COMANDO DA AERONÁUTICA

CENTRO DE INVESTIGAÇÃO E PREVENÇÃO DE ACIDENTES AERONÁUTICOS

FINAL REPORT
A - 073/CENIPA/2018

OCCURRENCE:	**ACCIDENT**
AIRCRAFT:	**PT-YZJ**
MODEL:	**BELL-407**
DATE:	**17APR2018**

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 Appendix 2, 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 17APR2018 accident with the BELL-407 aircraft model, registration PT-YZJ. The accident was classified as “[SCF-PP] System/Component Failure or Malfunction Powerplant – Engine Failure in Flight”.

During a shuttle flight, the crewmembers heard a loud rumble from the engine. Upon proceeding to a precautionary landing at approximately 200 ft. height, there was a flame-out, with an autorotation being performed, followed by landing.

The aircraft had substantial damage.

The two crewmembers and two passengers left unharmed.

An Accredited Representative of the National Transportation Safety Board (NTSB) - USA, (State where the engine was designed), and an Accredited Representative of the Transportation Safety Board (TSB) - Canada, (State where the aircraft was designed) were designated for participation in the investigation.

CONTENTS

GLOSSARY OF TECHNICAL TERMS AND ABBREVIATIONS

AD	Airworthiness Directive
ADF	Aircraft Registration Category of Federal Direct Administration
ANAC	Brazil's National Civil Aviation Agency
APP-LO	Approach Control - Londrina
CA	Airworthiness Certificate
CEB	Commercial Engine Bulletin
CEL	Aeronautical Maintenance Mechanic in the Airframe Specialty Rating
CENIPA	Aeronautical Accident Investigation and Prevention Center
CIV	Pilot's Flight Logbook
CMA	Aeronautical Medical Certificate
DOA	Air Operations Division
GMP	Aeronautical Mechanic Rating - Powerplant Group
GSO	Safety Manager
HMNT	Single-Turbo Helicopter Rating
IAS	Industry Aviation Services
METAR	Aviation Routine Weather Report
MMA	Aircraft Maintenance Mechanic License
NTSB	National Transportation Safety Board (USA)
PCH	Commercial Pilot License – Helicopter
PN	Part Number
PPH	Private Pilot License – Helicopter
PRF	Federal Highway Police
P-PSAC	Small Civil Aviation Service Provider
RPM	Rotations Per Minute
SBCG	ICAO Location Designator - Campo Grande Aerodrome - MS
SBFL	ICAO Location Designator - Hercílio Luz Aerodrome, Florianópolis - SC
SBMG	ICAO Location Designator - Silvio Name Junior Aerodrome, Maringá - PR
SERIPA V	Fifth Regional Aeronautical Accident Investigation and Prevention Service
SIGWX	Significant Weather
SIPAER	Aeronautical Accident Investigation and Prevention System
TSB	Transportation Safety Board (Canada)
UTC	Universal Time Coordinated

1. FACTUAL INFORMATION.

Aircraft	**Model:** BELL-407 **Registration:** PT-YZJ **Manufacturer:** Bell Helicopter	**Operator:** Federal Highway Police Department
Occurrence	**Date/time:** 17APR2018 - 1430 UTC **Location:** Mãe de Deus Farm **Lat.** 23°12’11”S **Long.** 052°15’45”W **Municipality – State:** Nova Esperança – PR	**Type(s):** as “[SCF-PP] System/Component Failure or Malfunction Powerplant” **Subtype(s):** Engine Failure in Flight

1.1 History of the flight.

The aircraft took off from the Campo Grande Aerodrome (SBCG) - MS, to the Hercílio Luz Aerodrome (SBFL), Florianópolis - SC, around 1020 (UTC) to carry out a transfer flight with two pilots and two passengers on board.

When 15 NM from the Silvio Name Junior Aerodrome (SBMG), Maringá - PR, where there would be an intermediate landing, the crew heard a noise coming from the engine, and the PIC started a precautionary landing.

At approximately 200 ft high, before landing on an unprepared field, there was a flame-out with an autorotation being performed, followed by landing.

The aircraft had substantial damage.

The two crewmembers and two passengers left unharmed.

1.2 Injuries to persons.

Injuries	Crew	Passengers	Others
Fatal	-	-	-
Serious	-	-	-
Minor	-	-	-
None	2	2	-

1.3 Damage to the aircraft.

The aircraft had substantial damage to the engine, tail rotor driveshaft, tail cone fairing and finlets, as well as minor damage to the main rotor blades.

Figure 1 - General view of the aircraft after the occurrence.

1.4 Other damage.

None.

1.5 Personnel information.

1.5.1 Crew's flight experience.

Flight Hours		
	PIC	SIC
Total	1.600:00	900:00
Total in the last 30 days	25:40	30:20
Total in the last 24 hours	02:20	02:20
In this type of aircraft	500:00	70:00
In this type in the last 30 days	25:40	30:20
In this type in the last 24 hours	02:20	02:20

N.B.: The data relating to the flown hours were obtained through the records of the pilots' CIV.

1.5.2 Personnel training.

The PIC took the PPH course at Edra *Aeronáutica*, Ipeúna - SP, in 2006; and the PCH course at the Air Operations Division of the Federal Highway Police, in 2012.

The SIC took the PPH course at Edra *Aeronáutica*, Ipeúna - SP, in 2009; and the PCH course at Rangel *Helicópteros Escola de Aviação Civil*, São Paulo - SP, in 2011.

The mechanic, who was on board as a passenger, worked for the aeronautical maintenance organization that provided service to the PRF under contract. He obtained his Aircraft Maintenance Mechanic (MMA) license in July 1978, completed the Allison Model 250 engine course in 1980 and the Bell 407 helicopter course in 1996. He was appointed inspector in 2015 and participated in the last recurrent training of his contracting company in 2016.

1.5.3 Category of licenses and validity of certificates.

The PIC and the SIC had the PCH License and had valid HMNT Rating.

The mechanic had an MMA License and had valid CEL and GMP Ratings.

1.5.4 Qualification and flight experience.

The pilots were qualified and had experience in the kind of flight.

The mechanic had 42 years of professional experience and had qualifications and experience in performing maintenance services on the Bell 407 aircraft.

1.5.5 Validity of medical certificate.

The pilots had valid CMAs.

1.6 Aircraft information.

The Bell 407 (PT-YZJ) aircraft, serial number 53342, was manufactured by Bell Helicopter in 1999 and was enrolled in the ADF Category.

The aircraft's CA was valid.

The airframe and engine logbook records were updated.

The last inspection of the aircraft, the "150 hours" type, was carried out on 03NOV2017 by the OM HELISUL, in Brasília - DF, with 124 hours and 40 minutes flown after the inspection.

The largest inspection foreseen in the aircraft maintenance program, the "300 hours" type, was carried out on 22AUG2017 by the OM HELISUL, in Brasília - DF, with 180 hours and 10 minutes flown after the inspection.

The aircraft was equipped with a Rolls-Royce Model 250-C47B engine, S/N CAE 847372 which was installed on 06JUL2015, with a total of 4.898 hours and 25 minutes of flight. On the date of the accident, the aircraft and engine had a total of 5.443 hours and 55 minutes of flight.

Maintenance interventions (repair, inspection, and overhaul) of this engine model could be carried out in a modular way, that is, only part of the engine could be removed (gearbox, compressor, or turbine) for preventive or corrective service.

On 22JUN2015, the compressor and gearbox were installed on the engine S/N CAE 847372, after the compressor was overhauled and the gearbox was repaired due to a leak.

At the time, there were two non-mandatory CEBs issued by Rolls-Royce: the CEB 72-5058, which recommended replacing the n°2 bearing, and the CEB 72-6081 which recommended replacing the oil injector (*piccolo tube*).

During the compressor overhaul, only the CEB 72-5058 (bearing n°2 replacement) was fulfilled. According to PT-YZJ maintenance records, the compressor and gearbox were not removed after installing the engine in July 2015.

<u>Application of the CEB 72-5058 and 72-6081 in the Rolls-Royce Model 250-C47B engine</u>

According to the motor manufacturer, replacing bearing no. 2, as per the CEB 72-5058, would improve its load moment. Its modification was motivated by occurrences of damage to this bearing in maneuvers (Figure 2).

B. Reason

To provide an improved No. 2 Bearing with increased moment load capability due to a limited number of occurrences that resulted in damage due to maneuvers.

Figure 2 - Description of the CEB 72-5058.

The CEB 72-6081 prevised the replacement of the *piccolo tube* (P/N 23063357) for a modified model (P/N M250-10767), seeking to decrease the temperature and improve the performance of bearing n° 2 (Figure 3).

B. Reason

The purpose of this CEB is to production and service release a new oil delivery tube to the M250-C28, C30, C40B, and C47 Series engine models.

For the M250-C28, C30 (except C30G and C30G/2 models), and C47 engines, incorporating the P/N M250-10767 Power Accessory Gearbox Oil Tube or the alternate P/N M250-10715 Power Accessory Gearbox Oil Tube will improve the oil delivery to the #2 thrust bearing. This change will decrease the bearing temperature and improve the bearing performance.

Figure 3 - Description of the CEB 72-6081.

The Rolls-Royce Corporation provided an analysis of the changes made to improve the *piccolo tube*, modified model (P/N M250-10767), cited in CEB 72-6081 (Figure 4).

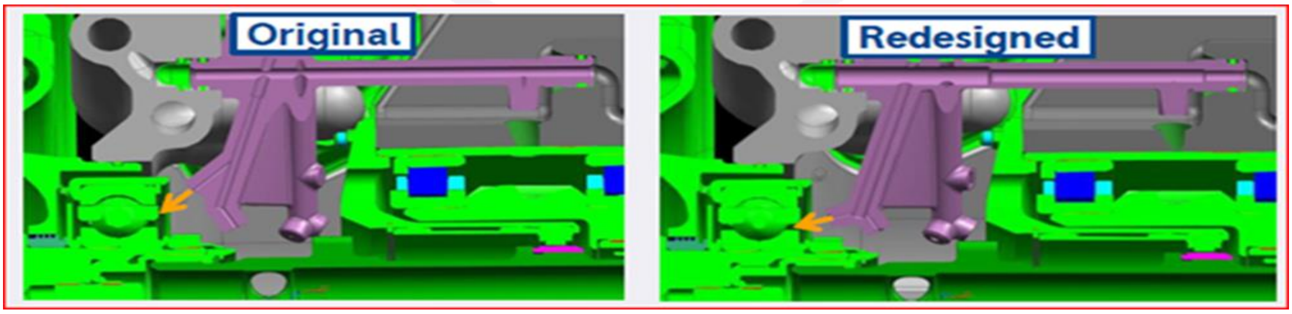

Figure 4 - Difference between the original *piccolo tube* and its new (redesigned) version.

Analysis shows that the angle of incidence of the oil jet was reduced, the oil injection hole was moved closer to the bearing, and the oil flow through the hole was unchanged. Tests carried out would have proven significant improvements in the passage of oil to the bearing and a reduction in its operating temperature.

Maintenance interventions are required in case the engine chip light comes on.

The Rolls-Royce maintenance manual mentioned that the engine lubrication system, model M250-C47B, had two sensors (magnetic plugs) responsible for monitoring the presence of filings in the engine that equipped the PT-YZJ aircraft. The accumulation of metallic particles in one of the sensors led to the lighting of an alarm light (engine chip) on the instrument panel of the aircraft.

In order to monitor the presence of magnetic particles in the engine, these magnetic plugs should be examined according to the periodicity defined in the manual or when the engine chip light turns ON, on the aircraft's instrument panel. Contaminant material accumulated on the sensors could be defined as paste or particles.

The paste would be a mixture of oil and carbon, the result of normal engine wear and motivated the cleaning of the sensors every 150 hours of operation. This interval should be reduced to up to 25 hours when an excessive amount of this contaminating material is found in the magnetic plugs.

During this cleaning, the magnetic plugs should also be inspected for the presence of metallic material in the form of slivers, flakes, or pieces. The existence of these magnetic particles indicated a probable failure in the bearings, gears, and/or abnormal engine wear.

Given the presence of this type of contaminating material in the sensors, a quantitative and qualitative analysis was necessary, and material with a diameter greater than 1/32 of an inch or more than four slivers per event was not acceptable.

If the presence of this type of material is confirmed, the engine should be removed and sent to an authorized maintenance organization for evaluation and repair.

If a material with a diameter of less than 1/32 of an inch or less than four slivers per event was present in the magnetic plugs, the maintenance procedures described in the engine manual M250-47B Operation and Maintenance 72-00- 00, pages 339 Sep 1/15, 349 Sep 1/17 and 341 Sep 1/17, as transcribed below:

> E. Magnetic Plugs (Ref. Figure 201, 72-60-00)
>
> [...]
>
> (3) Do the following maintenance steps as a result of a magnetic plug warning light indication.
>
> (a) Clean the magnetic drain plugs. Do a 30-minute ground run at the highest power setting possible without lift-off (without exceeding Max Continuous rating) with the rotor turning. Monitor engine operation limits and magnetic plug warning lights. If operation is correct, remove, examine, clean, and reinstall both magnetic drain plug detectors. Return the engine to service.
>
> NOTE: If there is another magnetic plug warning light after the engine has been returned to service, it must be considered another occurrence. (Refer to 8.E.(3)(d), this section, for limits on number of occurrences.)
>
> (b) If chips or flakes less than 1/32 in. (0.79 mm) diameter or fewer than four slivers are found during the 30-minute run, do the next step.
>
> (c) If there is a magnetic plug warning light during the first 30-minute ground run, the following steps must be taken before the second 30-minute ground run.
>
> 1 Drain the oil.
>
> 2 Clean the engine oil filter.

3 Replace the Scavenge Oil Filter.

4 Flush the aircraft oil system to remove any unwanted material.

5 Clean the engine magnetic drain plug detectors.

6 Service the engine oil system with fresh, clean oil.

7 Do a second 30-minute ground run at the highest power setting possible without lift-off (without exceeding Max Continuous rating) with the rotor turning. Monitor the engine operation limits and magnetic plug warning lights. If operation is correct, remove, examine, clean, and reinstall both magnetic drain plug detectors. Return the engine to service.

8 If there is a magnetic plug warning light during the second 30-minute ground run, remove the engine from service and send to a Rolls-Royce approved repair facility. Clean the aircraft engine oil system (Ref. para 8.E.(3)(c), this section).

NOTE: If a magnetic plug warning light comes on within the next eight hours of operation after the second 30-minute ground run, and the cause is found to be magnetic particles and debris (chips, flakes or slivers), remove the engine and send to a Rolls-Royce approved repair facility. Tag the engine and note the cause.

(d) If there is a maximum of four occurrences of a magnetic plug warning light within a 50-hour time period of engine operation, you must remove the engine for shipment to a Rolls-Royce approved repair facility.

According to these guidelines in the manual, after the first lighting of the engine chip light, cleaning of the magnetic plugs should be performed, followed by a 30-minute maintenance run to monitor the operating limits of the engine and the magnetic plugs.

If the run proceeded normally, the magnetic plugs should be examined, cleaned, reinstalled, and the aircraft returned to operation.

If the engine chip light came on and/or the presence of filings of less than 1/32 of an inch was verified, or less than four slivers during the 30-minute turn, the manual provided for draining the oil, cleaning the engine, changing the scavenge pump filter, clean the aircraft's oil system and refill the engine's lubrication system, and then perform a new 30-minute monitoring run.

After this second 30-minute run, if the operation was normal, the engine would be released to return to operation. If not, in case the engine chip light came on, the engine should be removed for maintenance by a manufacturer's representative.

If the aircraft was cleared for return to flight, the engine would also have to be removed if the engine chip light was activated within eight hours following the second 30-minute run, caused by filings (slivers, flakes, or chunks); or if this condition recurs four times within 50 hours of engine operation.

1.7 Meteorological information.

The METAR from the SBMG Aerodrome, 20 NM away from the accident site, provided the following information:

METAR SBMG 171300Z 09015KT 9999 FEW045 23/15 Q1022=

METAR SBMG 171400Z 07017KT 9999 FEW045 25/15 Q1022=

METAR SBMG 171500Z 07016KT 9999 FEW045 25/15 Q1021=

It was found that the conditions were favorable for the visual flight with visibility above 10 km and with few clouds. The wind had intensity between 15 and 17 kt.

The SIGWX generated at 0949 (UTC), valid until 0000 (UTC) on 18APR2018, illustrated the absence of meteorological formations in the accident region (Figure 5).

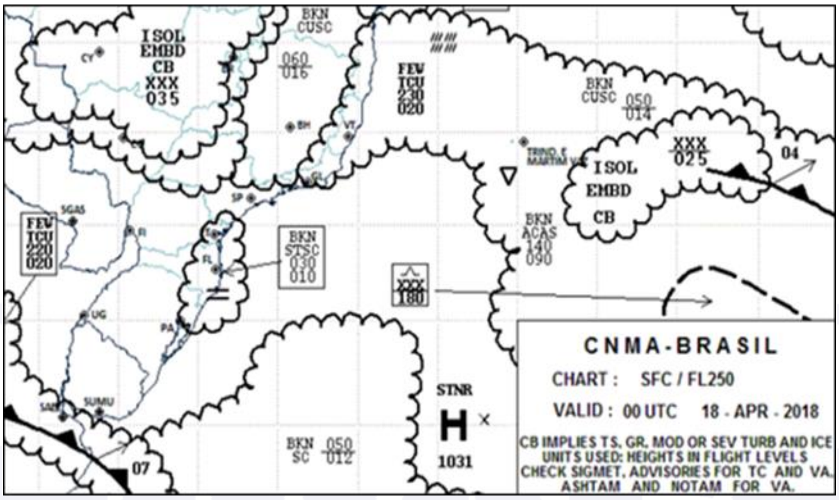

Figure 5 - SIGWX chart generated at 0949 (UTC) on 17APR2018.

1.8 Aids to navigation.

Nil.

1.9 Communications.

The crew informed, through radio contact with the APP-LO, that they would make an emergency landing in an unprepared field.

1.10 Aerodrome information.

The occurrence took place out of the Aerodrome.

1.11 Flight recorders.

Neither required nor installed.

1.12 Wreckage and impact information.

The autorotation landing took place on soft terrain (ploughed) that had a slight slope at 45º to the left of the aircraft's travel direction.

There was a collision of the main rotor against the tail boom, with the sectioning of the two finlets and the rupture of part of the transmission shaft of the tail rotor (Figures 6 and 7).


Figure 6 - Detail of the left finlet cutting angle caused by the main rotor.

Figure 7 - Detail of the point of impact of the main rotor blades against the tail boom.

There were no signs of tail rotor or tail skid contact on the ground. There was a slight sinking of the rear part of the right ski into the ground, but there was no deformation of the skis (Figure 8).

Figure 8 - Overview of the aircraft's stopping position.

1.13 Medical and pathological information.

1.13.1 Medical aspects.

Nil.

1.13.2 Ergonomic information.

Nil.

1.13.3 Psychological aspects.

No evidence was found that problems of physiological nature or incapacitation could have affected the flight crew performance.

1.14 Fire.

There was no fire.

1.15 Survival aspects.

Nil.

1.16 Tests and research.

The engine was disassembled and analyzed at the IAS, in Belo Horizonte - MG, and during its disassembly, when checking the compressor section, it was found that bearing n° 2 (P/N M250-10354B) was damaged, and the *piccolo tube* installed was P/N 23063357.

Bearing n°2 was in its correct position.

However, a section covering the area of approximately two spheres was missing.

The bearing retaining ring was also absent, with most of it located posteriorly inside the gearbox (Figures 9, 10, and 11).

Figure 9 - Bearing nº 2 in its correct position, but damaged.

Figure 10 - Bearing nº 2 after being removed from the aircraft.

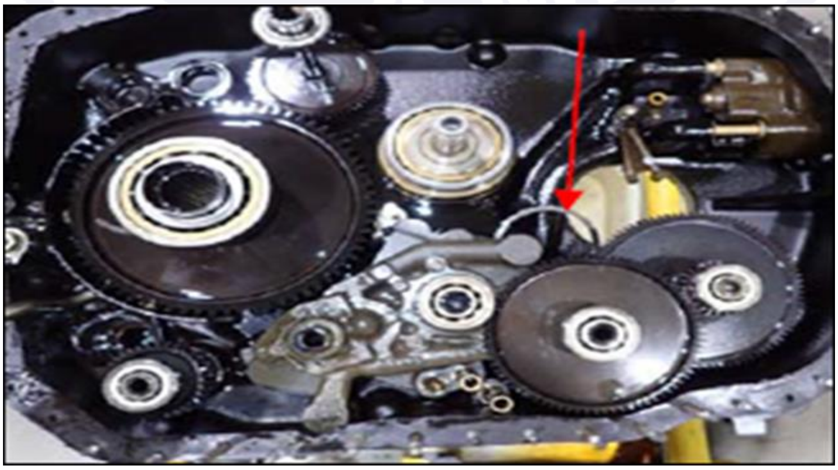

Figure 11 - Bearing Retaining Ring n°2 found inside the gearbox.

All spheres were present and retained within the bearing area, however, they exhibited evidence of slippage. Removal of bearing n°2 revealed marks on the two inner halves in the sphere rolling area (Figure 12).

Figure 12 - Scratch marks on the inner raceway of bearing n°2.

Disassembly of the compressor revealed that its rotating and stationary parts came into contact, resulting in the damage illustrated in Figures 13 and 14.

Figure 13 - View of the compressor axial stage.

Figure 14 - Damage to the compressor area.

Upon opening the gearbox, all internal gears and bearings were visually examined and found to be normal in appearance.

Non-compliance with the CEB N° 72-6081 was verified (replacement of *piccolo tube* P/N 23063357 by P/N M250-10767). However, the *piccolo tube* installed (P/N 23063357) was in its correct position and visually normal (Figure 15).

Figure 15 - *Piccolo tube* in its correct position.

No discrepancies or presence of metallic particles were found in the oil pump, being considered visually normal and with no visible metal.

When removing the magnetic plugs from the aircraft (Lower Magnetic plug and Upper Magnetic plug), a considerable amount of metal particles was found (Figures 16 and 17).

Figure 16 - Lower Magnetic Plug.

Figure 17 - Upper Magnetic Plug.

No damage or signs of abnormal burning were found in the combustion section.

Within the turbine section, on the front of the rear section of the turbine to compressor coupling, a carbon buildup of approximately 2 ½ inches was observed.

No other damage was found in the engine lubrication system besides those already mentioned in bearing n° 2 and magnetic plugs. The other bearings, lines, oil injectors, and other components of the system had freedom of movement and no obstruction.

Bearing n°2 and *piccolo tube* installed in the aircraft engine was sent to the Rolls-Royce laboratory in Indianapolis - United States, for further laboratory tests (Figures 18, 19, and 20).

Figure 18 - General view of bearing n°2 and damage to its rail.

Figure 19 - View of the general condition of the inner rings of bearing nº 2.

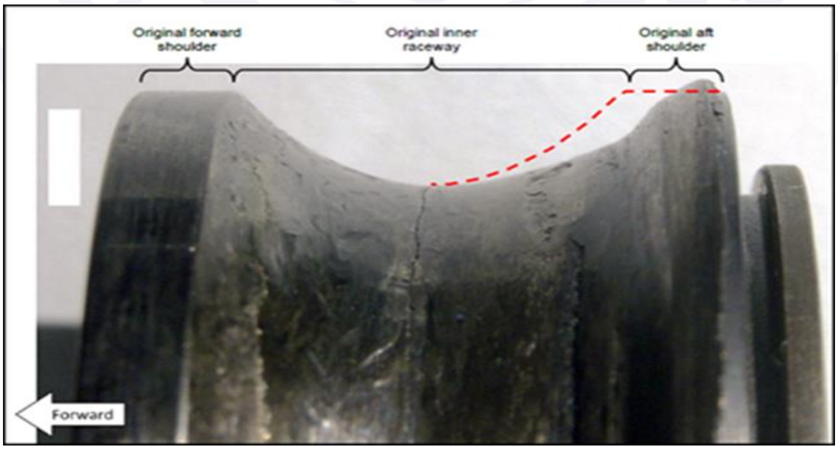

Figure 20 - Detailed view of the bearing's inner raceway, showing the profile distortion.
The red dashed line approximates the original profile of the sphere rolling area.

All spheres of bearing n°2 showed flattened parts, resulting from contact with the side of the inner ring (Figure 21).

Figure 21 - View of the damage caused to the spheres of bearing nº 2.

The bearing n°2 front and rear rails were fractured and detailed visual inspection revealed macroscopic indications consistent with progression of fatigue (Figures 22 and 23).

Figure 22 - View of the inner rails of bearing nº 2.

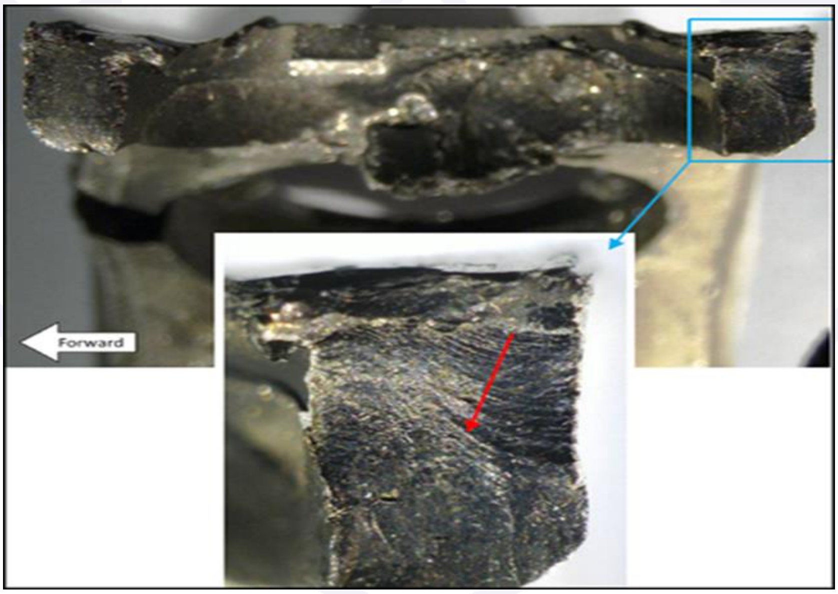

Figure 23 - Detailed view of the fractured rails of bearing n°2 showing macroscopic indications consistent with progression of fatigue (red arrow).

In the visualization of metallographic sections of the outer and inner rings and of a bearing nº2 sphere, it was possible to observe the extent of the raceway profile distortion and the thermal wear of the components. Thermal wear is indicated by the lighter areas shown in Figure 24.

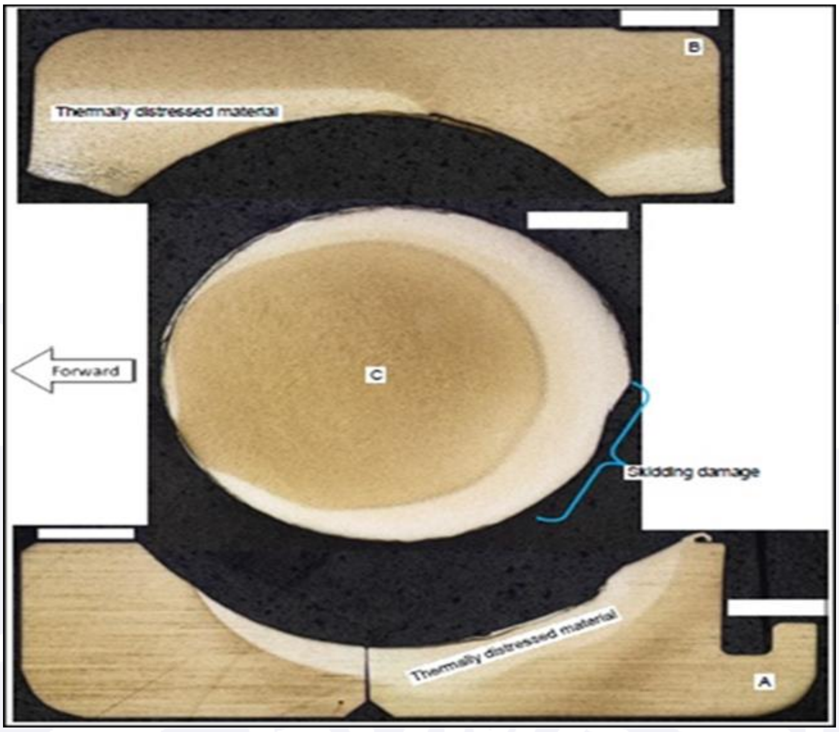

Figure 24 - Thermal wear of the material.

The visual examination of the main oil passage and oil directing duct to bearing n°2 did not reveal any blockage (Figure 25).

The normal continuity of the internal flow between the oil inlet port and the directing jet for bearing n°2 was confirmed through a liquid flow test in the *picollo tube*.

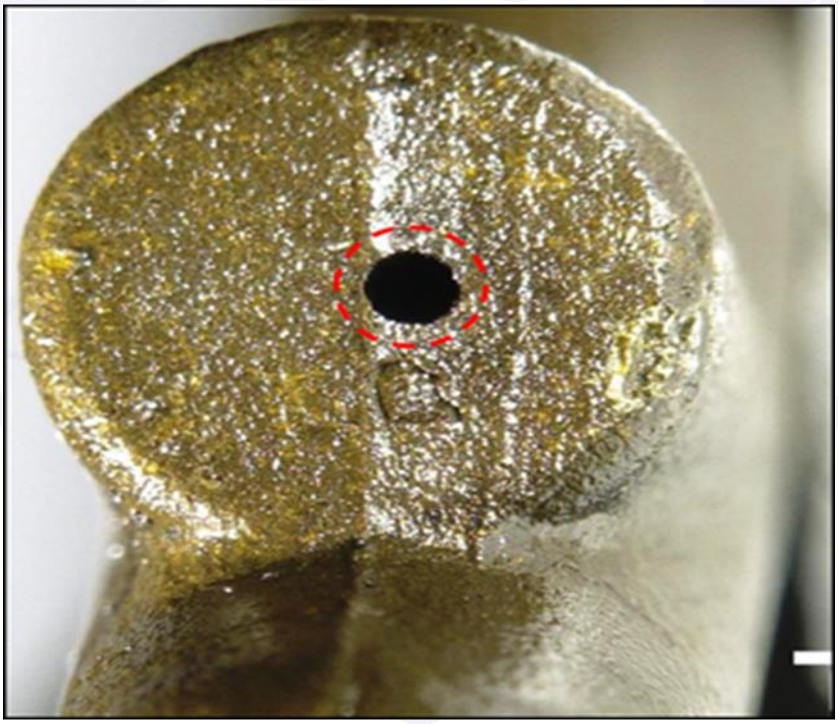

Figure 25 - *Piccolo tube* outlet hole.

In addition, the *piccolo tube* was subjected to radiographic inspection by computed tomography. The resulting radiographs did not reveal any internal blockage or discontinuity of the internal passages in the oil delivery tube (Figures 26 and 27).

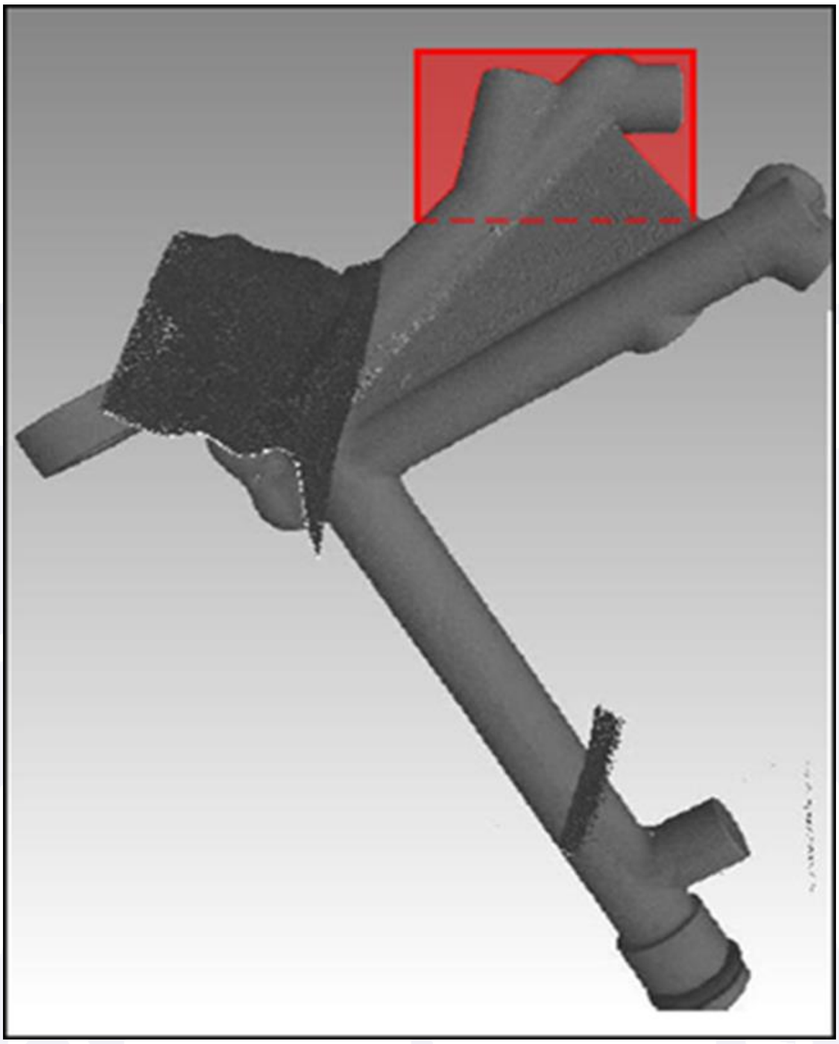

Figure 26 - Radiograph of the *piccolo tube*.

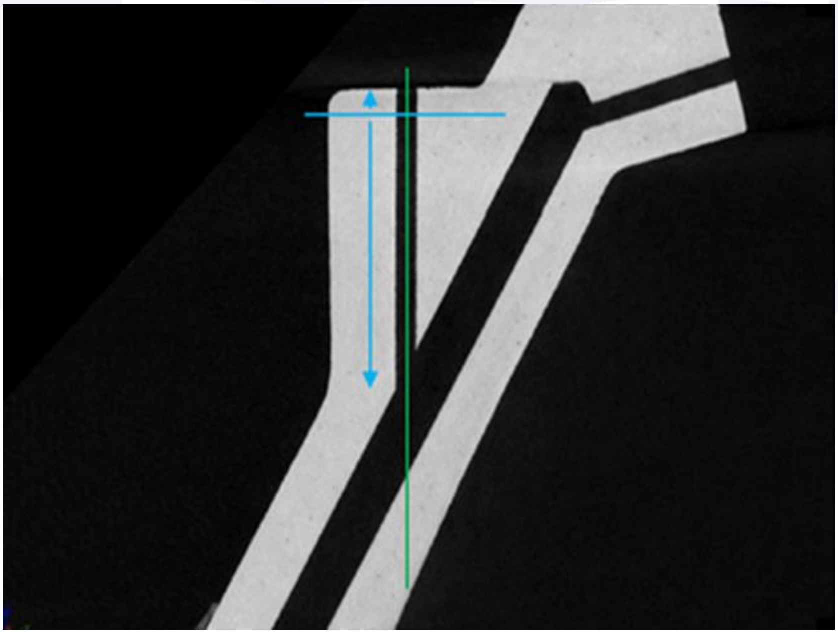

Figure 27 - Radiograph of the *piccolo tube*.

From the analysis of the report issued by Rolls-Royce, it was evident that:

- all components of bearing n°2 exhibited signs of heat stress. There was a pattern of thermal wear on the inner ring, outer ring, and spheres;

- Engine damage was consistent with a bearing nº2 failure due to insufficient cooling and directing the lubricating oil flow. All other damages were considered secondary;

- the continuity of the internal passages of the *piccolo* tube was confirmed, as there was no interruption of liquid flow through the tube during the laboratory test;

- the *piccolo tube* was subjected to radiographic inspection by computed tomography, and the radiographs revealed that there were no internal blockages or discontinuities in the passages;

- the microstructure and chemistry of bearing assembly n°2 were consistent with engineering design requirements;

- Bearing n°2 failure resulted in a loss of axial support of the compressor disk, allowing direct axial movement of the compressor disk from its normal position. As a result, the compressor disk came into contact with the compressor cover, resulting in a sudden drop in N1 RPM and a subsequent reduction in engine power; and

- the ECU data indicated that the engine controls responded properly to the N1 (RPM) reduction, increasing fuel flow. Subsequent data was consistent with the engine's expected response after failure.

Given the analysis of the conclusions pointed out in technical reports, it was concluded that the failure of the aircraft engine was due to poor lubrication of bearing nº 2 and its consequent overheating and rupture. All other damage was secondary to this failure.

1.17 Organizational and management information.

Maintenance services for the entire fleet of the Federal Highway Police helicopters were outsourced through a contract established with an aeronautical maintenance organization approved by the ANAC.

The maintenance contract prevised the support of a maintenance team at each of air operation bases and maintenance support within 48 hours, when the helicopter was out of the headquarters.

During an interview with the mechanic who was on board the aircraft and with two other professionals from the maintenance company, it was reported that whenever there was any kind of filings, the company's standard procedure was to change the engine oil.

In addition, it was reported that the maintenance company only carried out the control of the CEBs that involved component life limit or some AD, and that those CEBs that aimed only at updates were not observed with greater attention by the company.

Within the PRF structure, there was a DOA, located in Brasília - DF, and seven air operations bases distributed throughout the country. All aircraft belonged to the DOA cargo material, which managed all maintenance contracts.

The crew of the operating bases were administratively subordinated to the Regional Superintendencies of the PRF and operationally to the DOA. Because of this, the crewmembers sometimes had an accumulation of administrative tasks and this was reflected in the air activities.

The air activity within the PRF did not have macro planning and centralized control. Each base of operations carried out its operational missions independently.

In addition, air operations did not have their tasks well defined and with an adequate division of tasks between the DOA and the Superintendencies. According to the reports of pilots, there were conflicts of orders and, sometimes, the heads of the operational bases did not know whether to report to the DOA or the Superintendence, as in the case of the provision of new flight equipment.

The MGSO, revised in September 2017, provided that:

> All organizations involved with aviation, especially the P-PSAC, as is the case of the Air Operations Division of the Federal Highway Police, must have in their organizational structure, mandatorily, a GSO acting in the Prevention of Aeronautical Accidents and directly advising the Responsible Executive (Director of the PRF) as well as the Chief of the DOA and those responsible for the DOA Deconcentrated Bases. The PRF Director, the DOA Chief, and the GSO DOA have established lines of responsibility for their specific activities.

When analyzing the organization chart of the PRF Operations Director, it was observed that the GSO was subordinated to two coordination below the Operations Director, which contradicted the provisions of the MGSO (Figure 28).

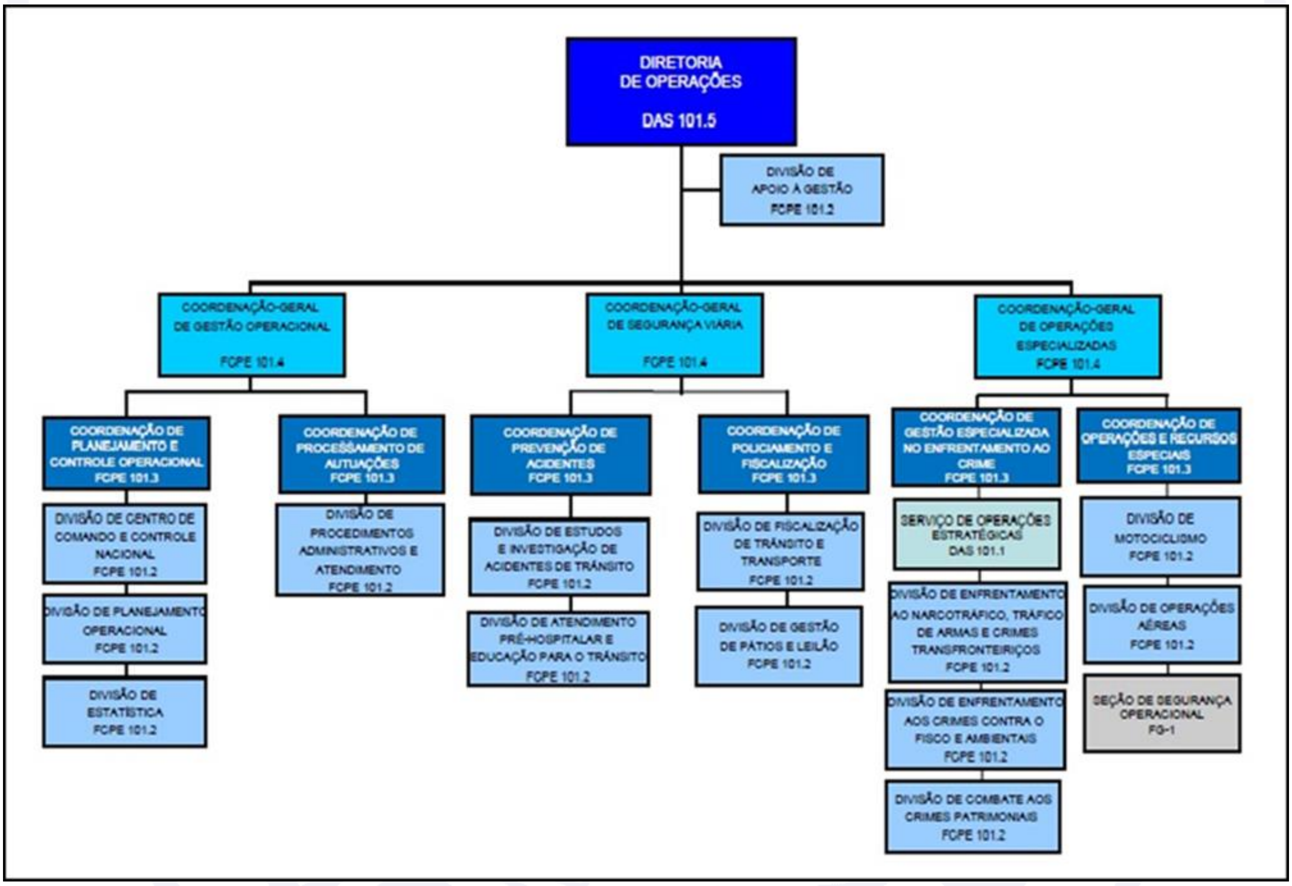

Figure 28 - Organizational Chart of the PRF Operations Director - distance from the GSO.

It was found that there was no effective advice from the GSO. In addition to not having an exclusive dedication to the position, there was no adequate support structure, sufficient staff, and adequate and updated qualifications. The flow of information on issues related to Flight Safety was not effective, which undermined the importance that should be given to matters related to safety by the Operations Director and the General Director of the PRF.

At the time of the accident, Annex A of the ANAC Resolution No. 106, of 30JUN2009, which approved the Operational Safety Management System for P-PSAC, did not provide a person responsible for the control of aircraft maintenance in the technical and administrative staff, with qualification and specific attributions for the maintenance of the operational safety performance of the referred Unit.

1.18 Operational information.

The take-off in SBCG was performed with a weight of 5,495.8 lbs. Therefore, 495.8 lbs above the maximum take-off weight, which was 5,250 lbs.

However, at the time of the accident, the aircraft was within the weight and balance limits stipulated by the manufacturer.

The crashed aircraft had the PRF operational base in Florianópolis - SC, as its headquarters. It was deployed in Dourados and Campo Grande - MS, to fulfill an operational mission.

During flights performed in Dourados - MS, the engine filings detection light came ON, on 09APR2018.

The PT-YZJ crewmembers recorded the engine chip light ON in the logbook and requested the support of the aeronautical maintenance company with which the Federal Highway Police had a contract, to reestablish the airworthiness of the aircraft.

Upon checking the magnetic plugs, a paste was found with tiny particles of filings in powder form.

According to the maintenance records, the helicopter was released for operation on 10APR2018, after replacing the oil, changing and cleaning the filters in the engine's lubrication system.

After carrying out some flights (10APR2018 - 25-minute test flight / 12APR2018 - three operational flights, totaling 2 hours and 10 minutes / 13APR2018 - three operational flights, totaling 2 hours and 25 minutes) that consumed a total of 5 hours, the mechanic found contaminating material when inspecting the aircraft's engine magnetic plugs, reporting the presence of "very few powdery particles".

Faced with this contamination, the mechanic performed a new oil change and inspection of the filter elements of the lubrication system on 13APR2018 confirmed in the aircraft airframe logbook.

After this oil change, the aircraft performed three operational flights on 15APR2018, totaling 2 hours and 18 minutes, and no abnormality was reported.

On 17APR2018, the aircraft took off from the Campo Grande Aerodrome (SBCG) to start a flight to Florianópolis - SC. The mechanic of the Maintenance Organization, with which the PRF had a maintenance contract, accompanied the transfer of the aircraft, since, during the route to Florianópolis, there would be some intermediate landings in places without maintenance support.

After an hour and twenty minutes of flight, a precautionary landing was carried out in the rural area of the municipality of Batayporã - MS, due to the lighting of the engine chip on the aircraft's panel.

After landing, the mechanic accompanying the shuttle flight inspected the magnetic plugs. He found the presence of contaminating material in the form of sludge and informed the pilots that it was “carbonization”.

The magnetic plugs were inspected and cleaned, and the crew decided to continue the flight. The pilots considered it safe to continue the flight to the nearest location, with the possibility of greater maintenance resources and a more careful evaluation.

However, after approximately 40 minutes of flight from the new take-off, a strong noise was noticed, followed by a loss of engine power and oil pressure, a drop in the rotation of the main rotor, and yaw of the aircraft to the right, in addition to the engine chip light coming on.

Autorotation was performed for landing in an unprepared area. Part of the aircraft's skis sank into the sandy terrain and the main rotor slammed into the finlets and tail boom.

According to the crew's reports, the engine came to a complete stop before touching the ground. After the forced landing, the rotor brake was applied and the equipment was turned off.

It should be considered that, when reaching very low values of main rotor RPM, the centrifugal force on the blades also decreases, which can cause excessive downward bending and flapping. This condition, associated with hard commands and/or landings, can lead to the rotor blade colliding with the tail boom.

Section 3 (Emergency/Malfunction Procedures) of the BHT-407-FM-1 flight manual in its topic 3-3-A-2 Engine Failure - In-Flight had the following procedures in item 7:

> 7. Apply collective as flare effect decreases to further reduce forward speed and cushion landing. Upon ground contact, collective shall be reduced smoothly while maintaining cyclic in neutral or centered position.

The Manual advised that the collective should be applied as the flare effect decreased and that after the aircraft was in contact with the ground, the collective application should be reduced, smoothly, while keeping the cyclic in a neutral or centralized position.

1.19 Additional information.

On 11DEC2015, Bell Helicopter issued the Information Letter No. IL 407-15-110 and addressed it to all Model 407 helicopter owners and operators.

In that document, Bell Helicopter reported that Rolls-Royce had made some upgrades to the 250-C47B engine through the following bulletins:

- CEB 72-6067, dated 11APR2011 - replacement of bearing no. 2;

- CEB 72-6071, of 14DEC2012 - replacement of Torquemeter Thrust (Ball) Bearing (new P/N M250-10398);

- CEB 72-6075, of 04MAR2013 - inspection of the magnetic plugs to verify the presence of filings from bearing n° 2, as well as the replacement of some bearings n° 2, P/N M250-10354, specified in this bulletin; and

- CEB 6081, from 20JAN2015 - replacement of the *piccolo tube* (Oil Delivery Tube).

In that letter, Bell Helicopter expressed that it was highly recommended to implement the aforementioned CEBs in the engines installed in model 407 helicopters.

On 17DEC2015, the Nicaraguan Institute of Aeronautics issued an AD, INAC-AD-E-2015/001, making it mandatory to comply with the CEB mentioned in Bell Helicopters' information letter IL 407-15-110.

Finally, the investigators' research did not identify AD emissions either in the engine's country of origin or in Brazil.

1.20 Useful or effective investigation techniques.

Nil.

2. ANALYSIS.

It was a transfer flight from SBCG, to SBFL, with two pilots and two passengers on board.

After an hour and twenty minutes of flight, a precautionary landing was carried out in the rural area of the municipality of Batayporã - MS, due to the lighting of the engine chip on the aircraft's panel. After landing, the mechanic accompanying the shuttle flight inspected the magnetic plugs. He found the presence of contaminating material in the form of sludge and informed the pilots that it was “carbonization”.

The magnetic plugs were inspected and cleaned, and the crew decided to continue the flight. The pilots considered it safe to fly to the nearest location, with the possibility of performing a more thorough assessment and finding better conditions for carrying out maintenance services.

After 40 minutes of flight since the new take-off, a strong noise was noticed, followed by loss of power and engine oil pressure, a drop in main rotor rotation, and a yaw of the aircraft to the right, in addition to the lighting of the engine light chip. Then, autorotation was performed to land in an unprepared area.

The landing took place on soft terrain (ploughed) that had a slight slope at 45º to the left of the aircraft's direction of travel. There was a collision of the main rotor against the tail boom, with the sectioning of the two finlets and the rupture of part of the transmission shaft of the tail rotor.

After researching the engine, it was concluded that there was deficient lubrication of bearing nº 2, which resulted in its overheating and rupture, causing the loss of the axial support of the compressor disc, allowing its direct axial movement from its normal position.

Regarding the airworthiness conditions of the aircraft, two aspects were considered: the first concerns the design modification carried out by the engine manufacturer, to reduce the probability of bearing nº 2 failure; and the second concerns maintenance interventions in the face of frequent lighting up of the aircraft's engine chip light.

As for the design modification, it was found that there were two CEBs issued by the engine manufacturer.

The CEB 72-5058 recommended the replacement of bearing n° 2, seeking to improve its load moment; and the CEB 72-6081, which prevised the replacement of the oil injector (*piccolo tube*), seeking to decrease the temperature and improve the performance of bearing n° 2.

The aforementioned bulletins were not mandatory. However, Bell Helicopter issued the Information Letter No. IL 407-15-110, and addressed it to all Model 407 helicopter owners and operators, recommending compliance.

The non-compulsory compliance with these CEBs was justified by the fact that, despite the possibility of having the Life Limit of Bearing nº2 reduced, the correct application of the procedures and maintenance interventions, already foreseen previously, were considered sufficient to avoid a catastrophic failure.

As verified during the investigation, the maintenance company adopted the practice of not implementing bulletins aimed at system updates, so only the CEB 72-5058, which recommended the replacement of bearing n° 2, was fulfilled in the PT-YZJ aircraft.

Although compliance with the CEB 72-6081 (*piccolo tube* replacement) is not mandatory, it could have been configured as a barrier to the accident, since it represents significant improvements (reduction in its operating temperature according to tests carried out by Rolls-Royce) regarding the delivery of oil to bearing nº 2.

Concerning maintenance interventions, given the frequent ignition of the engine chip light, it was found that the first occurrence of ignition occurred on 09APR2018, during flights performed outside the headquarters, in the city of Dourados - MS.

Under those conditions, according to the maintenance procedures described in the M250-47B Operation and Maintenance engine maintenance manual, a quantitative and qualitative analysis of the particles was necessary, and material with a diameter greater than 1/32 of an inch or more than four slivers per event.

If there was the presence of material with a diameter of less than 1/32 of an inch or less than four slivers per event, in this first event of turning on the engine chip light, cleaning of the magnetic plugs should be performed, followed by a maintenance turn of 30 minutes for monitoring the engine operating limits.

If the run took place normally and no new contamination of the plugs was identified, the aircraft could return to operation.

Once new contamination was identified, the manual prevised draining the oil, cleaning the engine filter, changing the scavenge pump filter, cleaning the aircraft's oil system, and refilling the engine's lubrication system, then performing a second run with 30 minutes of monitoring.

After this second 30-minute run, if the operation was normal, the engine would be released to return to operation; if not, in case the engine chip light came on, the engine should be removed for maintenance by a manufacturer's representative.

According to PT-YZJ maintenance records, paste with "tiny" dust particles of filings was found in the magnetic plugs. The investigation was not able to specify the size of these particles and did not identify reports of the presence of slivers.

After replacing the oil, changing and cleaning the filters of the engine's lubrication system, a 25-minute run was performed and the helicopter was released for operation on 10APR2018.

It was observed, therefore, that the first procedure performed was the replacement of the oil and the filters of the engine lubrication system, failing to perform the first maintenance run prevised in the manual, before the oil change. Only the run after the oil change was performed and then the aircraft was released for flight.

After returning to operation, the aircraft flew 5 hours and, on 13APR2018, the mechanic found contaminating material when inspecting the magnetic plugs, reporting the presence of "very few particles in the form of powder".

The maintenance manual provided that, after being released to return to flight, there would be a new activation of the engine chip light in the eight hours following the second 30-minute run, caused by filings (slivers, flakes, or pieces), or if this condition repeated four times within 50 hours of operation, the engine should be removed for service by a manufacturer's representative.

Although there was no new activation of the engine chip light on that occasion, a new oil change and inspection of the filter elements of the lubrication system was carried out on 13APR2018, confirmed in the aircraft's airframe logbook record. Again, steps of the procedure set out in the maintenance manual were not followed and the maintenance rotation was not carried out either before or after the oil change.

It should be considered that oil replacements, outside the sequence and steps foreseen for correction and monitoring of operating conditions, invalidated the control of the hours and frequency of activation of the engine chip light, preventing the correct diagnosis of the engine airworthiness conditions.

Additionally, the lack of a more accurate assessment of the filings dimensions found in the magnetic plugs may have masked a more critical deterioration in bearing n°2 condition that required maintenance intervention before releasing the engine for return to operation. After this second oil change, the aircraft flew 2 hours and 18 minutes on 15APR2018, and no abnormality was reported.

On17APR2018, the transfer flight from SBCG to SBFL was carried out with an intermediate landing scheduled for SBMG. One hour and twenty minutes into the flight, the engine chip light came on, and the crewmembers made a precautionary landing in a rural area. It was, then, a new ignition of the engine chip light, after an oil change and the second maintenance run prevised in the manual.

At that time, because less than eight hours had passed since the oil change, the aircraft's engine should have been sent to Rolls-Royce for repair. Therefore, the airworthiness of the aircraft should have been restricted at that time.

The magnetic plugs were inspected and the presence of contaminating material in the form of sludge was verified, being identified as a "carbonization". After cleaning the plugs, the aircraft was released for operation and transferred to SBMG.

After 40 minutes of flight, there was a catastrophic failure of bearing nº 2, causing the loss of engine power, which forced the crew to perform the landing in autorotation.

About the organizational culture of the maintenance company, it was reported that the interventions in engines with filings indication, performed by the company, had as default the engine oil change, without a detailed analysis.

This “standard” procedure of the company was followed by the mechanic, on 10APR2018, when releasing the PT-YZJ for the flight, without consulting the maintenance manuals, presenting itself as a latent condition. Thus, it was found that the procedures described in item 8.E.(3)a of the Rolls-Royce M250-47B - Operation and Maintenance manual were not followed.

In addition, the manual provided that if the chip detection light came on within eight hours of operation after the second maintenance run, due to magnetic particles, the engine should be sent to Rolls-Royce for evaluation and repair.

Considering that the second engine chip light came on less than eight hours after the second oil change, the aircraft should have been out of service and the engine sent to Rolls-Royce.

It was concluded, then, that the culture of performing the routine procedure of the maintenance company personnel that provided service to the PRF, instead of adherence to the procedures described in the maintenance manual, contributed to the occurrence of the accident.

Regarding the CRM, it was found that there may have been a poor perception and analysis of the risks involved in the frequent lighting of the engine chip light, in addition to a consensus to proceed with the flight, reinforced by the fact of being in an unsupported region.

The crew did not consider staying on the ground and looking for an alternative, demonstrating that they were not aware that the continuation of the flight, under those conditions, represented unacceptable risks to the operation.

Regarding the technical performance of the crewmembers, it was verified that the damage to the aircraft resulted from the autorotation landing when the main rotor collided with the tail boom. There was the splitting of the two finlets and the rupture of part of the transmission shaft of the tail rotor.

The aircraft manual recommended that the collective be applied as the flare effect decreased and that, after the aircraft was in contact with the ground, the collective application should be reduced, smoothly, while keeping cyclic in a neutral or centered position.

It should be considered that, when reaching very low values of main rotor RPM, the centrifugal force on the blades also decreases, which can cause excessive downward bending and flapping. This condition, associated with hard commands and/or landings, can lead to the rotor blade colliding with the tail boom.

There was no evidence of the skis deformation. However, the soft terrain may have masked a landing condition with a high sink rate, in addition to the fact that the slope of the terrain increased the degree of difficulty in the execution of the flare and the application of the commands.

Regarding the organizational environment of the Federal Highway Police (PRF), it was observed that there was no macro planning with adequate control of air activities and well-defined tasks, where each base of operation performed its operational missions independently.

There was a management conflict because the crew was administratively subordinated to the PRF Regional Superintendencies and operationally to the DOA. This fact denoted that there was an overload of administrative functions for the crewmembers and brought harm to a better dedication to air activities (study of operational procedures, knowledge of aircraft systems, management of cabin resources, and others).

According to reports from the crewmembers, the information flow regarding air activities and Flight Safety was not effective.

When analyzing the organization chart of the PRF Operations Director, it was observed that the GSO was subordinated to two coordination below the Operations Director, contrary to the provisions of the MGSO, which delegated to the GSO direct advice to the Responsible Executive (PRF Director), as well as to the DOA Chief and those responsible for the DOA Deconcentrated Bases.

Given the analysis of the organizational environment, it was concluded that there was inadequate planning and management supervision, both in the macro aspect and within the DOA, directly impacting Flight Safety and the organizational culture of the crew.

3. CONCLUSIONS.

3.1 Facts.

a) the pilots had valid CMAs;

b) the pilots had valid HMNT Ratings;

c) the mechanic had an MMA License and valid CEL and GMP Ratings;

d) the pilots were qualified and had experience in the type of flight;

e) the mechanic had qualifications and experience in performing maintenance services on the Bell 407 aircraft;

f) the aircraft had a valid CA;

g) at the time of the occurrence, the aircraft was within the weight and balance limits;

h) the airframe and engine logbook records were updated;

i) the weather conditions were favorable for the flight;

j) there were two CEBs issued by the engine manufacturer: CEB 72-5058 which recommended the replacement of bearing n° 2; and CEB 72-6081, which provided for the replacement of the oil injector (*piccolo tube*);

k) the maintenance company adopted the practice of not implementing bulletins aimed at system updates, so that only the CEB 72-5058 that recommended the replacement of bearing n° 2 was fulfilled in the PT-YZJ aircraft;

l) the procedures described in item 8.E.(3).a of the Rolls-Royce M250-47B - Operation and Maintenance manual were not followed;

m) with less than eight hours flown, after an oil change, the engine chip light came on again, however, the aircraft was released for flight, in disagreement with the procedures established by the engine manufacturer;

n) there was poor lubrication of bearing n°2, followed by overheating and rupture;

o) there was engine failure in flight;

p) the crew performed an autorotation landing;

q) there was a collision of the main rotor against the tail boom, the sectioning of the two finlets and the rupture of part of the transmission shaft of the tail rotor;

r) the aircraft had substantial damage; and

s) the two pilots and the two passengers left unharmed.

3.2 Contributing factors.

- **Organizational culture – a contributor.**

The culture of executing the company's routine maintenance procedure in an informal manner rather than adhering to the procedures described in the maintenance manual has contributed to the engine chip light condition not being handled properly.

- **Aircraft maintenance – a contributor.**

The engine oil replacements, in disagreement with the procedures provided in the maintenance manual, contributed to the condition of the engine chip light was not properly treated.

- **Decision-making process – undetermined.**

After landing in the rural area of the municipality of Batayporã - MS, the crewmembers decided to continue the flight, despite the engine chip light turning on and the contamination of the filings detector, disregarding previous events of a similar nature.

Such decisions may have denoted a deficient analysis by the aircraft crew of the risks involved, and consequent inadequate decision-making.

- **Managerial oversight – undetermined.**

There was inadequate planning and management supervision, both in the macro aspect and within the DOA, directly impacting Flight Safety and the organizational culture of the crewmembers.

4. SAFETY RECOMMENDATION.

A proposal of an accident investigation authority based on information derived from an investigation, made with the intention of preventing accidents or incidents and which in no case has the purpose of creating a presumption of blame or liability for an accident or incident. In addition to safety recommendations arising from accident and incident investigations, safety recommendations may result from diverse sources, including safety studies.

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 at the publication of this report:

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

A-073/CENIPA/2018 - 01 Issued on 12/05/2022

Evaluate the feasibility of issuing a Special Airworthiness Bulletin, to alert maintenance organizations and operators of model BELL-407 helicopters about the observance of the correct maintenance procedures referred to in this investigation.

A-073/CENIPA/2018 - 02 Issued on 12/05/2022

Work with Helisul Air Taxi Ltd., for that company to adopt maintenance practices that strictly follow the procedures established in technical orders and maintenance manuals of aeronautical product manufacturers.

A-073/CENIPA/2018 - 03 Issued on 12/05/2022

Disclose the lessons learned in this investigation to the Federal Highway Police so that the operator prioritizes the implementation of an operational safety culture within that organization, as recommended by the RBAC nº 90.

5. CORRECTIVE OR PREVENTATIVE ACTION ALREADY TAKEN.

On 11APR2019, the ANAC Resolution nº 512 approved the RBAC nº 90, entitled: "Requirements for Special Public Aviation Operations", in which the following general requirements for administration personnel of Public Air Units were established (UAP):

> (a) The UAP must have qualified technical and administrative personnel with specific attributions to maintain the operational safety performance of the Unit.
>
> (b) The UAP must have, at a minimum, the following administrative personnel:
>
> (1) UAP manager, under section 90.35 of these Regulations;
>
> (2) GSO, under section 90.37 of these Regulations;
>
> (3) chief of operations, under section 90.39 of these Regulations; and
>
> (4) responsible for controlling the maintenance of UAP's aircraft, as defined by it or in specific regulations.

On December 5th, 2022.