COMANDO DA AERONÁUTICA

CENTRO DE INVESTIGAÇÃO E PREVENÇÃO DE ACIDENTES AERONÁUTICOS

FINAL REPORT
A-070/CENIPA/2021

OCCURRENCE:	**ACCIDENT**
AIRCRAFT:	**PR-ORS**
MODEL:	**AT-502B**
DATE:	**11MAI2021**

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 considering 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 distinct 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 Final Report has been made available to the ANAC and the DECEA so that the technical-scientific analyses of this investigation can be used as a source of data and information, aiming at identifying hazards and assessing risks, as set forth in the Brazilian Program for Civil Aviation Operational Safety (PSO-BR).

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. Considering 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 11 May 2021 accident with the AT-502B aircraft, registration marks PR-ORS. The accident was typified as “[SCF-PP] Engine failure or malfunction”.

After takeoff, the aircraft’s engine lost power, and the pilot had to make an emergency landing some distance ahead.

The aircraft sustained substantial damage.

The pilot suffered no injuries.

Being Canada the State of manufacture of the aircraft’s engine, an accredited representative of the Canadian *Transportation Safety Board* (TSB) – was appointed for participation in the investigation.

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GLOSSARY OF TECHNICAL TERMS AND ABBREVIATIONS

ANAC	Brazil's National Civil Aviation Agency
ANP	Brazilian National Agency of Petroleum, Natural Gas and Biofuels
CA	Certificate of Airworthiness
CENIPA	Brazil's Aeronautical Accidents Investigation and Prevention Center
CIV	Pilot Logbook
CMA	Aeronautical Medical Certificate
CVA	Airworthiness-Verification Certificate
DCTA	Department of Science and Aerospace Technology
HSI	Hot Section Inspection
ITT	Inter-Turbine Temperature
MNTE	Single-Engine Land Airplane Class Rating
OM	Maintenance Organization
PAGA	Agricultural Pilot Rating (Airplane)
PCM	Commercial Pilot License (Airplane)
PIC	Pilot in Command
PN	Part Number
PPR	Private Pilot License (Airplane)
QAv	Aviation Kerosene
SIPAER	Aeronautical Accidents Investigation and Prevention System
SN	Serial Number
TPP	Private Air Service Aircraft Registration Category
TSB	Transportation Safety Board (Canada)
TSN	Time Since New
UTC	Coordinated Universal Time

1. FACTUAL INFORMATION.

Aircraft	**Model:** AT-502B **Registration:** PR-ORS **Manufacturer:** Air Tractor.	**Operator:** Private
Occurrence	**Date/time**: 11MAI2021 - 20:03 UTC **Location:** *Fazenda Savana* **Lat.** 11º33'12"S **Long.** 045°31'46"W **Municipality – State***: Riachão das Neves – Bahia.*	**Type(s):** [SCF-PP] Powerplant failure or malfunction

1.1. History of the flight.

At around 20:00 UTC, the aircraft took off from the airstrip for aero-agricultural use of *Fazenda Savana*, municipality of *Riachão das Neves*, State of *Bahia*, on a local agricultural spraying flight over a cotton plantation, with 01 POB (pilot).

After takeoff, the aircraft lost power, and the pilot decided to make an emergency landing ahead.

The aircraft sustained substantial damage.

The pilot suffered no injuries.

1.2. Injuries to persons.

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

1.3. Damage to the aircraft.

The aircraft sustained substantial damage. There was damage to the left main landing gear strut, to the left wing extrados, and to internal components of the engine.

1.4. Other damage.

NIL.

1.5. Personnel information.

1.5.1. Crew's flight experience.

FLIGHT EXPERIENCE	
	PIC
Total	2,306:00
Total in the last 30 days	86:20
Total in the last 24 hours	04:25
In this type of aircraft	1,119:00
In this type in the last 30 days	86:20
In this type in the last 24 hours	04:25

N.B.: flight experience data obtained through records of the Pilot Logbook (CIV)**.**

1.5.2. Personnel training.

The Pilot in Command (PIC) did his PPR course (Private Pilot – Airplane) in 2012, at the *Aeroclube de Itápolis*, State of *São Paulo*.

1.5.3. Category of licenses and validity of certificates.

The PIC held a PCM License (Commercial Pilot - Airplane), and valid MNTE (Single-Engine Land Airplane) and PAGA (Agricultural Pilot - Airplane) ratings.

1.5.4. Qualification and flight experience.

The pilot had qualification and experience for the type of flight.

1.5.5. Validity of medical certificate.

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

1.6. Aircraft information.

The SN 502B-2993 aircraft was a product manufactured by Air Tractor in 2014. It had been registered in the Private Air Services Registration Category (TPP).

The Airworthiness-Verification Certificate (CVA) was valid.

The records of the airframe, engine, and propeller logbooks were up to date.

The last inspection of the aircraft (type “100 hours”) was performed on 23 April 2021 by *Aba Manutenção de Aeronaves Ltda.* OM in the municipality of *Barreiras*, State of *Bahia*. The aircraft flew 39 hours and 20 minutes after the said inspection.

The last inspection for obtainment of the CVA was performed by *Aba Manutenção de Aeronaves Ltda.* OM in *Barreiras*, State of *Bahia*, on 25 September 2020. The aircraft flew 440 hours and 5 minutes after the referred inspection.

The maintenance of the PT6A-34AG engine equipping the AT-502B aircraft followed the requirements established in the Pratt & Whitney Canada Maintenance Manual.

In the context of the maintenance actions performed on the engine, one considered the intervals provided for scheduled interventions: Hot Section Inspection (HSI) and Overhaul, as well as the results of boroscopic inspections, results of the analyses of the lubricating oil and of the components with life limited by cycles or hours of operation. At the time of the accident (2021), the engine manufacturer had established execution of the HSI every 2,000 hours and Overhaul every 4,000 hours.

The SN PCE-PH1040 engine underwent a single HSI on 22 July 2019 when the frequency of inspections established by the manufacturer was one inspection every 1,750 hours. On the occasion, the engine had a *Time since New* (TSN) of 1,632 hours and 40 minutes. After undergoing the HSI, the engine was reinstalled in the PR-ORS, and operated for 1,006 hours and 30 minutes before sustaining a failure on 11 May 2021. The Overhaul was never performed, due to the fact that the engine had not reached the hours prescribed for that type of inspection.

The last boroscopic inspection of the aircraft's engine was carried out on 11 March 2021 by *Aba Manutenção de Aeronaves Ltda.* OM in *Barreiras*, State of *Bahia*, when the aircraft had a TSN of 2,480 hours.

One found that the operation of the SN PCE-PH1040 engine on the PR-ORS was in accordance with the standards and manuals in force.

1.7. Meteorological information.

The pilot did not report the presence of adverse weather build-ups.

According to data collected, the weather conditions were consistent with visual flights.

1.8. Aids to navigation.

NIL.

1.9. Communications.

NIL.

1.10. Aerodrome information.

NIL.

1.11. Flight recorders.

Neither required nor installed.

1.12. Wreckage and impact information.

The first touchdown took place approximately 1,200 m beyond the departure end of the airstrip for aeroagricultural use, on a secondary dirt road of *Fazenda Savana*. After traveling on the ground for approximately 157 meters, the aircraft came to a stop off the road, in a direction that was 90 degrees offset to the right (Figures 1 and 2).

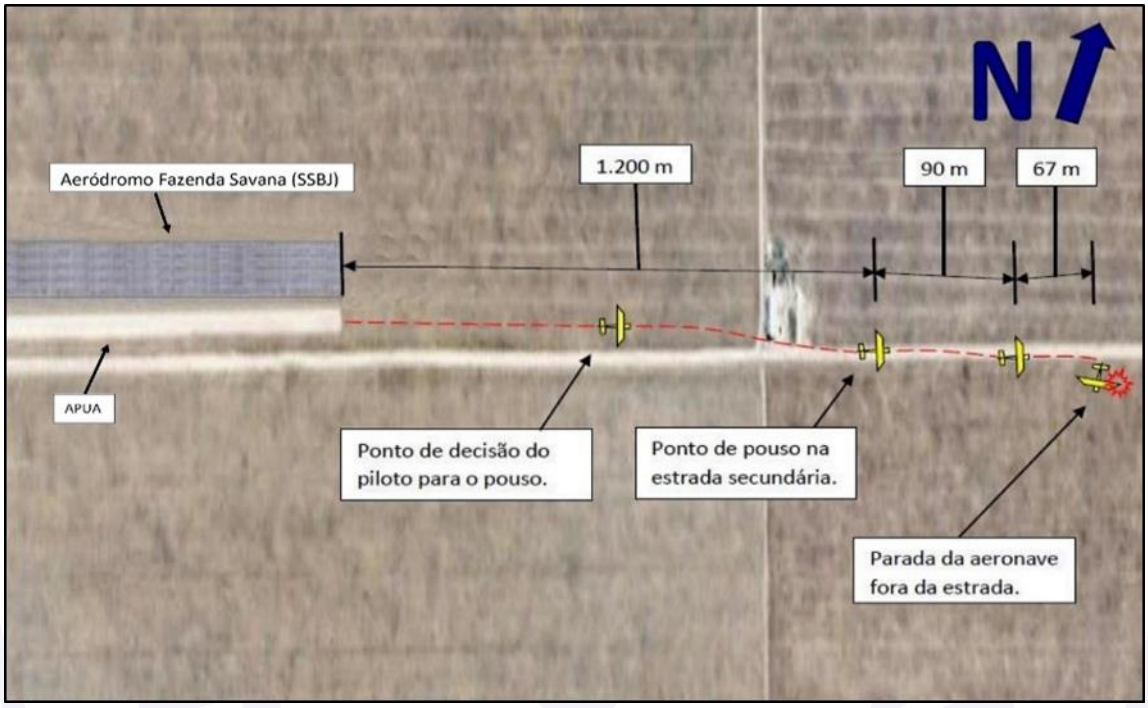

Figure 1 - Croquis of the accident.

Figure 2 - Aircraft at the stopping point, pointing in a direction 90 degrees offset to the right.

1.13. Medical and pathological information.

1.13.1. Medical aspects.

No evidence was found that physiological issues or incapacitation might have affected the crewmember's performance.

1.13.2. Ergonomic information.

NIL.

1.13.3. Psychological aspects.

There was no evidence that psychological issues might have affected the crewmember's performance.

1.14. Fire.

There was no evidence of either inflight or post-impact fire.

1.15. Survival aspects.

NIL.

1.16. Tests and research.

A fuel sample collected from the aircraft's tanks was subjected to exams at the Brazilian National Agency of Petroleum, Natural Gas and Biofuels (ANP).

The exams showed that the fuel sample had a clear limpid appearance and was free of water and solid material, thus complying with the ANP specifications for the characteristics evaluated.

At the scene of the accident, one observed that the propeller blades had not hit the ground.

The SN PCE-PH1040 engine was analyzed by the investigation commission. The technical work was done in the Pratt & Whitney's workshop in Brazil. Engine disassembly and analysis revealed the existence of damage resulting from intense rubbing between the compressor rotor and its housing (Figure 3).

Figure 3 - Rubbing marks observed on the spacer between the 1st and 2nd compression stages.

Additionally, severe damage was observed in the hot section of the engine, mainly in the region of the compressor turbine.

Among all the blade ruptures, the one indicated in Figure 4 had different characteristics on the rupture surface.

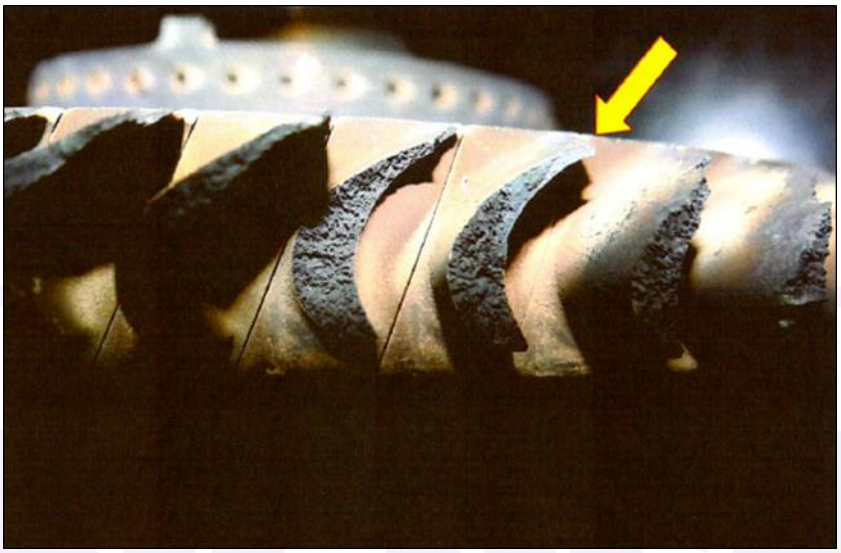

Figure 4 - Top view showing the type of flat fracture in one of the blades.

The investigation commission sent the CT disk assembly of the SN PCE-PH1040 engine to Canada for tests on the premises of the engine manufacturer's laboratory, specialized in failure analysis.

The objective was to identify the fracture mechanism of the blade nº 4 (PN 3120751-01) indicated in Figure 4.

Fatigue, generally speaking, is the designation for a failure mechanism of metallic materials to which mechanical components subjected to repeated cycles of tension and/or deformation are exposed. The deformations of mechanical components resulting from these stresses are not permanent deformations. In other words, when the stress is removed, the material returns to its original dimensions. The working stresses are lower in value than the yield stress, which induces permanent deformations.

Considering an element undergoing a fatigue process, three stages can be identified: crack initiation (nucleation), propagation, and structural separation.

Experiments on the behavior of materials under cyclic stress allow establishing reliable parameters. The number of cycles to which the item is subjected, without altering its structural characteristics, is used to classify the onset of a fatigue process, such as “high cycle fatigue” and “low cycle fatigue”.

The number of cycles for the onset of fatigue classified as “high cycle” depends on the characteristics of the material, such as chemical composition and crystalline arrangement. Essentially, events occurring within the range of 10^2 to 10^4 cycles can be considered high-cycle fatigue.

In turbine disks blades, the image of the surface of the fractured area can reveal which factors were involved in the process that resulted in the fatigue of the material, among which it is possible to mention:

- exceedance of stress limits, as a consequence of the load imposed on the component during the engine operation;
- chemical reactions, which may cause corrosion, associated with the contact of engine components with chemical products, in this case, agricultural pesticides; and
- exceedance of the thermal limits of the disk and blade structure.

The engine operates, adhering to the thermal limits of its components, blades included, through constant operation within the temperature boundary parameters. These parameters

are measured in the interturbine region and displayed in the cockpit as Inter-Turbine Temperature (ITT).

Laboratory analyses of the CT disc assembly showed that the failure in blade nº 4 likely occurred due to high cycle fatigue. Furthermore, the aforementioned analyses indicated that the loss of material from the trailing edge of the said blade made it impossible to determine the origin of the failure accurately. The other blades suffered rupture due to overload. The results of the analyses were confirmed by the investigation commission.

1.17. Organizational and management information.

NIL.

1.18. Operational information.

The aircraft was within the weight and balance limits specified by the manufacturer.

At the time of the engine failure, the plane had approximately 550 liters of Aviation Kerosene (QAv) and 1,500 kg of agricultural pesticide.

Prior to the emergency landing, the pilot jettisoned the agricultural pesticide.

1.19. Additional information.

In the scenario of aeroagricultural operations, the pesticides used in spraying, when in contact with engine components, may trigger a chemical reaction process. Furthermore, agricultural operations involve performing numerous reversal maneuvers, known as “ballooning”, which require frequent variations in power, which, in turn, alter engine temperature parameters.

“Ballooning” is a maneuver often performed in agricultural aviation during the application of pesticides. It is a reversal turn in which the pilot has to bank the aircraft's wings, increase the angle of attack and the load factor (G force) to reposition the plane, aiming for a new application pass over the plantation.

Upon being consulted, the aircraft operator informed that compressor washes would be carried out on two occasions: during scheduled inspections or when there had been a drop in engine performance.

With respect to turbine compressor washing, the Maintenance Manual (PN 3021242, 71-00-00 - Power Plant - Cleaning, nº 8, Compressor Turbine Wash - updated on 18 January 2021) in force at the time of the occurrence, described the following:

> *A. General*
>
> *This is a method for washing compressor turbine blades, while installed in the engine, to alleviate sulphidation attack and salt deposits.*
>
> *[...]*
>
> *Depending on the operating environment, the nature and frequency of wash carried out are recommended to be in accordance with Table 701.*

Table 701 Wash Schedule Recommendations

Environment	Wash	Frequency	Remarks
Continuously salt laden	Desalination (Compressor and CT) and External Engine Wash	Daily	Strongly recommended after last flight of day.
Occasionally operated in salt-laden or harsh environment	Desalination (Compressor and CT) and External Engine Wash	Weekly	Strongly recommended. Adjust interval to suit engine condition.

The table mentioned in the Maintenance Manual describes the calendar recommendation for washing the compressor.

“Sulphidation” is understood as the corrosion of carbon steel and other metallic alloys resulting from the reaction of the metal with hydrogen sulfide gas (H2S) and sulfur (S) and its compounds, in high temperature environments. The presence of hydrogen accelerates corrosion. This mechanism is also known as Sulphide Corrosion or Sulphidation.

With respect to the composition of pesticides, Rikardy Tooge, in the article “Find out what are the active ingredients of the best-selling pesticides in the world”, published on the https://www.aenda.org.br/noticia_imprensa/saiba-quais-sao-os-principios-ativos-dos agrotoxicos-mais-vendidos-no-mundo/, accessed on 31 January 2023, revealed that:

> Sulfur (11th best-selling in Brazil*)
>
> It is an active ingredient that can be applied in several ways. It can be used to control diseases (fungicide), to kill insects, and also as a fertilizer. In Brazil, it can be applied to avocado, pumpkin, zucchini, cotton, garlic, plum, peanut, potato, eggplant, coffee, cashew, onion, citrus, coconut, cabbage, cauliflower, chayote, pea, eucalyptus, beans, cowpea, snap bean, fig, guava, apple, papaya, castor bean, mango, quince, gherkin, watermelon, melon, corn, strawberry, turnip, cucumber, pear, peach, pepper, green pepper, jatropha, okra, cabbage, rose, soybeans, tomatoes, wheat and grapes.
>
> It is also authorized in the USA. In the EU, only for wheat and grapes.

1.20. Useful or effective investigation techniques.

NIL.

2. ANALYSIS.

It was a local crop-dusting flight with a pilot on board.

Shortly after takeoff, the aircraft lost power, and the pilot chose to make an emergency landing ahead.

The aircraft touched the ground approximately 1,200 m beyond the limits of the airstrip for aeroagricultural use on a secondary road of *Fazenda Savana*. After having traveled for approximately 157 m on the ground, the aircraft came to a stop outside the road limits.

There were no reports of adverse meteorological formations by the pilot, and the weather conditions prevailing at the time of the occurrence were consistent with visual flights.

The analysis of the fuel collected from the aircraft's tanks on the day of the accident showed normal results. Therefore, the possibility that the quality of the fuel might have contributed to the occurrence was ruled out.

That said, and taking into account that the pilot reported engine distress in flight, the most likely hypothesis considered was the occurrence of a problem in some component of the aircraft’s powerplant, which made it impossible for the engine to keep its operational performance in flight.

According to the technical analysis of the engine manufacturer's laboratory, the distress of the engine was related to the rupture of the blade nº 4 of the compressor turbine rotor.

Such rupture, according to the analyses of the engine carried out at the engine manufacturer's laboratory, occurred probably due to high cycle fatigue. Still according to the aforementioned analyses, the loss of part of the material from the trailing edge of the blade made it impossible to determine the origin of the failure accurately. Furthermore, one found that the other blades of the disk rotor suffered rupture due to overload, resulting from the fracture of the blade nº 4.

In general terms, high-cycle fatigue can be associated with the following factors:

- exceedance of stress limits - such a situation may be present in agricultural operations given the nature of the operation, in which pilots may operate the aircraft with frequent variations of power. It should be noted that this phenomenon is present in all engines and is not restricted to engines used in aero-agricultural operations. However, due to the lack of operational data, it was not possible to further research this factor; and

- chemical reactions - these are reactions that can cause corrosion of engine components due to possible contact with chemicals.

In fact, the presence of sulfur in agricultural pesticides, widely used in cotton crops, could contribute to sulphidation.

One way to mitigate the sulphidation phenomenon would be to adopt procedures to remove those chemicals, in the case in question, by washing the engine compressor, in accordance with the guidelines established in the Aircraft's Engine Maintenance Manual, chapter 71-00-00 - Power Plant - Cleaning, nº 8, Compressor Turbine Wash. It is worth clarifying that, in the context of operation of this aircraft, the compressor washing procedures were in accordance with the maintenance instructions in force.

With regard to a possible exceedance of temperature limits, such factor could not be ruled out, although nothing was found in the aircraft's records concerning that aspect.

According to the aircraft's documentation, all inspections were carried out as per its maintenance program.

The aircraft's documentation did not record any observations that identified signs of the beginning of a fatigue process in the engine's compressor blades.

3. CONCLUSIONS.

3.1. Findings.

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

b) the pilot held valid MNTE (Single-Engine Land Airplane) and PAGA (Agricultural Pilot - Airplane) ratings;

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

d) the aircraft had a valid CVA (Airworthiness-Verification Certificate);

e) the aircraft was within its prescribed weight and balance limits;

f) the records of the airframe, engine, and propeller logbooks were up to date;

g) the meteorological conditions were consistent with the type of flight;

h) the aircraft took off from the airstrip for aero-agricultural use of *Fazenda Savana* on a local aeroagricultural application flight;

i) after takeoff, the aircraft lost power, and the pilot made an emergency landing ahead;

j) prior to landing, the pilot jettisoned the agricultural pesticide;

k) the exams of the aircraft's fuel sample attested to its compliance with the ANP specifications;

l) the laboratory analyses of the CT disk assembly showed that the failure in the blade nº 4 was probably due to high cycle fatigue;

m) the aircraft sustained substantial damage; and

n) the pilot suffered no injuries.

3.2. Contributing factors.

Other – undetermined.

It is possible that a contingent extrapolation of the ITT limits, as well as the use of agricultural pesticides with sulfur in their composition, contributed to the initiation of the high cycle fatigue.

4. SAFETY RECOMMENDATIONS

None.

5. CORRECTIVE OR PREVENTATIVE ACTION ALREADY TAKEN.

None.

On April 15th, 2024.