COMANDO DA AERONÁUTICA

CENTRO DE INVESTIGAÇÃO E PREVENÇÃO DE ACIDENTES AERONÁUTICOS

FINAL REPORT
A-050/CENIPA/2015

OCCURRENCE:	**ACCIDENT**
AIRCRAFT:	**PP-LLS**
MODEL:	**EC155B1**
DATE:	**02APR2015**

NOTICE

According to the Law nº 7565, dated 19 December 1986, the Aeronautical Accident Investigation and Prevention System – SIPAER – is responsible for the planning, guidance, coordination and execution of the activities of investigation and prevention of aeronautical accidents.

The elaboration of this Final Report was conducted taking into account the contributing factors and hypotheses raised. The report is, therefore, a technical document which reflects the result obtained by SIPAER regarding the circumstances that contributed or may have contributed to triggering this occurrence.

The document does not focus on quantifying the degree of contribution of the different factors, including the individual, psychosocial or organizational variables that conditioned the human performance and interacted to create a scenario favorable to the accident.

The exclusive objective of this work is to recommend the study and the adoption of provisions of preventative nature, and the decision as to whether they should be applied belongs to the President, Director, Chief or the one corresponding to the highest level in the hierarchy of the organization to which they are being forwarded.

This Report does not resort to any proof production procedure for the determination of civil or criminal liability, and is in accordance with item 3.1, Annex 13 to the 1944 Chicago Convention, which was incorporated in the Brazilian legal system by virtue of the Decree nº 21713, dated 27 August 1946.

Thus, it is worth highlighting the importance of protecting the persons who provide information regarding an aeronautical accident. The utilization of this report for punitive purposes maculates the principle of "non-self-incrimination" derived from the "right to remain silent" sheltered by the Federal Constitution.

Consequently, the use of this report for any purpose other than that of preventing future accidents, may induce to erroneous interpretations and conclusions.

N.B.: This English version of the report has been written and published by the CENIPA with the intention of making it easier to be read by English speaking people. Taking into account the nuances of a foreign language, no matter how accurate this translation may be, readers are advised that the original Portuguese version is the work of reference.

SYNOPSIS

This is the final report of the 2 April 2015 accident with the EC155B1 aircraft, registration PP-LLS. The accident was classified as "*with flight controls*".

The aircraft got airborne as it was beginning to taxi toward the helipad at which it would undergo a dynamic balancing of the main rotor. Sometime later, the helicopter was sighted on an uncontrolled descending trajectory until colliding with buildings.

The aircraft was destroyed in the crash.

All the aircraft occupants perished in the crash site.

An accredited representative of the BEA (*Bureau d'Enquête et d'Analyses pour la Sécurité de L'Aviation Civile*), France (State of both aircraft and engine manufacture), was designated for participation in the investigation.

CONTENTS

GLOSSARY OF TECHNICAL TERMS AND ABBREVIATIONS

AP	Automatic Pilot
AMM	Aircraft Maintenance Manual
APM	Automatic Pilot Module
ALS	Airworthiness Limitations Section
AFCS	Automatic Flight Control System
AHRS	Attitude and Heading Reference System
ANAC	(Brazil's) National Civil Aviation Agency
ANP	National Petroleum Agency
BEA	*Bureau d'Enquête et d'Analyses pour la Sécurité de L'Aviation Civile*
CA	Airworthiness Certificate
CENIPA	Aeronautical Accident Investigation and Prevention Center
CHE	Company Homologation Certificate
CHT	Technical Qualification Certificate
CI	Investigating Committee
CIV	Pilot's Flight Logbook
CMA	Aeronautical Medical Certificate
COM	Maintenance Organization Certificate
CTP	MGB - Main Gear Box
DA	Airworthiness Directive
DCTA	Department of Aerospace Technology and Science
ea	Each
EC55	Type certification - Eurocopter (Airbus Helicopters) EC 155 B1
EMM	Engine Maintenance Manual
FAR	Federal Aviation Regulation
FOG	Fiber Optic rate Gyro
h	hour
Hover IGE	Hover In Ground Effect
IAE	Aeronautics and Space Institute
IAM	Annual Maintenance Inspection
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
Kg	Kilogram
Kt	Knot
Lat	Latitude
LOC	Localizer
Long	Longitude

Ltda.	Ltd.
m^2	Square meters
MHz	Megahertz
min	Minutes
mm	Millimeters
MOM	Maintenance Organization Manual
MPR	Manual of Procedures (ANAC)
MSM	Master Servicing Manual
MTC	Manual of Current Techniques
NA	Not applicable
NI	Not incorporated
NM	Nautical miles
NSCA	Norm of the Command of Aeronautics’ System
OS	Service Order
PA	Autopilot
PAMA-SP	Park of Aeronautical Material - São Paulo
P/N	Part Number
PLH	Airline Transport Pilot (helicopter category)
PPR	Private Pilot (airplane category)
RI	Investigation Report
RPM	Revolutions Per Minute
S/N	Serial Number
S365	Type Certification - Eurocopter (Airbus Helicopters) SA 365
SAS	Stability Augmentation System
SBSP	ICAO location indicator - Congonhas Aerodrome
SERIPA IV	4th Regional Aeronautical Accident Investigation and Prevention Service
SIPAER	Aeronautical Accident Investigation and Prevention System
THM	Theory Helicopter Manual
TSN	Time Since New
UTC	Universal Time Coordinated
VIP	Very Important Person

1. FACTUAL INFORMATION.

Aircraft	**Model:** EC155B1 **Registration:** PP-LLS **Manufacturer:** Eurocopter (Airbus Helicopters) France	**Operator:** *Seripatri Participações Ltda*.
Occurrence	**Date/time:** 02APR2015/ 20:00 UTC **Location:** *Fazendinha* Neighborhood. **Lat.** 23º33'57''S **Long.** 046º51'14''W **Municipality – State:** *Carapicuíba* – São Paulo	**Type(s):** With flight controls **Subtype(s):**

1.1 History of the flight.

The aircraft, with four crewmembers and a passenger on board, after performing procedures for analysis of vibration in its (Fenestron-type) tail rotor, commenced taxiing on the ground from the number-2 parking spot towards the helipad, where it would undergo a dynamic balancing of the main rotor.

While taxiing, the aircraft departed the ground before arriving at the helipad. After getting airborne, the aircraft gained altitude, left the departure area, and crashed into two residences located at a distance of approximately 1.27 NM from the point of departure.

The aircraft was destroyed in the crash.

None of the aircraft occupants survived.

1.2 Injuries to persons.

Injuries	Crew	Passengers	Others
Fatal	4	1	-
Serious	-	-	-
Minor	-	-	-
None	-	-	-

1.3 Damage to the aircraft.

The aircraft was destroyed by the impact forces.

1.4 Other damage.

There was damage to two residences located in the crash site.

1.5 Personnel information.

1.5.1 Crew's flight experience.

Hours Flown	
	Pilot
Total	3,582:00
Total in the last 30 days	05:00
Total in the last 24 hours	302:00
In this type of aircraft	00:00
In this type in the last 30 days	00:00
In this type in the last 24 hours	00:00

N.B.: Data provided by the aircraft operator, and contained in the Pilots' Electronic Logbook made available by the National Civil Aviation Agency (ANAC).

1.5.2 Personnel training.

The pilot did the Private Pilot course (airplane category) at the *Aeroclube de Itápolis* in 1973. His first certification in helicopters, included in the records of the National Civil Aviation Agency (ANAC), dated from February 1990.

1.5.3 Category of licenses and validity of certificates.

The pilot held an Airline Transport Pilot license (helicopter category), as well as valid technical qualification certificates for EC55, S365 type aircraft, and Multi-Engine Land Helicopters. He was also IFR- rated.

1.5.4 Qualification and flight experience.

The pilot had qualification and enough experience for the flight in question.

1.5.5 Validity of medical certificate.

The pilot had a valid aeronautical medical certificate (CMA).

1.6 Aircraft information.

The SN6909 aircraft was manufactured by Eurocopter (Airbus Helicopters) France in 2010, being registered in the Private Air Services (TPP) category.

The long haul EC155B1 twin-engine helicopter was capable of transporting a maximum of 13 passengers.

The helicopter airworthiness certificate was valid.

The records contained in the Part 1 of the airframe, number-1 engine, and number-2 engine logbooks were out-of-date. The last entry in the logbooks dated from June 2014, with a total record of 792.2 hours of operation.

However, the inspection sheet relative to the Service Order 165/15 stated that the aircraft had 1,842 cycles and 892.7 hours of operation.

Since its date of manufacture, the aircraft had always belonged to the same owner.

1.6.1 Primary Flight Controls

The primary flight controls are twofold (one per pilot) and mechanically interconnected, in addition to being of the irreversible type (hydraulically assisted). One of the characteristics of hydraulically-assisted systems is that just a little strength is necessary to move them.

To control the aircraft, pilots make use of the cyclic and collective controls, as well as of the pedals. Broadly speaking, the pilot's inputs are transmitted to the servocontrols by means of flexible ball-type control rods and bellcrank-type levers. The flexible ball-type controls are connected to the mixing boxes by means of the bellcranks. These latter ones, in turn, change the direction of the pilots' inputs, allowing the control mechanism to activate the main rotor servocontrols.

The cyclic control has the function of inclining the aerodynamic resultant from the main rotor in relation to the aircraft center of gravity, creating a momentum of either pitch (up/down) or roll.

The collective control produces an identical variation of pitch on all the blades, varying the intensity of the resulting force in the main rotor.

The pedal control actuates the pitch angle of the tail rotor blades, varying their aerodynamic resultant, and, consequently, providing yaw-control capability to the aircraft.

Since the cyclic and collective controls actuate on the main rotor, the movements of both controls are inserted in an array of components which control the aircraft swash-plate.

The entire assembly, in turn, is responsible for controlling the pitch-angle of the blades, by means of three servocontrols.

An identical movement of the servocontrols will produce an identical variation of the pitch-angle of all the blades, consequently varying only the intensity of the aerodynamic resultant from the main rotor (collective control).

A non-identical movement of the servocontrols will result in change of the direction of the resulting force, generating a momentum of pitch (up/down) and/or roll in the aircraft.

Figure 1 below, extracted from the Eurocopter (Airbus Helicopters) Theory Helicopter Manual (THM), shows how the flight controls accessible to the pilot are linked to each other, as well as to the servocontrols which move the aircraft swash-plate.

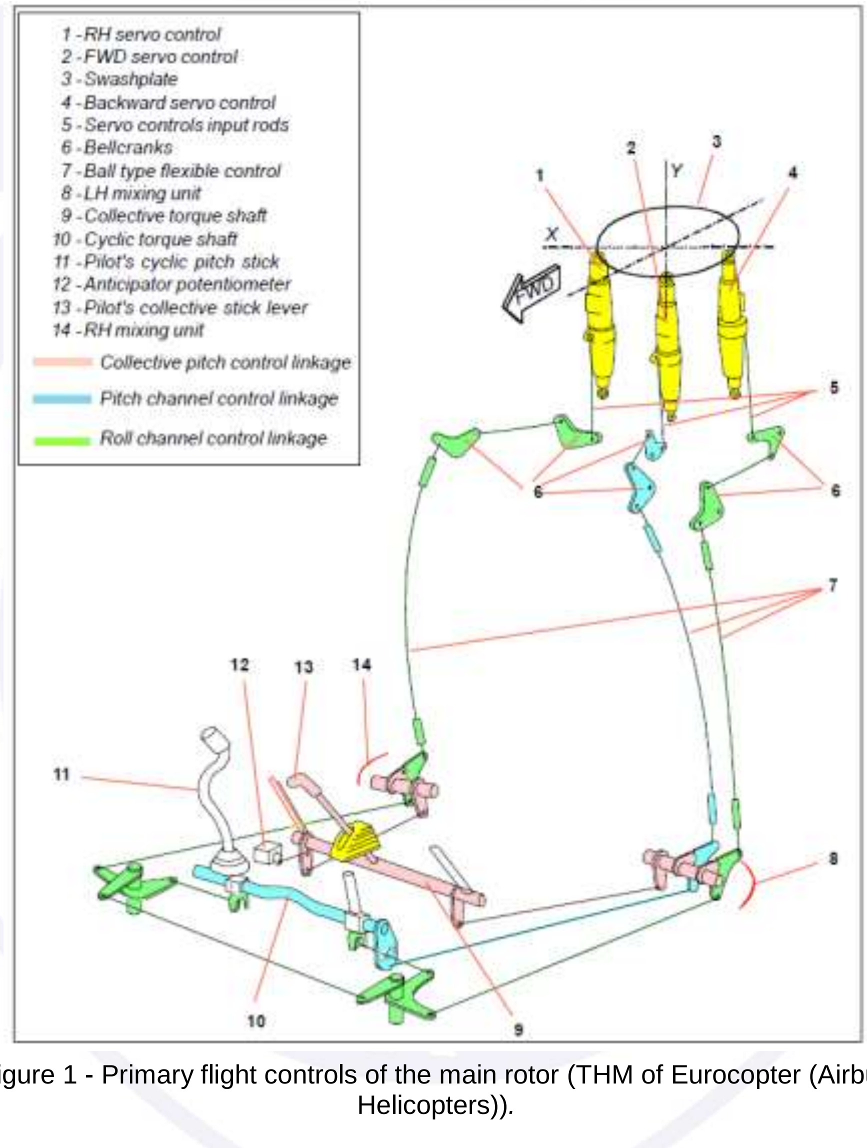

Figure 1 - Primary flight controls of the main rotor (THM of Eurocopter (Airbus Helicopters)).

In more detail, Figure 2 lists the names of the components composing the control mechanism of the main rotor.

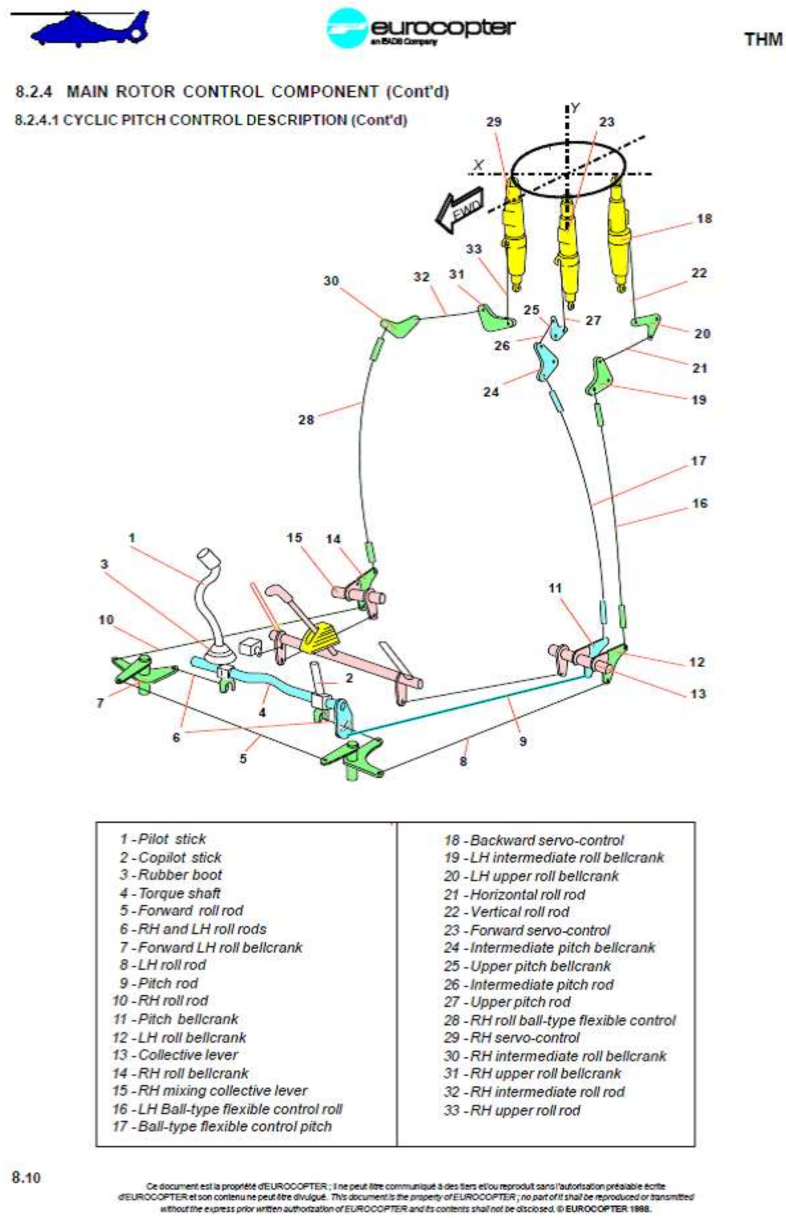

Figure 2 - Main components of the main rotor flight controls. (Eurocopter (Airbus Helicopters) THM).

The accident aircraft possessed three servocontrols, identified by the manufacturer as Right-hand servocontrol (A), Forward servocontrol (B), and Backward servocontrol (C). The relative positions of the servocontrols (A, B e C) are shown as viewed from above in Figure 3.

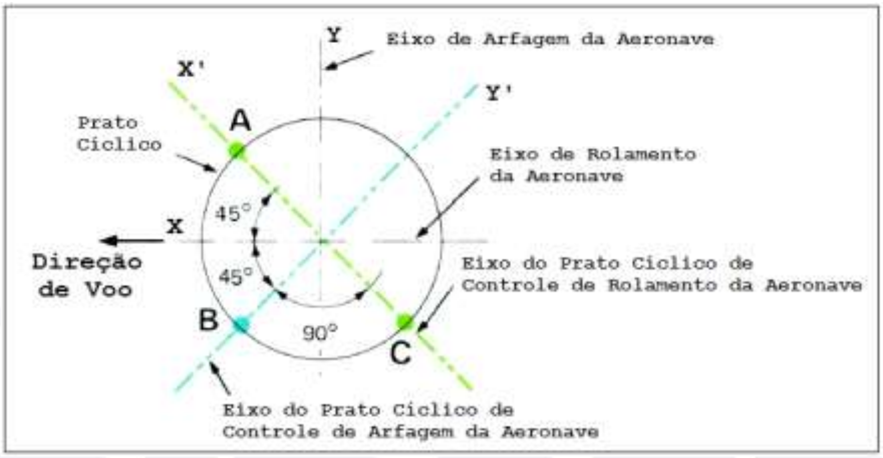

Figure 3 - Schematic position of the A, B, and C servocontrols as viewed from above (adapted, Eurocopter (Airbus Helicopters) THM).

For a pitch-up/down movement (rotation around the y-axis), only the B servocontrol will be moved up/down, resulting in rotation of the swash-plate around the x'-axis.

For a roll movement of the aircraft (rotation around the x-axis), the A and C servocontrols will be moved in opposite directions, with the B servocontrol remaining in a fixed position, causing rotation of the swash-plate around its y'-axis.

The collective control actuates by moving the three servocontrols equally, resulting in a movement of the swash-plate that is parallel to its initial position, just moving it vertically.

Figure 4 depicts the movement of the servocontrols resulting from the actuation on the individual flight controls.

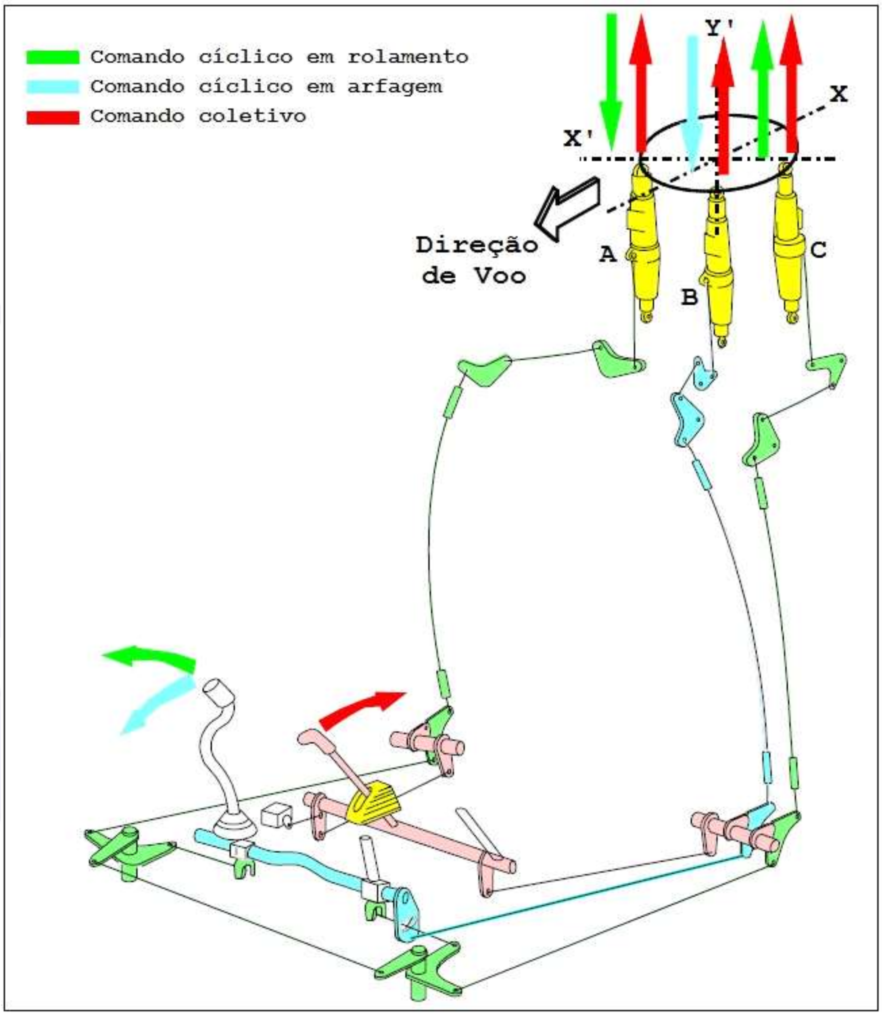

Figure 4 - Movement of the servocontrols in accordance with the pilot's inputs on the cyclic and collective control levers (Adapted from Eurocopter (Airbus Helicopters) THM).

The servocontrols actuate on the cyclic plate by means of hydraulic pressure, in accordance with the position of the flight controls. The architecture of the servocontrols, along with their main components, is shown in Figure 5.

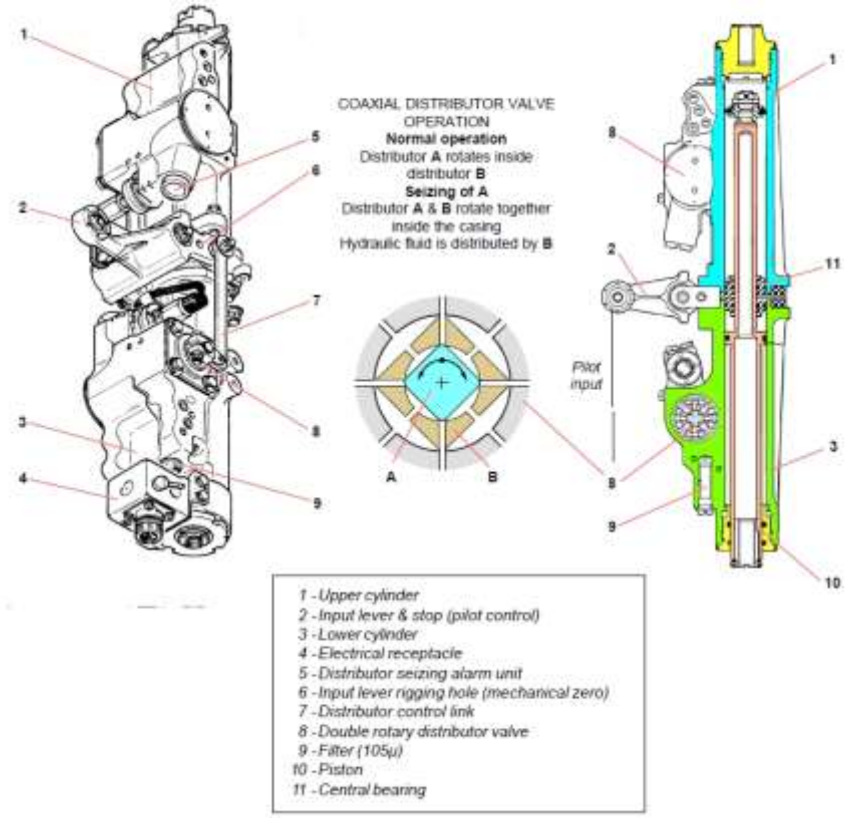

Figure 5 - Architecture and main components of a servocontrol of the EC155B1 helicopter (Eurocopter (Airbus Helicopters) THM).

The aircraft did not possess a system to indicate the position of the servocontrols. Figure 6 shows details of the functioning of the servocontrols in a schematic fashion.

The movement of the servocontrol is directly controlled by the pilot. While the input lever is being moved (item 2 of Figure 5), the servocontrol follows its movements. When the lever movements stop, the distributing valve gets centralized, and the servocontrol movements stop.

Figure 6 shows the servocontrol during a movement of retraction. By means of an action on the flight controls, the input lever is moved downward, actuating on the distribution valve, causing retraction of the servocontrol, opening the hydraulic pressure line for chamber A, and the return line for chamber B.

In Figure 6, the red color represents the pressure lines of the hydraulic fluid, while the green color represents the return lines. There are two rotary distributor valves on account of redundancy of the hydraulic systems.

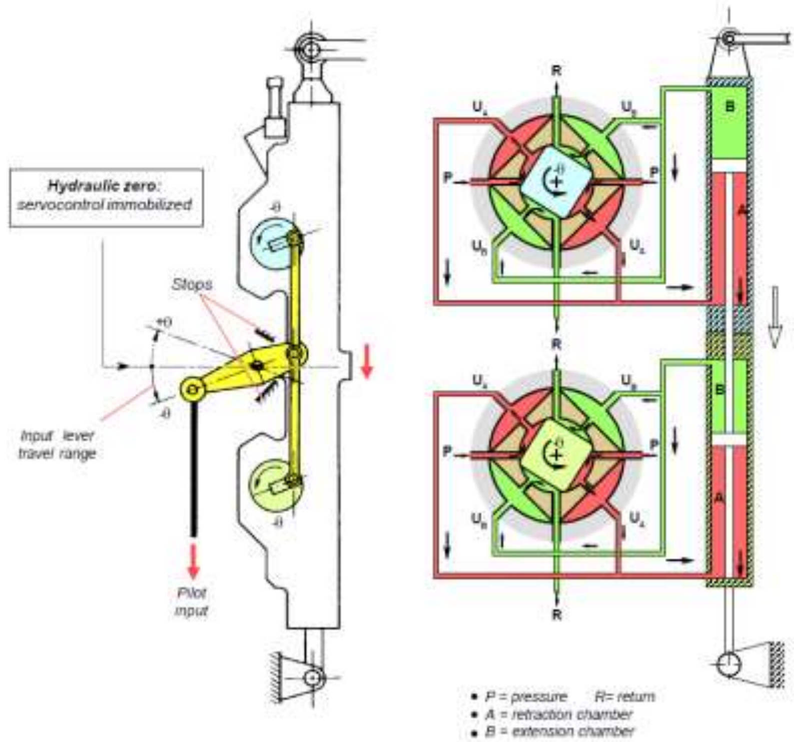

Figure 6 - Operation of a servocontrol in an EC155B1 aircraft.
(Adapted from the Eurocopter (Airbus Helicopters) THM).

1.6.2 Automatic Flight Control System (AFCS)

The Automatic Flight Control System (AFCS) controls the flight of the aircraft around four axes, thus considerably reducing the pilot’s workload, allowing him to conduct the flight without directly operating the flight controls.

The system had two modes of operation: basic and advanced guidance. In the basic mode, the system stabilizes the aircraft around the roll, pitch, and yaw axes (SAS – Stability Augmentation System). In the advanced mode, the system allows control of the helicopter trajectory throughout the various phases of flight.

The central component of the AFCS is the APM (Automatic Pilot Module). This module receives and processes pieces of information coming from a number of sources in the aircraft, and sends signals to the actuators in accordance with the mode of operation selected.

Among the functionalities of the APM, it is worth highlighting its ability to conduct internal tests of the module and series actuators, monitor angular velocity data provided by the Attitude and Heading Reference System (AHRS) and by the Fiber Optic rate Gyros (FOG). In addition, the APM is capable of recording messages of any existing failures and provide the crew with messages concerning the system status.

Moreover, the AFCS possesses an “SAS BACK UP” mode, which enhances stability around the roll and yaw axes, in case of normal-mode failure.

Figure 7 shows the main components which make up the AFCS system. This report will address the functioning of just some of the system components.

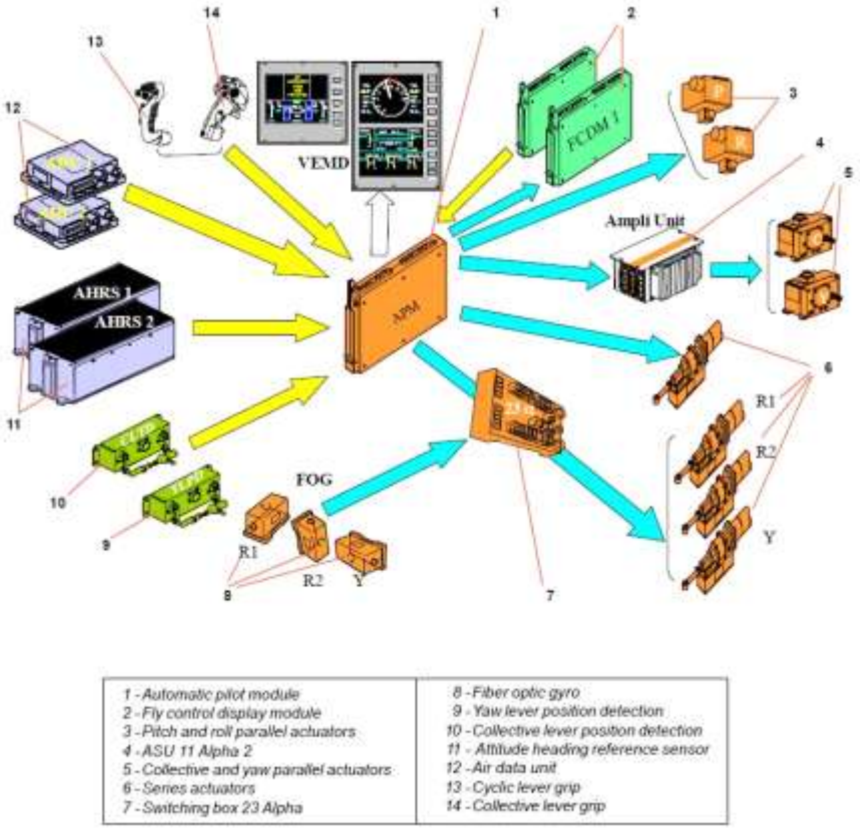

Figure 7 - Overview of the AFCS components (Eurocopter (Airbus Helicopters) THM).

For performing the functions described above, the AFCS counts on two types of actuators: series and parallel actuators.

The series actuators receive commands from the APM (in the normal mode of operation) or from the FOG sensors (in the “SAS BACK UP” mode). The AFCS has a total of four series actuators. Figure 8 shows the locations and names of these actuators.

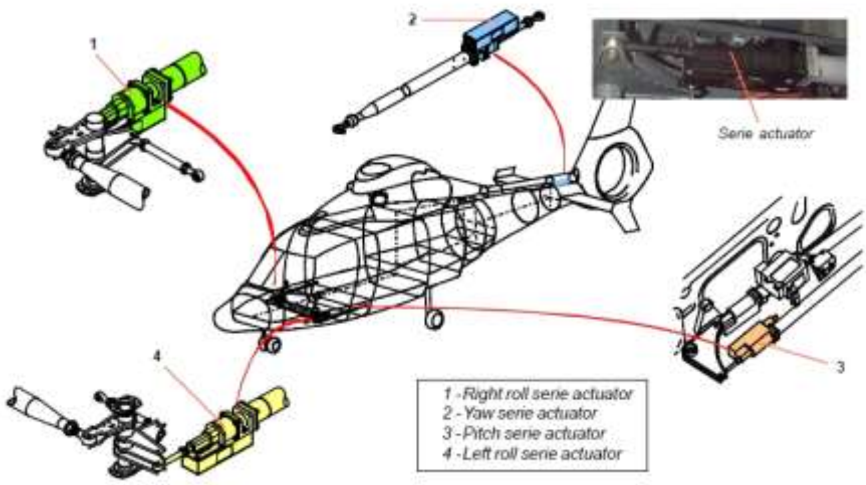

Figure 8 - Location of series actuators in the EC155B1 aircraft (Eurocopter (Airbus Helicopters) THM).

The command authority of the series actuators is ± 13.5% in pitch, ± 18% in roll, and ± 14% in yaw of the total course of each individual flight control.

If the position of the actuator rod is not in accordance with the position required by the control input, the actuator is automatically stopped, and its position stays locked.

It is worth pointing out that the failure described above is related to the automatic flight mode; therefore, in principle, the manual controls of the helicopter are not affected by the failure described.

The “SAS BACK UP” mode is engaged when the “SAS” button is pressed in either lever of the cyclic. In this mode, there are 3 (three) Fiber Optic rate Gyros (FOG), with two of them measuring angular speed variations around the roll axis, while the third one measures angular speed variations around the yaw axis. The FOG’s provide information to the series actuators for the stabilization of the helicopter.

The parallel actuators are associated with the trim system, allowing the pilots to correct certain helicopter tendencies, or adjusting it for a desired altitude, thus minimizing the workload in the pilots’ cabin.

The parallel actuators are commanded by means of the APM, both in the automatic advanced mode (guidance), with the autopilot engaged, and in the manual mode, by means of the switches on the cyclic and collective controls, known as “BEEP TRIM” switches.

The location of the parallel actuators is shown in Figure 9.

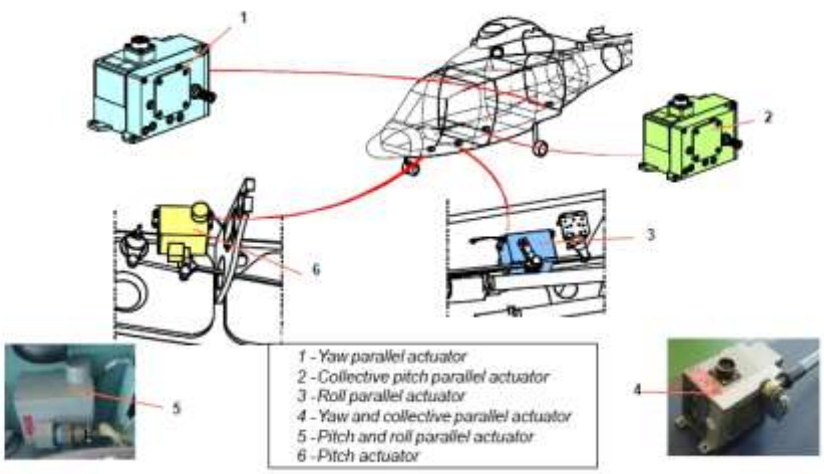

Figure 9 - Location of the parallel actuators of the EC155B1. (Eurocopter (Airbus Helicopters) THM).

1.6.3 - Maintenance

1.6.3.1 – Logbook Records

The last tag stuck to the Part 2 of the airframe logbook showed, among other inspections, the ones of “100 hours/2 months” (ALS 04-20-00) and “300 hours/12 months (MSM 05-20-00), as well as compliance with the Card AMM 62.23.02.991GRT01 – Non-rotating Swash-plate, done by the Helipark Maintenance Organization in *São Paulo* on 9 December 2014. The aircraft flew 44.7 hours after the aforementioned inspections.

The last basic maintenance intervention in the engines, “600 hours” type (MM 05-20-00) was performed by the Helipark maintenance organization in São Paulo, *São Paulo* state, and the aircraft flew 280.5 hours after that inspection.

The last basic maintenance intervention in the engines, “300 hours” type (MM 05-20-00) was performed by the Helipark maintenance organization in *São Paulo* on 27 February 2014, and the aircraft flew 188.7 hours after that inspection.

The last “50 hours”-type inspection of the aircraft was done by the Helipark maintenance organization in *São Paulo* on 9 December 2014, and the aircraft flew 44.7 hours after that inspection.

The last “IAM” inspection of the aircraft was done by the Helipark maintenance organization in *São Paulo* on 22 October 2014, and the aircraft flew 70.9 hours after that inspection.

1.6.3.2 – Maintenance Program

The maintenance program prescribed for EC155B1 aircraft was established by the manufacturer by means of the MSM (Master Servicing Manual – Maintenance Program), which defined the operational time limits along with maintenance intervals, and also by means of the ALS (Airworthiness Limitations Section), which addressed the airworthiness limitations and the checks.

All the procedures, pieces of information, as well as details of the maintenance tasks and operations to be provided to the EC155B1 helicopter, were described in the Airbus Helicopters Technical Publications.

1.6.3.2.1 – Maintenance Intervals:

Basically, the MSM prescribed the following maintenance intervals:

a) Daily Checks:

Daily Checks aimed to ensure operational availability of the helicopter, and had to be done by a maintenance-professional, a pilot, or a mechanic qualified by the maintenance organization of the operator. The Checks were defined as follows:

- “15 hours” Inspection (15 FH):
- To be done every period of 15 hours of flight or 7 days (whichever happened first); or before resuming flights if the helicopter did not fly for a period of 7 days or more, in accordance with the conditions defined in the Manual of Current Techniques and in the Engine Maintenance Manual.
- Acceptance of the helicopter by the pilot and/or incorporation of a change made to the helicopter.
- Pre-flight check in cold and very cold climate.
- Inspection of optional systems.

b) Supplementary check (S):

These supplementary checks were be done every 100-hour flight period, not exceeding 1 year. They aimed at verifying the condition of the components subjected to short inspection intervals (shorter than those of the basic inspection).

c) Additional Check (F):

This type of inspection was done in conformity with the FAR 43-11, and required by some government authorities under certain circumstances (renovation of airworthiness certificate, change of ownership, etc.). Type-F checks complemented type-S checks.

d) Basic Inspection (T or A):

The basic inspection consisted of verifications related to the operation of the aircraft, done at every 600-hour flight period (type T inspection) or every 2-year period (type A inspection). This basic inspection included functional tests for monitoring the behavior of components and systems, as well as verification of the condition of components with direct influence on the helicopter’s airworthiness status.

1.6.3.3 – Maintenance Services Provided

As part of its aircraft maintenance control policy, the operator hired Helipark (a maintenance organization) for the provision of services, in accordance with the Service Order no. 164/15, dated 11 February 2015. The aircraft was ferried to the Helipark facilities by the operator the day before (10 February 2015).

The Service Order listed the following tasks prescribed in the aircraft technical publications:

1. Daily Inspection;
2. “15 hours / 7 days” airframe inspection;
3. “2 years” airframe inspection;
4. “600 hours / 2 years” airframe inspection;
5. “1 month” airframe inspection;
6. “100 hours / 2 months” airframe inspection;
7. “90 hours” airframe PO inspection;
8. “100 hours” airframe inspection;
9. “100 hours / 6 months” airframe inspection;
10. “100 hours / 1 year” type-“S” airframe inspection;
11. “50 hours” airframe inspection;
12. “300 hours” airframe inspection;
13. “600 hours / 6 months” airframe inspection;
14. “3 months” airframe inspection;
15. “15 hours / 7 days” engine inspection (both engines);
16. “50 hours” engine inspection (both engines);
17. “6 months” airframe inspection;
18. “600 hours / 1 year” airframe inspection;
19. “1 year” airframe inspection;
20. “5 years” airframe inspection;
21. Compliance with certain Airworthiness Directives; and
22. Other maintenance services involving, replacement, removal, re-installation of components and paint retouch.

The Service Order also informed that the five blades of the main rotor (P/N 365A11-0080-01, with the following serial numbers: 2176, 2167, 2168, 2164 and 2175) were to be removed and re-installed after inspection and repairs conducted by Helibras – CHE 8004-01/ANAC (services detailed further in this report).

It is worth pointing out that some of the “calendar inspections” (1, 2, and 5 years, among others) were done in conjunction, in accordance with the maintenance manual of the aircraft manufacturer.

1.6.3.4 – Structure of the Service Order no. 164/15

Basically, the Service Order had the following format:

- fields containing information on the Maintenance Organization, on the client’s registration, as well as on the aircraft and engines;

- a column identified as SERVICE(S) TO BE DONE, subdivided into lines for each one of the Inspections/Checks which the aircraft had to undergo, grouped in accordance with the limits and criteria established in the Master Servicing Manual (MSM) or in the Airworthiness Limitations Section (ALS), as well as other maintenance services;

- a column identified as SERVICE(S) PROVIDED, subdivided into lines for the description of every Inspection/Check, and other maintenance services effectively provided to the aircraft;

- a column identified as H/H subdivided into lines for measuring the amount of work done by a person in a period of 1 hour;

- a column identified as MEC subdivided in lines for the signature of the Maintenance Mechanic which did the individual maintenance service, inspection/check;

- a column identified as INSP for the signature of the inspector who supervised every service provided by the Mechanic;

- a last line, with fields identified as Preliminary Inspection, Final Inspection, Service Order Opening Date, and Service Order Closing Date, in addition to other managerial items of information.

All the inspections done and maintenance services provided to the airframe had, in the "MEC" column, the signature of the mechanic who had done each individual task.

In relation to the inspector, the investigating committee observed that the field identified as Preliminary Inspection (prescribed for when the aircraft enters the maintenance organization) contained the mark of a stamp.

The "INSP" column did not show any signatures or stamps of the inspector (to indicate his acceptance of the services provided by the mechanic) in 42 out of the 43 maintenance tasks listed in the Service Order OS164/15.

1.6.3.5 – Inspection Sheets

The Inspection Sheets of the various inspections done to the PP-LLS aircraft were in accordance with the Master Servicing Manual (MSM) and Airworthiness Limitations Section (ALS) of the EC155B1. The Inspections Sheets relative to the inspection of the engines were in accordance with the Turbomeca (Safran Helicopter Engines) ARRIEL 2C2 engine maintenance manual.

Each inspection carried out on the aircraft consisted of a number of tasks, which were defined in accordance with certain time intervals or with the amount of hours flown (as described in the MSM/ALS), thus defining each one of the inspection sheets that composed the collection of sheets related to the aircraft.

The procedures for the accomplishment of each task were described in the aircraft maintenance manuals and/or other technical publications issued by the manufacturer with detailed information on: special tools (when needed); materials; components for routine replacement; applicable documentation, including instructions for removal/installation; general safety instructions; torque- and locking-related instructions; instructions on the application of products; and any necessary preliminary steps.

Each task composing the individual Inspection Sheet had a corresponding field for the entry of the mechanic's stamp or signature attesting completion of the task. The sheets also had a field for the entry of the inspector's stamp or signature to confirm his/her acceptance of the maintenance task performed by the mechanic.

All the accomplished tasks of the Inspection Sheets had the mark of the mechanic's stamp, either attesting that they had been effectively carried out, or, otherwise, indicating that some of the tasks were not applicable (NA), or even that certain items of equipment were not incorporated (NI) in the aircraft.

As for the entry of stamps or signatures by the inspector, only the tasks of the Inspection Sheets related to the engines were contemplated. In the other Inspection

Sheets, none of the tasks performed had the inspector's stamp/signature or date of acceptance of the tasks.

Just below the last task, every Inspection Sheet contained the following statement:

> This is to certify that the aircraft herein specified was inspected in accordance with the manufacturer's maintenance program, and that it was confirmed to be in airworthy conditions.

Below the referred statement, there was a field for the entry of the mechanic's stamp/signature, and another one for the Inspector's stamp/signature. All the inspection sheets had been signed / stamped by the mechanic. However, with the exception of the engine Inspection Sheets, none of the sheets contained the inspector's signature.

1.6.3.6 – Services Provided to the Main Rotor

Checks prescribed in the Master Servicing Manual for the Flexible Ball Control:

The Master Servicing Manual (MSM) prescribed that the Check of the Flexible Ball Control, described in the Aircraft Maintenance Manual (AMM) Task 67.10.00.224, was to be done every 6-month, 1-year, and 2-year interval. The execution of the 6-month and 1-year checks was associated with the operation of the aircraft under certain atmospheric conditions (humidity, salinity), as indicated in the MSM extract shown in Figure 10 below:

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Task Number Description/Remarks	Documentation	Interval	Margin
67/10/00/224/000/000 Ball control Tropical and damp atmosphere Check.	AMM 67.10.00.224	6 M	18 D
67/10/00/224/000/003 Ball control Salt-laden atmosphere Check.	AMM 67.10.00.224	1 Y	36 D
67/10/00/224/000/005 Ball control Check.	AMM 67.10.00.224	2 Y	73 D

Figure 10 - MSM extract showing the inspection intervals relative to the Task 67.1.00.224.

Records of the Task AMM 67.10.00.224 in the Inspection Sheets:

The Collection of Inspection Sheets had the stamp of the mechanic, indicating accomplishment of the Task AMM 67.10.00.224, at the following inspections: "2 years", "6 months", and "1 year". As previously commented, in the pertinent Inspection Sheets, there were no stamps to attest inspection/acceptance of the task by the inspector.

In the Task AMM 67.10.00.224 of the 1-Year Inspection Sheet, beside the stamp of the mechanic, the following hand-written annotations were seen: "OK 24/02 D55 (or DSS)". It was not possible to determine the meaning of these annotations, nor the person who made them.

Details of the Task 67.10.00.224 (Check Flexible Ball Control):

The Task 67.10.00.224 of the EC155B1 AMM was composed of six pages, which are depicted in Figures 11 through 16 below. The task had seven topics, sequentially identified from "A" to "G". From "A" to "E", the topics described all the pieces of information necessary for the Check of the Main Rotor Flexible Controls, including the preliminary steps; the materials and products utilized for corrosion removal and prevention; a list of the routinely replaced cotter pins; the applicable technical publications; and a NOTE relative to helicopters with VIP (Very Important Person) configuration.

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AMM EC155 BB1

Version: B, B1

Inspection Criteria - Main Rotor Flexible Ball Controls

Additional information from O.R.I.O.N.

Work card referenced in the MSM

MSM 05-20-00 ATA 67 (B1) ROTORS FLIGHT CONTROL

MSM 05-20-00 ATA 67 (B) ROTORS FLIGHT CONTROL

A. Special Tools

None.

B. Materials

CM 506	anti-corrosion agent
CM 518	anti-corrosion agent
Commercial	cloth

C. Routine Replacement Parts

AMM		Nomenclature	IPC
Figure	Item		Subject - Figure - Item
Figure 1	(4)	Cotter pin	67140201-380-
Figure 1	(4)	Cotter pin	67140201-430-
Figure 1	(4)	Cotter pin	67140201-480-
Figure 1	(9)	Cotter pin	67140202-180-
Figure 1	(13)	Cotter pin	67130101-340-
Figure 1	(19)	Cotter pin	67130201-170-
Figure 1	(23)	Cotter pin	67140101-180-

D. Applicable Documents

AMM 53-52-00-062	Removal / Installation - Oil Cooler Support Cowling
AMM 53-55-00-061	Removal / Installation - Bottom Structure Bottom Fairing

Figure 11 - Task 67-10-00-224, page 1 of 6 (AMM EC155).

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AMM 67-00-00-911	General Safety Instructions - Flight Controls
AMM 67-00-00-991	Torque Loading and Safetying - Flight Controls
AMM 67-14-01-061	Removal / Installation - Main Rotor Flexible Ball Control
MTC 20.02.06.404	Safetying with cotter pins
MTC 20.04.03.401	General method for reconditioning corroded metal surfaces

E. Preliminary Steps

1. Open the right and left bottom structure fairings.
2. Remove the fairings from below the bottom structure. Refer to the sub-task 53-55-00-021-001 of the AMM 53-55-00-061.
3. Remove the oil cooler support cowling. Refer to the sub-task 53-52-00-022-001 of the AMM 53-52-00-062.

> **i NOTE**
>
> *If the helicopter includes the VIP installations, do not remove the oil cooler support cowling. Open the inspection doors on each side of the oil cooler support cowling: these doors give access to the flight control bellcranks.*

4. Remove the covers and the trimming panels from the 9° frame on the left and right sides of the cabin.

F. Procedure

> **! CAUTION**
>
> **BEFORE YOU DO THE WORK ON THE FLIGHT CONTROLS, READ THE AMM 67-00-00-911.**

sub-task 67-10-00-224-001

1. Do an inspection of the main rotor flexible ball controls. *Figure 1*
   a. On the left roll channel, the right roll channel and the pitch channel, disconnect:
      (1) the cyclic-pitch input rods (14) from the left and right mixing units:
         (a) remove and discard the cotter pins (13) and (19),

Figure 12 - Task 67-10-00-224, page 2 of 6 (AMM EC155).

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(b) loosen and remove the nuts (12) and (18), the washers (11) and (17) and the bolts (10) and (16).

(2) the horizontal rods (5) on the transmission deck from the top levers of the flexible ball controls (15):

(a) remove and discard the cotter pins (4),

(b) loosen and remove the nuts (3), the washers (2), and the bolts (1).

b. Make sure that the lock plates of the top and bottom end-fittings of the flexible ball controls (15) are in position and in good condition.

c. Disconnect the top and bottom end-fittings from the flexible ball control (15).

(1) Remove and discard the cotter pins (9) and (23).

(2) Loosen and remove the nuts (8) and (22), the washers (7) and (21) and the bolts (6) and (20).

d. Manually make sure that each swivel bearing of the sheath stops moves freely, also make sure that there is no incorrect axial or radial play.

e. PRE MOD 0767B59, if a swivel bearing does not move freely:

(1) apply the anti-corrosion agent CM 506 on the swivel bearing of the sheath stop. Then manually make sure that the swivel bearing moves freely and that there is no incorrect axial or radial play,

(2) if the swivel bearing does not move freely. Refer to the AMM 67-14-01-061 and replace the flexible ball control.

f. POST MOD 0767B59, if a blockage is found, replace the flexible ball control. Refer to the AMM 67-14-01-061.

g. Clean the rods of the flexible ball controls (15) with a clean cloth.

h. Make sure that the ball control rods are in good condition. Manually make sure that there is no incorrect axial or radial play in the swivel bearings at the ends of the sliding rods.

i. If there are signs of corrosion:

(1) do a corrosion preventive treatment. Refer to the MTC 20.04.03.401,

(2) make sure that is no residue after cleaning,

Figure 13 - Task 67-10-00-224, page 3 of 6 (AMM EC155).

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! CAUTION

DO NOT APPLY THE ANTI-CORROSION AGENT ON THE RODS OF HELICOPTERS THAT FLY IN ATMOSPHERE THAT CONTAINS A LARGE QUANTITY OF SAND.

! CAUTION

POST MOD 0767B59, DO NOT APPLY ANTI-CORROSION AGENT CM 506 ON THE RODS OF THE FLEXIBLE BALL CONTROLS.

(3) apply a small quantity of the anti-corrosion agent CM 506 on the rods of the flexible ball controls,

(4) make sure that each flexible ball control (15) moves down correctly with its own weight.

j. Connect the top and bottom end-fittings of the flexible ball controls (15).

(1) Apply the anti-corrosion agent CM 518 on the surfaces of the bolts (6) and (20) that have no threads.

(2) Install the bolts (6) and (20), the washers (7) and (21) and the nuts (8) and (22).

(3) Torque the nuts (8) and (22). Refer to the AMM 67-00-00-991.

(4) Install the cotter pins (9) and (23). Refer to the MTC 20.02.06.404.

k. Manually operate each lever of the mixing units and make sure that each flexible ball control (15) moves freely (for the positions: low pitch, neutral, high pitch).

l. Connect the horizontal rods (5) on the transmission deck to the top levers of the flexible ball controls (15).

(1) Apply the anti-corrosion agent CM 518 on the surfaces of the bolts (1) that have no threads.

(2) Install the bolts (1), the washers (2) and the nuts (3).

(3) Torque the nuts (3). Refer to the AMM 67-00-00-991.

(4) Install the new cotter pins (4). Refer to the MTC 20.02.06.404.

m. Connect the cyclic pitch input rods (14) to the mixing units.

Figure 14 - Task 67-10-00-224, page 4 of 6 (AMM EC155).

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(1) Apply the anti-corrosion agent CM 518 on the surfaces of the bolts (10) and (16) that have no threads.

(2) Install the bolts (10) and (16), the washers (11) and (17) and the nuts (12) and (18).

(3) Torque the nuts (12) and (18). Refer to the AMM 67-00-00-991.

(4) Install the new cotter pins (13) and (19). Refer to the MTC 20.02.06.404.

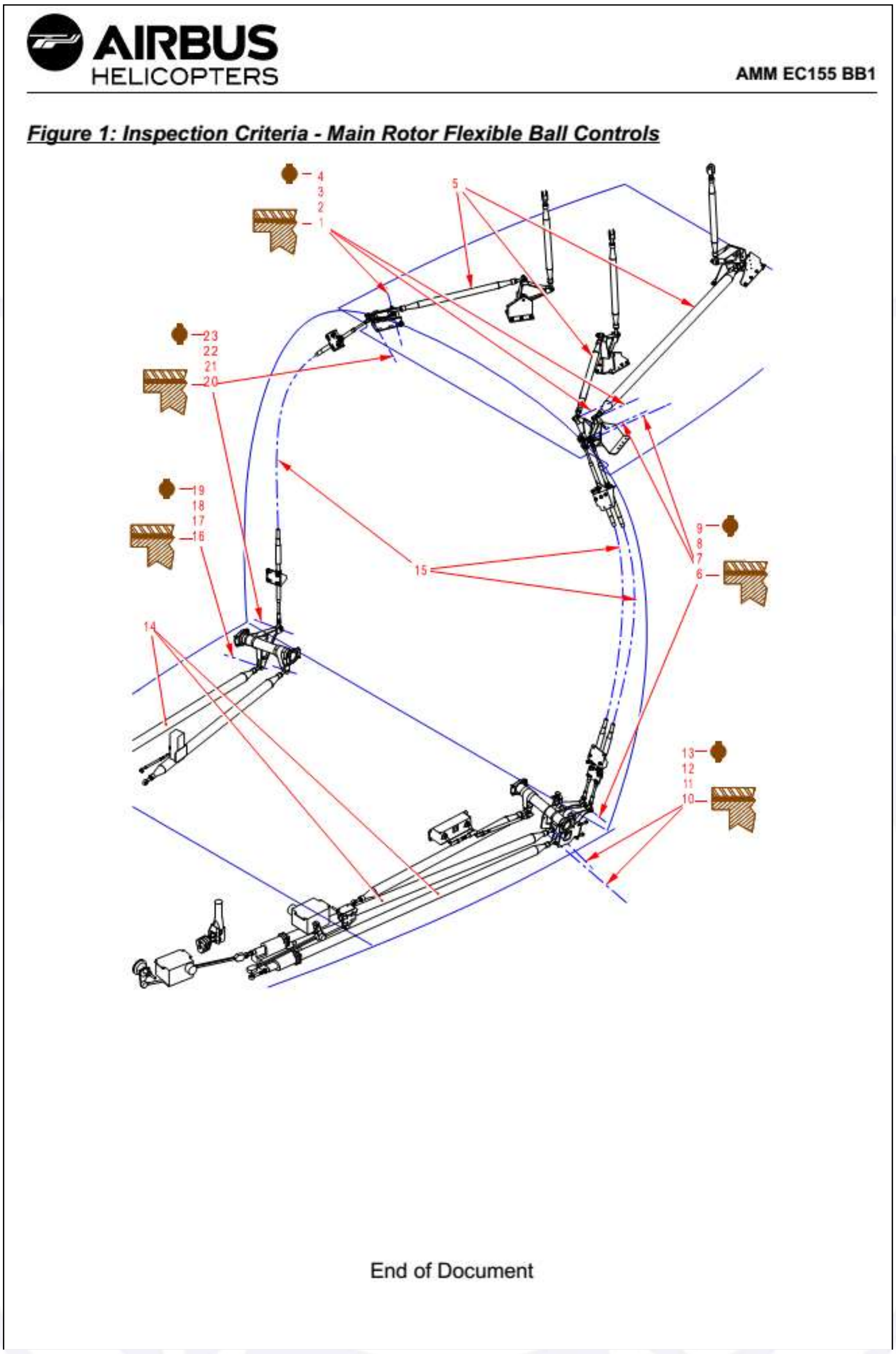
G. Final Steps

1. Install the covers and the trimming panels on the 9° frame on the left and right sides of the cabin.
2. Install the oil cooler support cowling. Refer to the sub-task 53-52-00-422-001 of the AMM 53-52-00-062.

> **i NOTE**
>
> *If the helicopter includes the VIP installations, close the inspection doors on the oil cooler support cowling.*

3. Install the fairings below the bottom structure. Refer to the sub-task 53-55-00-421-001 of the AMM 53-55-00-061.
4. Close the right and left bottom structure lateral fairings.

Figure 15 - Task 67-10-00-224, page 5 of 6 (AMM EC155).


AIRBUS HELICOPTERS

AMM EC155 BB1

Figure 1: Inspection Criteria - Main Rotor Flexible Ball Controls

End of Document

Figure 16 - *Task* 67-10-00-224, page 6 of 6 (AMM EC155).

The topic "F" (Procedure) of the task would normally be initiated with an alert (CAUTION) demanding the execution of the task 67-00-00-911 before work could be done to the flight controls (Figure 12).

In the sequence, topic "F" of the task detailed the Sub-task 67-10-00-224-001, and listed the entire procedure for the inspection to be done to the main rotor flexible ball controls (Figures 12 through 15). In a comprehensive manner, the task described the actions to be taken, and determined that, among other tasks, the following ones were to be performed:

- Disconnect the (cyclic-pitch) levers on both the left- and right-hand sides of the respective mixing units, discarding the cotter pins, and removing the nuts, washers, and bolts (Figure 12);
- Disconnect the horizontal rods of the transmission deck from the upper part of the flexible ball controls (Figure 13);

- Disconnect both ends (top/bottom end-fittings) of the three flexible ball controls (Flexible Ball Control), discarding the cotter pins, and removing nuts, washers, and bolts (Figure 13);
- Carry out the inspections and tests of the components of the flexible ball controls for freedom of movement, absence of both radial and axial plays, cleanliness, and protection against corrosion (Figure 13);
- Make sure that each one of the flexible ball controls moves downward in a correct manner under its own weight (Figure 14);
- Apply the paste for protection against corrosion on the surfaces of the bolts (but not on their threads), in accordance with the MTC Application instructions (Figure 14);
- Connect both ends (top/bottom end-fittings) of the three flexible ball controls in their respective mixing units, utilizing the bolts, washers, and nuts. Apply the correct torque on the nuts, and install the cotter pins (Figure 14);
- Manually, move each one of the levers of the mixing units, and make sure that each flexible control moves freely to the minimum pitch, neutral, and maximum pitch positions(Figure 14);
- Connect the horizontal rods of the transmission deck to the upper part of the flexible ball controls, utilizing the bolts, washers, and nuts (Figure 14);
- Apply the correct torque on the nuts, and install the cotter pins (Figure 14); and
- Connect the cyclic-pitch levers of the left- and right-hand sides to their respective mixing units, utilizing the cotter pins, and removing the nuts, washers, and bolts (Figure 14).

The task procedures made reference to components shown in Figure 16, on the last page of the task.

Task 67-00-00-911 General Safety Instructions - Flight Controls

The task 67-00-00-911 in the EC155B1 AMM was composed of three pages, which are depicted in the Figures 17 through 19 below. The task had seven topics, named from “A” to “G”. The referred task warned of the several precautions to be taken in relation to the maintenance tasks involving the flight controls.

In this sense, the task contained safety procedures, including a final verification of the Flight Control System after the provision of the services.

To that effect, a sequence was pre-established for the various components in the system of flight controls, including each bellcrank, point of articulation, stopper, and protection.

Still during the inspection, each control was to be moved slowly and smoothly, making sure that each control channel/canal was moving in the correct direction (Figure 18).

AIRBUS HELICOPTERS

AMM EC155 BB1

Version: B, B1

General Safety Instructions - Flight Controls

A. **Special Tools**

None.

B. **Materials**

None.

C. **Routine Replacement Parts**

None.

D. **Applicable Documents**

None.

E. **Preliminary Steps**

1. None.

F. **Procedure**

sub-task 67-00-00-911-001

! CAUTION

FOR THE FLEXIBLE BALL CONTROLS:

DO NOT PUT OIL OR GREASE IN THE SHEATH.

DO NOT DIASSEMBLE THEM.

DO NOT BEND THEM TO MAKE A "V" OR WITH A CURVE RADIUS OF LESS THAN 300 MM.

AFTER YOU REMOVE THE CONTROL, EXTEND IT TO ITS FULL LENGTH.

! CAUTION

DO NOT PRESSURIZE THE HYDRAULIC SYSTEMS WHEN THE PINS ARE IN POSITION OR WHEN THE FLIGHT CONTROLS ARE DISCONNECTED.

Figure 17 - Task 67-00-00-911, page 1 of 3 (AMM EC155).

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! CAUTION

PRESSURIZE THE HYDRAULIC SYSTEMS AND INSTALL THE PINS IN THIS SEQUENCE:

1) PRESSURIZE THE HYDRAULIC SYSTEM.

2) INSTALL THE PINS.

3) REMOVE THE PINS.

4) RELEASE THE PRESSURE FROM THE HYDRAULIC SYSTEM.

1. Before you adjust the control channel, find the causes of the changes in the reference.
2. Make sure that each pin has a safety pennant.
3. Be careful with the pins and lubricate them before you use them.
4. The reference pins must be installed in the control channels freely.
5. Do not use force to install the pins.
6. Find the cause of the incorrect positions of the adjustment holes:
   - deformation of the rod (buckled).
   - deformation of the structure.
7. After you do work on the flight controls, do a final inspection of the system. Make sure that all the flight controls operate correctly, that they are correctly safetied and that they have sufficient clearance at the bulkhead connectors.

   Do the inspection in this sequence: each bellcrank, each pivot point, each stop and each protection.

   During the inspection, move each control slowly and smoothly from the cockpit.

   Make sure that each control channel operates in the correct direction.
8. After you adjust the length of a rod, make sure that you cannot see the red safety groove.
9. Make sure that you can see the safetied items from the normal access points.
10. If necessary, replace the heat-shrinkable sheath or the sealant beads.
11. The pitch change rod identified with the yellow disc is the reference rod. You must not change the length of this rod.
12. The rods that are sealed with the white heat-shrinkable sheath (the fixed rods) have a mandatory length. These rods are adjusted before they are installed and you must not change their length.

Figure 18 - Task 67-00-00-911, page 2 of 3 (AMM EC155).

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13. The rods that are sealed with the black heat-shrinkable sheath the adjustable rods have their length adjusted when they are installed on the helicopter. You must not change this length.

14. When you adjust the rods that are not sealed, be careful not to damage the covers that seal the ball bearing or the spherical bearing end-fittings.

- Do not let a rod stay attached only at one end.
- Do not let a rod hang vertically from one attachment point.
- Put a support below the rod if only one end is connected.
- When you turn a rod to adjust it, use a stirrup to hold the rod ends in the yokes to prevent their movement.
- Do not use force to turn the rod more than the limits when you do the check for brinelling of the rod ends (to prevent damage to the bearing covers).
- Remove the rods to safety and unsafety the end-fittings with the tab washers. If necessary, make a sealant bead.

G. **Final Steps**

1. None.

End of Document

Figure 19 - Task 67-00-00-911, page 3 of 3 (AMM EC155).

Main Rotor Blades

Helipark sent the main rotor blades to Helibras (representative of the aircraft manufacturer in Brazil) for the provision of maintenance services.

For that purpose, Helipark issued a “Material Return Form” to Helibras on 12 February 2015. The form, in its field “Detailed Description of the Failure”, contained the following records related to the main rotor blades of the PP-LLS aircraft:

a) PU detaching from the tip of the main rotor blades, provide replacement – total of 5ea;

b) Provide replacement of the polyurethane on the intrados of the blade PN 365A11-0080-01, SN 2168.

After coordination with the operator, the 5 blades (P/N 365A11-0080-01, serial numbers 2176, 2167, 2168, 2164 and 2175) were sent to Helibras, where they arrived on 25 February 2015.

Helibras, after an inspection done on 27 February 2015, informed, by means of an internal document and a Service Order, that the five blades needed to be provided the following services:

a) Replacement of the intrados PU;

b) Replacement of the root PU;

c) Replacement of the tip cap PU (Parabolic Blade Tip);

d) Painting; and

e) Static balancing.

All the procedures required for the provision of the services listed above were prescribed in detail by the manufacturer in the following manuals: Aircraft Maintenance Manual, Manual of Current Techniques (MTC), and Manual of Revision and Repair. The tasks performed on each one of the five blades were registered in a Helibras internal document and in a Service Order.

The documents and Service Orders of the five blades contained the signature and registration number of the mechanic that provided the services. They also contained the signature of the inspector who inspected and accepted the tasks, as well as the signature of the technical manager of the dynamic assemblies sector, and of the maintenance and blade-repair workshop.

The investigating committee observed that all the services provided by the Helibras maintenance and blade-repair workshop were compulsorily logged in the BIRDS System (Airbus Helicopter Software), allowing traceability of the blades/services, which were also kept in a Helibras maintenance portfolio.

According to the map of the scheduled inspections and blade repairs presented, the paint services were initiated on different dates for each blade, between 13 and 19 March 2015.

On 23 March 2015, the lack of a diluent necessary for the painting process was detected. The lack of this diluent was considered by Helibras the root cause of the non-compliance with the programmed date of delivery of the blades to the client (27 March 2015).

The diluent was received on 27 March 2015. All the blades were submitted to the application of Wash Primer before being painted. The process of blade painting was considered completed by Helibras on 30 March 2015.

TYPE-3 paint was applied, in accordance with the charts CT 62.10.00.833 and MTC 20-60-00-433. The phase of paint drying complied with the 1-hour/60ºC parameter, in accordance with the chart MTC 20-60-00-433.

The time for full polymerization of the paint, in accordance with the chart MTC 20-60-00-433, was 7 days, but such time was not respected for any of the five blades.

When consulted about the non-compliance with the deadline of seven days for polymerization of the paint, Airbus Helicopter issued the Notice EAI 116/2016:

> In accordance with the Standard Practice Manual, card 20-60-00-433 “Preparation of primers and paints - Blade standard practices”:
>
> - If curing cycle applied is 1 hour at 60°C, blades can be fitted and dynamic balancing can be done right after.
>
> - If curing cycle applied is done at ambient temperature meaning that paint be fully cured after 7 days, it remains however that paint will have reached a level of maturity (conversion, elasticity, mechanical qualities) earlier than 7days sufficient to be fitted and used on aircraft.

According to the manufacturer (Airbus Helicopter), if the curing cycle applied had been the one of 1-hour at 60ºC, the blades could have been installed in the aircraft, and the dynamic balancing could have been done immediately afterwards. However, in the aircraft manual (MTC 20-60-00-433), there was no mention of installation and dynamic balancing of the blades, without their undergoing the full polymerization period of seven days.

The note issued by Airbus Helicopter also addressed the procedures and deadlines relative to the polymerization of the blades’ painting:

> Additional information:
>
> In the case of blades from the accidented (sic) aircraft, the paint has been found intact on all parts examined after accident, no evidence of paint flaking off, paint separation, paint missing were noted, meaning that waiting period painting and blade fitting on aircraft has been sufficient to ensure a good behavior of the paint.

After completion of the services provided by Helibras, the blades were sent to Helipark by means of the following Certificates of Release and Airworthiness (Form. SEGVOO 003): HBM-05893/15, HBM-05891/15, HBM-05892/15, HBM-05894/15 e HBM-05890/15. The blades arrived at Helibras on the evening of 1 April 2015.

On the morning of 2 April 2015, the blades were received by the Helipark technical team, which conducted a receipt inspection of the blades and analysis of the SEGVOO-003 documents. At the inspection, it was necessary to adjust some of the static tabs which were not in accordance with the angularity pre-established by the manufacturer, in accordance with the field no. 4 of the LOG CARD of each blade. Then, the blades were installed in the aircraft.

1.7 Meteorological information.

The flight was conducted in the day-time period, and the weather conditions were VMC.

According to a weather report from SBSP, located at a distance of 11.51 NM from the crash site, the wind was 140 degrees at 13 kt.

1.8 Aids to navigation.

Nil.

1.9 Communications.

All communications were made on the frequency of 131.325 MHz of the maintenance organization radio station.

1.10 Aerodrome information.

The occurrence was outside of aerodrome area.

Figure 20 - View of the Helipark from above (Google Maps).

1.11 Flight recorders.

Neither required nor installed.

1.12 Wreckage and impact information.

Images of videos conveyed through the mass media, and other ones made available to the Investigating Committee, showed that the helicopter descended along a predominantly vertical trajectory.

The crash occurred at a distance of 1.27 NM from the point of departure, and the aircraft collided with two houses, located in the coordinates 23°33’57”S / 046°15'14"W (Figure 21).

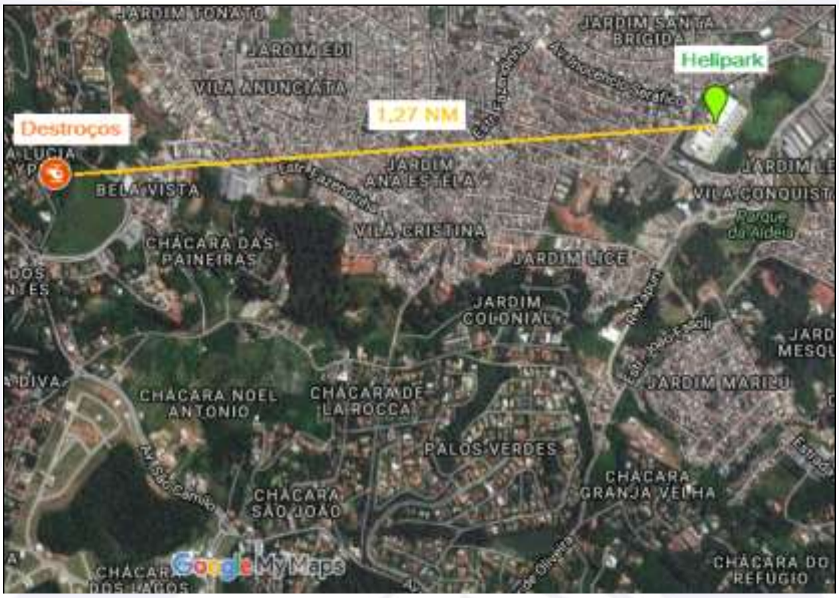


Figure 21 - Distance from the place of departure to the point of impact (Google Maps).

The collision of the aircraft occurred at a steep angle, and in an uncontrolled fashion, according to videos published by the media. The aircraft was destroyed by the impact, and its wreckage remained concentrated in an area of approximately 200 m^2.

The majority of the largest wreckage fragments remained concentrated in the yards of the two residences hit by the aircraft. One of the blades remained attached to the main rotor assembly, and two other ones were found within a radius of approximately 200 meters from the main point of impact. Small fragments were found a few days after the initial action had been completed. On 11 May 2015, SERIPA-4 was informed that a blade was seen nor far from the crash site. The blade was retrieved by investigators and taken to the SERIPA-4 installations. On 19 November 2015, Helipark forwarded the fifth (and last) blade that had been found.

The wreckage characteristics indicated that the impact against the houses had occurred with high energy. There was cabin separation, and detachment of the engine, main rotor, and tail rotor assemblies.

The retractable wheeled landing gear assembly was found in its down and locked position.

1.13 Medical and pathological information.

1.13.1 Medical aspects.

The pilot was neither a smoker, nor addicted to illicit drugs. The autopsy revealed no traces of alcohol in his blood, and his colleagues had never heard him complain about any physical (health) problems.

The pilot’s death was caused by multiple traumas resulting from the wounding action of a contusing agent.

1.13.2 Ergonomic information.

Nil.

1.13.3 Psychological aspects.

The pilot's career had begun more than thirty years before. According to reports, he strived to stay updated in operational terms. He was dedicated to his activities, including his family life, despite occasional absences on account of work duties. He had good relationship in the work environment, and displayed cooperative attitudes.

At the time of the accident, the pilot was in good health, and did not have any complaints related to stress, fatigue, or tiredness, according to interviewees. There was information that he had had adequate rest the night before the day of the accident.

Since 2008, the pilot had been working for the company that owned the aircraft. According to information, his professional profile was not compatible with the type of takeoff observed on the day of the accident.

The passenger onboard the aircraft was a helicopter pilot, and had occupied the left front seat. Despite being a pilot, the referred passenger was not certified in the model of the accident aircraft.

Workmates of the captain said they did not believe that he could have handed over the helicopter flight controls to the passenger sitting on the left front seat. Their perception was based on the captain's high level of professionalism and high sense of responsibility demonstrated throughout his career in aviation.

The mechanic responsible for the provision of the services had already worked for other maintenance companies. He had thirty year of experience in maintenance of aircraft, and was considered by the technical team as a competent detail-oriented professional. According to accounts, the mechanic was living a stable phase of his personal and professional life at the time he provided the maintenance services to the aircraft. The mechanic himself later confirmed such information.

Professionals of the maintenance organization reported that they had a high degree of confidence in the mechanic's performance, since he was known as a technician knowledgeable of the activities related to maintenance (service provision) and inspection (supervision) in that type of aircraft.

According to the very mechanic, he had fully completed the maintenance services, and had been supervised by an experienced inspector. However, no records were found in most of the inspection sheets with respect to acceptance of the services provided.

The supervision and acceptance of the tasks performed by the mechanic were the responsibility of the maintenance inspector. The inspector designated for monitoring the job being done by the mechanic had worked for Helipark since its foundation, and had started his career in the company as an assistant-mechanic. He was seen by his fellow workers as a responsible professional, who was also a very sociable and caring person.

In the last maintenance ground-running (accident flight) of the aircraft, the inspector (supervisor) also worked as a provider of balancing services, since the mechanic had been designated for the provision of maintenance services to another aircraft.

1.14 Fire.

No signs of either in-flight or post-impact fire.

1.15 Survival aspects.

Nil.

1.16 Tests and research.

The aircraft wreckage was examined in the premises of the *São Paulo* Park of Aeronautical Material (PAMA-SP) between 27 and 30 April 2015. Representatives of Turbomeca (Safran Helicopter Engines), Helibras, Airbus Helicopter, *São Paulo* State Civil Police, *São Paulo* State Institute of Forensic Science, Seripatri, and BEA participated in the activities.

-<u>Engines</u>

In the field investigation during the initial action following the accident, the engines were found separated from the fuselage in different rooms of a house (Figure 22).

Figure 22 - Location of the engines after the impact.

The Arriel 2C2 is a turbine engine with a single-stage axial compressor, a single-stage centrifugal compressor, an annular combustion-chamber, a single-stage high-pressure turbine, and a reduction gearbox with nominal power of 6,000 RPM (Figure 23).

The engine has the following dimensions: 1,166 mm of length; 465.5 mm of width; 609 mm of height, and a weight of 130 kg. The ignition system is of the low-tension type, including a high-energy generator, two injectors, and two ignition devices.

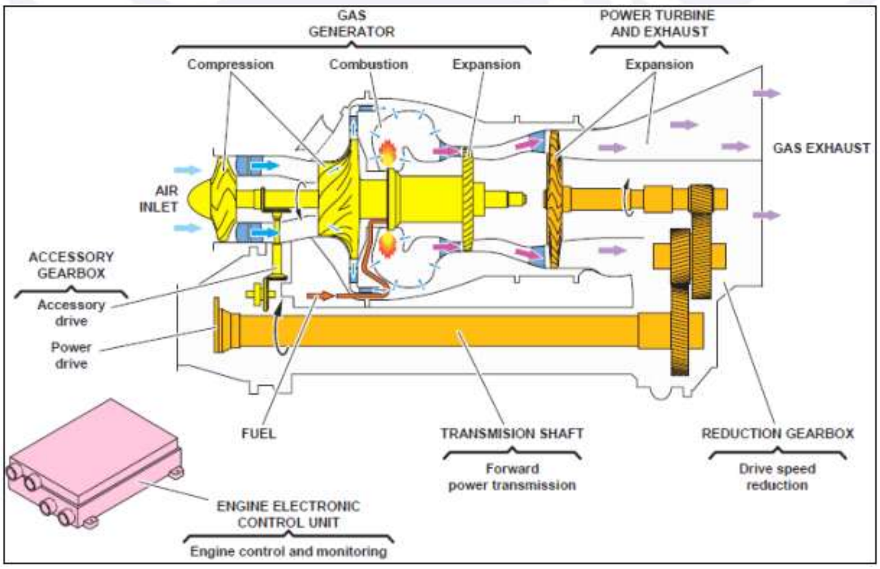


Figure 23 - Schematic view of the engine. (Eurocopter (Airbus Helicopters) THM).

The Arriel 2C2 engine is composed of five modules (Figure 24).

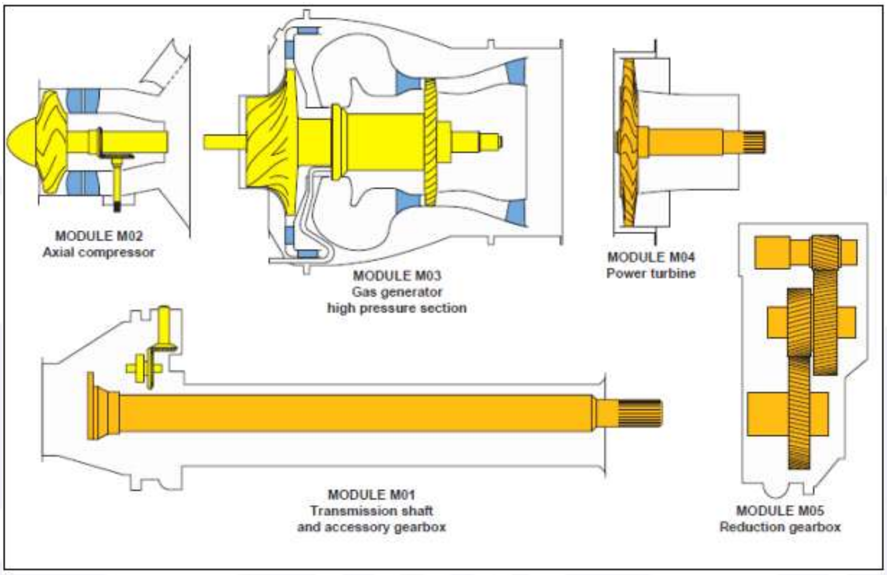


Figure 24 - Modules of the ARRIEL 2C2 engine.

Figure 25 - Engines prepared for analysis.

Before the engines began to be disassembled, there was a visual verification and manual check for the presence of external damage, integrity of the cablings, and attachment of the connections. All the pneumatic lines were confirmed to be connected and with correct torque.

All the magnetic detectors in the lubrication system of the engines were inspected. No metal particles were observed in any of the magnetic detectors (module 1, module 5, and general detector of the system) (Figure 26).

Figure 26 - Detectors and oil filter of the engine SN 26194.

In the inspection of the number-2 module on both engines, severe damage was observed to the blades of the axial stage of the compressors. Fragments of metal and non-metal material were found in the interior of engine diffusers. Such material had been ingested at the impact with the ground. These pieces of evidence indicated that, at the moment of the impact against the ground, the compressors were rotating at high speed.

In the number-3 module of both engines, the inspection revealed a large amount of material ingested at the impact, which had remained inside the combustion chambers. The erosion caused by the particles that collided with the leading edges of the stator blades and rotor of the compressors' turbine indicated normal operation of the engine at the moment of the accident.

The inspection of the number-5 module on both engines showed misalignment between the entry pinion and its shaft. Such misalignment was an indication that the engine was operating normally and developing power when it sustained an abrupt stop.

During the entire work of inspection and analysis, nothing was found that could have caused malfunctioning of the engines. The exams showed that, at the moment of impact, the engines were functioning normally and developing power.

Main Gear Box (MGB)

In the initial action after the accident, the MGB was found separated from the fuselage, in a room of one of the houses hit by the aircraft (Figure 27).

Figure 27 - View of the MGB impact on the roof and inside the room.

The MGB of the aircraft was also disassembled for being inspected (Fig. 28).

Figure 28 - View of the Main Gear Box (MGB).

When examined, all planetary gears, together with the solar gear, presented characteristics of normal operation. No filings were found in the oil-return screens. The bearings were rotated manually, and responded accordingly. No anomalies were found either in the lubrication pre-obstruction indicator, or in the detector of fillings.

The exams showed that, at the moment of the impact, the MGB was operating normally.

Bars for MGB attachment to the fuselage

The MGB was attached to the aircraft structure by means of four bars connected to four supports on the MGB deck.

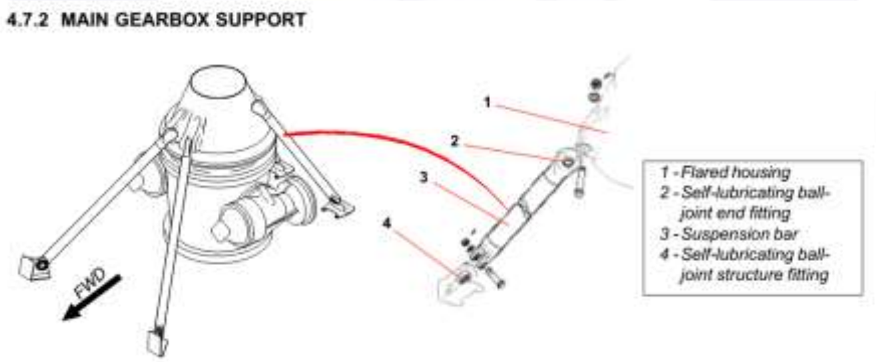


Figure 29 - Bars for MGB attachment to the fuselage. (Eurocopter (Airbus Helicopters) THM).

Fractures due to overload were observed in the bars for MGB attachment to the aircraft.

Figure 30 - MGB attachment bars.

One of the bars was not connected to the attachment support (yellow arrow in Figure 31), but there was evidence of connection, and presence of the bolt at the moment of impact. This was characterized by the marks left by the bolt thread (Figure 32), and by the ovalization and deformation due to opening at the end of the attachment bar (Figure 33).

Figure 31 - Attachment bars (red arrows) and attachment support (yellow arrow).

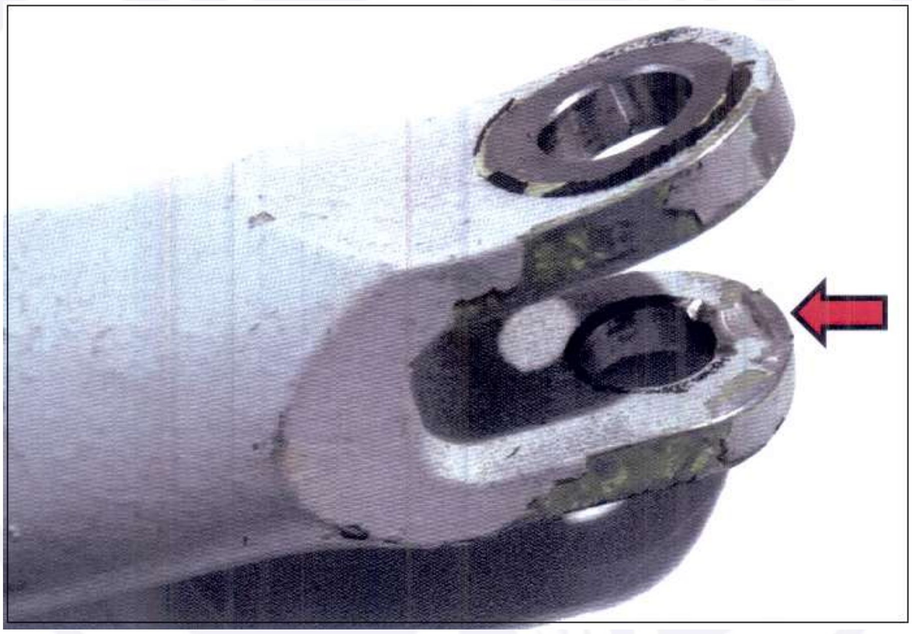


Figure 32 - Marks of impression due to contact with another body.

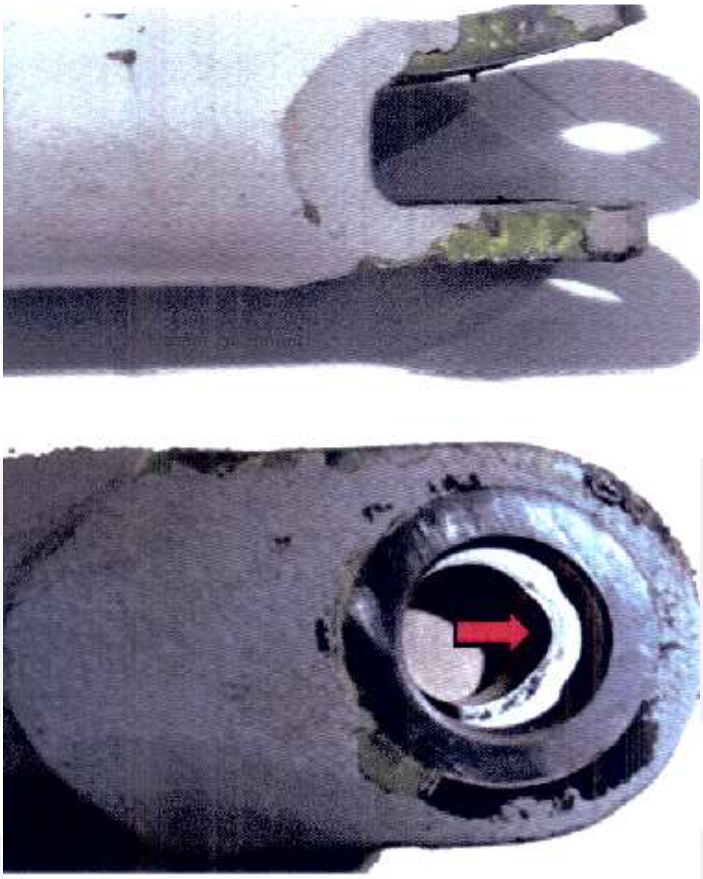


Figure 33 - Ovalization and deformation due to overload during opening effort at the end of the bar.

The factures found in the MGB attachment-bars are compatible with failure on account of overload caused by the fall and impact with the structures on the ground.

- Fuel and hydraulic fluid

At the initial action after the accident, investigators were able to collect samples of fuel and hydraulic fluid only from the aircraft drains.

The collected samples were submitted to laboratory analysis.

The result of the analysis showed that the samples were within the parameters established by the National Petroleum Agency and international organizations.

- Fuel:

ENSAIO	Especificado pelo Regulamento Técnico ANP nº 6/2009	AMOSTRA QAV ANV PP-LLS
6.1.1 Aspecto – Visual	(*)	(**)
6.1.2 Ponto de Fulgor TAG (°C)	40 (mín)	52 ± 1
6.1.3 Massa Específica a 20 °C (kg/m³)	771,3 a 836,6	802,5 ± 0,1
6.1.4 Corrosividade ao Cobre	1 (máx)	1
6.1.5 Destilação		
Ponto Inicial de Ebulição (P.I.E.) (°C)	anotar	149,7 ± 0,9
10 % evaporado (°C)	205 (máx)	177,0 ± 1,0
50 % evaporado (°C)	anotar	200,1 ± 0,8
90 % evaporado (oC)	anotar	229,9 ± 0,8
Ponto Final de Ebulição (P.F.E.) (°C)	300 (máx)	248,5 ± 0,8
Resíduo (% volume)	1,5 (máx)	1,0 ± 0,5
Perda (% volume)	1,5 (máx)	0,5 ± 0,5

Figure 34 - Results found in the sample of fuel.

- Hydraulic fluid:

PROPRIEDADE	Especificado pela MIL-PRF-83282D	AMOSTRA FLUIDO HIDRÁULICO ANV PP-LLS
6.2.1.1 Viscosidade cinemática a 40 °C (mm^2/s) ou (cSt)	14,0 (min)	15,9 ± 0,1
6.2.1.2 Viscosidade cinemática a 100 °C (mm^2/s) ou (cSt)	3,45 (min)	4,12 ± 0,08
6.1.2 Densidade relativa 15,6 °C / 15,6 °C	anotar	0,8508 ± 0,0001
6.1.3 Ponto de fulgor (°C)	205 (min)	224 ± 2
6.1.4. Ponto de combustão (°C)	245 (min)	243 ± 2

Figure 35 - Results from the hydraulic fluid test.

- <u>(Fenestron-type) Tail Rotor</u>

The tail rotor was found on the roof of one the houses hit by the aircraft (Figure 36).

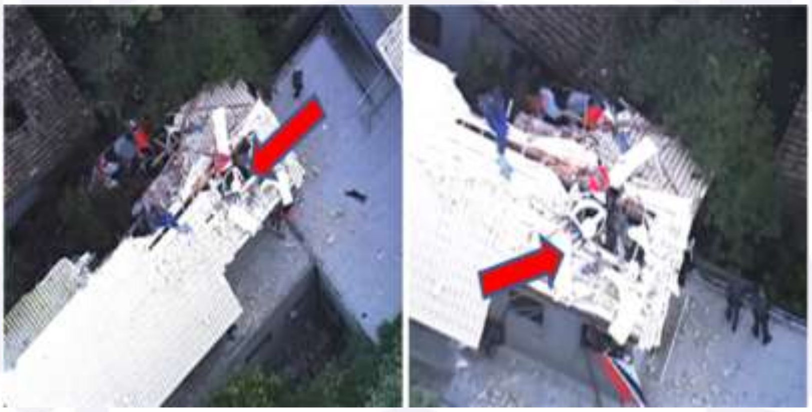


Figure 36 - Spot where the tail rotor was found.

In the interior of the Fenestron cowl, there were marks of rubbing and perforations with small cutting size made by the blades of the component. Friction-generated wear was also observed on the tips of some of the tail rotor blades which did not break.

The broken blades presented folding in the normal direction of movement, with signs of bending on account of overload. The number of broken blades and the damage characteristics were an indication that there was little or no power in the tail rotor at the moment of impact (Figure 37).

Figure 37 - Fenestron damage and marks.

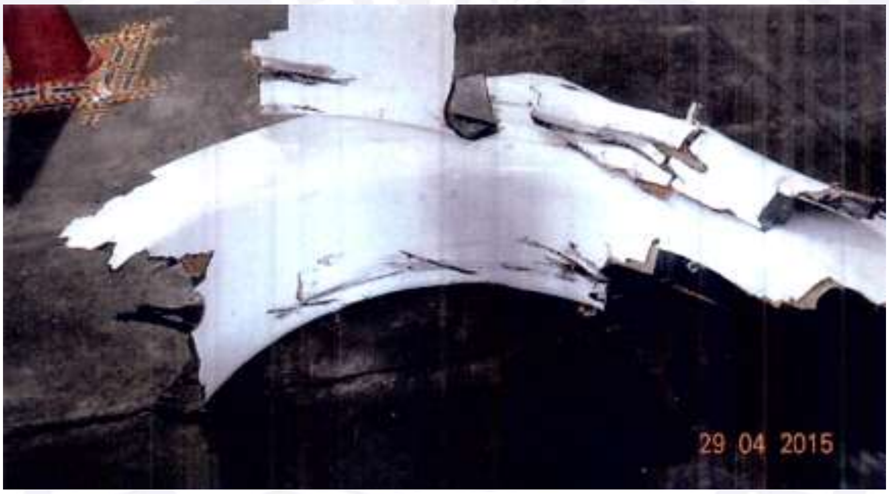


Figure 38 - Damage to the internal protection of the Fenestron.

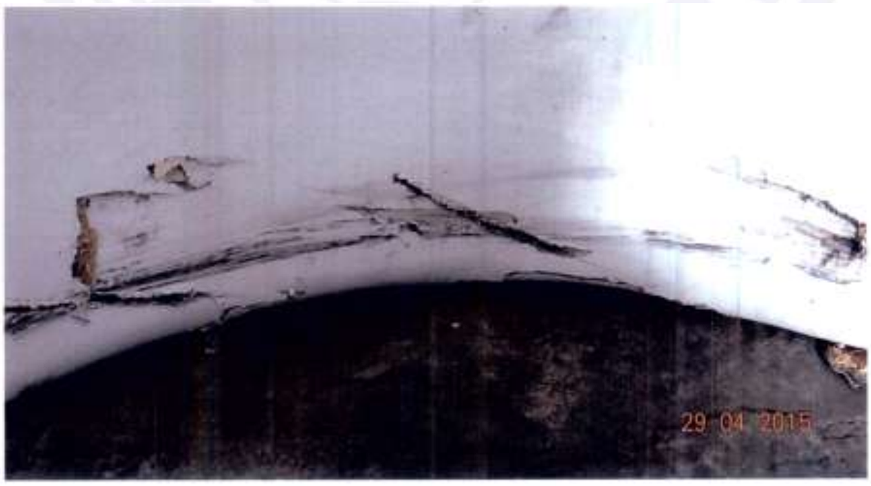


Figure 39 - Detail of penetration and cutting marks left by the tail rotor blades.

Figure 40 - Detail of the blades fractured by overload-induced flexion.

- Tail rotor driveshaft

In the field investigation at the initial action, the tail rotor driveshaft was found attached to the fuselage in its original position (Figure 41).

Figure 41 - Detail of the tail rotor driveshaft attached to the fuselage.

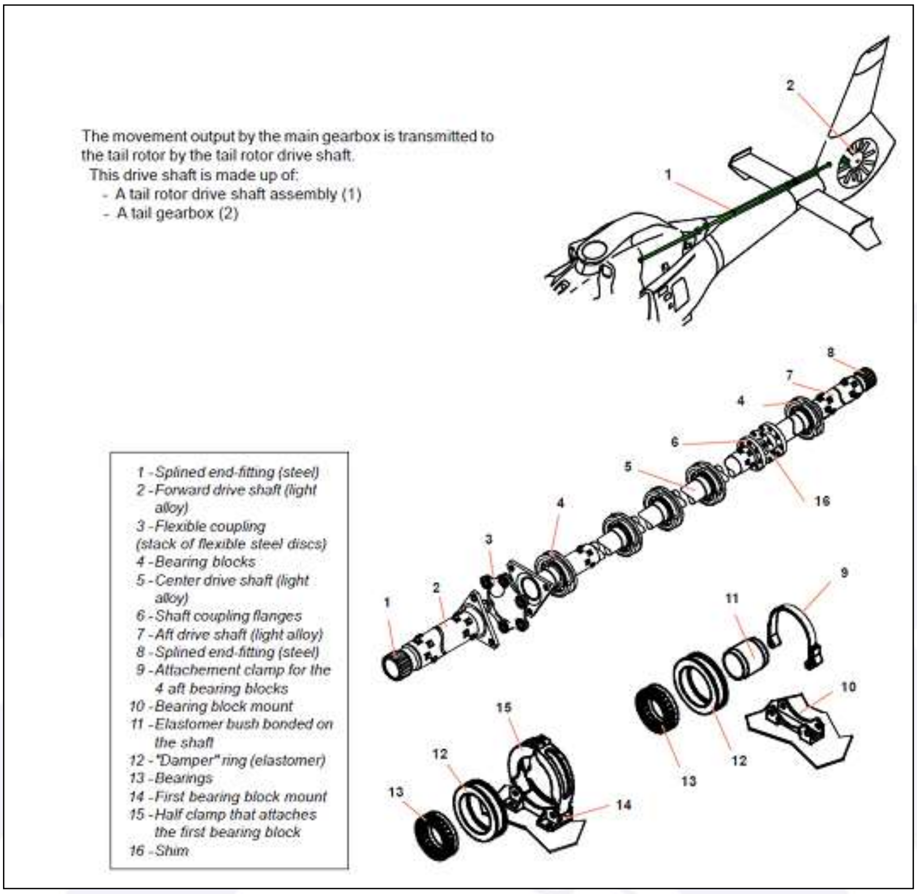


Figure 42 - Schematic representation of the tail rotor driveshaft (Eurocopter (Airbus Helicopters) THM).

The analysis revealed buckling of the shaft due to compression efforts (Figure 43).

Figure 43 - Tail rotor driveshaft, showing details of the buckling.

Some damage was found in the flexible couplings, but only little damage caused by abrasion in rotation.

The characteristics of the damage observed in tail rotor driveshaft indicated that the component was developing either little or no rotational movement at the moment of impact.

- <u>Main rotor assembly</u>

The main rotor assembly is composed of five blades. In order to facilitate the activities of maintenance, the blades are usually identified by means of adhesive tapes with reference colors. In the accident aircraft, the main rotor blades had been identified in the following manner:

S/N 2176 - white;

S/N 2175 - black;

S/N 2168 - red;

S/N 2164 - yellow; and

S/N 2167 - blue.

The roots of the five blades were found connected to their respective blade grips, close to the head of the main rotor and MGB. The white blade was the only one found connected to the main rotor head (Figure 44 A).

Figure 44 - View of the main rotor assembly, first in the crash site and later in the hangar (from different perspectives).

Two of the blades (namely, the red and the blue ones) were found at a distance of approximately two hundred meters from the point of main wreckage concentration (Figure 45).

Figure 45 - Location where the first blades were found (Google Maps).

On 11 May 2015, Helipark informed SERIPA-4 that the yellow blade had been located. Investigators were sent to retrieve the blade from the top of a 15m-tall tree.

In mid-November 2015, Helipark informed the CENIPA that the black blade had been found. The blade was collected and taken to the premises of the company, without previous authorization from the investigating committee. Thus, it was not possible to determine the exact location where the blade was found and the period of time during which the component remained with Helipark.

The exam of all the blade roots showed that the fractures observed were compatible with failure resulting from overload.

The exam of the red, blue, and white blades indicated that the damage found was caused by the impact or overload associated with the crash. Neither delamination nor detachment resulting from processing errors, nor even bubbles, were found that could be an indication of problems in the manufacture or repair of those blades. It was not possible to identify damage or defects that could have existed prior to the accident.

The exam of the yellow blade did not reveal the presence of bubbles on the surface that could have resulted from delamination or from detachment of the composite layers. No previous damage or a kind of damage that could have led to the accident was found, such as cracks, detachment, or delamination. The investigators observed that the leading edge of the blade remained composed, although showing signs of damage resulting from the crash. The damage to the yellow blade resulted from the accident, mostly due to impact and overload.

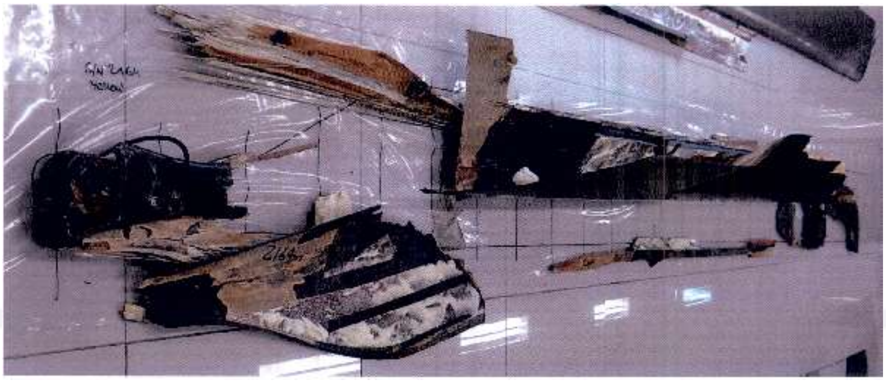


Figure 46 - Aspect of the yellow blade.

The exam of the black blade did not reveal either delamination or detachment resulting from processing errors, or even bubbles which might indicate problems in the manufacture or repair of the blade.

Damage was observed to the blade trailing edge, but there was no significant loss of internal material in the area of the damage, and it was possible to perceive the peaks and valleys of the failure. There was evidence that the damage to the trailing edge had occurred when the blade got fractured and separated.

It was not possible to identify whether any damage or defects were present in the black blade prior to the accident.

Figure 47 - View of the black blade.

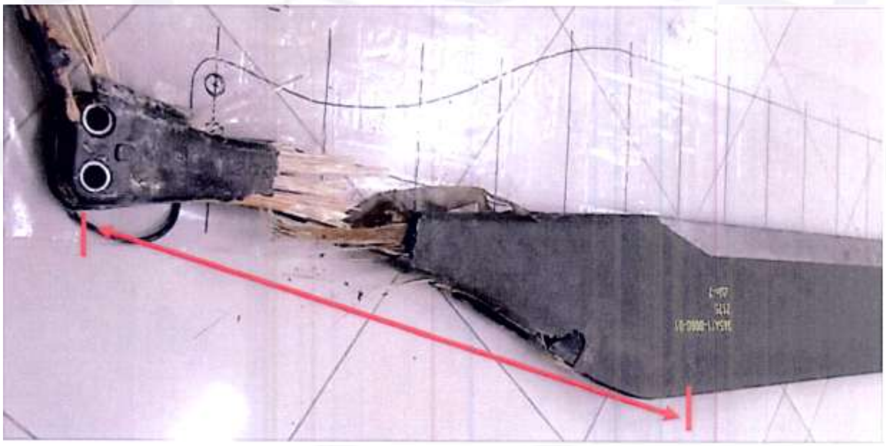


Figure 48 - Aspect of the damage to the trailing edge.

- <u>Flexible components of the flight controls</u>

The flexible components of the flight controls (Figure 49, items 16, 17, and 28) were found amid the aircraft fuselage wreckage.

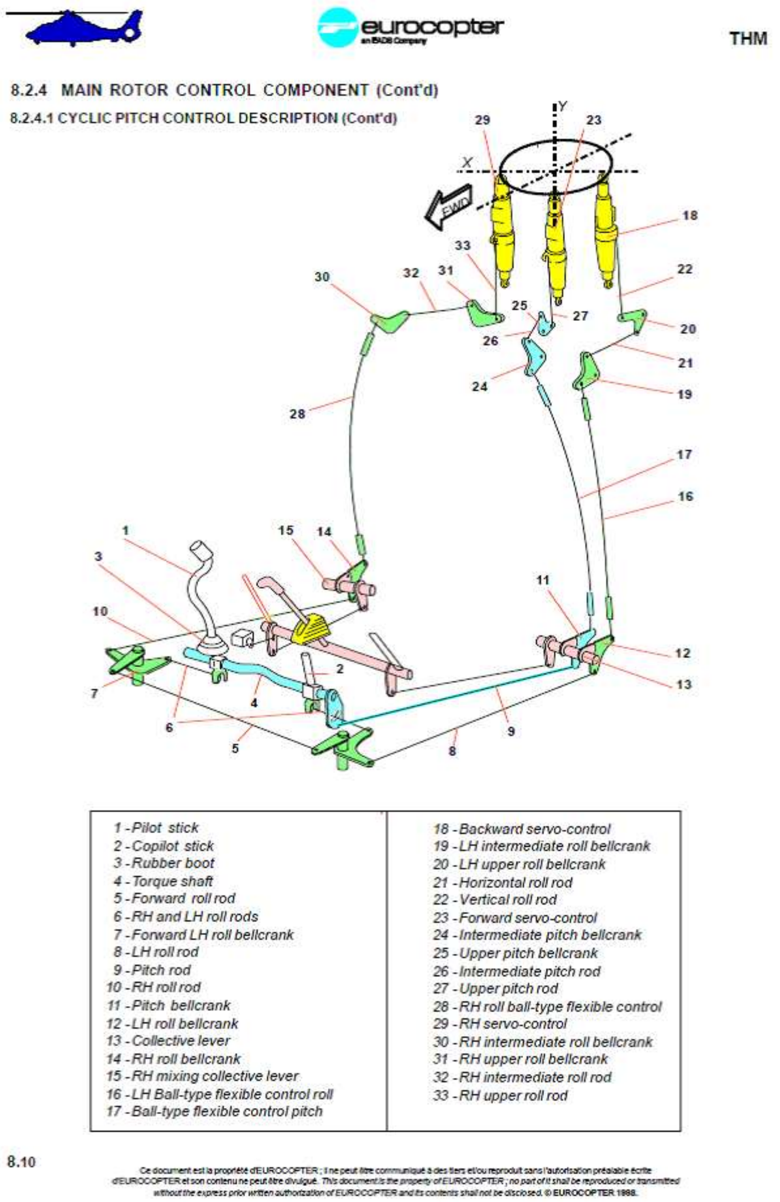


Figure 49 - Schematic representation of the flight control lines (Eurocopter (Airbus Helicopters) THM).

On the left side of the fuselage, investigators observed that the LH Ball-type flexible control roll (item 16 of Figure 49) and the Ball-type flexible control pitch (item 17 of Figure 49) were connected to the LH roll bellcrank (item 12 of Figure 49) and to the Pitch bellcrank (item 11 of Figure 49), respectively, by means of bolts, washers, nuts, and cotter pins. In other words, the fastening of these components was in accordance with the prescriptions of the manufacturer's manuals.

Figure 50 - LH Ball-Type flexible control roll and Ball-type flexible control pitch, LH roll bellcrank and Pitch bellcrank, as found in the wreckage. The red arrows indicate the cotter pins.

The end fittings of the flexible controls are covered with a layer of polymeric tape. There was neither damage nor wear to the polymeric tape on the external part of the end fittings of either the ball-type flexible control on the left side of the aircraft.

On the right hand side of the fuselage, the investigators observed that the RH roll ball-type flexible control (item 28 of Figure 49) was found not connected to the RH roll crank (item 14 of Figure 49). Figure 51 shows the general condition of this component, as observed during the analysis of the wreckage.

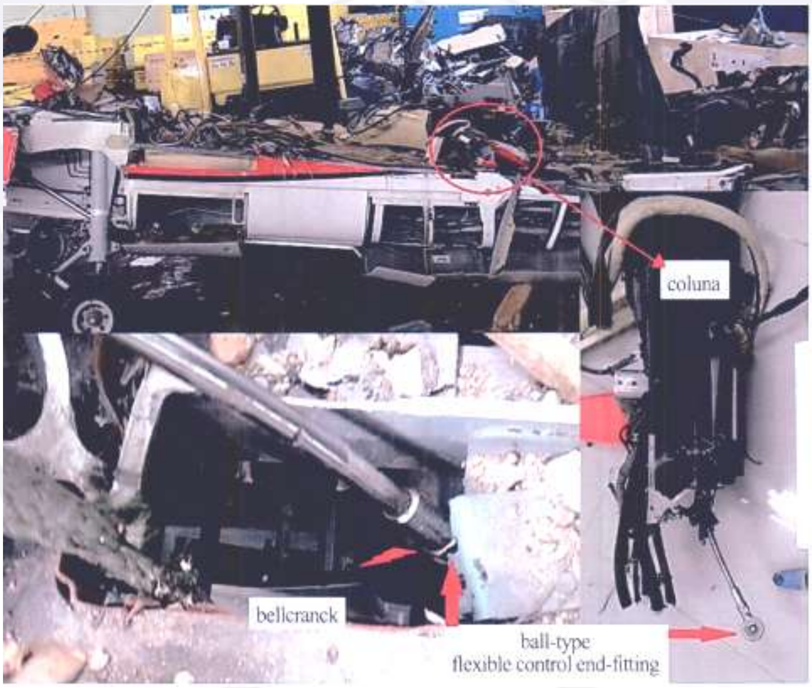


Figure 51 - Location and general condition of the RH roll ball-type flexible control and RH roll bellcrank.

The attachment of the flexible controls to the bellcranks is done in the same way, both on the left and right sides, by means of bolts, washers, nuts, and cotter pins.

As for the attachment of the components on the right-hand side, the investigators observed that, unlike the left side connections, the RH roll ball-type flexible control was found not connected from the RH roll bellcrank.

The bolt that was supposed to be fastening the right-hand side components was found intact, and lodged in the RH roll bellcrank, with its washer, and with the nut only partially screwed around the bolt thread, without application of torque, and without residues of anti-corrosion paste (CM 518 anti-corrosion agent). The bellcrank structure was intact. The RH roll ball-type flexible control was found not connected from the bolt - RH roll bellcrank assembly, as shown in pictures 52, 53, and 54. The cotter pin was not found.

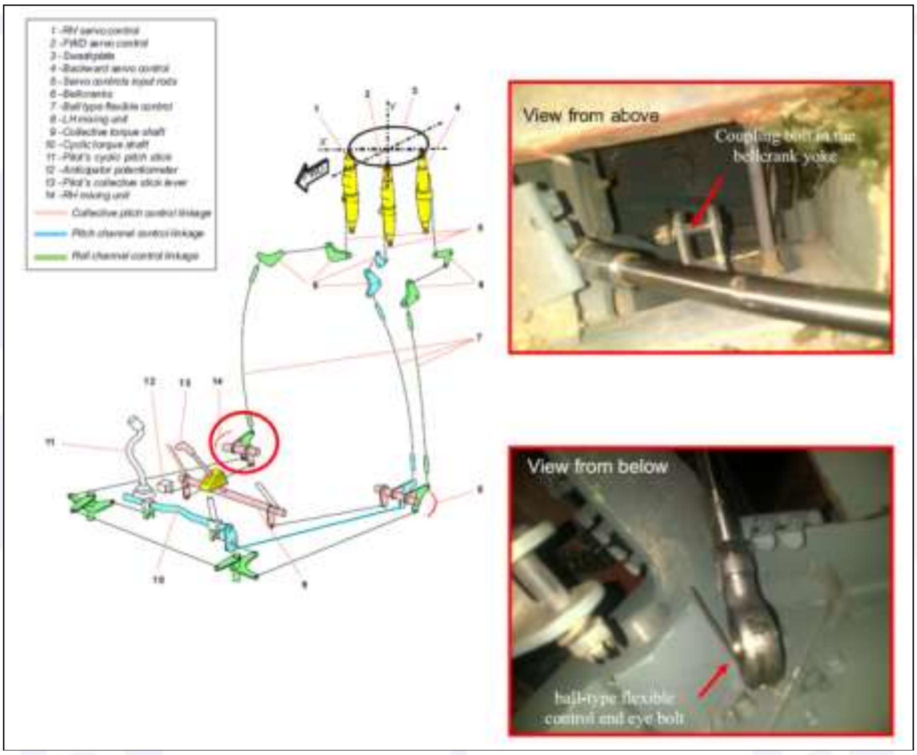


Figure 52 - Location and detailed view of the RH roll ball-type flexible control disconnected from the RH roll bellcrank.

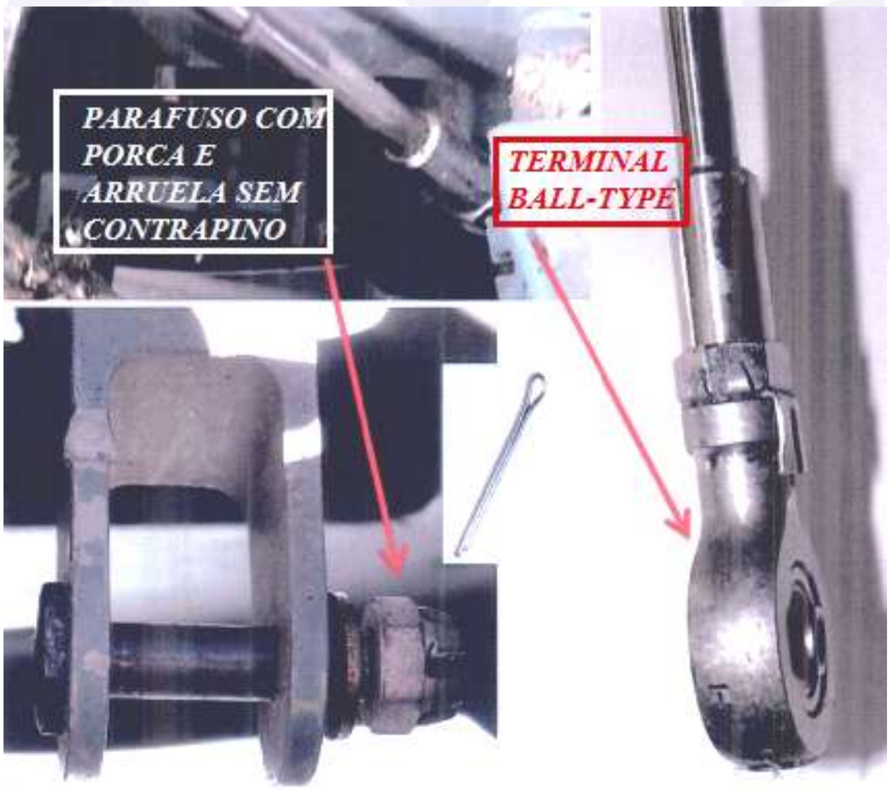


Figure 53 - RH roll ball-type flexible control and RH roll bellcrank as seen during the analysis of the wreckage.

Figure 54 - RH roll ball-type flexible control and RH roll bellcrank found disconnected and without the cotter pin.

In the exams, it was possible to observe the wear of the polymeric tape in the external part of the RH Ball-type flexible control end-fitting. The observed damage to the polymeric tape and the wear of the body of the bolt corroborated with the observation that the RH Ball-type flexible control was not connected with the RH roll bellcrank.

Figure 55 and Figure 56 show the wear of the polymeric tape on the end-fitting of the RH roll ball-type flexible control.

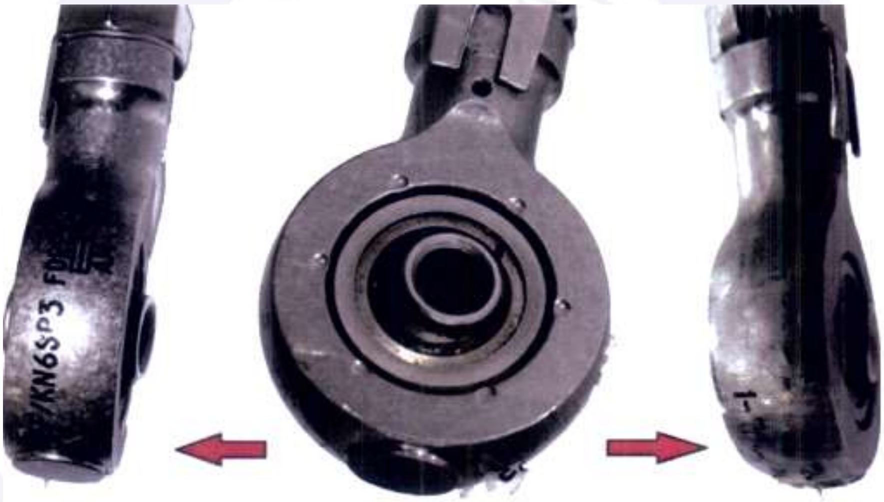


Figure 55 - End fitting of the RH roll ball-type flexible control. On the left, the arrow shows the part of the end-fitting without wear. On the right, the picture shows the part of the end-fitting with wear of the polymeric tape.

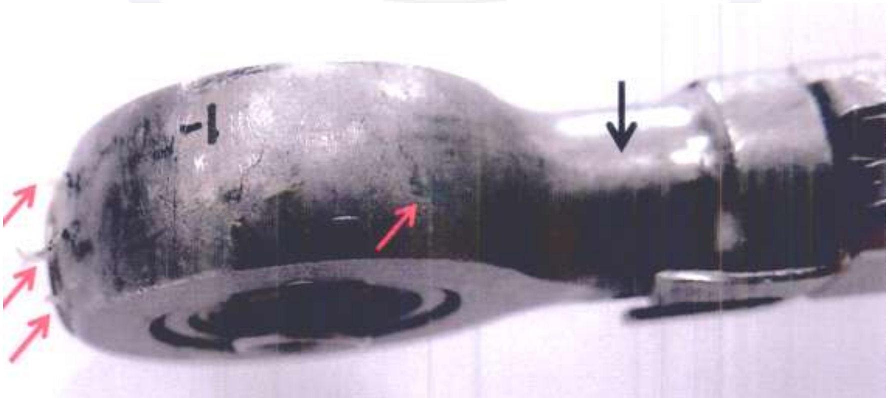


Figure 56 - Marks of friction on the end-fitting of the *RH roll ball-type flexible control*. Damaged polymeric layer is indicated by the red arrows, together with the area of strongest friction (black arrow).

Therefore, if one considers the wear of the polymeric material, the fact that the bolt was intact in the housing of the RH roll bellcrank, with washers, with a torqueless nut, and without the cotter pin, was an indication that the RH roll ball-type flexible control was not connected to the RH roll bellcrank before the impact.

Airbus Helicopter conducted tests aimed at analyzing the behavior of the RH roll ball-type flexible control and RH roll bellcrank, when disconnected.

The tests were done with the following configuration:

- Aircraft on the ground;
- Without the main rotor blades;
- Main rotor not rotating; and
- External equipment (hydraulic-test bench) for supplying hydraulic pressure to the main rotor servocontrols.

The utilization of the hydraulic-test bench had the objective of supplying the servocontrols with hydraulic pressure so that they had an inflight-like configuration.

The tests were conducted in two distinct positions: with the RH roll ball-type flexible control on top the RH roll bellcrank, and with the RH roll ball-type flexible control under the RH roll bellcrank.

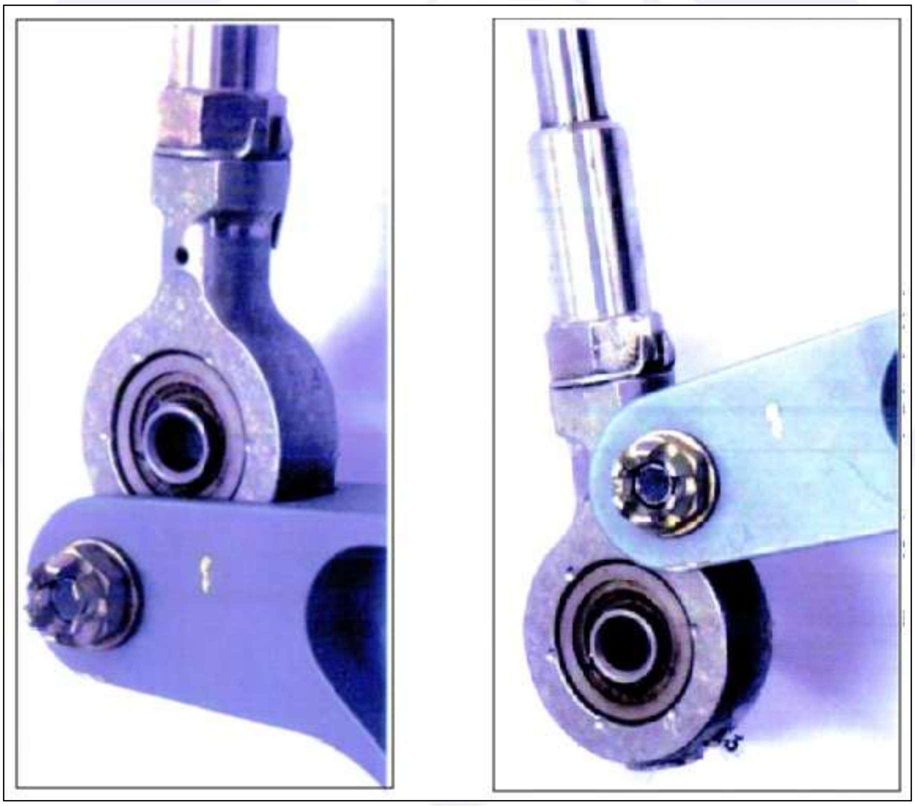


Figure 57 - Positions of the RH roll ball-type flexible control and RH roll bellcrank in the tests.

For the first position (end of the RH roll ball-type control placed on top of the bolt), the tests showed that the flexible control would not follow the movement of the respective bellcrank.

For the second position (end of the RH roll ball-type flexible control placed under the bolt), the test revealed that the flexible control would follow the movement of the respective bellcrank.

Different collective-control positions were tested: collective down (low pitch); collective in the middle (medium pitch); and collective up (high pitch).

For each one of the aforementioned positions of the collective control, the cyclic control was moved laterally.

When the collective control was in the low and medium pitch positions, the end of the RH roll ball-type flexible control remained under the bolt and followed the movements of the respective bellcrank, with a movement that was similar to the one of the corresponding servocontrol. When the collective-control was in the high pitch position, the end of the RH roll ball-type flexible control was seen to start escaping away from its position under the bolt.

1.17 Organizational and management information.

- Aircraft operator

The company operating the aircraft had a board of pilots and aeronautical mechanics dedicated exclusively to the operation of rotary-wing aircraft. The air operation management duties would normally be performed by the pilot and mechanic with the highest experience in their functions. Air movements, flight schedules, and maintenance activities (minor interventions) were carried out by a structure dedicated to the company's air operations.

The process of hiring pilots followed selection criteria, and was coordinated by the company's most senior pilot, aiming at employing technically dependable pilots. The perception of the group in relation to the salaries was that they were satisfactory.

In the work groups, there was an agreeable and cooperative personal relationship, which favored the fluidity of the communication processes, mainly in relation to the planning of the activities, although there was recognition that, for executive aviation, flexibility in planning was often times necessary.

On a regular basis, the operator used to send the aircraft for maintenance services at Helipark in São Paulo, São Paulo State. A pilot or a mechanic was usually designed for monitoring the services provided by the maintenance organization. Such monitoring was just partial and did not represent a formal procedure established by the operator.

The maintenance services provided to PP-LLS by Helipark in the days that preceded the accident were partially monitored by the mechanic responsible for the technical control of the operator's helicopters. The operator also designated a pilot of the company's board of crews for performing the procedures related to the dynamic balancing of the aircraft.

- Aircraft-Maintenance Organization

Helipark *Taxi Aéreo e Manutenção Aeronáutica Ltda*. was a company certified by ANAC, and held the Maintenance Organization Certificate no. 0203-01, issued on 30 January 2015.

The company offered a range of services, such as hangarage, refueling, maintenance, painting, upholstery, and air taxi, as well as exclusive services like, for example, armoring and birdstrike-resistant windshields.

In structural terms, the company had 10 parking spots connected to a 230-meter long and 6-meter wide taxiway. Its helipad was capable of receiving helicopters of up to 12 tons, that is, all the models operating in Brazil.

In relation to the professional formation and training of its personnel, the investigating committee observed that the company required all professionals to be certified for the exercise of their functions, including the one of assistant-mechanic.

The maintenance services provided to the aircraft in the days that preceded the accident were performed by a mechanic who had all the certifications required by ANAC, in addition to specific courses for the provision of services to that model of aircraft. Both the mechanic who did the maintenance services and the instructor who supervised the mechanic's job had the pertinent course related to that aircraft.

Helipark used to establish its own internal processes based on the Maintenance Organization Manual (MOM) and Manual of Quality Assurance (MGQ). The manuals contained the description of the organizational processes to be complied with, from the receipt up to the delivery of the aircraft to the operator.

According to the perception of the work groups, the maintenance company provided them with the technological structure and tools necessary for doing their work, in addition to an appropriate organizational support for the accomplishment of the activities.

In the stages related to the execution of such processes, there was a requirement for both the mechanic and the inspector to document full provision of the service and the supervision of the task performed.

During the investigation of the accident in question, the investigating committee observed that, although there was an inspector designated for supervising the execution of the tasks listed in the Service Order, some of the inspection sheets had not been signed by him.

The fact that the aircraft was scheduled to undergo a maintenance ground-running aimed at dynamic balancing without the signature of the inspector in the pertinent Inspection Sheets was not in accordance with the procedure defined by the company.

However, there were accounts informing that it was common behavior in the company to ignore the correct sequence of signatures in the maintenance documents, as was observed in this case. According to information received, such behavior, although known to the working teams, was not usually notified.

There were no reports of possible pressure from the operator on the maintenance organization demanding expeditious completion of the work.

The investigators observed that, at the time of the accident, it was common for the inspector to be engaged in the inspection of several aircraft at the same time.

Sometimes, inspectors were also required to work as maintenance service providers. In the case in question, besides monitoring and supervising the maintenance services, the inspector also worked as coordinator of the maintenance crew.

During the maintenance ground-running, the inspector (supervisor) began providing dynamic balancing services, because the mechanic that had originally been designated to the job had been sent to do work in another aircraft.

It was also observed that, in the accident flight, there was a person on board not directly involved with the activities and checks being performed in the aircraft. However, according to accounts, it was not possible to affirm whether such situation resulted from a usual behavior within the company.

- <u>Organization responsible for the inspection and repair of the blades</u>

Helibras held the Maintenance Organization Certificate no. 80090-01, issued by ANAC on 30 January 2015.

All the maintenance personnel involved with servicing the blades of the helicopter had the qualifications required by the civil aviation authority, as well as the specialized courses provided by the maintenance company.

The services provided by the maintenance organization comprised inspection and repair of the blades of the PP-LLS aircraft with a deadline set up for 27 March 2015. However, due to the lack of a diluent necessary for the painting process, the programmed deadline was not met, and the blades were delivered only on 1 April 2015.

For purposes of management and control of the maintenance services, the company had organizational processes formally established. Among such processes, there was the obligatoriness on the part of the maintenance and blade-repair workshop to keep pertinent records of the provided services in the AIRBUS Helicopters' BIRDS system.

In addition to these records, the phases of the services provided were registered in internal documents of the organization. In relation to the PP-LLS aircraft, such documents contained the signature and the registration number of the mechanic who performed the tasks, as well as the signature of the inspector responsible for the verification and acceptance of the mentioned tasks.

According to accounts, there was no pressure on the part of either the aircraft operator or Helipark for delivery of the blades, despite the failure of the maintenance organization to meet the prescribed deadline.

1.18 Operational information.

On 2 April 2015, after being provided with several services inside the hangar of the Maintenance Organization, the PP-LLS aircraft was towed to the apron, more precisely to the number-2 parking spot, in order to be submitted to analysis of tail rotor vibration.

The aircraft was refueled with 400.1 liters of aviation kerosene.

At about 13:10 local time, the verification of the tail rotor dynamic balance was initiated, in accordance with the manufacturer's manual. This job lasted approximately until 17:00 local time. When the tail rotor dynamic balance was completed, the main rotor dynamic balancing procedure began.

The main rotor dynamic balancing was done in two phases: hover flight in ground effect (a flight with the rotor operating near the ground at a height that was smaller than the rotor diameter), and forward flight. At the Helipark premises, the phase of verification of vibration during a hover flight was conducted at the helipad. For this reason, it was necessary for the helicopter to taxi on the ground (on its wheels) from the parking spot to the helipad.

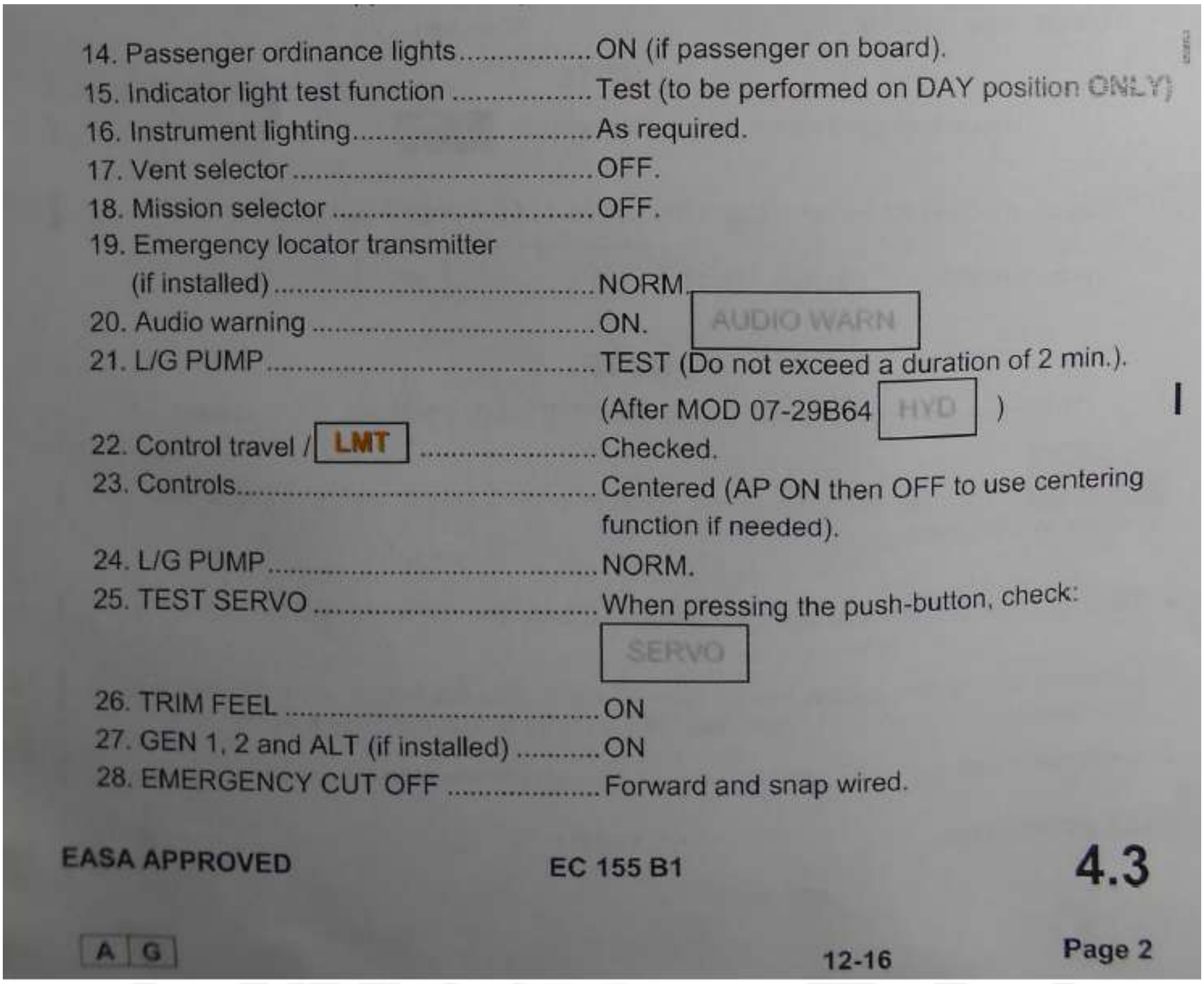
According to the manufacturer's Flight Manual (approved on 30 March 2007 and revised on 25 November 2013), the following topics with their respective procedures had to be performed during the flight up to the moment of the hovering:

1. Pre-Flight Inspections
    a. Exterior Inspection
    b. Interior Inspection
2. Starting Procedures
    a. Pre-Starting Checklist
    b. Engine Starting
    c. Post-Starting Checklist
3. Taxiing – Takeoff

a. Pre-Taxiing Checklist

b. Taxiing - Takeoff

Among the items contemplated in the Flight Manual, the topic number 2, letter “a” (Pre-Starting Checklist) prescribed a verification of the flight controls, as illustrated in Figure 58.



14. Passenger ordinance lights .... ON (if passenger on board).
15. Indicator light test function .... Test (to be performed on DAY position ONLY)
16. Instrument lighting .... As required.
17. Vent selector .... OFF.
18. Mission selector .... OFF.
19. Emergency locator transmitter
    (if installed) .... NORM.
20. Audio warning .... ON. AUDIO WARN
21. L/G PUMP .... TEST (Do not exceed a duration of 2 min.).
    (After MOD 07-29B64 HYD)
22. Control travel / LMT .... Checked.
23. Controls .... Centered (AP ON then OFF to use centering function if needed).
24. L/G PUMP .... NORM.
25. TEST SERVO .... When pressing the push-button, check: SERVO
26. TRIM FEEL .... ON
27. GEN 1, 2 and ALT (if installed) .... ON
28. EMERGENCY CUT OFF .... Forward and snap wired.

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Figure 58 - Portion of the Starting Procedures - Pre-Starting Checklist (EC155B1 Flight Manual).

The item 22 prescribed a verification of the course of the controls and functioning of the “LMT” light.

According to the THM of the EC155B1, the purpose of the Ground Limit Light Operation is to inform the pilot about the excessive effort to which the main rotor hub is submitted due to excessive use of the cyclic while the aircraft is taxiing.

> Ground limit light operation
>
> A cam is fixed at the left end of the pitch shaft. This cam actuates a micro-switch when the pitch control is in a position outside from 20% to 70% area. If the helicopter is on the ground, the micro-switch lights up the "LIMIT" warning on the instrument panel in the cockpit. This is intended to prevent the pilot from overstressing the main rotor hub by excessive cyclic during taxi.

Item 25 prescribed a test related to the illumination of the “SERVO” light.

The topic 3.2 of the flight manual listed a number of specific procedures to be performed during the first flight of the day, including the Test of the Autopilot. The objective of this test was to verify whether the Automatic Flight Control System (AFCS) was operative before takeoff. The test included verification of the in-series and parallel actuators of the AFCS. So, the objective of the test was not to verify the integrity of the connections of the flight controls or the functionality of the main rotor servocontrols.

Video-recordings from security cameras showed that the aircraft raised the tail and inclined to the left, causing the rear right-hand side landing gear to leave the ground. Then, the helicopter became fully airborne, and rotated the tail to the right, moving sideways to the right. In the sequence, the helicopter presented up and down nose oscillations, gaining altitude, and moving away from the Helipark installations.

1.19 Additional information.

From the regulations and norms governing the inspections, one can see that the objective of the basic inspection is to verify the overall condition of the helicopter, by means of detailed verifications for the presence of deformation, fractures, cracks, dents, corrosion, signs of overheating, wear, impacts, etc., in the systems and pieces of equipment.

- Text from the RBAC 145 (145.213) on Inspections done by Inspectors:

  "(a) Every maintenance organization shall inspect any item to which maintenance, preventative maintenance, or alteration services have been provided, as described in the paragraphs (b) and (c) of this section, before releasing the referred item to return to service".

  "(b) Every maintenance organization shall certify, by means of a maintenance release, that the item is airworthy upon completion of the maintenance, preventative maintenance, or alterations services, after:

  the maintenance organization provides service to the item; and

  an inspector inspects the item serviced, and confirms that it is airworthy in relation to the work done."

- Texts from the HELIPARK Maintenance Organization Manual (MOM) on Inspectors' Stamps, Signatures, Supervision and Inspection of Acceptance:

  9.2(b) the designated Inspectors shall make use of specific individualized stamps to indicate acceptance of an item or a particular inspection in the Inspection Sheets. The use of the referred stamp is always followed by the date on which the inspection was done."

  9.2(c) the use of the stamp must be the preferred means for indicating the completion or acceptance of a task in a maintenance document. Nevertheless, the professional may utilize his/her signature instead of the stamp, whenever deemed necessary or convenient. In the latter case, he/she must also provide his/her ANAC code number."

  3.1.8 – Maintenance Inspector: (...)

  3.1.8 (a) Specific duties: (...)

  3.1.8 (b) Possess adequate knowledge of the procedures established in this MOM and MGQ (Manual of Quality Assurance). Perform the procedures and supervise them, in addition to forwarding proposals for refinement to the technical manager when deemed necessary.

  3.1.8 (c) Supervise the provision of services, observing the use of appropriate techniques and tools, together with up-to-date publications."

  3.1.6 – Chief of Inspectors: (...)

  3.1.6 (a) Specific duties (...)

  3.1.6 (e) Exercise the necessary supervision so that all the services provided are adequately inspected and registered in their pertinent documentation, in accordance to the prescriptions of the legislation.

  3.1.3 – Technical Manager (RT):

3.1.3 (a) Specific duties (...)

3.1.3 (d) Supervise the workshop activities, so that the work is done in accordance with the procedures established in this MOM, guaranteeing conformity of the procedures with the requisites set forth by the regulations."

- Texts from the Manual of Quality Assurance (MGQ) on Final Inspections:

6.13.7 – Final Inspection:

6.13.7 (a) Every aircraft or product serviced by Helipark shall be submitted to a Final Inspection by a designated Inspector before receiving approval for return to service.

6.13.7 (e) If an inflight operation check is necessary to complement the inspection, repair, or modification in accordance with the RBHA 91.407, all the documentation must be filled out and updated before the flight, with the exception of the documentation relative to the flight in itself. After completion of the flight, any found discrepancies shall be included in the Service Order (FORM-MGQ(6) – 011), just after the last discrepancy annotated, in order to establish the temporal sequence of the discrepancies which occurred or were otherwise observed.

With respect to the presence of passengers on the flight, the civil Aviation regulations in force established the following:

- Text from the RBHA 91 (91.407):

91.407 - Operation after provision of maintenance, preventative maintenance, refurbishing, repairs, or modifications.

(a) No person is allowed to operate an aircraft that has been provided with maintenance, preventative maintenance, reconditioning, repair, or modification services, unless:

(1) it has been approved for return to service by an authorized person, duly qualified by the DAC, and in accordance with the RBHA 43, section 43.7.

(2) THE RECORDS OF THE MAINTENANCE LOGBOOKS required by the sections 43.9 or 43.11 of the RBHA 43, as applicable, have been entered.

(b) No-one is allowed to transport any person (with the exception of crewmembers) on an aircraft that has been provided with maintenance, reconditioning, repair, or modification services, which may have significantly altered or affected its flight characteristics, or substantially affected its inflight operation, until a pilot duly qualified in the aircraft, and holder of, at least, a private pilot license, flies the aircraft, while performing an operational verification of the services provided, and includes his flight and its result in the aircraft logbooks.

- Text from the MPR 100/SAR Revision 7, item 10.9, letters (e) and (f):

(e) The flight operated under the purposes described in 10.2 (a) (2) and (a) (3) shall always be conducted as a local day-time flight under Visual Flight Rules (VFR) within a Terminal Control Area (TMA) or, if there is not a TMA, within a radius of 100 km, with landing in the aerodrome of departure, with the minimum crew required by the EA, with no cargo or passengers on board, and with valid insurance.

(f) For the purposes of letter (e) above, the term "crew" contained in the paragraph 91.407 (b) of the RBHA/RBAC 91, in addition to the minimum crew for the aircraft to be operated, may include maintenance professionals in the minimum number necessary for the adequate conduction of the test to be done in flight.

The aircraft logbook no. 007 was found amid the wreckage of the PP-LLS aircraft. The last sheet with annotations in the logbook referred to the ferry flight toward the Helipark facilities on 10 February 2015. There were neither records relative to 2 April 2015, date of the accident, nor records referring to aircraft preflight inspection on that same date.

1.20 Useful or effective investigation techniques.

Nil.

2. ANALYSIS.

The PP-LLS aircraft had always belonged to the operator since its date of manufacture, and had 892.7 hours of operation (TSN).

On 10 February 2015, the aircraft was ferried to Helipark for being provided with maintenance services, including the “600 hours / 2 years” airframe inspection. For that purpose, a Service Order (OS 164/15, dated from 11 February 2015) was opened, describing the maintenance actions to be carried out. The Service Order also prescribed that the five blades of the main rotor were to be removed, inspected, repaired, and reinstalled by Helibras.

The Inspection Sheets related to the OS 164/15 listed the tasks to be performed on the occasion of the respective inspections. Among the prescribed tasks, there was the task 67-10-00-224, which contained a detailed description of the items to be complied with in the Main Flexible Ball Controls.

The mechanic responsible for performing the task 67-10-00-224 attested completion of the task by means of his personal stamp. The inspector’s stamp/signature was not present, an indication of failure in the organizational processes of the maintenance company in terms of effective monitoring and control of the services provided.

In light of the foregoing, there is no evidence that the inspector (designated for the acceptance of the task performed by the mechanic) supervised the services provided. The absence of records for attesting the acceptance of the tasks (stamp/signature and date) by the inspector was not in accordance with the RBAC 145.213, and with the MOM and MGQ of the maintenance organization.

Concomitantly with the services provided to the aircraft, the blades were sent to Helibras, which received them on 25 February 2015. The repair and maintenance services included the replacement of the polyurethane on the tips and intrados of the five blades, together with painting, replacement of the polyurethane on the roots, and static balancing.

For completion of the painting services, a diluent would be necessary. On 23 March 2015, the lack of the diluent was detected, leading to the discontinuation of the painting services in progress. After the diluent was received (27 March 2015), the services were resumed, and were completed on 31 March 2015.

Upon completion of the service, Helibras sent the blades to Helipark, which received them on the night of 1 April 2015. On the morning of 2 April 2015, Helipark technicians received the blades, conducted the receipt inspection, and made some necessary adjustments in the tabs. Shortly after, the blades were installed in the aircraft.

With the blades installed, the aircraft was placed on the number-2 parking spot in front of the hangar, and the maintenance ground-running was initiated for dynamic balancing of the tail- and main-rotors.

It is worth pointing out that the last written sheet of the aircraft logbook made reference to the ferry light of the aircraft toward the Helipark facilities. The lack of records related to 2 April 2015 may be an indication that the preflight inspection of the aircraft on the day of the accident was not done.

The time period between the initiation of the balancing job and the moment the aircraft started taxiing was of approximately four hours. In this period, several sessions of maintenance ground-running were executed, with the objective of balancing the tail rotor.

Initially, the activities had the participation of two collaborators of the operating company, as well as three other collaborators of Helipark. On account of other maintenance tasks, the mechanic that was performing the tail rotor balancing activities was called on to work in another aircraft, and moved away from the PP-LLS. From that moment on, one of the Helipark collaborators, who composed the maintenance crew in the role of inspector, began to perform the job of the mechanic, and completed the dynamic balancing of the tail rotor.

Some time later, another person (a helicopter pilot who had no employment bonds with either Helipark or the operator) joined the group that was working in the PP-LLS aircraft, and participated in the activities ever since.

The dynamic balancing of the tail rotor was done with the aircraft on the ground, whereas the dynamic balancing of the main rotor included a hover flight within the ground effect zone and a forward flight.

In such context, the hover flights of aircraft the size of the PP-LLS had to be conducted over the helipad and not over the parking spots. Thus, for doing the balancing of the main rotor, the pilot would have to move the PP-LLS, and taxi it from the number-2 parking spot to the helipad (Figure 59).

Figure 59 - Planned movement from the number-2 parking spot to the helipad.

During the investigation process, the investigators verified that the tail rotor dynamic balancing had been completed. Thus, the procedures for the dynamic balancing of the main rotor were initiated at about 17:00 local time.

The Helipark security cameras recorded the moment at which the persons boarded the aircraft. The captain took the right front seat, and the other person (the helicopter pilot that joined the group) took the left front seat. The maintenance inspector (who took over the dynamic balancing tasks) and the assistant-mechanic occupied the passenger cabin, accompanied by the mechanic that was representing the operator.

In accordance with the provisions of the RBHA 91.407, the person that was occupying the left front seat (normally reserved for the copilot) was not supposed to be on board. Despite being a helicopter pilot, this passenger was not certified in the type of aircraft, and did not belong either to the operator's board of pilots or to the maintenance organization.

Nevertheless, the MPR 100/SAR stated that the term “crew” contained in the paragraph 91.407 (b) of the RBHA 91, in addition to the minimum crew required for the aircraft to operated, could include maintenance professionals in the minimum number necessary for the proper conduction of the test to be done in flight. Such remark could be applied to the other maintenance professionals onboard the aircraft (the mechanic representing the operator and the maintenance assistant).

For performing the dynamic balancing of the main rotor, it was necessary to move the aircraft to the helipad, as mentioned earlier. The security cameras recorded images of the aircraft starting up the engines, and, then, initiating ground taxiing towards the helipad.

The images showed the aircraft performing an unusual movement at the beginning of the taxi. It raised the tail section and inclined to the left, causing the rear gear to lose contact with the ground. In the sequence, the helicopter lifted off the ground, and turned its tail to the right, moving sideways to the right. Then, it displayed up and down nose oscillations, and gained height, moving away from the Helipark installations.

From that moment on, it was not possible to accurately determine the aircraft trajectory toward the crash site, as well as the exact time the aircraft remained in the air. Security camera images showed the aircraft out of control, with some of the main rotor blades separating in flight. Then, the helicopter collided with residences in a gated community.

The aircraft wreckage was submitted to tests and research aimed at determining whether the aircraft systems and components were operating properly at the moment of the occurrence.

Exams of the engines revealed that, at the moment of impact, both of them were operating normally, and developing power.

The analysis of the MGB showed that it was functioning normally at the moment of the accident. The fractures observed in the MGB attachment bars were compatible with failure due to overload, caused by the fall and impact with the structures on the ground.

The result of the analysis of the samples of hydraulic fluid and fuel showed that they were within the limits set forth by the ANP and international agencies.

The characteristics of the damage sustained by the Fenestron blades and by the tail rotor driveshaft were an indication that there was little or no rotational movement in those components at the moment of impact.

As aforementioned, some of the main rotor blades separated from the aircraft while it was falling. Such separation affected the balance of the main transmission assembly. With its balance degraded, the main transmission probably reached levels of vibration above the limits to the point of harming the connection between the MGB and the tail rotor driveshaft. With the connection affected the transmission of power from the engines to the tail rotor may have been discontinued, causing the components to hit the ground with little or no rotational energy.

In relation to the main rotor assembly, the investigators observed that the roots of all five blades were found connected to the respective blade-grips close to the main rotor head and MGB. This fact shows that the blades had been installed in the aircraft in a correct manner. Exams of the root of all blades showed that the observed fractures were compatible with failure on account of overload.

As for the painting of the main rotor blades, TYPE 3 painting was utilized for the job. The complete cycle of polymerization for this type of painting was 7 (seven) days in accordance with the chart MTC 20-60-00-433. Considering that the painting services were finished on 31 March 2015, and that the blades were installed in the aircraft on 2 April

2015, the investigating committee concluded that the blades were installed in the aircraft before the end of the seven-day polymerization period.

Upon being consulted about the non-compliance with the seven-day period for full polymerization of the painting, Airbus Helicopter answered that, if the curing cycle applied was the 1-hour/60ºC, the blades could be installed in the aircraft, and the dynamic balancing could be done immediately afterwards. However, the aircraft manual (MTC 20-60-00-433) did not contain any information regarding installation and dynamic balancing of the blades before completion of the prescribed polymerization period.

Still according to Airbus Helicopter, the paint of the accident aircraft main rotor blades was found intact, without signs of paint scaling or separation, meaning that the time elapsed between the painting job and installation of the blades in the aircraft was enough for ensuring their good performance.

Exams of the main rotor blades showed that the damage sustained by them resulted from the accident, mostly due to either impact or overload. There were no signs of previous damage or defects that could have been detrimental to the structure of the blades.

In relation to the flight controls, the investigators observed that the RH roll ball-type flexible control was not found connected to the RH roll bellcrank. A few facts reinforced the conclusion that the end of the RH roll ball-type flexible control was not connected to the RH roll bellcrank before the impact, as listed below:

- the bolt that should have been fastening the components was intact, lodged in the RH roll bellcrank, along with its washer, with the nut partially screwed on its thread, without torque, and without residues of anti-corrosion paste;
- The structure of the RH roll bellcrank was intact;
- The structure of the RH roll ball-type flexible control was intact;
- There was friction-induced wear in the polymeric material, on one of the sides of the RH roll ball-type flexible control; and
- The RH roll ball-type flexible control was not connected to the bolt-RH roll bellcrank assembly.

In light of the aforementioned, the investigators concluded that the RH roll ball-type flexible control was not connected to the RH roll bellcrank before the takeoff of the accident flight.

The fact that the RH roll ball-type flexible control and the RH roll bell crank were found unconnected led the investigators to analyze the maintenance tasks performed to the aircraft before the accident.

The research done by the investigating committee showed that, among the tasks performed at the Helipark facilities, there was one identified as task 67-10-00-224 “Inspection Criteria - Main Rotor Flexible Ball Controls” (Figures 11 through 16).

The task prescribed that the flexible controls had to be disconnected from the respective bellcranks, in accordance with item “c” of the sub-task 67-10-00-224-001 (Figure 13). With the components disconnected, procedures related to inspection, cleaning, and anti-corrosion were to be performed. Finally, the task prescribed that the flexible controls were to be reconnected to the bellcranks, in accordance with the item “j” of the same sub-task (Figure 14). The task 67-10-00-224 also alerted that the task 67-00-00-911 was to be complied with, since it contained detailed specific procedures associated with the care to be taken in the tasks involving the flight controls.

Although the mechanic responsible for performing the task 67-10-00-224 attested its completion, by putting his stamp in the Inspection Sheets, it is possible that, while performing the task, he failed to notice that the end of the RH roll ball-type flexible control remained disconnected from the RH roll bellcrank. Since there were no records attesting acceptance of the task by the inspector, there is no evidence that the services provided by the mechanic were inspected by the maintenance inspector.

As mentioned before, the mechanic that had been doing the dynamic balancing of the tail rotor in the PP-LLS aircraft had to discontinue his job in order to accommodate a request for provision of maintenance to another aircraft. Such fact denotes that the work routine of the maintenance organization professionals was susceptible to interference and discontinuation which could break the sequence of the activities performed.

It is worth pointing out that, in the context of maintenance, such interruptions may favor the occurrence of distraction and suppression of phases during the execution of the activities. A similar situation may have occurred during the period in which the PP-LLS remained under maintenance, mainly during the execution of the task 67-10-00-224.

Adequate monitoring of the maintenance services provided is a critical barrier in terms of aeronautical accidents, since it allows identifying and mitigating the risks resulting from errors made during the execution of the tasks, thus guaranteeing better quality of the services provided.

The lack of records attesting acceptance of the task on the part of the inspector was an indication of the existence of flaws in the processes of monitoring, control, and supervision of the maintenance services provided. The release of the aircraft for the initiation of the procedures related to dynamic balancing of the main and tail rotors without formal acceptance expressed by the inspector was evidence of an unsafe condition (latent failure) in the maintenance organization, which deviated from the processes prescribed in the maintenance manuals. Such deviation of the organization processes probably contributed to the lack of connection between the RH roll ball-type flexible control and the RH roll bellcrank to go unnoticed.

It is worth highlighting that the inspector in charge of monitoring the task was also coordinator of the maintenance crew, besides being responsible for supervising the work being done in other aircraft. He would even contingently do the job of a mechanic in the provision of services. It is possible that such accumulation of functions by the inspector degraded his management of the tasks, lowering his level of attention, and negatively affecting his performance while working as inspector of the maintenance being provided to the PP-LLS aircraft.

Such scenario demonstrated that the organizational culture of the company might favor a context of general acceptance regarding the accumulation of functions, discontinuation of maintenance activities, and lack of pertinent records of the maintenance services provided. In this manner, the organizational culture present in this context allowed the adoption of informal practices that may have weakened the existing operational safety protective barriers.

The fact that the RH roll ball-type flexible control was found disconnected from RH roll bellcrank, made it necessary to evaluate the position of the components, and the influence of their positions on the aircraft flight controls. Thus, two hypotheses were raised in relation to the location occupied by the RH roll ball-type flexible control and RH roll bellcrank.

In the first hypothesis, one considered that the lower part of the RH roll ball-type flexible control end was on top of the bolt for attachment to the RH roll bellcrank. Figure 60 is an illustration of this hypothesis.

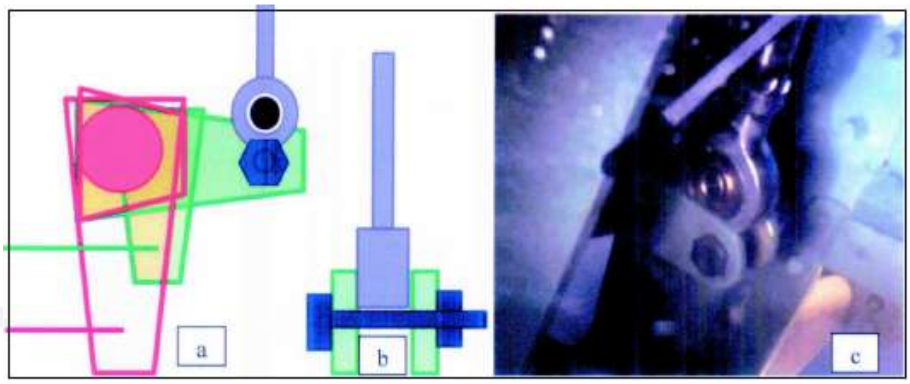

Figure 60 - Simulation of the RH roll ball-type flexible control positioned on top the bolt. a) schematic lateral view; b) schematic frontal view; c) in-perspective view of the components.

In order to make it easier to understand the behavior of the aircraft in the two hypotheses raised, it is necessary to review the functioning of the flight control lines.

As seen before, the functioning of the flight controls is directly linked to the actuation of the bellcranks and ball-type flexible controls (Figures 1, 2, 3, and 4).

The aircraft has three servocontrol, identified as follows: forward servocontrol, right-hand servocontrol, and backward servocontrol. Each servocontrol is controlled by a set composed of a bellcrank and a ball-type flexible control.

After separate analysis of the behavior of the RH roll bellcrank and of the RH roll ball-type flexible control, which compose the control mechanism of the Right Hand servocontrol, it is possible to observe the following behavior in relation to the cyclic and collective controls (Figure 62):

- When the collective control moves upward, the RH roll bellcrank moves in a way that displaces the RH roll ball-type flexible control downward. This movement results in an extension of the RH servocontrol, which moves upward. Such extension, associated with the analogous movement of the two other servocontrols, increases the pitch angle of all the blades in all the sectors of the rotating disk. The opposite is true when the collective control moves downward.
- When the cyclic control is moved to the right, the RH roll bellcrank moves in a way that displaces the RH roll ball-type flexible control upward, resulting in a retraction of the respective servocontrol, making it move downward. Such movement diminishes the pitch angle of all the blades in that sector of the rotating disk, and the helicopter rolls to the right.
- When the cyclic control is moved to the left, the RH roll bellcrank moves in a way that displaces the RH roll ball-type flexible control in a downward direction, resulting in an extension of the respective servocontrol, making it move upward. Such movement augments the pitch angle of the blades in that sector of the rotor disk, and the helicopter inclines to the left.

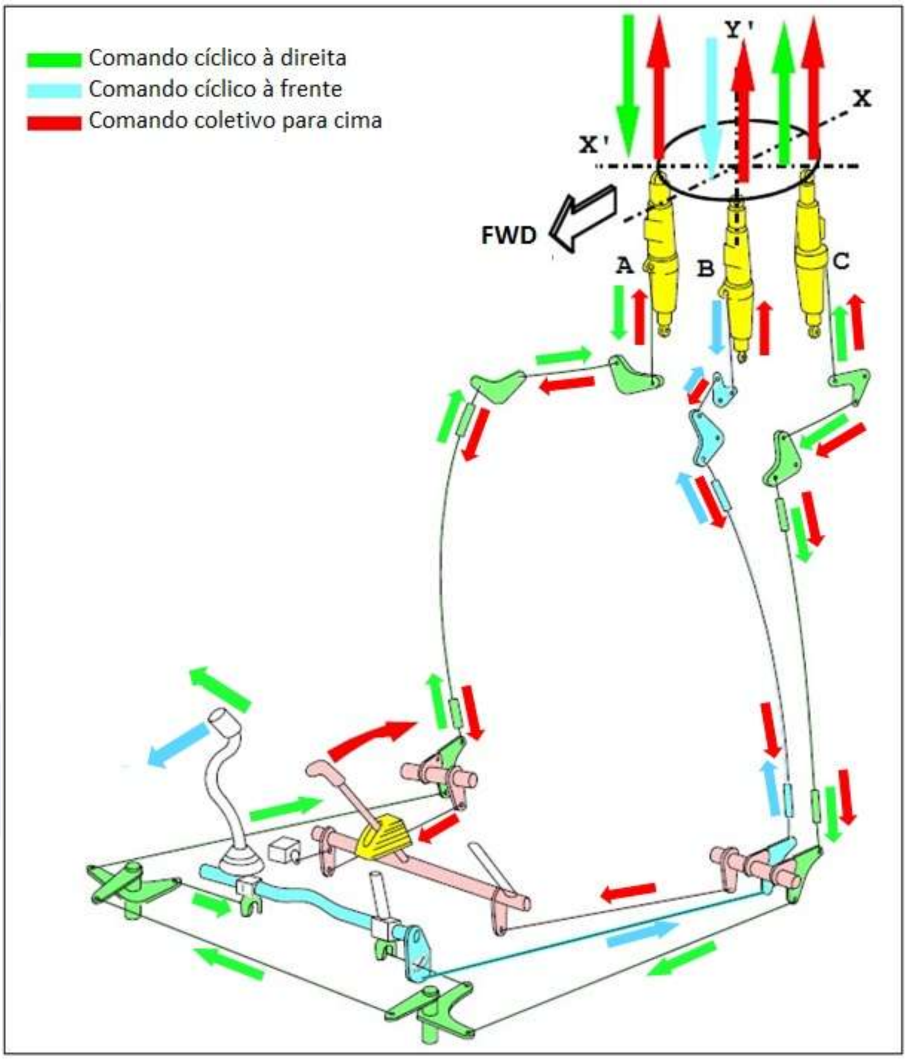

Figure 62 – Schematic representation of the cyclic and collective controls (adapted from the Eurocopter (Airbus Helicopters) THM).

Once the behavior of the components of the RH servocontrol's sequential actuation mechanism is understood, it is possible to analyze both hypotheses: RH roll ball-type flexible control either on top or under the bolt for attachment to the RH roll bellcrank.

In the relation to the first hypothesis, the test conducted by Airbus Helicopter confirmed that, in such situation, the flexible control would not follow the movement of the respective bellcrank. Thus, it would not be possible to control the RH servocontrol. As seen earlier, in order to make the aircraft take off, the three servocontrol would have to work collectively, augmenting the pitch angle of the blades in all sectors of the rotating disk.

The flexible controls of both the Forward and Backward servocontrols were found duly connected amid the wreckage. In such condition, when pulling the collective, two servocontrols (the Forward and Backward ones) would actuate correctly, while the RH servocontrol would not. Thus, the pitch angle of the blades would augment only in the sectors controlled by the forward and backward servocontrols. There would not be pitch angle augmentation in the sector controlled by the RH servocontrol. The aircraft would respond by inclining to the right, since the RH roll ball-type flexible control of the RH servocontrol would be in an unconnected position, supported from above, and would not follow the movement of its respective bellcrank.

The videos showing the aircraft as it started taxiing, also showed that it inclined to the left, counteracting the tendency of inclining to the right, which would be expected for the first hypothesis.

In view of the explained above, the investigating committee ruled out the possibility that the RH roll ball-type flexible control could have been positioned on top of the bolt for attachment to the RH roll bellcrank.

As for the second hypothesis (end of the RH roll ball-type flexible control placed under the bolt in the RH roll bellcrank), the tests conducted by Airbus Helicopter verified that, in such condition, the flexible control would follow the movement of the respective bellcrank. Such position (underneath the bolt) would allow the RH roll ball-type flexible control to be operated. Thus, the inputs made by the pilot would be passed to the RH servocontrol, albeit partially and in a way not congruent with the other servocontrols.

As stated earlier, the flexible controls of the forward and backward servocontrols were found correctly connected amid the wreckage.

The positioning of the RH roll ball-type flexible control under the bolt for attachment to the bellcrank would result in a misalignment of the positions between the servocontrols. Thus, with the cyclic control in NEUTRAL, the RH servocontrol would be determining a pitch angle larger than the one determined by the forward and backward servocontrols. As a result, the pitch angle of the blades would be larger in the sector of the rotor disk controlled by the RH servocontrol.

In such condition, when the collective was pulled, the forward and backward servocontrols would actuate symmetrically, while the RH servocontrol would be actuate in an out-of-phase manner. The RH flexible control would move to a position different from the position of the Forward and Backward servocontrols, and the pitch angle of the blades would be larger in the right-hand sector of the rotor disk. In view of such asymmetry, the expected response of the aircraft would be to incline to the left.

The videos showing the aircraft as it began to taxi, also showed that the helicopter inclined to the left, confirming the expected behavior resulting from the discrepancy of the position of the RH servocontrol in relation to the two other ones. Figure 63 shows the moment at which the helicopter inclined to the left as it started taxiing.

Figure 63 - Helicopter banked to the left at the initiation of the taxi on the ground, with estimated bank angle.

In addition, the observed damage to the polymeric tape on the end of the RH roll ball-type flexible control (Figures 55 and 56) and the wear seen on the bolt ratified that there had been rubbing between that surface and the bolt for attachment to the bellcrank.

While the characteristics of the contact between the flexible control and the bellcrank were maintained, control of the aircraft would be possible in spite of some difficulty, on account of the connection problems between the servocontrols. Should the flexible control escape from its position under the bolt in the bellcrank and contact between the parts ceased, the right-hand side servocontrol would no longer function properly, and would behave in an unpredictable fashion. The foreseeable result would be loss of control of the aircraft.

Since the functioning of the right-hand side servocontrol was considered unpredictable after the flexible control escaped from the bellcrank, it was not possible to determine in detail how the aircraft would behave after such disconnection occurred. However, security camera images showed the aircraft falling with little forward-speed, rotating around its vertical axis, and with parts (including some of the main rotor blades) separating in flight.

In view of the above mentioned, the investigating committee considered the second hypothesis as more likely in relation to the position of the RH roll ball-type control and RH roll bellcrank.

It is worth highlighting that, for both hypotheses, the improper positioning of the flexible control (either under or on top the bolt in the bellcrank) would not be perceptible to the pilot due to the sensation of strength while moving the cyclic and collective controls if one considers the characteristics of irreversibility of the hydraulically-assisted systems.

In an analogous manner, the AFCS would not detect the failure on account of the improper position of the flexible control (either under or on top the bolt in the bellcrank) since the automatic test of the system on the ground just verified the movement of the actuators but not the movement of the servocontrols located at the end of the operating sequence. So, it is likely that the AFCS automatic test on the ground showed a satisfactory result to the pilot, although the components were not connected in a correct manner.

Another aspect evaluated by the investigating committee refers to the aircraft occupants. As aforementioned, there was a passenger (a helicopter pilot, who was not certified in the type of the accident aircraft) taking the left front seat. This fact suggested the possibility that the passenger could be flying the aircraft on account of the unusual behavior of the aircraft at the commencement of the taxiing. However, such behavior was fully compatible with the conditions presented in the second hypothesis.

The evidence found during the investigation was not sufficient for determining which person was, in fact, flying the aircraft. However, considering the fact that the RH roll ball-type flexible control was not connected to the RH roll bellcrank, and also considering the observations presented in the second hypothesis, the investigating committee concluded that the outcome of the occurrence had direct relationship with the incorrect positioning of these components. Therefore, there was no direct relationship between the occurrence of the accident and the possibility that the person occupying the left front seat of the aircraft could be actuating in the aircraft controls.

3. CONCLUSIONS.

3.1 Facts.

a) The pilot held a valid Aeronautical Medical Certificate (CMA);

b) The pilot had a valid Technical Qualification Certificate (CHT);

c) The pilot had qualification and experience for the type of flight;

d) The aircraft had a valid Airworthiness Certificate;

e) The aircraft was within the weight and balance parameters;

f) The airframe, engine, and rotor logbook records were out of date;

g) The aircraft entered the maintenance organization on 11 February 2015 in order to undergo several inspections;

h) The “MEC” column of the Service Order had the signature/stamp of the mechanic for the maintenance tasks performed in the aircraft;

i) The “INSP” column of the Service Order had the signature/stamp of the inspector only for the acceptance of the maintenance tasks related to the aircraft engines;

j) Concomitantly with the inspections of the aircraft, the main rotor blades received repair and painting services in the workshop of the aircraft manufacturer representative in Brazil;

k) The repair and painting services were completed on 31 March 2015;

l) The blades were sent to the pertinent maintenance organization on 1 April 2015;

m) The blades were installed in the aircraft on 2 April 2015;

n) The time required for the full polymerization of the painting of the main rotor blades (seven days) was not complied with;

o) The aircraft logbook had no records related to 2 April 2015;

p) The dynamic balancing procedures were initiated on 2 April 2015;

q) The time-interval between the beginning of the services related to the dynamic balancing of the rotors and the accident flight was approximately four hours;

r) The mechanic that was conducting the activities of dynamic balancing of the tail rotor was called to work in another aircraft;

s) The inspector of the acitivites began to perform the mechanic’s tasks, and finished the dynamic balancing of the tail rotor;

t) There was a passenger (a helicopter pilot not certified in the accident aircraft type) occupying the left front seat of the aircraft in the accident flight;

u) Security cameras recorded the moment at which the aircraft started taxiing, and when it lifted off the ground;

v) The aircraft displayed unusual behavior at the beginning of the taxi;

w) The helicopter gained altitude and moved away from the place of departure;

x) The aircraft collided with residences located at a distance of 1.27 NM from the place of departure;

y) Exams showed that the engines were developing power at the moment of the impact;

z) Analysis of the MGB showed that it was operating normally at the moment of the accident;

aa) Analysis of the hydraulic fluid and fuel had results compatible with the parameters established by the National Petroleum Agency and international bodies;

bb) Analysis of the rotary components of the rear transmission assembly showed that the components impacted the ground with little or no rotational energy;

cc) The roots of all five blades were found connected to the respective blade-grips;

dd) Exams of the roots of the five blades of the main rotor showed that the damage to the roots was a consequence of the accident;

ee) Exams of the five blades of the main rotor showed that the damage observed in all of them resulted from the accident;

ff) Neither damage nor defects anteceding the ones caused by the accident were found that could have affected the structure of the five main-rotor blades;

gg) The RH roll ball-type flexible control was found disconnected from the RH roll bellcrank;

hh) The bolt for attachment of the RH roll ball-type flexible control and the RH roll bellcrank was found lodged in the RH roll bellcrank, with washer, and the nut partially screwed on the bolt thread;

ii) The maintenance tasks listed in the Service Order OS 164/15 included compliance with the task 67-10-00-224 "Inspection Criteria - Main Rotor Flexible Ball Controls";

jj) The task 67-10-00-224 required the flexible controls to be disconnected from the respective bellcranks, and reconnected upon completion of the service;

kk) There were no records attesting acceptance of the task 67-10-00-224 by the inspector;

ll) The prevailing meteorological conditions were favorable for the conduction of the flight;

mm) Security cameras recorded the aircraft on uncontrolled flight moments before the impact;

nn) The aircraft collided with houses located at a distance of 1.27 NM from the point of departure;

oo) The aircraft was destroyed in the crash; and

pp) All aircraft occupants perished in the crash site.

3.2 Contributing factors.

- **Attention - undetermined.**

Although accomplishment of the task 67-10-00-224 has been logged, the end of the RH roll ball-type control remained disconnected from the RH bellcrank. It is possible that, during the time the task was being carried out, the attention of the mechanic was diminished on account of a probable interruption and subsequent focusing on a new maintenance work.

- **Organizational culture - undetermined.**

The lack of compliance with organizational processes related to the monitoring and control of the maintenance activities was recurrent and accepted by the maintenance organization members. Such behavior denoted the existence of a fragile organizational culture as far as acceptable levels of flight safety are concerned. This scenario consisted of an unsafe condition (latent failure) in the organization, which may have contributed to this occurrence, inasmuch as it may have fostered the informality adopted in relation to the organizational processes.

- **Flight indiscipline - a contributor.**

The presence of a passenger onboard the aircraft during the maintenance operational check went against the Brazilian Aeronautical Homologation Regulation. This fact contributed to the aggravation of the consequences of the accident, since it resulted in an increase of the number of fatalities.

- **Aircraft maintenance - a contributor.**

Although accomplishment of the task 67-10-00-224 has been logged, the end of the RH roll ball-type control remained disconnected from the RH bellcrank. The task 67-10-00-224 required the task 67-00-00-911 to be read, as this latter prescribed detailed specific procedures concerning the care to be taken in relation to the tasks involving the flight controls. Full accomplishment of the tasks 67-10-00-224 and 67-00-00-911 would have ruled out the possibility of the RH roll ball-type control to remain disconnected from the RH bellcrank. The inappropriateness of the maintenance services contributed to allowing the “flight control actuators” on the right-hand side of the aircraft to remain unconnected.

- **Work organization - undetermined.**

The work routine of the maintenance organization professionals was susceptible to interference and interruptions leading to discontinuation in the sequence of the activities being carried out. Besides, the work organization was permissive in relation to the accumulation of functions. The difficulties imposed by such context may have affected the performance of the maintenance professionals who serviced the PP-LLS aircraft.

- **Organizational processes - undetermined.**

The absence of the inspector’s signatures/stamps in the Inspection Sheets revealed weaknesses in the organizational processes related to monitoring, control, and supervision of the tasks performed by the mechanic of the maintenance organization. This fact may have contributed to the failure to identify and correct the incongruences in the maintenance services in time to prevent the accident.

- **Managerial oversight - undetermined.**

The absence of records attesting task-acceptance by the inspector denotes the existence of flaws in terms of managerial oversight. Likewise, the, initiation of dynamic balancing, without previous completion of the maintenance tasks, together with Inspection Sheets not signed/stamped by the inspector, reinforces the perception of inadequate managerial oversight. The deviations observed in relation to the compliance with the organizational processes of monitoring and control of the maintenance activities may have contributed to the accident.

4. SAFETY RECOMMENDATION.

A measure of preventative/corrective nature issued by a SIPAER Investigation Authority or by a SIPAER-Link within respective area of jurisdiction, aimed at eliminating or mitigating the risk brought about by either a latent condition or an active failure. It results from the investigation of an aeronautical occurrence or from a preventative action, and shall never be used for purposes of blame presumption or apportion of civil, criminal, or administrative liability.

In consonance with the Law n°7565/1986, recommendations are made solely for the benefit of the air activity operational safety, and shall be treated as established in the NSCA 3-13 “Protocols for the Investigation of Civil Aviation Aeronautical Occurrences conducted by the Brazilian State”.

Recommendations issued prior to the publication of this report:

None.

Recommendations issued at the publication of this report:

To the Brazil's National Civil Aviation Agency (ANAC):

A-050/CENIPA/2015 - 01 **Issued on 04/04/2017**

Take pertinent measures before the operator in order to guarantee the establishment of an effective mechanism for controlling the currency of the records entered in the maintenance logbooks of the company's aircraft.

A-050/CENIPA/2015 - 02 **Issued on 04/04/2017**

Take pertinent measures before the operator in order to guarantee the adoption of operating procedures to curb the operation of flights by its board of pilots when there is no reference to the conduction of preflight inspection in the logbook records of the respective aircraft.

A-050/CENIPA/2015 - 03 **Issued on 04/04/2017**

Take pertinent measures before the operator in order to guarantee the adoption of procedures aimed at forbidding the presence of passengers on operational maintenance check flights in accordance with the legislation in force.

A-050/CENIPA/2015 - 04 **Issued on 04/04/2017**

Take pertinent measures before Helipark with the objective of guaranteeing the adoption of an effective mechanism for controlling the activities performed by the company, especially in relation to the records entered by mechanics and inspectors in the Inspection Sheets for confirmation of the services provided in accordance with the legislation in force.

A-050/CENIPA/2015 - 05 **Issued on 04/04/2017**

Analyze, in conjunction with the manufacturer, the relevance of specifying, by means of appropriate documentation, the requirements for completion of the blade polymerization process in less than seven days.

5. CORRECTIVE OR PREVENTATIVE ACTION ALREADY TAKEN.

On 6 August 2015, Airbus Helicopter issued the Safety Information Notice (SIN) nº 2928-S-00 as a complement of the SIN nº 2247-S-00, dated from 1 December 2010. The document reminded the maintenance personnel concerned that, after the provision of any maintenance services, particularly after a task involving the removal/disconnection of components considered as critical to flight safety, a detailed verification of both the service provided and the reassembly of the components is to be carried out before the aircraft can be released for flight.

On April 04th, 2017.

ANNEX A

COMMENTS BY THE BEA NOT INCLUDED IN THE FINAL REPORT

Below, there is a list of all the comments forwarded by the *Bureau d'Enquête et d'Analyses pour la Sécurité de L'Aviation Civile* which were not included in this Final Report wording.

- **COMMENT 1**

Regarding the following portion of the item "1.12 - Wreckage and impact information."

"One of the blades remained attached to the main rotor assembly, and two other ones were found within a radius of approximately 200 meters from the main point of impact."

Text proposed by BEA

The main Rotor Blades were still attached to the Main Rotor Head by their blade pins and the blade roots.

BEA´s comment

This description needs to be reformulated to indicate this important information and detail that the blades are broken in different area of their length but they were all connected to the Main Rotor Head by their root and blade pins.

CENIPA´s comment

The information that the roots of the five blades were found connected to their respective blade grips close to the Main Rotor Head and the Main Gear Box is clear on page 45, as part of item "1.16 - Tests and research - Main Rotor Assembly". The same information is detailed explained on page 61, as part of item "2 - Analysis".

- **COMMENTS 2, 3, 4 and 5**

Regarding the following portion of the item "1.16 - Tests and research – Main Gear Box."

"One of the blades remained attached to the main rotor assembly, and two other ones were found within a radius of approximately 200 meters from the main point of impact."

Text proposed by BEA

Include the "Main Rotor Head" in the parts of the text regarding the "Main Gear Box".

BEA´s comment

Main Rotor Head is missing on wording.

CENIPA´s comment

The Final Report has referred to the Main Rotor Head as a part of Main Rotor Assembly. The Main Gear Box was analyzed separately from the Main Rotor Head and others parts of the Main Rotor Assembly on the report wording.

- **COMMENT 6**

Regarding the following portion of the item "1.16 - Tests and research – Main Rotor Assembly."

"The white blade was the only one found connected to the main rotor head (Figure 44A)."

Text proposed by BEA

The white blade was the only almost complete blade recovered attached to the main rotor head (Figure 44 A).

BEA´s comment

Main Rotor Head is missing on wording.

CENIPA´s comment

Just before the sentence mentioned on Comment 6, the Final Report wording clearly explain that “the roots of the five blades were found connected to their respective blade grips, close to the head of the main rotor and MGB”.

- **COMMENTS 7 and 8**

Fully accepted.

- **COMMENT 9**

Regarding the following portion of the item “2 - Analysis.”

“The structure of the RH roll ball-type flexible control was intact.”

Text proposed by BEA

“At the end of this sentence add “despite the rupture and displacement of the 9° frame, indicating that:

- the RH roll ball-type flexible control was not connected during this rupture and,
- displacement phase occurred during the accident sequence.”

BEA´s comment

Change the text for clarification.

CENIPA´s comment

Just after the sentence mentioned on Comment 9, the Final Report wording clearly explain that “the investigators concluded that the RH roll ball-type flexible control was not connected to the RH roll bellcrank before the takeoff of the accident flight”.

- **COMMENTS 10 and 11**

Regarding the following portion of the item “2 - Analysis.”

“The videos showing the aircraft as it began to taxi, also showed that the helicopter inclined to the left, confirming the expected behavior resulting from the discrepancy of the position of the RH servocontrol in relation to the two other ones. Figure 63 shows the moment at which the helicopter inclined to the left as it started taxiing.”

Text proposed by BEA

It could be added in this chapter that the inclination of the main rotor disk during ground run on the Helipark parking was unusual.

BEA´s comment

In addition to the description of this sequence of the taxiing, it could be added the description of the ground run rotor turning on the Helipark parking as described in the On Site Wreckage Examination Report EAI n°: 41/2015 MM page 52 showing the inclination of the main rotor disk to the left side (see from the back) consistent with the RH flexible control end fitting located bellow the bolt.

CENIPA´s comment

During the investigation, the video mentioned on comments 10 and 11 was thoroughly analyzed. It was not possible to determine the exact left tilt angle of the main rotor disk due to the quality of the movie. So, it was not possible to determine if there was a significant left tilt on the PP-LLS main rotor disk nor it was possible to consider the left tilt of the main rotor disk as “unusual”.

- **BEA ADDITIONAL COMMENTS A, B, C and D**

Fully accepted.