AIRCRAFT ACCIDENT INVESTIGATION REPORT

PASSENGER INJURY AND AIRCRAFT DAMAGE

CAUSED BY HARD LANDING

PRIVATELY OWNED AÉROSPATIAL AS350B (ROTORCRAFT), JA6050

AOKI-MURA, CHIISAGATA-GUN, NAGANO PREFECTURE

AT ABOUT 09:33 JST, MARCH 23, 2021

June 7, 2024
Adopted by the Japan Transport Safety Board

Chairperson	TAKEDA Nobuo
Member	SHIMAMURA Atsushi
Member	MARUI Yuichi
Member	SODA Hisako
Member	NAKANISHI Miwa
Member	TSUDA Hiroka

1. PROCESS AND PROGRESS OF THE AIRCRAFT ACCIDENT INVESTIGATION

1.1 Summary of the Accident	On Tuesday, March 23, 2021, a privately owned Aérospatial AS350B, JA6050, took off from Tokyo Heliport in Tokyo to transport personnel, and while the helicopter was flying toward Matsukawa Temporary Operation Site, Matsukawa-mura, Kitaazumi-gun, Nagano Prefecture, its engine power decreased over the vicinity of Aoki-mura, Chiisagata-gun, Nagano Prefecture. Therefore, the helicopter attempted to make a forced landing on a farm road in Ogami, Aoki-mura, resulting in a hard landing, which caused the captain and three passengers to sustain serious injuries, and two passengers to sustain minor injuries. The helicopter was destroyed but no fire broke out.
1.2 Outline of the Accident Investigation	On March 23, 2021, the Japan Transport Safety Board (JTSB) designated an investigator-in-charge and two other investigators to investigate this accident. Participating in this investigation were accredited representative and advisors from the French Republic, which designed and manufactured the helicopter and the engine of the accident aircraft, and accredited representative and advisors from the United States, which designed and manufactured the equipment. Comments on the draft Final Report were invited from the parties relevant to the cause of the accident and the Relevant States.

2. FACTUAL INFORMATION

2.1 History of the Flight	According to the helicopter's flight plan, the GPS device records, and the statements of the captain, passengers and an eyewitness, the history of the flight is summarized as below: On March 23, 2021, at about 08:40 Japan Standard Time (JST: UTC + 9hrs, unless otherwise stated all times are indicated in JST on a 24-hour clock), the helicopter took off from Tokyo Heliport and headed for Matsukawa Temporary Operation Site, Matsukawa-mura, Kitaazumi-gun, Nagano Prefecture (hereinafter referred to as "Matsukawa Operation Site"), with the captain sitting in the right pilot seat and five passengers in other seats. (1) Statement of the captain After taking off from Tokyo Heliport, the helicopter detoured the control zone of Iruma Aerodrome, and climbed up to an altitude of 5,000 ft. And when the helicopter descended to an altitude of about 3,800 ft over the vicinity of Aoki-mura, Chiisagata-gun, Nagano Prefecture in slowly descending at an airspeed of 110 kt and a descent rate of 300 ft/min, the engine chip caution light*1 came on. After confirming that there was no abnormality in the engine instruments, the captain reduced the engine power and established approximately 90 kt airspeed. Since the helicopter was around the position it can arrive at Matsukawa Operation Site with four to five minutes, the captain was thinking whether to continue to fly to Matsukawa Operation Site, and looking for the appropriate site to land, the captain heard a "gooon" sound from the engine. It was about a minute after the engine chip caution light came on. At this time, the captain felt the helicopter yawing, immediately after that, the rotor rpm (NR) warning*2 sounded, and he recognized engine's flame-out*3 (refer to 2.8(2)b for the details of signs). As having confirmed the extended rice paddies area when the engine chip caution light came on, the captain turned the helicopter to the left toward that direction immediately after recognizing the flame-out and entered the autorotation*4 from about 1,500 ft above ground level (AGL). During the autorotation landing, viewing the two rice paddies like a runway to make it possible for the helicopter to land even when the landing position was slightly deviated, the captain made the helicopter descend aiming for the road between the paddy fields. And the captain noticed it was less than 60 kt, recognizing a lack of speed and thus increasing the speed. The captain tried to make a landing in a near-vertical position finally by making the altitude for starting the nose-up (flare*5) before touchdown as low as possible. When flaring the helicopter before the road of the landing point, as being

*1 The "engine chip caution light" refers to the lamp on the WARNING-CAUTION-ADVISORY PANEL in the cockpit, which lights up when the metallic particles are detected in the engine oil system. (See 2.8 (1)a)
*2 The "NR warning" is a continuous sound that sounds if the rotor rpm (NR) decreases below 360 rpm.
*3 "Flame-out" refers to the sudden loss of combustion in the turbine engine due to some factors.
*4 "Autorotation" refers to an autorotation flight, and flight condition in which the main rotor blades responsible for the lift are driven only by the aerodynamic force completely at the time of the rotorcraft in motion. (Airworthiness Inspection Manual)
*5 "Flare" refers to deceleration operation for landing, which allows the rate of descent to reduce by converting kinetic energy into potential energy.

unable to see the road in front which was hidden behind the instrument panel, the captain controlled the helicopter while looking to the side too. At about 5 m high, the rate of descent stopped, and while flaring out, the captain raised the collective pitch lever as the helicopter descended, but at a height of about 2 to 3 m, the collective pitch lever had reached the highest position, and the rate of descent became uncontrollable. From then, while the rate of descent was increasing, the helicopter was subject to impacts and made a forced landing.

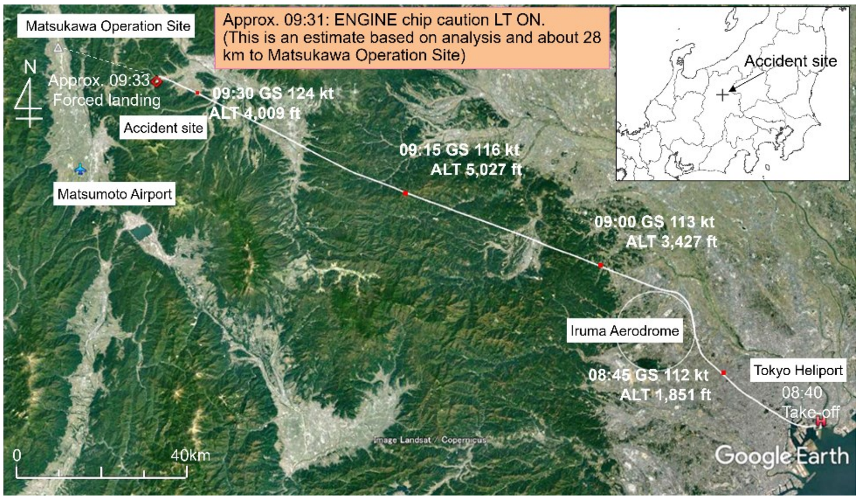


Figure 1: Estimated Flight Route of the Helicopter

(2) Statements of the Passengers (described according to the statement of Passenger A to which those by Passenger B, C and D were partially added)

During the flight, there was an impact of a thumping. The Passengers in the rear seats smelled something burning, and a warning sound was issued after a minute or two. The captain made an announcement that they were going to land, and then, the helicopter made a forced landing. The forced landing was something like falling freely from the height of the third floor of a building, and the door flew off at landing.

(3) Statement of the Eyewitness and Video Taken by the Eyewitness

When looking south from the ground of a paraglider school (located about 1,200 m north of the accident site), at about 09:30, the eyewitness heard a “pang” sound and saw white smoke rising from the helicopter that was heading northwest from the direction of Ueda city. As the helicopter suddenly turned to the left and started heading forward Mt. Ogami-dake, the eyewitness quickly started taking a video with the mobile phone.

The video taken by the eyewitness recorded a "pang" sound followed by a continuous engine sound like "pa, pang, pa, pa, pang", and the helicopter descending toward Mt. Ogami-dake. The wind direction indicator at the paraglider school showed an east-southeasterly wind of 3 to 5 m/s.

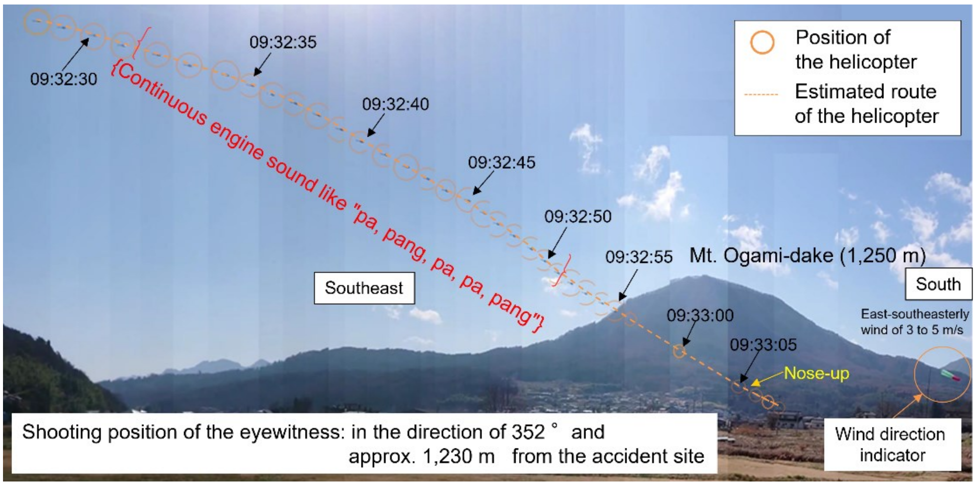


Figure 2: The Helicopter When Making a Forced Landing (created from the video taken by the eyewitness)

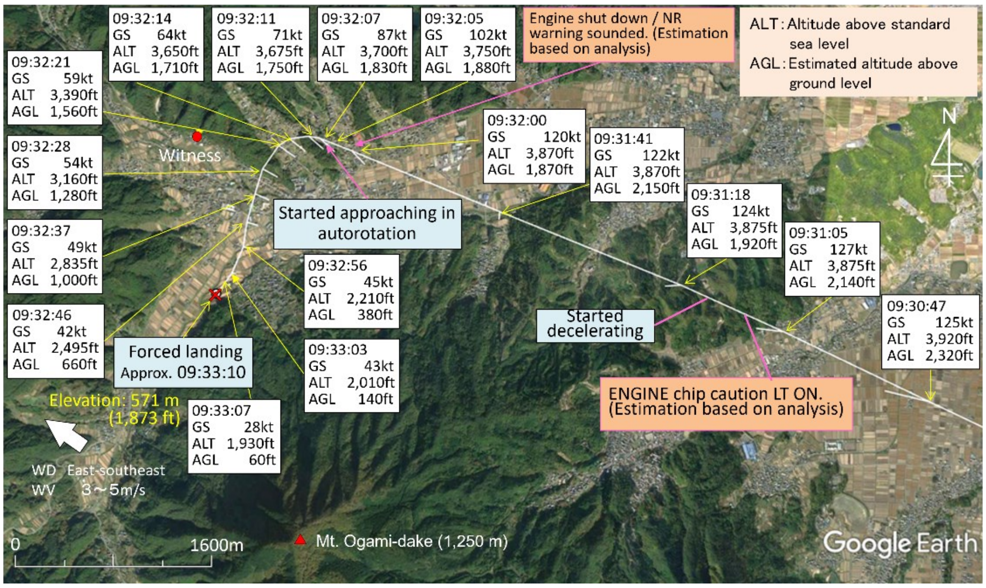


Figure 3: Estimated Flight Route of the Helicopter Immediately before the Forced Landing

The accident occurred on a farm road 28 km northeast (36°21'47"N, 138°07'13"E) of Matsumoto Airport at about 09:33:10, March 23, 2021.

2.2 Injuries to Persons	Captain: Serious injury Passengers: Three serious injuries and two minor injuries

2.3 Damage to the Aircraft

(1) Extent of Damage: Destroyed

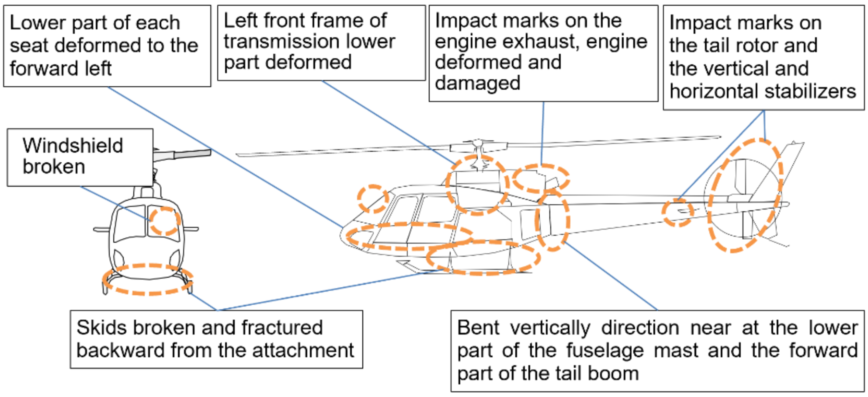


Figure 4: Overview of Damaged Parts of the Helicopter

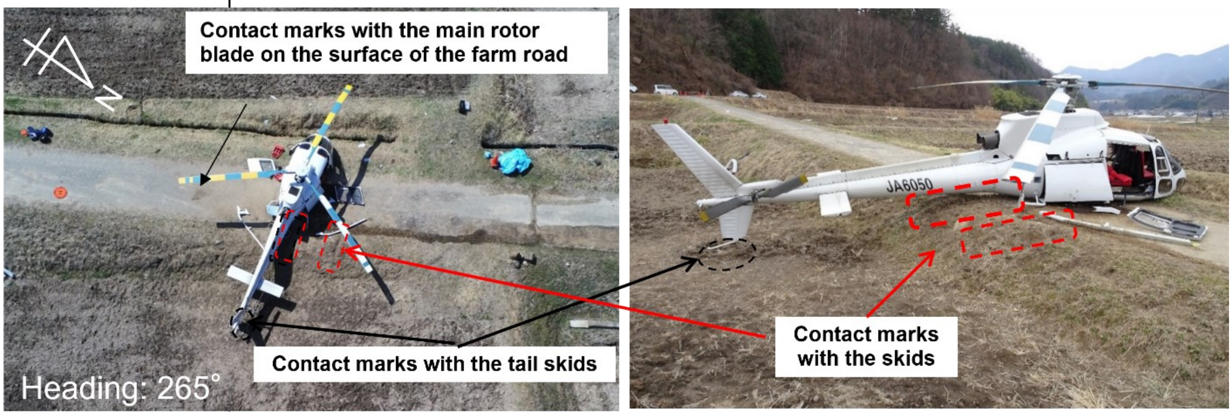


Figure 5: Contact Marks around the Helicopter

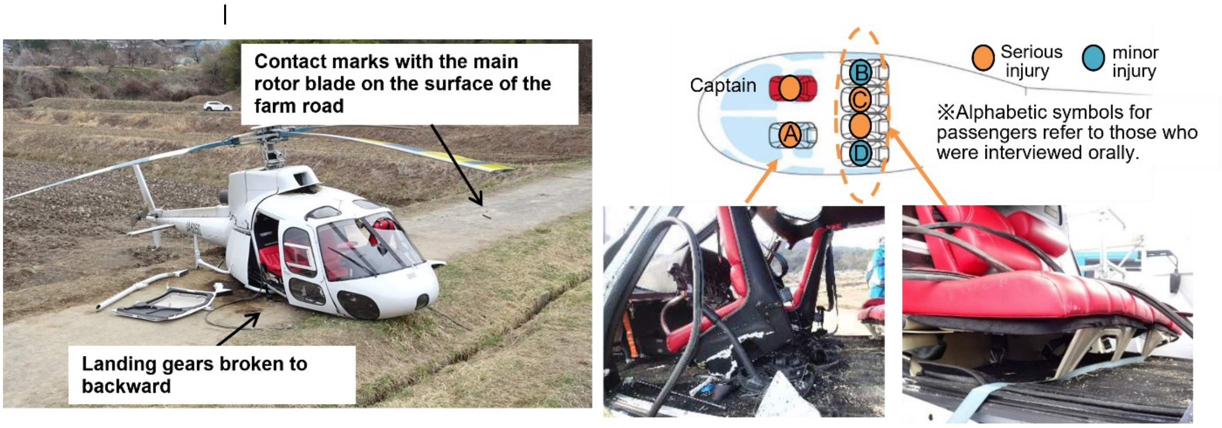


Figure 6: Damage to the Cockpit and Cabin Area

a. The fuselage was seriously bent backward and forward, and the cockpit windshield was partially broken.

b. The landing gears (skids) were all broken with the cross tubes rotating backward.

c. The left pilot seat was compressively buckled forward right, and the rear seats forward left.

d. There were impact marks on the tail rotor and the vertical and horizontal stabilizers.

e. Fire did not occur, but the fuel was leaked from the lower part of the fuselage.

f. Due to the touchdown impact, the Emergency Locator Transmitter (ELT) was activated. (Threshold value: 6 to 8 G)

(2) Conditions around the Accident Site

The site where the helicopter made a forced landing was on the asphalt farm road about 3.5 m wide that was located in the paddy field area. The helicopter made a forced landing facing in a 265° direction. There were touchdown marks of its landing gears on the bank of the farm road, and contact marks with the tail skids behind the position where the helicopter remained stationary. And there were contact marks with the main rotor blade on the surface of the farm road about 4 m left side of the helicopter.

(3) Engine Exterior Damage (for the engine interior damage, see 2.7 (1))

a. The power turbine bearing support in the center of the engine was deformed due to twist.

b. There were multiple impact marks inside of the exhaust.

c. The nozzle guide vanes were damaged.

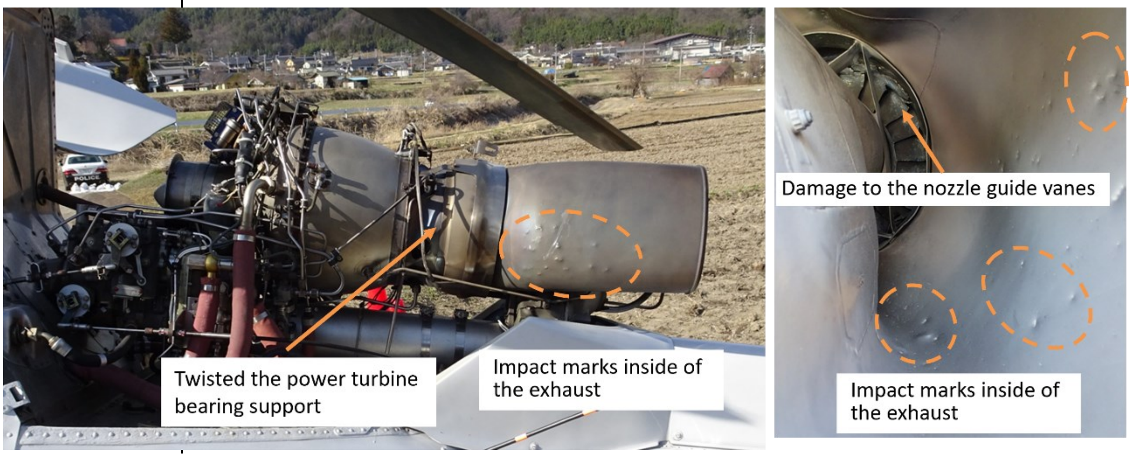


Figure 7: Engine Exterior Damage

2.4 Personnel Information	Captain: age 51	
	Private pilot certificate (Rotorcraft)	September 3, 1997
	Specific pilot competence	
	Expiry of practicable period for flight:	March 17, 2023
	Type rating for single-piston engine (land)	September 3, 1997
	Type rating for single-engine turbine (land)	January 19, 1998
	Class 2 aviation medical certificate	
	Validity:	December 25, 2021
	Total flight time	1,513 hours 28 minutes
	Flight time for the last 30 days	15 hours 00 minute
	Total flight time on the type of aircraft	1,359 hours 10 minutes
	Flight time for the last 30 days	15 hours 00 minute
2.5 Aircraft Information	(1) Aircraft	
	Type	Aérospatial AS350B
	Serial number	2425
	Date of manufacture	November 22, 1990
	Certificate of airworthiness	No. DAI-2020-082
		Validity: June 1, 2021

	Total flight time 6,659 hours 54 minutes (2) Engine Type Turbomeca ARRIEL 1B Serial number 4272 Date of manufacture December 19, 1989 Total time in service 12,593 hours 40 minutes The total time in service since the last periodical checks (200h, 150h, 100h, 50h and 30h checks were conducted at the same time on February 10, 2021) was 12 hours 36 minutes. (3) When the accident occurred, the weight of the helicopter was estimated to have been 1,845 kg, and that the position of center of gravity (CG) was estimated to have been at 3.24 m, both of which are estimated to have been within the allowable range (the maximum take-off weight of 1,950 kg and the CG range of 3.17 to 3.55 m corresponding to the weight at the time of the accident).
2.6 Meteorological Information	(1) Values Observed at the Regional Weather Station The weather observations at the Ueda Regional Meteorological Observatory Station, located about 14 km northeast of the accident site, around the time of the accident were as follows: 09:30 Wind direction: East-Southeast; Wind velocity: 0.7 m/s Temperature: 5.5℃ Sunshine duration: 1.0 hours Precipitation: 0.0 mm (2) Weather Conditions at the Paraglider School Located about 1,200 m North of the Accident Site About 09:30 Weather: Fair; Wind: East-Southeast; Wind velocity: 3 to 5 m/s (See Figure 2)
2.7 Teardown Investigation of the Engine and Maintenance Information	(1) Overview of Engine Damage In order to make a detailed examination for causes of the engine's power loss, the disassembly investigation of the engine was performed. Under the witness of an accredited representative of the French Republic, the investigations were performed in the facility of the design and manufacture company. The result was as follow: a. Gas Generator Section (a) There were the local thermal damages on the hollow shaft and the combustion chamber shroud. (b) Some of the HP2 turbine blades were damaged, and some were ruptured in the middle or near four-fifths of the trailing edges of the blades. In the rupture, no fatigue rupture nor sign of overtemperature were observed. (See Appendix 1 Figure A) b. Power Turbine Section (a) There were signs that the power turbine disk went in contact with the power turbine nozzle guide vane while it was rotating, and the power turbine bearing support twisted and damaged. All power turbine blades were missing and part of power turbine disk interslots were

missing. (See Appendix 1_Figure B)

(b)The power turbine front bearing rollers (5 mm diameter x 5 mm length) were found deformed: their diameter descreased by 1mm, and their length increased by 0,1 to 0.2 mm. And the front bearing inner race was melted and disappeared, a micrographic and EDS*6 analysis showed trace of the aggregation of metal materials (inner race, roller bearing, bearing cage, and power turbine shaft) within the outer race. (See Appendix 1_Figure C)

(c) The forward part of the power turbine shaft was melted and fractured. In addition, the surface of the ruptured rearward part discoloration, and the hardness inspection and metallurgical analysis confirmed it had reached to a high temperature of 1,300 °C or more. (See Figure 9 and Appendix 1_Figure D)

(d) The spline nut on the power turbine shaft was found in forward position by 2mm than nominal position, but the traces of glue residuals were noticed in the thread of the spline nut and on the shaft itself.

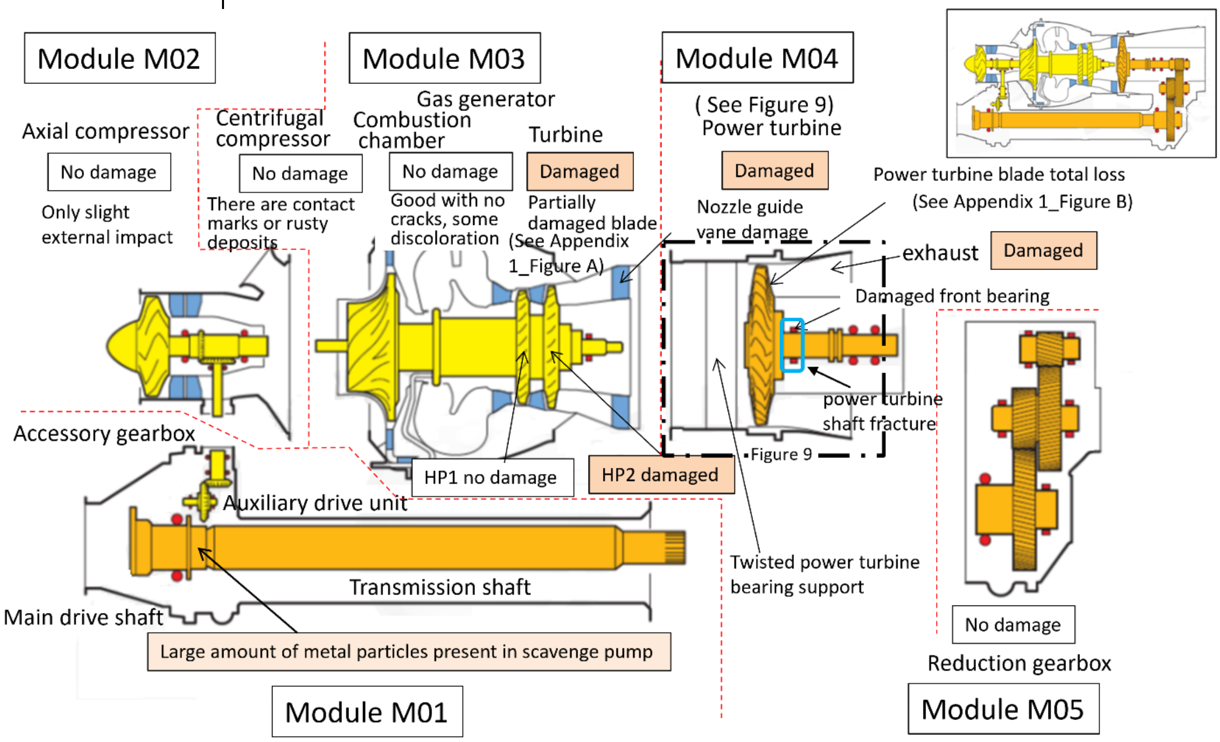


Figure 8: Engine Structure and Damaged Parts

*6 The "EDS" stands for Energy Dispersive X-ray Spectroscopy that is a method to obtain elemental information on samples and foreign substances by detecting character X-rays generated by electron beam irradiation with a detector attached to the electron microscope.

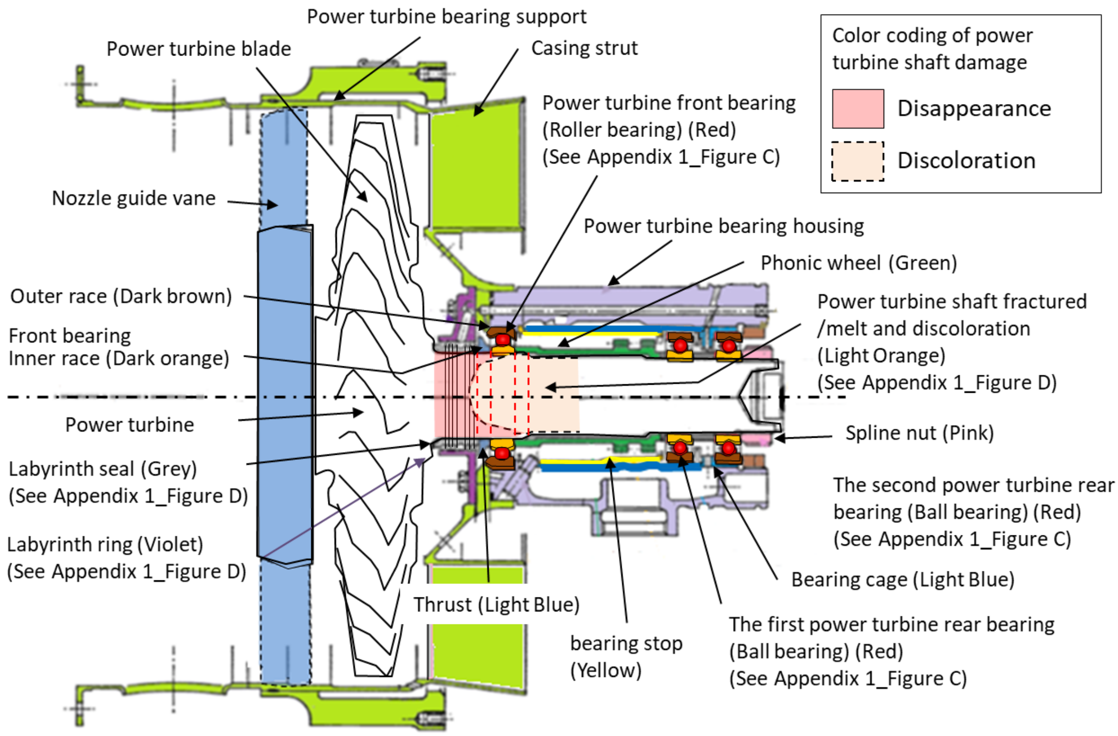


Figure 9: Names and Damaged Parts of Module M04 (Power Turbine Section)

c. Lubrication System of the Engine (See Appendix 2_Figure A and Table 1)

(a) The analysis of metallic particles contained in the oil did not detect any materials other than those related to the engine.

(b) Significant quantity of metallic particles was present in the scavenge pump*7 and the polluted engine oil contained metals including materials of the bearing and power turbine shaft.

(c) The disassembly inspection revealed that no sign of any engine oil overtemperature was found and the three power turbine bearings appeared to be lubricated. The collected engine oil did not contain any impurities other than the engine material.

(d) The significant amount of metallic particles were collected from the oil tank and oil filter*8.

(2) Engine Maintenance History

a. Time in service of the each engine part

The Turbomeca Arriel 1B engine is composed of five MODULEs and the periodic inspection time is set separately for each module so that all modules can be maintained separately. Table 1 shows the time in service after the periodic inspection of each MODULE and damaged area related parts as of the time of the accident, and all inspection times were observed.

*7 The "scavenge pump" is a pump to pump and return the engine oil containing air after lubrication and cooling back to an oil tank.
*8 An "oil filter" is a filter to remove foreign substances that can accumulate in engine oil.

Table 1: Time in Service of each MODULE and Damaged Area Related Parts

MODULE No.	Part name	Total Time in service TSN*9	Time in service TSO*10	Periodic inspection TBO*11	Exchange time
M01	Accessory gear box	7,336h40m			
M02	Axial compressor	12,593h40m	3,673h40m	6,000h	
M03	Gas generator	7,096h32m	2,981h32m	3,000h	
M04	Power turbine	10,998h10m	2,009h52m	6,000h	
M05	Reduction gearbox	8,413h32m	1,918h32m	3,000h	
M04	Front bearings	2,736h57m			3,000h
M04	First rear bearing	6,684h40m			7,200h
M04	Second rear bearing	6,684h40m			7,200h

b. Inspection of the engine magnetic plugs*12

It is stipulated that the module M01 and module M05 mechanical magnetic plugs shall be inspected and cleaned every 30 flight hours, and electrical magnetic plugs every 400 flight hours. During the periodic inspection approximately 13 flight hours before the accident, the engine magnetic plugs of the helicopter were inspected, which had confirmed there were no abnormality.

c. Maintenance of MODULE M04 front bearing

The power turbine front bearing are located in the bearing housing and replaced during 3,000-hour intermediate inspection. After the front bearing of the engine was replaced on June 8, 2012, it did not go over the power turbine front bearing use-limit and there was no abnormality related to the relevant parts, therefore, there was no opportunity of inspecting it directly.

2.8 Additional Information

(1) Information on GPS Device

The helicopter was equipped with a GPS device, and the location information for the flight on the day of the accident was in automatic mode, where data was recorded when changes such as directions, climbs, and descents occurred.

(2) Emergency Procedures of Aérospatial AS350B

The emergency procedures applicable to the situation at the time of the accident are stipulated in the flight manual of Aérospatial AS350B as follows:

a. Emergency procedures when engine chip caution light comes on.

CAPTION: ENG CHIP (Amber captions)

FAILURE: Metal particles in ENGINE oil system.

PILOT ACTION: LAND AS SOON AS POSSIBLE.

It is prohibited to take off again as long as the checks scheduled in TURBOMECA Maintenance Manual have

*9 "TSN" stands for Time Since New that and refers to the total time in service since its production.

*10 "TSO" stands for Time Since Overhaul and refers to the total time in service after it was overhauled.

*11 "TBO" stands for Time Between overhaul and refers to the time or cycle between overhauls.

*12 A "magnetic plug" is a device to magnetically attract and detect metallic particles contained in the oil within the engine and gear box. Electronic plug provides an alert to the engine chip caution light in the cockpit that comes on when metallic particles are detected. With the mechanical version, it is unable to check it during operation.

not been performed.

b. Emergency procedures after engine shutdown

ENGINE Failures

Flame-out in flight

The symptoms of an engine failure are as follows:

- *Jerk in the yaw axis (only in high-power flight).*
- *Drop in NR (aural warning sounds at NR less than 360 rpm).*
- *Torque at zero.*
- *Ng* (Gas Generator RPM) *falling off to zero.*
- *Generator* (Generator: DC power system) *caution light comes on.*
- *ENG.P* (Engine oil pressure) *low warning light comes on.*

In the event of an engine flame-out in flight, carry out autorotational transition procedure.

c. Autorotation landing

Autorotation landing procedure after engine failure

— *Set low collective pitch.*

— *Monitor and control NR.*

— *Establish approximately 65 kt (120 km/h - 75 MPH) airspeed.*

— *Move the Fuel Flow Control to the Shutdown position.*

— *According to the cause of ENGINE flame-out:*

- *Re-light the ENGINE.*
- *Otherwise: close: the Fuel Shut Off Cock,*
  Switch off: the following SWs: Booster Pump, Generator, Alternator (if installed),
  "MASTER SW" Electrical Master Switch (if smell of burning)
- *Manoeuvre to bring the helicopter into the wind in final approach.*
- *At a height of approximately 65 ft (20 m) above the ground, flare to a nose-up attitude.*

— *At a height of 20-25 ft (6-8 m) and at constant attitude, gradually apply collective pitch to reduce the rate-of-descent.*

— *Establish a level attitude before touch-down, and cancel any side-slip tendency.*

— *Gently reduce collective pitch after touch-down.*

(3) Rate of Descent and Collective Pitch lever in Autorotation

When autorotation was performed, the rate of descent changes depending on airspeed and aircraft weight. According to the simulation of the design and manufacture company, as shown in Figure 10, at 65 kt airspeed, which is the reference value specified in the emergency procedures, if the rotor rpm (NR) is maintained at 400 rpm, the rate of descent will be about 1,800 ft/min. The difference by weight is such that heavier the weight, the lower the rate of descent, but the collective pitch lever position will be slightly higher. If the airspeed is reduced below 40 kt, the heavier the weight, the higher the rate of descent.

Weight (kg)	Rate of descent (ft/min)	Collective pitch angle (°) motion range (Lowest - 0.6° to Uppermost + 14°)
1,625	1,970	- 0.07
1,900	1,800	0.71
2,225	1,695	1.47

IAS: 65 kt NR: 400 rpm

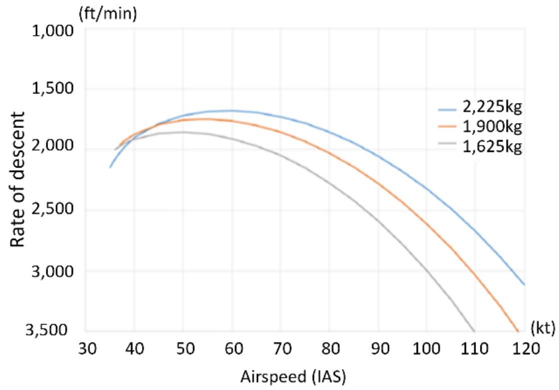


Figure 10: Rate of Descent and Collective Pitch Angle in Autorotation

(4) Captain's Experience of Autorotation Training

The captain obtained a private pilot certificate for single-piston engine in September 1997 and single-engine turbine in January 1998. In this training to acquire the competence certification, the captain experienced autorotation training at light weight, however, after obtaining the competence certification qualification, the captain had never experienced autorotation training including training with flight training device.

In the specific pilot competence review conducted every two years, autorotation is not an examination item but a question item for oral guidance on the height-velocity-envelope[*13].

(5) Owner and Flight Operation Type of the Helicopter

According to the statements of several persons concerned, the owner of the helicopter is Company A, and Company B had rented the helicopter from Company A. Company B operates the helicopter on the basis of membership but had not been approved for Air Transport Service[*14]. Each passenger was not a member. As one of them asked Company B to fly the helicopter from Tokyo Heliport to Matsukawa Operation Site through a member, who is the acquaintance, they got on the helicopter, and the passenger planned to pay the aircraft rental fee by transferring it to Company B's bank account at the end of the month. Company B requested Company C to dispatch the captain for the operation of the helicopter and having qualified as a private pilot[*15], the captain, an employee of Company C, was engaged in the helicopter private operation.

(6) The Notification to Caution about Air Transport Services that were Issued by The Civil Aviation Bureau (CAB), Ministry of Land, Infrastructure, Transport and Tourism (MLIT)

The CAB, MLIT is well known by making a leaflet in December 2017 regarding the following: "From a point of view that businesses for operating

*13 The "height-velocity-envelop, or H/V curve" is a graph charting the height and speed at which a helicopter can safely transition from normal flight to autorotation.

*14 The term, "Air Transport Services" means any business utilizing aircraft to transport passengers or cargo for remuneration upon demand.

*15 "Private pilot" denotes qualifications for scope of pilotage of an aircraft engaged in non-revenue flights, without receiving remuneration.

aircraft require a license because they involve great risks, and those who operate without a license is punished with imprisonment for up to 3 years or a fine of up to 3,000,000 yen."

https://www.mlit.go.jp/common/001599984.pdf

(only available in Japanese)

(7) Training for Flight Crew Members in Air Transport Services

For flight crew members who operate a single-engine rotorcraft with a maximum take-off weight not more than 9,080 kg in air transport services, the competency assessment and training procedures shall be stipulated in the Operation Manual based on the Operation Manual Detailed Assessment Procedures, and the autorotation training shall be conducted during the training for captain qualification.

(8) Past Similar Accidents of Aérospatial AS350B Helicopters

The accidents, in which Aérospatial AS350B helicopters made a forced landing due to its engine failure (engine chip caution light on) in Japan, are as follows:

Date of occurrence At about 10:53, January 28, 1997

Summary When an Aérospatial AS350B, JA9835 was flying over Nishiki Town, Taki-Gun, Hyogo Prefecture, its engine stopped. Therefore, it made a hard landing at the time of performing an autorotation landing on a rice paddy in the town. There were two persons on board, consisting of a captain and a cameraperson, and the cameraperson sustained a minor injury. The rotorcraft was destroyed, but no fire broke out.

3. ANALYSIS

(1) Flight from the Illumination of the Engine Chip Caution Light to the Forced Landing

The JTSB concludes as follows regarding "Flight from the illumination of the engine chip caution light to the forced landing."

The captain reduced power and decreased the speed after the engine chip caution light came on. According to the GPS records, while flying at a ground speed of 126 kt and at an altitude of about 3,900 ft (about 2,000 ft AGL), the helicopter started to reduce the speed from about 09:31:10, therefore the engine chip caution light probably came on around the point about 28 km to Matsukawa Operation Site. It is probable that one minutes later at about 09:32:05, feeling the warning sound and the helicopter yawing, the captain recognized that the engine power suddenly decreased and turned to left promptly, and entered autorotation from about 1,800 ft AGL. The Passengers in the rear seats stated that they smelled something burning before the warning sound, therefore, it is most likely that immediately after the engine chip caution light came on, the damage to the engine started in a short time, resulting in the engine power loss.

Besides, according to the video taken by the eyewitness, abnormal engine sound continued even during autorotation flight, therefore the engine was probably damaged and came to a stop.

After the engine's sudden loss of power, the captain maneuvered the helicopter to the direction of a possible forced landing site he had confirmed in advance when the engine chip caution light came on and tried to make a forced landing southwestward at an angle perpendicular to the farm road about 3.5 m wide between the paddy fields.

While the helicopter was approaching the forced landing site, the ground speed decreased gradually and increased temporarily, but as shown in Figure 2, at about 09:33:06, a flare maneuver was assumed to be performed with nose-up. On the bank of the farm road, there were touchdown marks of landing gears (skids) and on the ground surface short of the touchdown point, contact marks with the tail skids, and the landing gears were broken to the backward side, therefore, the helicopter probably touched down as keeping moving slightly forward after the flare maneuver. Besides, based on the Passenger's statement that making the forced landing was something like falling freely from the height of the third floor of a building and the captain's statement that the collective pitch lever had reached to the highest position at a height of about 2 to 3 m immediately before the touchdown, the helicopter highly probable touched down on the bank of the farm road at a nearly vertical descent angle while increasing the rate of descent. Furthermore, there were contact marks with the main rotor blade on the surface of the farm road on the left side of the helicopter, and the rear seats were buckled forward left, therefore, it is probable that a load was temporarily applied that caused the aircraft to tilt to the left after the touchdown.

(2) Analysis of the Process Leading to Engine Damage

The JTSB concludes that from the result of the detailed disassembly inspection of the engine conducted by the design and manufacture company, the process from the illumination of the engine chip caution light leading to the engine damage is probably as follows: (See Figure 11)

a. The reason why the engine chip caution light came on was probably because from the conditions of the pollution of the magnetic plug engine oil and the deterioration of the power turbine front bearing in Appendix 2_Figure A and Table 1, the metallic particles of power turbine front bearing (Bearing steel 80DCV40) and of the power turbine shaft (Heat-resistant alloy NCK19DAT) in the Module M04 were mixed into the oil system, which the electrical magnetic plugs (Appendix 2_Figure A (2)) first detected.

The significant amount of metallic particles collected from the oil tank and oil filter contained power turbine material, most of which probably came from the damaged power turbine.

b. Regarding the power turbine shaft, from its conditions of the damage of the melted parts and the aggregation of the metal materials on the front bearing outer race (See Appendix 1_Figure C), it is probable that the front bearing seizure. It was more likely that because of the front bearing becoming stuck, the inner race that was fixed to the power turbine shaft began to rotate and causing the power turbine shaft to heat up to the near melting point of 1,300°, in addition, due to thermal stresses [*16] the inner race disappeared, and the power turbine shaft fractured. Additionally, the power turbine spline nut had moved forward by more than 2 mm, and it is more likely that it moved forward when the power turbine shaft fractured. From there was evidence that the spline nut was fixed with adhesive, this fact that it had moved 2mm forward could be, it is unknown whether it comes from abnormal thermal exposition during the power turbine front bearing damage which would significantly lower the glue properties or from another factor like inappropriate gluing process.

c. The power turbine bearing support had impact marks, was twisted damaged, which was most likely caused by an impact with the rotating power turbine blades that were still bonded to the disk.

d. Considering that even during autorotation descent, abnormal engine sound continued, the gas generator turbine for the engine probably continued to rotate.

e. It is likely that the power turbine moved forward while rotating after the shaft fractured and

*16 "Thermal stresses" are the stresses produced at inside of object by any change in the temperature or geometrical constraint of the material. It occurs when thermal expansion or contraction is impeded due to some causes and causes compression stress in the high temperature region and tension stress in the low temperature region.

impacted the nozzle guide vanes. The resulted in significant damage to all blades and part of disk slots, whose broken pieces were scattered. Impact marks on the exhaust, tail rotor, and the vertical and horizontal stabilizers were probably caused by debris ejected through the engine exhaust.

f. It is highly probable that a power turbine front bearing deterioration led to the front bearing seizure and to the melting and fracturing of the power turbine shaft, resulting in the engine's sudden loss of power.

g. The disassembled engine examination revealed severe damage to the power turbine front bearing that was lubricated. The level of damage did not permit to determine the cause of its deterioration during the examination.

According to the design and manufacture company, in 2015, an aircraft accident occurred due to failures related to the relevant parts, but with circumstances different from those in this accident:

- a lack of lubrication of the power turbine front bearing due to clogging of the oil jet.
- no sign of glue to fix the spline nut at the rear of the power turbine shaft.

Although no other similar accident have occurred, in order to whether the problem is unique to the parts, it is desirable for the design and manufacturer company to collect the replaced parts of same type engine, and examine the deterioration status, and consider additional countermeasures.

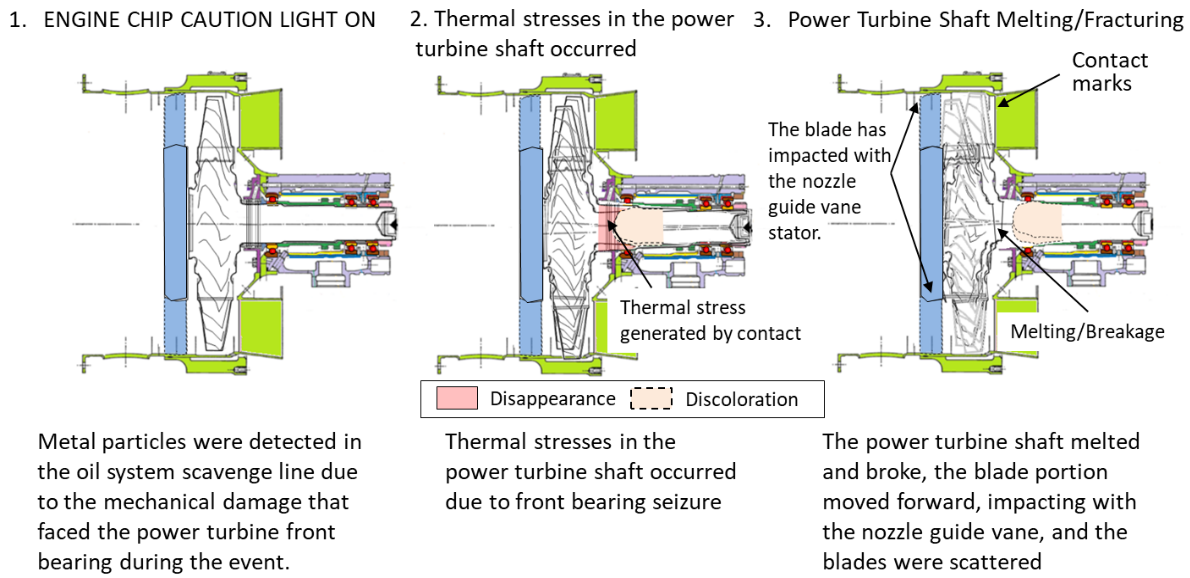


Figure 11: Melting and Rupture of Power Turbine Shaft

(3) Pilot's Response after the Illumination of the Engine Chip Caution Light

The JTSB concludes as follows regarding "Pilot's Response after the Illumination of the Engine Chip Caution Light."

When the engine chip caution light comes on, as specified in the flight manual, it is necessary to land as soon as possible, and it is desirable to execute a preventive landing. After the engine chip caution light came on, the captain confirmed that there was no abnormality in the engine instruments, established approximately 90 kt airspeed, and when looking for the appropriate site to land, the captain recognized the engine flame-out, quickly turned the helicopter to the direction of the extended rice paddies area, and performed the autorotation emergency procedures, therefore it is probable that damage to personnel and objects on the ground could have been prevented to a minimum.

Regarding the operations in autorotation, it is possible that due to the heavy weight, and the airspeed during approach was less than 65 kt, thus the rate of descent increased, as shown in Figure 10. In addition, it is probable that the touchdown maneuver became difficult to perform because it decelerated against the targeted road.

In the event of an engine shutdown while flying at low-speed and hovering altitude, a helicopter can generate a lift and lowering the rate of descent while decreasing NR with the operation of the collective pitch lever. In order to minimum the rate of descent at touchdown, it is desirable to lift the collective pitch lever to the highest position at touchdown, however, according to the statement of the captain, the collective pitch lever had reached to the highest position at about 2 to 3 m AGL, therefore, it is highly probable that from there, the rate of descent became uncontrollable, and the helicopter touched down while the descent was increasing, resulting in its hard landing.

In order to reduce the rate of descent during autorotation landing, as per the emergency procedures, it is necessary to maintain NR and airspeed until the start of flare maneuver. Besides, making an autorotation landing on a narrow place requires such advanced flight skills as reducing the rate of descent by performing deceleration procedures in flaring at low altitude before touchdown, and while returning the attitude, using the collective pitch lever just before touchdown in order to control the rate of descent. And when it is unable to bring the helicopter into the wind, or its the heavier the weight is, the more difficult operation is required, therefore, in order to reduce the load at touchdown as much as possible, it is important for a pilot to select the widest possible site and try to land.

(4) Estimation of Final Approach Profile based on Estimated Load Factor *17 at Forced Landing

The JTSB concludes as follows regarding "Estimation of Final Approach Profile based on Estimated Load Factor at Forced Landing."

Based on the damage to the helicopter at the time of the forced landing, the designer and manufacturer company estimated the load factor at the forced landing by means of the load factor limit line. It is highly probable that considering the damage to such as the airframe and equipment as shown in Figure 12, the inertia forward speed load factor (Nx) is estimated to be 11 G, and the inertia vertical speed load factor (Nz) is estimated to be 35 G. Besides, the vector-based calculation of the load factor results, as shown in Figure 13, revealed that the direction of the helicopter movement was about 73°. And from the ANALYSIS 3 (1), a combined radial and axial load of about 37 G was most likely applied in the approach direction of the helicopter at touchdown as the helicopter had made an approach at low speed in a steep angle of about 73° with its nose-up. Therefore, the inertia vertical speed load factor (Nz) of 35 G probably means that the helicopter touched down at a rate of descent of 1,656 ft/min or more.

Regarding structural strength, the provision in the Airworthiness Inspection Manual (Category of airworthiness: Rotorcraft, Normal N), which is applied to Aérospatial AS350B Rotorcraft, requires that the passengers on board are spared significant injury even in the event of landing in emergency conditions subjected to inertial forces of '4.0 G below'. The helicopter was subjected to a load at touchdown exceeding the strength demanding value, but the load was distributed as the helicopter was damaged, and such as in the landing gears, fuselage and seats were deformed, in addition, the heavy load on the upper part of the fuselage did not fall, it is

*17 "Load factor" is the ratio between load acting on an aircraft to the weight of the aircraft. (Airworthiness Inspection Manual) probable that the cabin structure was protected and damages to the captain and passengers were reduced.

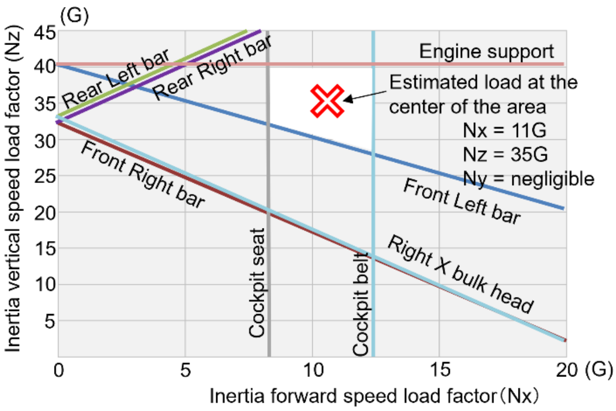


Figure 12: Estimated Load Factor at Forced Landing

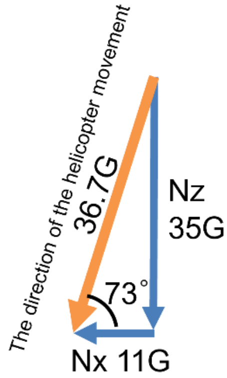


Figure 13: Approach Angle and Combined Load based on Estimated

(5) Flight Operation of the Helicopter, and Training Experience and Competence Certification Qualification of the captain

The JTSB concludes as follows regarding “Flight Operation of the Helicopter, and Training Experience and Competence Certification Qualification of the captain” as follows”.

The captain was qualified as a private pilot, the captain was engaged in the helicopter for private operation, and had properly taken the pilot competency assessment, but had not taken autorotation training after the change of rating as it was not required to take recurrent trainings. In addition, in this accident, it was the touchdown operation with heavy weight, something that the captain had never experienced during autorotation training when obtaining a private pilot certificate, which probable contributed to the maneuver of the helicopter at the time of the forced landing.

(6) Emergency Operations Training in Case of Engine Power Loss for Private Pilots Operating Single-Engine Helicopters

The JTSB concludes as follows regarding “Emergency Operations Training in Case of Engine Power Loss for Private Pilots Operating Single-Engine Helicopters.”

As private pilots who fly single-engine helicopters have limited opportunities to take the training of autorotation, one of emergency procedures taken at the time of engine power loss, it is important for them to fly considering the height-velocity-envelope, weight, and wind direction / velocity, and conduct trainings by imaging the landing site, approach direction, and operations at touchdown in case of attempting an autorotational forced landing in a daily basis.

(7) Flight Operation Type of the Helicopter

The JTSB concludes that “Flight Operation Type of the Helicopter” as follows.”

As described in 2.8 (5), the helicopter was operated by a private pilot for private operation, however, when operating an Air Transport Service, the method of skill examination and training of aircraft crew is stipulated in the operating regulations, and operations are conducted with permission based on Article 100 of the Civil Aviation Act, so need to be done safety that can be ensured by managing skills in accordance with the rules.

4. PROBABLE CAUSES

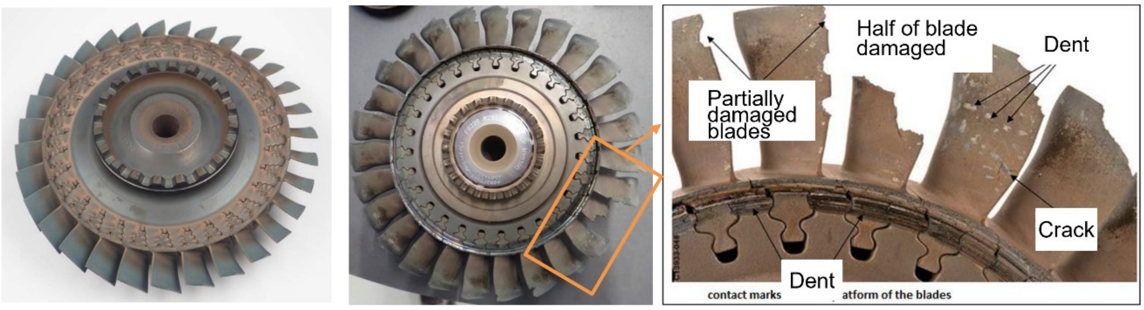
The JTSB concludes that the probable cause of this accident was that as the helicopter's engine power most likely decreased during cruising flight, the helicopter attempted to make a forced landing on a farm road in autorotation, and made a hard landing, resulting in injuries to the captain and passengers and the destruction of the helicopter.

It is highly probable that the helicopter's engine power decreased during the flight because the power turbine shaft fractured due to the engine's power turbine front bearing seizure, however, it was not possible to determine the cause of the power turbine front bearing seizure. And the reason why it became a hard landing at the time of the forced landing was most likely because in autorotation landing, the altitude at flare-out became high, and the rate of descent before the touchdown was not sufficiently controlled.

5. SAFETY ACTIONS

5.1 Safety Actions Required	(1) As private pilots who fly single-engine helicopters have limited opportunities to take the training of one of emergency procedures taken at the time of engine power loss, it is important for them to fly considering the height-velocity-envelope, weight, and wind direction / velocity, and it is important to conduct trainings by imaging the landing site, approach direction, and operations at touchdown in case of attempting a forced landing in autorotation in a daily basis. (2) In case of attempting a forced landing in autorotation, in accordance with the emergency operations procedures, it is necessary to maintain NR and airspeed before the start of flare maneuver. Making an autorotation landing on a narrow place requires such advanced skills of touchdown operations by flare, when is unable to bring the helicopter into the wind, or its weight is too heavy, in order to reduce the load at touchdown as much as possible, it is important for a pilot to select the widest possible site and try to land. (3) When the power turbine front bearing of the same type of engine was replaced, it is desirable for the design and manufacturer company collect the replaced parts, examine the deterioration status, and consider additional countermeasures.

Appendix 1: Damage to Engine Interior



HP1 turbine (from rear side)
HP2 turbine (from rear side)
Enlarged view of damaged HP2 turbine

Figure A: Damage to MODULE M03 Gas Generator Section

Nozzle guide vane (after cutting the casing strut from the rear)
Power turbine core
Enlarged view of the power turbine blade attachment

Figure B: Damage to MODULE M04 Power Turbine

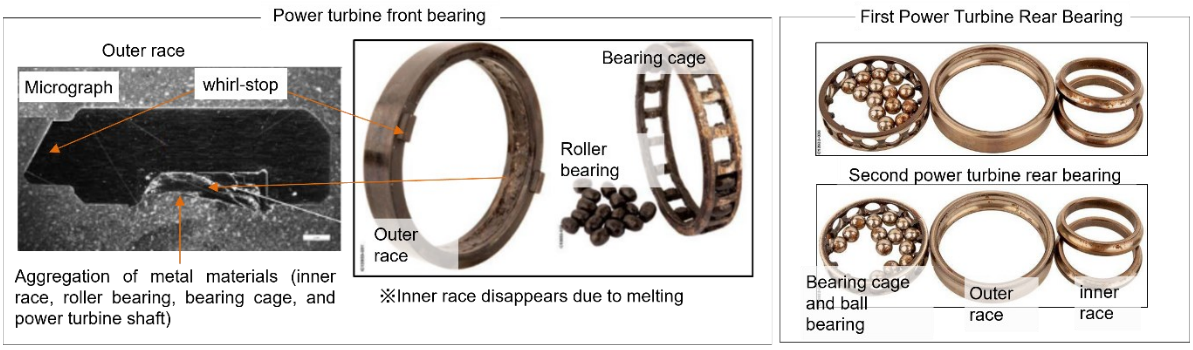
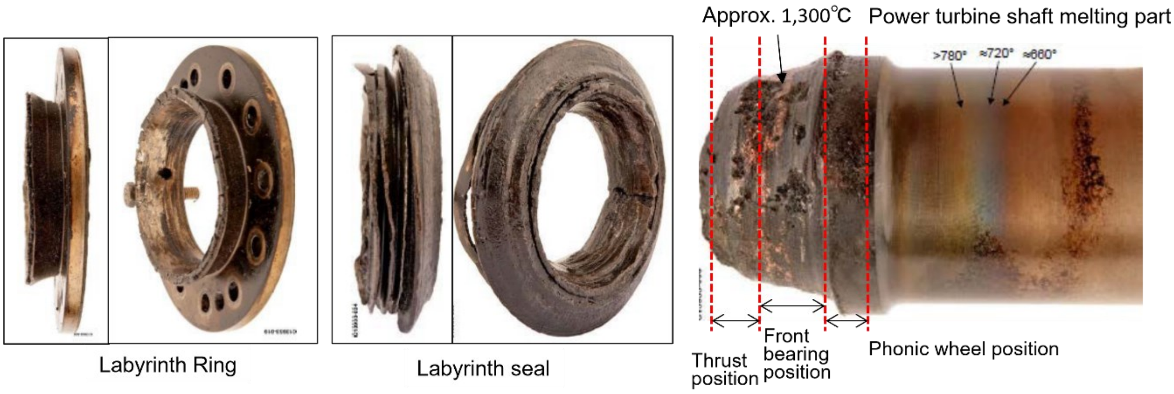


Figure C: Damage to MODULE M04 Power Turbine Bearing



Labyrinth Ring
Labyrinth seal

Figure D: Damage to MODULE M04 Power Turbine Shaft

Appendix 2: Engine Oil Contamination

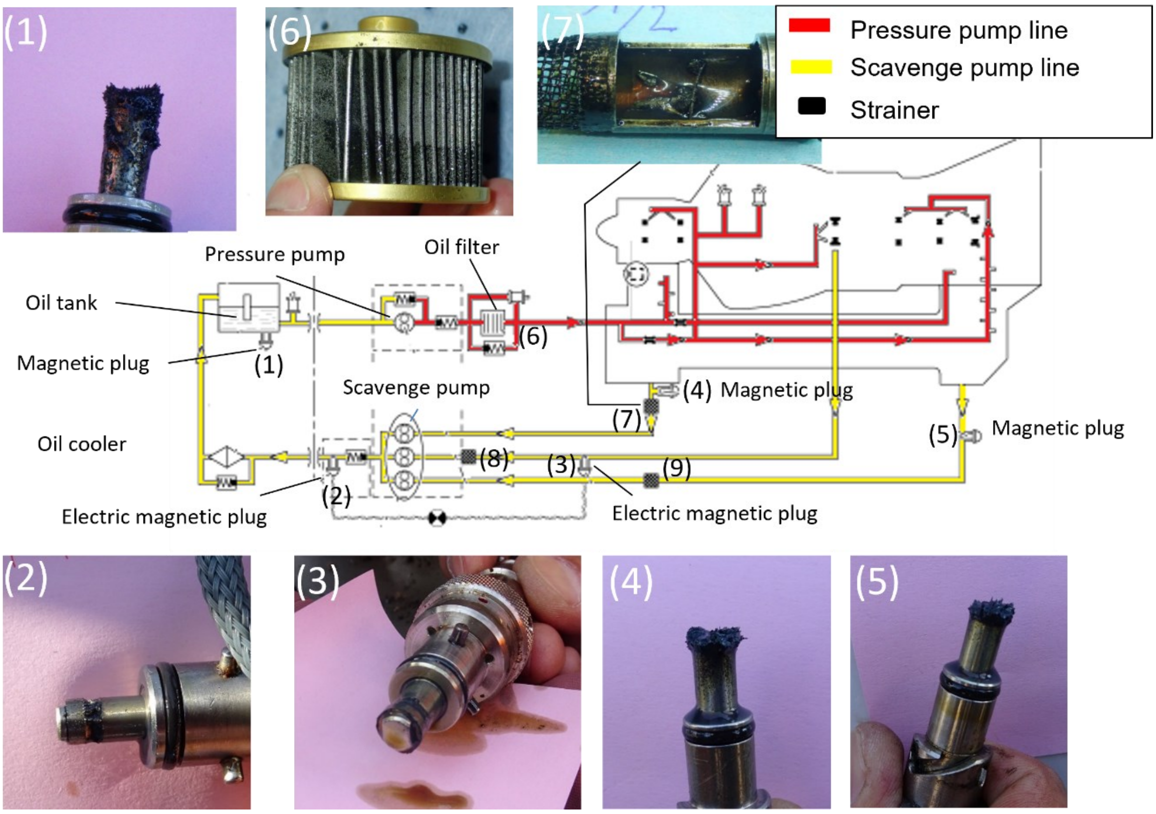


Figure A: Engine Oil Flow and Situation Contaminated by Metallic Particles

Table 1: Oil Contamination

NAME	Alarm function	Oil scavenge line	Metallic particle	Detection material
(1) Magnetic plug	×	All modules	Many	unconfirmed
(2) Electric magnetic plug	○	All modules	Little	Such as Iron alloys (35NCD16 and 16NCD13), Many engine parts materials
(3) Electric magnetic plug	○	Module M03	Little	Iron alloy (Unable to identify material)
(4) Magnetic plug	×	Modules M01 and M02	Many	Bearing material (80DCV40)
(5) Magnetic plug	×	Modules M04 and M05	Many	Bearing material (80DCV40)
(6) Oil filter and cartridge	×	All modules	Many	Power turbine shaft material (NCK19DAT)
(7) Strainer *18	×	Modules M01 and M02	Many	Power turbine shaft material (NCK19DAT)
(8) Strainer	×	Module M03	None	
(9) Strainer	×	Modules M04 and M05	None	

*18 A "strainer" is a device to remove large foreign objects from oil with a metal mesh.