Safety Investigation Report

AAIU
Air Accident Investigation Unit

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AAIU-2019-12-29-01

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Final

ACCIDENT
ROBINSON R44
AT WIJNENDALE (TORHOUT)
ON 29 DECEMBER 2019

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ABOUT THIS REPORT

This safety investigation report is a technical document that reflects the views of the investigation team on the circumstances that led to the accident and is conducted in accordance with Annex 13 to the Convention on International Civil Aviation and Regulation (EU) No 996/2010.

The sole objective of the safety investigation and the Final Report is the determination of the causes, and to define safety recommendations in order to prevent future accidents and incidents.
It is not the purpose of this investigation to apportion blame or liability.

In particular, Article 17-3 of Regulation (EU) 996/2010 stipulates that the safety recommendations made in this report do not constitute any suspicion of guilt or responsibility.

This investigation was conducted by the Air Accident Investigation Unit of Belgium, (AAIU(Be) further in this publication). It is the Belgian permanent national civil aviation safety investigation authority as defined in Article 4 of Regulation (EU) No 996/2010 and established in accordance with the Royal Decree of 8 December 1998.
This unit is part of the Federal Public Service Mobility and Transport and is functionally independent from the Belgian Civil Aviation Authority and other interested parties.

For this investigation, the AAIU(Be) got the support of NTSB (USA).

SYMBOLS AND ABBREVIATIONS

’	Minute
‘’	Second
°C	Degrees centigrade
AAIU(Be)	Air Accident Investigation Unit (Belgium)
AccRep	Accredited Representative of a State Investigation Unit
AGL	Above Ground Leve
AMC	Acceptable Means of Compliance
AMSL	Above Mean Sea Level
APR	Approach
ATC	Air Traffic Control
ATO	Approved Training Organization
ATSB	Australian Transport Safety Board
BCAA	Belgian Civil Aviation Authority
BLU	Code Blue
CAMO	Continuing Airworthiness Management Organization
CAVOK	Ceiling and Visibility OK
CofA	Certificate of Airworthiness
CW	Clockwise
CCW	Counterclockwise
CG	Centre of Gravity
DTO	Declared Training Organization
E	East
EASA	European Union Aviation Safety Agency
EMG	Emergency Descent
EU	European Union
ELP	English Language Proficiency
ELT	Emergency Locator Transmitter
EOL	Engine Off Landings
FCL	Flight Crew Licensing
FAA	Federal Aviation Administration (USA)
FE(H)	Flight examiner helicopter
FH	Flight hour(s)
FI(H)	Flight instructor helicopter
FIC	Flight information center
FIR	Flight information region
ft	Foot (Feet)
Gal	US gallon (+/- 3,8 liters)
GPS	Global Positioning System
Hz	Hertz
ICAO	International Civil Aviation Organization
i.a.w.	in accordance with
kt	Knot(s)
lbs	Pounds
LH	Left hand
LOC-I	Loss of Control In-flight
m	Meter(s)
MAG	magnetic direction
MAP	Manifold Air Pressure

METAR	Meteorological Aerodrome Routine Report
MTOW	Maximum Take-off Weight
N	North
NAA	National Aviation Authority
NTSB	National Transportation Safety Board (US)
OSD	Operational Suitability Data
PED	Portable Electronic Device
PIC	Pilot in Command
POH	Pilot Operating Handbook
PPL(H)	Private Pilot License helicopter
QNH	Pressure setting to indicate elevation above mean sea level
RH	Right hand
RHC	Robinson Helicopter Company
RM	Right Magneto
RoD	Rate of Descent
RPM	Revolutions per Minute
RRPM	Rotor RPM
RWY	Runway
SFAR	Special Federal Administration Regulation
SIB	Safety Information Bulletin
SN	Serial Number
SN	Safety Notice
TAS	True airspeed
TASE	Training Areas of Specific Emphasis
TWR	Tower
UTC	Universal Time Coordinated
VFR	Visual Flight Rules
Vne	Velocity never to exceed
Wgt	Weight
WHT	Code White

TERMINOLOGY USED IN THIS REPORT

Safety factor: an event or condition that increases safety risk. In other words, it is something that, if it occurred in the future, would increase the likelihood of an occurrence, and/or the severity of the adverse consequences associated with an occurrence.

Causal (safety) factor: any act, omission (individual), behaviour or condition (system) that produces an effect; eliminating a cause will eliminate the effect.

> **Direct causal factor:** the most obvious reason (acts or omissions, so mostly individuals) why an adverse event happens
>
> **Indirect causal factor:** A less obvious reason (acts, omissions, conditions) for an adverse event happening. The hazard has not been adequately considered via a suitable and sufficient risk assessment

Contributing (safety) factor: a condition that influences the effect by increasing its likelihood, accelerating the effect in time, affecting severity of the consequences, etc.; eliminating a contributing factor(s) won't eliminate the effect.

Other (safety) factor: a safety factor identified during an occurrence investigation which did not meet the definition of contributing safety factor but was still considered to be important to communicate in an investigation report in the interests of improved transport safety.

Safety issue: a safety factor that
(a) can reasonably be regarded as having the potential to adversely affect the safety of future operations, and
(b) is a characteristic of an organization or a system, rather than a characteristic of a specific individual, or characteristic of an operational environment at a specific point in time.

Safety action: the steps taken or proposed to be taken by a person, organization or agency on its own initiative in response to a safety issue.

Safety recommendation: A proposal by the accident investigation authority in response to a safety issue and based on information derived from the investigation, made with the intention of preventing accidents or incidents. When AAIU(Be) issues a safety recommendation to a person, organization, agency or Regulatory Authority, the person, organization, agency or Regulatory Authority concerned must provide a written response within 90 days. That response must indicate whether the recommendation is accepted, or must state any reasons for not accepting part or all of the recommendation, and must detail any proposed safety action to bring the recommendation into effect.

Safety message: An awareness which brings to attention the existence of a safety factor and the lessons learned. AAIU(Be) can distribute a safety message to a community (of pilots, instructors, examiners, ATC officers), an organization or an industry sector for it to consider a safety factor and take action where it believes it appropriate. There is no requirement for a formal response to a safety message, although AAIU(Be) will publish any response it receives.

INTRODUCTION

Classification:	Accident	**Occurrence category:**	LOC-I ARC
Level of investigation:	Standard investigation	**Type of operation:**	Non-commercial Cross country
Date and time[1]:	29 December 2019 11:36 UTC	**Phase:**	Approach (APR) Emergency descent (EMG)
Location:	(8820) Wijnendale	**Operator:**	Private
Aircraft:	Robinson R44 Raven II	**Aircraft damage:**	Destroyed
Aircraft category:	Helicopter	**Injuries:**	None

Abstract

The helicopter was approaching its final destination, a restaurant close to the castle of Wijnendale. Suddenly, the “low rotor RPM” horn activated and the pilot proceed to an emergency landing. Upon landing, the skids sunk in the ground and the helicopter tilted over its nose and crash landed on its RH side. The occupants climbed out, uninjured. The helicopter was destroyed.

AAIU(Be) was notified of the accident by Skeyes ACC at 13:25 UTC on 29 December 2019. The AAIU(Be) did not conduct an on-site visit. The aircraft has been moved to a helicopter maintenance organization, for a detailed examination.

Table 1 : Summary of factors

Organisational	Management – Policy/procedure – Adequacy of policy/proc – training organisation
Aircraft	Not determined
Human	Experience/Knowledge – Knowledge – Knowledge of equipment – Pilot Experience/Knowledge – Training –Initial instruct/training – Pilot Experience/Knowledge – Training –Type/qual of instruct/training – Pilot
Environmental	Physical environment – Wet/muddy terrain – Effect on outcome

[1] All time data in this report are indicated in UTC, unless otherwise specified

1 FACTUAL INFORMATION

1.1 History of flight

1.1.1 The flown route

The day before, the pilot prepared a cross-country flight with 3 passengers.

On the day of the crash, he arrived at the place of departure in Grobbendonk around 10:00 UTC with the passengers and performed a pre-flight check of the aircraft. The place of departure was a grass field on a private property in Grobbendonk. The pilot filed a flight plan because he intended to cross the Dutch border.

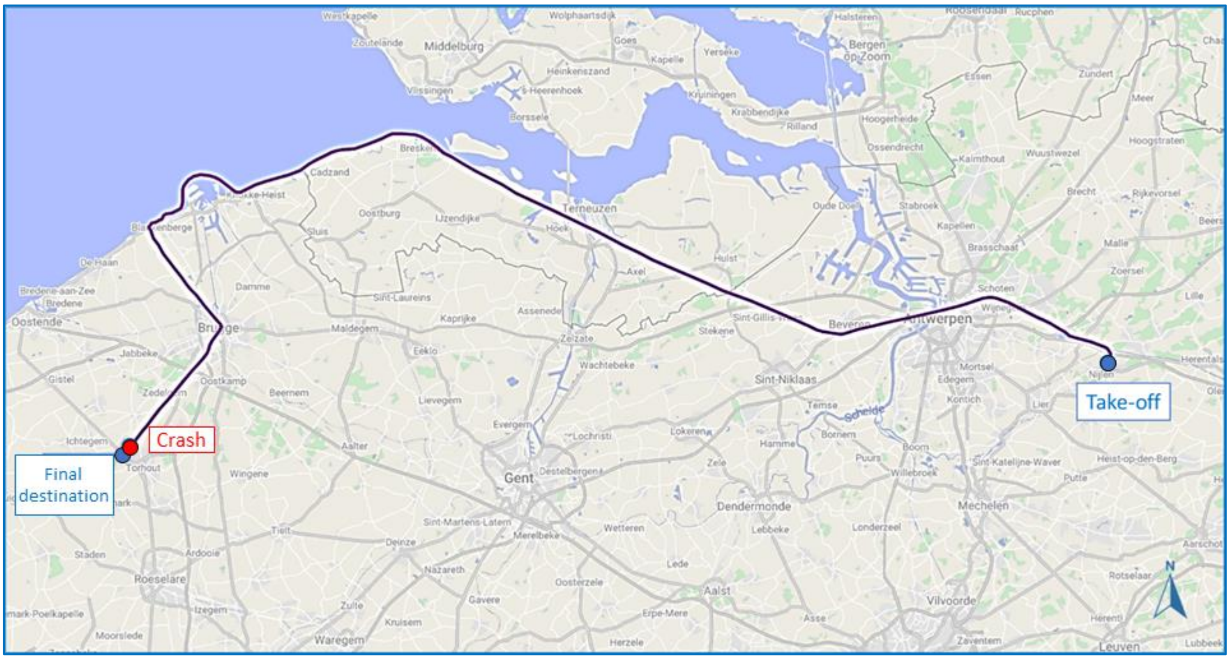

Figure 1 The flown route.

The helicopter took off at 10:36 UTC from Grobbendonk (see fig. 1).
He first flew to Antwerpen, Beveren and Sint-Gillis-Waas, and then set course to Terneuzen and crossed the Dutch border.
The helicopter continued his course to Breskens on the North-sea coast where it followed the coastline to Blankenberge. There it turned inland and set course to Brugge where it started its final leg in the direction to Torhout, before he would reach his final destination, a restaurant in the vicinity of the Wijnendale castle.

At one nautical mile from his final destination, the helicopter crash landed in a bare agricultural field in Wijnendale (see figures 2 & 3). The total flight took exact one hour.

Figure 2 The crash location

1.1.2 The final descent

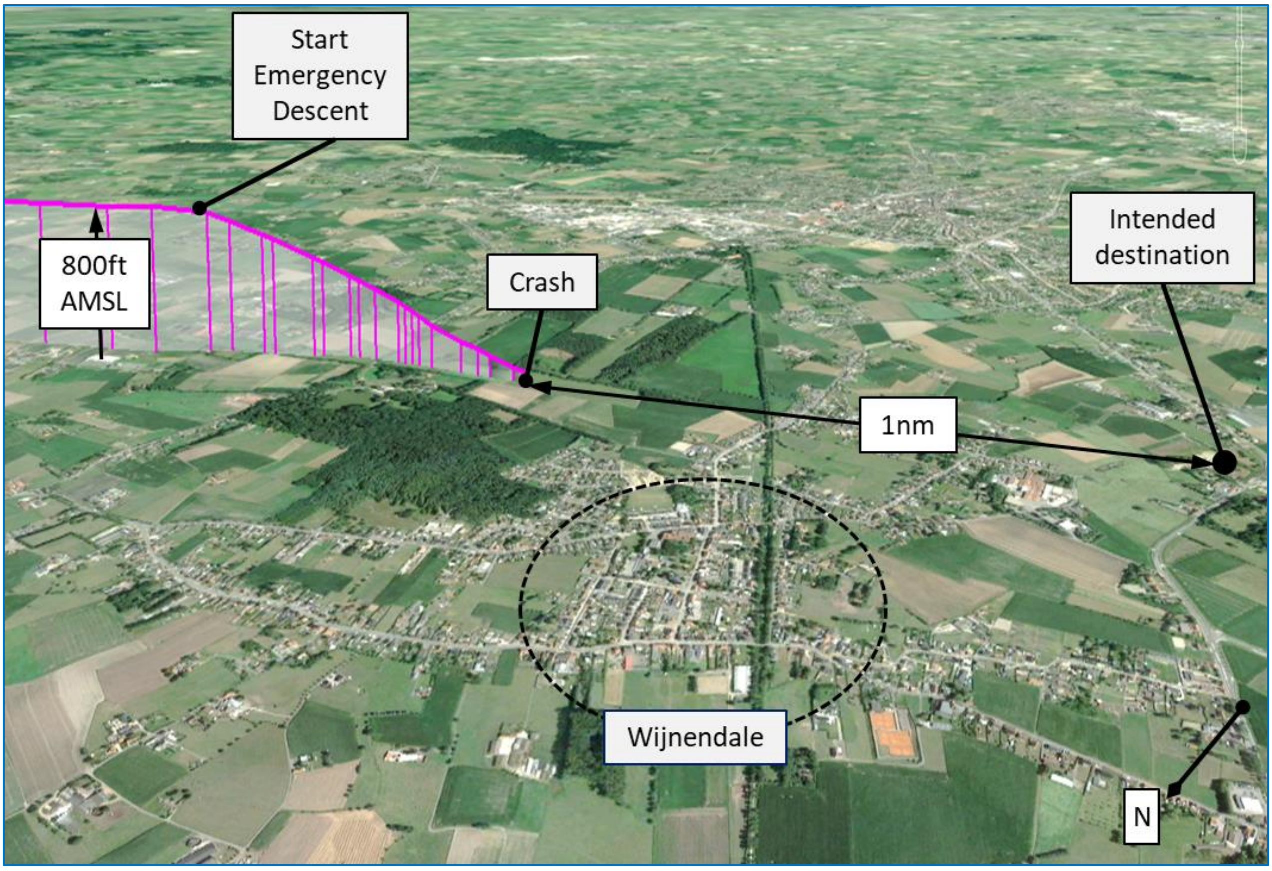

Figure 3 Detail of the emergency descent, crash location and final destination (Google Earth)

1.1.3 The pilot's report

After the accident the pilot sent a report with his witness account to the AAIU(Be).

Some relevant passages from the pilot's report:

> *"Prior to the flight, I went through the pre-start and the start-up procedure using (as always) the leaflet that is present in the front of the pilot seat. All checks were okay and I did not notice any issue in these checks before taking off."*

The following was reported about the flight:

> *"The flight was smooth. The weather was excellent and I felt no technical issues. I noticed also that relatively low power (MAP) was required during the flight."*
>
> *…*
>
> *"The last leg of the planned route was from Brugge to a restaurant close to Torhout. Distance is about 10 miles and the heading to steer was 213. When leaving Brugge behind us, the flight was still smooth. The weather was excellent and I felt no technical issues. We were then flying at an altitude of slightly under 1000ft. At about 3 miles from the final destination, I started a slight descent to start losing altitude and to reduce speed. Shortly thereafter (i.e. after slightly lowering the collective and slightly reducing speed), the low RPM horn went off."*

Then about the emergency:

> *"I immediately looked at the light panel and saw indeed the low RPM light on (no other lights were on). I then immediately lowered the collective, entered into autorotation (when entering into autorotation, I felt no left yaw) and looked at the (right) RPM tachometer to make sure that the needle was in the green.*
>
> *…*
>
> *I was relieved that the aircraft was in a stable descent and that we had a landing spot in sight and in reach. I then looked back inside. The (right) RPM tachometer was still in the green (very well in the middle). The low RPM horn will still ongoing (and continued till the very end). Then, I also looked at the (left) engine tachometer and saw the needle completely on top of the meter, ticking back and forth against the "ceiling" of the meter. Hence, the engine was still running. I thought that I maybe could recover lift force and I slightly manipulated the throttle. I heard (but badly with the headphone on) that the engine was responding to the throttle. I very slightly raised the collective again (I did not want to jeopardize my RPM balance on the right tachometer) but felt that there was only very little lift force coming in. So, I decided to abort the attempt to recover lift power and to focus on the further descent and landing.*
>
> *…*
>
> *When I looked back outside, the corn field was close and I saw that it was very wet…I expected that a sliding landing would become difficult.*
>
> *…*
>
> *So, I had no other choice then to continue the final descent to the corn field.*
>
> *…*
>
> *I tried to reduce speed as good as possible and I think we had little speed left at a height of about 3-5 meters. We had a little bit of right yaw just before touching the ground and I pushed my left pedal but there was no reaction.*
>
> *…*

The aircraft touched down on both skids. It was a firm impact but not as hard as I anticipated. However, as expected, at impact, the aircraft only did a very short slide due to the fact that it immediately sunk into the mud. Due to remaining horizontal speed, the abrupt stop in the mud resulted in the aircraft pitching forward (nose down and tail up) into the mud quite significantly and then the helicopter fell to the right side."

In an interview, the pilot further stated that:

It was the first time that he went to this landing site. In preparation a 'digital reconnaissance' of the site was made. Because there was a power line in the flight path, a shallow approach to the landing site was planned.

As for the throttle, the action was to turn the twist grip towards him, reduce the engine power and then turn the throttle back to its original position. The pilot heard the engine regime change. The throttle was not turned on for more power.

About the emergency descent, it was stated that the last phase of the autorotation was at a 3-meter high with a remaining forward speed of around 20 km/h and a steep final descent before touch down.

The clutch light was not seen 'turning on' during the flight. However, the investigation was unable to determine which Manifold Air Pressure (MAP) was indicated during the descent and whether the 'governor off' light was 'on'.

The touchdown was horizontal and flat with the skid, with a very slight nose down due to the residual forward speed. Then the helicopter stopped directly in the muddy ground with a forward motion (forward - right turning tendency at the front of the skid bogged down into the mud). The helicopter stopped the forward pivoting motion with the RH side cockpit lower nose bogged down into the mud.

1.2 Injuries to persons

Table 2: List of injuries

Injuries	Crew	Passenger	Others	Total
Fatal	0	0	0	0
Serious	0	0	0	0
Minor	0	0	0	0
None	1	3	0	4
Total	1	3	0	4

1.3 Damage to aircraft

The aircraft was destroyed.

1.4 Other damage

Some minor damage to the accident site, caused by the impact of the skids and main rotor, was found.

1.5 Personnel information

1.5.1 General pilot data

Table 3 : General pilot data

Nationality	Belgian citizen	Age	50 years
License	PPL (H) licence, first issued by BCAA on 17 January 2019		
Ratings	Robinson R44, valid until 31 January 2020		
Checks	Last check was the skill test PPL(H) performed on 4 January 2019		
Medical certificate	Class 2 certificate valid until 15 November 2020		

1.5.2 Flying experience of the pilot

Table 4 : Flying experience pilot

Aircraft:	Robinson R44
Total time:	Total Flight time: 134 Flight Hours (FH), of which 52 FH as Pilot In Command (PIC)
Total Past 90 Days:	December 2019: 2 flights – 1:42 FH November 2019: 3 flights – 4:00 FH October 2019: 4 flights – 3:12 FH September 2019: 3 flights – 2:54 FH
Total on Type Past 90 Days:	8:54 FH
Total on Type:	The R44 is the only type of helicopter flown by the pilot.

Before the accident, the pilot had already carried out several flights with passengers on board his helicopter.

1.5.3 The training organisation

The pilot completed his PPL(H) theoretical and flight training in a Belgian flight training organisation.
In 2013, the organisation was initially registered at the Belgian CAA in accordance with national regulations and was therefore approved to organize the PPL(H) and R44 training courses in compliance with JAR-FCL 2 requirements.
From 25 March 2019, the training organisation was registered as a Declared Training Organisation (DTO) with the BCAA. With its registration the organisation declared that all training was in compliance with the European Part-FCL regulations (EU) 1178/2011 and was therefore approved to organize the PPL(H) course on the Robinson R44.

The training organisation kept a training record of the pilot and contained amongst other documents:

- an overview of all the flight exercises that were performed.
- a flight report for each instruction flight. The report describes all the exercises that were covered in flight, the recorded flight time, the instructor's comments, a pre-flight briefing, a post-flight debriefing and the student’s comments.

1.5.4 The pilot's PPL(H) training

From the pilot's training record, the investigation determined:

- The pilot started his PPL(H) training on 1 November 2017.
- The training consisted of theoretical knowledge and flight training.
- After completing the theoretical knowledge training, the pilot passed his PPL(H) theoretical knowledge exam at the BCAA on 12 November 2018 and his PPL(H) skill test on 4 January 2019 with a Belgian flight examiner.
- The Robinson R44 was used for both the flight training and PPL(H) skill test.

Before applying for a PPL(H) license, the pilot gained a total 80:56 hours of flight training of which 70:42 FH of dual instruction, 10:14 FH of supervised solo, 06:12 FH of solo cross country and a long solo navigation flight on 15 December 2018.

The flight training program consisted of 27 flight exercises in accordance with the JAR-FCL training syllabus, in which the recognition and recovery from a low rotor RPM is not included as standard.

The pilot received training to recover different emergencies such as a governor failure, a tachometer failure and a power failure. During many flights, he also received training to perform Engine Off Landings (EOL) in autorotation. The pilot stated that he was instructed *"to land in autorotation when in doubt about the emergency*".

The training record shows that the pilot was trained to recover a Low Rotor RPM emergency. In some debriefing reports, the instructor instructed the pilot "*to perform an autorotation landing when the rotor RPM dropped below 97%"*. The pilot also was instructed *"to only lower the collective to increase the rotor RPM again"*.

Although no written evidence was found in the training record, the pilot stated that during instruction flight, the instructor commented that usually*, "he gripped the throttle of the collective too tightly and thus overriding the governor. He had to loosen his grip to enable the governor to control the RPM of the engine and the rotor".*

No evidence was found of an awareness training (in accordance with operational Suitability Data (OSD-FC R44) on the topics: Low-G hazards (loss of control, mast bumping) and rotor RPM decay (energy management, blade stall).

1.5.5 The flight instructors

The pilot received flight instruction for the PPL(H) from two flight instructors. Both instructors are experienced helicopter pilots on different types of helicopters including the Robinson R44. They also have extensive experience in teaching student pilots to obtain the PPL(H) license.

However, no clear evidence was found whether both instructors have completed theoretical knowledge training with the 'awareness training' and flight training on low rotor RPM recognition and recovery.

1.5.6 The PPL(H) skill test

The PPL(H) skill test was performed according to a standard scenario imposed by the European Part-FCL (Flight Crew Licensing) regulations.

The scenario consisted of 5 sections:

- Section 1: Pre-flight/post-flight checks and procedures.
- Section 2: Hover manoeuvres, advanced handling and confined areas.
- Section 3: Navigation – enroute procedures.
- Section 4: Flight procedures and manoeuvres by sole reference to instruments.
- Section 5: Abnormal and emergency procedures

From section 2 the pilot was, among other things, extensively tested on his performance of:

- Autorotation,
- Autorotative landing,
- Practice forced landings with power recovery

From section 5 the pilot was tested to recover from four different emergencies chosen by the examiner:

- Fuel system malfunction,
- Electrical system malfunction,
- Hydraulic system malfunction,
- Main rotor and/or anti-torque system malfunction

The pilot was not tested to recognize and recover from low rotor RPM.

On 11 January 2019 the pilot passed the skill test PPL(H) in his second attempt.

After succeeding the skill test PPL(H), the pilot obtained from the BCAA the privileges for both PPL(H) and the helicopter type Robinson R44 on his license.

1.6 Aircraft information

1.6.1 General information about the Robinson R44

The Robinson R44 is a four-place, single main rotor, single piston-engine helicopter.
There are two R44 models; The R44 and the R44 II. The major difference between models is the use of a carburettor on the piston engine in the model R44, and a fuel injected piston engine in the model R44 II. The R44 II or Raven II has increased power and gross weight.

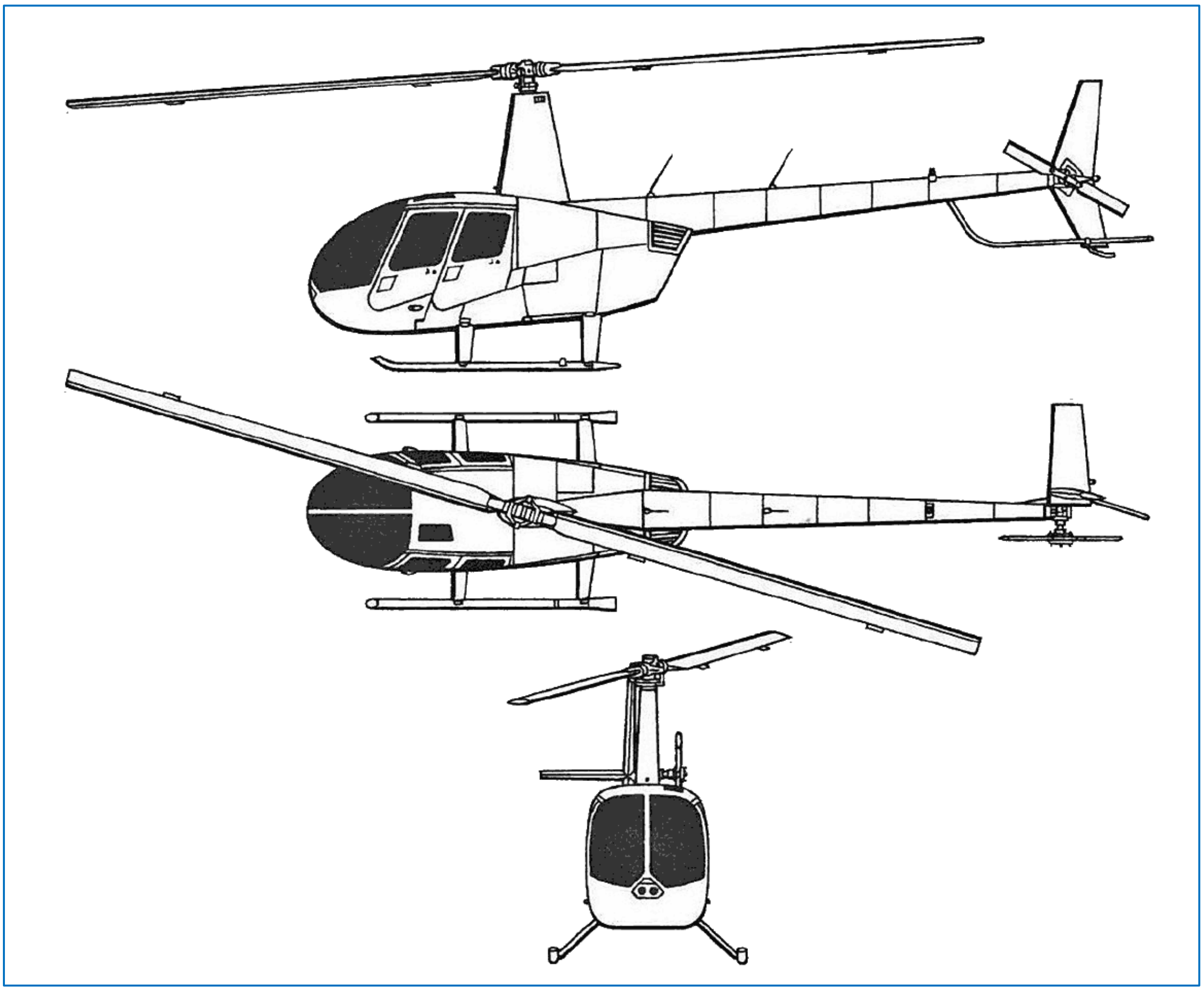

Figure 4 Three-view drawing of the R44

1.6.2 Aircraft main characteristics

Table 5 : Aircraft main characteristics

Model			R44 II (Raven II)
Dimensions	Fuselage	Overall Length	11659 mm (459 inches)
		Width	1283 mm (50,5 inches)
		Height	327 mm (129 inches)
	Main rotor	Diameter	10058 mm (396 inches)
	Tail rotor		147 mm (58 inches)
Number of Main rotor blades			2
Main rotor rotation direction			Counter-clockwise (CCW)
Minimum Flight Crew			1
Seating Capacity including pilot seat			4
Engine	Lycoming model		IO-540-AE1A5
	Max continuous power		205 BHP
	Takeoff (5-min) power		245 BHP
Fuel tanks with bladders		Main usable	112 liters (29,5 US gallons)
		Aux usable	64 liters (17,0 US gallons)
		Combined usable	176 liters (46,5 US gallons)
Airspeed	Power ON	Absolute Vne	120 Knots Indicated Air Speed (KIAS)
	Power OFF		100 KIAS
	Recommended	Max Cruise	110 KIAS
		Takeoff & Climb	60 KIAS
		Max Climb Rate, Min power required	55 KIAS
		Max Range	100 KIAS*
		Significant Turbulence	60 to 70 KIAS
		Landing Approach	60 KIAS
		Autorotation	60 to 70 KIAS*
*Certain conditions may require a lower airspeed			
Rotor Speed	Power ON	Maximum	408 RPM
	Power OFF	Minimum	360 RPM
*The gear reduction ratio between main and tail rotor is about 1:6			
Standard Empty Weight			663 kg (1460lb)
Maximum Gross Weight			1134 kg (2500lb)

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1.6.3 Description of relevant systems and equipment

1.6.3.1 Landing gear

The helicopter is equipped with a skid-type landing gear. A spring and yield skid type landing gear is used. Most hard landings will be absorbed elastically. However, in an extremely hard landing, the struts will hinge up and outward as the center cross tube yields to absorb the impact. Slight yielding of the aft cross tube is acceptable. However, yielding which allows the tail skid to be within 76 cm or 30 inches of the ground when the helicopter is sitting empty on level pavement requires cross tube replacement.

1.6.3.2 Drive System

A V-belt sheave is bolted directly to the engine output shaft. Four double V-belts transmit power to the upper sheave which has an overrunning clutch in its hub. The inner shaft of the clutch transmits power forward to the main rotor and aft to the tail rotor. Flexible couplings are located at the main gearbox input and at each end of the long tail rotor drive shaft.

1.6.3.3 Powerplant

The R44 II has one Lycoming model IO-540-AE1A5 six-cylinder, horizontally opposed, overhead-valve, air-cooled, fuel-injected engine with a wet sump oil system powers the helicopter. The engine is equipped with a starter, alternator, shielded ignition, two magnetos, muffler, two oil coolers, oil filter, and induction air filter.
A direct drive, squirrel cage style cooling fan mounted to the engine output shaft supplies cooling air to the cylinders and oil coolers via a fiberglass and aluminium shroud.

1.6.3.4 Flight controls

All primary controls are actuated through push-pull tubes and bellcranks.
Flight control operation is conventional. The cyclic is center mounted with the left and right control grips mounted to a cross tube which pivots on the center cyclic post.
Collective operation is conventional.

1.6.3.5 Engine throttle control and governor system

There are three ways to manipulate the engine throttle (see fig. 5):

1. The correlator: a mechanical linkage between the collective lever and the throttle. As the collective is raised, the throttle is opened and as the collective is lowered, the throttle is closed. This performs most of the throttle control in-flight. Provided the throttle is already partially open to achieve 102% RPM on the ground, full throttle can be achieved by the correlator.

2. The governor: an electronic throttle control using a controller unit and motor to fine tune the engine RPM through a friction clutch, which applies a twisting force to the pilot's throttle grip. The further away from the target speed (102 %), the faster the controller will move the throttle to return to the target, but it is very small, slow movements.

3. The pilot: in normal flight the pilot is not required to manipulate the throttle, but more aggressive manoeuvres or demanding environments may require the pilot to make manual adjustments. The governor can be overridden by the pilot gripping the throttle (twist grip located on the end of the collective lever) and turning as needed. The throttle opens when the twist grip is turned out board the pilot or clockwise (CW) when viewed looking aft.

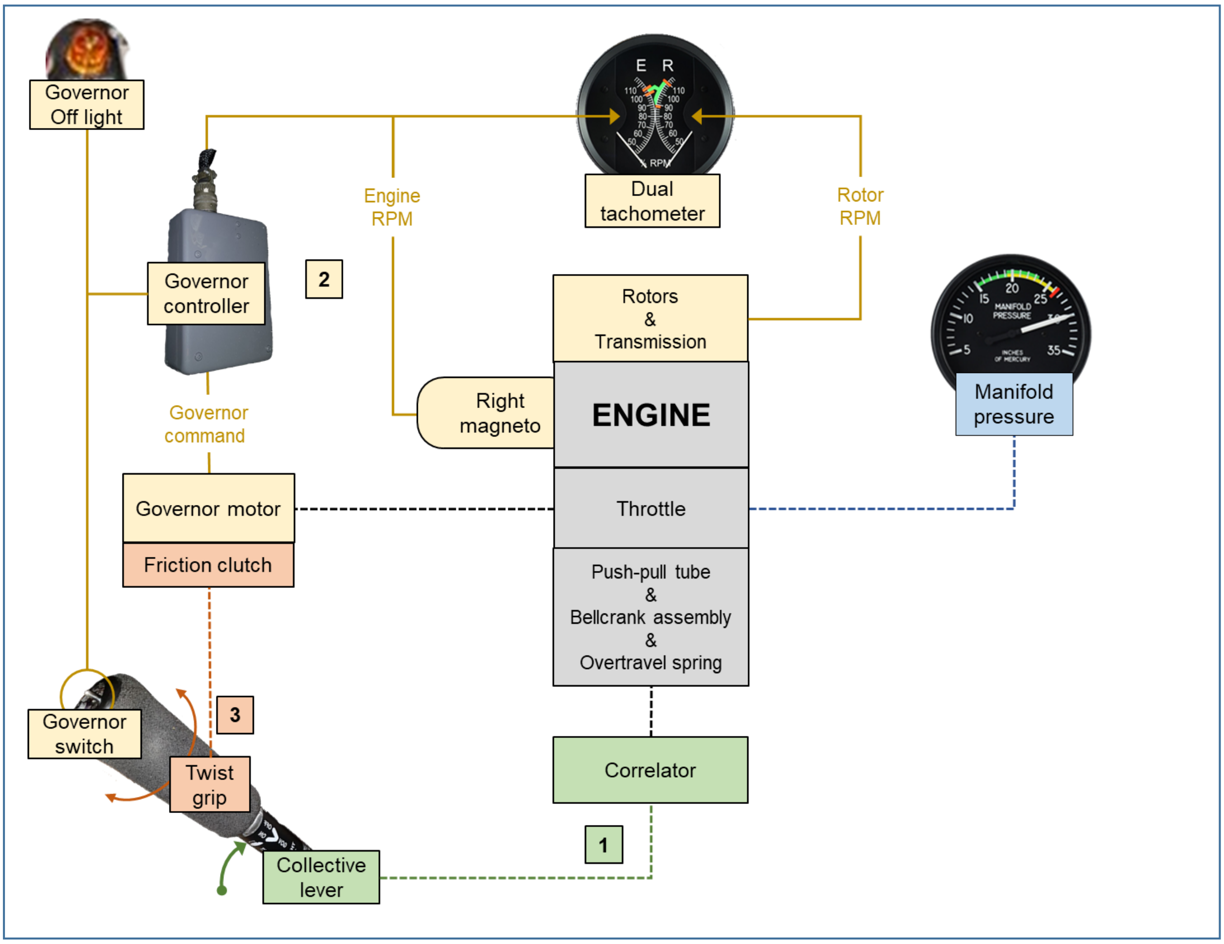


Figure 5 Schematic presentation of the engine throttle control

The MAP sensor measures air pressure downstream of the throttle, which is less than atmospheric pressure when the engine is running. The MAP will increase if the throttle is opened, or if the engine RPM decays, or combination of the two.

A second set of points in the engine right magneto (RM) senses engine RPM, which is sent to the governor controller unit. The unit provides the correction signal to the engine throttle via the governor motor, friction clutch and pilot's twist grip on the collective lever. This provides a closed-loop system to maintain RPM. The governor is active from 80% to112% engine RPM.

The governor switch is located at the end of the right seat collective lever.
When the switch is closed (position 'on'), the "governor off' light will extinguish to indicate the governor controller unit is receiving electrical power.

Both the engine tachometer and the governor controller unit receive a signal from the right magneto (RM). If the electrical wiring is damaged or there is a problem with the magneto tachometer contact points (such as contamination, oxidation or loose contacts), the tachometer will indicate irregular engine RPM and the governor controller unit will also operate erratically. However, such an erratic signal will not activate the "governor off" light.

1.6.3.6 The Low Rotor RPM warning system

The system consists of the following components (see fig. 6):

- Low rotor RPM warning light (amber) and horn. They are both electrical connected with each other. They are located respectively on and behind the front console.
- Collective switch. The switch disconnects the Low RPM warning light and horn from the warning unit when the collective is in the full down position. The switch is located below the aft support assembly of the collective lever.
- Low rotor RPM warning unit with starter lockout. The unit activates the warning light and horn when the Rotor RPM is at 97% or below. The Low RPM horn is silenced when the collective is fully down, and a lockout feature incorporated into the warning unit prevents starter activation while the clutch switch is in the engaged position, unless the rotor RPM is above 69%. This prevents damage to the drive system during start up and allows restarts during flight.
- Low RPM sender and Tach sender. Both sensors sense the rotor RPM but are working independently from each other. The Low RPM sender is connected to the low rotor RPM warning unit and the Tach sender is connected to the rotor tachometer (dual tachometer). These two magnetic senders are located at the main gearbox drive yoke. Each sender is on a separate circuit with its own circuit breaker. Hall effect sender-to-yoke magnets are located on the main gearbox drive yoke next to the rotor brake assembly.
- Engine right magneto. A second or separate set of points in this magneto provides the engine speed signal to the engine tachometer (dual tachometer) and the governor controller unit. The magneto is located at the left side of the helicopter.
- Engine and rotor dual tachometer. (See chapter Dual tachometer)
- Circuit breaker: The breaker disactivates the system and is located on the circuit breaker panel below the left front seat.

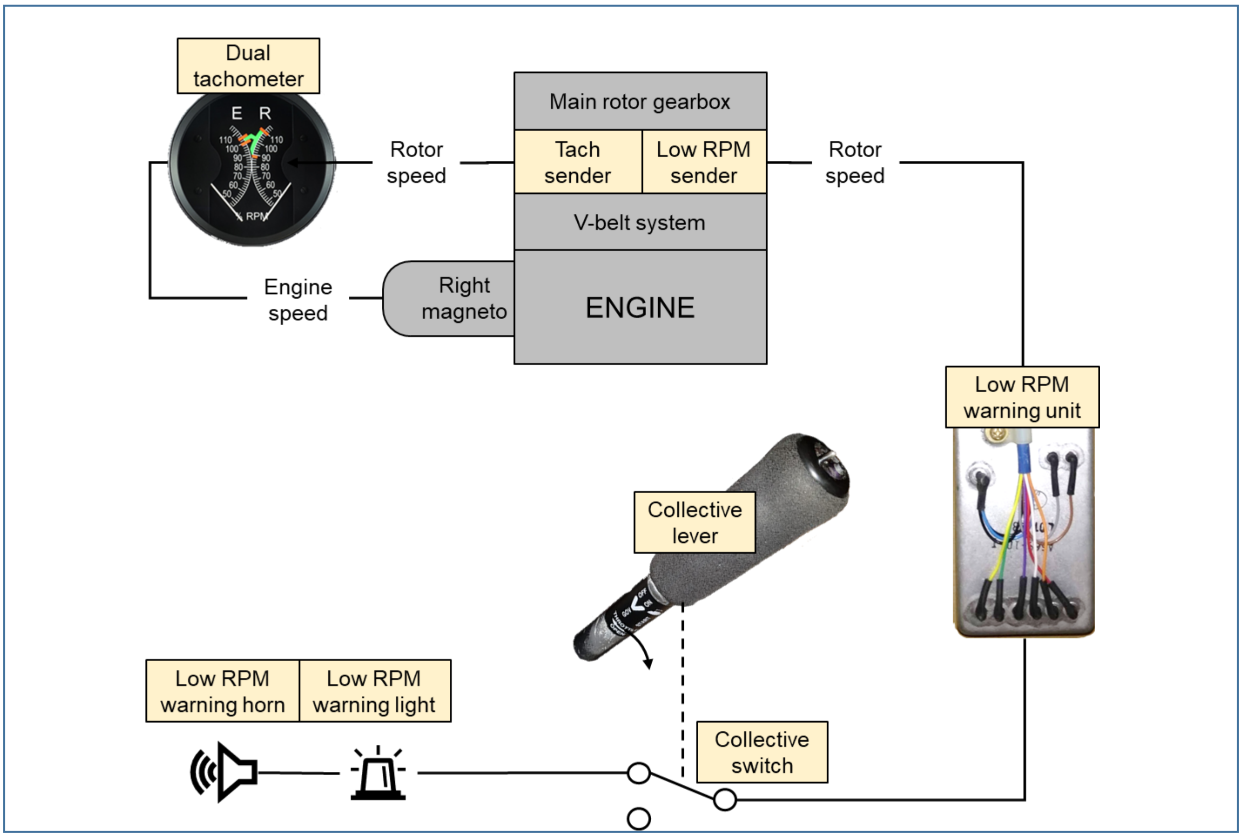


Figure 6 Schematic presentation of the Low RPM warning system

1.6.3.7 Instrument panel (see fig. 7)

Standard primary instrument includes an airspeed indicator, engine and rotor dual tachometer, altimeter, manifold pressure gage, and magnetic compass.

1.6.3.8 Dual tachometer

An electronic engine and rotor dual tachometer are standard. Engine tachometer signal is provided by a second set of breaker points in the engine RH magneto Rotor tachometer signal is provided by a magnetic sender at the main gearbox drive yoke.

1.6.3.9 Warning and caution lights

Warning and caution lights include clutch, main gearbox over-temperature, main and tail gearbox chip, engine fire, starter on ,low fuel, fuel filter, auxiliary fuel pump, low RPM, alternator, low oil pressure, rotor brake, carbon monoxide, governor off, and full throttle.
The clutch light indicates that the clutch actuator is operating. The low RPM light and horn indicate rotor RPM at 97% or below. The governor-off light indicates the RPM governor is switched off.

Figure 7 Cockpit panel of the accident helicopter with the relevant warning lights and instruments

1.6.3.10 Clutch actuator

After starting up, the engine is coupled to the rotor drive system through V-belts which are tensioned by raising the upper sheave. An electric actuator, located between the drive sheaves, raises the upper sheave when the pilot engages the clutch switch. The actuator senses compressive load (belt tension) and disactivate when the V-belts are properly tensioned and will automatically activate and re-tension as required during flight. The clutch caution light illuminates whenever the actuator circuit is energized, either engaging, disengaging, or re-tensioning the belts. The light stays on until the belts are properly tensioned or completely disengaged.

1.6.3.11 Seats and belts

The helicopter has 4 seats. Each seat is equipped with a combined lap belt and inertia reel shoulder strap and attached to 3 fixed points. The inertia reel is normally free but will lock if there is sudden movement as would occur in an accident.

1.6.4 Specific information about the accident helicopter

The accident helicopter was a Belgian registered Robinson 44 Raven II, manufactured in 2005 by the Robinson Helicopter Company (RHC).
At the time of the accident, the helicopter had flown a total of 2726,7 FH and had a valid Certificate of Airworthiness (CofA).

1.6.4.1 Helicopter maintenance information

A 100FH inspection was performed by a recognized maintenance organization, on 25 October 2019, about two months before the accident.
The inspection consisted of, among other things, a start and run-up of the helicopter. The governor and the low rotor RPM warning system were tested for operation within specified tolerances.
No anomaly was found during this inspection or previous inspections.

1.6.5 Operating the R44

1.6.5.1 The Pilot Operating Handbook (POH)

The following relevant information was found in the POH:

- A procedure to test the governor system and low rotor RPM warning system during the start and runup of the helicopter.
- The limitations of the rotor tachometer

ROBINSON
MODEL R44 II

SECTION 2
LIMITATIONS

INSTRUMENT MARKINGS

ROTOR TACHOMETER

Lower red line	90%
Green arc	90 to 108%
Upper red line	108%

- The procedure to recognize and respond to a power failure

> **ROBINSON** **SECTION 3**
> **MODEL R44 II** **EMERGENCY PROCEDURES**
>
> **POWER FAILURE – GENERAL**
>
> A power failure may be caused by either an engine or drive system failure and will usually be indicated by the low RPM horn. An engine failure may be indicated by a change in noise level, nose left yaw, an oil pressure light, or decreasing engine RPM. A drive system failure may be indicated by an unusual noise or vibration, nose right or left yaw, or decreasing rotor RPM while engine RPM is increasing.
>
> In case of power failure, immediately lower collective to enter autorotation and reduce airspeed to power-off V_{ne} or below.

- The procedure to respond on Low RPM horn & caution light

> **ROBINSON** **SECTION 3**
> **MODEL R44 II** **EMERGENCY PROCEDURES**
>
> **LOW RPM HORN & CAUTION LIGHT**
>
> A horn and an illuminated caution light indicate that rotor RPM may be below safe limits. To restore RPM, immediately roll throttle on, lower collective and, in forward flight, apply aft cyclic. The horn and caution light are disabled when collective is full down.

1.6.5.2 RHC Safety Notices

RHC has published several Safety Notices (SN) to raise awareness about a low rotor RPM:

- SN-10 Fatal accidents caused by low rotor RPM stall

> …
>
> *"No matter what causes the low rotor RPM, the pilot must first roll on throttle and lower the collective simultaneously to recover RPM **before** investigating the problem. It must be a conditioned reflex. In forward flight, applying aft cyclic to bleed off airspeed will also help recover lost RPM."*

The Safety Notice SN-10 is included in appendix of this report (see appendix 5.1).

- SN-24 Low RPM rotor stall can be fatal.

The Safety Notice SN-24 is included in appendix of this report (see appendix 5.2).

1.6.5.3 <u>R44 manoeuvre guide</u>

The guide describes all the flight exercises for the Robinson R44 training and includes the exercise Recognition and recovery from low rotor RPM.

An extract of the guide is included in appendix of this report (see appendix 5.3).

1.6.6 <u>Weight and balance:</u>

Before the flight, the pilot calculated the weight & balance (see fig. 8).

The calculation indicates that both on takeoff and on landing, the weight of the helicopter (Takeoff Wgt. ⊗ = 1130,8 kg, Landing Wgt. ⊗ = 1090,0kg) was within limits (Maximum Gross Weight = 1134 kg).

The longitudinal and lateral Center of Gravity (CG) of the helicopter also remained within limits during the flight. The lateral CG was slightly to the right of the helicopter's centerline.

	Longitudinal			Lateral	
	Weight kg	Arm inches	Moment kg.inches	Arm inches	Moment kg.inches
BEW	709.42	106.53	75574.5	-0.2	151
		CG LONG		CG LAT	
Pilot Seat	85	49.5	4207.5	12.2	1037
Seat 2	62	49.5	3069.0	-10.4	-644.8
Seat 3	50	79.5	3975.0	-12.2	-610.0
Seat 4	117	79.5	9301.5	12.2	1427.4
Baggage Pilot Seat	1	44.0	44.0	11.5	11.5
Baggage Seat 2	0	44.0	0.0	-11.5	-0.0
Baggage Seat 3	0	79.5	0.0	-12.2	-0.0
Baggage Seat 4	0	79.5	0.0	12.2	0.0
My Item #1	0	0	0.0	0	0.0
My Item #2	0	0	0.0	0	0.0
Doors Front	0.00	49.4	0	0	0
Doors Aft	0.00	75.4	0	0	0
Controls	-0.99	33.0	-32.7	-13.3	13.2
		CG LONG		CG LAT	
Zero Fuel Wgt.	1023	93.94	96138.8	1.35	1385.3
Fuel Main	69.4	106.0	7356.4	-13.5	-936.9
Fuel Aux	38.0	102.0	3876.0	13.0	494.0
		CG LONG		CG LAT	
Takeoff Wgt.	1130.8	94.95	107371.2	0.83	942.4
		CG LONG		CG LAT	
Landing Wgt.	1090.0	94.60	103116.4	0.94	1028.5

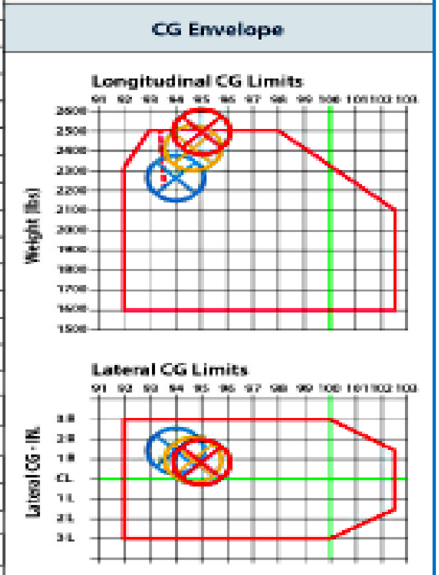


Figure 8 Weight & Balance calculation provided by the pilot

1.7 Meteorological conditions

The different METAR (actual weather report) at various locations from the accident site published shortly before the accident:

- Kortrijk Airport (28 km to the South) at 11:26 UTC

SPECIAL EBKT 291126Z WIND RWY 24 180/5KT MAX12 MNM3 VRB BTN 150/ AND 240/ VIS CAVOK T 04 DP // QNH 1036.6HPA MET QFE 1034.2HPA
Wind: 180 degrees 5kt variable between 150 and 240 degrees
CAVOK = Ceiling And Visibility OK and corresponds with a visibility of more than 10km and cloud base of more than 5000ft
Temperature 4°C
QNH 1036,6 hPa

- Ostend Airport (21km to the Northwest) at 11:20 UTC

EBOS 291120Z 17009KT CAVOK 03/01 Q1035 NOSIG=
Wind: 170 degrees 9kt
CAVOK
Temperature 3°C / dew point 1°C
QNH 1035 hPa
NOSIG = no significant change expected in the next 2 hours

- Koksijde Airport (30 km to the West) at 11:25 UTC

EBFN 291125Z AUTO 19006KT 6000 BKN140//// 04/01 Q1035 WHT=
Wind: 190 degrees 6kt
Code WHT = White; Is a military color code to indicate the amount and height of clouds and visibility. White corresponds with the lowest cloud base at 1500ft and a visibility of minimum 5km.
Temperature 4°C / dew point 1°C
QNH 1035 hPa

- Semmerzake radar station (42 km to the East) at 11:25 UTC

EBSZ 291125Z AUTO 19006KT 9999 SCT140/// BKN170/// 04/M02 Q1036 BLU=
Wind: 190 degrees 6kt
Code BLU = Blue and corresponds with the lowest cloud base at 2500ft and a visibility of minimum 8km.
Temperature 4°C / dewpoint -2°C
QNH 1036 hPa

1.8 Aids to navigation

The helicopter is equipped with a GPS type Garmin GNS530, but this device does not feature a memory that logs the flight data.

The pilot used a portable electronic device (PED) with a flight navigation software, to support his navigation during the cross-country flight. He used the same software to file a flight plan and to prepare his weight & balance calculation.

1.9 Communication

From the radar images and communication with ATC, the following information was retrieved.

The helicopter took-off in Grobbendonk which is located in the Antwerp CTR.
At 10:37:34, the pilot made contact with Antwerp Tower on frequency 135,205 and set his transponder code to 2000.

After leaving the Antwerp CTR in the North-East, the helicopter proceeded to the Dutch border and changed his transponder code to 7000. While flying in uncontrolled airspace class G, the pilot did not made contact with the Brussels FIC. The helicopter left the Belgian FIR at 10:54:35 UTC.

The helicopter re-entered the Belgian FIR at 11:12:45 and was heading along the coastline to Blankenberge. The pilot made contact with the Brussels FIC on frequency 126,900.

At 11:35:52 the helicopter flew at approximately 800 ft AMSL (QNH) and started to descent.
The helicopter disappeared from the radar display at 11:36:55.
No emergency call was sent.

1.10 Aerodrome information

The pilot intention was to land on the grass field near a restaurant in Torhout, his final destination. It's not a recognized heliport but the field was in the past, with the owner's permission, more than once used for the take-off and landings of helicopters.

Because the conditions of this unofficial landing site are difficult to determine in advance, an airborne reconnaissance is necessary to assess the suitability of the site for the individual pilot/aircraft capability, the given wind velocity at the time of arrival, the best approach/departure path and local hazards.

Not being familiar with the landing area, the pilot stated he made a 'digital' reconnaissance of the landing site and surroundings to prepare his flight. Because there was an electrical power line in the approach path near the landing site, the pilot intended to perform a straight and shallow approach.

1.11 Flight recorders

Although the helicopter was not equipped with a flight recorder nor it was required, the pilot had a PED (portable electronic device) with a flight navigation software and recorded the ground speed, altitude and coordinates of the helicopter with a varying sample rate.

Since the wind mainly came from the South (about 190° with a speed of 6kt), the true airspeed (TAS) of the helicopter would be slightly higher.

The following flight data has been retrieved from the final descent (see fig. 9):

- The helicopter began to descent at 11:36:02 or 54 seconds before the crashlanding.
- The descent started from a height of 670ft (AGL) or 800ft (AMSL).
- Initially ground speed was 72kt, but then gradually decreased as the helicopter descended. At 32 seconds before the emergency landing the speed dropped to below 55kt. This was at an altitude of about 300ft AGL.

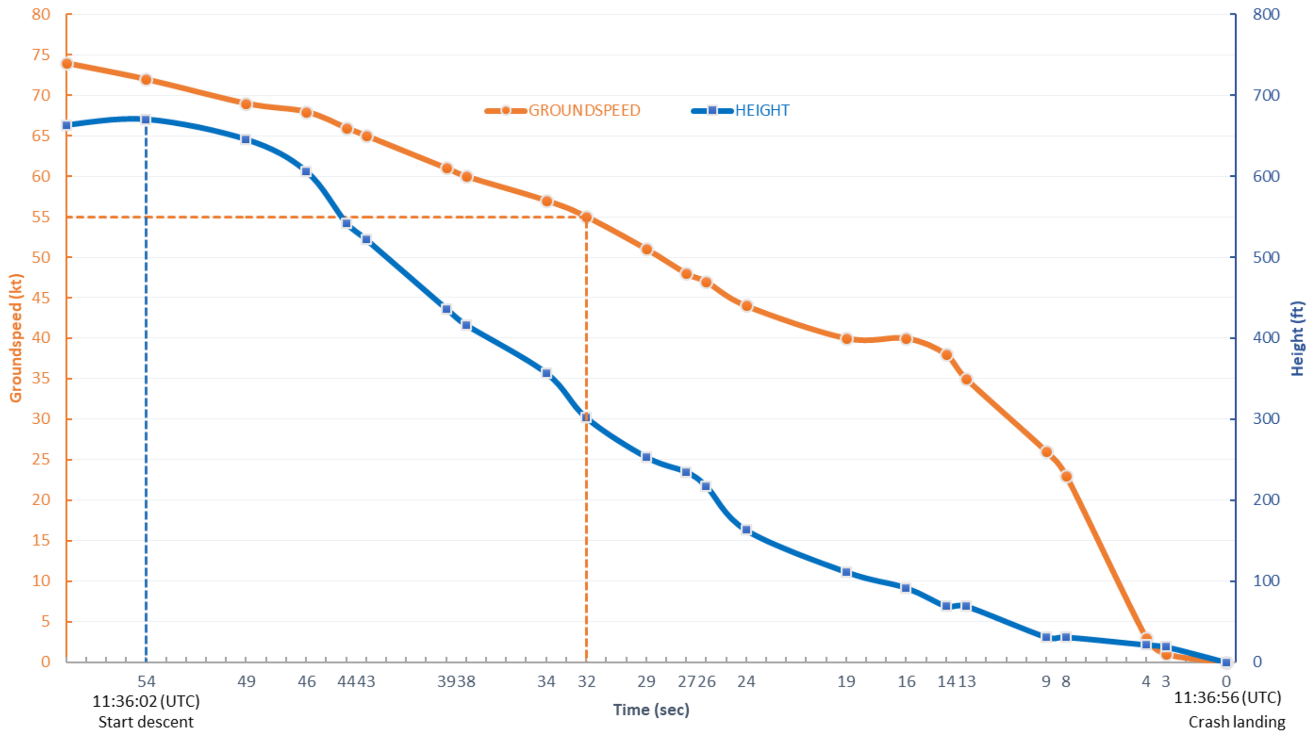


Figure 9 Height (ft) and groundspeed (kt) during the final descent

The Rate of Descend (RoD) and track were both derived from the flight data:

- The RoD was initially limited but increased to over 1000ft/min after 8 seconds. At about 100ft AGL, the RoD decreased again.
- On the last leg, the helicopter's track was approximately 205°.
  During final descent, the helicopter turned to the right and changed track to 235° in a straight line to its intended destination in Wijnendale.

1.12 Wreckage and impact information

The AAIU(Be) did not perform an on-site investigation of the crash.
The information about the position of the wreckage, ground marks and damage to the aircraft were derived from the pilot's witness account, pictures taken and recorded flight data.

1.12.1 The location of the wreckage and ground marks

The helicopter wreckage was located in a muddy chopped corn field.
The coordinates of the accident site are 51°5,428'N / 3°4,991'E, the elevation of the terrain is 133 ft or 36 m AMSL. The helicopter lay on its right side. Its nose was orientated to 263°.

The RH skid was buried in the clay ground.
Ground marks of the helicopter skids hitting and sinking in the ground were found at the LH side of the wreckage (see fig. 10). The marks were behind but in the same direction of the nose of the wreckage The marks were about 10 cm deep and 3 m long. The RH skid ground mark was longer than the LH skid ground mark.

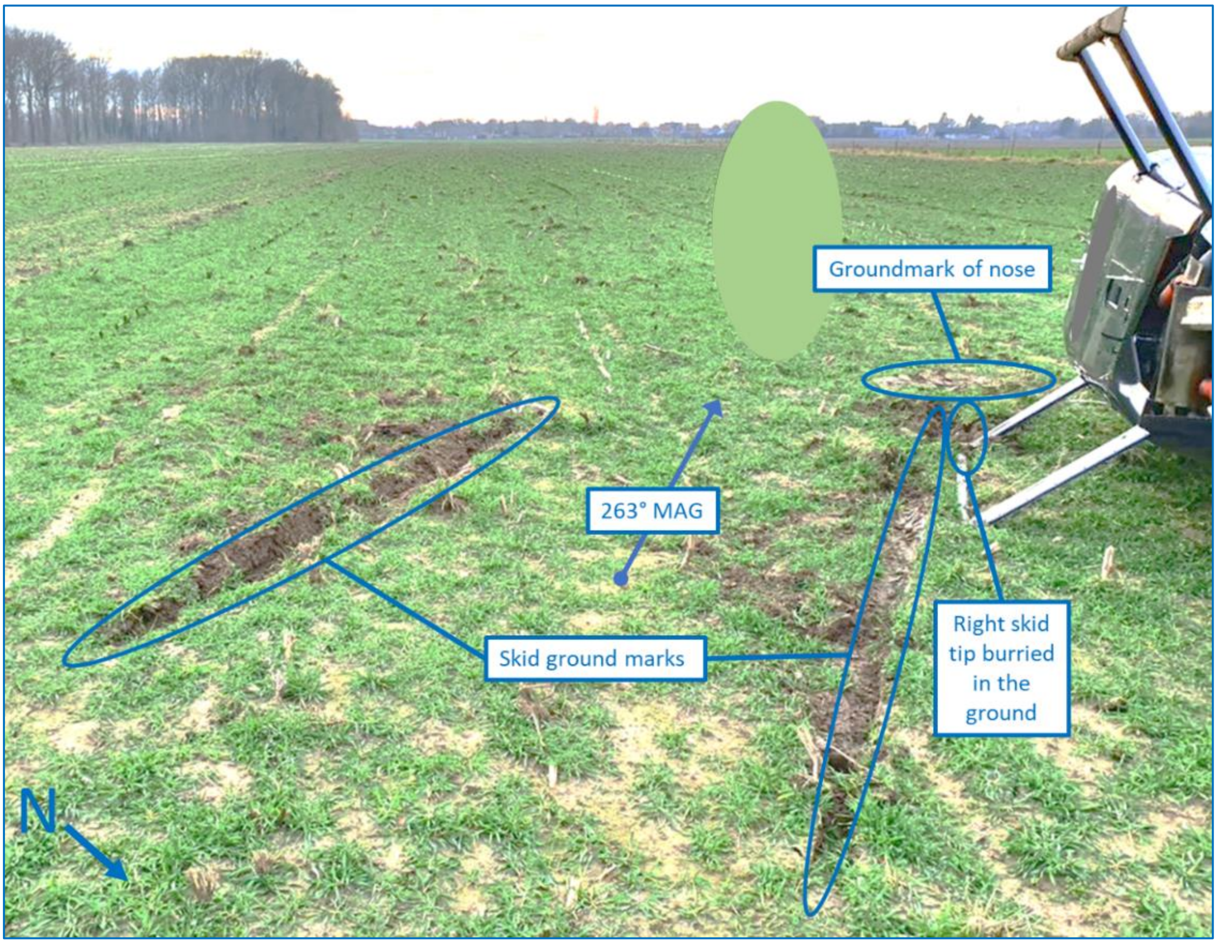


Figure 10 Direction of the helicopter and ground marks of skids and nose

Both main rotor blades were broken and showed traces of mud. One rotor blade tip was still buried in the clay ground. At several locations in front and at RH side of the wreckage, different ground marks were found of the main rotor hitting ground.

Several groundmarks of the helicopter's nose were also found showing that the helicopter continued to yaw to the right, pivoting on his RH skid as it tilted forward (see fig. 11).

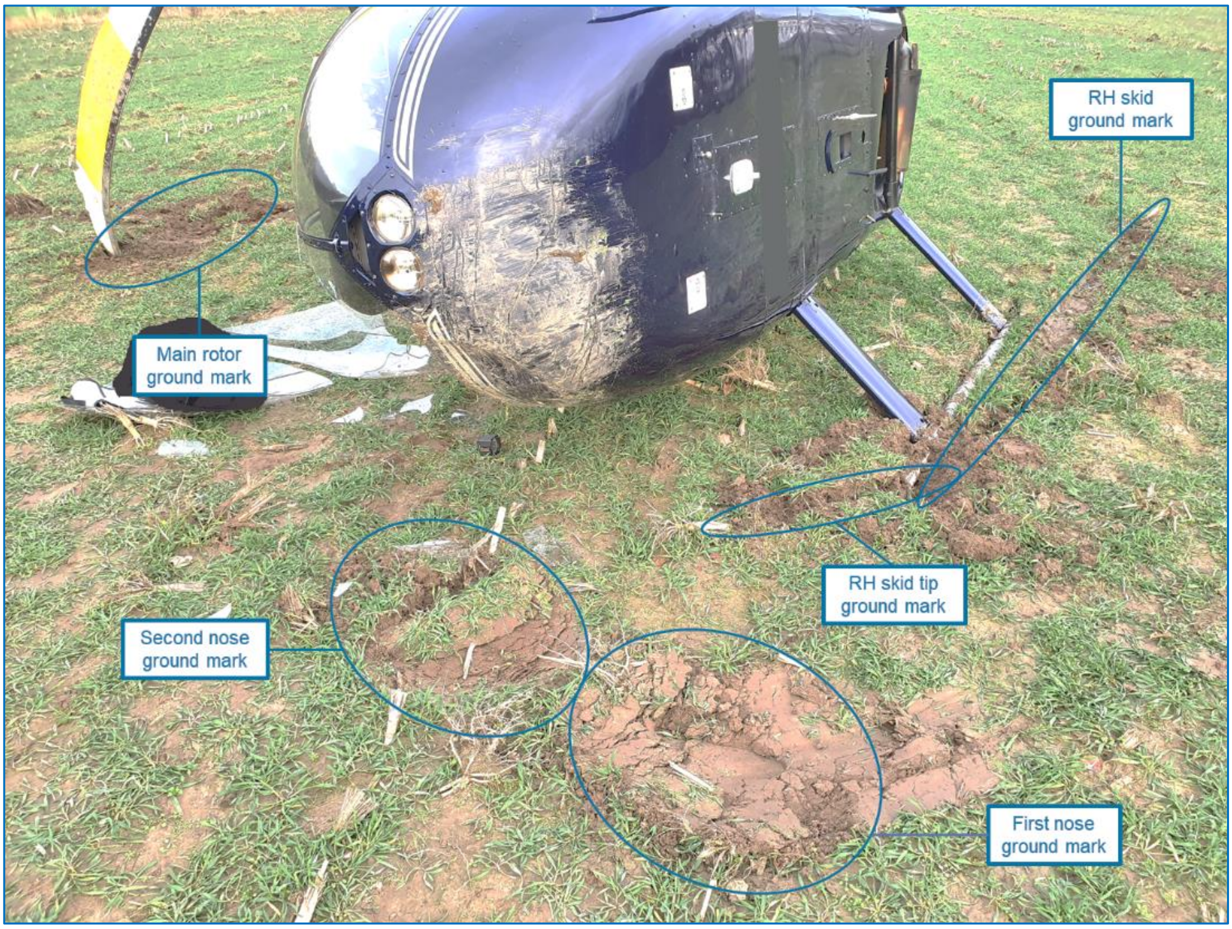


Figure 11 Detail of the nose and RH skid tip ground marks

1.12.2 Damage found on the accident site

The helicopter was still in one piece. The following damages could be observed (see fig. 12):

1. The aft end of tail boom before the tail rotor showed signs of interaction with the main rotor blade tips (yellow paint) and was sheared near its attachment point with the red-white tail rotor guard.
   One tail rotor blade was bent in the direction of thrust and showed interaction with the main rotor blade tips.
   The tail rotor skid was bent and was muddy.
   The lower vertical stabilizer was damaged by compression.
   The red-white tail rotor guard which has 2 attachment points (tail rotor assembly and tail boom) was bent but did not show any (impact) sign of mud.

2. The tail rotor boom showed damage from upwards bending at its connection to the fuselage;

3. The main rotor mast was deformed towards the rear.

4. The nose of the helicopter showed presence of mud up to the windshield. The mud trace is more present on the RH side;
   The right windshield was broken when the pilot and two passengers climbed out of the wreckage.

5. The main rotor blades were damaged but still in one piece.
   Traces of mud at both the blade tips shows interaction with the ground.

   The skids showed low or no deformation. The RH skid is muddier than the LH one.

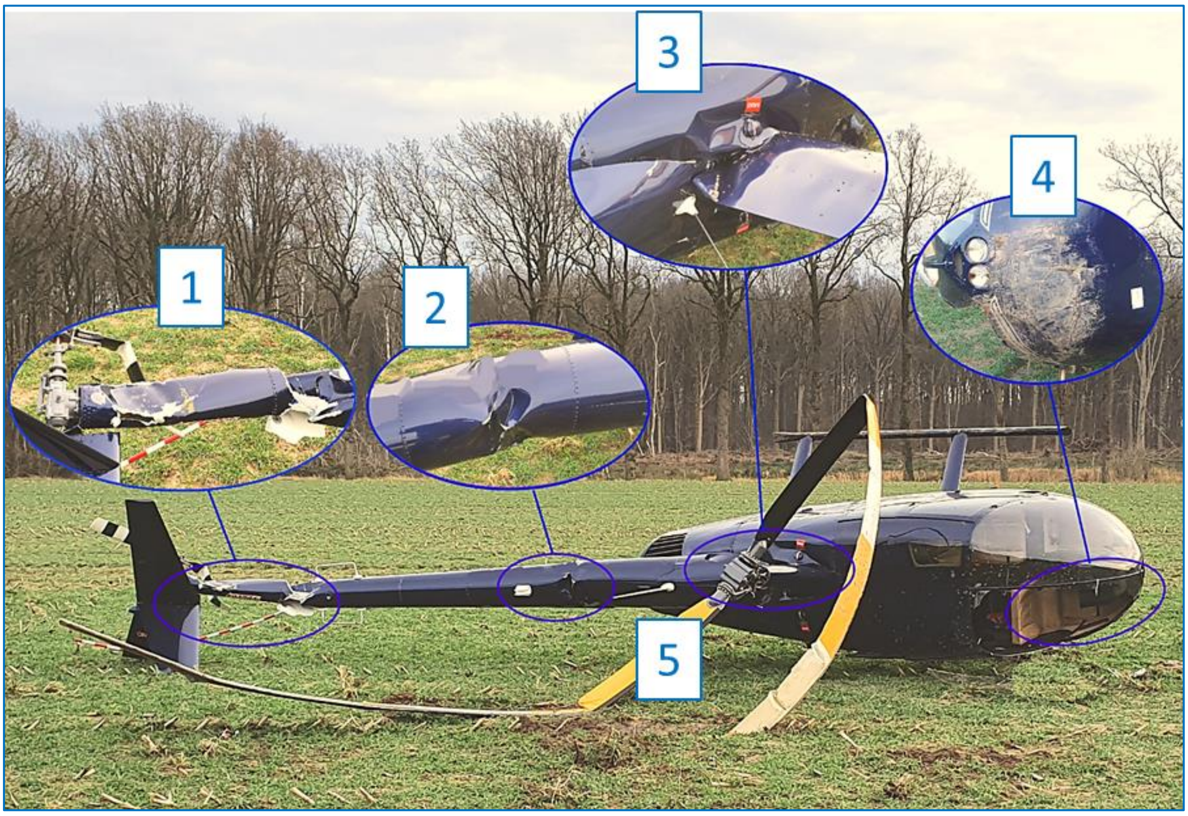


Figure 12 Aircraft damage

1.12.3 Inspection of the wreckage

A thorough inspection of the wreckage was carried out in a helicopter maintenance organization. The following evidence was found in the different aircraft systems:

1.12.3.1 The low rotor RPM warning system

- The low rotor RPM warning light and horn; The circuit breaker was still engaged. When electrical power was restored, the low RPM rotor warning light and horn were activated. No anomaly was found.
- The collective switch: Due to damage on the tubular frame structure and main rotor mast, the collective controls were blocked in the upward position. But when the control rods to the main rotor head were removed, the collective controls were released and the collective switch below the collective lever could be tested. The horn stopped and light extinguished when collective control was put in the full down position.
- The low rotor RPM warning unit itself was not tested.
- The low RPM sender and tach sender did not show obvious damage.
- To test their performance, the engine- and rotor dual tachometers were installed in another helicopter. No anomaly was found on both instruments.

1.12.3.2 The engine throttle control system

- The correlator: No obvious defect or damage was found on the correlator.
- The twist grip on the collective lever; No defect was found on the twist grip on the collective lever and tis connection to the engine.
- The governor;
    - On the accident site, the governor switch and circuit breaker were found both engaged.
    - The governor controller unit itself was not tested.
    - The other components of the governor system, such as the friction clutch, the governor motor and the mechanical connection with the engine throttle were isolated and tested for their function. No anomaly was found.
    - The engine right magneto speed signal; The magneto was tested to its performance by a specialized company in accordance with a prescribed protocol of the AAIU(Be). It consisted of a test of the produced tachometer signal and a check for excessive wear of the tachometer contact points in accordance with service instructions from RHC (service letter R44 SL-62). No insufficient point gap was found that would cause an erratic engine tachometer indication.
    - The electrical wiring was tested for its continuity of the right magneto signal to the dual tachometer and governor controller unit. No anomaly was found.

1.12.3.3 The engine

The engine was still connected to the lower sheave drum.
No anomaly was found that would indicate an engine failure.

1.12.3.4 The V-belt drive system

- The two forward V-belts were no longer in place on the sheave but in front of the upper sheave (see fig. 13). The two rear V-belts were still present on the drum but were moved forward on the sheaves.

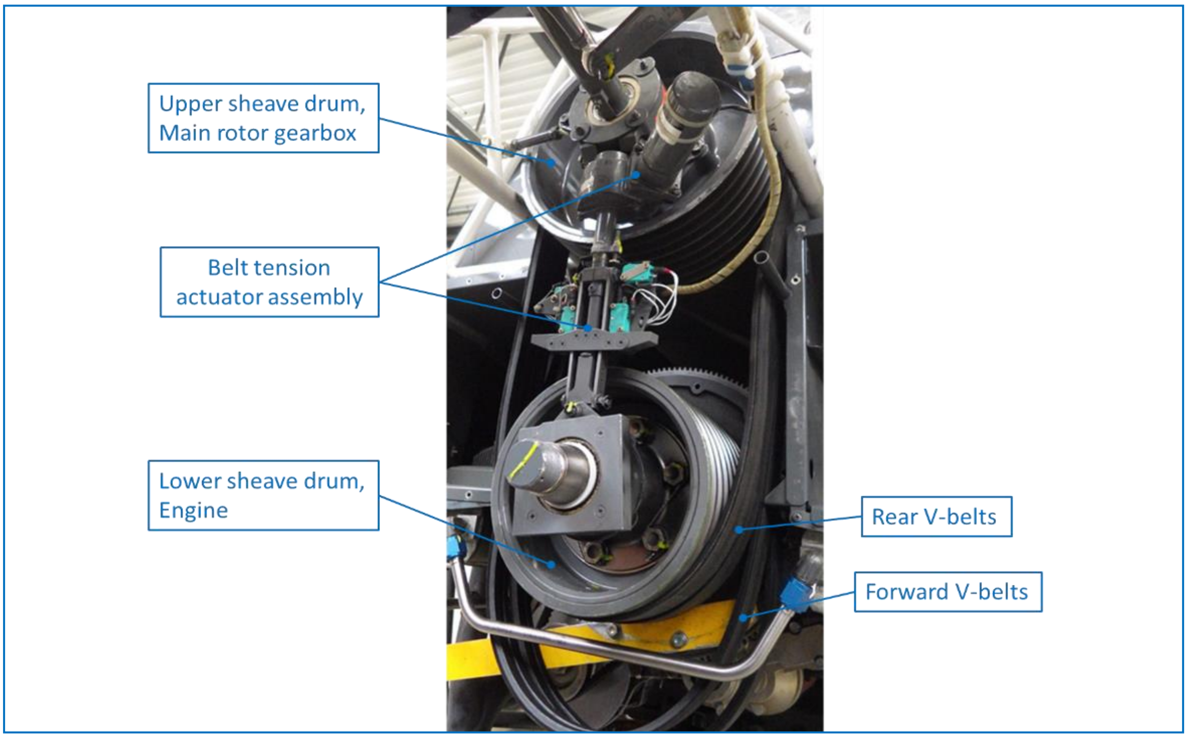


Figure 13 Damage on the drive belt system

- The V-belts were in good condition. No sign of damage or abnormal wear or tear was found (see fig. 14):

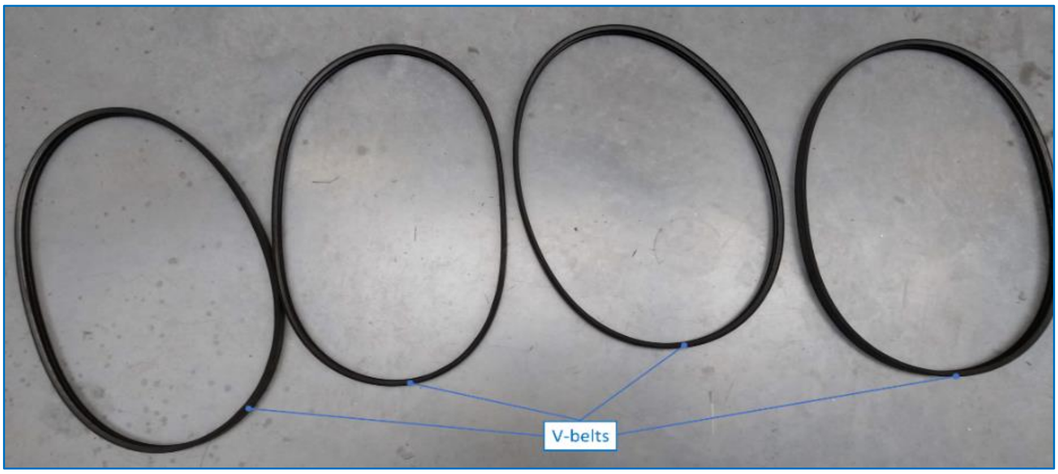


Figure 14 Condition of the V-belts

- The upper sheaves showed no catastrophic damage, only chafing sign on the outer rim caused by the impact. No abnormal wear and tear were found on the sheaves themselves. The upper sheave set, shaft and yoke were tilted slightly forward from their original position.

- The belt tension actuator assembly was damaged due to compression forces on impact.

- In the cockpit, the clutch actuator switch and the fuse were engaged and armed.

1.12.3.5 Other evidence found

- The tubular frame that supports the main rotor gearbox and holds the tailcone assembly was bent and broken on both sides nearby the yoke and the forward flex plate (see fig. 15).

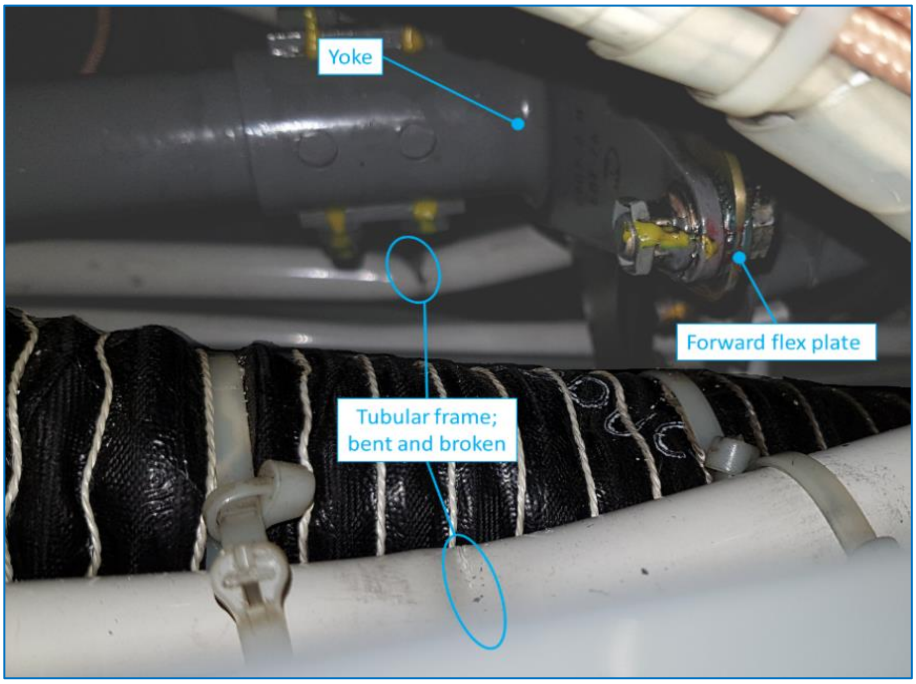


Figure 15 Damage on the tubular frame structure

- The fuel tanks, located near the main rotor shaft, were deformed but still intact. No leak was found in the bladder tanks.

- The landing skids showed no obvious signs of permanent deformation. The crossbar between the skids was not bent excessively which would indicate the landing was not excessively brutal.

- The aircraft was equipped with an Emergency Locator Transmitter (ELT) that activates at high G-forces. The ELT was armed but did not activate during landing.

- The firewall, located between cockpit and engine compartment, was deformed and sheared.

- The connection with rotor brake, located near the forward flex plate, was broken.

- The main rotor gear box, connected to the bottom of the main rotor shaft, was leaking oil and the oil level was below minimum.

- The freewheeling sprag clutch or overrunning clutch, which enables the main rotor to rotate in the event of engine failure, was working as intended. It showed free movement in one direction and locked in the other direction.

- The temperature strip (Telatemp) on the sprag clutch bearing did not indicated abnormal overheating.

1.12.4 The impact sequence

From the pilot's witness account, his photos and recorded flight data, the impact sequence was inferred (see Figure 16):

1. Shortly before touch down, the pilot performed a slight flare in an attempt to reduce vertical speed. Although the collective lever was also fully raised, there was still some horizontal and vertical speed left on landing. At that moment, the helicopter also began to yaw to the right

2. At 11:36:56 UTC, the helicopter landed firmly on both landing skids and sank in the muddy ground. The helicopter continued to slide forward in a direction of 263°.

3. After a short distance, the sliding stopped and the helicopter started to tilt forward on its RH front landing skid which was buried in the ground. As the LH skid left the ground, the helicopter yawed further to the right, pivoting on his RH skid.

4. When the nose made contact with the ground, the tilting of the fuselage stopped. As the main rotor hit the ground, the main rotor shaft bent backwards which caused the CCW rotating rotor hit the tail rotor and the boom on the LH side.

5. The blow from the main rotor on the tail rotor and boom made the helicopter fall to the right, where it came to rest. The main rotor blades kept chopping into the ground until they broke and got stuck in the mud.

The investigation could not determine when the tail rotor skid, the lower vertical stabilizer and the tail rotor boom were damaged in the impact sequence.

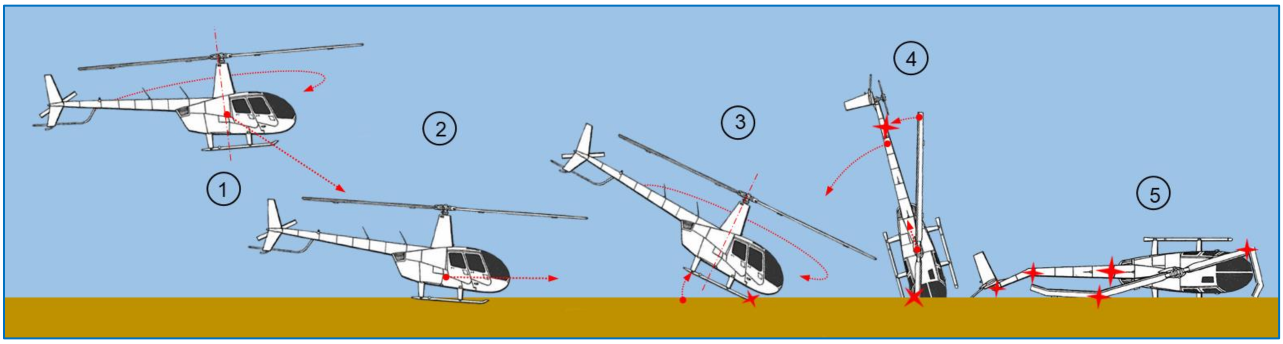


Figure 16 The impact sequence

1.13 Medical and pathological information

The pilot holds a valid class 2 EASA medical certificate without limitations.
On the day of the accident, there was no medical condition identified which would have been prevented the pilot from flying the helicopter.

1.14 Fire

There was no fire.

1.15 Survival aspects

The following evidence was found:

- The helicopter crash landed at a relatively low speed on a soft ground surface.
- The G-forces on impact were low. The Emergency Locator Transmitter (ELT) was not activated.
- On impact, all occupants were fastened in their 3-point seat belts.
- The helicopter was in contact with Air Traffic Control (ATC), but no emergency call was sent.
- Transponder was not set to emergency code 7700.
- Although the helicopter’s position on its side made it difficult for the occupants to exit the helicopter, all occupants were able to vacate the wreckage on their own.
- Besides the police, no other emergency services were present at the crash location.

1.16 Tests and research

1.16.1 Test of the dual tachometers

To test its performance, the dual tachometers was installed in another helicopter.
No anomaly was found.

1.16.2 Test of the RH magneto and engine tachometer signal

The magneto was tested to its performance by a specialized company in accordance with a prescribed protocol of the AAIU(Be). No anomaly was found.

1.17 Organizational and management information

The flight was a private flight. The rented aircraft was owned by the training organisation where the pilot followed his flight training.

1.18 Additional information

1.18.1 Regulation background

1.18.1.1 The FAA SFAR No. 73

The Federal Aviation Administration (FAA), who is the certifying authority of the Robinson type R44, issued in March 1995 a Special Federal Administration Regulation, the SFAR No.7 about Special Training and Experience Requirements for Robinson R22/R44. The FAA determined this emergency SFAR was needed to respond to the number accidents involving the Robinson model R22 and R44 helicopters since the certification of the aircraft in 1979. The intend was to increase awareness of and training for the potential hazards of particular flight operations in the Robinson Helicopters.

Many of these accidents were attributed to pilot performance or inexperience, leading to low rotor revolutions per minute (RPM), or low ‘‘G’’ conditions that resulted in mast bumping or main rotor-airframe contact accidents.

The FAA determined that additional specific pilot training is necessary for safe operation of these helicopters as part of a comprehensive program that responds to the high number of accidents involving these helicopters, and that all pilots, regardless of their level of experience, need to have a greater awareness of the flight conditions that have led to these accidents and a capability to respond appropriately when those conditions are encountered.

For this reason, the FAA imposes an awareness training requirement on all individuals operating Robinson R22 and R44 aircraft.
The awareness training is a theoretical knowledge instruction, and the program consists of the following subjects:

- Energy management
- Mast Bumping
- Low rotor RPM (blade stall)
- Low G hazards
- Rotor RPM decay

1.18.1.2 EASA SIB No. 2016-11: OSD for R22, R44 and R66 helicopters

In September 2009 the EASA issued a Safety Information Bulletin (SIB 2009-35) and recommended the National Aviation Authorities (NAA’s) to apply the SFAR No.73-2, which maintains the existing SFAR No.73.

In 2016, the EASA issued the SIB No. 2016-11, which replaced the SIB 2009-35, and recommended to make use of the OSD data for RHC R44 helicopters.

1.18.2 The Operational Suitability Data (OSD) of the R44 (RTR 465)

The European Commission has published on 27 January 2014 a new requirement in certification – "Operational Suitability Data" (OSD) – mandating (via amendments of Regulations (EU) No 748/2012 and No 1178/2011) that aircraft manufacturers, including those building helicopters, to submit data EASA considers important for safe operations. OSD covers pilot training, maintenance staff and simulator qualification; the master minimum equipment list (MMEL); and possibly other areas.

In December 2015, the Robinson Helicopter Company (RHC) in cooperation with EASA issued OSD for R44 helicopters (RTR 465). Some data are considered as mandatory [M] and bear the status of rule, other as non-mandatory [AMC] and bear the status of acceptable means of compliance. Furthermore, the amended Regulation (EU) 1178/2011 states that the type rating training courses shall include the mandatory training elements not later than 18 December 2017 or within two years after the operational suitability data was approved, whichever is the latest.

The OSD document RTR 465 describes amongst others:

8.5 Theoretical knowledge syllabus and test summary [AMC]

…

Awareness Training: Low-G hazards (loss of control, mast bumping); and rotor RPM decay (energy management, blade stall).

8.7. Training Areas of Specific Emphasis (TASE) [M]

The following training procedures require special attention and should be read in conjunction with the R44 POH, Robinson Safety Notices and the R22 Maneuver Manual found with the R22/R44 Flight Training Guide.

Training providers must comply with the following elements:

8.7.1. TASE / Training methodology for pilots and Instructors

…

- *Low RPM Recognition and Recovery*
  - *Low RPM warning horn and light activates when RPM decays below 97%.*
  - *The recovery technique for low RPM condition is simultaneous lowering of the collective and rolling-on of the throttle.*
  - *In forward flight, aft cyclic may also be used to recover RPM.*

…

Notes [M]:

An in-depth study of all safety tips and safety notices, listed in the R44 II Pilot's Operating handbook.

9. Specifications for Testing, Checking, Currency & Recent Experience

…

9.5. Flight Instructor Pre-Requites [M]

A flight instructor may provide instruction in a Robinson R44 only if that instructor-

(i) Has completed all of the training in paragraph 8.5, that includes the awareness training

…

(iii) Has completed flight training in a Robinson R44 on the following abnormal and emergency procedures-

(a) Enhanced training in autorotation procedures.

(b) RPM control without the use of the governor; and

I Low rotor RPM recognition and recovery.

1.18.3 (EU) Regulation No 1178/2011

The European aircrew regulation (EU) Regulation No 1178/2011 requires the following:

FCL.205 Conditions

Applicants for the issue of a PPL shall have fulfilled the requirements for the class or type rating for the aircraft used in the skill test, as established in Subpart H.

FCL.725 Requirements for the issue of class and type ratings

(a) … The type rating training course shall include the mandatory training elements for the relevant type as defined in the operational suitability data established in accordance with Annex I (Part-21) to Commission Regulation (EU) No 748/2012.

Appendix 9 Training, skill test and proficiency check for MPL, ATPL, type and class ratings, and proficiency check for IRs

CONTENT OF THE TRAINING/SKILL TEST/PROFICIENCY CHECK

…

4. Unless otherwise determined in the operational suitability data established in accordance with Annex I (Part-21) to Regulation (EU) No 748/2012 (OSD), the syllabus of flight instruction, the skill test and the proficiency check shall comply with this Appendix…

1.19 Useful or effective investigation techniques

Not applicable.

2 ANALYSIS

2.1 The technical condition of the helicopter

2.1.1 The engine throttle control and low rotor RPM warning system

The electrical wiring of the magneto tachometer contact points was inspected, and no anomaly was found that could indicate irregular engine RPM and erratic governor operation.
In addition, no technical anomaly was reported from previous flights.

Based on the statement of the pilot:

- the operation of the governor and the low rotor RPM warning system were checked during the start and run-up of the helicopter.
- the flight went smoothly without any technical problem before the emergency.

The investigation concluded that the engine throttle control system and the low rotor RPM warning system therefore were operating properly before impact.

All components of the engine throttle control system and the low rotor RPM warning system were inspected and showed no anomaly.

The investigation could not find element confirming the pilot's statement that "*the engine RPM gauge needle was ticking completely on top of the tachometer*" during the emergency descent.

2.1.2 The engine and V-belt drive system

The investigation determined the engine was operating properly prior to impact, based on the following;

- no anomaly was found on the engine;
- the pilot did not experience a change in noise level, a nose left yaw, an oil pressure light, or decreasing engine RPM during the flight;
- the engine responded when the throttle was slightly turned on during the final descent;

However, the engine was unable to provide the necessary power to cushion the landing.

The investigation determined the power drive system was also operating properly prior to impact, based on the following;

- no abnormal wear and tear were found on the sheave drums during the technical inspection;
- although no longer in place, all four V-belts were still present and in a good condition;
- the pilot did not experience an unusual noise or vibration and a yaw movement during the flight;
- the pilot did not see the amber clutch light 'on' during the flight.

The V-belt drive system failure sequence is further described hereunder (see chapter 2.6).

Further;

- the recorded flight data and the pilot's account indicate that it is likely that the engine was driving the main rotor during the descent.
- the main rotor ground markings at the accident site indicate that the main rotor was driven on impact.

The investigation can therefore exclude a power failure leading to the accident.

The inspection of the helicopter did not reveal any other technical anomaly and the investigation concluded that the overall condition of the helicopter showed no deficiency before impact.

2.2 The low rotor RPM emergency

In the absence of flight data /voice /video recorder such incident with a light helicopter (which is quite a complex machine compared with a standard general aviation airplane) would be difficult to analyse. Luckily, some flight data were available, owing to the memory of the GPS.

Therefore, in absence of clear evidence, the investigation was unable to determine with certainty the cause of the low rotor RPM alarm.

However, without a proper reconnaissance of the landing site, the little experienced pilot may have experienced a higher level of stress as he approached the unknown landing site in a helicopter with 3 passengers on board.

And as commented on during his PPL training, the pilot may also have been holding the throttle on the collective too tightly as well. Then, when the collective lever was lowered for the final descent, the twist grip then was turned inboard to the pilot (counterclockwise) causing the governor to override by the friction clutch and then reduced the engine and rotor RPM.

When the rotor RPM dropped below 97%, the low rotor RPM warning light and horn were activated.

Although a recognition and recovery procedure was provided in the POH of the Robinson R44, this emergency situation was not recognized.

2.3 The pilot's response

When the low rotor RPM alarm activated, the pilot decided to apply the procedure of autorotation and land in the open field ahead of him, as he has been instructed to do so when in doubt about the emergency.

But since it was confirmed that there was no power failure (see chapter 2.1.2), it was actually not necessary to apply the procedures for autorotation.

Had the throttle been rolled immediately to the pilot's outboard (clockwise) and simultaneously the collective lever been lowered and aft cyclic had been applied also to reduce forward speed, the rotor RPM would have been restored and the alarm deactivated.

2.4 The energy management during the descent

Although the weight of the helicopter remained within limits, with four people on board, the helicopter was heavy. With such a weight, the helicopter needed more rotor thrust to maintain altitude.

However, with this weight, the helicopter should normally regain sufficient energy in the rotor to increase the rotor RPM again during descent. But when the pilot lowered the collective lever, this was likely not enough to reduce both the aerodynamic drag on the rotor and the engine power output. This resulted in the rotor not being declutched from the engine and thus remaining driven.

Subsequently, because the engine throttle was probably not fully open (see chapter 2.2), the helicopter therefore was unable to regain sufficient rotor RPM. And while the rotor tachometer gauge remained in the green zone above 90%, the low rotor RPM warning light and horn were activated when the rotor RPM dropped below 97%. This small reduction of rotor RPM caused a significant loss of thrust produced by the rotor.

In addition, the helicopter gradually lost its forward airspeed during descent and did not maintain the speed that requires the least power, the 'minimum power speed'. When the helicopter slowed down below minimum power speed, it moved towards the 'back-end' of the power curve, making the rotor less efficient (see fig. 17). Therefore, at lower air speeds, the helicopter needed more rotor thrust to maintain altitude.

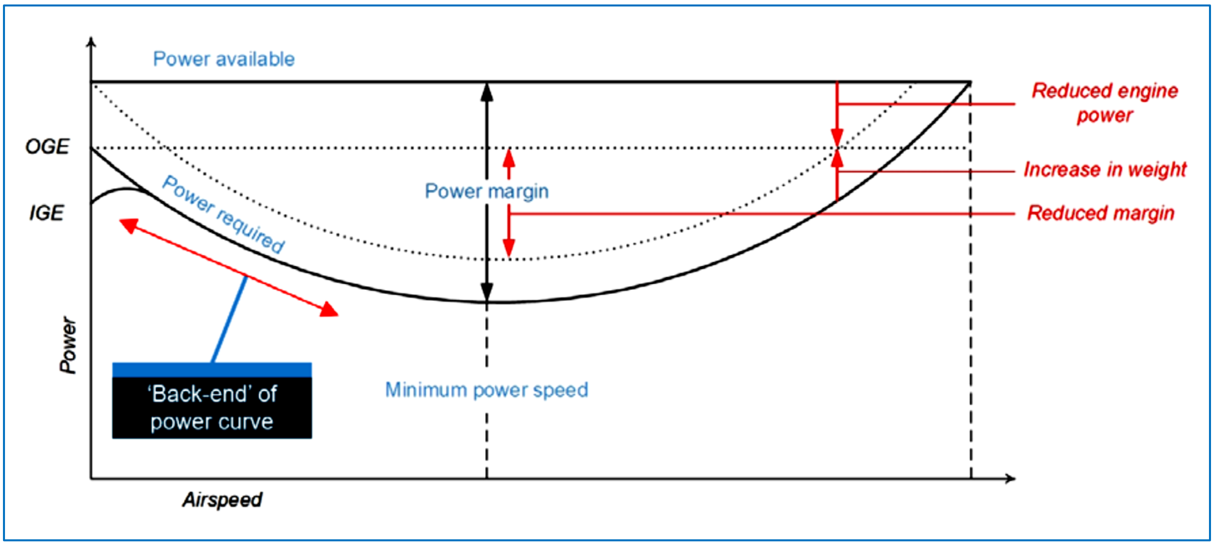


Figure 17 Typical power curve of a helicopter (source: ATSB)

2.5 The settling of the helicopter in the muddy ground

Shortly before landing, at about 3 meters above the ground, the helicopter's forward speed became very low, and despite a slight flare, the helicopter rotor then was unable to provide sufficient thrust to reduce its rate of descent (RoD). As a result, the helicopter settled and made a firm landing despite the collective lever being fully extended.

Because the tail rotor of the helicopter spins about 6 times faster then the main rotor, the small reduction in main rotor RPM resulted in an immediate loss of anti torque thrust provided by the tail rotor and a loss in yaw control of the helicopter. The helicopter, with a CCW rotating main rotor, therefore yawed to the right shortly before landing.

Moreover, despite the landing area, from higher altitude, was deemed suitable for wind direction and clearance from obstacles, at lower altitude the wet and muddy ground surface revealed to be unsuitable for landing. Unfortunately, at this low altitude, the pilot had no choice but to continue the landing.

As a result, upon landing, the helicopter's skids sank into the mud causing a firm braking action preventing the helicopter from sliding further and causing the helicopter to tilt forward until the main rotor hit the ground.

However, no indication of hard landing was found on the helicopter structure and systems; the low speed and muddy ground could have limited the forces at impact.

2.6 The V-belt drive system failure sequence

On landing, the helicopter's skids sank into the mud causing a firm braking action preventing the helicopter from sliding further and causing the helicopter to tilt forward.

When the nose of the helicopter hit the ground, the fuselage then suddenly stopped tilting forward but the angular momentum probably kept the tail rotor assembly moving upwards **(1)** (see fig. 18).

When the main rotor hit the ground, the main rotor shaft bent backwards **(2)** and deformed and broke the tubular frame structure near the main rotor gearbox supports.

Both events rotated and moved the shaft and the upper sheave set from its original position **(3)** and resulted in the V-belts moving forward and leaving the upper sheaves to the front of the helicopter **(4)**.

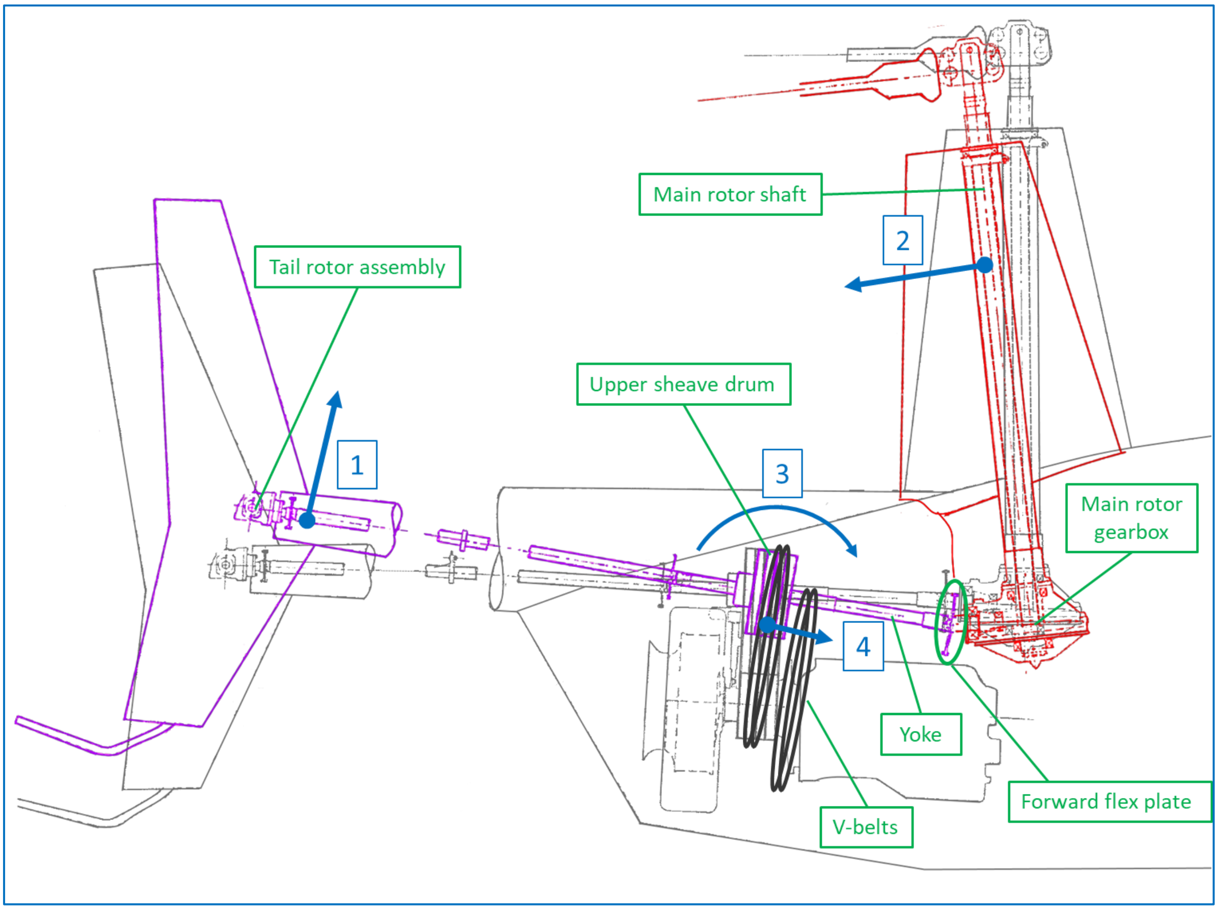


Figure 18 The V-belt drive system failure sequence

2.7 The pilot's PPL training and skill test on the Robinson R44

Only one year before the accident happened, the pilot had completed his PPL training and did not have much experience as a Pilot In Command (PIC). He also has not been retested for his flying skills since his initial PPL skill test. Therefore, the manner in which his basic flight training and skill test have been conducted, contributes to the pilot's response to the emergency.

Although the flight training was extensive and well documented, the specific Robinson R44 flight exercise 'Low Rotor RPM Recognition and Recovery' was not included as a standard exercise in the PPL training program but was only taught on an ad hoc basis.
Further it appears from the instructors' comments in the pilot's training record that this specific exercise was not taught in accordance with the procedure in the Robinson R44 Pilot Operating Handbook (POH), Safety notice SN-10 and the R44 Maneuver Guide.

In addition, the pilot convinced himself, that when in doubt about any emergency, he had to make a landing in autorotation. In this particular case, an autorotation was not necessary.
Since this specific flight maneuver is a complex skill to acquire (because, among other things, it is related to the terrifying thought of crashing), it can give the student the impression that a landing in autorotation is the cure for all problems.
While from an instructor's perspective flight training touches on all aspects of flying (by putting things in perspective and instructing that autorotation is one, but not the only solution to a problem), it's not clear if this message really comes across from the student perspective (I have to master the autorotation, that is THE topic during examination and it could save my life…).

The PPL(H) skill test report further showed that the pilot was tested extensively on his performance of a landing in autorotation but has not been tested to recognize and recover a low rotor RPM.
Although the (EU) regulation No 1178/2011 in FCL.205 Conditions, requires for the issue of a PPL, that applicants shall have fulfilled the requirements for the class or type rating for the aircraft used in the skill test, the pilot received the privileges for both PPL(H) and Robinson R44 on his pilot license, after passing the PPL(H) skill test.
But because the scenario of PPL(H) skill test does not include this specific R44 exercise as standard, and because the flight examiner FE(H) did not choose to demonstrate this emergency exercise, the pilot therefore was not tested to recognize and recover a Low Rotor RPM.

In conclusion, after passing the skill test, the pilot received privileges for PPL and type rating Robinson R44 on his pilot license but was not properly trained and tested to recognize and recover from low rotor RPM.
The pilot was conditioned to land in autorotation in doubt about the emergency.

2.8 The Operational Suitability Data (OSD)

Due to past accidents, the manufacturer, the Robinson Helicopter Company (RHC) has provided additional information to support the training on a Robinson R44 and raise awareness of low rotor RPM.

In addition, the (EU) Regulation No 1178/2011 requires that type rating training courses shall include the mandatory training elements as defined in the operation suitability data (OSD) for R44 helicopters (RTR465).

This OSD includes:

- Theoretical knowledge syllabus and test summary, which includes awareness training on the topics: Low-G hazards (loss of control, mast bumping); and rotor RPM decay (energy management, blade stall);
- Training Areas of Specific Emphasis (TASE), which require training providers to train low rotor RPM recognition and recovery and an in-depth study of all safety tips and safety notices, listed in the R44 II Pilot's Operating handbook;
- Pre-Requites for Flight Instructors, requires flight instructors to have completed theoretical knowledge training with the awareness training and flight training on low rotor RPM recognition and recovery before instructing in a Robinson R44.

However, although the operational suitability data (OSD) for R44 helicopters (RTR465) was already published in 2015 and all type rating training courses should have included the mandatory training elements not later than December 2017,

- The PPL training program on a Robinson R44 of the flight training organization registered in 2019 did not include the theoretical knowledge training with the awareness training and a study of the Safety Notices, and flight training on low rotor RPM recognition and recovery, and
- No evidence was found whether both instructors have completed theoretical knowledge training with the awareness training and a study of the Safety Notices, and flight training on low rotor RPM recognition and recovery,

we therefore conclude that the mandatory training elements as defined in the operational suitability data (OSD) for R44 helicopters (RTR465) were not properly implemented**.**

2.9 Survival aspects

Neither an emergency call was sent, nor was the transponder set to the emergency code 7700. But seen that the event happened on rather low altitude it is reasonable to assume that the pilot had no time and was focused on the problem and try to land the aircraft safely on ground (aviate, navigate, communicate).

The helicopter came down in a cultivated field in a rather desolate landscape surrounded by other fields and small woods but clear of immediate obstacles. The downside of this is that in the case they were hurt and not able to vacate the aircraft themselves, it's not sure that someone witnessed or heard the crash landing and that emergency services could be notified in time.

3 CONCLUSIONS

3.1 Findings as to causes and contributing factors

- The helicopter showed no technical anomaly and was working properly shortly before the accident.
- The pilot did not recognize and respond adequately to the low rotor RPM condition.
- The pilot was conditioned to land in autorotation when in doubt about the emergency.
- The helicopter did not regain rotor RPM during the descent.
- Shortly before landing, there was not enough energy in the rotor to cushion the landing.
- Upon landing, the helicopter's skids sank into the mud and prevented the helicopter from sliding further causing the helicopter to stop abruptly and tilt forward until the main rotor hit the ground.
- The impact of the helicopter damaged the V-belt drive system
- The pilot was not properly trained in the recognition and recovery from a low rotor RPM condition.
- The pilot was not tested on his ability to recognize and recover from a low rotor RPM during his PPL skill test.
- The mandatory training elements as defined in the Operational Suitability Data (OSD) for R44 helicopters (RTR465) were not properly implemented.

3.2 Findings as to factors that increase(d) risk

- No emergency call was/could be made prior to the impact. In case the impact forces were too low to trigger the ELT, but the occupants were trapped, it's not sure that the emergency services were notified as the aircraft came down in a field in a desolate area.

3.3 Other findings

- Despite the finding under, the landing happened in a large area clear of any obstacle, which contributed positively to the outcome.
- The pilot's flight training was extensive and well documented.
- The cross-country flight was well prepared. Before the flight, the pilot filed a flight plan and a weight and balance calculation.
- Without flight data, cockpit voice and/or video recorders incidents like this are difficult to analyse.

4 SAFETY ACTIONS AND RECOMMENDATIONS

4.1 Safety issue: Mandatory training elements as defined in the Operational Suitability Data (OSD) for R44 helicopters not properly implemented in training course.

It was found that the pilot, receiving training in 2019, was not trained properly and was therefore not able to recognize and recover from a low rotor RPM emergency, although the item 'Low RPM recognition and Recovery' is included in the mandatory list of Training Areas of special emphasis (TASE) in the OSD of December 2015. The mandatory training elements of this OSD should have been included in all training courses no later than December 2017. Therefore;

Safety recommendation: BE-2022-01:

It is recommended that the Belgian Civil Aviation Authority (BCAA) assures that the mandatory training elements as defined in the Operational Suitability Data (OSD) RTR 465 are properly implemented by organizations that using the Robinson R44 helicopter for pilot training.

5 APPENDICES

5.1 RHC Safety Notice SN-10: Fatal accidents caused by low rotor RPM stall

Safety Notice SN-10

Issued: Oct 82 Rev: Feb 89; Jun 94

FATAL ACCIDENTS CAUSED BY LOW RPM ROTOR STALL

A primary cause of fatal accidents in light helicopters is 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.

The R22 and R44 have demonstrated excellent crashworthiness as long as the pilot flies the aircraft all the way to the ground and executes a flare at the bottom to reduce his airspeed and rate of descend. Even when going down into rough terrain, trees, wires or water, he must force himself to lower the collective to maintain RPM until just before impact. The ship may roll over and be severly damaged, but the occupants have an excellent chance of walking away from it without injury.

Power available from the engine is directly proportional to RPM. If the RPM drops 10%, there is 10% less power. With less power, the helicopter will start to settle, and if the collective is raised to stop it from settling, the RPM will be pulled down even lower, causing the ship to settle even faster. If the pilot not only fails to lower collective, but instead pulls up on the collective to keep the ship from going down, the rotor will stall almost immediately. When it stalls, the blades will either "blow back" and cut off the tail cone or it will just stop flying, allowing the helicopter to fall at an extreme rate. In either case, the resulting crash is likely to be fatal.

No matter what causes the low rotor RPM, the pilot must first roll on throttle and lower the collective simultaneously to recover RPM **before** investigating the problem. It must be a conditioned reflex. In forward flight, applying aft cyclic to bleed off airspeed will also help recover lost RPM.

5.2 RHC Safety Notice SN-24: Low RPM rotor stall can be fatal

ROBINSON
HELICOPTER COMPANY

Safety Notice SN-24

Issued: Sep 86 Rev: Jun 94

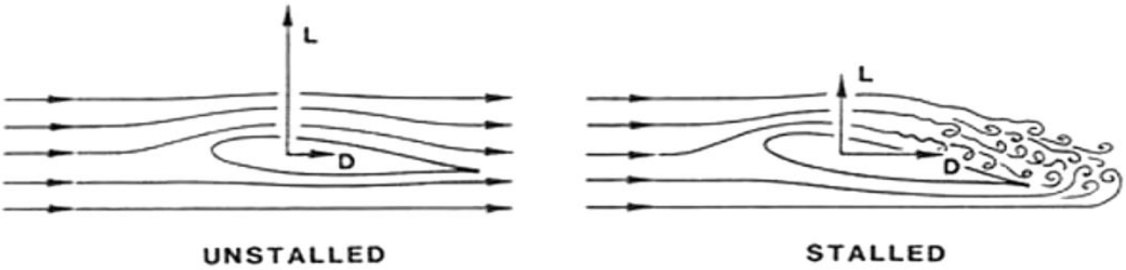
LOW RPM ROTOR STALL CAN BE FATAL

Rotor stall due to low RPM causes a very high percentage of helicopter accidents, both fatal and non-fatal. Frequently misunderstood, rotor stall is not to be confused with retreating tip stall which occurs only at high forward speeds when stall occurs over a small portion of the retreating blade tip. Retreating tip stall causes vibration and control problems, but the rotor is still very capable of providing sufficient lift to support the weight of the helicopter.

Rotor stall, on the other hand, can occur at any airspeed and when it does, the rotor stops producing the lift required to support the helicopter and the aircraft literally falls out of the sky. Fortunately, rotor stall accidents most often occur close to the ground during takeoff or landing and the helicopter falls only four or five feet. The helicopter is wrecked but the occupants survive. However, rotor stall also occurs at higher altitudes and when it happens at heights above 40 or 50 feet AGL it is most likely to 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 thing happens during rotor stall with a helicopter except it occurs due to low rotor RPM instead of low airspeed. As the RPM of the rotor gets lower, the angle-of-attack of the rotor blades must be higher to generate the lift required to support the weight of the helicopter. Even if the collective is not raised by the pilot to provide the higher blade angle, the helicopter will start to descend untii the



Wing or rotor blade unstalled and stalled.

Page 1 of 2

ROBINSON
HELICOPTER COMPANY

Safety Notice SN-24 (continued)

upward movement of air to the rotor provides the necessary increase in blade angle-of-attack. As with the airplane wing, the blade airfoil will stall at a critical angle, resulting in a sudden loss of lift and a large increase in drag. The increased drag on the blades acts like a huge rotor brake causing the rotor RPM to rapidly decrease, further increasing the rotor stall. As the helicopter begins to fall, the upward rushing air continues to increase the angle-of-attack on the slowly rotating blades, making recovery virtually impossible, even with full down collective.

When the rotor stalls, it does not do so symmetrically because any forward airspeed of the helicopter will produce a higher airflow on the advancing blade than on the retreating blade. This causes the retreating blade to stall first, allowing it to dive as it goes aft while the advancing blade is still climbing as it goes forward. The resulting low aft blade and high forward blade become a rapid aft tilting of the rotor disc sometimes referred to as "rotor blow-back". Also, as the helicopter begins to fall, the upward flow of air under the tail surfaces tends to pitch the aircraft nose-down. These two effects, combined with aft cyclic by the pilot attempting to keep the nose from dropping, will frequently allow the rotor blades to blow back and chop off the tailboom as the stalled helicopter falls. Due to the magnitude of the forces involved and the flexibility of rotor blades, rotor teeter stops will not prevent the boom chop. The resulting boom chop, however, is academic, as the aircraft and its occupants are already doomed by the stalled rotor before the chop occurs.

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5.3 Extract from the RHC R44 maneuver guide

ROBINSON R44 MANEUVER GUIDE

RECOGNITION AND RECOVERY FROM LOW ROTOR RPM

PURPOSE:

To become thoroughly familiar with the recognition of low rotor RPM and the techniques of recovery. Prior to performing this maneuver, the pilot should be familiar with RHC Safety Notices #10 and #24.

DESCRIPTION:

Cruise flight, takeoff & approach

A) Entry and Recognition

During cruise flight, takeoffs and approaches, at 102% RPM, the instructor will, turn the governor off, then slowly decrease the throttle to 95% RPM. The low RPM condition will be recognized by:

1. A noticeable decrease in engine noise.
2. Aircraft vibrations and cyclic stick shake especially at higher airspeeds.
3. The low rotor RPM warning horn and light at approximately 97% RPM.

The instructor should demonstrate the further increase in vibration and decrease in engine noise by decreasing the RPM to 92% RPM.

B) Recovery Technique

Upon recognizing the low RPM condition, simultaneously add throttle and lower the collective half an inch to one inch to regain operating RPM. Larger collective movements will require additional throttle due to the correlator. A gentle aft cyclic movement will prevent the nose from going down and inhibiting the recovery, but the primary recovery controls are the collective and throttle. Avoid any forward cyclic input, which will inhibit RPM recovery. Once RPM is regained, slowly raise the collective to reduce the sink rate, while closely monitoring the RPM.

At a Hover

During hovering flight at 102% RPM, the instructor will turn the governor off and slowly decrease the throttle to 95% RPM. Note the obvious decrease in engine noise and the tendency for the aircraft to settle back toward the ground. As the aircraft settles, the tendency for some pilots will be to increase the collective to stop the descent. This may only increase the RPM decay and increase the descent. Recovery is the same as in forward flight. Lower the collective simultaneously adding throttle. If RPM cannot be regained prior to ground contact, insure that the helicopter touches down in a level attitude.

PERFORMANCE STANDARDS:

The pilot should be able to recognize and recover from low rotor RPM prior to reaching 90% RPM.

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