COMANDO DA AERONÁUTICA

CENTRO DE INVESTIGAÇÃO E PREVENÇÃO DE ACIDENTES AERONÁUTICOS

FINAL REPORT
A - 207/CENIPA/2013

OCCURRENCE:	**ACCIDENT**
AIRCRAFT:	**PR-MXM**
MODEL:	**R66**
DATE:	**20NOV2013**

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 20 November 2013 accident with the R66 aircraft, registration PR-MXM. The aeronautical accident was classified as “loss of control in flight”.

The pilot lost control of the aircraft in an abrupt manner when it was passing the altitude of 400ft at the beginning of the descent procedure towards the landing site. The aircraft separated in three parts still in flight, and fell vertically on a body of water.

The aircraft sustained substantial damage.

The pilot suffered fatal injuries.

An accredited representative of the *National Transportation Safety Board* – NTSB, USA, was designated for participation in the investigation.

CONTENTS

GLOSSARY OF TECHNICAL TERMS AND ABBREVIATIONS

ANAC	(Brazil's) National Civil Aviation Agency
CA	Airworthiness Certificate
CMA	Aeronautical Medical Certificate
CENIPA	Aeronautical Accident Investigation and Prevention Center
CG	Center of Gravity
CHT	Technical Qualification Certificate
CIV	Pilot's Flight Logbook
DCTA	Aerospace Technology and Science Department
DIVOP	Technical Bulletin
FAR	Federal Aviation Regulation
FAA	Federal Aviation Administration
FSB	Flight Standardization Board
IAM	Inspeção Anual de Manutenção
Lat	Latitude
Long	Longitude
METAR	Routine Meteorological Aerodrome Report
MPH	Manual of Homologation Procedures
NTSB	National Transpostation Safety Board
PPH	Private Pilot (Helicopter category)
PCH	Commercial Pilot (Helicopter category)
RBAC	Brazilian Civil Aviation Regulation
RPM	Revolutions per minute
RS	Safety Recommendation
SBJR	ICAO location designator – *Jacarepaguá* Aerodrome
SFAR	Special Federal Aviation Regulation
SIWS	ICAO location designator – Porto Bello Hotel helipad
SERIPA	Aeronautical Accident Investigation and Prevention Service
SIPAER	Aeronautical Accident Investigation and Prevention System
TCDS	Type Certificate Data Sheet
TMA-RJ	Terminal Control Area – Rio de Janeiro
TPP	Private Air Services
UTC	Coordinated Universal Time
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions
V_{ne}	Never Exceed Airspeed

1. FACTUAL INFORMATION

AIRCRAFT	**Model:** R66 **Registration:** PR-MXM **Manufacturer:** Robinson Helicopter	**Operator:** Hotel Portobello S/A
OCCURRENCE	**Date/time:** 20NOV2013 / 10:23 UTC **Location:** Junqueira Beach **Lat.** 22º59'20"S **Long.** 044º15'00"W **Municipality – State:** Mangaratiba - RJ	**Type:** Loss of control in flight

1.1 History of the occurrence

At 10:02 UTC, the aircraft departed from SBJR destined for the Hotel Porto Bello Helipad (SIWS) in the municipality of *Mangaratiba*, State of Rio de Janeiro, on a ferry flight, with only the pilot on board.

The aircraft was passing the altitude of 400ft while descending towards the destination when all of a sudden the pilot lost control of it. The helicopter broke in three parts and fell vertically on the water.

1.2 Injuries to persons

Injuries	Crew	Passengers	Third parties
Fatal	**1**	-	-
Serious	-	-	-
Minor	-	-	-
Uninjured	-	-	-

1.3 Damage to the aircraft

The aircraft sustained substantial damage to the whole structure.

1.4 Other damage

None.

1.5 Information on the personnel involved

1.5.1 Flight experience of the crew

Hours Flown	
	Pilot
Total	627:48
Total in the last 30 days	02:35
Totalin the last 24 hours	00:20
In this type of aircraft	236:50
In this type in the last 30 days	02:35
In this type in the last 24 hours	00:20

N.B.: Source of information on the hours flown: Pilot's Flight Logbook.

1.5.2 Professional formation

The pilot did his Private Pilot course (helicopter category) at the *Escola de Aviação SKYLAB* in 2008.

1.5.3 Validity and category of licenses and qualification certificates

The pilot had a Commercial Pilot license (helicopter category), and his technical qualification for R66 type aircraft was valid.

1.5.4 Qualification and experience in the type of flight

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

1.5.5 Validity of the medical certificate

The pilot had a valid Aeronautical Medical Certificate (CMA).

1.6 Aircraft information

The R66 aircraft (SN0195) was manufactured by the ROBINSON HELICOPTER COMPANY in 2012, and was registered in the Private Air Services category.

Its airworthiness certificate (CA) was valid.

The airframe, engine, and rotor logbook records were up-to-date.

Although the investigation commission was not able to determine the weight of the aircraft at the moment of the occurrence, the helicopter was presumably within the weight and balance limits specified by the manufacturer.

The last inspection of the aircraft (Annual Maintenance Inspection) was done on 12 November 2013 by HELIBASE AVIAÇÃO in Arujá, State of São Paulo. After the inspection, the aircraft flew 2 hours and 35 minutes.

The last maintenance of the aircraft (600 hours / 12 months) was done on 3 September 2013 by HELIBASE AVIAÇÃO in Arujá,State of São Paulo. The aircraft flew 67 hours after the overhaul.

The *Rolls Royce* 250-C300/A1 engine (SN RRE-200199) installed in the aircraft since new had a total 365 hours, the same total of the airframe.

1.7 Meteorological information

The weather at the aerodromes of departure and destination, as well as en route, was favorable for VFR operations.

See the METARs below of the aerodromes in the region, relative to 20 November 2013 (10:00 UTC):

METAR SBJR 201000Z 36006KT CAVOK 28/24 Q1014=

METAR SBSC 201000Z 02008KT CAVOK 26/22 Q1014=

METAR SBAF 201000Z 00000KT CAVOK 26/20 Q1015=

METAR SBGL 201000Z 07004KT CAVOK 26/20 Q1015=

METAR SBRJ 201000Z 34005KT CAVOK 28/22 Q1014=

According to accounts, the approximate wind direction in the site of the occurrence varied between 315º and 340º, with strength between moderate and strong.

There were no records of turbulence in the Rio de Janeiro Terminal Area (TMA-RJ), nor any Aerodrome warnings regarding the possibility of strong winds with gusts.

1.8 Aids to Navigation

Nil.

1.9 Communications

Nil.

1.10 Aerodrome information

The occurrence was outside of aerodrome area.

1.11 Flight recorders

Neither required nor installed.

1.12 Wreckage and impact information

The radar image of the route flown by the aircraft shows that it flew close to Junqueira Beach, which lies at the foot of the south face of a hill with maximum elevation of 1,100ft (Figures 1 and 2).

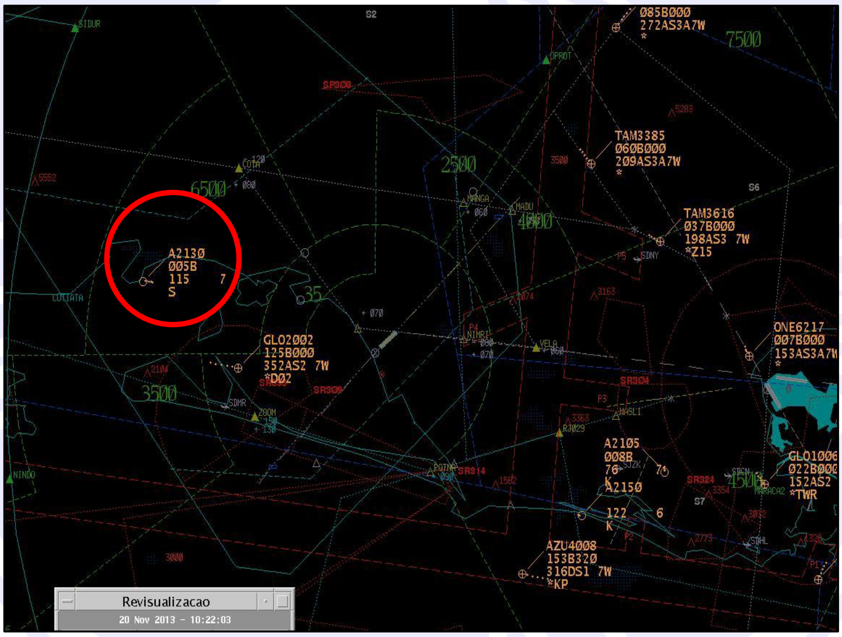

Figure 1 – Radar image prior to the occurrence involving the PR-MXM. In highlight (red circle), the position of the aircraft flying over the south side of Junqueira beach elevation.

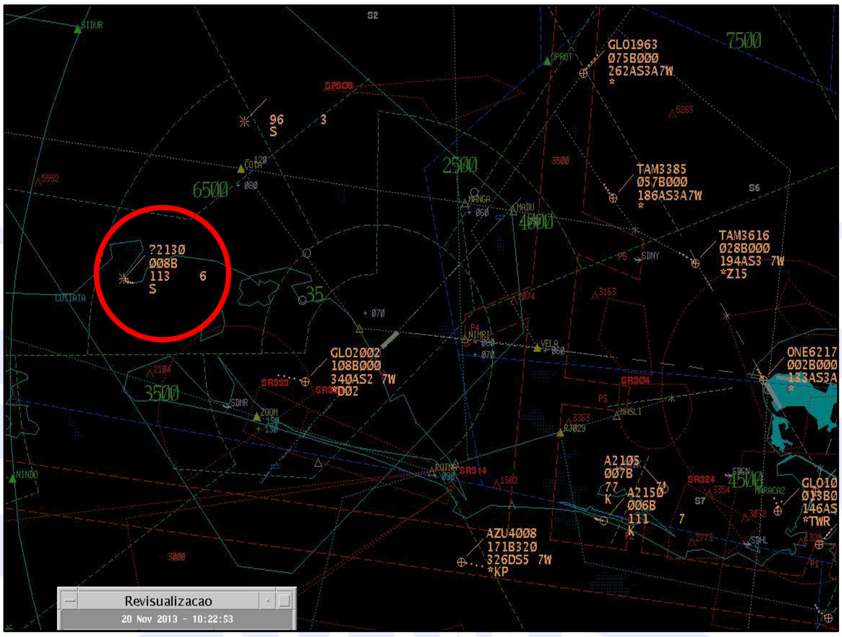

Figure 2 – Radar image shortly before the occurrence with the PR-MXM. In highlight (red circle) the position of the aircraft flying around the Junqueira beach elevation.

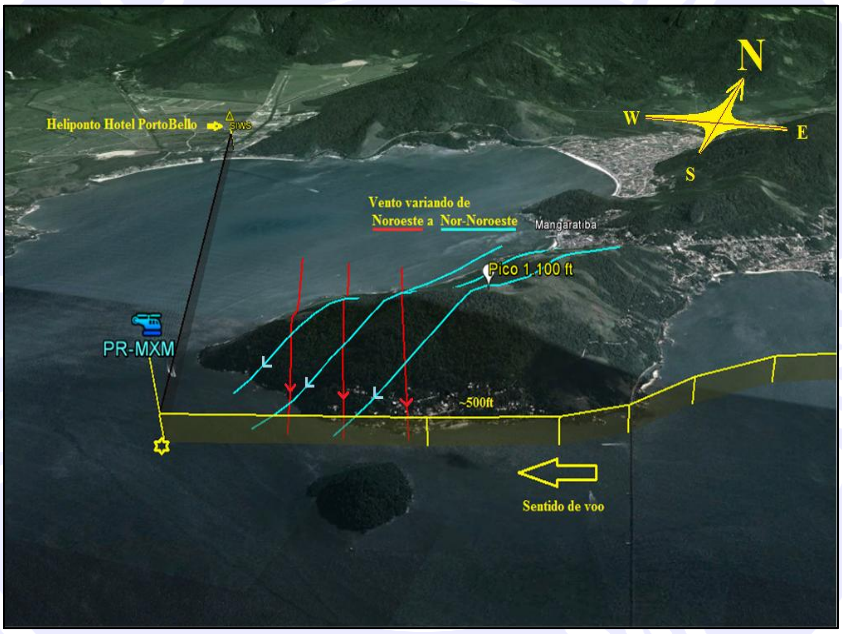

Figure 3 – Sketch of the route, wind (estimated), and relief.

During the descent, the aircraft sustained a sudden loss of control, broke into three parts, and plummeted vertically toward the water.

From the reports made by local residents, it was possible to make a triangulation based on the position of each one, and retrieve the aircraft wreckage, as shown in the figures 4 and 5.

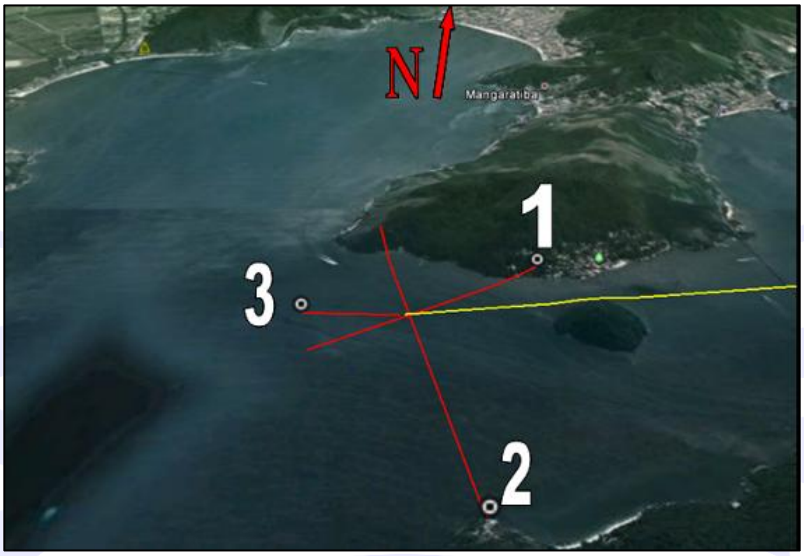

Figure 4 – Triangulation made according to the position of the witnesses.

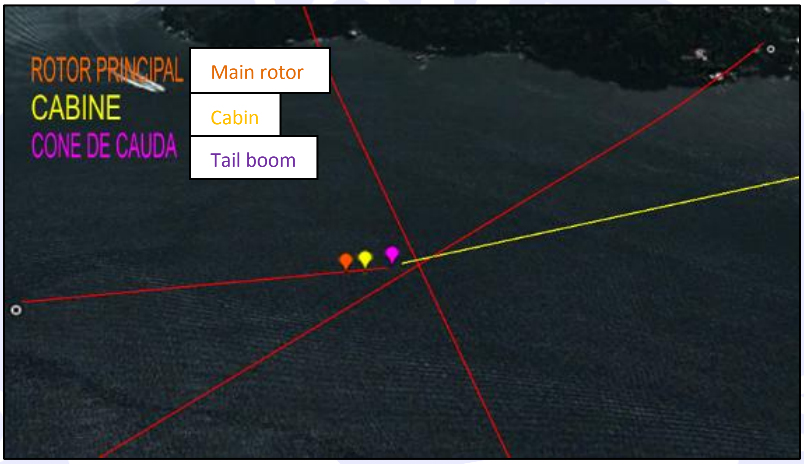

Figure 5 – Sketch of the places where the parts of the aircraft were found.

The wreckage retrieved was taken to the SERIPA III hangar, where a bi-dimensional reconstitution was made, as illustrated in figures 6, 7, and 8.

Figure 6 – 2D-reconstruction of the aircraft in the SERIPA III hangar.

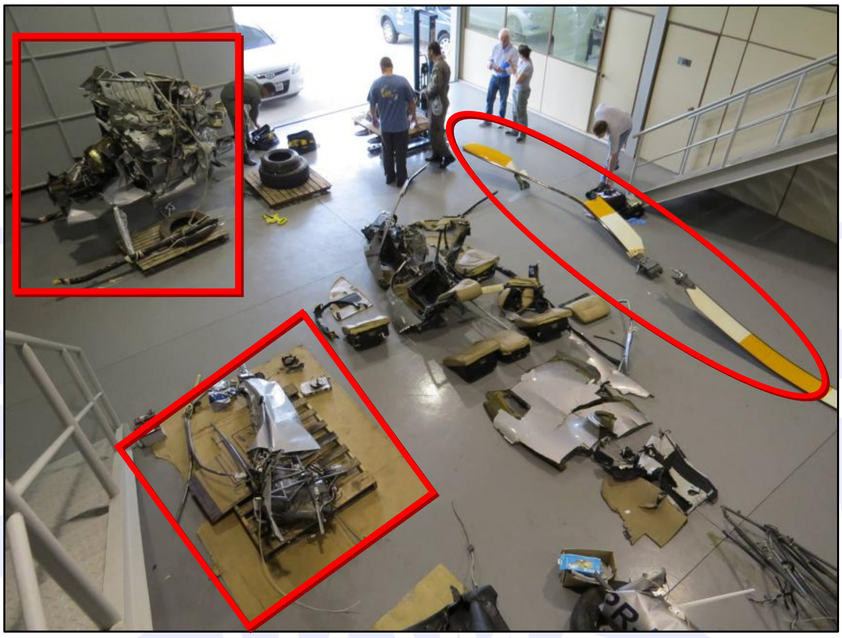

Figure 7 – 2D-reconstruction of the aircraft in the SERIPA III hangar. In highlight, the main transmission box, part of the cabin, and main rotor.

Figure 8 – Reconstruction of the aircraft in the SERIPA III hangar, with the tail boom in highlight.

During the reconstruction of the aircraft, the investigation commission observed that one of the main rotor blades was deflected upward on its first one-third measured from the blade-root (Figure 9).

The other main rotor blade had a downward deflection close to its root (Figure 10), and a bend to the left on the leading edge in the direction of rotation, with absence of material of the blade profile, measuring approximately 1 meter. At about 2.10 meters from the blade root, there was a break perpendicular to the blade length (Figure 11).

Figure 9 – Main rotor blade deflected upward.

Figure 10 – Main rotor blade deflected downward.

Figure 11 – Leading edge of the blade showing curvature in the direction of rotation, absence of material of the blade profile, and a fracture perpendicular to blade length.

The left skid had a fracture in the back (Figure 12).

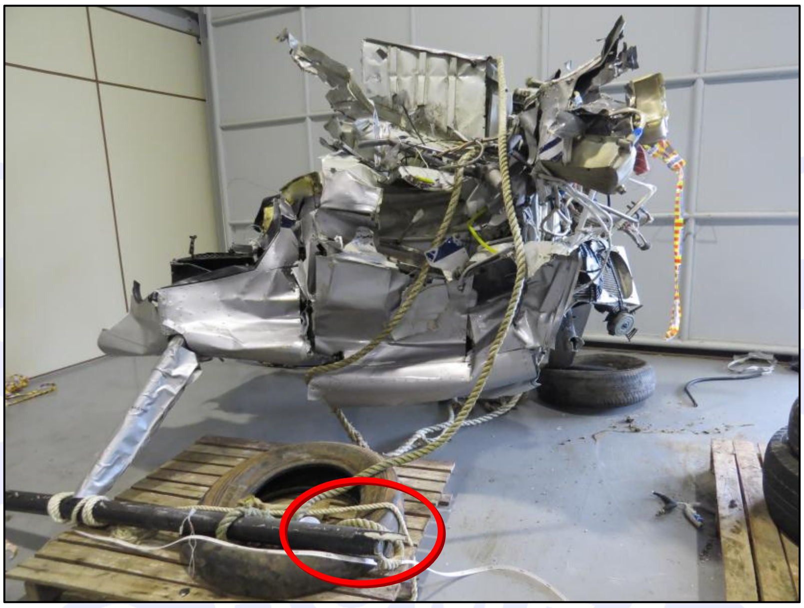

Figure 12 – Left ski with a breakage in the back part.

The teeter stops of the main rotor head were broken (Figure 13).

Figure 13 – Broken teeter stop of the main rotor head.

The forward strut fairing of the left skid presented deformation (Figure 14), while the strut fairing of the right skid and part the right side of the fuselage had little damage (Figure 15).

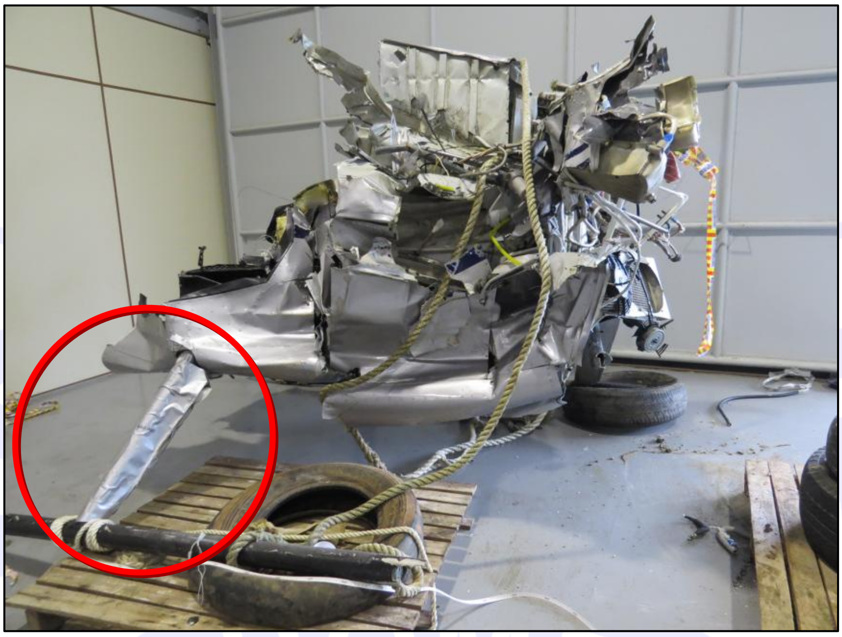

Figure 14 – Forward strut fairing with deformation.

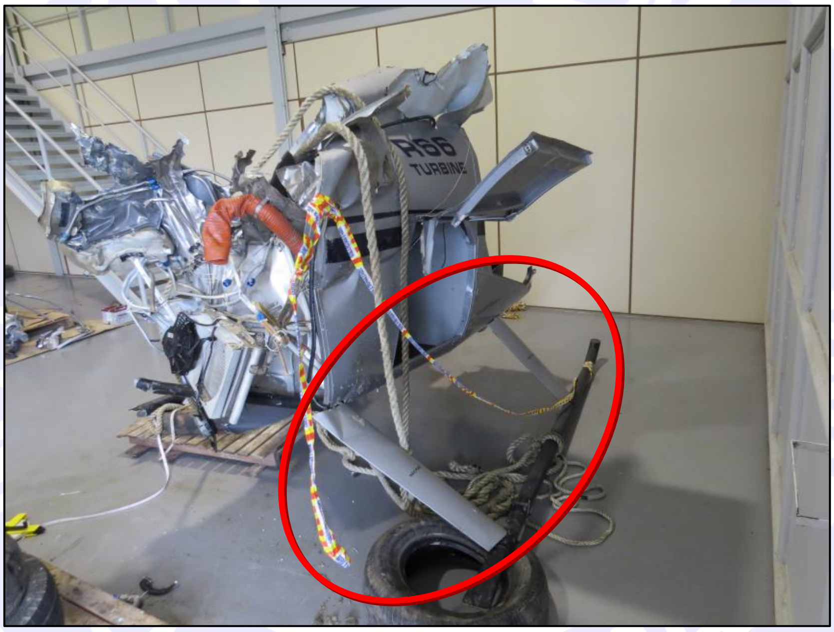

Figure 15 – Strut fairing of the right skid and part of the fuselage with little damage.

The tail boom had a breakage due to torsion from the left to the right, as seen from above (Figure 16).

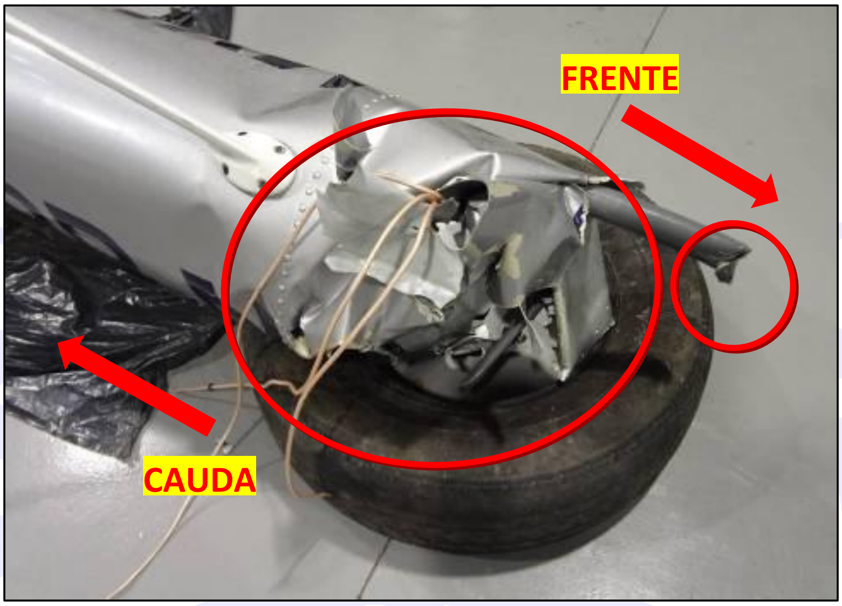

Figure 16 – Tail boom with breakage due to torsion from the left to the right, viewed from above.

1.13 Medical and pathological information

1.13.1 Medical aspects

The investigation commission found no evidence of physiological issues or incapacitation affecting the pilot's performance.

1.13.2 Ergonomic information

Nil.

1.13.3 Psychological aspects.

No evidence was found of psychological issues that might have affected the pilot's performance.

1.14 Fire

No evidence was found regarding either inflight or post-impact fire.

1.15 Survival aspects

Nil.

1.16 Tests and research

After the retrieval of the aircraft wreckage, the aircraft engine was examined at the headquarters of the SERIPA III with the participation of the investigator in charge (IIC), as well as representatives of the Robinson Helicopter Company (aircraft manufacturer) and Rolls-Royce (engine manufacturer).

The engine analysis report stated that there was no evidence of problems that could have hindered the normal operation of the aircraft engine.

The pitch links (Figure 17), the blade spindles (Figure 18), the cyclic control assembly (Figure 19), and the frame (Figure 20) were sent to the Aerospace Technology and Science Department (DCTA) for analysis of the components and identification of the type of breakage and possible material failures.

Figure 17 – Pitch links of the aircraft sent to the DCTA for analysis.

The blades were cut off near the root in order to facilitate their transport. The fact that the blades were cut off did not hamper the analysis of the spindles.

Figure 18 – Spindles of the aircraft sent to the DCTA for analysis.

The cyclic control assembly sent to DCTA included the friction adjustment mechanism.

Figure 19 – Cyclic control assembly, including the friction adjustment mechanism, sent to the DCTA.

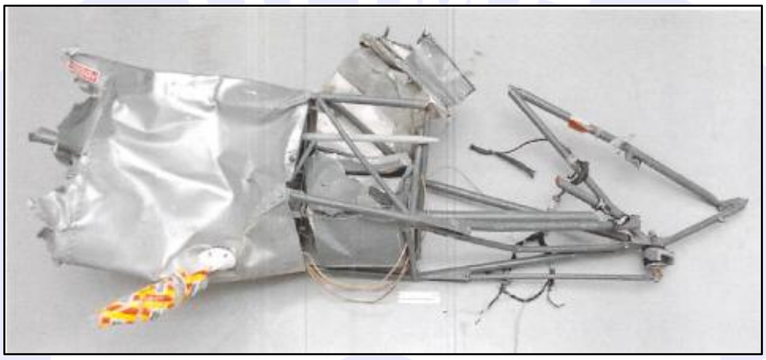

Figure 20 – Aircraft frame sent to the DCTA.

The DCTA report concluded that all components analyzed had signs of damage due to overload.

The fracture surfaces of the blade spindles and pitch links had dents and an incline of approximately 45 degrees, indicative of overload (Figures 21 and 22).

Figure 21 – Blade spindle fracture surface.

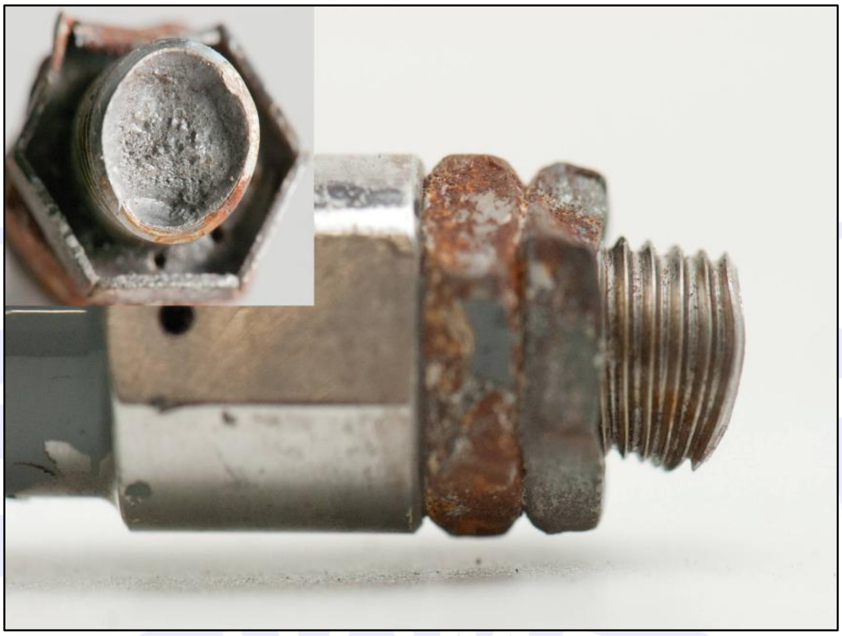

Figure 22 – Bending and deformation with a 45°-incline.

The cyclic control featured aspects, such as dents and deformation, mainly in deflection (Figure 23).

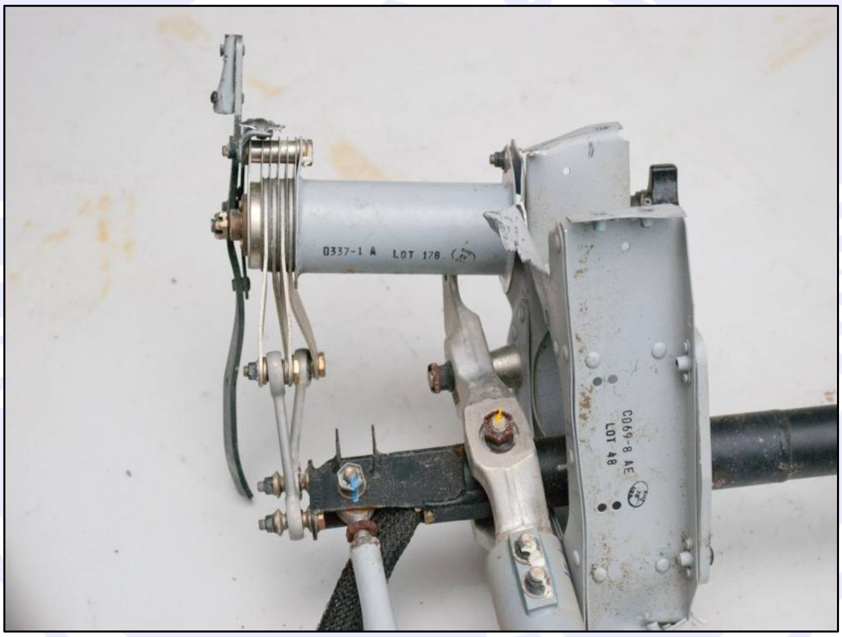

Figure 23 – Bending and deformation in the movable parts of the cyclic control caused by overload.

The moving parts of the cyclic had relatively free movements, in spite of the level of corrosion that the parts had sustained on account of the period it stayed immersed in saline water.

The cyclic friction system was set in the counterclockwise stop position or minimum friction position.

Figure 24 – Cyclic friction adjustment bolt at the counterclockwise stop: no friction applied.

In Figure 24, it is possible to observe that the nut and bolt of the mechanism present signs of corrosion throughout the surface. In this counterclockwise stop condition, there is no separation of the nut-bolt from the mechanism stop. When the knob of the cyclic friction adjustment was turned in a clockwise direction, there was separation between the nut-bolt and the mechanism stop, as shown in Figure 25.

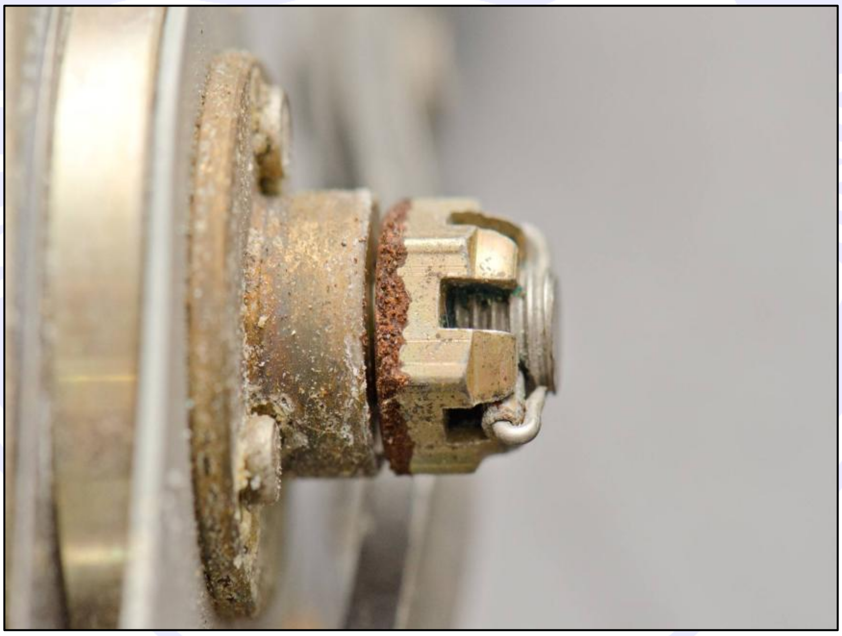

Figure 25 – Separation between the nut and bolt of the friction adjustment mechanism stop.

At this time, it was possible to see that there was no corrosion inside the stop of the “nut-bolt” system (Figure 26), indicating that these surfaces were not exposed during the time the aircraft remained submerged in saline water.

Figure 26 – Absence of corrosion inside the “stop” of the nut-bolt system.

In the analysis of the frame, only signs of fracture due to overload were found. The existing corrosion in the observed parts did not seem to have begun prior to the accident. Aspects, such as the 45º-incline of the fracture surface (Figure 27), and plastic deformations in the flight control tubes (Figure 28), in addition to other aspects such as "fish mouth" in the breakage of the tubes (Figure 29), which are characteristic of failure due to overload, were observed in the fractures of the frame.

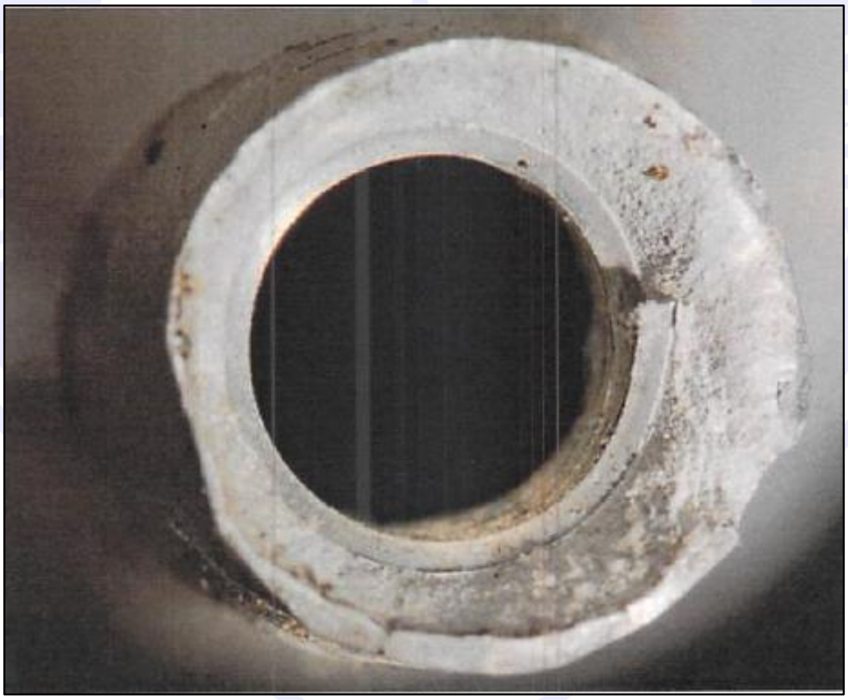

Figure 27 – Flight control tube broken as a result of overload, with a 45º-incline on the fracture surface.

Figure 28 – Flight control tube broken as a result of overload, showing plastic deformation.

Figure 29 – Frame tube broken as a result of overload, with “fishmouth” type deformation at the point of breakage.

No aspects of fracture attributable to fatigue were found in the parts examined by the DCTA.

The main transmission of the aircraft was examined at the manufacturer's headquarters in Torrance, California, USA, in the presence of investigators of the SERIPA III, and representatives of the National Transportation Safety Board (NTSB), Federal Aviation Administration (FAA) and Robinson Helicopter Company (Figure 30).

The report of the analysis stated that no evidence was found of material or mechanical failure that could result in abnormal operation of the component.

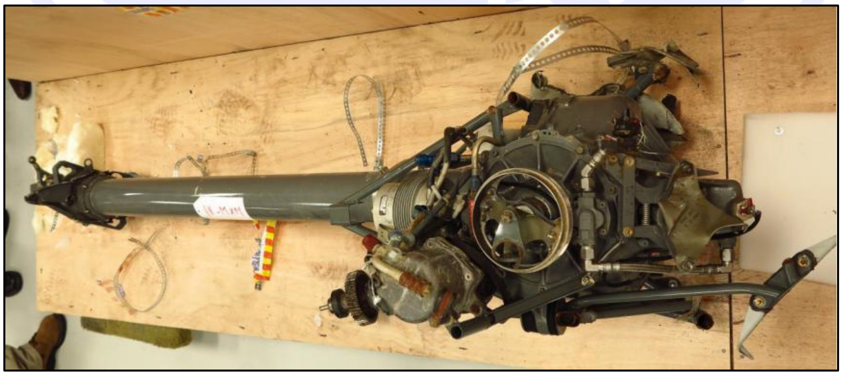

Figure 30 – Main transmission of the aircraft analyzed at the manufacturer’s headquarters.

1.17 Organizational and management information

Nil.

1.18 Operational information

After takeoff from SBJR, the aircraft flew VFR to SIWS, on a route close to the coastline. The expected enroute elapse time was 30 minutes, and only the pilot was on board. The aircraft would be used on another flight departing from the hotel.

Given the wind direction in the site of occurrence, the aircraft flew on the leeward side of the hill where, normally, downdrafts are expected due to the existence of natural obstacles (Figure 31).

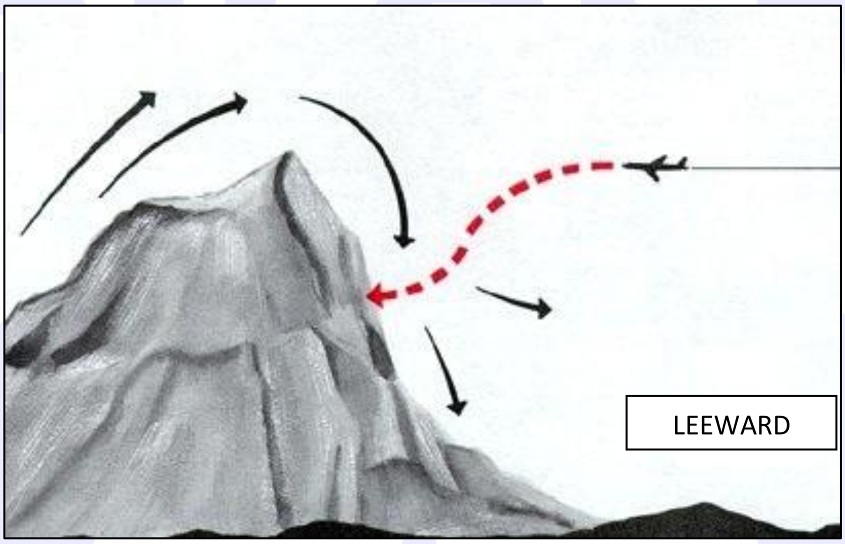

Figure 31 – Illustration of wind predominance close to elevations.

At Junqueira Beach, locals reported having viewed the aircraft flying normally and making a slight turn to the right. Then they heard a loud bang, and saw objects falling vertically through the air and landing on the sea. The tail boom was separated from the cabin. Witnesses said they saw neither fire nor smoke.

The terminal radar located on Santa Cruz Air Force Base, at a distance of 18 NM and in direct line of sight with the aircraft, showed in the final minutes of the flight an aircraft ground speed varying between 122kt and 113kt, at an altitude between 500ft and 400ft.

It was not possible to determine the weight of the aircraft at the time of the occurrence. However, the investigation commission verified that the aircraft was refueled with 229 liters in *Jacarepaguá* Aerodrome.

Considering that the maximum capacity of the aircraft fuel tank was 282 liters, and that the fuel tank had a residual non-usable amount of three liters, it was possible to estimate that the aircraft had an amount of fuel varying between 232 and 282 liters at the moment of departure.

Moreover, considering that the density of the aviation kerosene used was 0,8196 kg/l, it is possible to estimate that there was an amount between 190kg and 231kg of fuel in the tank.

Adding the pilot's weight (80kg) and the basic aircraft weight (603kg) to the above figures, the resulting weight at the moment of departure should be between 873 and 914 kg.

According to the Aircraft manual, the Robinson R66 Maximum Takeoff Weight was 1,225kg.

The section 2 of the *Pilot´s Operating Handbook (Limitations)* established that the *Never-Exceed Airspeed* (V_{ne}) on account of the aircraft weight was 130kt (Indicated Airspeed) for weights over 998kg, 140kt for weights below 998kg, and 100kt for autorotation (Figure 30).

ROBINSON
MODEL R66

SECTION 2
LIMITATIONS

SECTION 2

LIMITATIONS

AIRSPEED LIMITS

NEVER-EXCEED AIRSPEED (V_{ne})

2200 lb (998 kg) TOGW or above	130 KIAS
Below 2200 lb (998 kg) TOGW	140 KIAS
Autorotation	100 KIAS

For V_{ne} reductions with altitude and temperature, see placards on page 2-9.

Figure 30 – Aircraft speed limits on account of weight.

On page 2-9 of the same section, the VNE limits are described as a function of temperature and pressure altitude. For a wide range of temperatures at sea level (between -30°C and 40°C), the aircraft airspeed limit was 130kt (Figure 31).

POWER-ON V_{ne} - KIAS

PRESS ALT-FT	OAT- C° -40	-30	-20	-10	0	10	20	30	40	50
SL	129									127
2000	124		130					126	122	
4000	119	127			129	125	121	117	114	
6000	114	122		125	121	117	113	108		
8000	109	117	121	116	112	107	102	97		
10000	105	112	112	106	101	96	91	86		
12000	100	106	101	95	90					
14000	96	95	89	NO FLIGHT						
16000	90									

BELOW 2200 LB (998 KG) TOGW, ADD 10 KIAS

NOTE: 65 KIAS MAXIMUM ABOVE 83% TORQUE

Figure 31 – Aircraft speed limits on account of temperature and pressure altitude. (*Section 2 – Limitations, page 2-9, R66 Pilot´s Operating Handbook*).

1.19 Additional information

1.19.1 Mast bumping

Mast bumping is a characteristic aerodynamic effect of two-blade helicopters, which have a main rotor head of the semi-rigid type.

Mast bumping is a phenomenon that occurs only in helicopters equipped with semi-rigid rotors, and is often triggered by inappropriate action by the pilot on the cyclic control in a flight condition with load factor below 0.5 g.

The mast bumping event causes damage to the main rotor head and, in more severe cases, to the rotor mast itself. The most severe consequence is the breakup of the aircraft in flight with separation of the rotor and fuselage (in-flight breakup).

Inappropriate cyclic control inputs by the pilot may trigger a low-G condition, with reduction of the main rotor traction. In aircraft with a tail rotor located above the CG, this condition generates a roll tendency to the side of the tail rotor traction (Figure 32).

Abrupt movements of the cyclic in straight and level flight, or at the end of a climb, may put the helicopter in a flight condition with a load factor below 1g (low-G) or even negative G. With a low load factor, the traction of the semi-rigid main rotor in flight is significantly reduced, to the point that the lateral actuation of the cyclic has little or no effectiveness. Thus, the tail rotor, being usually installed above the CG of the aircraft, generates a roll momentum to the side of its traction.

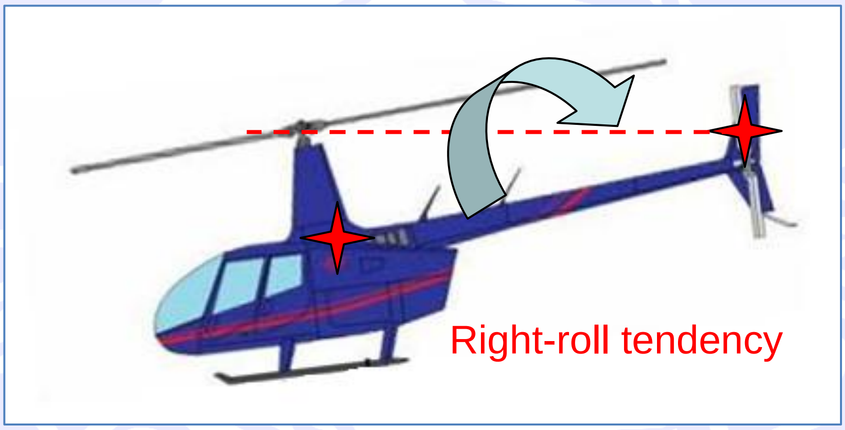

Figure 32 – Illustration explaining the right-roll tendency under *low-G* conditions.

In helicopters with rotors turning counterclockwise, if there is an attempt to counteract the natural tendency of the aircraft to roll to the right, mast bumping may occur with catastrophic consequences, such as an in-flight breakup.

On a flight with a low load factor, the main rotor still responds to the cyclic inputs but, since it is no longer producing effective traction, the response is not transmitted to the fuselage. If the pilot tries to correct the right-roll momentum by moving the cyclic to the left, something that is perfectly feasible, the pitch angle of the blades may increase to the extent of allowing the occurrence of mast bumping. Due to unpredictable oscillations of a system sustained rotor separation, such condition may result in a fuselage breakup in flight.

In addition to inappropriate cyclic control inputs by the pilot, other conditions may start a mast bumping condition, such as turbulence, wind gusts, and lateral flights at a speed close to the maximum speed allowed in the manual.

1.19.2 Aircraft characteristics

R66 helicopters have a two-blade rotor of the semi-rigid type (*seesaw*).

As described in the item 1.19.1, semi-rigid rotors are susceptible to the occurrence of the mast bumping phenomenon, if they are subjected to flight conditions with low or negative G forces, this phenomenon may be induced or aggravated.

This phenomenon may be aggravated by a forward cyclic input, as described in the flight manual, R66 Pilot's Operating Handbook, published by the manufacturer, specifically at CAUTION of page 2-5, Section 2 - Limitations (Figure 33)..

ROBINSON MODEL R66 — SECTION 2 LIMITATIONS

FLIGHT AND MANEUVER LIMITATIONS

Aerobatic flight prohibited.

CAUTION

Abrupt control inputs may produce high fatigue stresses and cause catastrophic failure of a critical component.

Low-G cyclic pushovers prohibited.

CAUTION

A pushover (forward cyclic maneuver) performed from level flight or following a pull-up causes a low-G (near weightless) condition which can result in catastrophic loss of lateral control. To eliminate a low-G condition, immediately apply gentle aft cyclic. Should a right roll commence during a low-G condition, apply gentle aft cyclic to reload rotor <u>before</u> applying lateral cyclic to stop roll.

Maximum operating density altitude 14,000 feet.

Maximum operating altitude 9000 feet AGL to allow landing within 5 minutes in case of fire.

Closing throttle (twist grip) in flight prohibited above 10,000 feet density altitude to avoid possible engine flameout.

Closing throttle (twist grip) in flight prohibited with cabin heat ON to avoid possible engine flameout.

Minimum crew is one pilot. Solo from right seat only.

Forward left seat belt must be buckled.

Operation up to 100 KIAS approved with any combination of cabin doors removed. All seat belts must be buckled and loose items in cabin must be properly secured during doors-off flight.

FAA APPROVED: 25 OCT 2010 — 2-5

Figure 33 – Prohibition of aerobatic flight, and warnings concerning *low-G.*

The Safety Notice no. 11 - Section 10 - also describes the danger of a low-G condition caused by cyclic control forward inputs after a climb or at level flight, describing the strong right-roll tendency produced by the combination of the reaction of the main rotor torque with the traction of the tail rotor (Figure 34).

ROBINSON
HELICOPTER COMPANY

Safety Notice SN-11

Issued: Oct 82 Rev: Nov 00

LOW-G PUSHOVERS - EXTREMELY DANGEROUS

Pushing the cyclic forward following a pull-up or rapid climb, or even from level flight, produces a low-G (weightless) flight condition. If the helicopter is still pitching forward when the pilot applies aft cyclic to reload the rotor, the rotor disc may tilt aft relative to the fuselage before it is reloaded. The main rotor torque reaction will then combine with tail rotor thrust to produce a powerful right rolling moment on the fuselage. With no lift from the rotor, there is no lateral control to stop the rapid right roll and mast bumping can occur. Severe in-flight mast bumping usually results in main rotor shaft separation and/or rotor blade contact with the fuselage.

The rotor must be reloaded before lateral cyclic can stop the right roll. To reload the rotor, apply an immediate gentle aft cyclic, but avoid any large aft cyclic inputs. (The low-G which occurs during a rapid autorotation entry is not a problem because lowering collective reduces both rotor lift and rotor torque at the same time.)

Never attempt to demonstrate or experiment with low-G maneuvers, regardless of your skill or experience level. Even highly experienced test pilots have been killed investigating the low-G flight condition. Always use great care to avoid any maneuver which could result in a low-G condition. Low-G mast bumping accidents are almost always fatal.

NEVER PERFORM A LOW-G PUSHOVER!!

Figure 34 – *Safety Notice* 11.

Still in Safety Notice SN-32 – High Winds or Turbulence - Section 10 - there is a description of procedures which should be adopted and/or avoided in the presence of high wind conditions or turbulence, so as to reduce the possibility of *Mast Bumping* associated with inadequate control inputs by the pilot (Figure 35).

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HELICOPTER COMPANY

Safety Notice SN-32

Issued: March 1998 Revised: May 2013

HIGH WINDS OR TURBULENCE

A pilot's improper application of control inputs in response to high winds or turbulence can increase the likelihood of a mast bumping accident. The following procedures are recommended:

1. If turbulence is expected, reduce power and use a slower than normal cruise speed. Mast bumping is less likely at lower airspeeds.
2. If significant turbulence is encountered, reduce airspeed to 60 - 70 knots.
3. Tighten seat belt and firmly rest right forearm on right leg to prevent unintentional control inputs.
4. Do not overcontrol. Allow aircraft to go with the turbulence, then restore level flight with smooth, gentle control inputs. Momentary airspeed, heading, altitude, and RPM excursions are to be expected.
5. Avoid flying on the downwind side of hills, ridges, or tall buildings where the turbulence will likely be most severe.

The helicopter is more susceptible to turbulence at light weight. Use caution when flying solo or lightly loaded.

Figure 35 – *Safety Notice* 32.

1.19.3 SFAR73 and Flight Standardization Board – FSB – Report, Robinson R-66 Helicopter

In the investigations of accidents involving R22 and R44 helicopters, American flight safety authorities reached the conclusion that these types of aircraft were associated with a larger number of fatal accidents due to contact between the main rotor and the fuselage than other types of helicopters with piston engines.

In the R22, the number of accidents in which either main rotor low RPM or a low-G condition had been present was larger than in the other models of the helicopters investigated.

Thus, complementing the Federal Aviation Regulation (FAR) Part 61, in 1995, the FAA issued the *Special Federal Aviation Regulation N.73* (SFAR 73), which had the purpose of establishing training criteria and experience requirements for everyone who intended to operate or work as pilot in command of R22 or R44 Robinson helicopters.

According to the FAA, after the adoption of the SFAR 73, there was a significant reduction in the number of accidents involving mast bumping or contact of the main rotor with the fuselage. According to studies conducted by the FAA in 2008, the benefits of the SFAR 73 outran the cost of its implementation

With the advent of the R66 Robinson Helicopter, the FAA issued in 2010 a memorandum (*Flight Standardization Board – FSB – Report, Robinson R-66 Helicopter*), dealing with the validation of training, check and update requirements for crews operating the R66 Robinson helicopter in accordance with FAR Parts 91 and 135. This FSB Report was also issued as support guidance for Air Companies operating under Parts 61 and 141, as well as for FAA Main Operating Inspectors, in the utilization of applicable training programs. An Attachment to the FSB Report contained a summary of the on-the-ground an in-flight training program of the R66 Robinson helicopter.

In this memorandum, the FSB concluded that the R66 Robinson helicopter was a refined variant of the R44. The cabin of the R66 is 8 inches wider and the main rotor mast is 8 inches higher than the corresponding parts of the R44. The gross weight was increased to 2,700 pounds. The main rotor blades have a longer chord and are heavier than the ones utilized in the R44. Besides, a RR300 turbine replaced the six-cylinder piston engine. Many of the R66 components are similar to those of the R44, with addition of extra material for the strengthening of critical areas.

The FSB was initially concerned with the content of the SFAR 73, which specified training, evaluation, and check requirements relative to R22 and R44 Robinson helicopters. Owing to the fact that the R66 is a larger variant of the R22 and R44 helicopters, the FSB decided to evaluate the R66 as to its operational suitability, specific characteristics of flight, specific requirements relative to pilot training, evaluation, and checks.

The FSB identified that the R66 did not have piloting peculiar or uncommon characteristics in relation to the themes listed in the SFAR 73: (I) Energy Management, (II) Mast Bumping, (III) Low RPM or Blade Stall, (IV) Hazards associated with low-G and (V) Low RPM of the rotor.

The R66 showed normal performance, consistent with other helicopters with a similar rotor design. Nevertheless, the FSB noted that it was essential for the pilot to have knowledge of certain aerodynamic factors related to his type of rotor system, including operations with low G and recovery techniques, rotor blade stall potential, energy management and techniques for recovery from low RPM of the rotor.

There was consensus within the FSB that, due to the fact that the R66 performance and flight aspects were compatible with helicopters of a similar design, there was no need of a specific training requirement concerning peculiar flight characteristics. Moreover, the FSB defined that the inclusion of the R66 in the SFAR 73 was not appropriate, and that the R66 was not to be utilized as credit for the compliance of the SFAR 73 by R22 and R44 helicopter pilots, since, according to the primary certification authority, there were no type rating requirements for R22, R44, and R66 helicopters.

The SFAR 73 is not applied in Brazil.

1.20 Utilization of other investigation techniques

Nil.

2. ANALYSIS

The conclusion of the engine and main transmission analysis reports showed no evidence of any material of mechanical failure that could have resulted in abnormal operation of these components prior to the occurrence.

At the moment of the accident, the conditions of ceiling and visibility in the departure and destination aerodromes, as well as en route, were favorable for VFR flights.

The wind direction was varying between northwest and north-northwest, at moderate to high intensity. There were no records of turbulence in the TMA-RJ, nor any publication of Aerodrome Warning, concerning the possibility of strong winds with gusts. At Junqueira Beach, locals reported that the wind was strong at the time of the occurrence, and that it was blowing from the continent toward the sea.

It was not possible to determine the weight of the aircraft at the time of the occurrence. However, the investigation commission estimated the weight of the aircraft between 873kg and 914kg, that is, below the maximum takeoff weight prescribed by the manufacturer (Section 2 – Limitations).

After taking off, the aircraft flew VFR along the coastline.

According to the radar, the ground speed of the aircraft while en route was between 122kt and 110kt, that is, within the V_{ne} limits established by the manufacturer.

The aircraft altitude varied between 500ft and 400ft, in a way compatible with a stabilized flight in VMC.

By means of radar synthesis, it was possible to determine that the pilot flew near Junqueira beach, which lies at the foot of an elevation (south side) 1,100ft high in its maximum quota (see Figures 1 and 2). Such flight trajectory passed through a region which, on account of the relief and weather conditions at the time of the occurrence, might present turbulence and down drafts.

Such factors increased the probability of the aircraft to encounter conditions favoring the occurrence of mast bumping or strike of the main rotor blades against the fuselage, and are corroborated by the aircraft manufacturer in the Safety Notice 32, and by the FAA in the Chapter 11 of the FAA-H-8083-21A (*Helicopter Flying Handbook*).

Another possibility for the onset or aggravation of a mast bumping event was directly related to cyclic control inputs by the pilot after encountering turbulent flight conditions.

The commission also analyzed the possibility that the pilot, in the attempt to correct the attitude of the aircraft after experiencing a lack of stability on account of the turbulence, might have moved the cyclic forward, an action that would have aggravated a low-G condition, fostering the onset of mast bumping. These factors are corroborated by the manufacturer in the Safety Notice 11. However, no evidence was found to confirm such possibility.

The possibility of a mast bumping event is also strengthened by the analysis of the aircraft wreckage. It was observed that one of the teeter stops had marks compatible with a possible contact between the main rotor head or blade spindle and the aforementioned protection (figure 13).

It was also observed that one of the main rotor blades had a downward deflection close to its root, an indication that the aircraft had experienced a mast bump/extreme teetering event.

The same blade had a curvature in the direction of rotation (leading edge), with absence of material of the blade profile. This blade curvature in the direction of rotation was compatible with the curvature of the right side of the pilot cabin, indicating a possible collision of the blade with the structure of the aircraft.

The collision of the blade with the aircraft structure justifies the breakage (due to overload) of the entire rotary assembly of the main rotor head, including the spindles and pitch links (Figures 17 and 18).

After the impact of the blade with the aircraft fuselage, there was (possibly) a sudden/instantaneous reduction of the main rotor RPM favoring the breakage (on account of torsion) and subsequent separation of the aircraft tail boom (Figure 16).

Then, on account of inertia, the rotor blade, after colliding with the fuselage, continued its movement and, without the action of the pitch links, entered a negative-pitch angle and ended up striking the back of the left skid, breaking it, as identified in the analysis of the wreckage.

Also, during the investigation, a few aspects were observed in relation to the R66 helicopter certification

According to the primary certification authority of the helicopter, the R66 is a refined variant of the R44 Robinson helicopter.

The FAA issued a memorandum (*Flight Standardization Board* (FSB) *Report*, *Robinson R-66 Helicopter)*, identifying that the R66 had not shown piloting characteristics considered peculiar or uncommon in relation to the themes of the SFAR 73: (I) Energy Management, (II) Mast Bumping, (III) Low RPM or Blade Stall, (IV) Hazards associated with low-G and (V) Low RPM of the rotor.

The R66 showed normal performance, consistent with other helicopters with a similar rotor design. However, it was essential for the pilot to have knowledge of certain aerodynamic factors related to his type of rotor system, including operations with low G, recovery techniques, rotor blade stall potential, energy management and techniques for recovery from low RPM of the rotor.

There was consensus within the FSB that, due to the fact that the R66 performance and flight characteristics were typical and ordinary when compared to helicopters of a similar design, it did not require specific training relative to any peculiar flight characteristics.

Moreover, the FSB defined that the inclusion of the R66 in the SFAR 73 was not appropriate, and that the R66 was not to be used as credit for the compliance of the SFAR 73 by pilots operating R22 or R44 helicopters.

In Brazil, on the occasion of the validation of the R22 and R44 models, the SFAR 73 (*Robinson* R22/R44 *Special Training and Experience Requirements*) had not yet been issued by the primary certification authority.

It was not possible to determine whether the pilot involved in the occurrence had theoretical knowledge or had undergone practice training to recognize the aerodynamic factors related to the main rotor system of the aircraft he was operating.

3. CONCLUSIONS

3.1 Facts

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

b) The pilot had a valid technical qualification certificate (CHT);

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

d) The aircraft had a valid airworthiness certificate (CA);

e) The airframe, engine, and rotor logbook records were up-to-date;

f) The meteorological conditions at the aerodromes of departure and destination, as well as enroute, were favorable for VFR operations;

g) The engine analysis report stated that no evidence had been found of problems that could hinder the normal operation of the engines before the occurrence;

h) The main transmission analysis report stated that no evidence of failure of material or mechanical nature had been found that could have resulted in abnormal operation of the component before the accident;

i) The frame, pitch links, and spindles analysis report stated that the components sustained fracture on account of overload;

j) One of the main rotor blades presented a downward deflection at the beginning of its extension (from the root), and a curvature in the direction of rotation on the leading edge, with absence of material of the blade profile;

k) One of the teeter stops was damaged;

l) The aircraft broke up into three parts in flight, and fell vertically on the water;

m) The aircraft was destroyed; and

n) The pilot suffered fatal injuries.

3.2 Contributing factors

- **Application of controls – undetermined**

It is possible that the pilot, in the attempt to correct the aircraft attitude when experiencing destabilization caused by turbulence, may have moved the cyclic forward, an action that may have aggravated the low-G condition, fostering the onset of mast bumping or the striking of the blades against the fuselage.

- **Adverse meteorological conditions – undetermined**

Although the prevailing weather conditions were favorable to VFR flights, the wind was strong in the site of the occurrence, in a direction that varied from north to north-northwest.

Such windy conditions, associated with the relief in the region, were favorable to the occurrence of turbulent air drafts, which had the potential to create a low-G condition for an aircraft flying through that region.

- **Training – undetermined**

It was not possible to confirm whether the pilot had theoretical knowledge or undergone practice training to recognize the aerodynamic factors associated with the main rotor system of the aircraft he was flying.

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 made upon publication of this report.

To the National Civil Aviation Agency (ANAC):

A-207/CENIPA/2013 - 01 **Issued on 22/04/2016**

Include, in the syllabus of private and commercial helicopter pilot courses, mandatory theoretical classes on the phenomena of low-G and mast bumping.

A-207/CENIPA/2013 - 02 **Issued on 22/04/2016**

Evaluate the applicability and feasibility of delivering the training as described in the SFAR 73 in Brazil.

5. CORRECTIVE AND/OR PREVENTATIVE ACTION ALREADY TAKEN

CENIPA issued a Technical Bulletin (DIVOP) nº. 04/2014 on14 June 2014 on the effect of turbulence on helicopters. The document discussed the possibility of loss of control in flight in the event of a helicopter flight in a region with turbulence and strong winds.

The Robinson Helicopter Company made some changes in the R66 aircraft operating manual:

a) Inclusion of a warning in Section 4 - Normal Procedures with respect to flight in turbulent region, with an instruction to reduce speed while on cruise flight (Figure 42);

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MODEL R66

SECTION 4
NORMAL PROCEDURES

CRUISE

1. Beep RPM as required to 100%.
2. Set torque as desired with collective. Observe torque, MGT, and V_{ne} limits.
3. Verify gages in green, no cautions or warnings.
4. Engine anti-ice as required.

CAUTION

If turbulence is expected, reduce power and use a slower than normal cruise speed.

NOTE

Avoid large, rapid power changes. The engine governor reacts slowly and RPM excursions may occur.

NOTE

When loaded near aft CG limit, slight yaw oscillation during cruise can be stopped by applying a small amount of left pedal.

DOORS-OFF OPERATION

Maximum airspeed with any door(s) off is 100 KIAS. Warn passengers to secure loose objects and to keep head and arms inside cabin to avoid high velocity airstream.

CAUTION

Ensure all seat belts are buckled during door-off flight. Rear outboard seat bottoms may lift if not restrained.

CAUTION

Flight with left door(s) removed is not recommended. Loose objects exiting left doors may damage tail rotor.

FAA APPROVED: 20 JAN 2015 **4-10**

Figure 42 – Change in the aircraft manual regarding flight under conditions of turbulence.

b) In the description of the system, the replacement of the information that the friction adjustment is normally utilized on the ground, by the information that the adjustment is to be used with caution in flight, since excessive use could make it difficult for the pilot to control the helicopter (Figure 43).

ROBINSON
MODEL R66

SECTION 7
SYSTEMS DESCRIPTION

CONTROL FRICTION ADJUSTMENT

Cyclic and collective controls are equipped with adjustable friction devices. The collective friction lever is located near the aft end of the pilot's collective. It is actuated aft to increase friction and forward to release it.

The cyclic friction knob is located left of the cyclic stick. Turning the knob clockwise applies friction to both longitudinal and lateral cyclic.

CAUTION

Control friction must be used with caution in flight. Excessive friction may make the helicopter difficult to control.

The pedals actuate push-pull controls connected directly to the tail rotor pitch control and do not incorporate any friction devices. An elastomeric trim spring provides a left pedal force to balance feedback forces in flight.

ENGINE CONTROLS

A twist grip throttle control is located on each collective stick. The controls are interconnected and actuate the engine fuel control input lever via a push-pull cable. The throttle is normally not used for control but is set either fully closed (idle position) or fully open.

The engine incorporates a hydromechanical governor which attempts to maintain 100% engine output shaft RPM when the throttle is in the open position. A linkage provides the power turbine governor with collective inputs to help anticipate changing power demands.

Large power changes or varying environmental conditions may cause the governor RPM setting to vary by a few percent. A momentary toggle switch (beep switch) on the collective stick is provided to trim, or "beep", the governor setting to the desired RPM. The switch controls an actuator which adjusts the linkage between the collective and power turbine governor. Holding the beep switch up or down will change rotor RPM approximately one percent per two seconds.

REVISED: 20 JAN 2015 7-8

Figure 43 – Change in the aircraft manual regarding control friction adjustment.

Recently, Robinson Helicopter Company added the observation to avoid flying in areas with turbulence or strong winds on the Safety Notice nº 32 (Figure 44)

ROBINSON
HELICOPTER COMPANY

2901 Airport Drive, Torrance, California 90505 Phone (310) 539-0508 Fax (310) 539-5198

Safety Notice SN-32

Issued: March 1998 Revised: May 2013; Feb 2016

HIGH WINDS OR TURBULENCE

Flying in high winds or turbulence should be avoided.

A pilot's improper application of control inputs in response to turbulence can increase the likelihood of a mast bumping accident. If turbulence is encountered, the following procedures are recommended:

1. Reduce power and use a slower than normal cruise speed. Mast bumping is less likely at lower airspeeds.
2. For significant turbulence, reduce airspeed to 60–70 knots.
3. Tighten seat belt and rest right forearm on right leg to minimize unintentional control inputs. Some pilots may choose to apply a small amount of cyclic friction to further minimize unintentional inputs.
4. Do not overcontrol. Allow aircraft to go with the turbulence, then restore level flight with smooth, gentle control inputs. Momentary airspeed, heading, altitude, and RPM excursions are to be expected.
5. Avoid flying on the downwind side of hills, ridges, or tall buildings where turbulence will likely be most severe.

The helicopter is more susceptible to turbulence at light weight. Reduce speed and use caution when flying solo or lightly loaded.

Figure 44 - Change in the aircraft manual for the flight in turbulent areas or high winds.

On April 22th 2016.

APPENDIX A - NTSB Comments not incorporated into the report

Below are listed all comments submitted by the National Transportation Safety Board (NTSB), and the Robinson Helicopter Company, which were not incorporated into the text of this Final Report.

a) Comment 1

A-207/CENIPA/2013 - 01

Include, in the syllabus of private and commercial helicopter pilot courses, mandatory theoretical classes on the phenomena of low-G and mast bumping.

NTSB Comment

Although all three aircraft (R22, R44 and R66) have the same rotor system design, and have similar characteristics in terms of the Low-G mast bump phenomenon, the three aircraft have significant differences in rotor and airframe inertia, as well as power plant characteristics. Therefore, they have very different characteristics in terms of power margin, rotor RPM decay rate, and response rate. The three aircraft do not have similar handling characteristics, particularly as they pertain to Low RPM rotor stall, autorotation, and power/RPM management.

Arguing of CENIPA

The argument was not accepted since the statement does not relate to the implementation of training for a particular type of aircraft.

The intent of the recommendation is that the Brazilian helicopter pilots, regardless of model flying, to start their theoretical training know these aerodynamic phenomena, even though particular phenomena of two blade rotorcraft.

b) Comment 2

A-207/CENIPA/2013 - 02

Evaluate the applicability and feasibility of delivering the training as described in the SFAR 73 in Brazil.

NTSB Comment

SFAR 73 currently applies to the R22 and R44 aircraft; we do not feel it should also be applied to the R66. The aspects of the SFAR that pertain to Low-G mast bumping are applicable to the R66, but the training and awareness requirements would be more appropriately included in the standard helicopter training syllabus for all 2 blade rotorcraft. - RHC supports the recommendation for the Brazilian authority to apply the training specified in SFAR-73 to R22 pilots.

Arguing of CENIPA

The argument was not accepted, given that the item at any time deals with the applicability of SFAR 73 for R66.