CIAIAC

COMISIÓN DE
INVESTIGACIÓN
DE ACCIDENTES
E INCIDENTES DE
AVIACIÓN CIVIL

Report A-008/2015

Accident involving an Airbus helicopters AS 355 NP aircraft, registration EC-KYJ, operated by TAP Helicopters at the helipad on the Catalonia Race Track (Montmelo, Barcelona), on 26 March 2015

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Foreword

This report is a technical document that reflects the point of view of the Civil Aviation Accident and Incident Investigation Commission (CIAIAC) regarding the circumstances of the accident object of the investigation, and its probable causes and consequences.

In accordance with the provisions in Article 5.4.1 of Annex 13 of the International Civil Aviation Convention; and with articles 5.5 of Regulation (UE) n.º 996/2010, of the European Parliament and the Council, of 20 October 2010; Article 15 of Law 21/2003 on Air Safety and articles 1, 4 and 21.2 of Regulation 389/1998, this investigation is exclusively of a technical nature, and its objective is the prevention of future civil aviation accidents and incidents by issuing, if necessary, safety recommendations to prevent from their reoccurrence. The investigation is not pointed to establish blame or liability whatsoever, and it's not prejudging the possible decision taken by the judicial authorities. Therefore, and according to above norms and regulations, the investigation was carried out using procedures not necessarily subject to the guarantees and rights usually used for the evidences in a judicial process.

Consequently, any use of this report for purposes other than that of preventing future accidents may lead to erroneous conclusions or interpretations.

This report was originally issued in Spanish. This English translation is provided for information purposes only.

Table of contents

Abbreviations

00° 00′ 00″	Sexagesimal degree, minute and second
00 °C	Degrees centigrade
AEMET	National Weather Agency
AEO	All Engines Operating
AESA	National Aviation Safety Agency
bar	Unit of atmospheric pressure
BEA	Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation civile
CAS	Calibrated Airspeed
CPL(H)	Commercial pilot license (helicopter)
DIFF PWR	Power differential
EASA	European Aviation Safety Agency
EASB	Emergency Alert Service Bulletin
ENG	Engine
EOP	Engine oil pressure
EOT	Engine oil temperature
FADEC	Full authority digital engine control
FATO	Final approach and takeoff area
FI(H)	Flight instructor (helicopter)
FLI	First limit indicator
FLT	Flight
ft	Feet
ft/min	Feet per minute
GPS	Global Positioning System
h, hr	Hour(s)
hp	Horsepower
IAS	Indicate airspeed
IR	Instrument flight rating
kg	Kilogram(s)
kt	Knot(s)
l	Liter(s)
LH	Left hand
m	Meter(s)
mm	Milimeter(s)
N	North
N_1	Compressor % RPMs
N_2	Power turbine speed in %
N_R	% rotor RPMs
NM	Nautical mile(s)
OAT	Outside Aire Temperature
OEI CONT	Maximum continuous power with one engine inoperative
OEI MAX	Maximum power with one engine inoperative
PT	Power turbine
RACC	Real Automobile Club Catalonia
RH	Right hand
rpm	Revolutions per minute
TOT	Turbine outlet temperature
TRI(H)	Type rating instructor (helicopter)
TRNG	Training
TRQ	Torque
VEMD	Vehicle and engine multifunction display

Synopsis

Owner and operator:	TAF Helicopters
Aircraft:	Airbus helicopters France AS 355 NP; registration EC-KYJ
Date and time of accident:	Friday, 26 March 2015; at 10:45 h[1]
Site of accident:	Helipad at the Momtmeló Race Track (Barcelona)
Persons onboard:	1, crew (uninjured) and 2, passengers (uninjured)
Type of flight:	State flight – Police
Phase of flight:	Approach – Emergency descent during approach
Date of approval:	30 November 2016

Summary of accident

On Thursday, 26 March 2015, an Airbus helicopters France AS 355 NP helicopter, registration EC-KYJ, operated by TAF Helicopters for the Catalonia Regional Police took off from the Sabadell airport (Barcelona) with a pilot and two officers onboard.

While in cruise flight, CHIP 2 warning light turned on in the cockpit indicating metal particles in the right engine[2]. The right engine oil pressure indicator on the VEMD was in the red area with a value of 12,3 bars underlined in red, out the limit of 10 bars maximum.

The pilot decided to make a landing in the training mode at the helipad on the Catalonia Race Track in the locality of Montmelo (Barcelona). As he was flying the short final approach landing, the right engine failed when part of the power turbine and the exhaust pipe detached, damaging various components and, most notably, shearing the tail rotor shaft.

The pilot completed the landing and all the occupants exited the aircraft under their own power and with no injuries.

The damaged engine then caught fire, which the occupants kept from spreading to the rest of the aircraft by using two hand-held fire extinguishers. The fire was eventually put out with help from a truck that was on the track that was equipped with a tank and a pump. The helicopter sustained significant damage to its engines and tail cone.

[1] All times in this report are local.
[2] This report also refers to the left engine as no. 1 and the right engine as no. 2.

The Investigation has concluded that there was fatigue on the thread of the clamping screw at the front of the PT shaft and also that the management of the CHIP 2 warning procedure has not been carried out in accordance with the procedure described in the flight manual.

As the right engine has not been shut down, the working conditions of the engine has been deteriorated until the rupture of the PT drive shaft at the level of the clamping screw and the destruction of the PT thrust bearing and as a consequence the loss of axial retention on the PT shaft.

The entire engine failure occurred during the short final approach landing when right engine power demand was requested. The PT shaft then was ejected. It damaged several components including the tail rotor shaft and caused a fire in the right engine.

1. FACTUAL INFORMATION

1.1. History of the flight

On Thursday, 26 March 2015, an Airbus helicopters France AS 355 NP helicopter, registration EC-KYJ and operated by TAF Helicopters, took off from the Sabadell airport en route to Sant Iscle de Vallalta, a town in the north of the province of Barcelona. This helicopter was providing services to the Catalonian regional police (Mossos d'Esquadra) and was carrying, in addition to the pilot, two officers who were members of said police force. According to information provided by the occupants, during the return flight, while in cruise flight over the Montnegre Valley and on an approximate heading of 220°, an altitude of 2,000 ft and IAS of 100 kt, one of the officers noticed that the warning light on the chip detector for the right engine (CHIP 2) had turned on. The pilot said that he immediately reduced the speed and power, and verified that the pressure and temperature for the oil in the right engine were within normal limits. He then adjusted the controls on the right engine to keep its torque below 40% and set it to training (TRNG) mode.

He then decided to proceed to the helipad located in the firefighting base in the town of Dosrius (Barcelona), and to fly in from the south. He thus made a right turn and approached the helipad on a north heading. The pilot said that after establishing the power, the helicopter settled at a 50 ft/min descent rate. However, to reach this helipad, he had to go over a mountainous area, which would have required a climb. Since the engine conditions did not allow for such a climb, he decided to keep turning and head instead to the helipad located at the Montmelo Race track (Barcelona), which was some 8 NM away. He steadied on heading 210° and proceeded to said helipad.

As the pilot was preparing to land via threshold 21 at the Montmelo Race Track helipad, he heard a strange noise, though no warning lights came on in the instrument panel.

Figure 1. Approximate flight path of the helicopter

As they were flying over the final approach and takeoff area (FATO), the noise grew louder, the helicopter started to shake and the pedals became unresponsive (yaw control). The pilot finally made a running landing as the skids slid over the paved surface. At the end of the landing run, the helicopter turned to the left.

After the aircraft came to a stop, the pilot stopped the engines and noticed smoke issuing from the engine housing. At the same time one of the officers said that the right engine was on fire. All three occupants exited the aircraft under their own power. The pilot went back and took the onboard fire extinguisher to try to dowse the fire but could not do so. Eventually, a truck on the track that was equipped with a tank and a pump, and whose help they had requested, proceeded to their aid and was able to extinguish the flames.

The flight lasted a total of 35 minutes.

1.2. Injuries to persons

Injuries	Crew	Passengers	Total in the aircraft	Others
Fatal				
Serious				
Minor				Not applicable
None	1	2	3	Not applicable
TOTAL	**1**	**2**	**3**	

1.3. Damage to aircraft

The aircraft sustained significant damage to both engines and the tail cone, including the shearing of the tail rotor shaft.

1.4. Other damage

There was no other damage.

1.5. Personnel information

The pilot had a helicopter commercial pilot license (CPL(H)), issued by Spain's National Aviation Safety Agency (AESA) on 11 March 1994. The license included ratings for the

AS 355/355N/SP helicopter types, valid until 31 January 2016, for instrument flight (IR), valid until 30 June 2015, for helicopter flight instructor (FI(H)), valid until 23 January 2018, and for type rating instructor (TRI(H)), valid until 30 April 2015. He also had a class-1 medical certificate that was valid until 10 December 2015.

He had a total of 6,623 flight hours, of which 2,118 had been on the type.

1.6. Aircraft information

1.6.1. *General information*

The AS355 NP helicopter was built by Airbus Helicopters in 2008 with serial number 5767. It's has a dry weight of 1,666 kg and a maximum takeoff weight of 2,600 kg.

It is 10.93 m long, 3.14 m high, 1.87 m wide (2.28 m wide base at the skids). The main rotor has three blades and a diameter of 10.69 m, while the rear rotor has two blades and a 1.86 m diameter.

The accident helicopter was equipped with two TURBOMECA ARRIUS 1A1 engines. The left (no. 1) engine had serial number 3045 and was installed on June 2008, and the right (no. 2) engine had serial number 3044 and was installed in June 2008, and reinstalled in October 2011 (After been returned to the engine manufacturer for bench testing only but the engine was neither overhauled nor disassembled).

On the day of the accident, the aircraft had 2,592:00 h of operation, the left engine had the same hours and the right engine had 2,425 h (842 h after only bench testing in the engine manufacturer facility). The last maintenance inspection, a 100-hr check, had been carried out on 6 March 2015 with 2,566:44 h on the Airbus Helicopters, the same hours on the left engine and 2,399:20 h on the right engine. It had flown 27 hours since the last inspection, which covered[3] the engines (regular inspection and over speed check), air conditioning, optional equipment, fuselage, worm drive, main rotor mast, main gearbox, tail rotor gearbox and tail rotor shaft.

The last maintenance check of the engines (600-hr inspection) was carried out with 2,090:36 h on the Airbus Helicopters and left engine and 1,923:12 h on the right engine. As detailed in the work order, during this check the engines had been removed for the inspection, as required by the maintenance manual. This inspection was carried out in December 2013 and the Airbus Helicopters was returned to service on 15 January 2014.

[3] Without going into details, save for the engines.

The maintenance work was done by SABADELL AIRBUS HELICOPTERS SERVICE CENTER, S.L.,[4] as per the maintenance manual approved by AESA on 02 December 2013.

1.6.2. *Engine lubrication system*

Each engine has a separate oil cooling system. The engine oil tanks are located in the main gearbox compartments on the mechanical floor, the oil radiators and electric fans are located in front of the main gear box compartment on the cabin. In flight, both lubrication systems are monitored by way of oil pressure and temperature indications that are shown on the VEMD (Vehicle and Engine Multifunction Display)[5].

If the oil pressure drops, a caution light will turn on in the caution light panel with the message ENG P.1 or ENG P.2. If one of the chip detectors were to detect the presence of magnetic particles, the caution light will turn on with the message CHIP 1 or CHIP 2.

1.6.3. *Engine fire detection system*

The Airbus Helicopters features a fire detection system for the critical engine areas and the main gearbox. The system's detectors monitor for both slow and fast increases in temperature.

Specifically, for the engines, each engine compartment has an independent detection system consisting primarily of four temperature sensors, one relay unit and one fire warning light (FIRE ENG LH or RH) in the cockpit. Two of the four sensors are set to 200 °C and are installed in the front part, while the other two are set to 400 °C and are located in the rear. These sensors monitor the flow of air ventilating the engines and those areas susceptible to flammable liquid leaks.

If the temperature in the area where the sensors are located were to increase, a warning light in the cockpit labeled FIRE ENG LH or RH would turn on for the left or right engine, respectively.

1.6.4. *Information in the flight manual*

The Airbus Helicopters flight manual has some content worth noting, as it contains procedures for handling emergencies and training to simulate an engine failure. Section 3. Emergency procedures.

[4] Approval AESA ref. ES-145-036.

[5] The VEMD has a non-volatile memory that stores flight parameters and messages. This aircraft did not have any other device with a non-volatile memory from which data could be extracted.

"3.1 General

The emergency procedures describe the actions that the pilot must take in various emergency situations. The wide variety of external factors and the characteristics of the terrain being overflown, however, mean that the pilot has to adapt to conditions based on his own experience. To help the pilot in his decision-making process, four expressions are used:

LAND IMMEDIATELY, meaning without the slightest delay; LAND AS SOON AS POSSIBLE, meaning land in the nearest location available but do so safely; LAND AS SOON AS PRACTICABLE, meaning land in the nearest place where proper technical assistance can be provided (if continued flight operations are not recommended); and finally, CONTINUE FLYING, which allows continuing with the flight as planned and having the necessary repairs be carried out at the destination as per the maintenance manual.

3.12.3 Engine oil system

If the CHIP warning comes on in the caution light panel, proceed as follows:

CHIP # 1 or 2: metal particles in the affected engine oil system.

Check and monitor the oil pressure and temperature readings for the affected engine.

Depending on flight conditions, shut down the affected engine. Land as soon as practicable.

During approach, affected engine on FLT if necessary."

Figure 2. Engine switch positions

The flight manual describes the procedure for simulating an engine failure and must be used only for training. The name of this procedure is TRAINING MODE.

It provides the training procedures for flying with one engine In “training mode”, the system allows practicing OEI procedures with reduced weight, using procedures at power levels that will not cause damage. To this end, when the switch is set to training mode (TRNG), the system allows:

- Simulating a loss of engine power by adjusting N_2 to be equivalent to 355 RPM N_R (training idle N_2).
- Adjusting FADEC N_1 sets the other engine to OEI training levels.

> “1.2 CONTROLS AND INDICATIONS
>
> The training mode is activated via the engine start switch (OFF-TRNG-FLT) located in the top panel. In normal flight, selecting TRNG in the start switch for ENG.1 or ENG.2, respectively, results in the following:
>
> - ENG.1 or ENG.2 set to idle N_2 (N_2 equivalent to 355 RPM N_R),
> - N_1 OEI MAX limit armed in ENG.2 or ENG.1 (unless OEI CONT was mistakenly preset in AEO mode),
> - “TRNG + DIFF PWR” lights turned on in the caution light panel, audible “GONG” sounded three times,
> - First limit indicator (FLI) set to OEI mode associated with the OEI MAX limit, and caution lights illuminated.
>
> To return to normal flight mode, the engine start switch for ENG.1 or ENG.2 is set to the flight (FLT) position.
>
> *Operational safety devices*
>
> In addition to the use of power limiters in the engines, additional safety devices are available when training mode is in use:
>
> If necessary, as soon as rotor RPMs (N_R) fall below 355, the engine that was at idle provides the energy demanded up to the actual OEI rate selected by the pilot during the exercise. In any event, the maximum power associated with OEI (OEI MAX) will be available as soon as rotor RPMs (N_R) drop to or below 330.
>
> *NOTE*
>
> If the engine supplying power were to fail, it would not be necessary to set the ‘OFF/FLT/TRNG’ start selector on the engine to the FLT position.”

1.6.5. *Performances*

The weight and balance was calculate by the investigator team and also by the manufacturer of the helicopter. The conclusion was that in accordance with the flight manual, Section 2 "Limitations", Paragraph 2.2 "Weight and balance limitations", the weight & balance of the aircraft was within the limits:

One Engine Inoperative (OEI) Performance[6]

The flight manual, Section 2 "Limitations", Paragraph 2.4.3.2 "One engine inoperative limitations" gives the following limitations:

	FLI value	N_1 (%)*	TOT (°C)	TRQ (%) per engine
CONT (unlimited)	12	102.5	812	115
OEI MAX (t ≤ 2.5 min)	13.2	104.1	885	131
OEI MAX transient (t ≤ 5 s)	14	104.4	886	147.8

* N_1 limitations change accordingly to HP, OAT and speed, above indicated limitations values are absolute N_1 limits.

The flight manual, Section 5 "Approved performance data", Paragraph 5.8 "Single engine hover performance" indicates that the maximum weight is around 2,300 kg at 2,000 ft/10 °C and around 2,400 kg at 0 ft/15 °C.

So, the aircraft didn't have the single engine hover performance in OEI max at 2,000 ft/10 °C and at 0 ft/15 °C and so didn't have the single engine hover performance in OEI max at 2,000 ft/10 °C and at 0 ft/15 °C.

However, OEI max transient during a time equal or lower than 5s was still available above the OEI max power.

The flight manual, Section 5 "Approved performance data", Paragraph 5.9 "Single engine hover performance" indicates that the maximum weight is around 2,150 kg at 2,000 ft/10 °C and around 2,300 kg at 0 ft/15 °C.

The flight manual, Section 5 "Approved performance data", Paragraph 5.11 "Single engine rate of climb" indicates that the maximum rate of climb is around 700 ft/min at IAS 55 kt in OEI continuous at 2,000 ft/10 °C and around 800 ft/min at CAS 55 kt in OEI continuous at 0 ft/15°.

[6] The data will be given at 2,000 ft/10 °C & 0 f/15 °C for a gross weight of 2,450 kg.

So, the aircraft had the single engine rate of climb of 700 ft/min at CAS 55 kt in OEI cont at 2,000 ft/10 °C and of 800 ft/min at CAS 55 kt in OEI cont at 0 ft/15 °C.

Engine failure training Performance[7]

For this paragraph, the flight manual, Section "Supplement", Supplement 6 "Engine failure training procedures (training mode)" is used.

The paragraph 1.1 "Principle" explains the "training mode":

> "The 'training mode' system enables OEI procedures to be practiced using non-damaging power levels with helicopter weight reduced accordingly.
>
> To this end, when selecting the Engine Starting Switch on 'TRNG' the systems enables, at the same time to:
>
> - Simulate an engine power loss by governing N2 to 355* equivalent NR rpm (N2 Training Idle).
> - Set the FADEC N1 stops on the other engine to OEI training levels."

* The NR rpm normal operating range is between 375 and 394 and given in the flight manual, Section 2 "Limitations", Paragraph 2.4.1. "Main rotor limitations".

The paragraph 1.3 "Functional safety devices" explains the functioning of the engine on "training mode" when significant power is requested by the pilot:

> "In addition to the use of non-damaging engine limitations, safety devices are available at the same time as the Training mode is in use:
>
> In the event of a missed exercise, as soon as NR drops below 355 rpm, the "Idled" engine provides power accordingly to demand, up to the actual OEI rating corresponding to the rating selected by the pilot during the exercise and in any case actual OEI MAX rating will be available as soon as NR ⩽ 330 rpm."

The paragraph 2.2 "Engine limitations" gives the following limitations:

Power limit	FLI value	N_1 (%)*	TOT (°C)	TRQ (%)
OEI CONT	12	98.7	749	81
OEI MAX	13.2	104.1	773	90

* N_1 limitations change accordingly to Hp, OAT and speed, above indicated limitations values are absolute N_1 limits.

[7] The data will be given at 2,000 ft/10 °C & 0 ft/15 °C for a gross weight of 2,450 kg.

The paragraph 5.1 “Maximum weight on clear heliport” gives the following aircraft weight limitation.

The use of the training mode was limited to an aircraft weight at 2,300 kg at 2,000 ft/10 °C and 0 ft/15 °C. So, the training mode didn’t have to be used.

The paragraph 5.6 “Rate of climb in training mode at Vy” indicates that the maximum rate of climb is around 0 ft/min at CAS 55 kt in OEI continuous training at 2,000 ft/10 °C and around 50 ft/min at CAS 55 kt in OEI continuous training at 0 ft/15 °C.

So, the aircraft didn’t have a single engine rate of climb in OEI CONT (continuous) control training at 2,000 ft/10 °C and had a single engine rate of climb around 50 ft/min at CAS 55 kt in OEI CONT (continuous) control training at 0 ft/15 °C. However, OEI max training was still available above the OEI control training power.

1.7. Meteorological information

Spain’s National Weather Agency, AEMET, reported that the skies were clear and visibility was good. The temperature was 15 °C and there was a very slight wind from the west.

1.8. Aids to navigation

Not applicable.

1.9. Communications

Not applicable.

1.10. Aerodrome information

The helipad where the aircraft landed is situated inside the facilities of the Catalonia race track, located in the town of Montmelo (Barcelona). This track is a public facility owned by the consortium created by the Catalonian regional government, the Royal Automobile Club of Catalonia (RACC) and the Montmelo town hall. The helipad is asphalted and measures 105 m × 21 m. It is at an elevation of 149 m and the FATO headings are in a 03/21 orientation.

On the date of the accident, the heliport was in the process of being certified for public use. This approval was pending, and as a result the helipad was being upgraded. The pad was already asphalted and a hangar and offices were being built. The approval for

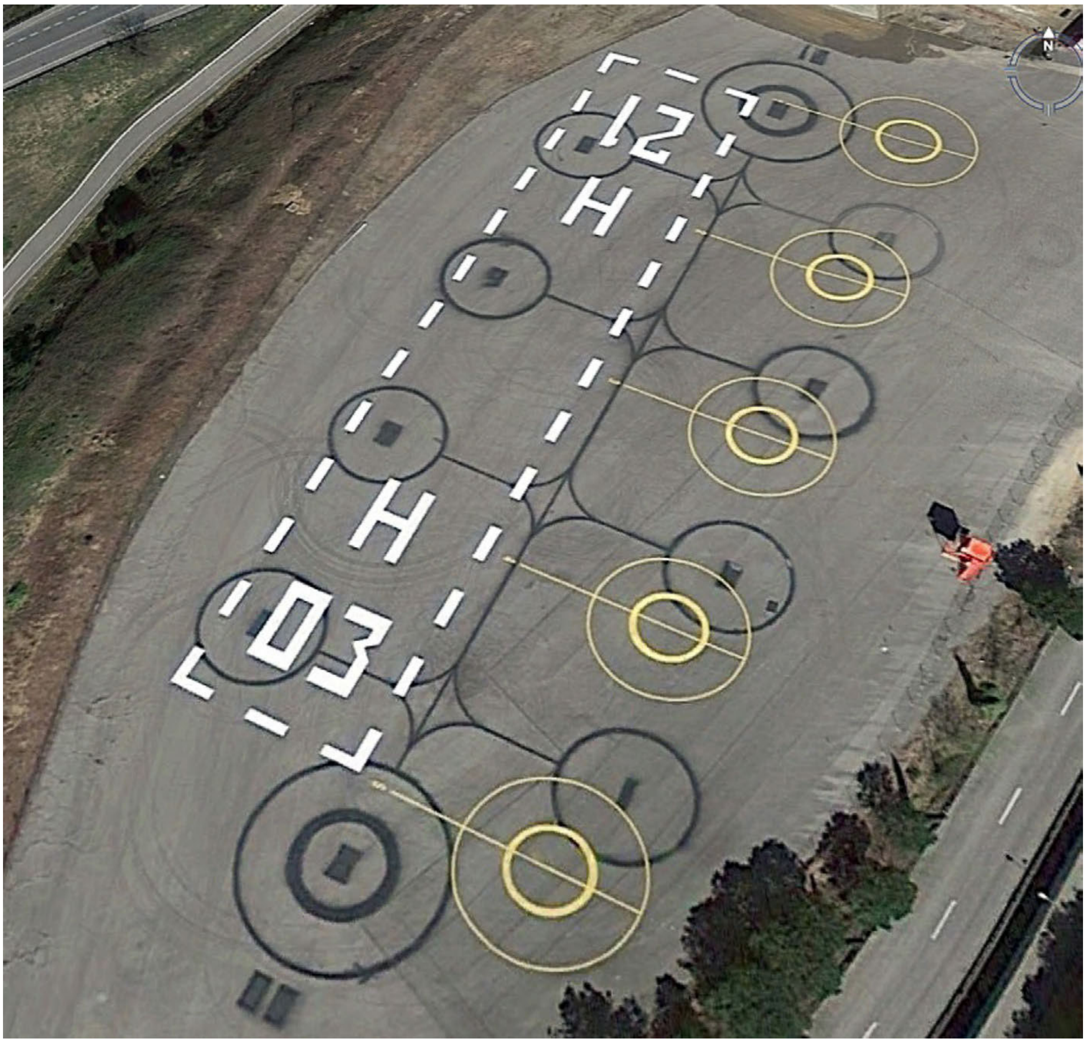

Figure 3. Helipad at the Catalonia race track

this work was received in December 2014, and the heliport was approved for operations in May 2015.

Before that, this heliport was only used during the Formula 1 Grand Prix and in the MotoGP Grand Prix, during which times a "TEMPORARY PRIVATE USE" permit was requested for use solely and exclusively during these events. The rest of the year it was not in use.

1.11. Flight recorders

The helicopter did not have flight recorders onboard, nor were they required for the aircraft type. It did, however, have a GPS fleet tracking unit from which investigators obtained the flight path. The passengers also took some photographs of the VEMD display and the alerts shown on it as soon as the first warning was received, as shown in the figure below.

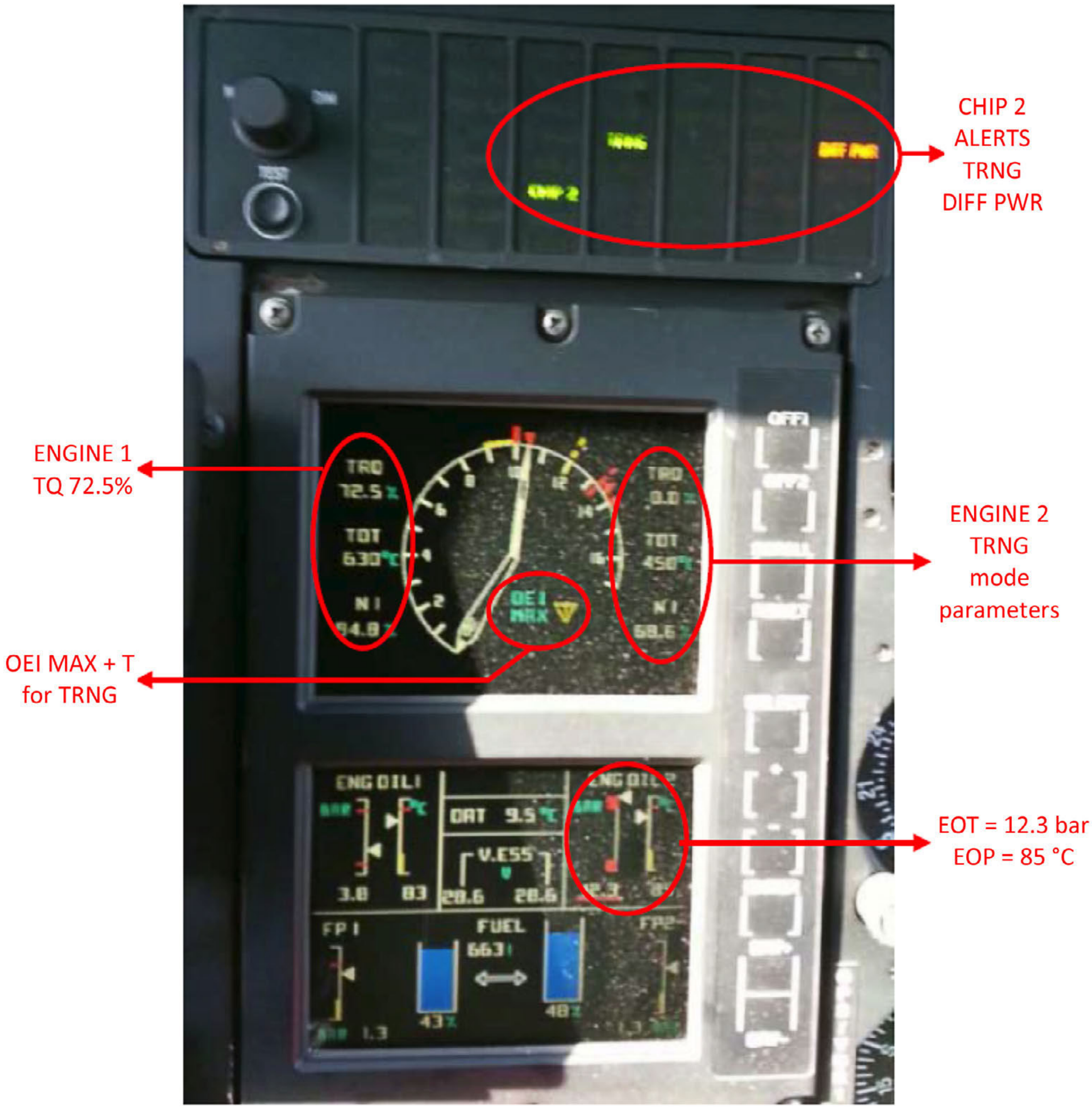

Figure 4. Photograph of the VEMD display taken during the flight

1.12. Wreckage and impact information

The helicopter made a running landing on runway 21, moving some 15.4 m left, intermittently sliding on the skids (see diagram). The aircraft stopped on the pavement facing east.

The only large pieces that detached were part of the power turbine shaft and disk for the right engine and its exhaust pipe.Also found scattered over the FATO were turbine blades and debris from the engine bearings. The skids, fairing, cockpit and the fuselage in general, as well as its mechanical components, appeared to be in fairly good condition.

The right engine was destroyed. Also damaged were the right engine covers and its firewall. The tail rotor drive shaft was sheared by the engine fragments that detached.

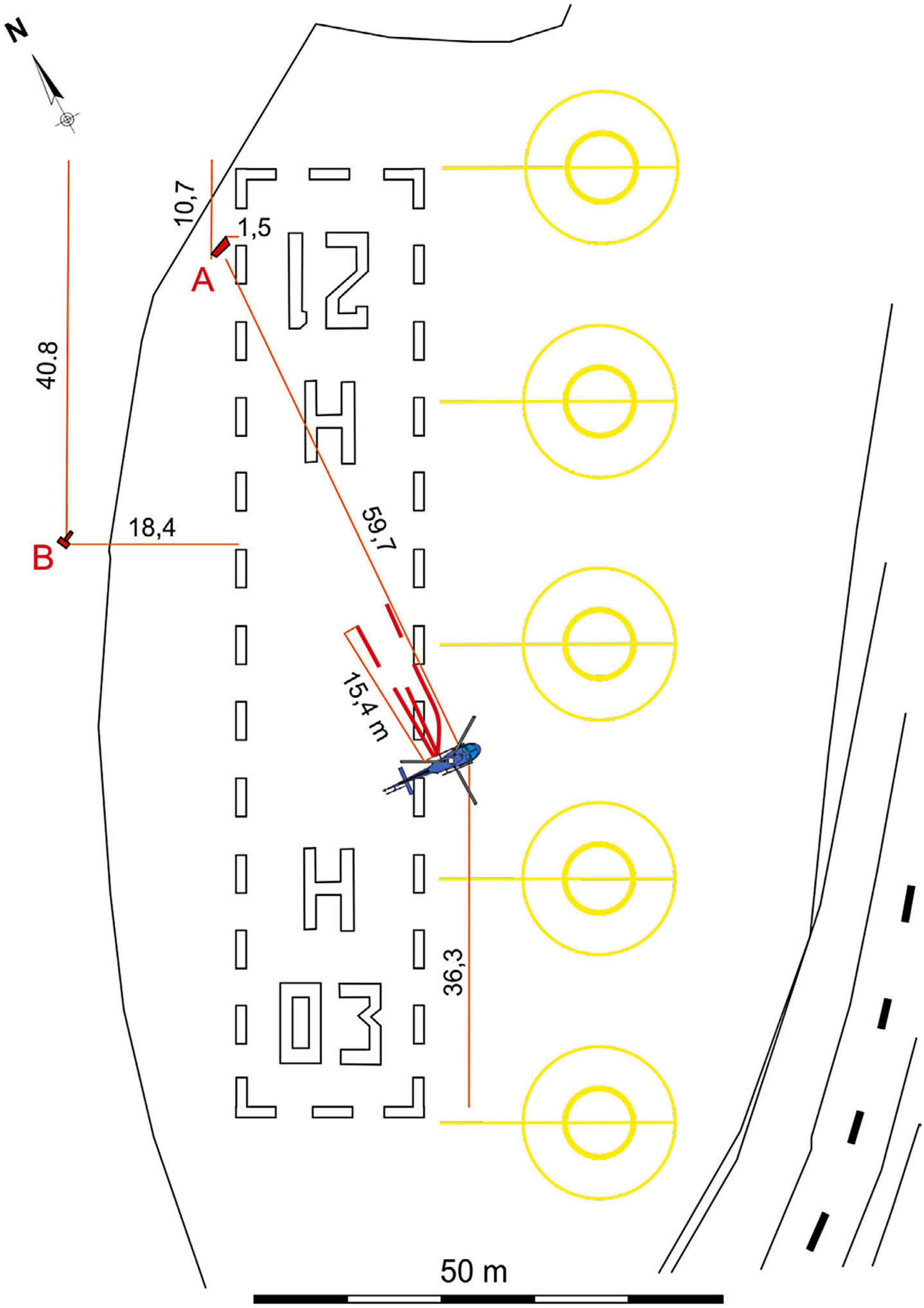

Figure 5. Sketch of the debris field

The figure above shows a sketch detailing the final position of the aircraft[8] and the positions of the main components that detached.

1.13. Medical and pathological information

Not applicable.

1.14. Fire

A fire broke out in the right engine after the emergency landing. The fire was detected by the aircraft's occupants once on the ground when they saw flames in the right engine housing. At first they tried to douse the flames using the extinguisher in the helicopter, but they were quickly aided by race track employees, who reported to the scene in a truck equipped with a water tank and a pump, with whose help they were able to quickly extinguish the fire.

1.15. Survival aspects

The pilot and passengers exited the helicopter under their own power and were not injured.

1.16. Tests and research

1.16.1. *Inspection of the engines*

The right engine was thoroughly inspected once the helicopter was removed from the accident site and taken to a hangar.

A preliminary visual inspection revealed that both the left engine and its housing contained a large amount of soot from the fire. The right engine and its housing had been severely damaged by the fire, and the rear section of the engine was missing. The housing side of the firewall was also heavily damaged.

Upon disassembling the right engine for a more thorough check, its components were found to be firmly attached, the oil filter was contaminated by a large amount of particles in aluminiumand there were particles in the chip detector. There was a large amount of metallic debris in the rear baggage compartment.

[8] The nozzle was found at point A and the turbine drive shaft at point B.

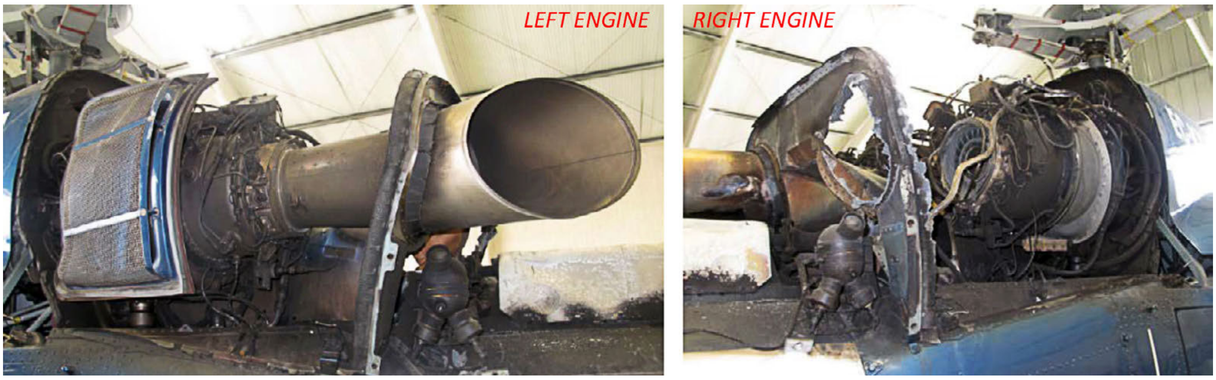

Figure 6. Condition of the engines after the accident

Several holes were found in the engine compartments, especially the one for the right engine. Both engine covers also exhibited heavy damage, as did the exhaust area, especially the one for the right engine.

The part of the tail rotor fairing close to the engines had fire damage.

Investigators were unable to check the fire detection circuit for faults as it had been seriously damaged by the fire.

The right engine was removed and sent to France to be inspected at the manufacturer's facilities under the supervision of an accredited BEA (Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile) representative.

As the various components were being removed for a detailed inspection, the gas generator and the moving parts on the power turbine were found to have seized. The blades on the centrifugal compressor were inaccessible and the shaft on the power turbine disc was broken in two separate areas, and part of it had detached. The other part was found in the tail cone area.

The reduction gear and accessories driving gear trains rotated freely and their respective axles were properly connected. The engine's attachment fittings were also in good condition.An inspection of the fuel system revealed that the pre-clog indicator for the fuel filter was not activated, the manual control lever was activated and rotated freely, and the lines were properly connected. The solenoid valve had been damaged by the fire.

As for the lubrication system, there were chips in the detectors and in the tank, and the system's lines were connected and in good condition.

As concerns the fire detection system, the rear detectors were heavily damaged, while the front ones were in good condition.

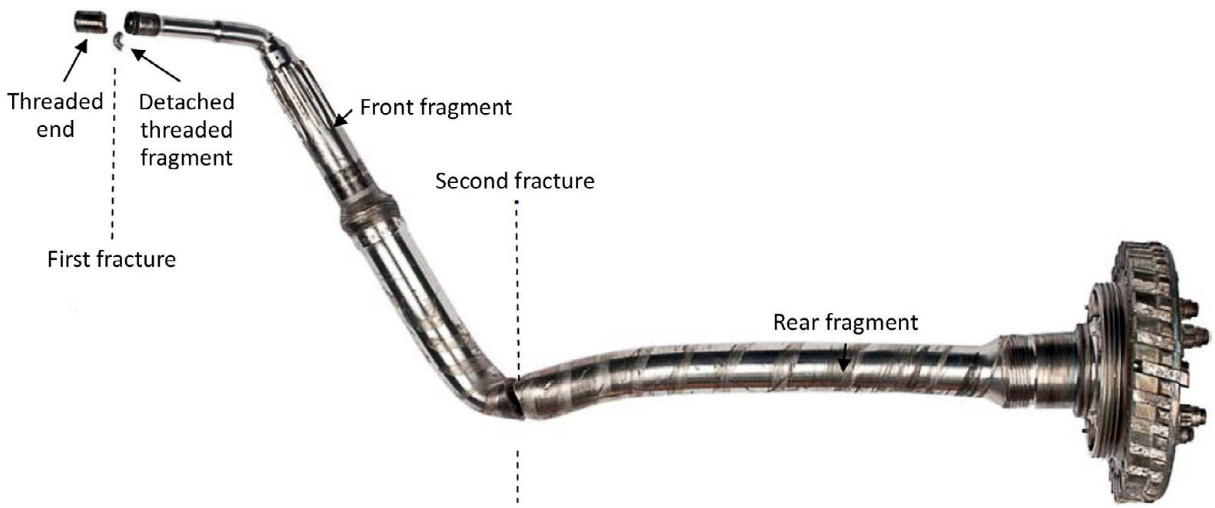

Figure 7. Identification of PT shaft fractures

The speed sensors on the power turbine were removed to access the shaft. The sensors were found to be damaged and the power turbine drive shaft was broken from the end of the threaded part, and the nut was completely destroyed.

The power turbine drive shaft and its fractures were analyzed in the laboratory. It was determined that the fracture had resulted from fatigue on the thread of the clamping screw at the front of the shaft.

The crack grew gradually over time and when it failed completely, it resulted in the release of the tightening tension on the force transmission cone which led to an axial overload of the Power Turbine (PT) trust bearing. This overload caused the destruction of the bearing and as a consequence, the loss of axial retention on the PT shaft. On power demand, the PT shaft moved backwards. When it was partly ejected, the contact between the rotating PT and the parts behind it led to the deformation and static rupture of the shaft seated on the rear bearing housing. The rear section of the PT shaft became separated from the engine.These two fractures affected the following four fragments:

- The rear section of the shaft where it attaches to the power turbine wheel.
- The front section of the shaft where it attaches to the drive gear.
- The threaded end at the front of the shaft, which is used to tighten the drive gear.
- A flake corresponding to a thread over one third of the circumference, the ruptured surface shows that thisflake was positioned between the threaded end of the shaft and the front section of the shaft bearing thedrive gear.

The rear fragment was bent mainly from the surface of the support bearing to the fracture point, and there were several helical friction marks with approximately approximately ten instances of pitch on the LH side, varying from rear to frontbetween 35 and 15 mm, extending from the thrust bearing tightening threading to the rupture point.

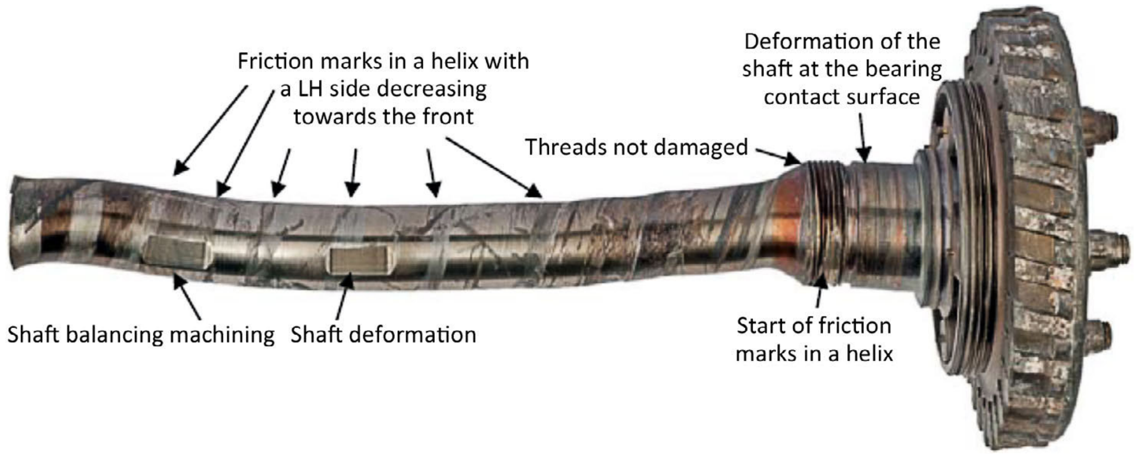

Figure 8. Damage on the PT shaft bear fragment

The front section had a 60° bend associated with the fracture in the area where the shaft diameter changed, and a ductile fracture from excessive loading. There were also friction marks centered on the front surface of the drive gear.

It also exhibited axial pit marks between 3 mm and 17 mm in front of the drive gear cone.

There were helical friction marks with pitch of approximately 13 mm on the left side, at the point where the rear fracture occurred. These marks increased in intensity toward the surface near the drive gear cone.

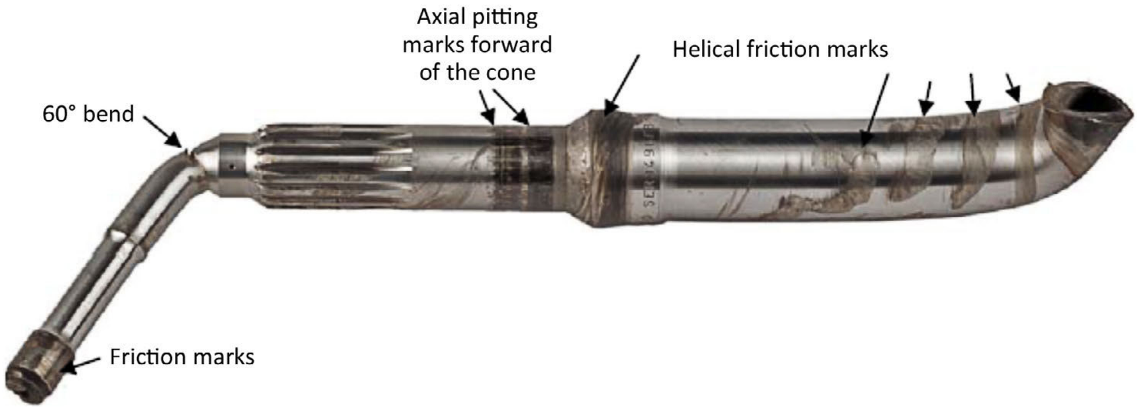

Figure 9. Damage on the front fragment of the PT shaft

At the threaded end of the forward segment there was a propeller-shaped break with pitch of approximately 1 mm on the right side, friction marks around the edges of the broken surface and signs of fatigue on the fracture surface. However, the area where the crack had started was not visible because of the friction marks around the fracture surface. There were also impact marks on the threads.

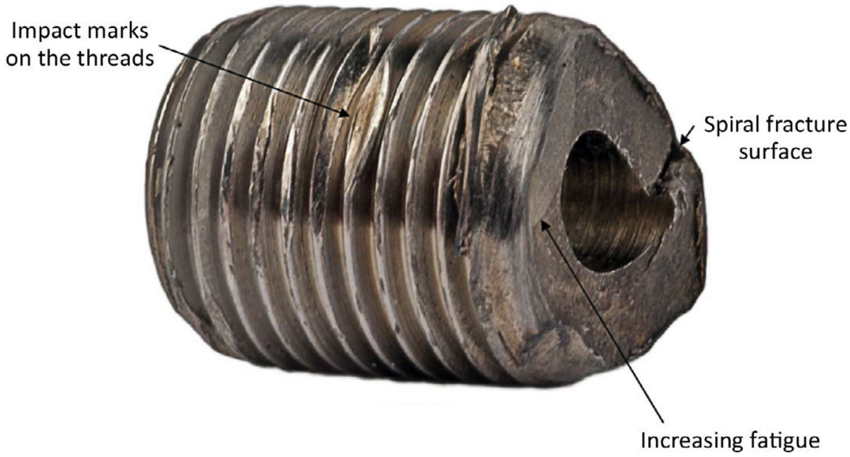

Figure 10. Damage on the trheaded end of the PT shaft

The locknut on the gear exhibited uneven wear and extrusion on the surface in contact with the gear. The threads outside the area affected by the deformation on the locknut surface were not damaged, nor were the tips of the grooves on the side of the locknut.

Figure 11. Drive gear tightening nut

1.16.2. *Analysis of the VEMD and the fire suppression system*

The VEMD was sent to an Airbus helicopters facility in France to be inspected under the supervision of a BEA accredited representative.

The flight parameters recorded on its non-volatile memory were extracted and found to be consistent with already known data and provided no new information.

As for the engine fire suppression system, it could not be analyzed because its wiring and sensors had been severely damage by the fire and by the damage to the engine.

The fire had been detected on the ground, and not during the flight.

Moreover, prior to the flight the pilot had verified the system as per the pre-flight checklist.

1.17. Organizational and management information

The Catalonia regional police have an aviation service for surveillance, control and patrol tasks. This service is based at the Sabadell airport (Barcelona). The aircraft are not operated or maintained by the police force; instead, these services are contracted out to the company that operated the aircraft, which also provided the pilots.

1.18. Additional information

1.18.1. *Pilot's statement*

The pilot was interviewed, and he said that he had taken off from the Sabadell airport along with two Catalonia regional police force officers on a police control and surveillance flight over the area of Sant Iscle de Vallalta. As they were returning to the departure airport, the officer seated to his left informed him that the CHIP 2 warning light on the VEMD display had just turned on. He checked the engine oil pressure and temperature readings and saw that they were within their normal operating limits. He then decreased the power on the right engine until it stabilized at 40% and he selected training mode (TRNG) on the right engine start switch.

He decided to proceed to a firefighting base located in the town of Dosrius, to the southwest of Sant Iscle de Vallalta. The helicopter could not maintain level flight with the power setting selected, and was descending at approximately 50 ft/min. He turned right and attempted to make the approach along the south side of the mountain on a northerly heading, but he realized that to reach the valley where the base was located he had to climb. As he was unable to gain altitude, he continued turning in the same direction while maintaining the existing flight parameters and headed to the helipad at the Catalonia race track in the town of Montmelo (southwest of Dosrius), thinking that he would be able to make a forced landing with no complications given the presence of a posted and asphalted FATO area there.

When they were in the vicinity of Dosrius, he noticed that the oil pressure in the affected engine was 12.3 bar (the limit is 10 bar) and that the oil temperature in the engine was 85 °C (the limit is 107 °C). He gave his mobile phone to an office and asked him to take some pictures of the VEMD display to document the situation. At that point the helicopter was flying "correctly" (in the sense that there was nothing unusual and all parameters were within limits). He estimated that the helipad was some 8 NM away.

Based on the IAS (70 kt) and the distance to Montmelo, he calculated it would take them 6 to 7 minutes to reach the helipad. He thus considered the possibility of stopping the right engine completely; however, given the helicopter's configuration at the time and the 660 l of fuel onboard, he thought he would need a torque of at least 115% in the running engine to maintain sufficient altitude to reach the landing site. Flying 7 NM at an IAS of 70 kt meant being in an OEI MAX configuration three times longer than permitted (2.5 minutes). He thus decided to run the left engine without maximum OEI and to keep the right engine in TRNG mode.

Whereas the engine oil temperature remained at 85 °C, the pressure reading started to oscillate, reaching 11 bar. Upon reaching the track, the pilot turned left to align the helicopter on the 210° runway heading.

While on short final, he heard a strange noise, which he discussed with the passengers, one of whom confirmed it was coming from the helicopter. There were no unusual indications in the warning light panel and no changes in the VEMD. Once inside the FATO the noise grew louder and the helicopter started to vibrate. The descent rate increased and he tried to control it with the cyclic and collective. He then realized that the pedals were not controlling the torque, and he expected a turn to the left. Before touching down he applied power gradually and made a running landing, during which the helicopter yawed some 90° to the left.

Once on the ground and with the helicopter stopped, he closed the two fuel valves by placing the start switch for both engines in OFF. He disconnected all the systems and set the master switch to OFF. He then saw smoke. One of the officers exited the helicopter and said there was a fire in the right engine, so he followed the other occupants and exited the helicopter. He decided to return to the helicopter, however, and take the extinguisher from the cockpit, which he discharged into the right engine exhaust nozzle. This helped somewhat, but the fire was still burning. They used another extinguisher in the area to fight the fire but they were unable to douse it completely. Finally, a truck they had called previously arrived at the scene equipped with a water tank and a pump and put out the fire.

As for possibly using the engine fire suppression system during the flight, the pilot stated that he had not received any indication of a fire in the cockpit. He only learned of the fire after they were on the ground. He also stated that the suppression system had been verified during the performance of the pre-flight checklist.

1.18.2. *Statement from the occupant in the front left seat*

They had flown from the Sabadell airport to Sant Iscle de Vallalta and he was seated to the pilot's left, operating the camera. Shortly after finishing the surveillance tasks in the area, he noticed that the CHIP 2 warning had turned on in the VEMD screen. He informed the pilot, who immediately started taking the actions needed to respond to the warning.

The pilot asked him to look up this warning in the checklist so he could verify the actions to take, and although the officer was not used to searching in this type of document, he managed to find it. At the same time, they started weighing the pros and cons of going to the different alternate heliports nearby instead of returning to the Sabadell airport, and the pilot decided to try to land at the heliport at the Dosrius base.

As they approached Dosrius, their altitude gradually diminished but to reach the helipad, they had to go over a mountainous area. The pilot warned them they would be unable to reach the other side of the mountain and he decided to land elsewhere. He was constantly informing the pilot of power lines and other obstacles on the ground that he saw, since they were flying low. He was also on the lookout for additional warnings in the cockpit. During that segment of the flight the pilot asked him to take a general picture of the two data display screens.

They continued to fly low en route to the Sabadell airport. The pilot decided to go to the heliport at the Catalonia race track (in Montmelo). The other officer, who was seated behind them, suggested the option of landing at the heliport in Roca. The pilot considered this but ruled it out since he could not be sure of making a safe landing there.

Upon spotting the Catalonia race track, the pilot confirmed that they would be landing at that heliport. While they were on the final approach path, they started hearing noises behind them. He said that these noises may have come from the motorcycles that were running on the race track at high speed, but the pilot confirmed the mechanical nature of the noises. At that moment, as they were entering the FATO, they heard a loud bang and felt the helicopter shake. He then saw the pilot lower the collective lever. A few seconds later they started to make contact with the ground, sliding before coming to a stop with a 90° turn to the left.

At that moment he saw smoke out the right side window and the other officer exiting the helicopter. He asked several times out loud if they should exit, but received no reply. The other officer warned them of a fire in the right engine. After this he exited immediately and stood a safe distance away in front of the helicopter. The other two occupants exited the helicopter before returning to remove some things from it.

He then approached some people who worked at the track to ask them to call emergency personnel and to bring an extinguisher. They brought an extinguisher shortly afterwards and offered to call a truck on the track that was equipped with a tank and a pump, which he accepted. He also asked them to request the truck urgently, since he saw the two other occupants attempting to put out the fire with the extinguisher from the helicopter, but there was still a lot of smoke.

The truck arrived quickly and finished putting out the fire. The smoke dissipated right away. After clearing it with the track manager, they left the tanker truck at the site and cordoned off the area around the helicopter since, despite the fence around the area, there were people congregating nearby.

1.18.3. *Statement from the occupant in the rear right seat*

He stated that they had conducted a police surveillance operation in the area of Sant Iscle de Vallalta and that afterward "they were returning to the base at the Sabadell airport". Then, the officer seated in the front warned the pilot that the CHIP 2 indicating light had just turned on. After shifting slightly to the left from his position in the rear right seat he was able to see that the orange indicating light had in fact turned on.

The pilot then put the right engine in TRAINING mode, informing them of every action he took, what his intentions were and the procedures he was carrying out during the flight. He also told them he would try to land at the base in Dosrius, which was approximately "between their 4 and 5 o'clock positions" and a little bit above their flight level. He started a turn to the right in an effort to put the helicopter on a north heading to the approach path for the Dosrius helipad, but the pilot then told them that they did not have enough power to clear the mountain without straining the other engine, so he continued turning and proceeded to the area of Roca while descending very gradually.

The pilot asked the officer seated in the front seat to look up the procedure in the flight manual, which they reviewed out loud. From his position he then saw that the oil pressure in the right engine was reading high, "a little over 12 bar", which he called out. The pilot acknowledged his report and informed him that he was monitoring the oil pressure. The other officer, after checking the procedure for the CHIP 2 indicating light, handed him the manual at his request so he could check the procedure for a high oil pressure. They then reached the shopping area in Roca de Valles, and he told the pilot that he recalled there was a helipad in the area in case he wanted to land there. But the pilot replied that for safety reasons, he preferred a less problematic area and that the Montmelo race track was nearby and had a helipad where they could make a safer landing.

While on final approach, the officer seated in the front wondered if the noise they were hearing could be from the motorcycles that were running on the track, to which both he and the pilot replied that no, that the noise was coming from behind them. The noise was intermittent but a few seconds later, and after clearing the perimeter fence around the FATO at the track, the noise grew louder. They then heard a loud, sharp bang, followed by a small yaw and considerable vibrations. He then felt the helicopter descend and an initial impact against the ground, followed by a second. The helicopter then started sliding on its skids and started to turn left. When it stopped, the cabin filled with dense smoke that made it a little hard to breathe. He then opened the side door and exited the aircraft. He looked at the right engine and saw smoke issuing from it. He then realized that both the pilot and the other officer were still in their seats. He told them three separate times that there was a fire and that they had to evacuate the aircraft. The officer left immediately and returned to tell the pilot, who was still busy in the cockpit, that there was a fire and that they had to leave now. The pilot exited the helicopter and they ran to what they deemed to be a safe location.

Moments later the pilot returned to the helicopter to empty the contents of the cockpit extinguisher on the part of the engine that was burning, and the officers looked for extinguishers and notified passersby to help them put out the fire, which was still burning. His colleague notified others while he assisted the pilot using an extinguisher given to him by a security guard who was in the area. Shortly afterward a truck equipped with a tank and pump arrived at the site and directed water at the area indicated by the pilot, which completely doused the fire.

Once the area was safe, they cordoned it off to safeguard the aircraft and the scattered debris and, aided by police forces they themselves had notified, they restricted access to the site.

1.19. Useful or effective investigation techniques

During the investigation, the engine manufacturer was asked if it was aware of any other similar events in which the turbine drive shaft had fractured due to fatigue on the thread of the clamping screw located at the front end of the shaft, to which the manufacturer replied in the negative. There was an event where in 2014 a military helicopter had sustained a broken engine drive shaft caused by wear on a bearing at the rear of the shaft, which resulted in a considerable temperature increase that degraded the shaft's mechanical characteristics.

Following this event, an Emergency Alert Service Bulletin (EASB) was issued by Airbus Helicopters on 23 June 2015 to clarify the flight manual to reflect a situation in which an indication is received in the cockpit from the chip detector on either engine. The clarification of 3.12.3 in the flight manual specifies that when OEI flight condition is established the affected engine must be shut down and it is requested to land as soon as practicable.

Then for landing and if necessary the affected engine can be restarted. But a caution is written in this case asking the pilot to monitor engine parameters (TQ, TOT, N1, EOP, EOT) and if these parameters fluctuate or if their limits are exceeded the engine must be shut down immediately.

The EASA also issued an airworthiness directive on 25 June 2015 that approved this clarification to the flight manual and warned that a cockpit indication from the chip detector on either engine could suggest the potential deterioration of a bearing on the turbine shaft and that if corrective actions were not immediately taken, could cause the shaft to fracture and fragment, with the ensuing ejection of various components.

In the frame of module 01 (reduction gear module) or module 02 (gas generator module) replacement, it is necessary to unscrew/screw the Power Turbine (PT) nut. During these maintenance actions, the thread end part of the PT shaft is visually checked for good condition. There is no other specific maintenance action affecting the PT shaft.

The engine manufacturer noted that although it could not determine the exact cause of the fracture, the reason for the fatigue fracture of the thread on the nut is still being investigated. Airframe and engine manufacturer indicated that if the pilot had applied the flight manual procedure when the CHIP 2 warning appeared by stopping the right engine, the flight could be conducted until the landing without any other incident.

To prevent such event to happen again Airbus Helicopters and EASA respectively issued an Emergency Alert Service Bulletin and an Emergency Airworthiness Directive to clarify the emergency procedure in case of CHIP warning.

2. ANALYSIS

2.1. General

The accident flight of helicopter EC-KYJ was conducted pursuant to all applicable requirements and approvals, both as concerns the aircraft status and the pilot qualifications.

Three aspects were analyzed in this accident. The first involves the engine failure, the second the fracture and its progression and the third the pilot's handling of the engine failure.

2.2. Engine failure

The investigation showed that the warning CHIP 2 appeared during the flight with a right engine oil pressure over the limits. These information alerted the pilot that the right engine was not working normally and that it was necessary to apply the emergency CHIP 2 procedure as requested and detailed by the flight manual.

The emergency procedure defined in the flight manual requested to shutdown the right engine. However, the pilot din't follow this procedure and the right engine failure was caused by the power demand used during the short final/landing of the helicopter.

Initially, there was a fatigue in the thread of the nut used to tighten the front end of the PT drive shaft. As the right engine was not shutdown, the fracture grew over time and when it finally broke completely, it resulted in the release of the tightening tension on the forcé transmission cone which led to an axial overload of the PT thrust bearing. This overload caused the destruction of the bearing and as a consequence, the loss of axial retention on the PT shaft. On the power demand during the landing, the PT shaft moved backwards. When it was partly ejected, the contact between the rotating power turbine and the parts behind it led to the deformation and static rupture of the shaft seated on the rear bearing housing.

When the shaft broke, its aft end was ejected uncontrollably, damaging every component in its path.

All of the damage found in the engine and gears were produced as a result of the initial failure. Any other cause contributing to the development of the failures has been ruled out.

The last maintenance inspection which was not related to a visual inspection of the thread end part of the PT shaft could not detect its status.

2.3. Analysis of the fracture and its progression

During the investigation, the engine manufacturer could not identify the root cause of the fatigue phenomenon on the PT shaft thread.

On the other hand, the fracture grew after the warning CHIP 2 (indicating the presence of metallic particles in the right engine) appeared while the right engine was running until the rupture.

To prevent such event to occur again Airbus Helicopters and EASA respectively issued an Emergency Alert Service Bulletin and an Emergency Airworthiness Directive to clarify the emergency procedure in case of CHIP warning. So such event will not occur again if the emergency CHIP procedure is applied.

The application of the emergency CHIP procedure will not prevent an eventual other fatigue of a nut because the root cause has not been identify but will prevent such event (right engine destruction and airframe damage) to occur again.

In addition after a warning CHIP appeared, troubleshooting and maintenance operations are carried out to identify the reason of this warning. According to the results of the troubleshooting, the inspection of the nut could be carried out if it is suspected.

2.4. Handling of the emergency

The pilot's experience, both overall and in the helicopter type, was ample. As for the officers, even though neither one was assigned any technical duties during the flight, they could be regarded as having some training due to their experience in similar flights and to the information they had been provided during those flights concerning the various system warnings that can be received in the cockpit during operations.

Of note in this regard is the fact that the officer seated next to the pilot was the first to notice the chip detector light in the cockpit for the right engine. The officer seated in the back was also watchful and warned of the oil pressure. In other words, despite not having formal training, they were alert and aware of what was happening in the cockpit and made the pilot's job easier by informing him of potential obstacles that could affect the flight. They even helped him execute checklists and proposed alternative landing areas. The cooperation between the officers and the pilot is deemed to have been beneficial during the emergency.

Despite not having any kind of device to record the communications in the cockpit, in light of the three occupants' statements, the pilot's actions during the emergency, remaining calm and keeping control of the aircraft.

The decision making regarding, especially as concerns the choice of landing field and the evaluation of the potential approach and landing difficulties associated with each, was correct. This allowed the pilot to plan the landing in the field that offered the highest assurance of making a safe landing.

A warning CHIP 2 was received in the cockpit indicating the presence of metal particles in the right engine and an oil pressure of 12.3 bars, over the limits (10 bars), was indicated on VEMD. The pilot decided to interrupt his flight and to perform a landing in the training mode.

He did not apply the CHIP 2 emergency procedure as requested by the flight manual and made errors in the computing performances of the helicopter. He applied a training mode procedure scheduled only for training.

He noticed that the oil pressure was out the limits and in the red area but did not really take into account to reconsider the non- scheduled procedure he had applied. He could have compared the right engine oil pressure to the oil pressure of the left engine which was at around 3.8.

If the pilot had shut down the right engine when the CHIP 2 appeared as requested by the flight manual, the PT shaft would not have broken and the fire would not have occurred. The pilot has to apply the appropriate CHIP 2 procedure, especially as both passengers could help him in verifying the procedure in the flight manual. In such conditions, the best plan was to carry out precautionary approach with a running landing as the pilot did not know and check the correct performances of the helicopter at that time.

In the end, the pilot decided to head to a safe landing area, meaning that it would not require any more power from the functioning engine to reach it. This area was practically on the same course they were on and did not require making any risky turns. It also had an adequate and well posted surface.

There was no fire warning or smoke in the cockpit. During the approach, the affected engine was in TRNG mode, which reduced the vibrations and noises. It was during the landing flare, when the power demanded from the engines increased, that the noise and vibrations also increased until the first fracture of the drive shaft, which triggered the rest of the damage to the engine.

As for the final landing, it was performed correctly considering that the pilot had no control over the yaw movement (since the tail rotor transmission had broken following the detachment of the drive shaft). The pilot let the helicopter slide on its skids without making any motions that could have compromised the safety of the occupants. Proof of this is the fact that the aircraft was barely damaged as a result of the landing maneuver.

As concerns the evacuation of the helicopter and the subsequent extinguishing of the fire, the occupants' actions also seem to have been correct.

First they ensured their own safety, then they notified the people who could render assistance, namely the track personnel, who were the ones who eventually provided them with a truck with a tank and pump to put out the fire. And while they waited for it to arrive, they tried to douse the flames with extinguishers to keep the fire from spreading to the rest of the aircraft.

Finally, they cordoned off a safety perimeter to keep others from entering the area and being injured. This was all undoubtedly driven by the experience and training of the officers in emergency situations.

3. CONCLUSIONS

3.1. Findings

- The helicopter took off from the Sabadell Airport on a police surveillance mission.
- The pilot and aircraft involved in the accident flight complied with all the necessary requirements.
- Weather conditions were acceptable for the flight and did not limit the flight or have any effect on the accident.
- During the flight, a warning was received in the cockpit indicating the presence of metal particles in the right engine, as a result of which the pilot decided to make an emergency landing.
- The pilot placed the right engine in training mode which is not the emergency procedure defined in the flight manual which requested to shut down the right engine in case of warning CHIP 2.
- In the training mode the deterioration of the right engine has continued until the rupture of the clamping screw at the front of the PT shaft which led to an axial overload of the PT thrust bearing. This overload caused the destruction of the PT thrust bearing and as a consequence the loss of axial retention on the PT shaft.
- After considering to make an approach to a helipad in the town of Dosrius, the pilot decided to land at the helipad at the Catalonia race track
- During the short final approach/landing, when power demands were being placed on both engines, the PT drive shaft of the right engine moved backwards. When it was partly ejected, the contact between the rotating PT and the parts behind it led to the deformation and the static rupture of the PT shaft seated on the rear bearing housing. The rear section of the PT shaft became separated from the engine, destroying the parts downstream.
- No one was injured during the landing. The most significant damage to the helicopter affected the right engine and the tail cone.
- Once on the ground, the occupants noticed that the right engine was on fire and exited the aircraft.
- There were no signs of a fire during the flight.
- The occupants returned to the aircraft and put out the fire using two extinguishers and a truck with a tank and a pump that was in the area.
- The analysis of the turbine drive shaft on the right engine confirmed the presence of two fractures.
- There were signs of fatigue on the fracture surface of clamping screw at the front of the PT shaft. However, the area where the crack had started was not visible because of the friction marks around the fracture surface.
- There was a static rupture of the PT shaft seated on the rear bearing housing.
- The study conducted by the manufacturer did not allow to identify the root cause of fatigue which led to the thread fracture.
- When the shaft detached, it damaged several components in the tail cone, especially the tail rotor shaft, and caused a fire in the right engine which spread to the left engine.

3.2. Causes/Contributing factors

The Investigation has concluided that there was fatigue on the thread of the clamping screw at the front of the PT shaft and also that that the management of the CHIP 2 warning procedure has not been carried out in accordance with the procedure described in the flight manual.

As the right engine has not been shut down, the working conditions of the engine has been deteriorated until the rupture of the PT drive shaft at the level of the clamping screw and the destruction of the PT thrust bearing and as a consequence the loss of axial retention on the PT shaft.

The entire engine failure occurred during the short final approach/landing when right engine power demand was requested. The PT shaft then was ejected. It damaged several components including the tail rotor shaft and caused a fire in the right engine.

4. SAFETY RECOMMENDATIONS

No recommendation has been issued because during the investigartion to prevent such event to occur again Airbus Helicopters and EASA respectively issued an Emergency Alert Service Bulletin and an Emergency Airworthiness Directive to clarify the emergency procedure in case of CHIP warning. So such event will not occur again if the emergency CHIP procedure is applied.

The application of the emergency CHIP procedure will not prevent an eventual other fatigue of a nut because the root cause has not been identified but will prevent such event (right engine destruction and airframe damage) to occur again.

In addition, after a CHIP warning appears, troubleshooting is carried out to identify the reason of this warning. According to the results of the troubleshooting, corrective maintenance may lead to the engine investigation and repair. This will cover any kind of damage, including the nut failure observed in this event.