## DATA SUMMARY

### LOCATION

| | |
|---|---|
| Date and time | **18 September 2011, 16:50 LT**[1] |
| Site | **El Puerto de Santa María (Cádiz)** |

### AIRCRAFT

| | |
|---|---|
| Registration | **D-HONY** |
| Type and model | **BELL 206B** |
| Operator | **Rotorflug GmbH** |

#### Engines

| | |
|---|---|
| Type and model | **ALLISON 250-C20B** |
| Serial Number | **1** |

### CREW

#### Pilot in command

| | |
|---|---|
| Age | **49 years old** |
| Licence | **CPL(H)** |
| Total flight hours | **2,506 h** |
| Flight hours on the type | **327 h** |

| INJURIES | Fatal | Serious | Minor/None |
|---|---|---|---|
| Crew | | **1** | |
| Passengers | | **1** | **1** |
| Third persons | | | |

### DAMAGE

| | |
|---|---|
| Aircraft | **Significant** |
| Third parties | **Façades of surrounding buildings** |

### FLIGHT DATA

| | |
|---|---|
| Operation | **Aerial work – Commercial - Filming** |
| Phase of flight | **En route** |

### REPORT

| | |
|---|---|
| Date of approval | **24th October 2012** |

[1] All times in this report are local (UTC-2).

# 1. FACTUAL INFORMATION

## 1.1. History of the flight

At approximately 16:30, the helicopter, operated by Rotorflug, took off from the Jerez Airport to film different locations in the Cadiz and El Puerto de Santa Maria area. The pilot and a production company executive were in the front seats, while the center rear seat was occupied by the camera operator.

Some 20 minutes after taking off, while they were filming over the town center of El Puerto de Santa Maria, the helicopter started a sudden uncommanded rotation to the right. The pilot unsuccessfully tried to regain control of the aircraft, which eventually fell on a city street, hitting several buildings during the descent (figure 1).

The camera operator who was travelling in the rear seat exited under his own power with only slight injuries. Both the pilot and the other occupant seated to his left were rendered unconscious by the impact and had to be rescued by passersby, who extracted them from the helicopter.
Emergency services were immediately notified, with the police, firefighters and medical personnel arriving on the scene a few minutes after the impact.

**Figure 1.** Helicopter wreckage

There were no injuries among the passersby or the local residents. There was some damage to nearby buildings and significant damage to the helicopter.

## 1.2. Personnel information

The pilot obtained his helicopter private pilot license (PPL(H)) in 1995 and his commercial pilot license (CPL(H)) in 2005.

He had a type rating to fly as pilot in command on the Agusta A109, Bell 206, Robinson 22 and Robinson 44 types. He also had a flight instructor type rating (TRI) for the Bell 206, Robinson 22 and Robinson 44, and a commercial and private pilot flight instructor (FI) rating.

The pilot had successfully completed his last proficiency check to renew his Bell 206 type rating in April of 2011. Also that April he received training and was tested on the safety and emergency equipment onboard the Bell 206, he did a line check onboard a Bell 206 and took a CRM refresher course, all in compliance with the requirements that European regulations[2] impose on companies that engage in commercial helicopter transport.

According to his statement, he estimated that he had some 50 hrs of experience on film flights. In Spain he had only flown about 3 h on the circuit at the Son Bonet Aerodrome (Mallorca) from May to June 2010.

He had a valid Class 1 medical certificate, in force on the day of the accident.

It was his first in a series of scheduled flights in replacement of another pilot who had been flying the same helicopter in the two previous weeks as part of a contract to film locations along the Spanish and Portuguese coasts. He had flown into Jerez that same morning on a three-hour flight from Frankfurt (Germany). He had about four hours to rest before the flight. He had had a total of 21 flight hours and 129 duty hours in the three weeks prior to the accident. He had rested the day before.

Within Rotorflug, he held the position of Flight Operations and Training Manager.

## 1.3. Aircraft information

The Bell 206B JetRanger II is a five-seat helicopter powered by a 400-hp Allison 250-C20B turbine. Both the main and tail rotors have two blades each.

[2] JAR-OPS3 or Joint Aviation Requirements for engaging in commercial air transportation operations in civil helicopters.

The accident helicopter was made in 1978 and had 15,878 flight hours. The engine had 7,426 operating hours since its manufacture.

In February 2011 the aircraft had successfully undergone an airworthiness inspection, after which it was issued the corresponding airworthiness review certificate (ARC), which was valid at the time of the accident.

### 1.3.1. *Description and maintenance of the anti-torque rotor system*

The drive shaft from the engine to the tail rotor connects the freewheel with the gearbox in the tail rotor.

The drive shaft is divided into eight segments. These segments are coupled through a combination of geared adapters and a group of unlubricated laminated steel rings. The lugs at the rear of each segment are threaded onto the set of rings, which are in turn screwed onto the adapter that is geared with the next segment. Bearings hold each shaft segment to the tail boom structure (figure 2).

The maintenance program specifies a visual check of the general condition of the couplings and bearings every 100 flight hours or annually, as well as a more detailed inspection every 300 h. The bearings must also be lubricated annually. According to the aircraft's maintenance records, both inspections and the lubrication had been performed within the specified periods. There were no indications in the records of any repairs made to or defects found in the transmission.

The final transmission segment is geared through the adapter in the tail rotor gearbox, which reduces the rpm's and transmits the shaft's rotational motion to the rotor blades. It has its own lubrication system, which features an electromagnetic detector to pick up the presence of metallic particles, indicated by a light in the cockpit. The gearbox is attached to the tail cone structure with four threaded steel bolts.

According to the maintenance program, the gearbox must be checked every 100 h for oil leaks, contamination, structural cracks or defects in its mount to the helicopter. The oil must be changed every 200 h or annually, and it must undergo a thorough inspection every 3,000 h. All of these tasks were listed as completed within the required times in the maintenance records checked. The gearbox had been installed on the helicopter in September 2007 and had a service life of 2,100 h left at the time of the accident until its next overhaul, which is scheduled every 6,000 h.

As for the tail rotor, it must undergo a visual inspection and have several of its components lubricated at intervals of 50, 100 and 300 h. The maintenance records checked showed these tasks as having been completed within the specified intervals.

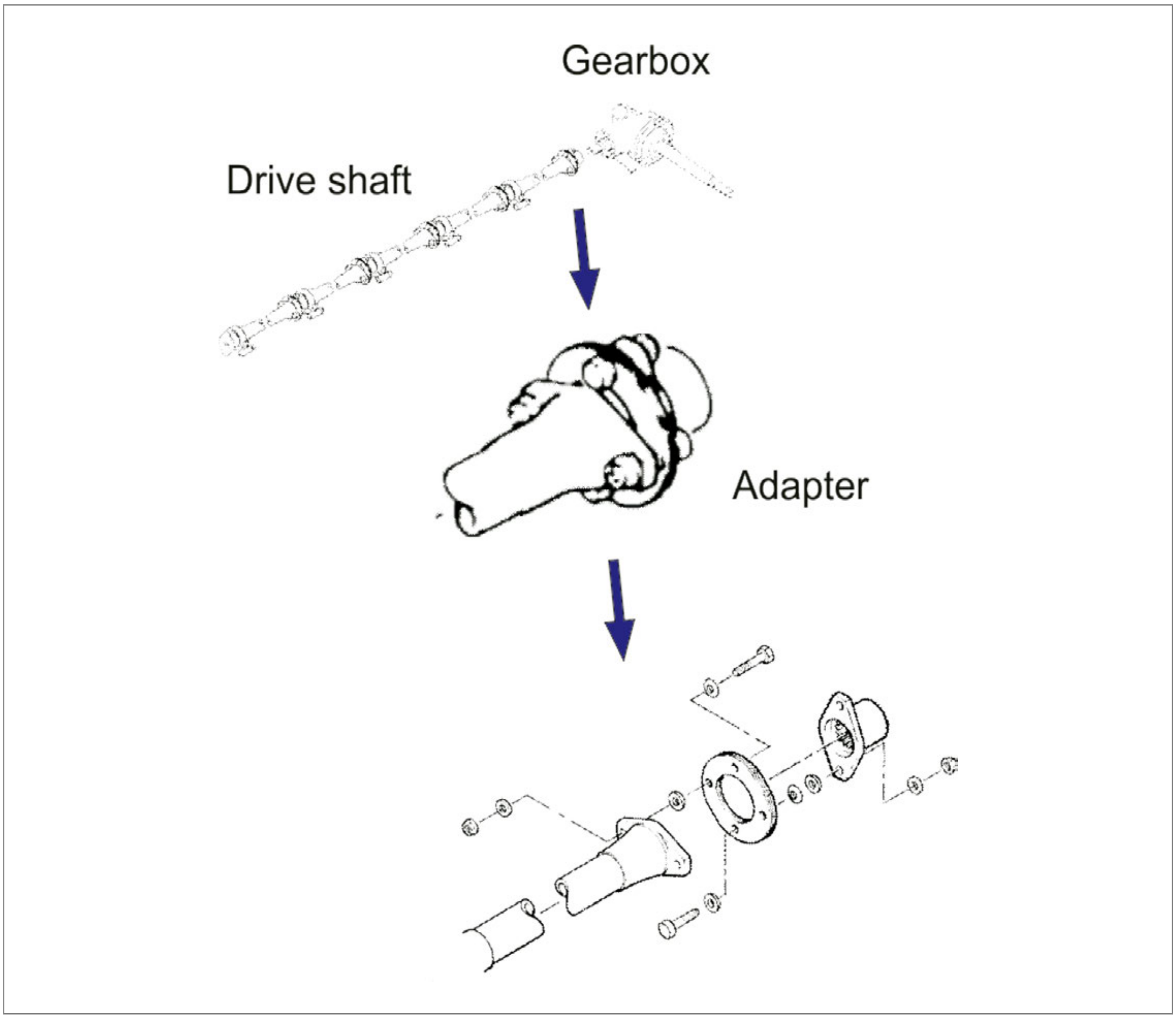



**Figure 2.** Diagram of the aft section of the tail rotor transmission

The control records for every tail rotor component with service life limitations showed that they were all within their limits.

The maintenance program also includes a corrosion control program that consists of inspections quarterly or every 100 h (whichever comes first). The last corrosion control inspection had been conducted in July 2011.

The installation of the camera on the helicopter was allowed by a Supplemental Type Certificate (STC). Associated with this modification was a Supplemental Flight Manual that provides the necessary data to take into account the camera's effect on the weight and balance.

A few days before the start of work in Spain, another modification was implemented that consisted of raising the height of the skids. Its effect on the weight and balance was negligible and not taken into account.

### 1.3.2. *Weight and balance of the aircraft*

The weight and balance information found onboard reflected the values for the last weighing of the helicopter conducted in March 2010.

The weight and position of the center of gravity had been calculated taking into account the fuel onboard (510 lb), the lubricating oil, the weight of the crew and their baggage, as well as the values provided by the manufacturer for both the longitudinal and lateral positions of each of these components.

Under this scenario, the takeoff weight on the first flight of the day was 3,198 lb, very close to the maximum authorized weight of 3,200 lb. Considering this initial weight and taking into account the approximate fuel consumption (85 kg/hr), the position of the center of gravity over the course of the flight was verified to have remained within the limits specified in the Flight Manual.

## 1.4. Meteorological information

The day was relatively hot with an ambient temperature of 26 °C at the time of the accident. The wind at that time was mainly from the W-SW at a speed of between 10 and 12 kt.

## 1.5. Communications

At 16:21 the pilot requested clearance from the control tower to start up, which was immediately granted. The tower then cleared him to taxi to the hold point and at 16:30 to take off from runway 20.

At 16:35 he was transferred to Seville Approach, to which he reported that he would be flying at 1,000 ft and requested clearance to enter the Rota CTR, inside of which is El Puerto de Santa María. ATC cleared him to enter the CTR, which the pilot acknowledged, reporting that they would proceed directly to Cadiz.

There were no more communications between the helicopter and ATS stations. The pilot did not report any type of emergency.

## 1.6. Flight recorders

The aircraft was not equipped with a flight data or cockpit voice recorder. The relevant aviation regulations did not require any type of recorders to be carried onboard.

A portable GPS unit was recovered and used to obtain flight path information.

The footage recorded by the camera installed on the helicopter in the minutes leading up to and including the loss of control prior to the impact was also recovered.

### 1.7. Wreckage and impact information

The helicopter fell to street level, coming to rest on its left side. The cockpit retained its structural integrity for the most part. There were significant dents and fractures to the front left side and the front windshield was broken.

The tail boom was bent in front of the horizontal stabilizer, which had torn its outer skin. There were several impact marks in the area closest to the tail rotor and it was resting on the ground atop its horizontal stabilizer and one of the tail rotor blades. Both the tail rotor transmission and the control bar to change the pitch of the blades were bent and broken in the same area where the tail boom had bent. There were no signs of wear or corrosion in the fracture area.

Debris that had detached from the walls of buildings on either side of the street as the result of a strong impact from a sharp edge was also identified (figures 3 and 4).

There were also impact marks on window grills in one of the buildings.

The outer half of one of the main rotor blades was found on the roof of a nearby building, next to the corner of a wall where two deep impact marks were found. There

Figure 3. Marks on building wall

Figure 4. Marks on building wall

was a metal fence around said roof that was badly bent and partially detached. The other blade had lost a part of the area near its tip.

The pitch control rods for the main rotor were broken. The gear between the drive shaft and the main rotor gearbox was also broken.

One of the tail rotor blades had broken and its outer section detached. The other blade was bent and partially detached halfway along its length.

Three of the four bolts that attached the right-angle gearbox on the tail rotor to the tail boom structure had detached. The gearbox was still attached with one bolt, though it was slightly rotated with respect to its normal position. The broken sections of the other bolts were found inside the tail boom with their threads firmly in place.

The aft segment of the tail rotor drive shaft had decoupled from the gearbox when the lug that attaches it to the gearbox adapter broke. The adapter, and part of the broken lug still screwed onto it, was found on the ground just below the tail. Neither the adapter nor the broken segment showed any external signs of corrosion.

There was a strong smell of fuel coming from the wreckage and various components and materials in the cockpit showed signs of having been doused by fuel.

The hydraulic system switch was in the ON position. The fuel shut-off switch was OFF with its guard lifted. The throttle twist grip was in the "Flight" position and the battery and generator switches were both ON. The battery had been disconnected from within its housing at the nose of the helicopter.

## 1.8. Tests and research

### 1.8.1. *Reconstruction of the flight path*

The information obtained from the footage of the onboard camera, from the surveillance radar (SSR) and from the GPS receiver recovered from the wreckage allowed investigators to reconstruct the aircraft's flight path leading up to the accident (figure 5).

The aircraft entered El Puerto de Santa Maria from the E, flying along the river and making two right-hand 360° turns over a location NE of the impact site. It then returned to the river and flew SW before proceeding to the town center on a path perpendicular to the river.

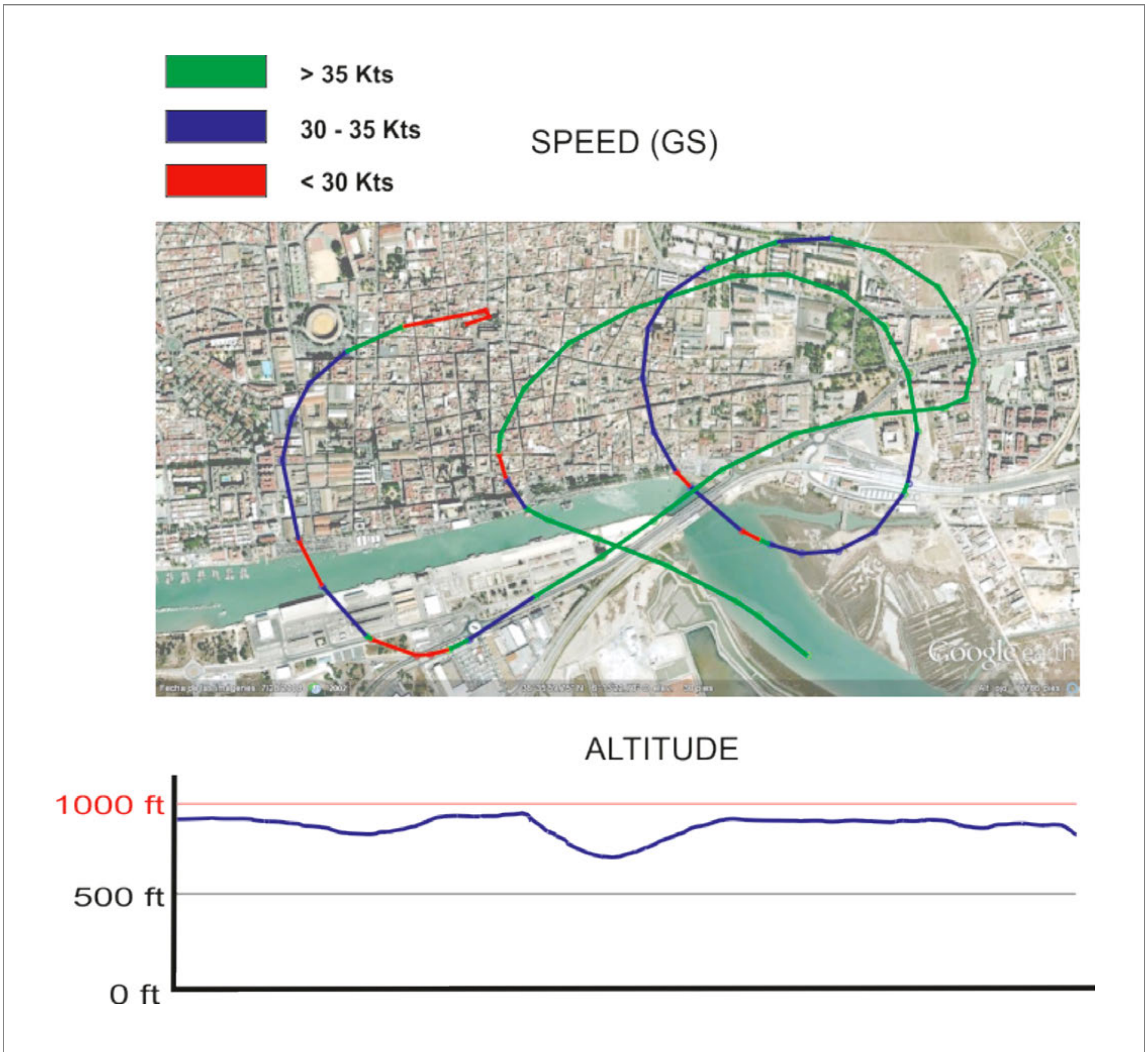



**Figure 5.** Flight path of the helicopter over the city

After starting a turn to the right, and while on a NE course (parallel to the river), the helicopter started yawing to the right suddenly. It is estimated that in about 3 seconds, the helicopter had turned 180° and reached a turn rate of about 90°/s. The aircraft completed approximately four full turns while losing altitude until finally, near the ground, the turn rate slowed. Immediately afterward, the descent rate slowed coincident with an increase in the turn rate just before impact. The complete sequence from the initial loss of control to impact lasted about 35 seconds.

The images of the final few seconds as the turn rate decreased showed that the helicopter's forward speed at that time was practically zero.

The AGL during the flyover of the city varied between 700 and 900 ft. During the full turns, the ground speed (GS) was between 25 and 35 kt, increasing to 55 kt during a straight-line segment to change location. In the seconds before the loss of control, the helicopter was at an altitude of 900 ft and flying at a GS of 30 kt.

### 1.8.2. *Simulation of anomalies in the anti-torque rotor*

In order to analyze the motion observed in the helicopter after the loss of control, investigators asked the manufacturer to simulate the flight dynamics of a Bell 206 after a loss of the tail rotor. The cases considered were a full loss of rotor thrust and a full loss of the torque supplied by the tail rotor under loading and aerodynamic speed conditions similar to those present on the accident flight. The simulations considered no pilot inputs and then an input to the cyclic intended to regain speed. The results are shown graphically in Appendix I.

The actual behavior of the aircraft at the start of the event, in terms of the increasing turn rate, was most closely mirrored by the total loss of thrust case, and not by the loss of torque case (which are representative of a fault in the tail rotor drive). In the second case the rotation was less pronounced and fast action by the pilot effectively served to control the yaw, which was suppressed in a few seconds.

It was also noted that in those cases where the tail rotor was lost, the rotor continued rotating at high rpm's for a long period of time due to aerodynamic effects.

### 1.8.3. *Inspection of the wreckage*

The helicopter wreckage was inspected, in particular the tail rotor system.

The cyclic control was bent but its motion was still transmitted to the cams that operate the hydraulic actuators. The collective control could not be moved due to the collapsed condition of the cockpit.

The main rotor blades turned freely atop the pitch control mechanism.

The positions of both the anticipator actuator and the cam that operates the fuel control unit (angular positions of 70° and 90°, respectively) indicated that there was a power demand on the engine.

The throttle control relayed commands to the fuel control unit in the engine.

The power turbine and the axial compressor rotor were seized and had extensive residue from an extinguishing agent. The compressor blades showed wear from material ingestion.

The main rotor gearbox turned freely from the engine shaft. Its particle detector was clean and there were no signs of particle accumulation.

The engine's drive shaft could be turned in one direction but not in the other, due to the seized engine. This indicated the proper operation of the freewheel.

There was continuity from the yaw control pedals, which moved freely, through the system of bars and cams to the control bar in the tail boom. The bar itself was broken in about the same area as the drive shaft, where the structure of the tail boom was bent. All signs indicated that this damage had taken place post-impact.

The pitch of the tail rotor blades was manually adjustable and its motion was transmitted backwards through the pitch control mechanism to the cam that is actuated by the control bar in the tail boom.

The tail rotor shaft inside the gearbox moved freely without any restriction. The various sections of the tail rotor drive shaft were inspected and the condition and lubrication of the bearings, rings and coupling adapters was checked. No signs were found of excess stress or of corrosion.

The particle detector in the tail rotor gearbox was clean, with no signs of particles. The casing that protects the box was scratched on the inside, probably due to contact with the gears in the box or with the end of the drive shaft which, as already noted, had decoupled. Its appearance indicated contact lasting only a few seconds and not with a component that was rotating at high rpm's.

The decoupling occurred due to the break of the lug that housed one of the mounting screws and due to the stripping of the thread on the other screw. Both pieces were sent to a laboratory for analysis of the fracture.

The results ruled out microstructural flaws or heterogeneities causing the fracture of either the shaft or the mounting screw. In the first case, the material was identified as

AW 2014 aluminum, while the steel in the screw was identified as being alloyed with chrome, nickel and molybdenum. Both materials complied with the aircraft manufacturer's specifications. The shaft fractured due to excess stress under flexural tension. The screw was stripped of its thread by shear tear out.

The torque on the mounting nuts for the four bolts that attach the gearbox to the tail boom was quite high, and two of them had sealing wax that indicated that they had not been moved from their position. The three bolts that had sheared and whose halves had been found inside the tail boom structure were sent to a laboratory for analysis.

The analysis indicated that the bolts were made of chrome, nickel, molybdenum steel, as required by the helicopter manufacturer. There were no flaws or heterogeneities on the threaded surface that could have weakened their strength. A detailed study of the fracture surface pointed to a ductile tearing mechanism under shear stress. There were no significant differences in terms of the failure modes of the three screws, nor any signs of fatigue weakening. The probable cause of the fracture was identified as the impact.

### 1.8.4. *Witness statements*

#### 1.8.4.1. Pilot's statement

The pilot stated that the purpose of the flight was to film two locations in El Puerto de Santa Maria.

The flight involved circling above the objective making right-hand turns at an indicated airspeed of between 40 and 50 kt. So as to keep the helicopter's skid out of the field of view of the camera, the pilot induced some slip by pressing lightly on the right pedal and pushing the cyclic in the opposite direction. The desired altitude above the objective was 1,000 ft. He had about 50 h of flying experience using this technique.

After making two or three full turns above the first objective, they went to film the second one.

While on a northeasterly heading, the helicopter pitched down suddenly. He responded by correcting the motion with the cyclic. He then heard two mechanical sounds and the helicopter immediately started yawing right at an increasing rate. He immediately applied left pedal, but there was no response. He then gently pushed the cyclic forward and backward to check the helicopter's response to this control, and noted that it was as expected. Since the yaw motion was out of control, he reduced power gently and lowered the collective in an effort to achieve a controlled descent so as to gain translational speed and try to reestablish a stable flying condition. The yaw rate decreased, but it did not disappear completely. At one point he noticed that they were at the same altitude as the steeples of a church, that the loss of altitude had been excessive and that it was impossible to regain altitude, so he decided to make an emergency landing. He saw a flat area of ground with some vegetation, which he believed to be a park or garden, and he decided to try to land there. Seconds before touching down, he pulled on the collective to reduce the descent rate, but as he did the yaw rate started to increase once more. They impacted the ground and he lost consciousness, only to regain it once he was in the ambulance.

He insisted that all of his control inputs were smooth.

He also stated that since there were no abnormal indications in the cockpit, he thought the problem must have been caused by a loss of torque or control of the tail rotor, and that he acted in keeping with this interpretation.

When asked about the behavior of the helicopter, he replied that it responded properly at all times to power demands and to movements of the cyclic. He did not recall any abnormal indications in the cockpit. Every engine parameter was in the green zone, with the torque gauge at about 70% and the rpm's at 100% in the seconds before the loss of control.

He reported being familiar with the phenomenon known as loss of tail rotor effectiveness (LTE) and taught the topic regularly as an instructor.

When asked whether he was aware of any publications by Germany's civil aviation authority (LBA) on this phenomenon, he replied in the negative.

He indicated that he didn't know nor he has ever used the Spanish Air Traffic Regulations (RCA).

He also stated that on these flights, they did not consider any potential problem areas they might fly over beforehand; rather, it was the pilot who, over the course of the flight, was responsible for deciding on possible escape routes and areas suitable for conducting an emergency landing if needed.

### 1.8.4.2. Camera operator's statement

During the turn to film the second location, he felt the helicopter vibrate, though within what he regarded as normal. It then started turning sharply to the right. Apparently the pilot reacted quickly and managed to reduce the turn rate almost completely by the time they reached the ground.

The pilot was talking to himself repeating the phrase "pitch down stick forward". He described the descent rate as moderate and saw how the helicopter almost came to a stop just before the impact at the same time as the helicopter made a new 180° turn until they crashed.

He reported that the engine remained operating after the impact and he noticed a strong smell of fuel. The pilot and the other occupant were unconscious. He exited the helicopter and disconnected the battery by opening the nose compartment. He saw how passersby helped the pilot and the other occupant, pulling them from the helicopter.

He had not heard any unusual noises just prior to the loss of control.

#### 1.8.4.3. Other accounts

The occupant seated alongside the pilot could not specify whether he had heard any unusual noises before the loss of control. He reported that the speed during filming flights did not exceed 50 kt.

All of the accounts made by passersby and residents of the city confirmed the helicopter's abnormally high turn rate about its own axis. They also confirmed the reduction in its rotation speed for a few seconds prior to impact as the helicopter neared the ground.

All of the witnesses confirmed the noise of the engine in flight and some also recalled having heard the engine after the impact.

## 1.9. Organizational and management information

### 1.9.1. *The company and its Operations Manual*

The helicopter was owned by the Rotorflug GmbH company.

This company had been contracted to film coastal areas of Spain and Portugal, including both natural and urban areas of special interest to tourism.

Rotorflug GmbH is headquartered in Germany. It has an Air Operator Certificate (AOC) issued by the German aviation authority (LBA) and is approved as a Flight Training Organization (FTO), being authorized to give type rating courses on the Bell 206, Robinson 22 and Robinson 44 helicopters, as well as nighttime flight courses. Its AOC encompasses the locations in Egelsbach, Germany and San Bonet, Spain, though training in the latter is limited to dual-control flights until the student's first solo flight.

The company is also approved as a Part 145 Maintenance Center and a Continuing Airworthiness Management Organization (CAMO). This includes the authorization to conduct the airworthiness checks of the helicopters in its fleet and to issue the corresponding airworthiness review certificate (ARC).

Its Spanish subsidiary, Rotorflug SL, based in Palma de Mallorca, handles the company's activities on Spanish soil but it does not hold any aviation authorizations.

The accident helicopter was based at the San Bonet Aerodrome, from which the company organized tourism, film, photography and training flights by virtue of its authorization as an air operator (AOC) on the one hand and as a training center (FTO) on the other.

Rotorflug has an Operations Manual based on JAR OPS 3 and JAR-FCL regulations[3].

In the "Organization and Responsibilities" section of the manual, it states that certain activities (including filming) shall be conducted pursuant to JAR OPS 3 requirements, with the exceptions provided by the regulations in the case of VFR flights with fewer than nine passengers and machines whose maximum certified takeoff weight is under 3,175 kg[4].

The Manual makes references to the flight altitude for VFR operations, specifying a minimum safety altitude when flying over cities of 1,000 ft when within 600 m of the tallest object.

The "Regulations" section in the manual states that JAR OPS 3 and German specific regulations define the regulatory environment of operations, though in the case of flights outside of Germany the regulations of the State in question shall be applicable. The AIS is specifically mentioned as a source of information.

There is a section in the manual specifically devoted to aerial work. One of the sub-sections is on film and photography flights, and states that flying below specified altitudes shall require the necessary permits from the authorities. As a general rule, filming of important events shall be from an altitude above 1,000 ft. Finally, as regards the conduct of the flight, it notes that the use of altitudes below the minimum safety altitude (even if authorized) shall be limited to those cases in which it is absolutely necessary. The manual highlights the special care that must be taken during these activities in terms of the reserve power available and of the wind components present in the case of slow flights.

As required by JAR OPS 3, the manual indicates that helicopters operating in performance class 3[5] (which includes all single-engine helicopters) shall under no circumstances do so in so-called hostile environments, which includes populated areas without suitable

[3] JAR FCL 2 (Joint Aviation Requirements.Flight Crew License Helicopters). Regulation applicable throughout Europe involving the conditions for exercising the duties of a civil helicopter pilot. Contains the stipulations that govern training centers..

[4] For these types of operations, JAR OPS 3005 (f) and (g) allow for reduced requirements in different areas, such as flight documentation, acceptance and notification of passengers, fuel policy and safety procedures.

[5] JAR OPS 3 defines performance class 3 operations as those in which an engine fault in any phase of flight may require an emergency landing.

emergency landing spots. The Manual does not have a specific procedure for determining whether an area (populated or not) is defined as a hostile area, nor a specific procedure for determining the flight conditions or the specific precautions that pilots must take to fly over congested area beyond the aforementioned minimum altitude limitations.

There is a specific section in the Manual that is applicable to Rotorflug SL operations in Mallorca. It states that the Operations Manual shall in general be applicable, and further stipulates those requirements applicable to operations in Mallorca involving:

- Scenic flights.
- Filming and photography.
- Training.

The manual designates an Operations Manager in Mallorca who, along with the company's Operations Manager, must assure that operations are carried out in conformance with the Operations Manual and with German and Spanish law. The document states that the flight level shall comply with the Operations Manual and with Spanish law.

While not specifically envisaged in the manual, the company reported that the pilots who operated the aircraft based in Palma de Mallorca received specific information on Spanish laws, and in particular on Spain's Air Traffic Regulations.

The Operations Manual specifies the contents of the various courses given by the company both as a training organization (FTO), in keeping with the requirements of JAR FCL 2, and as an air operator, pursuant to, in this case, JAR OPS 3 requirements. The type rating training programs include knowledge of and training on situations involving tail rotor malfunctions. They do not explicitly include a separate reference to the loss of tail rotor effectiveness (LTE) phenomenon.

The syllabus for the course given to pilots joining the company required by JAR OPS 3 contains a part devoted to emergencies and to safety equipment that does specifically mention the measures to take if faced with an LTE phenomenon. The reference documentation used to study the phenomenon is a circular issued by the American civil aviation authority (FAA)[6].

### 1.9.2. *Oversight by the authorities*

As a general rule, engaging in aerial work in Germany does not require prior authorization from the aviation authority[7].

6 AC 90-95 Unanticipated Right Yaw in (US Manufactured) Helicopters

7 A so-called "Allgemeinerlaubnis" is issued, which is a purely administrative authorization given by local authorities as long as the petitioning company has commercial pilots and the necessary insurance for the aircraft it intends to operate.

The issuance of an air operator certificate (AOC) and the authorization as a flight training organization (FTO) requires the aviation authority to verify compliance with the joint aviation requirements (JAR).

As part of the LBA's biannual audit program of German operators, Rotorflug's facilities, means and procedures in Palma de Mallorca were audited in May 2011.

While the LBA did inform Spanish authorities of the audit and its results, the latter did not actively participate in said audits.

The inspections conducted did not specifically include a check of the company's knowledge and enforcement of Spain's Air Traffic Regulations.

Previously, in March 2010, Rotorflug had contacted Spain's Aviation Safety Agency (AESA) to request permission to engage in aerial photography activities with the accident helicopter. In compliance with applicable laws[8] and by virtue of the authorization granted by the German authority (LBA) to engage in such activities, AESA replied to this request by stating that Rotorflug could film anywhere on Spanish territory that was not designated as a prohibited or restricted area. The authorization, however, was subject to compliance with the requirements of the Air Traffic Regulations, specifically with Book Five[9], as well as with the contents of the AIP and with Civil Aviation General Directorate Circular n.º 343 C[10], when applicable. AESA provided links to the webpages that contained both the Air Traffic Regulations and the AIP information with its approval.

Beyond this communication, AESA did not conduct any inspections at the company's base in Palma de Mallorca either in the area of operations or maintenance.

## 1.10. Additional information

### 1.10.1. *Regulations on single-engine helicopter operations*

Both Germany's regulation on aerial activities[11] and JAR OPS 3 specify that operations in single-engine helicopters must ensure that in the event of an engine failure, the helicopter must be able to safely make a forced landing.

[8] DIRECTIVE 2006/123/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 12 December 2006 on services in the internal market.
Law 25/2009, of 22 December, which modifies various laws to adapt them to the law on free access to service activities and their exercise.
Law 17/2009 of 23 November, on free Access to services and their exercise.

[9] Book Five of the Air Traffic Regulations contains stipulations specifically applicable to helicopter operations.

[10] Circular n.º 343 C, dated 19 May 1995, deals with the requirement to solicit permission to engage in aerial work activities in areas of the air space where VFR flights are not normally allowed.

[11] Betriebsordnung für Luftfahrtgerät (LuftBO).

JAR OPS 3 specifically limits flights in this type of helicopter to non-hostile environments, not including congested areas[12] that do not have adequate sites for a safe forced landing.

For its part, Book Five of Spanish Air Traffic Regulations, devoted specifically to helicopter operations, establishes stricter conditions for flying over urban centers in a single-engine helicopter:

> "5.1.7. Flying over urban areas.
> Single-engine helicopters shall not fly over urban areas with more than 50,000 inhabitants, except when engaged in a duly justified mission involving an urgent evacuation or medical transportation.

According to the municipal registry, the population of El Puerto de Santa Maria on 20/02/2012 exceeded 90,000.

### 1.10.2. *The loss of tail rotor effectiveness phenomenon*

The loss of tail rotor effectiveness, or LTE, is a critical, low-speed aerodynamic flight characteristic that can result in an uncontrolled, uncommanded rapid yaw that does not subside of its own accord and, if not corrected by the pilot, can result in the loss of aircraft control. LTE is one of the leading causes of helicopter accidents involving a loss of control and can appear in any helicopter with an anti-torque rotor. Both Bell Helicopters[13] and the FAA[14] have written informative material on this phenomenon.

The phenomenon is typical in out-of-ground-effect flights at indicated airspeeds (IAS) below 30 kt and is aggravated by high weight, high power demand situations and right turns.

In the case of helicopters whose main rotor turns counterclockwise (such as the Bell 206), the interference from the vortices produced by the main rotor on the air flow to the tail rotor when the relative wind is from 285° to 315° can also contribute to changing the thrust effect on this rotor, leading to the appearance of the phenomenon.

To recover from LTE the pilot must quickly and forcefully apply the pedal opposite to the direction of the yaw and simultaneously move the cyclic forward to gain speed. Altitude permitting, power should be reduced by lowering the collective.

In July 1994, the NTSB published four safety recommendations issued to the FAA involving the need to educate and train pilots on the phenomenon. All of them resulted

[12] Section 3.480 (4) of JAR OPS 3 defines a congested area in terms of a city or populated area as any area utilized primarily for residential, commercial or recreational purposes.
[13] Operational Safety Notice OSN 206-83-10, Operational Safety Notice OSN 206 83-10, Information Letter 206-84-81.
[14] OAC 90-95 Unanticipated Right Yaw in (US Manufactured) Helicopters.

in actions by the FAA, including the publication of an advisory circular on the LTE phenomenon and its inclusion in the pilot training reference text "Rotorcraft Flying Handbook".

Recently, other accident and incident investigation commissions, such as the AAIB[15] in the UK and the AAIU[16] in Ireland, issued various recommendations in the wake of accidents where LTE was identified as a contributing factor so as to raise awareness of this phenomenon among operators and pilots, including the need to include the LTE phenomenon in pilot training programs. These recommendations were directed at both national authorities (the CAA and IAA, respectively) and at the EASA as the supranational European authority.

The CIAIAC also, in the wake of the accident of a Bell 206 in 2005, issued a safety recommendation along these lines to the DGAC.

Both the CAA in the UK and the IAA in Ireland proceeded to issue publications[17] intended to familiarize operators with the LTE phenomenon and to recommend to said operators that they distribute the information among their crews.

The EASA, for its part, issued a safety bulletin[18] in 2010 that recommended to national authorities that they ensure that helicopter training programs include material on the LTE and recovery techniques.

No evidence has been found to indicate that the German (LBA) or Spanish (AESA) civil aviation authorities have taken any actions in response to the recommendation in the EASA bulletin.

## 2. ANALYSIS

### 2.1. Analysis of a potential mechanical failure

The flight had transpired normally without any indication of a mechanical problem. There were no particularly demanding maneuvers performed in the instants leading up to the loss of control that could have resulted in loads above those typical of more or less level flight.

Neither the pilot's nor witnesses' statements point to a fault of the powerplant. The condition of the main rotor blades as well as the morphology of the damage identified

[15] Accident of a Bell 206B Jet Ranger III, G-BAML on 30 May 2003. Final Report n.° EW/C2003/05/07.
Accident of a Robinson R44, G-SYTN on 8 May 2005. Final Report N.° EW/G2005/05/07.
[16] Accident of a Bell 206B Jet Ranger II, G-AYMW on 5 April 2004. Final Report N.° 2004/0021
[17] Flight Operations Department Communication (FODCOM) 1/2004.
[18] EASA SIB 2010 of 12 February 2010, revised by SIB 2010-12R1 of October 2010.

on the buildings indicate contact between the blades and the outside walls of the buildings during the descent before the helicopter reached the ground.

The breaking of the pitch control components and of the connection between the drive shaft and the main rotor gearbox is compatible with a sudden interruption of the rotor's rotation upon impact. This is all consistent as well with the demand condition reflected in the positions of the throttle and anticipator.

The appearance of a possible mechanical noise just before the loss of control, reported by the pilot and indicative of a hypothetical mechanical fault, was not corroborated by the other two passengers. Beyond this perceived noise, the pilot did not mention any other anomaly in the tail rotor control system, such as a blockage of the pedals or, on the contrary, excessive play in the pedals.

The maintenance data revealed that all of the required inspections of the tail rotor systems had been completed and that limited life components were tracked and within limits.

Post-accident inspections revealed proper performance of the components in the tail rotor drive shaft and in the tail rotor pitch control mechanism used to change blade pitch using the pedals in the cockpit.

The breaks identified in the transmission components were analyzed in a laboratory, the results of which indicated the breaks had occurred due to excess stress, probably as a consequence of an impact. There was no evidence of fatigue, corrosion or maintenance or construction defects. The fact that the elements that detached after the break (mounting bolts on the tail rotor gearbox and the drive shaft adaptor) were found among the main wreckage reinforce the hypothesis that they detached during the impact with the buildings and the ground near the final site where the main wreckage came to a stop. Moreover, the marks left on the outer casing by the broken end of the drive shaft and by the gearing in the box were not consistent with having these components turning at high rpm's or with prolonged contact, as would have been the case had the transmission failed in flight, as evidenced by the computer simulations.

The simulations also indicated that had the transmission failed under these flight circumstances, the pilot would have regained control immediately by pushing the cyclic forward, in contrast to what happened on the day of the accident, when the helicopter's response to this action by the pilot was mostly ineffective. While the results of a theoretical model must be taken with some reservations, it can be stated that in this regard and at least qualitatively, the actual behavior did not correspond to that expected from a failure of this type.

Both the footage recovered from the camera and the analysis of the flight path indicate that during the descent, the helicopter did not attain an appreciable translational speed that, due to the effect of the vertical stabilizer, would have contributed to regaining control. The helicopter's final reaction, in which the turn rate was reduced considerably despite the negligible translational speed, reveals that in some way, the anti-torque rotor was responding to the pilot's input.

## 2.2. Analysis of the flight and the LTE phenomenon

The helicopter had taken off with a weight very close to its maximum certified takeoff weight. The drop in weight as a result of fuel consumption after twenty minutes of flight would have been minimal (20-25 kg), and therefore the power demand while flying over the city under those load conditions and on a relatively hot day would have been high.

While filming, the helicopter was flying out of ground effect (at an altitude of around 1000 ft), circling to the right at an indicated airspeed (IAS) that, in light of the predominant wind speed (10 to 12 kt from the SW) and the ground speed recorded by radar and GPS, could have been considerably below 30 kt when making turns with a tailwind (NE course). The pitching motion noticed by the pilot just before the loss of control could have been caused by a gust of wind that struck the helicopter from behind.

The loss of tail rotor effectiveness phenomenon is well known and has been described as a loss of lift that is more likely to appear when several factors combine together. These factors were present at the time of the loss of control: low-speed flight (IAS < 30 kt) out of ground effect, turn to the right, high weight and power demand as well as a relative wind azimuth from the left with respect to the direction of flight (from 285° to 315°), caused by the slight slip induced by the pilot in an effort to improve the camera's field of view.

In addition, the characteristics of the yaw movement observed during the accident show similarities with the results of the theoretical simulations of an absence of lift in the anti-torque rotor, a condition that, to a certain extent, may be regarded as representative of the LTE phenomenon.

Once LTE occurs, the recovery technique recommends applying left pedal and pushing the cyclic forward in an effort to gain translational speed, which contributes to vertical stability.

Although the pilot did not interpret the situation as an LTE, the pilot's initial reaction, to apply left pedal to compensate for the yaw and his repetition of the phrase "pitch down, stick forward", as manifested by one of the occupants, was along the lines of what is recommended when faced with an LTE, namely to gain speed and reduce power.

However, as the pilot stated, his first reaction was not to move the cyclic forward. He first checked the response of the control by moving it back and forth before deciding to push it forward. He did lower the collective, a recommended action if at a high enough altitude. This delay could have had a critical effect on the recovery maneuver and probably caused an initial loss of altitude that was not accompanied by an increase in horizontal speed. The pilot also noted that all of his control inputs were smooth, in contrast to the forcefulness recommended in these cases.

The pilot's ability to react could have been diminished by the relatively intense workday, which had started early that morning and included an airplane trip to go to Spain.

In any event, the helicopter did not attain a high enough translational speed, as was reflected in the footage, and therefore the stabilizing effect that the air flow rushing over the vertical stabilizer would have had was not available. This translated into a new increase in the turn rate when the pilot pulled on the collective to slow the loss of altitude.

The fact that the helicopter was flying over a congested urban area limited the pilot's ability to react when close to the ground after he had decided to make an emergency landing, and resulted in there being no suitable place to land.

## 2.3. Analysis of regulatory knowledge and its oversight

Rotorflug is a German company, and its authorizations were issued by that country's civil aviation authorities. Its operations on Spanish territory are recognized by a policy of mutual acknowledgment of administrative authorizations within the EU, by an AOC that is valid throughout Europe and by an authorization as a training center that was issued in accordance with JAR regulations (adopted by Spain and Germany) that, though limited, explicitly includes operations from a Spanish aerodrome.

The aerial work operations are described in the operations manual, itself approved in accordance with JAR OPS 3, and were therefore authorized and also subject to JAR requirements, save for the exceptions provided by the JAR itself.

In this regulatory scenario, a new authorization from Spanish authorities was not needed for the company to operate within Spanish territory, even though Rotorflug was subject to Spanish laws on flights within Spanish air space, as was made explicit by the Spanish authority.

Although this commitment to abide by Spanish law was formally acknowledged in the Operations Manual, the pilot was not familiar with the basic document that specifies the rules of the air in Spanish territory, namely, the Spanish Air Traffic Regulations. This is made more significant by the fact that he was the company's training and flight operations manager.

Both European and German regulations include safeguards to preclude having single-engine helicopters fly over areas where making an emergency landing could prove hazardous. These stipulations are listed in the company's operations manual, and rely on the pilot's good judgment and on maintaining a minimum safe altitude to enforce these requirements.

The relevant regulation in Spain is more restrictive and explicitly forbids flying over cities of a certain size. The pilot's ignorance of this regulation resulted in the aircraft flying over a city whose population is well above the limit specified in Spanish law.

This serves to underscore the problem associated with engaging in this type of activity beyond the borders of the supervising state. Aerial work in general, and aerial filming in particular, has very specific characteristics in terms of altitudes, speeds and areas of operation. Add to this the heterogeneity of the regulatory framework, and the result is an activity that differs in many respects from the commercial transport operations that are regulated in JAR OPS 3.

These special characteristics make them more sensitive to the particularities of the operating environment, and thus require a knowledge of said environment that is even more detailed than that needed for a transport operation in which the aircraft is limited to taking off from an aerodrome, reaching the altitude necessary for more or less level cruise flight and descending to land at a destination aerodrome, all within a more internationally uniform and consolidated regulatory framework.

The validity of flying licenses, which are issued after a process of study and familiarization with local and international regulations, goes a long way to ensuring that pilots are knowledgeable of the regulations in the country that authorizes an operation. However, when pilots are operating in a different country, and especially when they are involved in aerial work, where the regulatory framework is more heterogeneous, an additional effort is required by both the operator and by the supervisory authorities.

The operator apparently had mechanisms in place to ensure that pilots who regularly flew out of Palma de Mallorca were familiar with Spanish regulations. That was not the case, however, with the pilot in command of the accident helicopter who, despite not having flown on a regular basis before in Spain, did not receive specific training in this area.

As regards the supervision, while there was some contact between German inspectors and their Spanish counterparts, this contact was sporadic and lacked the planning necessary to ensure a proper allocation of tasks and exchange of information.

As a result, a safety recommendation is issued to the company to ensure that those pilots engaged in operations outside Germany, whether permanently or temporarily, possess proper knowledge of the regulations of the country in which they operate. By extension, recommendations along these lines are also issued to the supervisory civil aviation authorities in Spain and Germany to have them establish the mechanisms necessary to ensure proper supervision of this aspect. The participation of the authority in the country of operations in the supervisory process will undoubtedly have a positive effect on the proper interpretation and application of local regulations, which will have a favorable impact on safety.

### 2.3. Analysis of LTE training

It is obvious that LTE has contributed to many loss of control events involving helicopter operations. Various authorities and organizations have admitted as much, and have taken measures intended to improve pilots' knowledge of this phenomenon. However, and despite the involvement of the EASA, the response has not been uniform. Neither the LBA in Germany nor the AESA in Spain has taken any measures in response to the recommendation issued by the EASA.

The pilot was experienced, was aware of the phenomenon and familiar with the documentation issued by the FAA in this respect. And yet the flight parameters, not only in the seconds before the accident but for the duration of the flight, were conducive to the possible appearance of LTE.

This highlights the fact that the pilot's sensitization to the risk associated with the appearance of this phenomenon may not have been adequate. This is particularly troublesome considering that the pilot was the company's flight operations and training manager, and therefore charged with promoting awareness and prevention of this phenomenon among the company's pilots.

It seems reasonable, then, to insist once again at both a company and authority level on the need to raise pilot awareness of LTE in an effort to avoid flight configurations that could favor the appearance of this phenomenon. Two safety recommendations are issued in this regard.

## 3. CONCLUSION

### 3.1. Findings

- The helicopter had a valid airworthiness certificate and was maintained in accordance with the approved maintenance program.
- The helicopter's balance was within limits and the weight was close to the maximum allowed takeoff weight.
- The pilot had a valid license and medical certificate, both in force.
- The aerial work authorizations issued in the country of origin (Germany) were automatically validated in Spain.

- The flight transpired without any apparent faults from the time of takeoff until the sudden loss of control.
- While flying over the filming area, the aircraft made 360° turns at an altitude of between 700 and 1,000 ft. The ground speed was steady at around 30 kt.
- While circling, the pilot induced a slight inward slip to improve the camera's field of view.
- The wind in the area of the flight at the time of the accident was moderate and resulted in a tailwind at certain points in the turns.
- The characteristics of the flight in terms of its speed, the direction of the turn, the weight and altitude have all been identified as risky from the standpoint of inducing an LTE event.
- The pilot was familiar with the loss of tail-rotor effectiveness phenomenon and with the reference documentation published by the FAA that discusses said phenomenon.
- The tests and inspections conducted on the aircraft wreckage did not show any evidence of a mechanical failure in the anti-torque rotor system.
- The helicopter was flying over a congested urban area.
- The pilot was unfamiliar with Spain's Air Traffic Regulations.
- The inspections conducted at the company's facilities in Spain had not checked for the existence of a procedure to assure that crews had proper knowledge of Spain's aviation rules.
- The authority of the country where the operation was conducted (Spain) did not take part in the supervisory activities.
- Neither the supervisory authority in Spain (AESA) or in Germany (LBA) has taken any measures in response to the EASA's issuance of safety bulletin SIB 2010-12R1 on providing LTE training to helicopter pilots.

### 3.2. Causes

The accident was most likely the result of a loss of control caused by the appearance of the loss of tail-rotor effectiveness phenomenon.

## 4. SAFETY RECOMMENDATIONS

**REC 61/12.** It is recommended that the operator, Rotorflug GmbH, establish the necessary measures to enhance pilot awareness of the LTE phenomenon, and in particular of the danger posed by flying in conditions that increase the probability of the phenomenon occurring.

**REC 62/12.** It is recommended that Spain's Aviation Safety Agency (AESA) and the Luftfahrt Bundesammt (LBA) take measures along the lines recommended by the European Aviation Safety Agency (EASA) in SIB 2010-12R1.

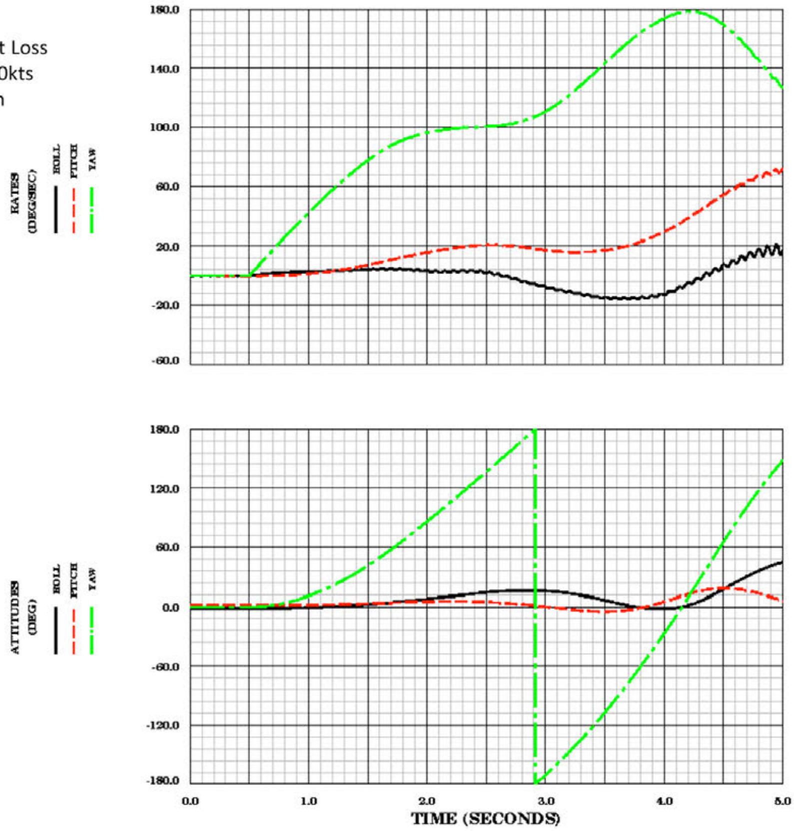
**REC 63/12.** It is recommended that the operator, Rotorflug GmbH, establish procedures to ensure that all of its pilots who engage in aerial work activities outside of Germany are familiar with local aviation regulations in the state of operation.

**REC 64/12.** It is recommended that the Luftfahrt Bundesammt (LBA), as part of its activities to supervise German operators who engage in aerial work in other states, and in concert with these states, ensure that procedures are implemented to ensure that all of their pilots are familiar with local aviation regulations in those states in which they operate.

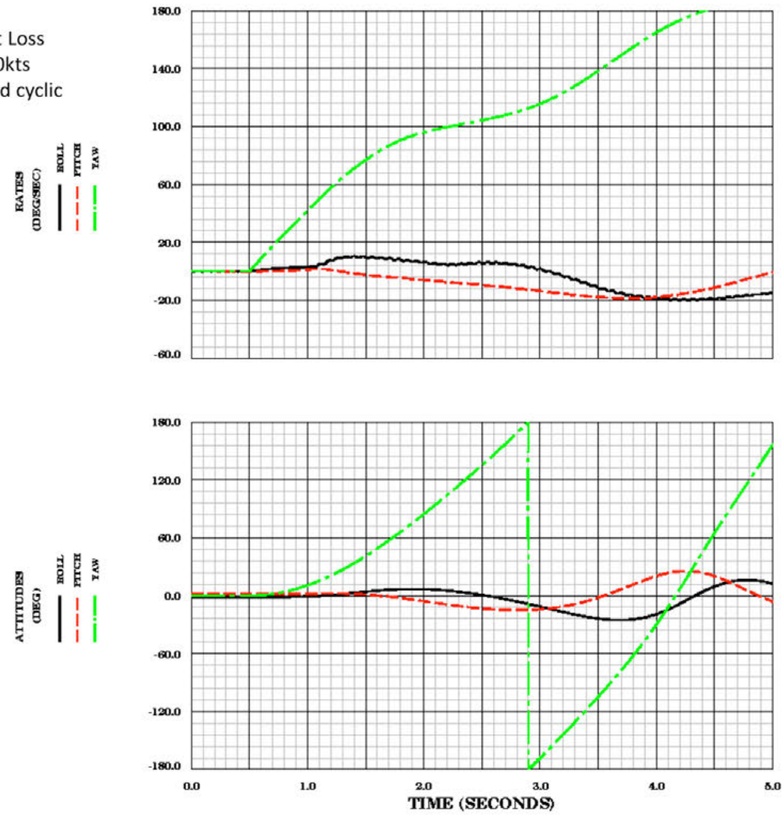
**REC 65/12.** It is recommended that Spain's Aviation Safety Agency (AESA) ensures, in concert with supervisory authorities in the country of origin, that foreign operators who engage in aerial work operations in Spain are familiar with Spain's aviation regulations and take them into account in their procedures.

# APPENDIX I
## Simulation results for 20 kt IAS

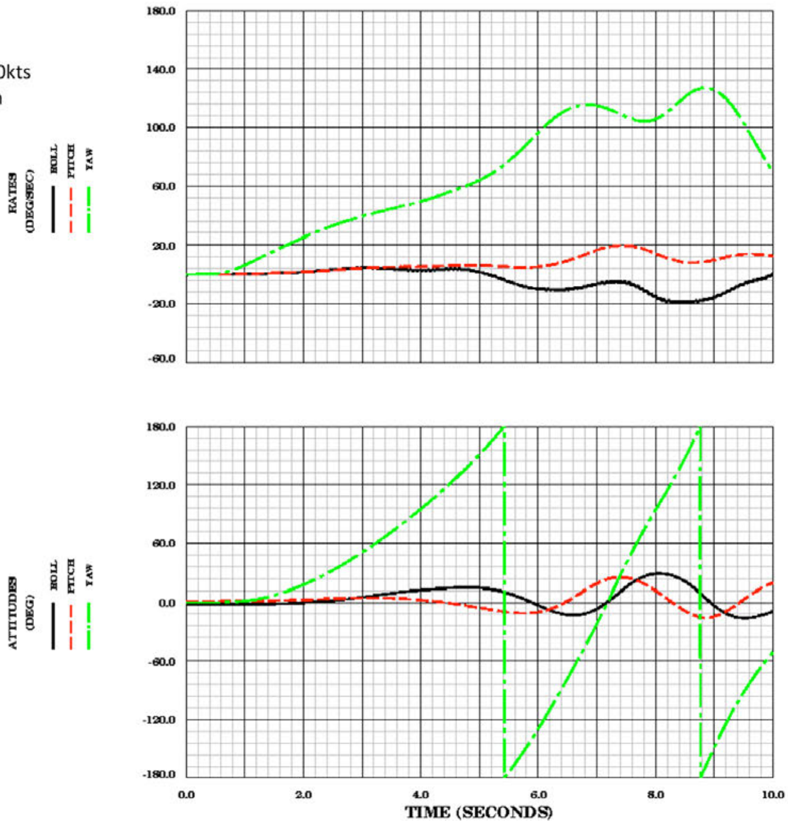
Case #2
Instant Jet Thrust Loss
Forward Flight-20kts
No Pilot Reaction




Case #4
Instant Jet Thrust Loss
Forward Flight-20kts
Pilot adds forward cyclic



Case #6
T/R Torque Loss
Forward Flight-20kts
No Pilot Reaction




Case #8
T/R Torque Loss
Forward Flight-20kts
Pilot adds forward cyclic