Final report no. 2430
of the Swiss
Transportation Safety Investigation Board STSB

concerning the accident of the helicopter Bell 505 Jet Ranger X, HB-ZWC,

on March 12, 2024

Egg, 3 km south of Weinfelden, municipality of Bussnang (TG)

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General information on this report

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

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

The definitive version of this report is the original report in German.

All information, unless otherwise indicated, relates to the time of the accident.

All times in this report, unless otherwise indicated, are stated in Local time (LT), valid for the territory of Switzerland, which corresponds to Central European Time (CET) at the time of the accident. The relation between LT, CET and Coordinated Universal Time (UTC) is:

LT = CET = UTC + 1 hour.

[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 28 November 2024 (SR *0.748.0*).

Article 24 of the Federal Aviation Law of 21 December 1948, as amended on 1 January 2025 (LFG, 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 Transport Incidents, as amended on 1 January 2025 (OSITI, SR *742.161*).

Summary

Aircraft type	Bell 505 Jet Ranger X	HB-ZWC
Operator	Heli Sitterdorf AG, Flugplatz, 8589 Sitterdorf	
Owner	Heli Sitterdorf AG, Flugplatz, 8589 Sitterdorf	

Flight instructor	Swiss citizen, born in 1968
Licence	Commercial Pilot Licence Helicopter (CPL(H)) according to the European Union Aviation Safety Agency (EASA), issued by the Federal Office of Civil Aviation (FOCA)

Flight experience				
	Total	1544:37 h	**Within the last 90 days**	79:48 h
	on the [Unfall / schweren Vorfall]	145:37 h	**Within the last 90 days**	15:03 h

Student pilot	German citizen, born in 1965
Licence	None (in training)

Flight experience				
	Total	7:31 h	**Within the last 90 days**	7:31 h
	on the type involved in the accident	7:31 h	**Within the last 90 days**	7:31 h

Location	Egg, 3 km south of Weinfelden, municipality of Bussnang (TG)		
Coordinates	726 122 / 266 832 (Swiss Grid 1903) N 47° 32' 24'' / E 9° 06' 50'' (WGS[2] 84)	**Altitude**	500 m/M
Date and time	12 March 2024, 11:40 LT		

Type of operation	Training
Flight rules	Visual Flight Rules (VFR)
Point of departure	Sitterdorf aerodrome (LSZV)
Destination	Sitterdorf aerodrome (LSZV)
Flight phase	On the ground/taxiing or taxiing
Type of accident	Loss of control on ground

Injuries to persons

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

Damage to aircraft	Severely damaged
Other damage	Minor damage to the ground surface

[2] WGS: World Geodetic System, geodetic reference system: The WGS 84 standard was adopted for aviation by the International Civil Aviation Organization (ICAO) in 1989.

1 Factual information

1.1 Pre-flight history and history of the flight

1.1.1 General

The following description of the pre-flight history and course of the flight is based on the information provided by the flight crew and the recordings of the on-board navigation instruments.

It was a training flight as part of the basic training for obtaining a private pilot's license.

1.1.2 Pre-flight history

The flight instructor began his working day at the aerodrome of Sitterdorf (LSZV) by preparing the Bell 505 helicopter, registered as HB-ZWC, for the planned training flight. He carried out a pre-flight check and found no defects on the helicopter. He then refueled the helicopter to a quantity of 455 lb with Jet A-1 fuel, enriched with an anti-icing additive.

At around 09:50, the flight instructor began the flight preparation with the student pilot. The flight crew discussed the weather data, the weight and center of gravity calculations and the planned exercises. The focus of the flight program was on exercises for attitude flying, lifting off and touching down the helicopter and reconnaissance of a landing site in a field.

1.1.3 History of flight

At 11:07, the flight crew took off with the HB-ZWC from the helipad in front of the hangar and flew south according to the defined helicopter route. Attitude flight exercises were carried out on the way to the planned landing site in Egg (municipality of Bussnang, TG).

At 11:29, the flight instructor demonstrated the reconnaissance procedure, followed by an approach to hover. This was followed by hovering exercises for around two minutes (see Figure 1 , A, B and C). Due to the south-westerly wind direction, with a strength of 10 to 13 kt and gusts of up to 20 kt, the helicopter nose was facing west.

After landing, which took place around 60 m further west of the location of the hovering exercises (see Figure 1 , D), a debriefing took place for around two minutes with the rotor running. Among other things, the particular attention required at the controls during lift off and touch-down was discussed. During this debriefing, the flight instructor demonstrated how the downwash of the helicopter could be seen visually in the meadow by raising and lowering the collective pitch control slightly for several times. The flight crew then began, without time pressure, preparations for take-off in a westerly direction.

At 11:39:44, the student pilot began to lift off, slowly raising the collective. Around 10 seconds later, the helicopter began a rapid and accelerating rolling movement to the right around the longitudinal axis (dynamic rollover). In the next 4 seconds, the lateral attitude changed from around 0.6° to the left to around 21.6° to the right. At this point, the instructor instinctively tried to stop the rolling movement by quickly lowering the collective (see Figure 2), but was unsuccessful. The last recorded bank angle at 11:39:59 was around 38.5° to the right (see Figure 2).

The helicopter tilted further to the right, the rotor blades hit the ground, and the main rotor was separated.

The flight instructor immediately shut off the engine. Both occupants then left the helicopter independently. The flight instructor suffered a minor head injury, and the student pilot complained of a slight back pain.

The emergency locator transmitter (ELT) was not triggered by the accident. No fuel leaked and no fire broke out.

Figure 1 : Last part of the flight path before the accident. Area B (red circle) between A and C corresponds to the point where hovering exercises were carried out for about two minutes. D corresponds to the touchdown point and E to the final position of the helicopter. Source of the base map: Swisstopo, edited by the STSB.

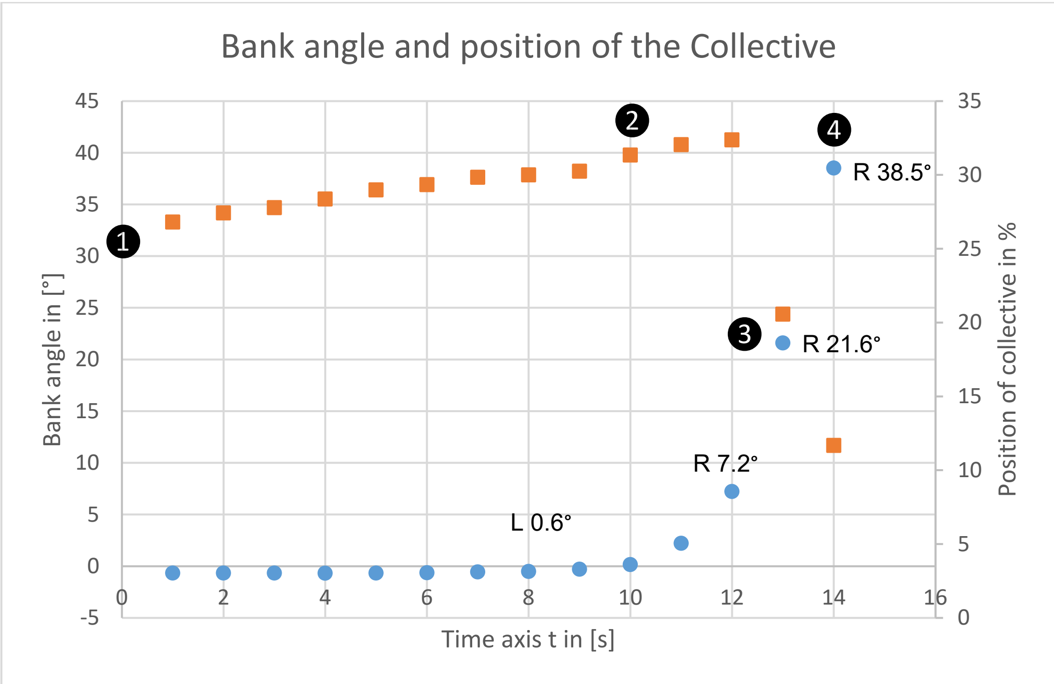

Figure 2 : Recordings of the on-board navigation instruments for the last 16 seconds before the accident, indicating the bank angle in degrees (blue dots) and the position of the collective in % (orange squares) with the start of the lift-off procedure ❶ and the increasing bank angle ❷ as well as a variation of the collective with subsequent rapid reduction ❸ up to the last recorded data point of the bank angle ❹.

1.2 Aircraft information

1.2.1 General information

The Bell 505 Jet Ranger X is a five-seater, single-engine turbine helicopter. The helicopter has a skid landing gear and a conventional tail rotor with non-hydraulically assisted control. The two-bladed main rotor rotates counterclockwise when viewed from above and is controlled via hydraulically assisted control rods.

The helicopter was equipped with an Arrius 2R turboshaft engine manufactured by Safran Helicopter Engines. The engine has a take-off power of 522 shp[3].

The HB-ZWC was built in 2019 and imported to Switzerland in March 2020. The helicopter was equipped with a high skid landing gear, which is available as an option, and with step bars and bear paws mounted on both sides to prevent it from sinking into the snow or soft surfaces (see chapter 1.4).

At the time of the accident, the helicopter had around 700 operating hours' Time Since New – (TSN).

1.2.2 Performance and center of gravity calculation

The mass at the time of the accident was around 1450 kg. The performance calculation showed a mass reserve of over 600 kg in the hovering in ground effect (HIGE)[4].

At the time of the accident, the mass and the center of gravity were within the limits permitted by the manufacturer.

1.2.3 Maintenance

The installation of the high skid landing gear and the bear paws were signed off on August 5, 2022.

The last inspection of the bear paws was certified on June 2, 2023, at 606:40 operating hours as part of a 300-hour/12-month inspection.

The last planned maintenance work on the HB-ZWC helicopter was certified on December 15, 2023, at 676:01 operating hours as part of a 100-hour/6-month inspection.

1.3 Findings at the scene of the accident

The helicopter was lying on its right side, the airframe and the tail boom were intact except for the fairings in the upper airframe area (see Figure **3**). The tail boom had broken away and was bent in the area of the attachment points to the airframe. In this area, the tail rotor drive shaft was separated, and the tail rotor control cables were under high tensile stress.

The main rotor mast was broken above the main gearbox; the entire main rotor system was about 20 meters away from the helicopter in the field.

The impact mark of a main rotor blade was visible on the ground to the north of the helicopter cabin. The outer end of one rotor blade was severed by around 40 cm.

[3] shp: *shaft horsepower*, Anglo-Saxon unit for measuring shaft power (1 shp corresponds to 0.746 kW).

[4] Since aerodynamic performance plays a central role in this case, the table for flight with underload is used, which refers to a larger total flight mass.

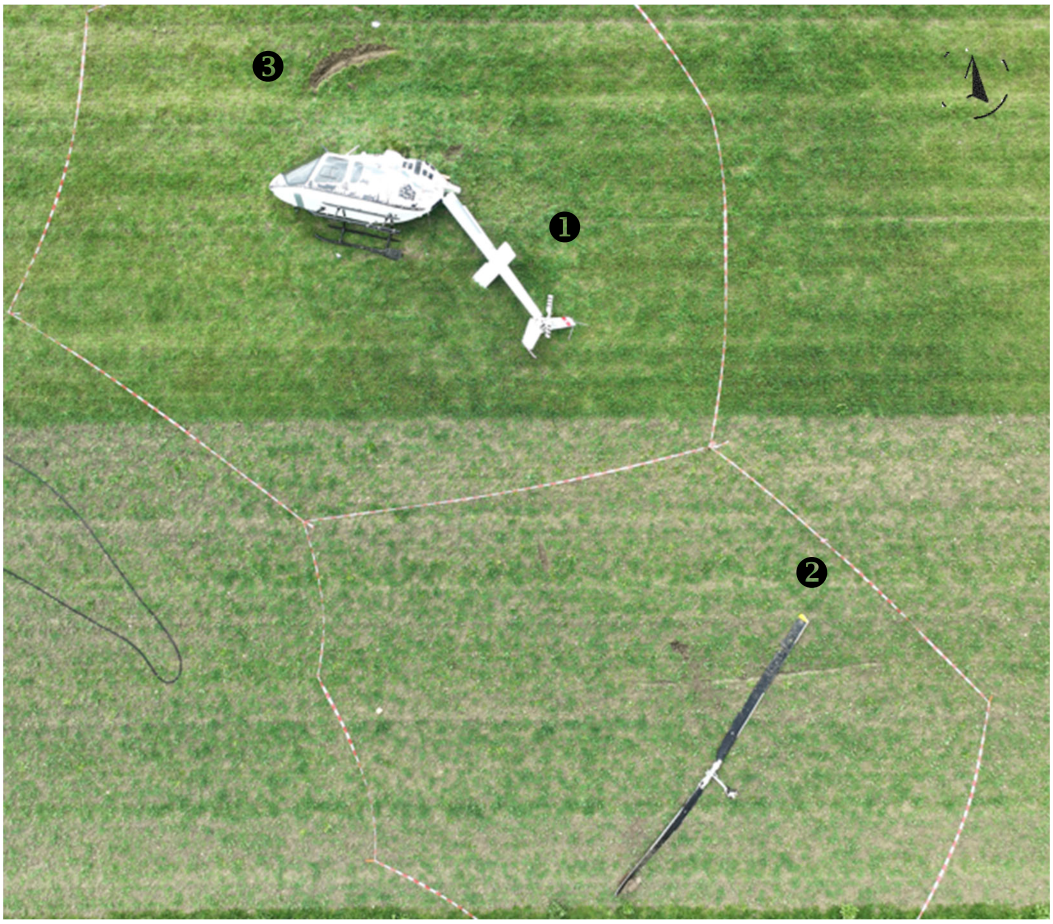

Figure 3 : Final position of the HB-ZWC with bent tail boom 1 and detached main rotor system 2. Above the airframe, the impact mark of a main rotor blade can be seen in the ground 3. Source: Thurgau cantonal police.

The entire tail rotor system including the control system was intact.

The skid landing gear remained undamaged. Bear paws were fitted to both the left and right aft ends of the landing gear skid tubes (see chapter 1.4) to prevent sinking into the snow or a soft surface. The left bear paw was turned slightly inwards.

The bear paw of the right skid was turned markedly inwards. A ground scar was visible close to the bear paw of the right skid which had been pressed sideways into the ground (see Figure 4).

The field sloped slightly to the south. The ground was soaked and soft.

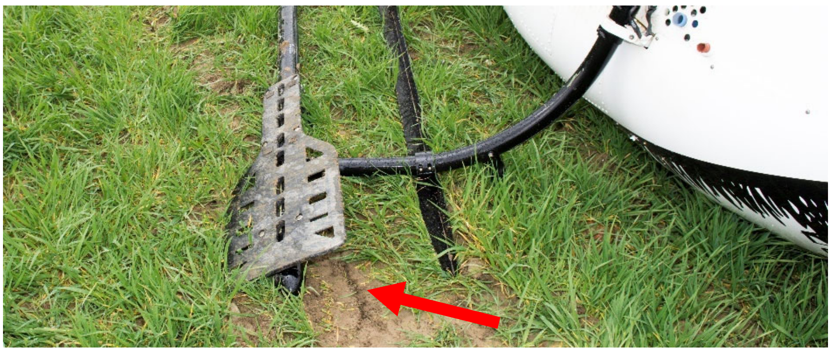

Figure 4 : Right skid with bear paw turned markedly inwards. A ground scar caused by the bear paw pressed laterally into the ground can be seen in the ground (red arrow).

1.4 Information on the settling protection of the skid landing gear

1.4.1 Authorisation

There is a Supplement Type Certificate (STC) for the landing gear bear paw settling protector; this is approved by EASA under the STC number 10065747 for installation on the Bell 505 helicopter type. The STC holder is the company Alpine Aerotech, based in Canada.

Part of this approval is the document AAL-390-025-701, Revision B, "Instruction for Continuing Airworthiness (ICA)", to ensure airworthiness. It contains specific instructions for the assembly/disassembly, maintenance and repair of the bear paws.

1.4.2 Maintenance instructions

In accordance with ICA AAL-390-025-701, the manufacturer requires a daily inspection of the bear paws to be carried out before the first flight of the day. A 300-hour/12-month inspection is also required, depending on which interval limit is reached first. The checkpoints of the respective inspection are listed below:

<u>Daily check</u>

- General inspection of all components for their general condition.
- General inspection of all components to ensure that they are correctly attached.

<u>300-hour/12-month inspection</u>

- Detailed inspection of all components for corrosion, cracks and damage.
- Detailed inspection of all components for excessive wear.
- Detailed inspection of all components for proper integrity and condition.
- Detailed inspection of all components and fastening elements for proper security and torque.

1.4.3 Installation instructions

In the ICA, Chapter 3, "General Notes", the STC holder specifically states that the fasteners must be tightened to the tightening torque listed in the currently valid version of FAA Advisory Circular AC 43.13-1, Table 7-1, unless otherwise specified. All dimensions are given in imperial units (inches/pounds).

According to a precautionary note contained in the installation instructions of the bear paws, the self-locking fastening nuts should initially not be tightened with the full torque while the helicopter is raised off the ground, but only with a minimal torque.

Furthermore, the STC holder specifies that the self-locking fastening nuts (see Figure **5** , No. 1) should only be tightened evenly with a torque wrench to 40 in/lb once the helicopter is back on the ground. It is important to note that a thin-walled socket is required to properly tighten the self-locking fastening nuts. The fastening straps (strap assy; see Figure **5** , No. 4) are labeled with this tightening torque, although the writing was difficult to read.

The screw connections are galvanized round-head screws with square neck and galvanized, self-locking hexagon nuts with plastic insert.

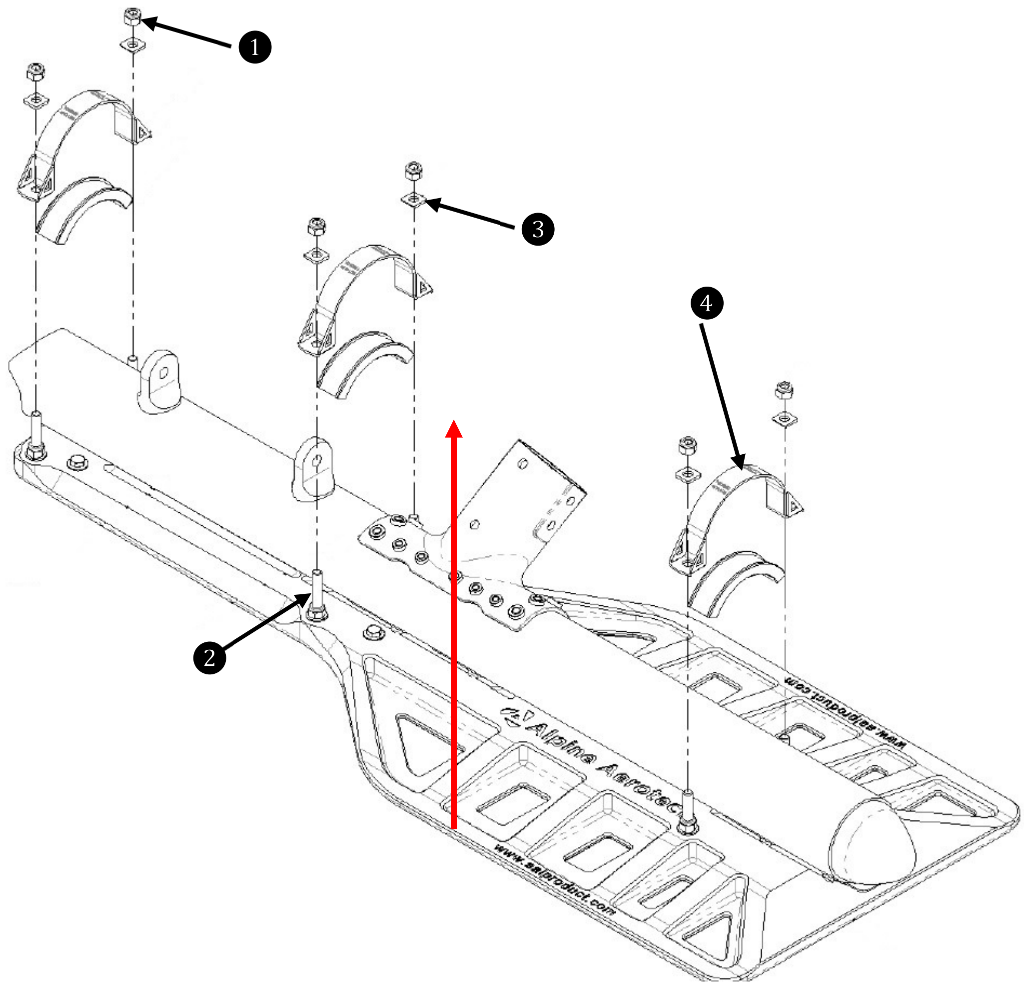

Figure 5 : Assembly drawing of the bear paw with fastening nut ❶, screw ❷, washer ❸ and fastening bracket ❹. The red arrow indicates the point at which the force to turn a bear paw around the longitudinal axis of the runner was measured. Source: ICA of the STC holder.

1.4.4 Instructions in the supplement to the flight manual

The Flight Manual Supplement does not contain any instructions for the flight crew to be observed by them during daily checks or pre-flight checks.

1.5 Technical investigation

1.5.1 General

The HB-ZWC was subjected to a detailed inspection in the presence of representatives of the helicopter manufacturer. All damage could be consistently traced back to the accident. Apart from the loose screws connecting the bear paws (see chapter 1.4), no defects were found on the helicopter.

1.5.2 Settling protection of the skid landing gear

When the helicopter was raised, the bear paws on the left and right skids could be rotated by hand around the longitudinal axis of the respective skid with little effort.

According to the STC holder Alpine Aerotech, the force required to turn a properly tightened bear paw around the longitudinal axis of the skid should be around 220 to 270 N (measured with a spring balance on the outer edge of the bear paw, see red arrow in Figure 5). This value is not noted in the technical documentation (see chapter 1.4.2 and chapter 1.4.4). In this case, the required force was around 20 N.

On the bear paws of the left and right skid, the washers on the 12 bolted connections could be partially moved by hand. The fastening nuts on all bolted connections were turned almost equally onto the bolts or there was the same amount of play between the washers and nuts.

The measured torque for all bolted connections was between 1.5 Nm and 2 Nm (corresponding to 13.3 in/lb and 17.7 in/lb), which corresponds to the tare torque for this type of bolted connection.

1.6 Medical findings

Both crew members were wearing 4-point safety belts, which withstood the strain.

Neither crew member was wearing a pilot's helmet.

The flight instructor, who was in the left-hand seat, suffered a laceration to his head as a result of the impact, which was most probably caused by a structural or control element in the cockpit.

The student pilot stated that he felt slight pain in his back.

1.7 Meteorological information

1.7.1 General weather conditions

Switzerland was on the western edge of a high-altitude low, which was in front of a warm front approaching from the west. Close to the ground, the high with its center over the Pyrenees caused a southwesterly wind.

1.7.2 Weather at the time and location of the accident

The following information on weather, at the time and location of the accident is based on webcam images and measurements taken at a weather station, which were compared with a model analysis for the accident site.

Weather/clouds	Overcast, with base above 4000 ft AMSL[5]
Meteorological visibility	10 km or more
Wind	From 240 degrees with 13 kt, gusts up to 20 kt[6] From 260 degrees with 10 kt
Temperature / dew point	7 °C / 6 °C
Atmospheric pressure (QNH)	QNH[7] LSZR: 1019 hPa
Warnings	None

[5] AMSL - *Above Mean Sea Level*.

[6] According to measurements at Sitterdorf airfield, 12 km east-southeast of the accident site.

[7] Pressure reduced to sea level, calculated with the values of the ICAO standard atmosphere.

1.8 Additional information

1.8.1 Flight characteristics of a helicopter

1.8.1.1 Aerodynamics of the main rotor of a helicopter in ground effect

When a helicopter is close to the ground, an interaction between the air and the ground develops below the rotor, which is known as the ground effect. This phenomenon is particularly noticeable up to a height of the main rotor above the ground that corresponds to about half the rotor diameter. A helicopter hovering under the influence of the ground effect (Hovering In Ground Effect - HIGE) in calm conditions requires up to 30% less power compared to hovering outside of the ground effect (Hovering Out of Ground Effect - HOGE).

If the helicopter begins to move in any direction from a hover (or is blown by the wind), the power required increases exponentially up to a point defined as the translational point. At this point, from an aerodynamic point of view the main rotor transitions from hovering to forward flight (Effective Translational Lift - ETL). Beyond this point, the power required decreases exponentially with the increase in airspeed due to the development of additional lift from the forward motion. Experience shows that this point is reached at a relative wind speed of over 15 kt and is dependent on the type of helicopter. Conversely, it can be said that the rotating main rotor of a helicopter stationary on the ground, which is blown by a wind (or a gust) with a higher speed than the translation speed, (rapidly) experiences an increase in lift.

The increase in lift can also occur when the wind or gust decreases, and the air speed decreases rapidly towards 0 kt[8].

The air, which is pressed to the ground in the HIGE state, leaves the helicopter radially outwards in the area below the main rotor when there is no wind, and the helicopter is stationary or hovering and rises upwards again in a vertical rotary motion. This rising air is outside the rotor blade tips when there is no wind or when hovering. However, it becomes noticeable when the helicopter catches up with this area when picking up speed. This and the increase in speed result in different angles of attack (AoA) in the front and rear areas of the rotor plane: While the rotor disk is lifted in the front area, it is pushed down in the rear area (see Figure 6). This phenomenon is known as the "transverse flow effect".

In combination with the gyroscopic phenomena, which act with a precession of 90°, this results in a lateral deflection. In this case, this is to the right, which results in a rolling movement of the helicopter. This phenomenon is known as "inflow-roll". Conversely, it can also be said here that the rotating main rotor of a helicopter stationary on the ground, which is blown by a wind (or a gust), can develop an "inflow-roll" phenomenon.

[8] See EHEST Leaflet HE 21 Helicopter Performance (EASA), Graph B on the Figure at page 13.

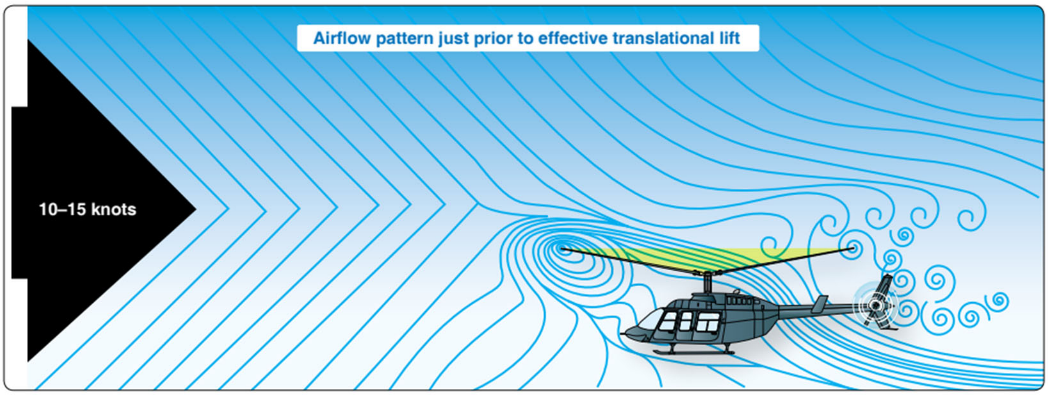

Figure 6 : Airflow around the helicopter at a speed just below the ETL point. Source: FAA Rotorcraft Flying Handbook, Ed. 2019, Fig. 2.40.

1.8.1.2 Dynamic rollover

The distance between the point of application of the aerodynamic forces on the main rotor and the part with which the helicopter touches the ground (typically the wheeled landing gear or skid landing gear) results in a lever arm that can lead to a roll or pitch tendency. The rotor blades have a limited range of motion in the flapping direction[9], as described in a generic way in the FAA Helicopter Flying Handbook (FAA, Ed. 2019)[10]. If the longitudinal or roll attitude angle of a helicopter exceeds this range, which is specified as 5 to 8°, the maneuverability provided by the cyclic blade pitch is no longer sufficient to keep the lift force vertical. A lateral component develops which causes the helicopter to tip.

This phenomenon is known as dynamic rollover.

The lateral component can only be reduced by reducing the total lift with a lowering of the collective lever.

In the case of a helicopter with a main rotor rotating counterclockwise from a bird's eye view, winds coming from the front left quadrant (see chapter 1.8.1) and inputs of the tail rotor control to the left increase the risk of a dynamic rollover (see also the summary report on the accident involving the B505 HB-ZWR helicopter). If a skid is stuck to the ground for any reason - as in this case the right skid - a momentum is generated around the longitudinal axis, which inevitably converts the upward or downward movement of the helicopter into a rolling movement.

[9] The rotor blades or the rotor head rotate around the flapping hinge in the flapping direction and the rotor blade tips move up and down accordingly.

[10] FAA: Federal Aviation Administration.

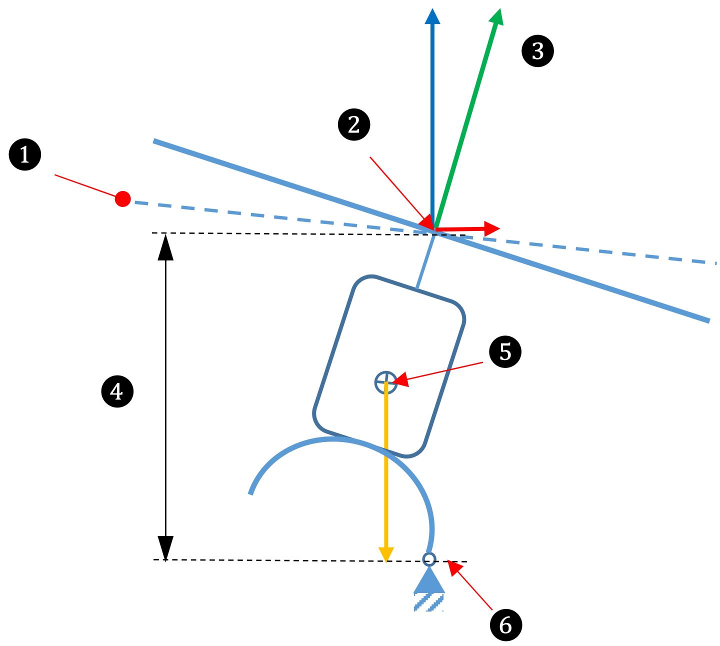

Figure 7: Schematic representation of the dynamic rollover with a helicopter in the direction of flight. Maximum deflection of the main rotor plane to the left ❶; point of application of the aerodynamic forces on the main rotor head ❷; resulting aerodynamic force (perpendicular to the rotor plane, green vector) ❸, lateral component (red vector), vertical lift component (blue vector); lever arm ❹ between the point of application of the aerodynamic forces ❷ and the point of contact on the ground ❻; center of gravity of the helicopter with the weight force (orange vector) ❺; point of contact on the ground of the skid incl. bear paw ❻.

1.8.2 Application of bolted connections in aviation

1.8.2.1 Determining the total tightening torque

FAA Advisory Circular AC 43.13-1B contains methods, techniques and procedures of well-defined inspections and repairs. The STC holder of bear paws refers in its ICA to AC 43.13-1 regarding the application of the correct tightening torque.

According to AC 43.13-1, unless otherwise specified by the manufacturer, the threads of the bolt and nut must be dry and clean before the self-locking fastening nut is screwed onto the bolt.

To determine the tare torque, the self-locking fastening nut is turned until it is almost in contact with the washer or bearing surface and the torque is measured using a torque wrench with a dial gauge. The tare torque is then added to the recommended or desired torque to obtain the final torque.

It is also possible to read off the total tightening torque in a table in AC 43.13-1. This table contains the recommended torque limit values based on the bolt diameter. However, it should be noted that the torque values listed only apply to cadmium-plated steel nuts of the fine or coarse thread series currently used in the aircraft industry.

1.8.2.2 Safety instructions from the helicopter manufacturer

On May 16, 2024, the helicopter manufacturer published the Operation Safety Notice GEN-24-53 due to occasional discrepancies reported to the manufacturer in component installations or components showing signs of wear due to loss of clamping force or loose connections caused by incorrectly tightened fasteners.

Some recent events have indicated that the correct torque values were not always applied when using self-locking fasteners. It is particularly problematic when fasteners remain in service even though they should have been replaced due to damage or failure to reach the required minimum torque value. When mounting tail or main rotor drive shafts, for example, an incorrect torque of the fastening elements can lead to the bolt breaking and thus to the failure of the drive system concerned.

The use of colored torque seal is strongly recommended by the manufacturer. The primary function of applying torque seal is to indicate that the correct final torque has been applied to the fasteners. A secondary function of the torque seal is to provide visual indication of fasteners that may have lost torque during operation. Damaged or missing torque seal may indicate fastener movement and the loss of clamp load connection.

2 Analysis

2.1 Technical aspects

The right bear paw was found markedly rotated inwards, the left bear paw slightly rotated inwards (cf. Figure 4).

Both bear paws could be rotated by hand around the longitudinal axis of the respective skid with little effort. This most likely resulted in the right bear paw rotating against resistance on the ground and pushing it into the soft surface while the helicopter was moving sideways, either during landing or take-off. This made the right skid the pivot point of the dynamic rollover. This circumstance is considered a contributing factor to the accident.

Based on the findings of the bolted connections on the bear paws, it can be concluded that all self-locking fastening nuts of the bear paws were not tightened to the correct final torque, consisting of the friction drag torque or tare torque and the desired torque or recommended torque of 40 in/lb.

The torque value found on the bolted connections corresponded only to the tare torque for this type of fasteners. Whether this was due to the use of an unsuitable socket wrench insert with an excessively thick wall, contrary to the STC holder's instructions in the installation and maintenance documents, or due to an incomplete installation process, remains open.

The bear paws, which were practically loose due to the insufficient tightening torque of the fastening nuts, were not detected either after installation or during the last 300-hour/12-month inspection, nor during the daily inspection in accordance with the ICA.

According to the STC holder, the force required to turn a bear paw on the skid tube should be between 220 and 270 N. However, this value was not mentioned in the installation and maintenance documents. A corresponding checklist item on the installation instructions and in the flight manual supplement would most likely have made it possible to detect the loosely installed bear paws, which is why the STSB issues a safety advice (see chapter 4.2.1).

Since it is difficult to check whether the installation and the torque are correct when the helicopter is standing on the ground with its skids, the daily inspection is of great importance.

2.2 Human and operational aspects

The crew discussed the weather conditions and also the prevailing wind during the flight preparation and thus were aware of this. The flight instructor also discussed the careful control inputs that are necessary when lifting off or touching down the helicopter. The recordings of the position of the collective prove the slow movement.

The exercises and demonstrations flown during the field landing were mainly in one direction, so that the wind was always in the front left quadrant, which corresponds to common practice and the information in the flight manual.

At the time of the accident, the helicopter had a mass of around 1450 kg, which reduced the inertial stability on the one hand and influenced dynamic stability on the other. The dynamic stability was also reduced by the rather high-power reserve of around 28%, especially as even small changes in lift have a noticeable effect on the helicopter.

Due to the aerodynamics of the main rotor (see chapter 1.8.1) and the prevailing, moderately gusty wind conditions, it is possible that the helicopter was caught by a gust of wind from the front left quadrant and the wind speed rose above the ETL point. This constellation reduces the required hovering power. Furthermore, it cannot be ruled out that the wind speed around the ETL point decreased due to the abrupt decrease of a gust, which also caused an excess of power.

In combination with the lift that had already been generated to overcome the transverse flow, an unexpected deflection of the rotor plane occurred, which suddenly exacerbated the developing situation of dynamic rollover.

As a dynamic rollover can only be effectively countered up to a lateral position of 8 to 10 degrees, the time for the instructor to intervene was limited to less than two seconds. In addition, two-bladed rotors are known to react relatively slowly to control movements and the tendency to roll over is increased by the high center of gravity (high skid landing gear). For these reasons, the flight instructor was no longer able to prevent the helicopter from tipping over.

The head injuries suffered by one crew member could in all probability have been prevented by wearing an integral pilot helmet[11].

The fact that special attention is required when a helicopter lifts off in winds from the front two quadrants and at speeds corresponding to the Effective Translational Lift (ETL) point is not sufficiently considered in the current theoretical principles and manuals, particularly in connection with the risk of a dynamic rollover. For this reason, the STSB issues a safety advice (see chapter 4.2.2).

[11] The STSB has already issued a safety recommendation on this subject in its final report on the HB-XQS helicopter accident of March 5, 2006.

3 Conclusions

3.1 Findings

3.1.1 Technical aspects

- The helicopter was authorized to fly according to Visual Flight Rules – VFR.
- Both the helicopter's mass and center of gravity were within the permitted limits of the flight manual at the time of the accident.
- The last inspection of the bear paws was certified on June 2, 2023, at 606:40 operating hours as part of a 300-hour/12-month inspection.
- The bolted connections on the bear paws were loose, which meant that the bear paws could rotate around the longitudinal axis of the respective skid without much force being applied.
- The emergency locator transmitter (ELT) was not triggered.

3.1.2 Crew

- The crew had the required licences for the flight.
- There are no indications that the crew suffered any health impairments during the[Unfall / schweren Vorfall] .

3.1.3 Accident Flight

- The training flight took off at 11:07 and was uneventful until the next touchdown at a field landing site.
- During the subsequent take-off procedure, the helicopter rolled onto its right side within 4 seconds (dynamic rollover). Despite countermeasures taken by the flight instructor, the rollover process could not be stopped in time.

3.1.4 General conditions

- The wind came from the front left quadrant with moderate gusts and a speed of 10 to 20 kt.
- The helicopter was equipped with a high landing gear.
- The mass at the time of the accident was around 1450 kg, resulting in a mass reserve of around 600 kg or 28% in relation to the available power.

3.2 Causes

In order to achieve its objective of prevention, a safety investigation authority shall express its opinion on risks and hazards that have been identified during the investigated accident and which should be avoided in the future. In this sense, the terms and formulations used below are to be understood exclusively from the perspective of prevention. The determination of causes and contributory factors does not, in any way imply the assignment of blame or the determination of administrative, civil or criminal liability.

The[Unfall / schweren Vorfall], in which the helicopter rolled over onto its right side, was due to fact that the flight instructor was unable to stop the dynamic rollover that developed during the lift-off process.

The following factors contributed to the accident:

- Loose bolt connections of the bear paws, which led to the right-hand bear paw twisting, getting stuck in the ground and thus becoming the pivot point of the dynamic rollover.
- The combination of wind speeds within the range of the translation speed, a wind direction from the front left quadrant, a high landing gear and a high-power reserve due to the low mass of the helicopter.

4 Safety recommendations, safety advice and measures taken since the accident

4.1 Safety recommendations

According to international[12] and national[13] legal bases, all safety recommendations are addressed to the supervisory authority of the competent state. In Switzerland, this is the Federal Office of Civil Aviation (FOCA) or the supranational European Union Aviation Safety Agency (EASA). The competent supervisory authority must decide on the extent to which these recommendations are to be implemented. Nonetheless, any agency, organization and individual is invited to strive to improve aviation safety in the spirit of the safety recommendations expressed.

The STSB shall publish the anwers of the relevant federal office or foreign supervisory authorities at http://www.sust.admin.ch to provide an overview of the current implementation status of the relevant safety recommendation.

None

4.2 Safety advice

The STSB may publish general relevant information in the form of safety advice[14] if a safety recommendation in accordance with Regulation (EU) No. 996/2010 does not appear to be appropriate, is not formally possible, or if the less prescriptive form of safety advice is likely to have a greater effect.

4.2.1 Check for correct installation of the bear paws

4.2.1.1 Safety deficit

A Bell 505 Jet Ranger X helicopter was equipped with a settling protection - bear paws system by means of a Supplemental Type Certificate (STC).

The STC holder's supplement to the flight manual does not contain any information on the procedures for checking the security of the bear paws seat during flight operations. These are only described in general terms in the Instruction for Continued Airworthiness (ICA), and should be applied by trained personnel during daily and periodic checks.

The loose bolted connections of the bear paws went unnoticed for a long time. The loose installation contributed to the accident because the bear paws could easily turn around the skid and thus become the pivot point of the dynamic rollover.

4.2.1.2 Safety advice No. 64

Target group: STC holders of bear paws Alpine Aerotech, maintenance companies and owners of helicopters equipped with bear paws.

The persons addressed by the safety notice should ensure that the maintenance and flight personnel have appropriate information so that the fit and strength of the

[12] Annex 13 of the *International Civil Aviation* Organization (ICAO) and Article 17 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.

[13] Article 48 of the Ordinance on the Safety Investigation of Transport Incidents (of December 17, 2014, as of January 1, 2025 (VSZV, SR *742.161*).

[14] Article 56 of the Ordinance on the Safety Investigation of Transport Incidents of December 17, 2014, as of January 1, 2025 (VSZV, SR *742.161*).

installation can be checked effectively during installation and during the periodic and daily checks of the bear paws.

4.2.2 Operation of helicopters in the air speed range of effective translational lift

4.2.2.1 Safety deficit

A Bell 505 Jet Ranger X helicopter rolled over onto its right side due to a dynamic rollover. The helicopter was equipped with a high landing gear, had a calculated mass reserve of more than 28% and was operated at wind speeds with light gusts between 10 and 20 kt, which came from the front left quadrant. This corresponds to the air speed at which the transition to Effective Translational Lift (ETL) takes place and the inflow roll phenomenon becomes more noticeable.

The fact that special attention must be paid when a helicopter takes off with wind from the front two quadrants and at speeds corresponding to the Effective Translational Lift (ETL) point is given too little consideration in the current theoretical principles and manuals in connection with a dynamic rollover event.

4.2.2.2 Safety advice no. 65

Target group: Flight crews and flight schools

Flight crews should be made aware of the influence of inflow roll at wind speeds in the range of the ETL point in connection with the development of a dynamic rollover condition.

4.3 Measures taken since the accident

The measures known to the STSB are listed below without comment.

None

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

Bern, 11 March 2025 Swiss Transportation Safety Investigation Board