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Swiss Transportation Safety Investigation Board STSB

Final Report No 2417

by the Swiss Transportation Safety Investigation Board STSB

concerning the accident of the helicopter Guimbal Cabri G2, HB-ZVK,

on 30 September 2021

Ägerten, Neuendorf (SO)

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General information on this report

The sole purpose of an investigation into an aircraft accident or serious incident is to prevent further accidents or serious incidents from occurring. It is therefore expressly not the purpose of this safety investigation and report to establish blame or to determine liability.[1]

Should this report be used for purposes other than those of accident prevention, this statement should be given due consideration.

The German version of this report is the original and is therefore definitive.

Unless otherwise indicated, all information refers to the time of the accident.

Unless otherwise indicated, all times mentioned in this report are in the *local time* (LT) applicable to the territory of Switzerland at the time of the accident which is Central European Summer Time (CEST). The relationship between LT, CEST and Coordinated Universal Time (UTC) is:

LT = CEST = UTC + 2

[1] Article 3.1 of the 12th edition of Annex 13, effective from 5 November 2020, to the Convention on International Civil Aviation of 7 December 1944 which came into force for Switzerland on 4 April 1947, as amended on 18 June 2019 (SR *0.748.0*)

Article 24 of the Federal Act of 21 December 1948 on Aviation, as amended on 1 May 2022 (AviA; SR *748.0*)

Article 1, point 1 of Regulation (EU) No 996/2010 of the European Parliament and of the Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation and repealing Directive 94/56/EC, which came into force for Switzerland on 1 February 2012 pursuant to a decision of the Joint Committee of the Swiss Confederation and the European Union (EU) and based on the agreement of 21 June 1999 on air transport between Switzerland and the EU (Air Transport Agreement)

Article 2 paragraph 1 of the Ordinance of 17 December 2014 on the Safety Investigation of Transportation Incidents, as amended on 1 February 2015 (OSITI; SR *742.161*)

Summary

Aircraft type	Guimbal Cabri G2			HB-ZVK
Operator	Swiss Helicopter AG, Hartbertstrasse 11, 7000 Chur			
Owner	Swiss Helicopter AG, Hartbertstrasse 11, 7000 Chur			

Flight instructor Swiss citizen, born in 1966

Licence Commercial Pilot Licence Helicopter (CPL(H)) in accordance with the European Union Aviation Safety Agency (EASA), issued by the Federal Office of Civil Aviation (FOCA), authorised as a flight instructor for helicopters (FI(H))

Flying				
	Total	2,691:38 hrs	**During the last 90 days**	118:54 hrs
	On the Vorfallmuster	155:02 hrs	**During the last 90 days**	18:49 hrs

Trainee pilot Swiss citizen, born in 1980

Licence None (in training)

Flying hours				
	In total	29:38 hrs	**During the last 90 days**	14:49 hrs
	On the Vorfallmuster	28:22 hrs	**During the last 90 days**	14:11 hrs

Location Ägerten, commune of Neuendorf, canton of Solothurn, Switzerland

Coordinates 628 010 / 237 358 (*Swiss Grid* 1903) N 47° 17' 12'' / E 007° 48' 32'' (WGS[2] 84) **Altitude** 432 m/M

Date and time 30 September 2021, 14:02

Type of operation	Training
Flight rules	Visual Flight Rules (VFR)
Point of departure	Pfaffnau heliport (LSXP)
Destination	Pfaffnau heliport (LSXP)
Flight phase	Landing
Type of accident	Loss of control

Injuries to persons

Injuries	Crew members	Passengers	Total number of occupants	Third parties
Fatal	0	0	0	0
Serious	0	0	0	0
Minor	0	0	0	0
None	2	0	2	Not applicable
Total	2	0	2	0

Damage to aircraft Seriously damaged

Third-party damage None

[2] WGS: World Geodetic System, reference geo-data system: The WGS 84 standard was adopted by a resolution of the International Civil Aviation Organization (ICAO) in 1989.

1 Key information

1.1 Background and flight events

1.1.1 General

The information provided by the crew and data from a GPS[3]-based navigation system were used for the following description of the background and flight events.

1.1.2 Background

The flight instructor and trainee pilot met on the morning of 30 September 2021 at the Pfaffnau heliport (LSXP) and carried out the briefing and pre-flight checks on the helicopter together. The training programme included simulated autorotations to near the ground. A first flight was undertaken in the morning in the Pfaffnau region lasting around an hour. After the debriefing, the crew went to lunch. The flight instructor and trainee pilot met up again at the heliport at 13:00 and prepared for the second flight. They carried out pre-flight checks on the helicopter again. The training programme included autorotation training with a steep turn.

1.1.3 Flight events

The Guimbal Cabri G2 two-seat helicopter registered as HB-ZVK took off from Pfaffnau heliport at 13:37 and flew in a north-westerly direction to Neuendorf, where the crew performed a first autorotation exercise. The helicopter then flew to a nearby plain surrounded by forest. Here the trainee pilot performed six more autorotation exercises within around 15 minutes whereby, without advance warning, the flight instructor turned the throttle twist grip so far off that the engine governor was deactivated (cf. section 1.5). At an altitude of around 200 metres (or about 650 ft) above the ground, the flight instructor opened the throttle twist grip, reactivating the engine governor, and communicated this to the trainee pilot. The flight instructor made sure the engine and main rotor speed indicators were synchronised, i.e. aligned, using the electronic pilot monitor (cf. section 1.4.1) in the cockpit. The trainee pilot then performed the autorotation exercises until going into hover flight. According to the crew's statement, there were no abnormalities in terms of the helicopter's flight characteristics and engine performance during these exercises.

During the eighth autorotation exercise, the trainee pilot approached the landing site on the right-hand side of a road (cf. Figure 1). The final approach was too high and, as a result, was extended on the left-hand side of the road. Consequently, the trainee pilot changed course by about 45 degrees to the left on final approach. He performed a flare manoeuvre close to the ground, reducing the vertical and horizontal speed. He then used the collective pitch control (subsequently referred to as the 'collective') to reduce the vertical speed and to stabilise the helicopter in a horizontal position in hover flight. At the same time, the trainee pilot pressed the right foot pedal to counteract the increasing yawing moment to the left during this flight phase due to the anticipated engine power. The helicopter turned slightly to the right around its vertical axis. During this phase the engine and main rotor speeds had sharply fallen and the corresponding acoustic warning message had been activated. The indicator needles of the main rotor and engine speed had been synchronised on the electronic pilot monitor.

The flight instructor attempted to turn the helicopter nose back to the flight direction by pressing the left foot pedal, but did not succeed. The helicopter hit the ground hard, causing a main rotor blade to hit and destroy the tail boom (cf. Figure 2). The

[3] GPS: global positioning system

flight instructor indicated that he had then presumably closed the throttle twist grip before turning off the engine that was still running by closing the fuel valve and switching off the electrical on-board power supply. The crew was uninjured.

The flight instructor indicated that there is a known phenomenon where the main rotor speed falls slightly when pulling the collective during the helicopter's flare manoeuvre before increasing again due to the engine power.

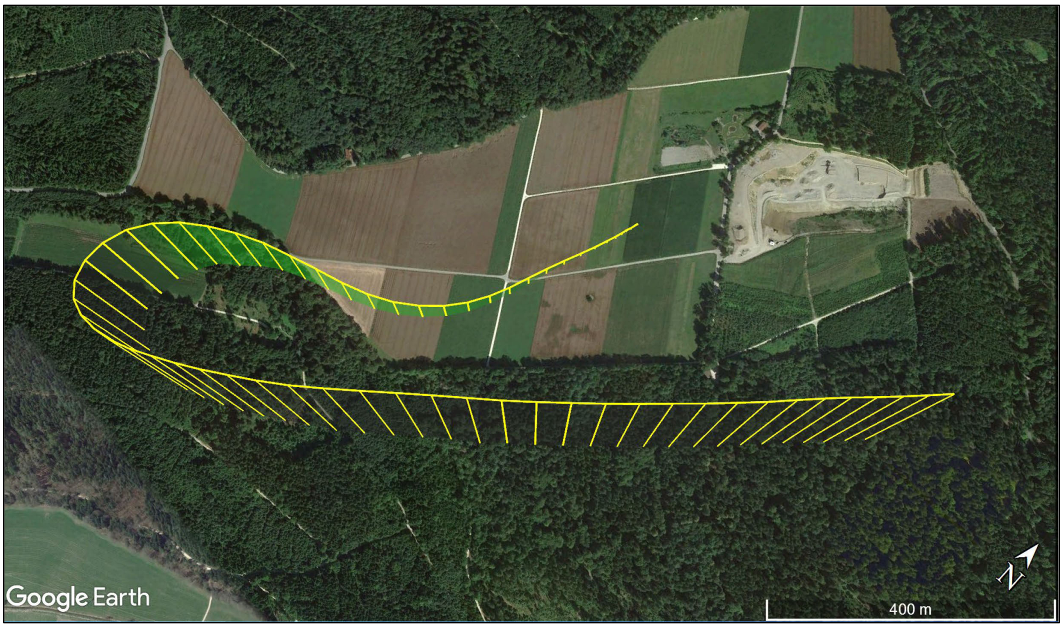

Figure 1: The final landing approach before the accident according to the GPS data recording device, shown in Google Earth.

Figure 2: Final position of the HB-ZVK helicopter looking north-east with a detached enclosed tail rotor.

1.2 Information on the crew

The flight instructor has held the flight instructor licence since January 2017 from which time he has been providing training in the Airbus Helicopter H120 helicopter type. He has been using the Guimbal Cabri G2 helicopter type since March 2019. In the three months prior to the accident, he flew the Airbus H120 and Guimbal Cabri G2 helicopter types alternately, sometimes also on the same day. During this period, he flew in total around 100 hours in the H120 and just under 20 hours in the Cabri G2.

The trainee pilot has been undertaking basic training to obtain the Private Pilot Licence Helicopter (PPL(H)) since April 2021. At the time of the accident, he had flight experience of just under 30 hours in the Guimbal Cabri G2 helicopter type and undertook his first solo flight in July 2021.

1.3 Aircraft information

1.3.1 General information

Aircraft type	Guimbal Cabri G2
Design	Single-engine lightweight two-seater helicopter with skid landing gear, a right-rotating main rotor with three blades, torque balance with an enclosed tail rotor.
Manufacturer	Hélicoptères Guimbal (France)
Construction year	2021
Serial number	1279
Engine	Lycoming Engines O-360-J2A, air-cooled, four-cylinder boxer engine, maximum take-off power for 5 minutes of 119kW (160HP) at 2,700 RPM[4], nominal power of 108kW (145HP) at 2,700 RPM.
Operating hours	Airframe 223:48 hours (TSN[5])
	Engine 223:48 hours (TSN)
Maximum permitted take-off mass	700kg
Mass and centre of gravity	The helicopter's mass at take-off was around 650kg. Both the mass and centre of gravity were within the limits permitted according to the flight manual (FM) throughout the entire flight.
Maintenance	The last scheduled maintenance work was certified on 10 September 2021 at 199:05 operating hours as part of a 100-hour inspection.

[4] RPM: revolutions per minute

[5] TSN: time since new

1.3.2 Lift of the main rotor and performance of the tail rotor

In its documentation, the helicopter manufacturer describes how the main rotor can generate lift in hover flight with rotor speeds of well below the nominal rotational speed and even below the minimum rotational speed of 450 RPM. However, in such a situation the thrust of the enclosed tail rotor is not enough to maintain effective control of the helicopter in the vertical axis. Even when the right foot pedal is fully pressed, the helicopter starts to yaw out of control to the left. When such loss of control occurs, pulling the collective further reduces the main rotor speed and the yawing increases.

1.3.3 Manufacturer information on autorotation training

The helicopter manufacturer's service letter 19-002 A contains the following information:

"It is common practice on certain helicopter types to end an autorotation with a power recovery during, or just after, the flare.

This practice is not recommended on the Cabri. When performing a power recovery, the engine governor will re-engage as soon as the engine speed reaches 2000 RPM and will open the throttle fully. The engine torque will then be maximum, which can lead to loss of control in yaw, as described above.

The safest way to perform an autorotation with power recovery is to not rotate the twist grip during the maneuver. Lowering the collective to the lower stop will be enough to desynchronize the rotor and the engine. […]

It is also possible to perform an autorotation with the engine idling, by rotating the twistgrip against the idle mechanical stop. In this case, power recovery must be carried out early, no lower than 300 ft AGL, as described in the OSD[6] *Flight Crew.* […]

Finally, if the conditions and the pilot's skills are appropriate, performing a full down autorotation will prevent the risk of loss control in yaw.

Power recovery during or after the flare of an autorotation using the twist grip is risky and must be avoided."

1.4 Recording equipment

1.4.1 Electronic pilot monitor and data recorder

The Guimbal Cabri G2 helicopter type is equipped with an electronic pilot monitor (EPM) which monitors 36 parameters and in which various system statuses are displayed on an LCD screen (cf. Figure 3). From the helicopter serial number 1260 on, these parameters are logged in the integrated data recorder (*enregistreur de paramètres* – EDP). This kind of data recorder is not mandatory for this aircraft category.

The following parameters are displayed on the EPM:

- Power indicator (multiple limit indicator (MLI))
- Engine and main rotor speed (tr/min)
- Operational status of the carburettor heat (RECH) and temperature (CARB.°C)

[6] OSD: operational suitability data

Figure 3: Image of the EPM. Source: Hélicoptères Guimbal

HB-ZVK with serial number 1279 was equipped with a data recorder. However, this had stopped recording any parameters around two months before the accident. The helicopter manufacturer is aware of the issue of the data recorder's unreliable performance and is looking for a solution, considering installing a video recording device in the cockpit in the foreseeable future that records various parameters and images of the cockpit and instruments. This kind of system is already being used by other helicopter manufacturers.

1.4.2 Flight path recording device

The flight data of the last flight was recorded on the electronic navigation device, which was a Garmin GTN650Xi. This data was read and analysed.

1.5 The engine's throttle control

1.5.1 Throttle twist grip

The engine speed is controlled by a throttle twist grip positioned at the front end of the collective. If the throttle twist grip is turned to the left, the engine speed increases. Conversely, turning it to the right reduces the engine speed. Idle speed is achieved before the throttle twist grip reaches the mechanical stop. There is therefore an angle of rotation between the idle position and the mechanical stop at which the position of the throttle valve remains at idle regardless of the position of the throttle twist grip, provided the collective is at the lower stop (fully pushed). This angle of rotation is approximately 100°.

1.5.2 Throttle correlation cam

The throttle twist grip's rear shaft end is connected to the throttle correlation cam (TCC) by a rod assembly (cf. Figure 4). This TCC operates the carburettor's throttle valve via a bell crank lever and a flexible throttle cable. Through this mechanism, the throttle valve opens automatically when the collective is pulled and the engine power increases.

This mechanism can also be deactivated to allow the collective to be fully pulled without the throttle valve opening automatically. To do this, the pilot has to fully close the throttle twist grip until reaching the mechanical stop.

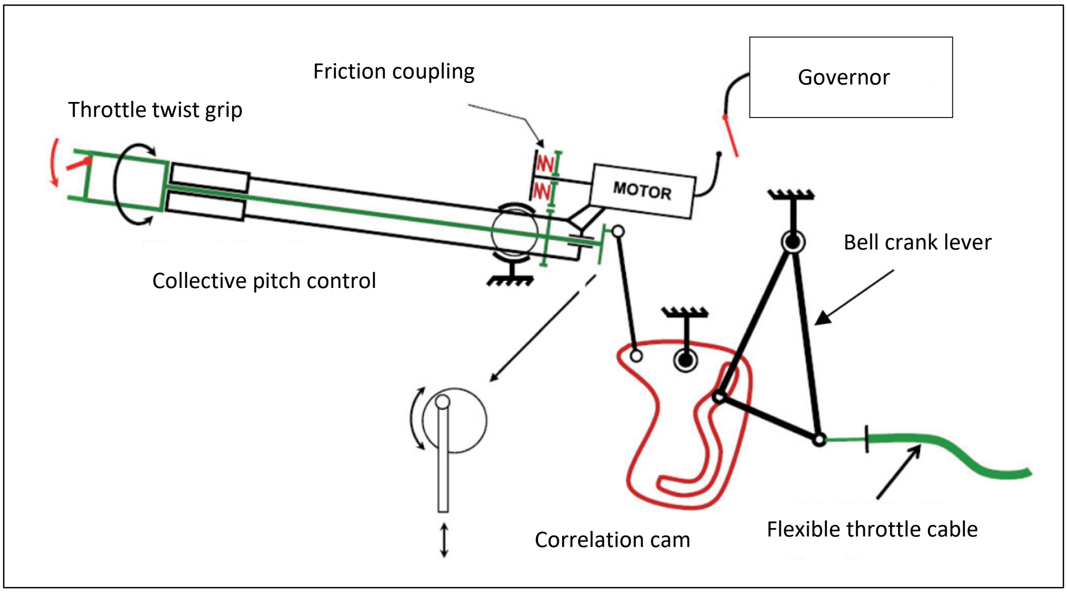

Figure 4: Schematic diagram of the throttle control: The electronic engine speed governor is switched on or off by means of a toggle switch at the end of the collective (red switch with arrow, red contact on the speed governor motor). Source: Hélicoptères Guimbal.

1.5.3 Electronic engine governor

The Guimbal Cabri G2 helicopter is equipped with an electronic engine governor which constantly keeps the engine at the nominal speed of 2,650 RPM regardless of the power requirements. The engine governor is only activated at an engine speed of over 2,000 RPM. If the pilot reduces the engine speed to below 2,000 RPM, such as during simulated autorotation, then the engine governor is deactivated. As soon as the pilot increases the engine speed to over 2,000 RPM, the engine governor is reactivated and automatically accelerates the engine to the nominal speed of 2,650 RPM.

An electric motor controlled by the engine governor powers the throttle twist grip’s shaft via a friction coupling. This coupling enables the pilot to override the electric engine. The engine governor can be activated and deactivated via a switch on the collective.

1.6 Initial findings on the helicopter

The collision with the ground pushed the helicopter airframe to the left side of the landing skids’ cross bars. A main rotor blade hit and destroyed the tail boom. The tail rotor transmission shaft and the flexible tail rotor push-pull control were torn out of the tail boom. The control cable was detached in the area of the tail rotor unit (cf. Figure 5).

Figure 5: The HB-ZVK's destroyed tail boom with the tail rotor torn out

1.7 Meteorological data

The weather conditions were sunny at the time of the accident. A gentle northerly wind was blowing between the south foot of the Jura and Upper Aargau.

Weather conditions	Sunny and low wind
Clouds	1/8 – 2/8 at 6400ft AMSL[7]
Visibility	20 km
Wind	030 degrees, 4 knots
Temperature and dew point	15°C / 6°C
Air pressure	QNH[8]: 1027hPa
Risks	None

1.8 Technical investigation

The technical investigation of the helicopter found that the throttle correlation cam (TCC) had broken off (cf. Figure 6). The flexible tail rotor push-pull control could be pulled out of the drill hole on the engine fire bulkhead by a few centimetres. The fixing bracket of the tail rotor push-pull control (cf. Figure 7) was bent and the cable

[7] AMSL: above mean sea level

[8] Pressure reduced to sea level, calculated using the values of the ICAO standard atmosphere

was no longer in its proper position. No other damage to the flight control system and the helicopter structure in the cockpit area was found.

The engine was removed from the helicopter and underwent testing. The engine worked perfectly and all parameters measured were within the operational limits defined by the manufacturer.

Figure 6: Broken off parts of the throttle correlation cam (TCC)

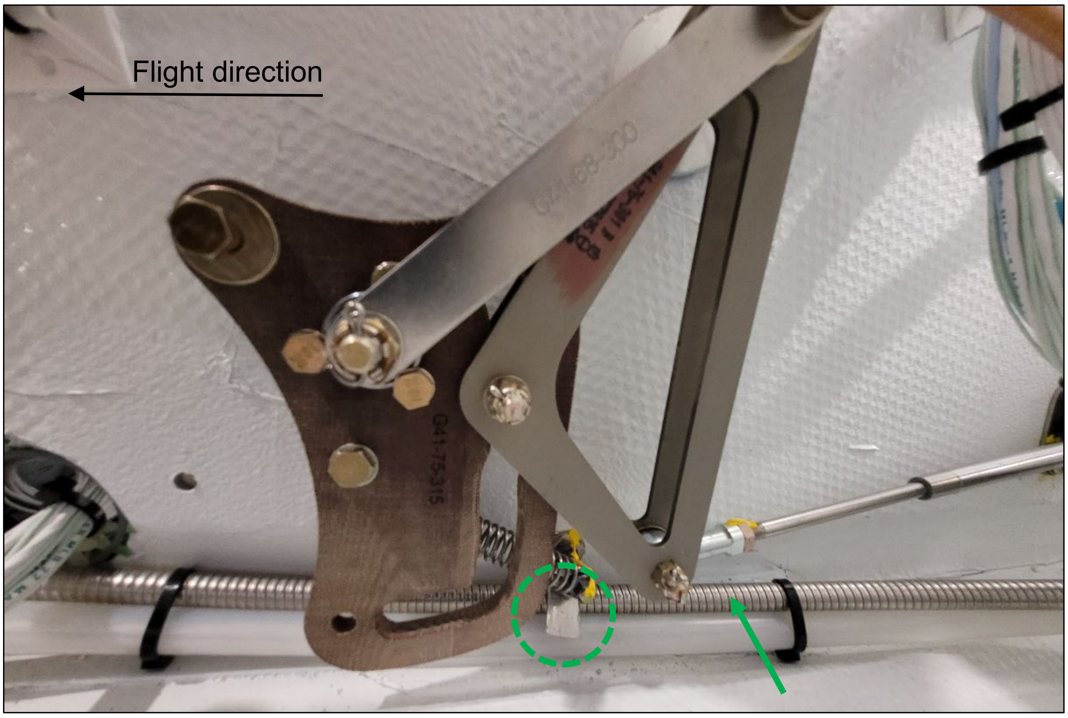

Figure 7: Example of the installation of the throttle correlation cam (TCC) and the guidance of the flexible tail rotor push-pull control cable (green arrow) and the fixing bracket (dashed green circle). Source: Hélicoptères Guimbal.

1.9 Test results

When tractive force was applied to the torn-out flexible tail rotor push-pull control, the cable became taut, causing it to move sideways from the bent fixing bracket towards the broken-off throttle correlation cam (TCC), as illustrated in Figure 8.

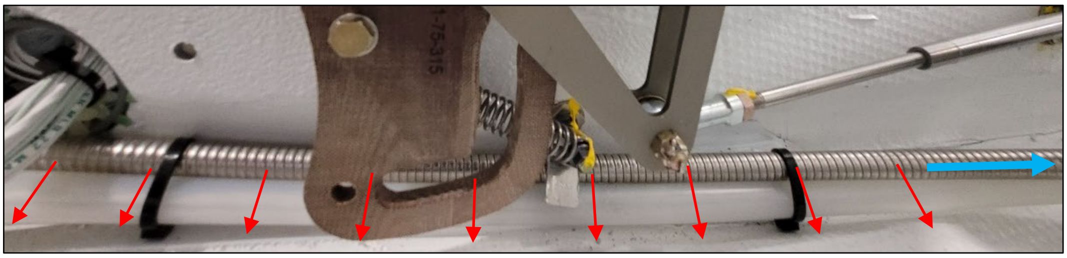

Figure 8: Direction of movement of the flexible tail rotor push-pull control cable (red arrows) upon application of tractive force to the right (blue arrow). Close-up of Figure 7.

The various positions of the throttle correlation cam (TCC) were analysed based on the respective positions of the collective and throttle twist grip in a helicopter type identical in construction to the HB-ZVK. The results are shown in diagram format in Figure 9.

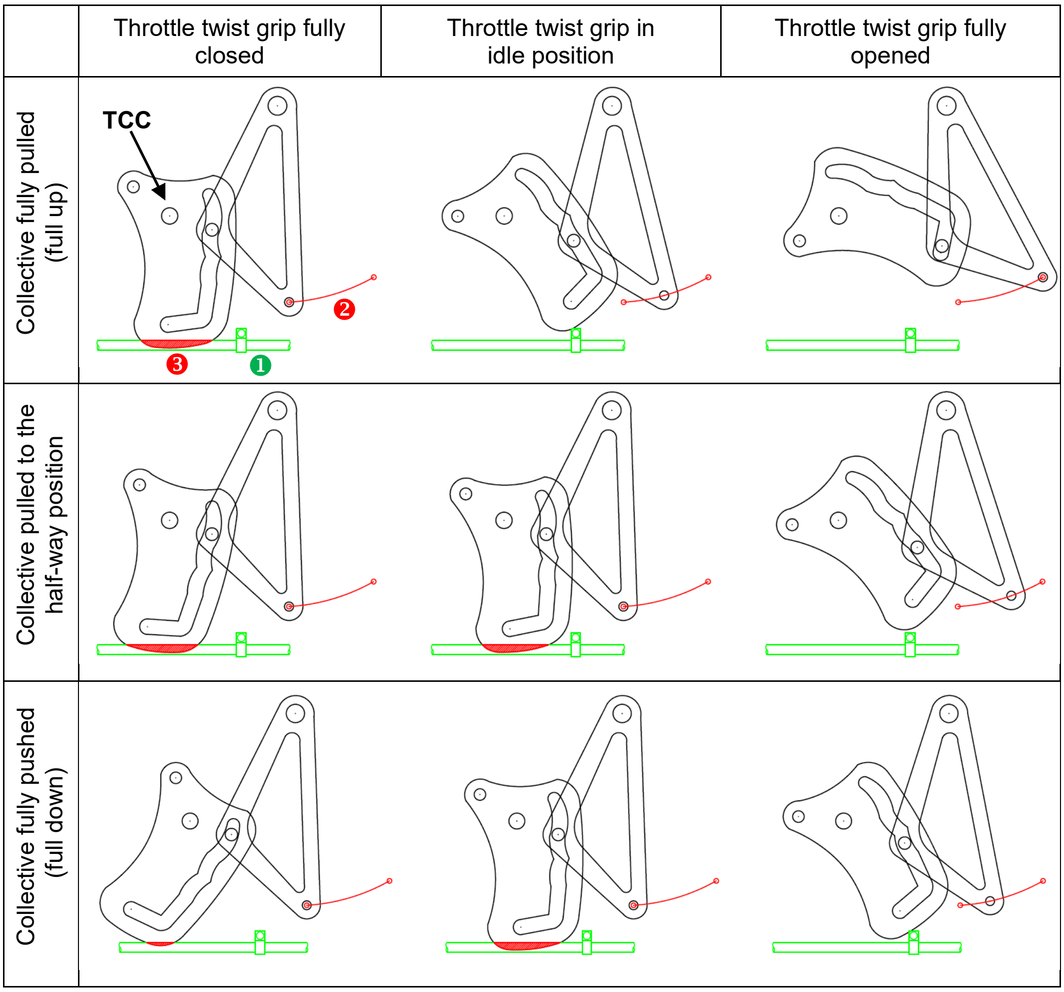

Figure 9: Position of the throttle correlation cam (TCC) depending on the position of the collective and the throttle twist grip; flexible tail rotor push-pull control with fixing bracket (green ❶); operating area of the flexible control cable to the throttle valve of the carburettor (red curve ❷ with idle position left, full throttle right); overlapping of the tail rotor push-pull control and TCC (red area ❸).

2 Analysis

2.1 Technical aspects

The investigation did not produce any indication of pre-existing technical faults which could have caused or had an impact on the accident.

The helicopter was equipped with an electronic pilot monitor (EPM) with an integrated data recorder but which had not recorded any data for a longer period of time. This meant no system data was available for the investigation, in particular on the position of the throttle twist grip (cf. section 1.4.1). The helicopter manufacturer is aware of the issue with unreliable data logging and is looking for a corresponding solution. Complete recording of flight data is not only essential for accident investigations and therefore advisable, but also of great benefit for the helicopter manufacturer, maintenance operations and the aircraft operator.

Nevertheless, the in-depth technical investigation provided reliable evidence regarding the position of the throttle twist grip at the time of the helicopter's impact (cf. section 1.9).

When the helicopter crashed, a main rotor blade hit and destroyed the tail boom. High tractive forces were exerted on the flexible tail rotor push-pull control, pulling it backwards from the engine bulkhead firewall and tearing it out of the fixing bracket near the throttle correlation cam inside the fuselage. As a result, the flexible tail rotor push-pull control cable exerted a large lateral force on the throttle correlation cam, causing it to break (cf. section1.9, Figure 8). No other plausible explanations for the fracture of the throttle correlation cam were found.

Testing showed that such a fracture is only possible when the throttle correlation cam is in certain positions, or more specifically when the position of the throttle correlation cam and that of the flexible tail rotor push-pull control overlap. This occurs either when the throttle twist grip is fully closed – regardless of the position of the collective – or when the throttle twist grip is in idle position and the collective is fully closed or pulled to the half-way position (cf. section section1.9, Figure 9, positions with area colored in red). In summary, it can be stated that, according to the test arrangement, such a fracture of the throttle correlation cam is only possible with the throttle twist grip closed or the throttle twist grip in the idle position according to the test arrangement.

This suggests that the throttle twist grip was not open at the time of the crash and, with a high degree of probability, was not open during the final approach which explains why the main rotor speed decreased during the flare manoeuvre.

2.2 Human and operational aspects

2.2.1 Flight events

The two training flights carried out on this day, during which simulated autorotations were practised, went as planned until the accident. The procedure used by the flight instructor was in line with the information provided by the helicopter manufacturer (cf. section 1.3.3).

In this case, the crew performed seven simulated autorotations immediately after one another which were all carried out without incident and to the satisfaction of the flight instructor. During the subsequent autorotation exercise, the main rotor speed dropped unexpectedly for the crew during the flare manoeuvre. As a result, the autorotation had to be completed without engine power until landing (so-called "sharp" autorotation[9]). The helicopter hit the ground hard.

The crew indicated that they respectively had opened the throttle twist grip in the landing approach during the autorotation exercises and that the engine and main rotor speed indicators were synchronised on the electronic pilot monitor. This contradicts the technical findings, suggesting that the throttle twist grip was not open in the final approach during the last autorotation exercise (cf. section 2.1). The possibility of the throttle twist grip closing due to the collision can be ruled out.

The following section outlines psychological aspects concerning possible reasons why the throttle twist grip was not open or why the crew believed that they had opened it during the eighth autorotation exercise.

2.2.2 Psychological analysis

Most aircraft accidents occur during phases when the workload in the cockpit is high. An autorotation exercise can be categorised as such a phase. Distraction can have a major impact on a pilot’s cognitive resources during such phases.

The performance of the overall ‘helicopter/pilot’ system depends on the pilot’s processing capacity. This is influenced by the number and nature of the tasks to be performed, which in turn depend on the design of the user interface (design of the cockpit, throttle grip, etc.).

Pilots tend to misprioritise the tasks to be performed more frequently during phases of high workload.

From a psychological perspective, the events may have been (partially) caused by the following factors in the case of this accident:

Seven autorotation exercises had already been successfully performed, which may have led to tiredness. The fact that the landing approach was too high during the eighth exercise may have put additional strain on the flight instructor’s cognitive resources. The primary task (flying) may also have been influenced by secondary and tertiary tasks (navigation, explanations, checks, etc.). It is conceivable that this concentration of demands temporarily led to a brief state of cognitive saturation explaining why an important part of the primary task (opening of the throttle twist grip) was forgotten.

Perceptual and memory errors have been a well-established and much-researched phenomenon in psychology for over a century. Perception and memory depend on factors such as assimilation, storage and recall. Research has frequently been carried out on witness statements and has shown that they can sometimes unintentionally differ significantly from reality. Mistakes and distortions can slip in during each of the phases of assimilation, storage and recall of the events experienced.

In the present case, there is also the possibility that the crew experienced perceptual or memory errors concerning the use of the throttle grip. This could occur because the assimilation, storage and recall of the relevant information – influenced by previous procedures in the helicopter or possibly limited or influenced by factors such as stress, ‘tunnel memory’ or ‘expectation effect’ – may not accurately reflect what actually happened.

[9] A "sharp" autorotation is a common term in aviation and describes the execution of an emergency landing without engine power until a complete landing is made. In contrast, during an autorotation exercise with power recovery, the helicopter is brought into a stable hover with engine power after the flare manoeuvre.

3 Conclusions

3.1 Findings

3.1.1 Technical aspects

- The helicopter was authorised to fly.
- Both the helicopter's mass and centre of gravity were within the permitted limits set out in the flight manual for the duration of the entire flight.
- The investigation did not produce any indications of pre-existing technical faults that could have caused or influenced the accident.
- The last scheduled maintenance work was certified on 10 September 2021 at 199:05 operating hours during a 100-hour inspection.
- The flexible tail rotor push-pull control was ripped out due to the main rotor blade hitting the tail boom.
- The throttle correlation cam was broken.
- This breakage was most probably caused by the tail rotor control cable being pulled out, which can only happen if the throttle twist grip is closed or in idle position.
- The engine worked perfectly on the test bench and all parameters measured were within the operational limits defined by the manufacturer.

3.1.2 Crew

- The flight instructor held the documents required for the flight.

3.1.3 Verlauf des schweren Vorfalls

- The crew took off in the HB-ZVK helicopter from Pfaffnau heliport at 13:37 for a training flight.
- The trainee pilot performed seven autorotation exercises whereby the flight instructor closed the throttle twist grip without advance warning during the flight and the trainee pilot initiated autorotation.
- At around 200 metres above the ground, the flight instructor re-opened the throttle twist grip.
- In the subsequent eighth autorotation exercise, the main rotor speed fell during the flare manoeuvre. As a result, the autorotation had to be completed without engine power until landing (so-called "sharp" autorotation).
- The helicopter hit the ground hard.
- The crew was uninjured.
- The weather had no influence on the accident.

3.2 Causes

To achieve its purpose of prevention, a transportation safety investigation board must address the risks and dangers involved in the investigated incident and which should be avoided in future. The terms and wording used below are only to be interpreted in terms of prevention. The establishment of the causes and contributing factors does not attribute blame in any way or determine liability under administrative, civil or criminal law.

The accident, where the helicopter hit the ground hard during an autorotation exercise, was due to the main rotor speed falling unexpectedly during the flare manoeuvre and therefore the autorotation had to be completed without engine power until landing ("sharp" autorotation).

The findings from the investigation suggest that the throttle handle was not open, which is why the engine was unable to deliver the required power to transition the helicopter to a stabilized, powered flight state (autorotation with power recovery).

4 Safety recommendations, safety advice and measures taken since the schweren Vorfall

4.1 Safety recommendations

None

4.2 Safety advices

None

4.3 Measures taken since the schweren Vorfall

None

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

Bern, 23 March 2024 Swiss Transportation Safety Investigation Board