, the rotor RPM fell below the critical level.

i) The most likely cause of the loose spark plug was that it had not been tightened well enough during the 100-hour inspection in November 2018, about 41 flight hours before the accident took place.

j) There is nothing to indicate that the main rotor was rotating after the helicopter hit and fell along the trunk of a 30-meter fir tree.

k) The branches on the tree cushioned the fall to the ground, and the relatively low fall velocity was the direct reason it was possible to survive the accident.

4. SAFETY RECOMMENDATIONS

The Norwegian Safety Investigation Authority makes no safety recommendations in connection with this investigation.

The Norwegian Safety Investigation Authority

Lillestrøm, 16 September 2020

APPENDICES

Appendix A: Abbreviations

APPENDIX A: ABBREVIATIONS

AGL	Above Ground Level
ARC	Airworthiness Review Certificate
BTDC	Before Top Dead Center
CAMO	Continuing Airworthiness Management Organisation
E	East (East latitude)
EASA	European Aviation Safety Agency
ft	Feet – (0.305 m)
ICAO	International Civil Aviation Organization
in	inch (2.54 cm)
In.Hg	inches of mercury
kt	knot(s) – Nautical Mile(s) (1 852 m) per hour
lb	pound(s) (0.454 kg)
MHz	MegaHertz
N	North (North latitude)
NSIA	Norwegian Safety Investigation Authority
psi	pounds per square inch (.068 atm)
RON	Research Octane Number
RPM	Revolutions Per Minute
UTC	Coordinated Universal Time
VFR	Visual Flight Rules