HELICOPTER CRASH DURING A PHOTO FLIGHT

In the Netherlands, efforts are made to limit the risk of accidents and incidents as much as possible. However, when incidents or near incidents do occur, repetition can be avoided by carrying out a proper investigation into the cause, without seeking to apportion blame. It is essential that the investigation takes place independently of the parties involved. The Dutch Safety Board itself therefore decides when to conduct an investigation, and during these investigations takes into account citizens' dependence on authorities and companies. In a number of cases, the Safety Board is legally obliged to carry out an investigation.[1]

GENERAL INFORMATION

Incident number:	2010042
Classification:	Accident
Date and time of incident:	27 June 2010, around 12.55 hours[2]
Location of incident:	Maasvlakte, municipality of Rotterdam
Registration:	PH-ECJ
Aircraft model:	Eurocopter EC 130 B4
Aircraft type:	Helicopter
Flight type:	Photo flight
Flight phase:	Hover
Damage to the aircraft:	Completely destroyed
Number of crew members:	One
Number of passengers:	Four
Injuries:	Four people died, one person was severely injured
Other damage:	Environmental damage
Light conditions:	Daylight

[1] The Safety Board's investigations explicitly do not seek to apportion blame or liability. Statements made in the context of a Safety Board investigation, information gathered by the Safety Board, results of technical examination and analyses, and documents produced (including the published report) cannot be used as evidence in criminal, disciplinary or civil proceedings.

[2] All times in this report are local times unless stated otherwise.

SUMMARY

The helicopter was carrying out a photo flight over the Maasvlakte, where a cycle race was being held. The passengers, three photographers and an organisation staff member were taking photographs of the cyclists. While the helicopter was hovering on the spot at low altitude, the aircraft suddenly rotated rapidly around its normal axis and lost some altitude. This rotation did not stop, and the helicopter rapidly lost altitude. The helicopter crashed at a high vertical speed. Four of the occupants, including the pilot, died as a result of the impact, and the fifth occupant was severely injured. The helicopter was completely destroyed.

1. FACTUAL INFORMATION

1.1 Course of the flight

The helicopter with registration PH-ECJ departed at around 11:00 hours on 27 June 2010 from Amsterdam Heliport for a flight to Rotterdam The Hague Airport. The pilot was the sole occupant. The estimated quantity of fuel on board was 427 kg, the maximum quantity. The PH-ECJ was hired to carry out a photo flight of the Tour du Port, a cycle race that was being held on the Maasvlakte. Three photographers and an organisation staff member were due to embark at Rotterdam airport for this purpose. The helicopter arrived there at around 11:25 hours, and the passengers subsequently embarked. The pilot sat in the front left seat, the organisation staff member next to him and a photographer in the front right seat. The two other photographers sat at the rear of the helicopter on the left seat and the adjacent seat. The two right seats at the rear of the helicopter were unoccupied. The PH-ECJ took off at 12:12 hours and flew to the Maasvlakte. Radar images show that the helicopter arrived at this location at around 12:20 hours and circled above the Maasvlakte and the environs of Brielle and Oostvoorne for around half an hour. The helicopter then flew to the area where the cycle race was taking place.

The cycle race organisers had also hired a second helicopter to record video footage. On board this helicopter were the pilot and a cameraman. Both helicopters flew above the Maasvlakte and took shots of the cyclists. At around 12:55 hours, the cyclists rode along Westplaatweg in a north-easterly direction. The helicopter carrying the cameraman flew at the end of the group and the PH-ECJ carrying the photographers was at that point hovering on the spot over the Westplaatweg, ahead of the group of cyclists, so that the cyclists were travelling towards it. The left rear door of the helicopter was opened. The helicopter was hovering at an altitude of around 220 feet[3] above the road with the longitudinal axis transverse to the road, whereby the right side of the helicopter was facing the direction from which the cyclists were approaching. The photographer seated in the front was sitting on this side, while the two other photographers were sitting on the other side. The helicopter suddenly rotated rapidly around its normal axis and lost some altitude. The rotation did not stop, and the helicopter subsequently rapidly lost altitude and after a number of seconds collided sharply with the ground.

[3] Around 67 metres.

Figure 1: the PH-ECJ after the accident.

Help arrived almost immediately due to the cycle race. Those who were first to arrive at the scene stated that the person who had been sitting in the front right seat of the helicopter was lying next to the helicopter, while the remaining occupants were still inside the helicopter. Three occupants died during or shortly after the accident, the two others were severely injured and were taken to the hospital where one later died. The helicopter was completely destroyed (see figure 1).

A number of witnesses to the accident were interviewed. Although the statements varied, the similarities were that everyone saw the helicopter hovering on the spot over the road at a low altitude, suddenly start to rotate and rapidly lose altitude. The helicopter hit the ground in a matter of seconds. A number of the witnesses stated that the helicopter rotated towards the right, while others stated that the helicopter rotated towards the left. The sole passenger to survive the accident was unable to remember the accident.

1.2 Injury

Injury	*Crew*	*Passengers*	*Total*
Died	1	3	4
Seriously injured	-	1	1
Lightly injured	-	-	-
Total	1	4	5

Table 1: overview of injuries sustained by the occupants.

1.3 Damage to the helicopter

The helicopter's landing gear was severely damaged. The entire front of the helicopter was knocked off; only the bottom plate was left. The dashboard, the fuel shut-off handles and the rotor brake in the cockpit were consequently missing, amongst other things.

The main gear box and main rotor head system[4] had been partly torn loose from the fuselage and was leaning over to the left. Three of the four gearbox supports were broken. The three main rotor blades were severely damaged and partly broken, and the rotor blade suspension system on the rotor mast was also severely damaged.

[4] Gear box and rotor head

The tail and the tail rotor sustained relatively minor damage. The tail was cracked at the junction with the fuselage and was bent to the right in relation to the fuselage. The underside of the tail was knocked away to the right at the level of the tail rotor.

Of the second pilot's control instruments, at the middle seat, the cyclic[5] had been removed prior to the flight. The collective[6] and pedals were not removed or covered prior to the flight. The middle seat and the right pedal were cut away by the emergency services after the accident in order to free the victim who had been sitting in the middle seat and whose foot was trapped underneath the pedal. The occupant who was severely injured was sitting on the left rear seat in the cabin.

1.4 Other damage

The ground where the helicopter landed was contaminated with fuel and was later dug up.

1.5 Crew

The pilot was a 54-year-old male. He flew for the helicopter company on an on-call basis, whereby he carried out an average of two flights per week. He had held a Dutch commercial pilot licence for helicopters (CPL(H)) since 1993. He was qualified to operate three types of helicopter. He followed the EC 130 B4 type training between 28 November 2007 and 12 December 2007. This training course consisted of eight hours of theory training and five hours of practical training. He carried out a 'prof check' flight for the helicopter types EC 120B and EC 130 B4 on 9 October 2009. He passed all of the test components.

The pilot's logbook was not found. It was not on board the helicopter, it was not at his home and it was also not at the helicopter company. The number of flight hours in the overview has been calculated based on the logbooks of a number of helicopters and a personal record from December 2008. The last two flights he had carried out with the EC 130 B4 were on 26 May and 10 June 2010, and lasted 1:41 and 2:11 hours respectively. These were transport flights.
He held a valid class 1 and 2 medical certificate, valid until 7 April 2011 with the endorsement 'commercial single-pilot with pax'[7], valid until 7 October 2010.

Records from the helicopter company showed that he carried out different types of flights, including transportation flights, scenic flights and 'relay' flights, which are used to transmit radio or tv images. He was not very experienced in performing photo and film flights.

Type of licence	CPL(H) since 17 August 1993
Type rating	EC 130 B4, captain, VFR, valid until 1 November 2010 Bell 206/206L, captain, VFR, valid until 1 July 2011 EC120, captain, VFR, valid until 1 November 2010.
Ratings	RT/VFR flights only
Total number of hours	Approximately 1580 hours
Number of hours for type	87 hours

Table 2: pilot's licence details and flight hours.

[5] The cyclic is a control instrument used to change the pitch of the blades of the main rotor individually. This ultimately causes the helicopter move forwards, backwards or sideways. The cyclic is usually located in front of the pilot.
[6] The collective is a control instrument used to change the pitch of the main rotor blades collectively, causing the helicopter to climb or descend. The collective is usually located on the left side of the pilot's seat. Changing the pitch of the blades also changes the power.
[7] Commercial transport of passengers as the sole pilot.

1.6 Helicopter

Registration: PH-ECJ
Aircraft model: Eurocopter EC 130 B4
Manufacturing serial number: 3604
Year of manufacture: 2002
Certificate of airworthiness: valid from 2 February 2010 to 20 February 2011
Certificate of registration: issued on 20 February 2003

The Eurocopter EC 130 B4 is equipped with a gas turbine, make and model Turbomeca Arriel 2B1.

The PH-ECJ was a single-engine helicopter with seven seats, three at the front and four at the rear. According to the flight manual, the pilot sits in the front left seat and the second pilot, where present, in the middle seat. The helicopter has a tri-blade main rotor that rotates to the right, and has a Fenestron tail rotor.[8] There are a number of differences between the conventional tail rotor and the Fenestron. The Fenestron is built into the tail and the tail rotor has a smaller diameter. In spite of its smaller diameter, the Fenestron generates the same amount of airflow as a conventional tail rotor. However, the Fenestron requires greater pedal pressure when hovering in order to initiate or stop a rotation than the conventional tail rotor.

On 14 May 2010 a 100-hour inspection was carried out on the PH-ECJ. The helicopter had 666.54 flight hours at that time. No defects were found in the engine or the airframe. All the applicable Airworthiness Directives (ADs) and Service Bulletins (SB) had been complied with. Up to the day of the accident, the helicopter had flown 679:02 hours. On the day before the accident, the PH-ECJ carried out five flights with a total flight time of 4:20 hours. Nothing out of the ordinary was noticed during these flights.

The helicopter had a maximum permitted takeoff weight of 2427 kg. At the time of the accident, the estimated weight of the helicopter was approximately 2084 kg. The centre of gravity was 3.2546 meters from the reference point.

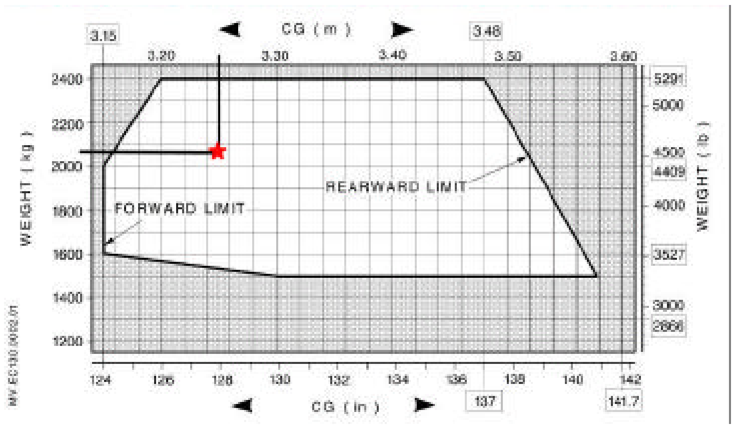


Figure 2: diagram showing weight and centre of gravity.

1.7 Meteorological data

According to reports from the Royal Netherlands Meteorological Institute (KNMI) the weather in the area at the time of the accident was as follows:

[8] The Fenestron is a tail rotor that is built into the tail of the helicopter. The rotor consists of a number of small rotor blades whose pitch is changed collectively, thereby increasing or reducing the lateral force on the tail.

General:	On the flank of an area of high pressure with the centre above the Baltic Sea, a weak easterly current was bringing dry, unstable air.
Wind:	On the ground: 360 degrees 10 knots 500 feet: 010 degrees 5 knots 1000 feet: 020 degrees 5 knots
Temperature	On the ground: 25 °C 500 feet: 23 °C 1000 feet: 22 °C
Visibility	More than 10 kilometres
Cloud	None
Ice accretion	None
Turbulence	None
Updraughts	Moderate
Atmospheric pressure	1019 HPa

Table 3: meteorological data at the time of the accident (source KNMI).

1.8 Navigational aids
The flight was carried out by sight.

1.9 Communication
After leaving the air traffic control zone of Rotterdam there was no further radio communication with the PH-ECJ.

1.10 Flight recording equipment
The PH-ECJ was not equipped with a system that records flight data and cockpit conversations. This is not required for this type of helicopter.

1.11 Wreck/impact information
The helicopter crashed into a dune area next to the road. This area was covered with low bushes. These bushes were knocked away in a circular sweep to the left and front of the helicopter.

Figure 3: aerial photograph of the accident site (source National Police Services Agency [KLPD]).

Following the examination at the scene, the helicopter was transferred to a hangar for comprehensive technical examination. Technical examination was carried out on a number of occasions spread over a long period. The helicopter was made in France. The examination therefore took place with the aid of examiners from the French Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation civile (BEA) assisted by examiners from the manufacturer Eurocopter and the engine manufacturer Turbomeca. The electronic equipment on board the helicopter was also read out by the BEA where possible. The results of these examinations were:

The helicopter:

- The frame and the landing gear were severely damaged as a result of the impact at high vertical speed.
- The entire main rotor system was severely damaged.
- The rotor blades had been ripped backwards away from the suspension system and showed damage as a result of horizontal and vertical force caused by impact with the ground.
- The connection between the engine and the main gear box was broken.
- The tail rotor (Fenestron) was almost undamaged.
- The couplings from the drive shaft to the tail rotor were broken.
- The cable that controls the pitch of the tail rotor blades was intact and twisted around the broken off drive shaft.
- The control instruments in the cockpit (cyclic, collective and pedals) were in good working order and were connected to the control sticks. The mixing unit where the sticks come together was broken in a number of places.
- The controls for the main rotor blades and the tail rotor were in good working order.
- In view of the distortion of the helicopter, the speed of descent at the time of impact was at least 4.3 m/s (846 feet/min.) and vertical acceleration was at least 20G.

The damage observed was caused by the accident. The type of damage indicated that the main rotor and the tail rotor were being propelled at the time of the accident. No evidence was found that indicated a technical problem with the helicopter.

The engine:

- All moving parts of the engine were able to freely rotate.
- Damage to the axial compressor blades indicated that these were rotating at the time of impact.
- Signs were found that the engine was supplying power to the gear box at the time of impact.
- There was around 300% overtorque (overload) in module 5 of the engine at the time of impact. [9]

No evidence was found that indicated a technical problem with the engine.

1.12 Medical information

A post-mortem examination was carried out on the pilot's body. The pilot's death was caused by the accident. An injury was found that could be consistent with a position of the right foot on a pedal at the time of impact.

[9] Module 5 is the gear box between the turbine and the drive shaft.

1.13 Safety features

The helicopter is equipped with high energy absorption seats. The absorption of energy takes place via the depression of a frame onto which the seat is mounted. On maximum depression there was a downward acceleration of at least 14G for a person weighing 77 kg. In the helicopter the frames below the pilot's seat, below the front right seat and below the two left rear seats were fully depressed. The frame below the two right rear seats in the helicopter was not depressed.

Following the impact, four of the five occupants were still sitting in the seats and within the safety belts. The fifth occupant, the person who had been sitting in the front right seat, was found next to the helicopter.

1.14 Examination of electronic equipment

The following electronic equipment was examined in the BEA laboratory:

- Vehicle and engine multifunction display (VEMD)
- Digital engine control unit (DECU)
- GPS receiver

The VEMD has two screens that display the various engine and helicopter parameters in the cockpit. It replaces the traditional instruments. The VEMD also records this data. Examination of the VEMD revealed that one of the two modules (AV1) was damaged to such an extent that it was not possible to download the data from the memory chip. However, it was indeed possible to download the data from the memory chip of the second module (AV2). This data showed that data was stored for a period of 53 minutes and 21.5 seconds, and that there were no failures or exceeding of the limits of the helicopter and engine.

The DECU has a system that signals and records errors in the engine system. The data from the DECU showed that eight failures were recorded on channel A after 55 minutes and 3 seconds. Four failures were recorded after 55 minutes and 3 seconds on channel B and eight failures after 55 minutes and 5 seconds.
According to the investigation report all the recorded and confirmed failures occurred on impact. None of these failures could have explained the accident; rather, they were all a result of the impact.

It was not possible to read any data from the GPS because the 'track recording' option was not switched on.

The conclusion from the examination was that the data from the VEMD and the DECU was mutually consistent. The fact that the VEMD did not record any failures was probably due to the break in contact between VEMD and the DECU or due to the loss of power supply. The difference in data storage period can be explained by the fact that the DECU was switched on earlier than the VEMD on starting up the helicopter.

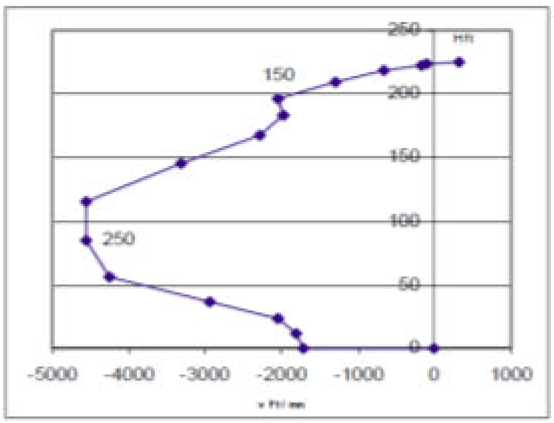
1.15 Video footage

After the accident it emerged that the helicopter accident was visible on the video footage recorded from the other helicopter. An attempt was made to reconstruct the accident using this video footage.

The quality of this footage is poor due to the large distance, and it is therefore impossible to determine the helicopter's movements with complete certainty. The footage starts at the time the helicopter was hovering on the spot with its nose pointing south. It is not known what the helicopter was doing before that. After a few seconds the helicopter rotates approximately 180 degrees, whereby the front of the helicopter is pointing north and the helicopter loses some altitude. The rotation direction is very likely to have been to the right. After this the helicopter rapidly loses altitude, and the rotation does not stop. It is impossible to determine the direction in which the helicopter is rotating at this point. The helicopter continues to rotate until it hits the ground, which takes place 6.5 seconds after the start of the rotation.

Eurocopter technicians have analysed the footage frame by frame (380 frames) and have drawn up a report of this analysis. Amongst other things, this analysis has been used to calculate the vertical speed of the helicopter relative to the altitude and relative to the time. The rotational speed has also been calculated. These are shown in the diagrams below. The graphs start at frame 50 at the time that the helicopter starts to move and end at frame 355, the time at which the helicopter hits the ground (the figures alongside the points indicate the frame number).
The findings from the footage analysis include the following:

- The helicopter was flying at an altitude of around 220 feet (frame 30).
- The front of the helicopter was pointing approximately south (170°).
- The helicopter started to turn, most likely towards the right.
- After around 2 seconds the helicopter had rotated approximately 180 degrees and had lost altitude (frame 130).
- During these 2 seconds the speed of descent increased to around 1300 feet per minute.
- After around 2.5 seconds the speed of descent had increased to around 2000 feet per minute (frame 150).
- The loss of altitude then rapidly continued to increase, accompanied by an increase in the speed of descent to a maximum of around 4500 feet per minute (frame 230).
- After around 6.5 seconds the speed of descent fell again to around 1700 feet per minute (frame 350).
- The impact then occurred.
- The speed of rotation fell during the descent.
- The helicopter rotated a total of 440 degrees.



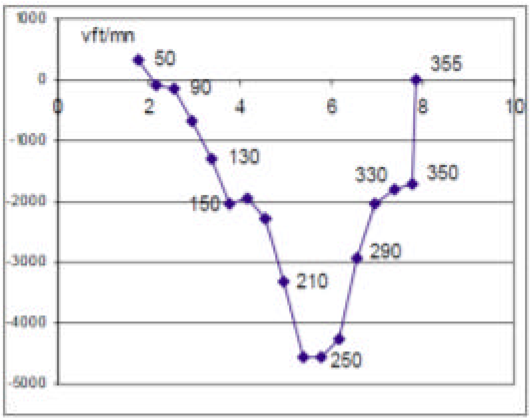


Figure 4: vertical speed in feet/minute relative to the altitude (l) and time (r).

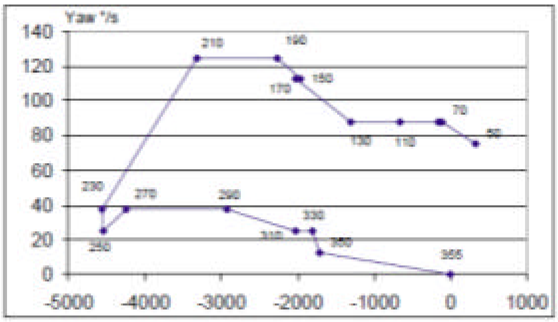


Figure 5: the rotation speed in degrees/second in relation to the vertical speed.

1.16 Additional information

The location

The Maasvlakte is a developing harbour and industrial area. It consists of a large sandy area surrounded by water, with the Slufter, a large body of water, in its centre. The site of the helicopter crash features a road with a narrow strip of dunes and sandy terrain to the south. The site is also surrounded by water, with the North Sea and the Slufter to the west and the Haringvliet estuary to the south. A large number of wind turbines are positioned around the Slufter. Three of these wind turbines are aligned to the north of the accident site.

Figure 6: the area of the Maasvlakte where the accident occurred.

Flying low

Under Article 45 of the Air Traffic Regulations (Luchtverkeersreglement) the minimum VFR-altitude[10] for aircraft is:

a) *above areas with contiguous buildings, including industrial areas and port areas, or above gatherings of people: at least 300 m (1000 feet) above the highest obstacle, situated within a distance of 600 m from the aircraft*

[10] VFR= visual flight rules, rules that apply under visual flight conditions.

b) *in areas not included under a: at least 150 m (500 feet) above the ground or water, or at a higher altitude determined by Our Minister.*

According to the Exemption Regulations under the Air Traffic Regulations (Vrijstellingsregeling Luchtverkeersreglement), this provision does not apply to flights such as those carried out for the purpose of producing audio or visual recordings for the professional gathering of news and cartography:

- *that do not take place within an air traffic control zone or above areas with contiguous buildings, including industrial areas and port areas, or above gatherings of people and,*
- *that are carried out with an aircraft or helicopter by a captain who holds a CPL.*

In this case, the minimum altitude is 60 metres (200 feet) above the ground or water.

2. ANALYSIS

The Dutch Safety Board has analysed the incident based on the factual findings described in chapter 1. The role of the helicopter, the role of the pilot and the flight are analysed in that order below.

2.1 The helicopter

The PH-ECJ had a valid certificate of airworthiness and all prescribed inspections and maintenance had been carried out. All the applicable Airworthiness Directives and Service Bulletins had been complied with. The helicopter had flown for 4:20 hours on the previous day, whereby no faults or other irregularities were detected.

The PH-ECJ had sufficient fuel on board to carry out the flight and its weight and centre of gravity fell within the limits during the flight.

It can be concluded from the technical examination that the PH-ECJ was in good working order and that there is no evidence that the accident was caused by a technical fault. The absence of the front of the helicopter after the accident can be explained by the fact that the main rotor blades were bent downwards at the time the PH-ECJ hit the ground and knocked off the entire front of the helicopter as they were rotating. This also caused the overgrowth around the front left side of the helicopter to be knocked away. The rotor blades were rotating at a high speed of rotation at the time of impact. The blades are less likely to bend at a high speed of rotation. The fact that the rotor blades had bent so far in spite of this that they knocked off the front of the helicopter indicates that there was a high speed of descent.

The broken couplings from the engine to the main gear box and from the tail gear box to the tail rotor were caused on the impact with the ground. In view of the fact that the control cable was twisted around the shaft, it is likely that the drive shaft was rotating at the time the helicopter hit the ground. Evidence was found on the Fenestron tail rotor that indicates that the tail rotor was rotating during the impact with the ground. It is possible to conclude from this that the tail rotor was being driven at the time of impact.

All damage to the helicopter was caused by the impact with the ground. The damage made it impossible to assess the position of the control instruments at the moment of impact.

Examination of the engine revealed that the engine was running at the time the helicopter hit the ground. The overtorque (overload) of approximately 300% measured in the engine was probably caused by the fact that the main rotor blades were being driven at the time that they suddenly stopped on impact with the ground. The engine continued to run, resulting in overload. It is possible to conclude from this that the engine was also supplying power to the rotor blades via the gear box.

There is no evidence that a technical fault in the engine played a role in causing the accident. This is also confirmed by the absence of error messages in the electronic equipment (VEMD and DECU) during the flight.

It can be concluded from the distortion of the seat frames that the PH-ECJ hit the ground[11] at a significant vertical acceleration of at least 14G. Based on the damage to the frame of the helicopter, the manufacturer calculated that the acceleration was probably more than 20G.

2.2 The pilot

The pilot held a valid licence and a valid medical certificate to carry out the flight. Because his logbook was not found, the exact number of hours he had flown cannot be confirmed. He had around 1580 hours of experience and had a valid licence for three types of helicopters. His own records from 21 December 2008 revealed that he had at that time recorded 1495 flying hours in four different types of helicopter. On that date the overwhelming majority of his flying hours had been on the Eurocopter EC120, with 615 hours. He had also recorded 45 hours on the EC130 on that date and the helicopter logs showed that by the time of the accident he had reached a total of 87 hours on the EC130.

The pilot was licensed to fly three types of helicopter: EC 120, EC 130 B4, and Bell 206/206L. The EC120 and EC130 B4 are the same type of helicopter and are both equipped with a Fenestron tail rotor. In terms of flight characteristics there is little difference between the two helicopters, except that the EC130 B4 is heavier and has a more powerful engine. The flight test carried out with the EC 120 was therefore also valid for the EC 130 B4. The Bell 206/206L is a different type of helicopter: the main rotor rotates to the left and has two blades, and the helicopter has a conventional tail rotor.
The personal record from 21 December 2008 showed that at that time he had flown 245 hours on the Bell 206/206L.

The helicopter company records show that although he was not very experienced in performing photo and film flights, he did regularly perform relay flights. For these flights, the helicopter maintains altitude for a length of time with little forward speed, making the helicopter heavy due to the quantity of fuel.

From the above we can conclude that he was an experienced helicopter pilot with plenty of flying experience in the Eurocopter EC120 and EC130, which are both equipped with a Fenestron tail rotor. There is no evidence that a lack of experience with either this type of helicopter or the type of flight were factors in the cause of the accident.

The Safety Board remains puzzled as to why the pilot's logbook was never found.

[11] 14G is equal to 14 times gravity.

2.3 The flight

Two aspects played a role in the accident: the continuous rotation of the helicopter and the rapid descent followed by the impact. We will first analyse the rotation of the helicopter, followed by the rapid descent and any connection between the two.

2.3.1 The rotation

As the main rotor of the EC 130 rotates towards the right, in the event of failure of the tail rotor the fuselage of the helicopter will respond by rotating towards the left. This justifies the conclusion that the rotation towards the right was initiated by an input and was not caused by failure of the tail rotor. Analysis of the footage revealed that the rotation took place at a speed of more than 80 degrees per second. This speed is higher than usual and is also higher than is comfortable for the occupants. It also follows from this that a significant pedal input was required in order to reach the calculated speed of rotation.

It is not known how this large input was initiated. It may be that the pilot wanted to make a rapid turn. The first group of cyclists were cycling towards the helicopter. The right side of the helicopter was facing the side from which these cyclists were approaching, so that the people sitting on the right side of the helicopter had a view of the cyclists who were cycling towards the helicopter.

It is possible that the pilot wanted to turn the helicopter 180 degrees to give the photographers sitting at the rear left of the PH-ECJ the opportunity to photograph the leading group of cyclists through the open sliding door, as this turn meant that the left side of the helicopter was facing the group of cyclists cycling towards the helicopter.

As previously stated, the main rotor of the EC 130 was rotating towards the right and a rotation towards the left will use less engine power as the fuselage already has a tendency to turn towards the left in response to the direction of rotation of the main rotor. The fact that the pilot nevertheless chose to turn right can be explained by the fact that a right-turn meant the pilot and passengers would not lose sight of the group of cyclists.

Another explanation for the quick rotation is that a passenger initiated it or exacerbated it. As stated, only the cyclic had been removed from the second pilot's seat, where a passenger was seated: the collective and the control pedals were still in situ. It is therefore possible that the rotation was caused by the input of the passenger who was sitting in the co-pilot's seat. Investigation into other helicopter accidents has revealed that passengers can sometimes unintentionally grip or push against one of the control instruments, thereby affecting the steering or impeding or preventing control by the pilot.

In the case of the PH-ECJ this could have occurred if the passenger in the co-pilot's seat unintentionally braced himself with his feet on the pedals or if his foot came to be underneath or between these pedals. In both cases, this would have instigated a rotation and could have limited the pilot's ability to stop it. It is also possible that the pilot instigated the rotation and that the passenger braced himself against the pedals, exacerbating the rotation. In any of these scenarios, the pilot could have countered the rotation by applying greater force to the left pedal. However, this would take strength and time, and particularly in the case of the Fenestron tail rotor a rapid response and greater pressure on the pedals is required to stop a rapid rotation. Finally, there is also the possibility that during the rotation an unsecured object came to be underneath one of the pedals, hindering its use. However, there was no way to verify this.

The helicopter was equipped with dual controls: those for the pilot, who sat in the left-hand seat, and those for the middle seat, which was occupied by a passenger on this flight. Only the cyclic had been removed from the control instruments; the collective and pedals were still there. In accordance with JAR-OPS 3.100, passengers are only permitted to be in the cockpit under the conditions stipulated by the operator in the Basic Operational Manual (BOM).

However, JAR-OPS 3.001 also states that these regulations only apply to commercial air transport using civilian helicopters. They do not apply to flights categorised as 'aerial work' where there are no more than six people on board required to perform the aerial work. Where the purpose of the flight is to take photos and film recordings, this would be considered aerial work.

The helicopter company's Basic Operations Manual (BOM) includes the following passage:

JAR-OPS 3.100 / 3.005f
Dual controls are only installed during introduction/training/multi-crew/check-flights.
Transport flights with a passenger occupying a pilot's seat are only allowed if:
• The dual controls are removed.
• The passenger is instructed not to distract the pilot and not to interfere with equipment and controls.

However, the BOM is also only valid for flights where JAR-OPS3 is applicable. The presence of dual controls was therefore permitted for this flight. Investigations into other helicopter incidents have shown precedents where passengers unintentionally influenced the helicopter's controls by grasping hold of or bracing against a control instrument. There have also been incidents where, for example, carrying straps have got caught behind a control instrument, affecting the steering.

The regulations thus distinguish between commercial transport and aerial work. The difference lies in the nature of the flight. Transport involves taking passengers from one place to another, or taking them on a tour. With aerial work, the helicopter is used as a platform to carry out other activities, such as taking photos or recording film. In both cases, there are often people in the helicopter cabin who are not crew members and in some cases occupy a seat ordinarily designated for a second pilot. It is odd that both the law and BOM require the control instruments to be removed for one of those flight types but not the other. In either case, there could be people in the cockpit who are not crew members and who could influence the steering of the helicopter. It would therefore be advisable to harmonise the rules in this area for both types of flight and to remove the dual controls when there is no second pilot and a passenger is occupying that second pilot's seat on flights where that is permitted.

Given the wind speed, it is thought unlikely that the wind, which had been blowing straight into the tail of the helicopter, caused or exacerbated the rotation. The wind was too weak to do so.

The footage shows that the helicopter was still rotating immediately before the aircraft hit the ground. In view of the quality of the footage it is not possible to determine with absolute certainty in which direction the helicopter was rotating. The most likely answer is towards the right. As the start of the rotation was very probably towards the right, the helicopter's direction of rotation during the rapid descent would have changed if the helicopter turned left on falling, however this is unlikely. No change in direction was visible on the footage or reported by witnesses. Furthermore, the underside of the tail was knocked away towards the right at the level of the tail rotor and the bushes to the left of the tail sustained more damage than those on the right side. This indicates that the tail of the helicopter was moving towards the left.

The helicopter rotated a total of 440 degrees, which is almost one and a quarter times around the axis. The speed of rotation was highest at the start of the descent and fell during the final part of the descent. This indicates that the pilot somehow managed to slow down the rotation. Eurocopter's analysis shows that the pilot probably pulled the collective and compressed the right pedal during the final part of the descent, causing the speed of rotation to remain between 20 and 40 degrees per second. This explains the pilot's injury, which indicates that he had his right foot on the pedal.

It is not known why the rotation was not brought to a complete stop. No findings were made that could explain this. It is therefore only possible to name or exclude potential causes.

- We can exclude the possibility that the accident was caused by failure of the tail rotor or the power supply to the tail rotor. As previously stated there was no evidence of a defect prior to the accident. In addition, if the tail rotor had not been working properly the rotation would have slowed down and the helicopter would have started to turn the other way. Loss of tail rotor effectiveness is unlikely for the same reason.

- It is also unlikely that the rotation was not stopped because the pilot became unwell. The post-mortem examination revealed no evidence of this. If the pilot had indeed become unwell, the helicopter would have turned the other way. Moreover, it is clear from the analysis of the footage that the pilot operated the control instruments during the descent up until the last moment.

- As reported, it is possible that a passenger influenced the rotation by placing his feet on, between, or under the pedals. In any of those instances, it would be impossible to fully depress the pedals and therefore impossible to stop the rotation. After the accident the right pedal had to be cut out as the passenger's foot was trapped underneath this pedal. However, it is not known whether his foot became trapped before or after the impact.

- As described below, the rapid descent was probably due to 'Vortex ring state' (see chapter 2.3.2). One of the consequences of this situation described in the literature is that random movements around the three axes of the helicopter can lead to a total loss of control over the aircraft. *("Random pitching, rolling and yawing motions can lead to a total loss of control in flight").*[12] Movements around the yaw axis (yawing) can cause the helicopter to rotate.

2.3.2 The rapid descent

The analysis of the footage shows that the helicopter descended during the first rotation, followed by a rapid increase in the speed of descent and then impact.

The speed of descent increased during the first part of the rotation and was approximately 670 feet per minute when the helicopter had rotated approximately 135 degrees. The speed of descent then rapidly increased to around 1300 feet/minute when the helicopter had rotated approximately 180 degrees.

Investigations were carried out into the cause of this descent. No explanation was found as to why the helicopter reached a speed of descent of more than 600 feet per minute during the rotation,

[12] 'Principles of helicopter flight', W.J. Wagtendonk, 2006.

other than that the pilot pulled the collective. He could have done this in order to avoid an overtorque. This is because executing a rapid turn through a strong pedal input requires a lot of engine power. This takes away power to the main rotor. The engine system is designed to then automatically generate more power to prevent the helicopter from descending. To prevent too much power being delivered to the rotor power system, the pilot presses down a little on the collective, which slightly lessens the power to the rotor system (torque). But this does cause the helicopter to descend. The helicopter's descent during the rotation was therefore probably due to an action by the pilot. However, we cannot exclude the possibility that this was caused by one of the passengers accidentally leaning on the collective. If this had happened, the pilot would have noticed immediately because he always has a hold of the collective.

A speed of descent of more than 600 feet per minute falls within the range in which what is known as 'vortex ring state' can occur.

In short, 'Vortex ring state' or 'Settling with power' is a potentially hazardous situation in which the main rotor blades of a helicopter enter the turbulent air generated by the rotor blades themselves. [13] This causes the airflow on the inside of the rotor surface, which under normal conditions moves downwards, to move upwards.

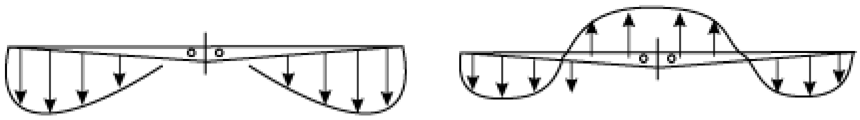


Figure 7: airflow under normal conditions and during 'vortex ring state' (source: internet).

This causes the rotor blades to lose lift, and the helicopter's speed of descent will rapidly increase. Speeds of descent of 5000 to 6000 feet/minute are possible under these conditions. An attempt to flow down the speed of descent by increasing power (pulling the collective), is ineffective or counterproductive.

'Vortex ring state' can develop when three things occur at the same time:

- A low or zero forward airspeed (less than 30 knots).
- Exceeding a particular rate of descent (around 400 to 800 feet/minute, depending on the type of helicopter and the conditions).
- The use of some power (20 to 100 percent).

If a helicopter encounters this situation, the aerodynamic effect on the rotor blades can cause significant and sudden movements around the yaw axis, longitudinal axis and transverse axis of the helicopter. These yaw, roll and pitch motions can lead to loss of control over the helicopter.

[13] Sources: W.J. Wagtendonk, 'Principles of helicopter flight', 2006; 'Rotorcraft Flying handbook', FAA document H-8083-21, 2000 and 'Safety considerations for helicopter pilots', EHEST, 2010.

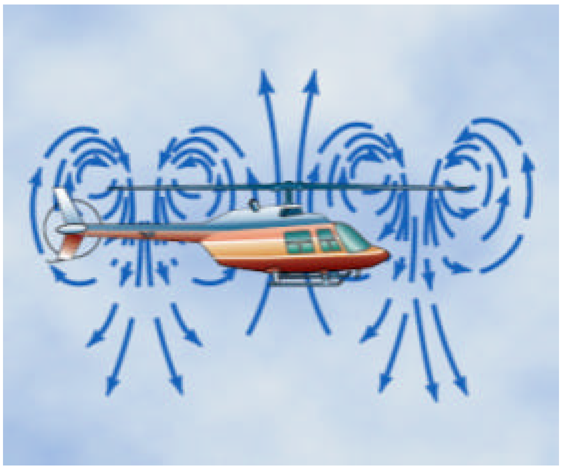


Figure 8: air circulation in a 'vortex ring state' (source FAA 'Rotorcraft Flying handbook).

According to the literature, one of the situations in which a risk of 'vortex ring state' exists is the performance of a photo flight, as the three conditions described above could potentially occur at the same time.

The best way to correct a 'vortex ring state' is to increase the forward speed and to push the collective, thus reducing power. A considerable altitude is required for this. The professional literature recommends an altitude of at least 1500 feet for demonstrations of and training in this situation.

The dangers of 'vortex ring state' are indeed addressed during helicopter pilot training with a strong focus on avoiding situations in which 'vortex ring state' can occur, particularly on steep approaches. No practical exercises are carried out.

The rapid increase in the speed of descent can be explained by the fact that the PH-ECJ evidently quickly entered the 'vortex ring state'. Eurocopter's analysis shows that the speed of descent then rapidly increased to around 4500 feet per minute. This can be explained by the reduction of power. Reducing power will slow the rotation towards the left. Power was then clearly increased again, causing the speed of descent to fall back to around 1800 feet per minute. The reduction of power is a reaction that is in keeping with a manoeuvre to correct 'vortex ring state': in this manoeuvre power is reduced and forward speed is built up by moving the cyclic forward. The fact that the speed of descent fell again after a few seconds because power was evidently applied is consistent with pulling the collective. This could have been a reaction by the pilot in an attempt to reduce the speed of descent once it emerged that a collision with the ground was inevitable.

The altitude at which the PH-ECJ was hovering, around 220 feet, was absolutely too low to safely correct this situation. Although a minimum altitude of 1500 feet is recommended in practice situations, in view of the speed of descent that can develop it is wise to fly at a higher altitude. Moreover, it is difficult for a helicopter pilot who has never experienced this type of situation to recognise that the helicopter has entered a 'vortex ring state'. Within the time it takes to recognise the situation, the high speed of descent means that the helicopter has already lost considerable altitude. The pilot must then commence the correction procedure.

In summary, the most likely explanation is that the helicopter made a rapid 180-degree right turn in the first instance. During this manoeuvre the helicopter lost altitude, on which the aircraft entered a 'vortex ring state' and the rotation was not stopped. In view of the helicopter's low altitude, it was no longer possible to correct this situation.

2.3.3 *External influence*

The investigation looked into the possibility of the accident having been caused or influenced by any external factors. The first step was to investigate whether the characteristics of the surroundings had any influence. The Maasvlakte consists mainly of sand, a surface known to radiate a great deal of heat in hot weather. Other surfaces, such as water, radiate much less heat, so the air in the area where the accident took place would have been uneven in temperature. On the day of the accident the temperature was around 25 °C and the sea was still relatively cold at around 15 degrees. The investigation checked with the Royal Netherlands Meteorological Institute (K.N.M.I.) whether this uneven heating could cause serious turbulence, enough to hinder control of a helicopter. According to an expert at the K.N.M.I., this was very unlikely. There would have been air currents as a result of the uneven heating, but this would not have been significant. There is thus no reason to believe that local weather conditions contributed to the accident.

Three wind turbines are located north of the accident site. These turbines have an axis height of 65 metres and a rotor diameter of 70.5 metres. The film showed that the rotor blades were turning and that the wind, given the direction of the rotor heads, was coming from a northerly direction. This is consistent with the weather data provided by the K.N.M.I. Given the wind direction at that time, any wake created by the turbines would have been directed towards the spot where the helicopter was (see figure 5).

At the request of the Safety Board, ECN Wind Energy carried out a study into the wake parameters of the three wind turbines. The most important wake parameter is the turbulence intensity. Turbulence intensity is a measure of turbulence, meaning the swirls of air created by disturbances in the air flow by, for instance, trees, buildings or wind turbines. Turbulence intensity is defined as the standard deviation of wind speed divided by the average wind speed.

The study showed that without any wake effects, turbulence intensity at an altitude of 80 metres would have been around 13%. The maximum absolute increase of turbulence intensity caused by the wind turbine wake at the accident site would have been around 10%, at an altitude of 85 metres. Therefore the turbulence intensity including the wake effects would have been a maximum of 23% at an altitude of 85 metres. The helicopter was flying at an altitude of a round 67 metres. Assuming a wind speed of 5 to 10 knots, the wind speed could therefore have ranged from 7 to around 23 km/hr. [14] It is unlikely that such wind speeds would cause a rotation of the speed calculated for the PH-ECJ.

2.3.4 *Altitude*

The investigation revealed that the regulations permitted the helicopter to fly below the minimum altitude of 500 feet. In accordance with the general exemption, the location, the nature of the flight and the pilot's qualifications meant that it was possible to fly at an altitude of up to 200 feet. Due to the purpose of the flight, namely to take photographs, it is standard practice to fly at a low altitude. However in view of the combination with a low, or no, forward speed, this is a critical operation that can lead to a hazardous situation. This altitude offers little opportunity to safely correct an emergency situation. If an emergency situation such as 'vortex ring state' occurs, an altitude of 200 feet is absolutely insufficient, but also in the event of engine failure with a single-engine helicopter, 200 feet in combination with little or no forward speed does not offer a great deal of margin to safely escape from this emergency situation.

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[14] 5 knots = 9.26 km/hr – 23% = 7.1 km/hr. 10 knots = 18.52 km/hr + 23% = 22.8 km/hr.

The pilot of a helicopter must therefore consider the benefit and the necessity of flying at a low altitude with little forward speed versus the risk this entails.

3. CONCLUSION

It was not possible to establish a clear cause of the accident involving the PH-ECJ with certainty. The Dutch Safety Board can only identify a number of potential causes and exclude various factors:

- The incident started with a rotation that was not stopped, followed by a descent. The failure to stop the rotation cannot be explained. Possible causes include:
  - Lack of control due to 'vortex ring state'.
  - Passenger influence.
  - Insufficient reaction by the pilot to stop the rapid rotation.
- The only possible explanation for the start of the descent is action by the pilot.
- The rapid descent was probably due to a 'vortex ring state'.
- The low altitude at which the hover was carried out was insufficient to correct the situation that occurred.
- A technical cause is unlikely.
- A medical cause is unlikely.

4. RECOMMENDATIONS

It is recommended that the State Secretary for Infrastructure and the Environment works with the European Aviation Safety Agency (EASA) to ensure that regulations pertaining to the removal of flight controls during aerial work are brought in line with regulations for commercial transport.

Appendix 1

In accordance with the Dutch Safety Board Act a draft version of the report was submitted to the parties involved for review. The purpose of this review is to avoid any factual errors. The following parties have inspected the report:

- The pilot's surviving relatives
- The passengers' surviving relatives
- The surviving passenger
- The helicopter company
- Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile (BEA)
- European Aviation Safety Agency (EASA)

Some of their comments have been adopted and included in the report. These are not further elaborated on. The comments not included in the report are presented below, with the reason for not including them.

<u>The pilot's surviving relatives</u>

Item 1.5 The pilot's logbook was not found. If the pilot was not recording his flying hours electronically, there must have been a logbook. Where did this end up and why does the operator have no record of the number of flying hours?

Dutch Safety Board comment:
After the accident all the documents found on board the helicopter were confiscated by the Aviation Police. The logbook was not recovered. The pilot's family carried out its own searches on the computers for any files with records of flying hours but to no avail. All pilots are required to record their flying hours, but in spite of every effort having been made, no record was found.
The operator is not obliged to record pilots' flying hours. However, on the request of the Safety Board the helicopter company did its best to compile an accurate record of the pilot's flying hours, based on the helicopter logs. Another helicopter company also provided a record of the pilot's flying hours dated 21 December 2008. As a whole this provided a reasonable record of his flying hours.

Item 1.12 In a helicopter you always keep both feet on the pedals and I would actually expect the pilot to have applied the LEFT foot because he wanted to stop the right-turn rotation. What kind of injury was found to the left foot?

Dutch Safety Board comment:
The pathologist's report refers only to injury and damage consistent with the right foot being positioned on a pedal at the time of the crash. The report says nothing about the left foot.

The helicopter company

Page 2.
It does not seem plausible to us that the helicopter was hovering entirely motionlessly in the air. During photo flights our pilots will always try to maintain some speed in the helicopter. It is common to make a somewhat wider turn at somewhat higher speed when, for instance, keeping up with cyclists.
Turning on the spot is not standard practice because this can lead to unfavourable winds to the tail. We would normally fly in a circle.

Dutch Safety Board comment:
At the time of the helicopter coming into view, it was hovering motionlessly. We do not know what flying manoeuvres the helicopter might have made before then. This has been clarified in the report.

Page 5.
Regarding the fenestron rotor, we would like to add that a fenestron rotor is actually less effective. The reference in the report to it having "the same diameter" is inaccurate.
The fenestron was designed primarily to protect the rotor blades, not to increase their effectiveness. This design requires shorter blades. More blades are therefore fitted to deliver the same power as a conventional rotor. This reduced effectiveness requires greater pedal inputs and much greater engine power. To compensate for that you pull on the collective, which is counterproductive in a vortex ring state. There is greater resistance compared to a conventional rotor: at most around 30 to 35%, whereas a conventional rotor uses at most 12 to 18% of power.

Dutch Safety Board comment:
The report was written in consultation with the helicopter manufacturer, Eurocopter. It was deliberately written concisely but without contradicting what the helicopter company wrote.

10. The report indicates that the passenger in the middle at the front was stuck under the right pedal and had to be freed from it after the accident. The report also says that Eurocopter's analysis states that the pilot is thought to have pulled on the collective close to the ground and applied the right foot.
But the report says nothing about the position of the pedals after the accident.
Can this still be ascertained?

Dutch Safety Board comment:
Due to the impact itself and the work of the emergency services in freeing the passengers, the position of the pedals can no longer be ascertained.

13. We are wondering why the flight was not re-enacted/simulated (at a higher altitude and/or with a greater safety margin)? See our comments under item 7.

Dutch Safety Board comment:
Following consultation with Eurocopter, it was decided not to carry out a test flight due to the risk factor.

Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile (BEA) and the European Aviation Safety Agency (EASA) had no comment on the report. No response was received from the other parties involved.