AA2020-2

AIRCRAFT ACCIDENT INVESTIGATION REPORT

TOHO AIR SERVICE CO., LTD.
J A 9 6 7 2

April 23, 2020

Japan Transport Safety Board

The objective of the investigation conducted by the Japan Transport Safety Board in accordance with the Act for Establishment of the Japan Transport Safety Board and with Annex 13 to the Convention on International Civil Aviation is to determine the causes of an accident and damage incidental to such an accident, thereby preventing future accidents and reducing damage. It is not the purpose of the investigation to apportion blame or liability.

TAKEDA Nobuo
Chairman
Japan Transport Safety Board

Note:

This report is a translation of the Japanese original investigation report. The text in Japanese shall prevail in the interpretation of the report.

AIRCRAFT ACCIDENT

INVESTIGATION REPORT

UNCONTROLLED CRASH
TOHO AIR SERVICE CO., LTD.
AEROSPATIALE AS332L (ROTORCRAFT),
REGISTERED JA9672,
IN UENO-MURA, TANO COUNTY,
GUNMA PREFECTURE, JAPAN
AROUND 14:29 JST, NOVEMBER 8, 2017

March 27, 2020

Adopted by the Japan Transport Safety Board

Chairman	TAKEDA Nobuo
Member	MIYASHITA Toru
Member	KAKISHIMA Yoshiko
Member	MARUI Yuichi
Member	MIYAZAWA Yoshikazu
Member	NAKANISHI Miwa

SYNOPSIS

< Summary of the Accident >

While an Aerospatiale AS332L, registered JA9672, operated by Toho Air Service Co., Ltd., was flying from Arakura temporary helipad in Hayakawa Town, Minami-koma County, Yamanashi Prefecture, to Tochigi heliport for ferry flight, the tail rotor was separated from the airframe over Ueno-mura, Tano County, Gunma Prefecture, and the aircraft became uncontrollable and crashed around 14:29 JST on November 8, 2017.

Four crew members, consisting of a captain, a mechanic in charge and two mechanics were on board, and all of them were killed.

The aircraft was destroyed and there occurred the outbreak of fire.

< Probable Causes >

In this accident, it is highly probable that, when the Helicopter attempted an emergency landing due to abnormal vibrations occurring in the airframe in flight, the tail rotor was separated leading to loss of control and subsequent crash.

It is highly probable that the separation of the tail rotor from the airframe was caused by imbalanced rotation of the tail rotor due to the fracture of the spindle bolt of the flapping hinge of the White Blade, which generated excessive vibrations and damaged the section attached to the tail rotor.

It is highly probable that the fractured spindle bolt was caused by damaged and stuck bearings of the flapping hinge. Besides, it is highly probable that this resulted from the fact that the damaged condition of the bearings was not grasped in inspections and maintenance work performed on the Helicopter and the appropriate measures were not taken.

< Recommendations >

1. Recommendations to Toho Air Service Co., Ltd.

In this accident, the information on the malfunction of the flapping hinge of the white blade was not reported and appropriate maintenance was not performed in the disassembly maintenance work for the flapping hinge of the White Blade. Besides, the information issued by Airbus Helicopters with regard to the usage of the grease was not disseminated, and maintenance work in the event of parking at high temperature and high humidity was not thoroughly performed. It is probable that either case was related to the factors of the accident.

In the view of this accident investigation, in order to contribute to the prevention of recurrence of similar cases of accident, the Japan Transport Safety Board submits recommendations pursuant to the provision of the Article 27, paragraph (1) of the Act for Establishment of the Japan Transport Safety Board to Toho Airlines Co., Ltd. as follows:

1) In the event that malfunction including damage, which is not described in manual or the like of the designer and manufacturer, is found during maintenance inspection work, report to the designer and the manufacturer for their technical review, and take necessary measures for the malfunction in accordance with their instructions.

2) From technical point of the view, promptly review the malfunction information, notified in relation to caution in maintenance work that was notified by the designer and the manufacturer, and disseminate such information to mechanics on-site.

Major abbreviations and acronyms used in this report are as follows:

AD: Airworthiness Improvement Directive

ALS: Airworthiness Limitations Section

ASE: Automatic Stabilization Equipment

ASB: Alert Service Bulletin

CG: Center of Gravity

CF: Centrifugal Force

EASA: European Union Aviation Safety Agency

IAS: Indicated Air Speed

MET: Maintenance Manual

MGB: Main Gear Box

MRB: Main Rotor Blade

MRM: Mechanical Repair Manual

MSM: Master Servicing Manual

MTC: Standard Practices Manual

TGB: Tail Gear Box

Unit Conversions:

1 ft: 0.3048 m

1 kt: 1.852 km/h (0.5144 m/s)

1 kg: 2.205 lb

1 N: 0.10197 kgf

1 mm: 0.039 in

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1 PROCESS AND PROGRESS OF THE AIRCRAFT ACCIDENT INVESTIGATION

1.1 Summary of the Accident

While an Aerospatiale AS332L, registered JA9672, operated by Toho Air Service Co., Ltd., was flying after taking off from Arakura temporary helipad in Hayakawa Town, Minami-koma County, Yamanashi Prefecture, to Tochigi heliport for ferry flight, the tail rotor was separated from the airframe over Ueno-mura, Tano County, Gunma Prefecture, and the aircraft became uncontrollable and crashed around 14:29 JST (JST: UTC+9 hours; unless otherwise noted, all times are indicated in JST in this report on a 24-hour clock) on November 8, 2017.

Four crew members, consisting of a captain, a certifying mechanic and two mechanics, were on board, and all of them were killed.

The aircraft was destroyed and there occurred the outbreak of fire.

1.2 Outline of the Accident Investigation

1.2.1 Investigation Organization

Upon receipt of the notice of the occurrence of the accident, the Japan Transport Safety Board designated an investigator-in-charge and two investigators to investigate the accident.

1.2.2 Representatives of the Relevant State

An accredited representative of the French Republic, as the State of Design and Manufacture of the aircraft involved in the accident, participated in the investigation.

1.2.3 Implementation of the Investigation

November 9 until 12, 2017:	On-site investigation
November 13:	Interviews and documents investigation
November 15 until 17:	Wreckage investigation and interviews
December 18, 2017 until: November 15, 2018:	Disassembly investigation of the tail rotor and analysis of inspection result of the flapping hinge (performed at the facility of the manufacturer of the aircraft by the attendance of the French bureau of civil aircraft accident investigation (BEA)

1.2.4 Provision of Factual Information with Civil Aviation Bureau

On November 21, 2017, the factual information on "Spindle bolt fractured at the attached section to the tail rotor blade" was provided to the Civil Aviation Bureau, as obtained through the investigation. In response to this information and the Airworthiness Directive issued by EASA, the Civil Aviation Bureau issued their Airworthiness Directive on November 21, 2017 to users of the same type of aircraft across the nation to perform an emergency inspection of the section in question and to report the inspection result to the aircraft manufacturer.

1.2.5 Comments from Parties Relevant to the Cause

Comments were invited from the parties relevant to the cause of the accident.

1.2.6 Comments from the Relevant State

Comments were invited from the Relevant State.

2. FACTUAL INFORMATION

2.1 History of the Flight

An Aerospatiale AS332L (hereinafter referred to as "the Helicopter"), registered JA9672, operated by Toho Air Service Co., Ltd. (hereinafter referred to as "the Company"), was flying from Arakura temporary helipad to Tochigi heliport for ferry flight on November 8, 2017. In the Helicopter, a captain sat in the right pilot's seat, a certifying mechanic *1 A (hereinafter referred to as "CM A") sat in the left pilot's seat and two mechanics sat in the rear seats.

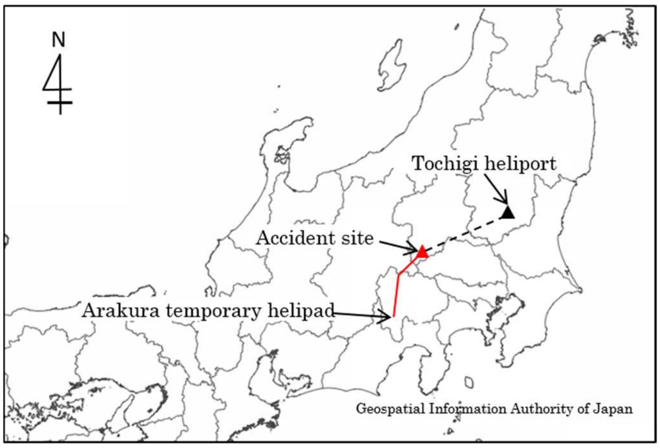

Figure1: Estimated flight route of the Aircraft

The outline of the flight plan of the Helicopter was as follows:

Flight rules: Visual flight rules, Departure aerodrome: Arakura temporary helipad, Estimated off-block time: 14:10, Cruising speed: 120 kt, Cruising altitude: VFR, Flight route: Usui Pass and Isezaki, Destination aerodrome: Tochigi heliport
Total estimated elapsed time: One hour and 30 minutes, Fuel load expressed in endurance: Two hours and 45 minutes, Persons on board: Four

According to the flight records and maintenance history of the Company, ATC radar track records, and statements of a pilot and an operation controller of the Company and witnesses, history of the flight up to the accident was summarized as follows:

2.1.1 History of the Flight by Flight Records and Radar Track Records

Around 14:04	Took off from Arakura temporary helipad
Around 14:12	Position reporting from the Helicopter to the operation controller of the Company
At 14:22:21	Radar detected flight track supposedly of the Helicopter at an altitude of 6,600 ft over Kawakami Village, Minami-saku County, Gunma Prefecture
At 14:27:02	Flight track supposedly of the Helicopter disappeared from radar at an altitude of 6,900 ft over Ueno-mura, Tano County, Gunma Prefecture
Around 14:29	Crashed on the bridge over a tributary to the Kanna River in Ueno-mura, Tano County, Gunma Prefecture

2.1.2 Statements of Mechanics of the Company

(1) Mechanic A (See Figure 15 for the flapping hinge parts.)

Disassembly maintenance of the flapping hinge of the tail rotor of the Helicopter was performed as 500-hour and 1,000-hour inspection items during the period from March 21 until May 16, 2017.

*1 "certifying mechanic" is a designated mechanic from eligible mechanics based on the maintenance manual, and performs the final check of the aircraft after maintenance.

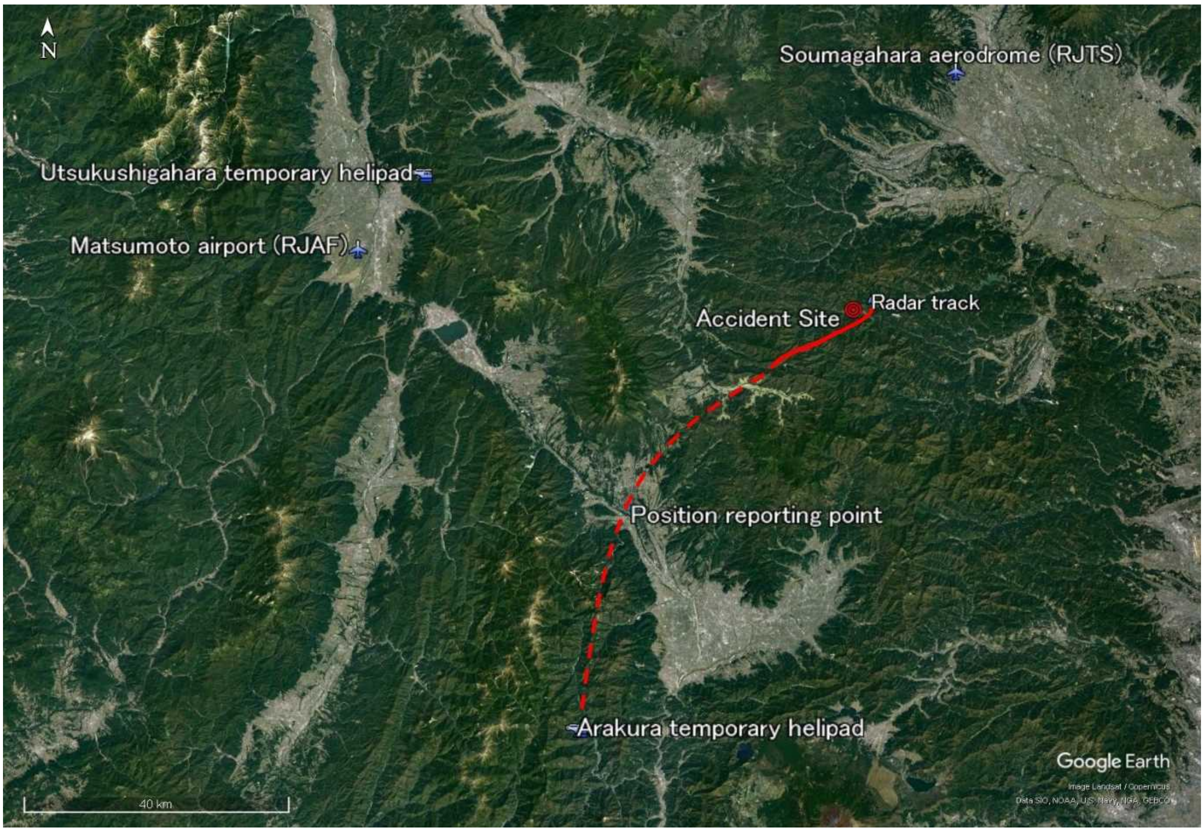

Figure 2: Enlarged image of estimated flight route of the Aircraft

According to a mechanic (hereinafter referred to as "Mechanic A") who assisted the maintenance work at that time, all five spindle bolts were smoothly pulled out (see Figure 15 for the flapping hinge parts) and all stop washers were replaced due to cracks. He remembered that the inner ring and the outer bearings were not removed in this maintenance work. Some of five spindle bolts had corrosion and were polished for removal of the corrosion with a brass brush. The final inspection and re-assembly of the spindle bolts were performed by CM A. The maintenance record at this time did not contain any other description than malfunction of the stop washer and its replacement. The seal was not replaced against the spindle bolt removal-installation procedures, which require the replacement.

(2) Mechanic B

The Helicopter commenced ferry flight for cargo transportation on May 30 after completing 500-hour and 1,000-hour inspection on May 16, 2017 and receiving airworthiness inspection thereafter. According to a mechanic (hereinafter referred to as "Mechanic B") who assisted the maintenance work, the grease discharged from the flapping hinge of the White Blade (hereinafter referred to as "the White Blade") contained a very little amount of darkening in post-flight greasing up around the middle of June; however, the flapping hinge did not have any abnormality in its motion. Since then, Mechanic B had confirmed the condition of the darkening mixed in the discharged grease in every post-flight inspection. The grease seemed darken a little at the beginning, and gradually got darker as flight time increased. It seemed that apparently black grease began to be discharged in the middle of July when play in the direction of drag began to occur. Thereafter, Mechanic B increased the grease up amount in every post-flight inspection until a clear grease was discharged. At that time, some of the flapping hinge of other tail rotor blades discharged a black grease when the Helicopter flew after rainfall or flew for five hours or more; however, they were not as black and contaminated as the White Blade.

During the 50 hour-inspection performed on August 30, it was found that the White Blade had a 0.4 mm play; however, it had no abnormality in its motion.

In another 50-hour inspection performed on September 19, the play of the White Blade remained same, i.e. 0.4 mm; however, because the motion of the blade was not smooth, the CM A decided to remove the spindle bolt of the flapping hinge of the White Blade to see its condition in the 250-hour inspection scheduled from September 20 until September 23 at Tochigi heliport. Because the spindle bolt was not smoothly pulled out on September 20, Mechanic B sprayed lubricant on it and pulled it out tapping with a brass rod. The CM A decided to replace the inner ring and the washer because he confirmed cracks in the inner ring without having the inner ring removed. The removed stop washer was not so much scraped off; however, the contact face of the yoke (See Figure 15), to which the stop washer was attached, was scraped off. Replacement work on September 23 after receipt of replacement parts was performed in a way to insert a new inner ring from the top to push out the one to be removed (hereinafter referred to as "the Old Inner Ring") in order to prevent dust from getting into the outer bearings (See Figure 18). Because the Old Inner Ring was broken into fragments, it was replaced by receiving the fragments in a vinyl bag, which were discarded as kept in the bag. This way of replacement work hindered the condition of the outer bearings inside the spindle and the existence of residue associated with the fracture of the inner ring from being confirmed when the inner ring was replaced. Besides, the stop washer was replaced when the inner ring was replaced, but the seal was not replaced.

Because checking the removed spindle bolt revealed the existence of red rust and black rust scattering on it, the surface of which was polished by an abrasive sponge. The spindle bolt was pasted by grease without completely removing the rust, and was installed in the flapping hinge.

In checking after the replacement, the White Blade moved smoothly in the direction of flapping; however, the play in the direction of drag remained unchanged at 0.4 mm.

(3) Maintenance Administrator

The information with regard to the cracks of the inner ring of the Helicopter confirmed on September 20, 2017 was distributed to senior manager of maintenance department, one of the maintenance administrators, and managers of control planning section, inspection section and operation maintenance section through e-mail sent by persons in charge at control planning section and procurement section; however, senior manager did not issue any special instruction or take countermeasures because aircraft status chart and aircraft malfunction report were not made up, and he recognized that the issue had been corrected by replacement of general parts in the inspection work.

(4) Person in Charge for Maintenance Malfunction

According to person in charge for malfunction at control planning section, he came to notice that malfunction occurred in the inner ring when he was asked to confirm rework instruction of the tail gear box (TGB) by the CM A, and sent the inter-office email to major maintenance administrators simply informing of malfunction occurring in the tail rotor system because he did not hear further detail and was unable to make judgment based on conjecture.

(5) Person in Charge for Ordering Parts

According to the person in charge of ordering parts at the procurement section, he inquired the CM A about the malfunction of the inner ring because he was requested by the CM A to order AOG (Aircraft on the Ground) and deliver the parts to the site. Then, the person in charge of ordering completed paperwork described in the format that the cracks occurred at the edge of the inner ring, and issued an order sheet for the new inner ring to a designated distributor and forwarded it to major maintenance administrators by the inter-office email.

2.1.3 Statements of Pilot and Operation Controller of the Company

(1) Pilot Holding a Pilot Certificate of the Helicopter

According to a pilot (hereinafter referred to as "Pilot A") holding a pilot certificate of the Helicopter belonging to the Company, the Helicopter was used mainly for cargo transportation and was operated by a sole pilot holding the pilot certificate on board. Three pilots holding the pilot certificate took turns operating every several days for cargo transport.

Pilot A transported cargo as a pilot of the Helicopter from October 24 until November 2, 2017, when he switched the operation with the captain. When Pilot A performed ground run on October 31, 2017, he felt low-frequency lateral vibrations in a cycle shorter than a second (hereinafter referred to as "the Lateral Vibrations") in the pilot's seat. There occurred no change in the level of the vibrations in flight, even when Pilot A thereafter hovered and accelerated, but vibrations like precession*2 occurred. ASE mode*3 was used as a flight control system at any time. When Pilot A consulted with the CM A about the condition of the vibration while flying, he was told that the Lateral Vibrations were supposed to be an influence of a small amount of oil leakage from the sleeve of the main rotor blade (MRB), which would be left until December when the regular inspection was scheduled for. Pilot A thereafter flew the Helicopter for about 12 hours in total until November 2, 2017, and there was no change in the conditions of the Lateral Vibrations. Pilot A did not note the Lateral Vibrations as a malfunction in the record sheet, but verbally conveyed the conditions of the Lateral Vibrations to the captain at the accommodation when he switched the operation to the captain on November 2.

(2) Operation Controller of the Company

According to the operation controller of the Company, he was asked by the captain to confirm meteorological conditions up to Tochigi heliport at around 13:30 on November 8, 2017. There are two different ways available from Arakura temporary helipad to Tochigi heliport; the southern route flying over Chuo Expressway, and the northern route passing over the vicinity of Usui Pass, and therefore the operation controller told the pilot that cloud base of the southern route was lower on that day. The operation controller was reported by the captain that the flight plan was the northern route. Around 14:12 thereafter, the operation controller received take-off time from Arakura temporary helipad and position reporting from the Helicopter via Utsukushigahara radio station of the Company.

2.1.4 Statements of Witnesses A through D

(1) Witness A (in the position "A" in Figure 5)

A witness A saw the Helicopter turning and abruptly descending after flying over at a little higher altitude.

(2) Witness B (in the position "B" in Figure 5 and 6)

A witness B heard an unfamiliar and abnormal noise of "clapping" from the Helicopter that was coming close while going round the riverside and took two photos (Figure 3) of the Helicopter wondering what was happening.

(3) Witness C (in the position "C" in Appended Figure 6)

A witness C saw parts dropping from the Helicopter that was flying along the Kanna River at a low altitude and crashed falling headlong. Immediately after the crash, the witness C heard a noise of explosion and saw a pillar of fire shooting up.

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*2 "Precession" is also referred to as "gyrating movement" or "gyroscopic precession", and denotes swinging movement of rotating axis of autorotating object in such a way to make a circle around.

*3 "ASE mode" denotes a flight control mode equipped in the similar types of aircraft, and activating this mode makes the aircraft to maintain the standard position of it attitude, direction and altitude.

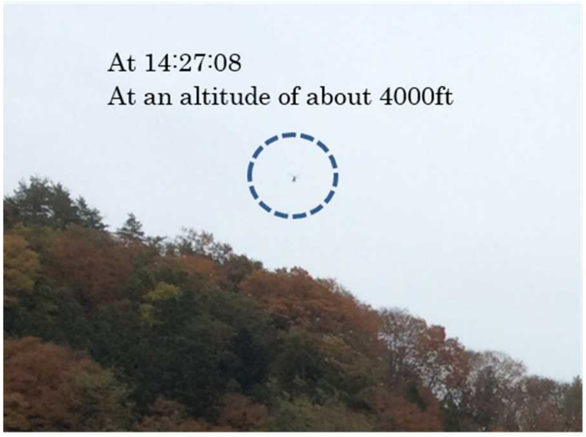

Figure 3-1: Approaching the Helicopter

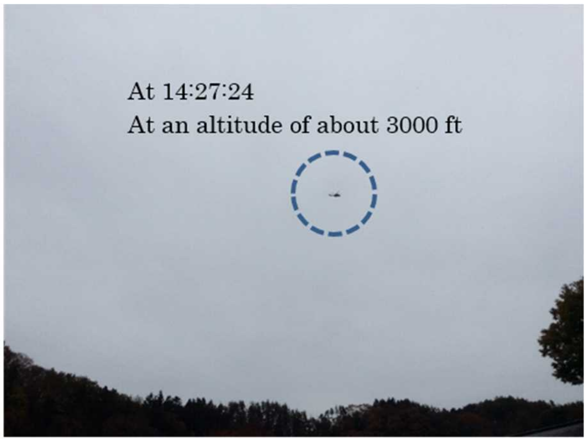

Figure 3-2: Approaching aircraft while going around

Figure 3-3: Enlarged 3-2

Figure 3: Approaching aircraft while going around

(4) Witness D (in the position "D" in Appended Figure 6)

A witness D at first heard a noise of explosion like boom from the upper stream direction of the Kanna River when he was at work on the riverside, and then visually recognized the Helicopter, and saw a white smoke or something coming out from the aft airframe. Immediately thereafter, the witness D saw propellers dropping from the aft airframe of the Helicopter, the Helicopter veering to the left, red parts dropping from the Helicopter when the nose was lowered, turning three times or so followed by crashing, and a pillar of fire shooting up.

2.1.5 Radar Track Records

Although the Helicopter was flying in visual flight rules and communication with ATC was not set, the flight track supposed to be of the Helicopter was recorded on ATC radar during the period from 14:22:21 until 14:27:02.

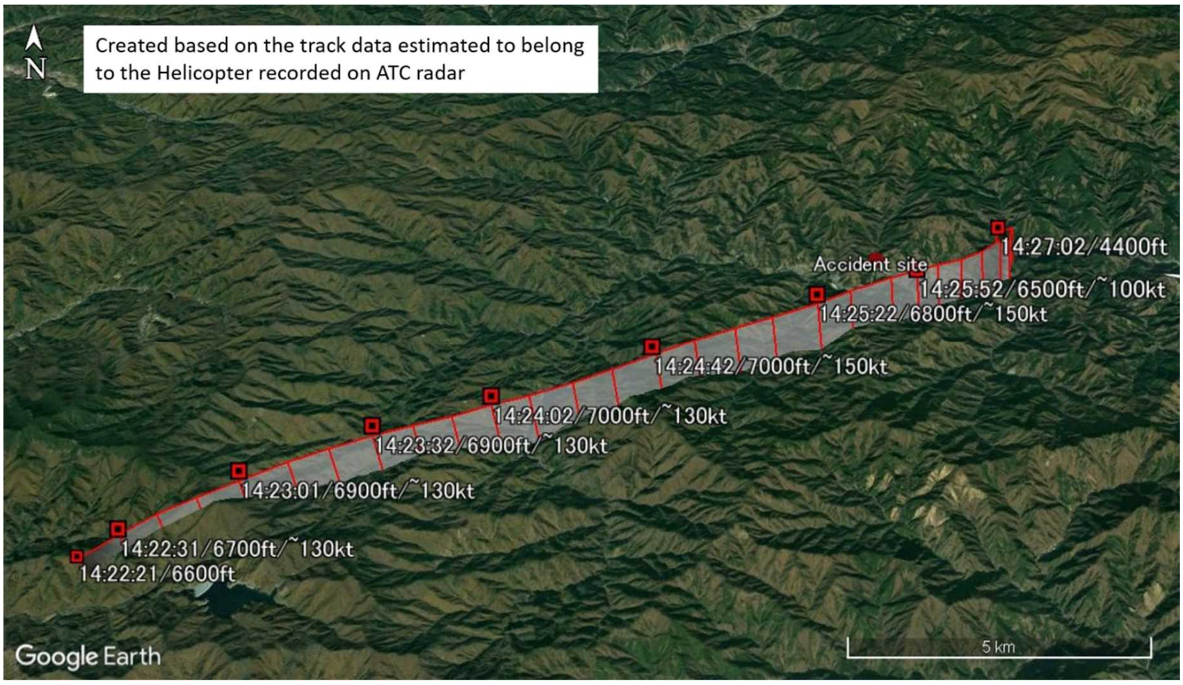

Figure 4: Flight path based on the track data of the Helicopter

According to the ATC radar track of the estimated Helicopter records from 14:22:21 until 14:27:02, the Helicopter climbed to a pressure altitude of 7,000 ft at a mean ground speed of about 130 kt (the speed was a calculated figure based on the radar track records, and the same applies hereinafter), and then was in level flight at a mean ground speed of about 150 kt. The Helicopter performed the first deceleration from a mean ground speed of about 150 kt to 100 kt around 14:25:52. Then, the Helicopter continued to fly at a mean ground speed of about 100 kt while gradually descending for about 30 seconds. After the second abrupt deceleration, the Helicopter commenced an abrupt descending at a mean ground speed of about 80 kt and at a mean descent rate of about 3,800 ft/minute turning to the left around 14:26:32.

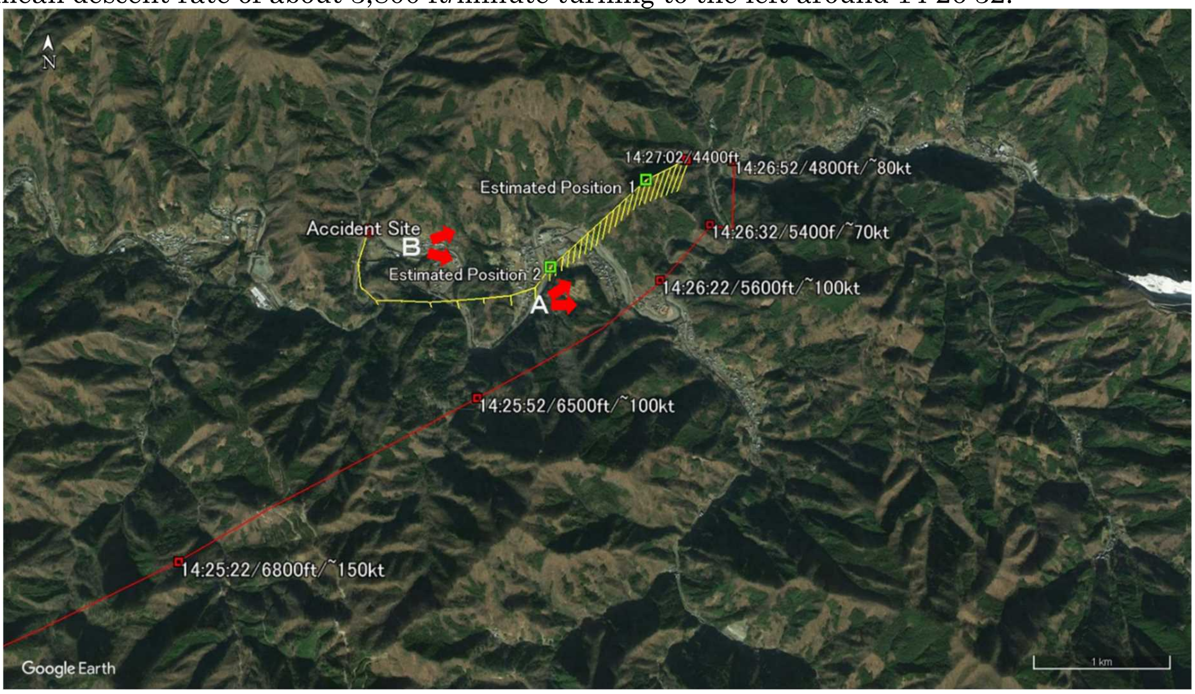

Figure 5: Estimated flight route from witnesses' information and radar track records

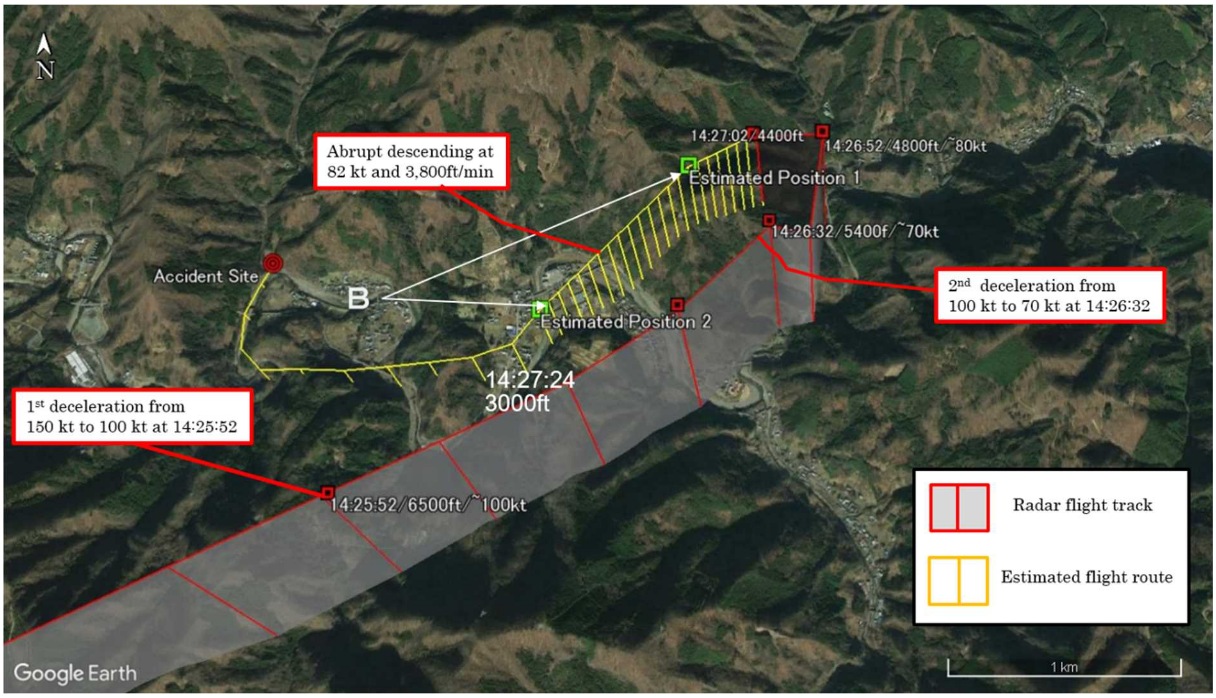

Figure 6: Arupt descent of the Aircraft during emergency operation

The place of occurrence of this accident was Ueno-mura, Tano County, Gunma Prefecture (36 ° 05'06" N, 138 ° 46'11" E) and the time of the occurrence was November 8, 2017 around 14:29. (See Figure 1 and 2)

2.2 Injuries to Persons

A total of four crew members, consisting of the captain, the mechanic in charge and two mechanics, were on board, and all of them were killed.

2.3 Damage to the Aircraft

2.3.1 Extent of Damage

Destroyed.

2.3.2 Damage to the Aircraft Components

(1) Fuselage: burned out
(2) Tail assembly: separated and damaged
(3) Engines: damaged and deformed
(4) Rotor system: damaged
(5) Control system: partially burned out system out in fuselage, and damaged in tail boom

Figure 7: Damaged airframe conditions at the accident site

2.4 Other Damage

2.4.1 Damaged Conditions of the Bridge

- Deteriorated concrete strength and axial force of bolts
- Deformed and fractured guard fence
- Burned out guard rail

2.4.2 Damaged Conditions of Electric Wires and Communication Cables

- Damaged high voltage and low voltage electric wires
  Damaged wires caused blackout in Ueno-mura from 14:29 until 16:19.
- Cut broadcasting optical cables
- Cut telephone junction cables

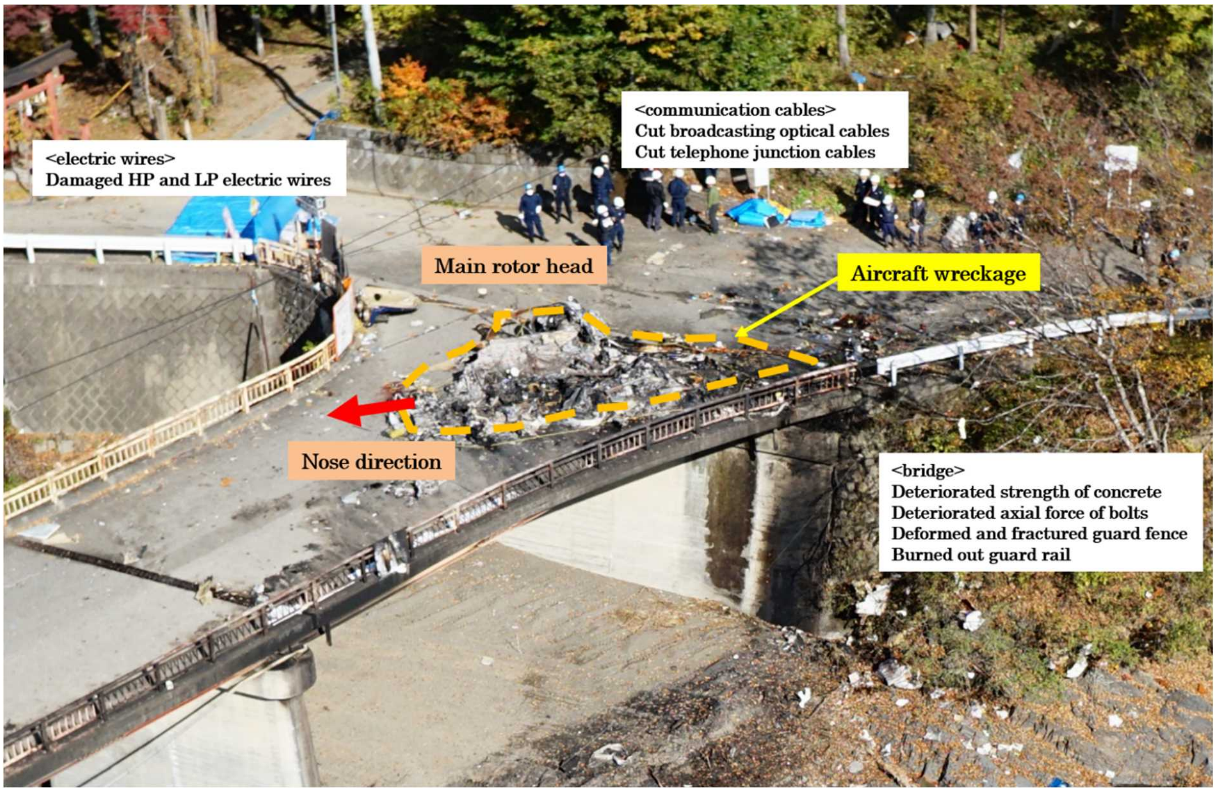

Figure 8: Damaged conditions other than the Aircraft

2.5 Personnel Information

(1) Captain male, age 60

Commercial pilot certificate (rotorcraft) — August 28, 1979

Pilot competency assessment — Expiry of practicable period for flight — September 14, 2018

Type rating for land single turbine — August 25, 1979

Type rating for land multi turbine — August 28, 1979

Type rating for Aerospatiale SA330 — March 14, 1996

Class 1 aviation medical certificate

Validity — April 28, 2018

Total flight time — 10,437 hours 10 minutes

Flight time in the last 30 days — 29 hours 58 minutes

Total flight time on the type of the aircraft — 3,333 hours 00 minutes

Flight time in the last 30 days — 29 hours 58 minutes

(2) Certifying Mechanic A male, age 50

Second class aircraft line maintenance technician (rotorcraft)

Type rating for Aerospatiale SA330 — December 20, 1995

Type rating for Aerospatiale AS355F2 — January 23, 1996

Type rating for Eurocopter EC135 — February 16, 1998

2.6 Aircraft Information

2.6.1 Aircraft

Type — Aerospatiale AS332L

Serial number — 2173

Date of manufacture — October 26, 1987

Certificate of airworthiness — No. TO-29-075

Validity — June 13, 2018

Category of airworthiness

rotorcraft, transport, TA class, TB class or special aircraft X

Total flight time 11,058 hours 38 minutes

Total time in service of the tail rotor 1,686 hours 00 minutes

Flight time after regular inspection (50-hour inspection performed on October 12, 2017) 29 hours 48 minutes

(See Appended Figure 1: Three-view Drawing of Aerospatial AS332L)

2.6.2 Weight and Balance

Weight of the Helicopter immediately before the accident is estimated to have been 6,418 kgs and the position of center of gravity (CG) 4.53 m, respectively, both of which are estimated to have been within allowable range (maximum take-off weight was 8,600 kgs).

2.7 Meteorological Information

2.7.1 Meteorological Conditions in the Vicinity of the Accident Site

Aeronautical weather observations for Soumagahara aerodrome located about 43 km north-northeast of the accident site around the time of the accident were as follows:

14:00 Wind direction; unstable, Wind velocity; 2 kt, Prevailing visibility; 10 km or more, Prevailing weather;
Cloudy, Cloud: Amount 1/8, Type Altostratus, Cloud base 7,000 ft
Cloud: Amount 3/8, Type Altocumulus, Cloud base 10,000 ft
Cloud: Amount 7/8, Type Cirrus, Cloud base 20,000 ft
Temperature: 15 ℃; Due point 10 ℃
Altimeter setting (QHN) 29.89 inHg

Observations for the city hall of Ueno-mura located about 700 m northeast of the accident site around the time of the accident were as follows:

14:30 Wind direction; west-northwest, Wind velocity; 0.5 m/s, Weather; cloudy, Temperature; 13.9 ℃, Atmospheric pressure; 1,013.0 hPa

2.7.2 Meteorological Change in the Area Where the Helicopter Parked Post-Flight before the Accident

Daily change of weather (temperature, humidity and mean steam pressure) of the area where the Helicopter parked during the period from May 30, 2017 after the completion of 1,000-hour regular inspection until September 20 when 250-hour regular inspection was performed was as shown in Appended Figure 2. There were many days with the average daytime temperature exceeding 25 ℃ in early July through late August. There were many days with the average humidity exceeding 70% in early July through late August, and particularly days exceeding 80% lasted in the middle of August. Days with high steam pressures lasted in the middle of July through middle of August.

2.8 Communication Information

After taking off from Arakura temporary helipad in visual flight rules, the Helicopter sent position reporting saying “took off from Arakura temporary helipad, time 14:03 and fuel remaining 1,100 kgs” around 14:12 over the vicinity of Nirasaki City via Utsukushigahara radio station that the Company established for base communications. Since then, there was no communication with ATC and the Company, and there was no declaration of emergency or code change in the event of transponder (automated response device) emergency.

2.9 Accident Site and Wreckage Information

2.9.1 Accident Site Situations

The accident site was on the bridge over the tributary to the Kanna River mainstream that flows in the mountainous areas, and there were electric wires and cables for cable TV above the bridge.

2.9.2 Detailed Conditions of Damage (See Appended Figure 4)

(1) Fuselage

- Fuselage was severely burned out by the fire occurred immediately after the accident and did not retain the original figure.

(2) Tail Section (See Figure 9: Location where major parts of tail assembly were found)

- The tail boom dropped on the location about 20 m away from the airframe and the tail rotor dropped on the location about 60 m away from the airframe, respectively.
- The tail boom had two contact marks with the MRB and was fractured into pieces as shown in Figure 10.
- Third and sixth tail rotor drive shafts had contact marks with the main rotor that fractured them. (See Appended Figure 5: Tail Rotor drive shaft had contact marks)
- The tail rotor drive shaft had contact marks with the drive shaft guide, twisted at the joint and separated.
- Upper section of the inclined drive shaft had contact marks with the pylon fairing.
- The spindle bolt at the flapping hinge of the White Blade of the tail rotor was fractured and the White Blade slid off from the hinge (see Figure 11: Fractured spindle bolt of the White Blade).

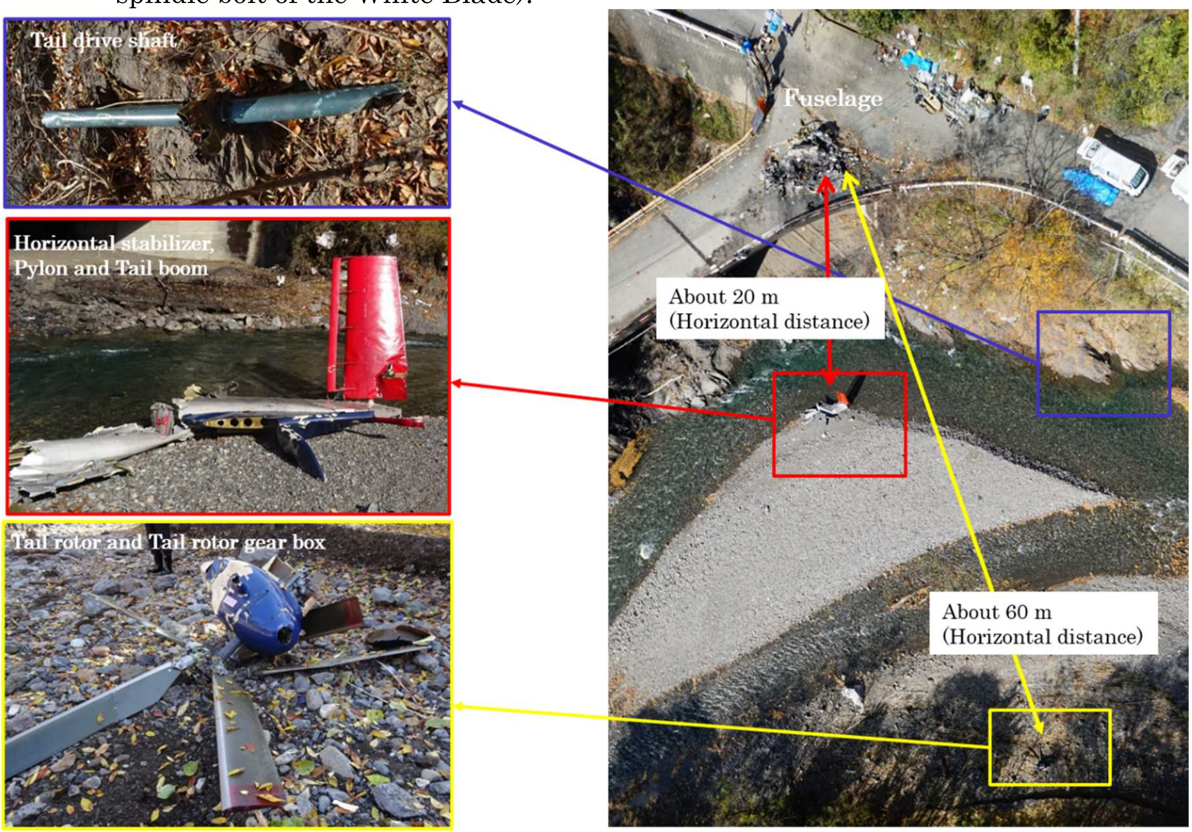

Figure 9: Locations where major parts of tail assembly were found

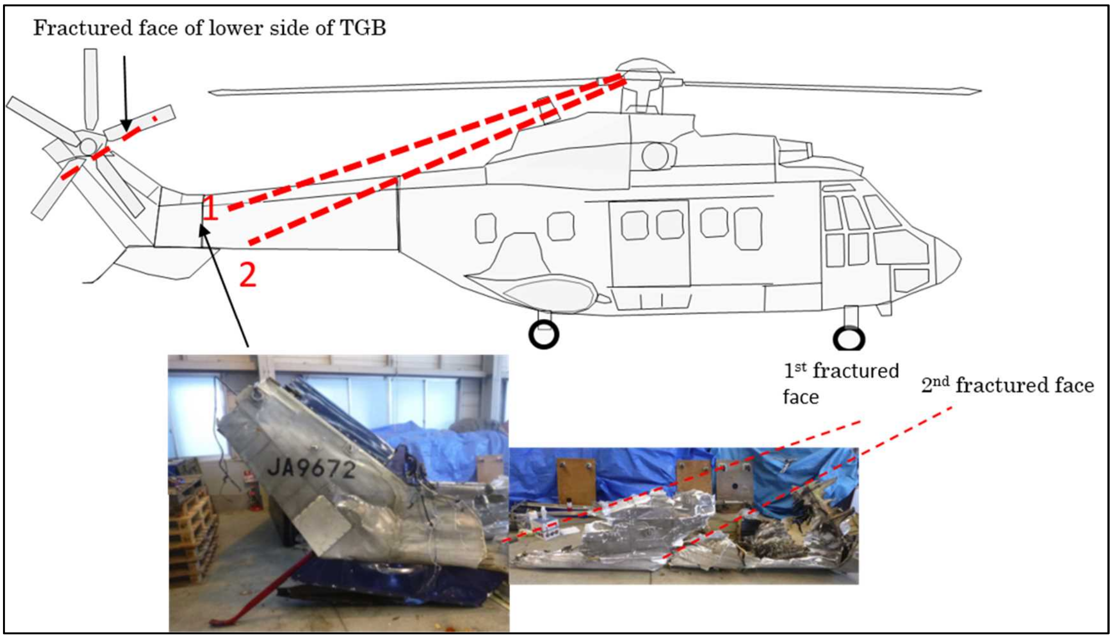

Figure 10: The sections of airframe and its lower side of TGB fractured by main rotor

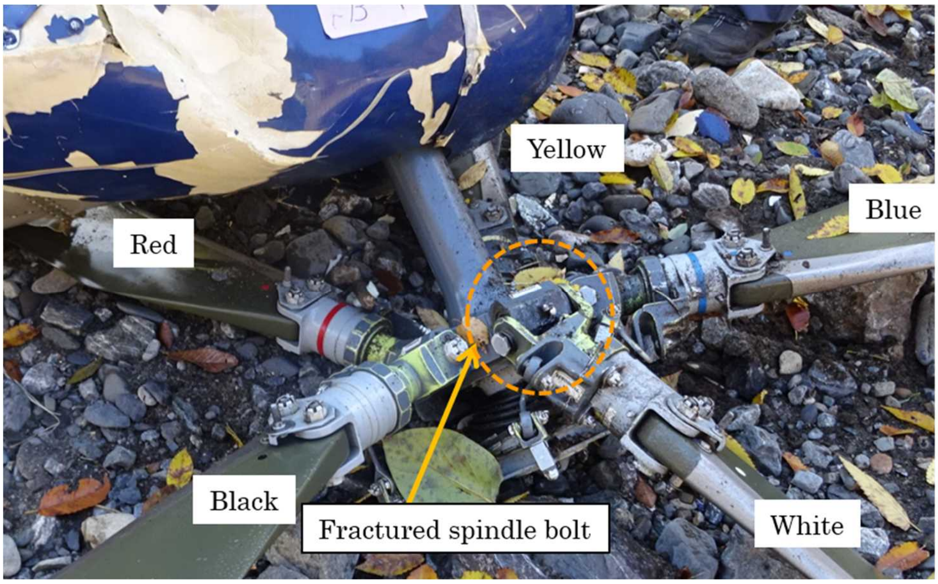

Figure 11: Fractured spindle bolt of the White Blade

(3) Engines

- Both engines were burned out and deformed like being twisted in the direction of the compressor rotation.

(4) Rotor System

- All four MRB were destroyed at the attached sections.
- The mast of the main rotor had the wires, which had been stretched above the bridge, winding around.
- The transmission was largely cracked and fractured.

(5) Gears

- Gears were fractured at the attached section and were separated around the airframe.

2.10 Medical Information

According to the information from the Gunma Prefectural Police, the cause of the death of all four persons including the captain, the CM A, and two mechanics were a traumatic shock.

2.11 Information Related to Fire, Fire Fighting and Rescue

2.11.1 History of Fire, Fire Fighting and Rescue

According to the fire-fighting force of Ueno-mura of Gunma Prefecture, the history of fire and fire-fighting was as follows:

14:29 Reports from witnesses
14:29 Outbreak of blackout around Ueno-mura
14:36 Fire-fighting vehicles arrived at the accident site
15:07 An air ambulance helicopter landed at the village square temporary helipad in Ueno-mura
15:20 A medical doctor who arrived at the accident site confirmed the death of the four persons
15:21 The Fire was put out
16:19 The Blackout was restored around Ueno-mura (except for the vicinity of the accident site)

2.11.2 Situations of Fire Breakout

The Helicopter was destroyed with the fuel catching fire, and the leaked fuel was spread over and burned the vicinity of the accident site.

2.12 Airframe Structure of the Same Type of Aircraft

2.12.1 Transmission and Rotor Systems of the Same Type of Aircraft

(1) Main Transmission System

The main transmission system transfers power from the two engines through the main gearbox (hereinafter referred to as "MGB") to drive the main rotor and the tail rotor drive shaft.

(2) Main Rotor

The main rotor consists of the four rotor blades as shown in Figure 12 and rotates at 265 rpm clockwise as seen from the above. There are three hinges such as the pitch hinge, the flapping hinge and the drag (lead lag) hinge*4 at the attached section to MRB and drive MRB into each direction. The frequency adapter is mounted to the attached section to the blades as shown in Figure 13 and absorbs the motion in the direction of the drag. Oil in the reservoir tank is supplied to the pitch hinge.

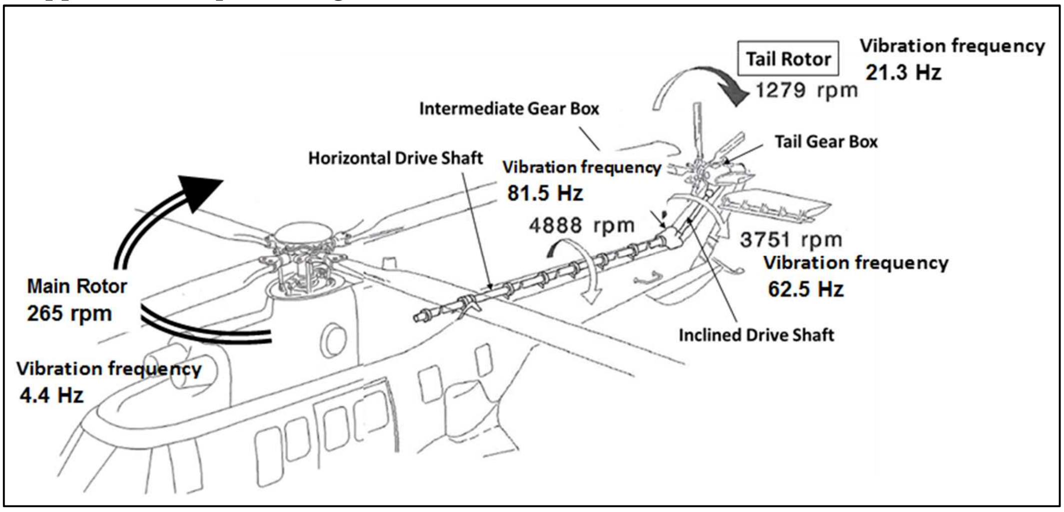

Figure 12: RPM of main rotor and tail rotor systems

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*4 "drag (lead lag) hinge" denotes a hinge that acts in back and forward directions along the rotating face.

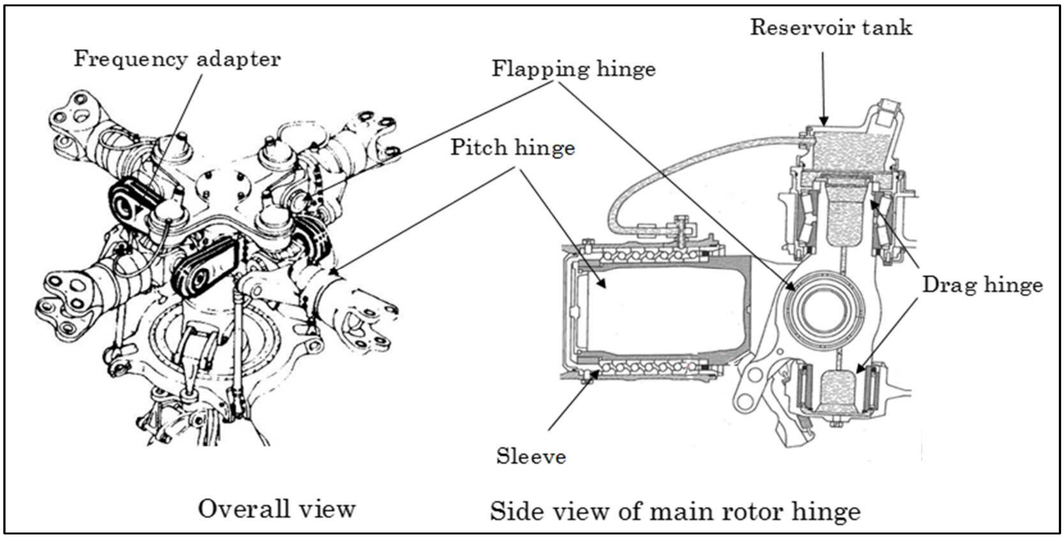

Figure 13: Main rotor head

(3) Tail Rotor Transmission System

The tail rotor transmission system transfer power via the drive shaft of the upper portion of the tail pylon as shown in Figure 12. Rotation from MGB at 4,888 rpm is transferred to the intermediate gearbox from the horizontal drive shaft and is decelerated to 3,751 rpm. The inclined drive shaft maintains rpm and transfers it to the tail gearbox (hereinafter referred to as "TGB"). TGB decelerates rpm to 1,279 rpm and rotates the tail rotor.

(4) Tail Rotor

Five tail rotors are mounted on the right side of the upper section of the pylon as shown in Figure 12 and rotate counterclockwise, as seen from the right side of the airframe. The tail rotor has a rotational speed of 1,279 rpm, modifies anti-torque generated by the main rotor, and controls the airframe in yawing. Each blade is five color-coded of red, yellow, blue, white and black for an easy identification.

There are flapping hinge and pitch hinge at the attached section to each tail rotor blade, but there is no drag (lead lag) hinge as shown in Figure 14, and the spindle supports the force in drag plane(lead lag). Pitch angle can be altered by the pitch horn linking with motion of the pitch change spider in the center of the tail rotor.

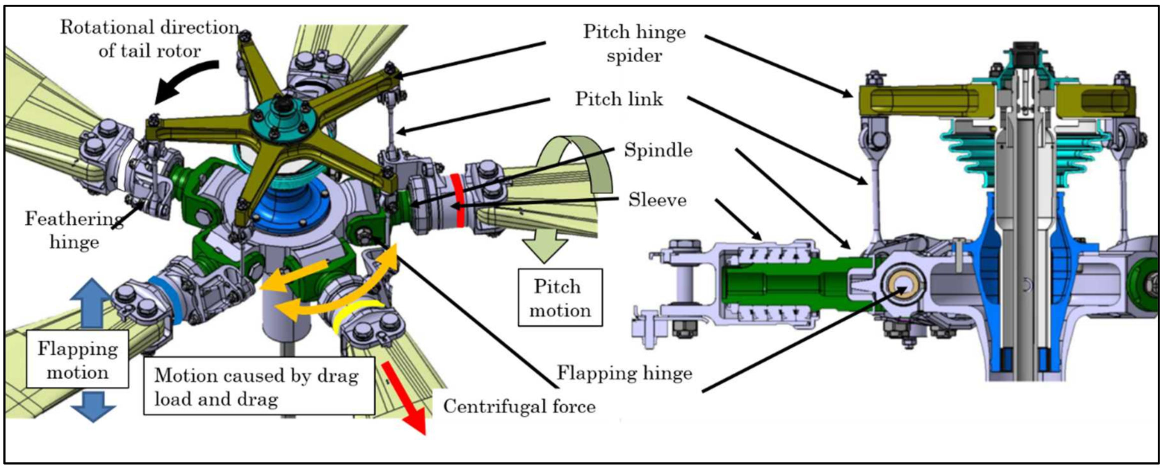

Figure 14: Structure and nomenclatures of tail rotor

(5) Parts and Roles of the Flapping Hinge

The spindle playing a role of the flapping hinge is jointed to the tail rotor hub by the spindle bolt, which has the inner ring and the outer bearing on its outside the inner ring as shown in Figure 14, producing a smooth motion in the direction of the flapping while receiving centrifugal load. Besides, loads at the flapping hinge are as follows:

- Static load of the spindle bolt by tightening; 29,000 to 35,000 N
- Centrifugal load at the nominal rpm; 67,000 N
- Load by thrust (when hovering at the maximum take-off weight); 1,400 N
- Lead lag moment (the maximum flight load); 300+/-760 N·m

Load on the spindle bolt can be considered at each yoke. Load in the axial direction statically receives tightening tensile force, and shearing load receives static CF and static and dynamic loads in the lead lag direction. The parts of the flapping hinge are as shown in Figure 15 and their roles are as shown in Table 1.

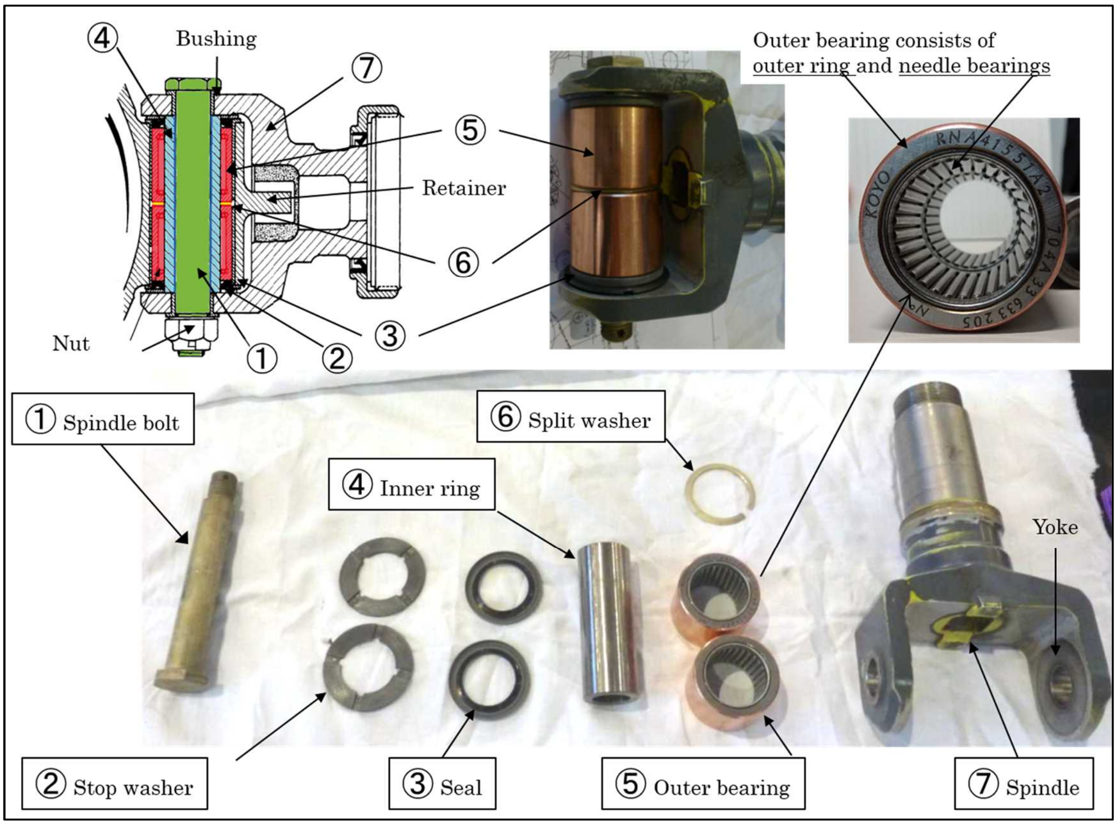

Figure 15: Flapping hinge parts

Table 1: Nomenclatures and roles of flapping hinge parts

No.	Nomenclature	Role
1	Spindle bolt	Linking spindle with tail rotor hub and acting as axis of flapping motion of blades.
2	Stop washer	Plastic washer appropriately maintaining gap between spindle and tail rotor hub.
3	Seal	A rubber seal paired with a metal ring on its inside sticking to the outside of outer bearing for grease leakage prevention, waterproof and dust prevention.
4	Inner ring	Acting as the internal rolling surface for the needles during flapping motion (the outer rolling surface being the outer bearing race).
5	Outer bearing	Assembly of needles and outer race acting as an external rolling surface for the needles during flapping motion.
6	Split washer	Metallic washer inserted between two outer bearings to press-fit the tail rotor hub to keep the appropriate gap between the outer bearings.
7	Spindle	Linking tail rotor blades with tail rotor hub.

2.12.2 Tail Rotor Control System of the Same Type of Aircraft

The tail rotor control system of the same type of aircraft has two fundamental functions of anti-torque function and control function in the direction of yaw as shown in Figure 16, and alters the pitch angle of the tail rotor blades. The tail rotor control system is linked by cables, bell crank, and tail servo control.

As an anti-torque function, the aircraft has an automated anti-torque function operated by a collective pitch setting in order to counter the torque by the main rotor.

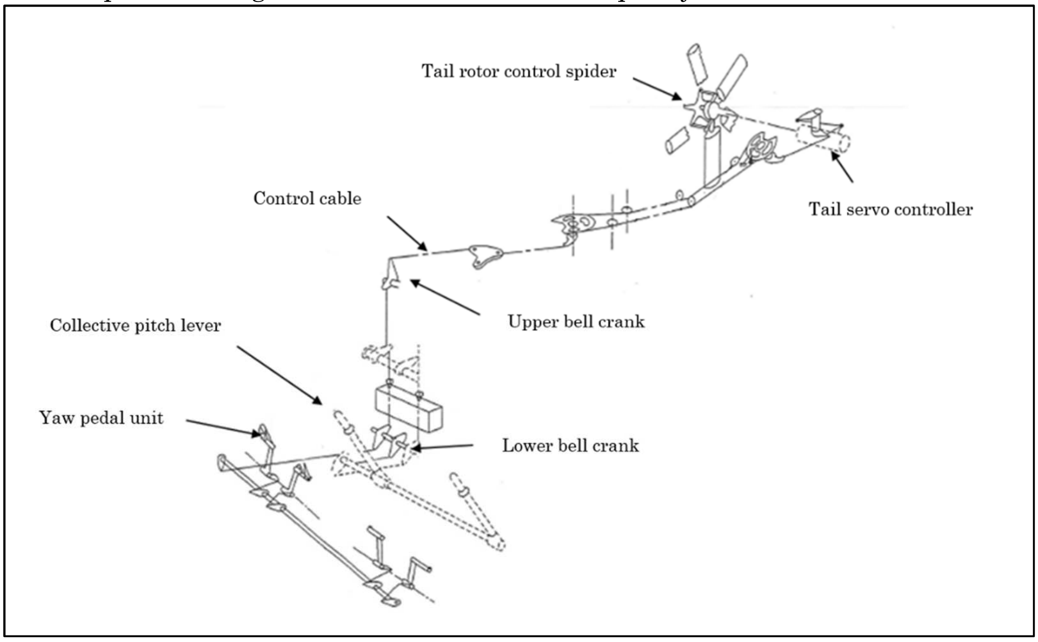

Figure16 Tailrotor control system

2.12.3 Design Change History of Tail Rotor Flapping Hinge of the Same Type of Aircraft

There were two changes instructed for the tail rotor flapping hinge as described below, and the Helicopter had already incorporated these two changes:

(1) MOD 07. 66142 (in 1995)

Purpose: To disperse load between two bearings for improvement

Contents:

- Pairing the outer bearings
- Minor adjustment of the inner ring diameter (+0.006 mm)
- No change in the materials

(2) MOD 07. 66082 (in 1990)

Purpose: To mitigate stress of threads and peening pressure

Contents: Reduction of tightening torque of the spindle bolt

Before reduction; 120 to 140 N·m dry

After reduction; 75 to 90 N·m dry

2.13 Maintenance History and Flight Situations

2.13.1 Overhaul History of the Tail Rotor of the Helicopter

There was no service life prescribed for the complete tail rotor assembly but on some components, and it was set to receive overhaul maintenance at 3,000 hours or 24 years, whichever comes first. According to the maintenance record of the Helicopter, overhaul of the tail rotor was performed during the period from March 12 until June 3, 2014. In the overhaul, detailed disassembly maintenance of the flapping hinge was performed with no malfunction noted in the maintenance record.

For each component except the spindle of the flapping hinge (Tables 1 No1 to No6), there is no individual setting of the limit usage time, but it is necessary to indicate the replacement in the maintenance record. According to the maintenance records of the Aircraft, since June 2014, there was no record of seal replacement at the time of inspection of the flapping hinges every 1,000 hours.

2.13.2 1,000-Hour Inspections Performed since Overhaul in March 2014

According to the maintenance record, a 1,000-hour inspection of the flapping hinge had been performed twice since the overhaul in March 2014; from February 20 until May 21, 2015, and from March 18 until May 16, 2017 (hereinafter referred to as "the Previous 1,000-Hour Inspections").

2.13.3 Maintenance History since March 2017 until immediately before the Accident

According to the maintenance record and the statement of mechanic staff of the Company, the maintenance history of the Helicopter performed since the Previous 1,000-Hour Inspections until immediately before the accident was as follows (parts of the flapping hinge are shown in Figure 15, and the inspection items are detailed in 2.16.1):

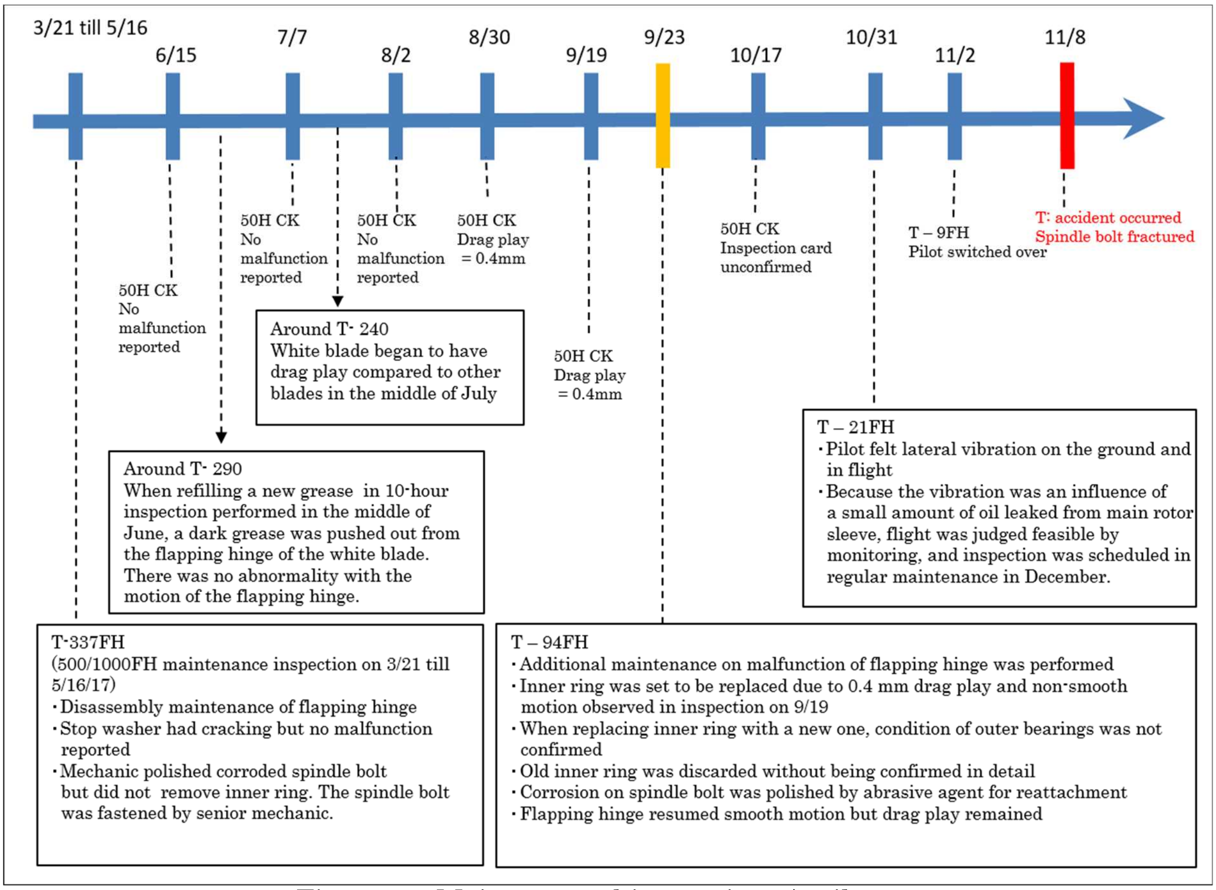

Figure 17: Maintenance history since April 2017

(1) As shown in Figure 17, 500-hour and 1,000-hour inspections related to the tail rotor flapping hinge were performed from March 21 until May 16, 2017. The spindle bolt was pulled off smoothly; however, all stop washers were replaced with new ones due to deterioration and cracks. Some of the spindle bolts had corrosion and were polished with a brass brush for removal. Attachment and final inspection of the spindle bolts were performed by the CM A. Maintenance record noted nothing but malfunction of the stop washer and its replacement, and the seal was not replaced against the spindle bolt removal and installation procedures, which require the seal replacement.

(2) In greasing up the flapping hinge of the White Blade of the Helicopter in a 10-hour inspection performed in the middle of June 2017, it was confirmed that an old grease pushed out had turned black.

(3) The Helicopter received a 50-hour inspection three times during the period from June 15 until August 2, 2017, with no malfunction found.

(4) The White Blade began to have the drag play compared to other blades from around the middle of July 2017, with a black grease leaking. Although some of the flapping hinges of other blades also had a black grease leaking when flying after rainfall or for five hours or more, it was not as black and contaminated as the White Blade.

(5) The White Blade had a measured play of 0.4mm (the maximum acceptable play was 0.6mm or less) in the direction of drag in 50-hour inspections performed on August 30 and September 19, 2017. Other tail rotor blades had no play. Because the White Blade did not move smoothly in the inspection performed on September 19, the CM A decided to confirm the condition of the flapping hinge by removing the spindle bolt of the White Blade as additional maintenance in the inspection commencing on September 20.

(6) The additional maintenance on the flapping hinge of the Helicopter was performed at Tochigi heliport on September 20 through September 23, 2017, simultaneously with a 250-hour inspection. Because the spindle bolt stuck when pulling out, mechanics sprayed lubricant on it and pulled it out slightly tapping with a brass rod. Because the CM A confirmed cracks

in the inner ring without removing it, he decided to replace the inner ring and the stop washer and performed the replacement work on September 23, 2017. The replacement work was performed in a way to insert a new inner ring from the top and to push out the one to be removed as shown in Figure 18 in order to prevent dust from getting into the outer bearings. Because the Old Inner Ring was broken into pieces, it was replaced by receiving the fragments into a vinyl bag, which were discarded as kept in the vinyl bag. Due to this way of the replacement, the condition of the outer bearings inside the spindle and the Old Inner Ring pushed out could not be confirmed when the inner ring was replaced. Besides, although the stop washer was replaced when the inner ring was replaced, the seal was not replaced against the spindle bolt removal and installation procedures, which require the replacement (see 2.16.1 (7)).

Because checking the removed spindle bolt revealed the existence of red rust and black rust scattering on it as shown in Figure 18, the surface of which was polished by an abrasive sponge; however, the spindle bolt was put by grease without completely removing the rust and was installed in the flapping hinge.

In checking after the replacement, the White Blade moved smoothly in the direction of flapping; however, the drag play still remained.

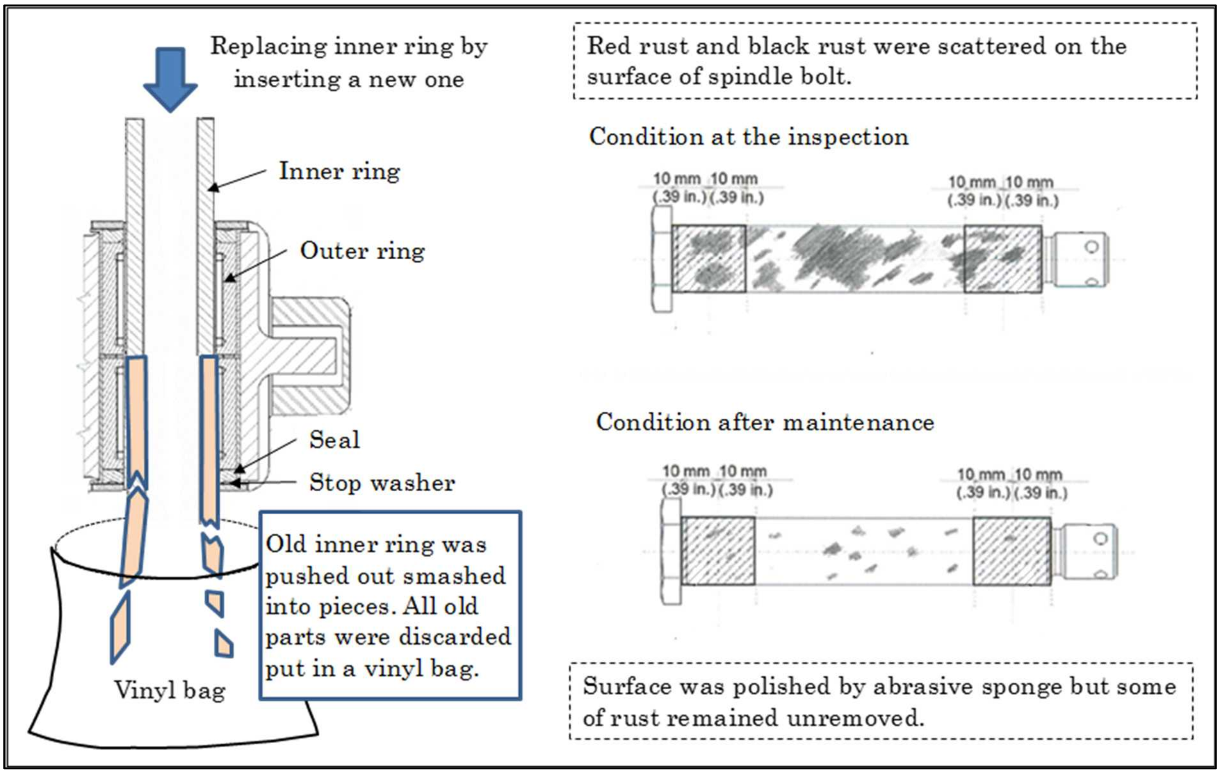

Figure 18: Way of replacing inner ring and condition of spindle bolt

(7) In 50-hour inspection performed on October 12, 2017, motion of the White Blade in the direction of flapping was free from sticking; however, the drag play was confirmed.

(8) The CM A was consulted by Pilot A on October 31, 2017, about the occurrence of the Lateral Vibrations. CM A presumed that the Lateral Vibrations were the consequence of a small amount of oil leakage from blue and yellow sleeves of MRB. The amount of oil leakage of the Helicopter was small with no tendency to increase, and it was decided to continue flying the Helicopter while monitoring it at the daily check and was set to be treated in the regular inspection scheduled for December.

2.13.4 Flight Time of the Helicopter since the Previous 1,000-Hour Inspections

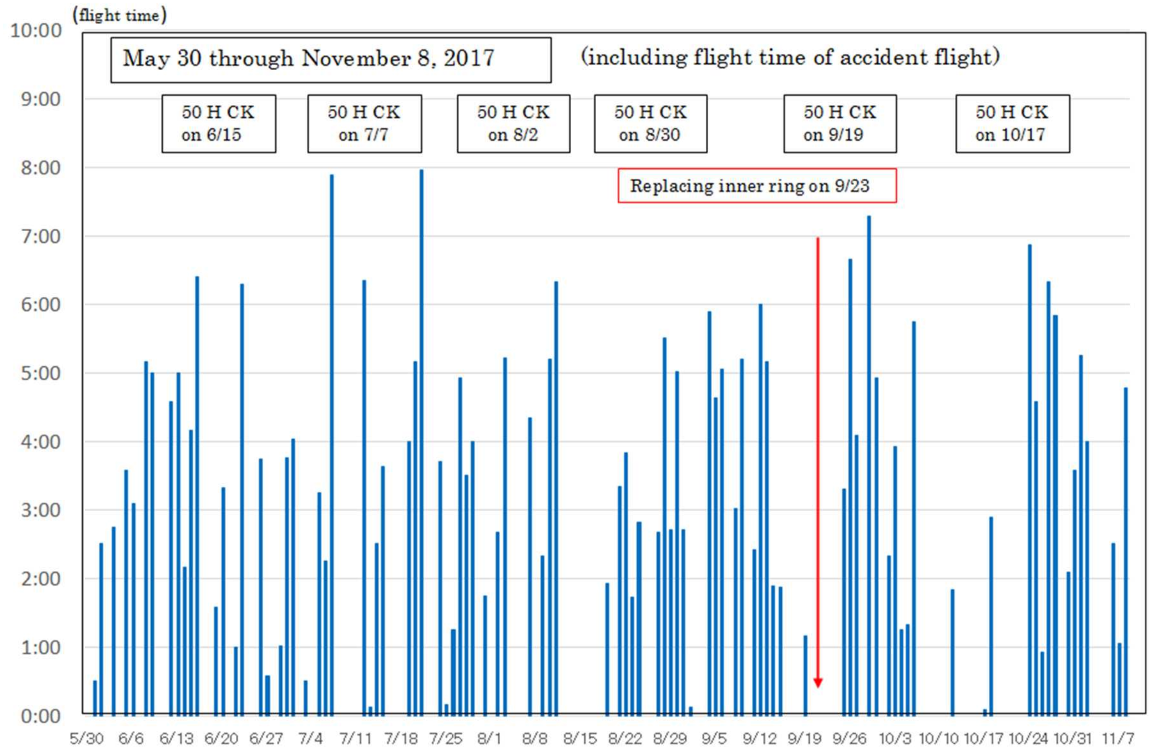

Figure 19: Flight time of the Helicopter since the Previous 1,000-Hour Inspections

Flight time of the Helicopter since the Previous 1,000-Hour Inspections are as shown in Figure 19. In particular, the accumulated flight time until September 23, 2017, when the inner ring of the flapping hinge was replaced, was about 243 hours, and the same from the replacement of the inner ring until the accident was about 94 hours.

2.13.5 Parking Situations of the Helicopter

Parking situations inside or outside hanger of the Helicopter during the period from May 30 until September 20, 2017, after the Previous 1,000-Hour Inspections are as shown in Appended Figure 2-3, and parking inside hanger accounted for 57% (equivalent to 65 days) and outside hanger 43% (equivalent to 49 days), respectively, during the period. When parking at Tochigi heliport and Matsumoto airport at night, the Helicopter was inside a hanger, and when parking at other airports and heliports, parking was outside a hanger. When parking outside a hanger, the Helicopter had covers on the main rotor head and the tail rotor head. Besides, in the event of parking over 24 hours, inside a hanger was 35 days and outside was 9 days, respectively.

2.14 Examination and Research Information

2.14.1 Features of Damaged Parts

According to ASM International Handbook and FAA Aviation Maintenance Technician Handbook-Airframe Volume 2, 2012, types and characteristics of damage generating on metal parts are as follows:

(i) Fatigue fracture (ASM International Handbook)

A fracture that is the result of repetitive or cyclic loading is known as a fatigue fracture. Fatigue striations often bow out in the direction of crack propagation and generally tend to align perpendicular to the principal crack propagation direction. However, variations in local stresses and microstructure can change the orientation of the plane of fracture and alter the direction of striation alignment.

(ii) Fretting (ASM International Handbook)

Fretting, sometimes referred to as static adhesive wear, is wear that occurs between two closely contacting surfaces having oscillatory relative motion of extremely small magnitude.

(iii) False brinelling (Aviation Maintenance Technician Handbook-Airframe Volume 2, 2012)

False Brinelling caused by vibration of the bearing while in a static state. Even with a static overload, lubricant can be forced from between the rollers and the raceway.

(iv) Brinelling (Aviation Maintenance Technician Handbook-Airframe Volume 2, 2012)

Brinelling caused by excessive impact. It appears as indentations in the bearing cup raceways. Any static overload or severe impact can cause true brinelling that leads to vibration and premature bearing failure.

(v) Spalling (ASM International Handbook)

Spalling is a type of surface damage where material separates from the surface in the form of flakes or chips.

2.14.2 Outline of Investigated Items

Examination on the tail rotor system was performed at the facility of the Helicopter manufacturer by the attendance of the French accident investigation bureau (BEA). Outline of the investigated items were described as follows.

(1) Detailed Investigation on Parts Related to the Tail Rotor of the Helicopter
- (i) Spindle bolts
- (ii) Inner ring
- (iii) Outer bearings
- (iv) Other tail rotor flapping hinge
- (v) Grease condition

(2) Detailed Investigation on Parts based on Emergency Inspection of Flapping Hinge
- (i) Spindle bolts
- (ii) Inner ring
- (iii) Condition of tightening torque
- (iv) Condition of flapping hinge scratches

2.14.3 Detailed Investigation Results of the Flapping Hinge of the White Blade

(1) Spindle bolt

The spindle bolt of the White Blade showed a fatigue fracture generated by cracks with two initiating points as shown in Figure 20. H1 crack with the initiating point at the bolt head propagated in the direction of 45 degrees. T1 crack propagated in the direction perpendicular to the axis and fractured the bolt.

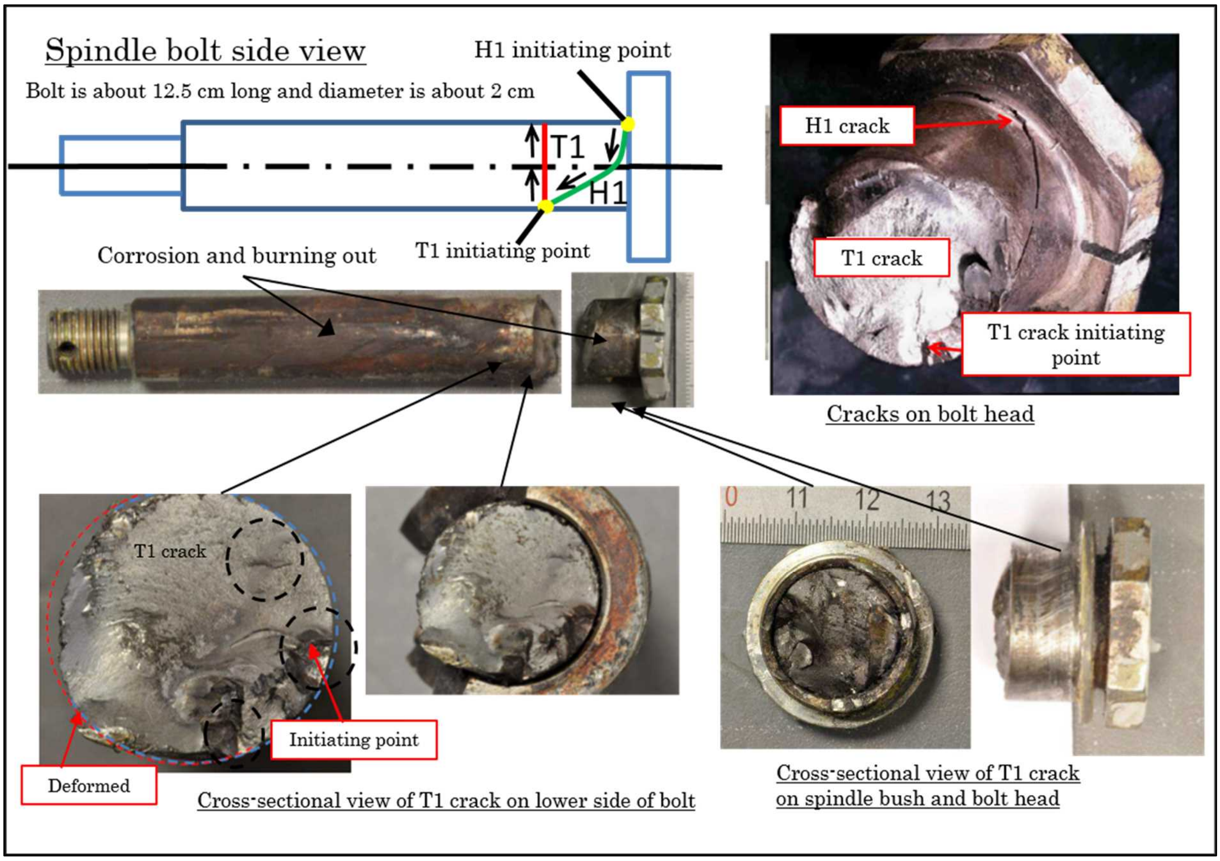

Figure 20: Fractured spindle bolt

(2) Inner Ring

The inner ring was found in a fractured condition together with many fragments as shown in Figure 21. Due to some fragments lost, a partial restructuring of the inner ring indicated that the fractured sections of the inner ring lost some fragments equivalent to 8% in weight. Investigation of the fractured face revealed that propagating cracks were generated in many different sections of lateral face, inner face, and outer face. The cracks were propagated in the directions from inner diameter to outer diameter, from outer diameter to inner diameter, and from lateral face; however, it was impossible to identify all initiating points of cracks. Besides, corrosion was not identified in the initiating areas. Half around of the outer diameter section suffered damage from false brinelling.

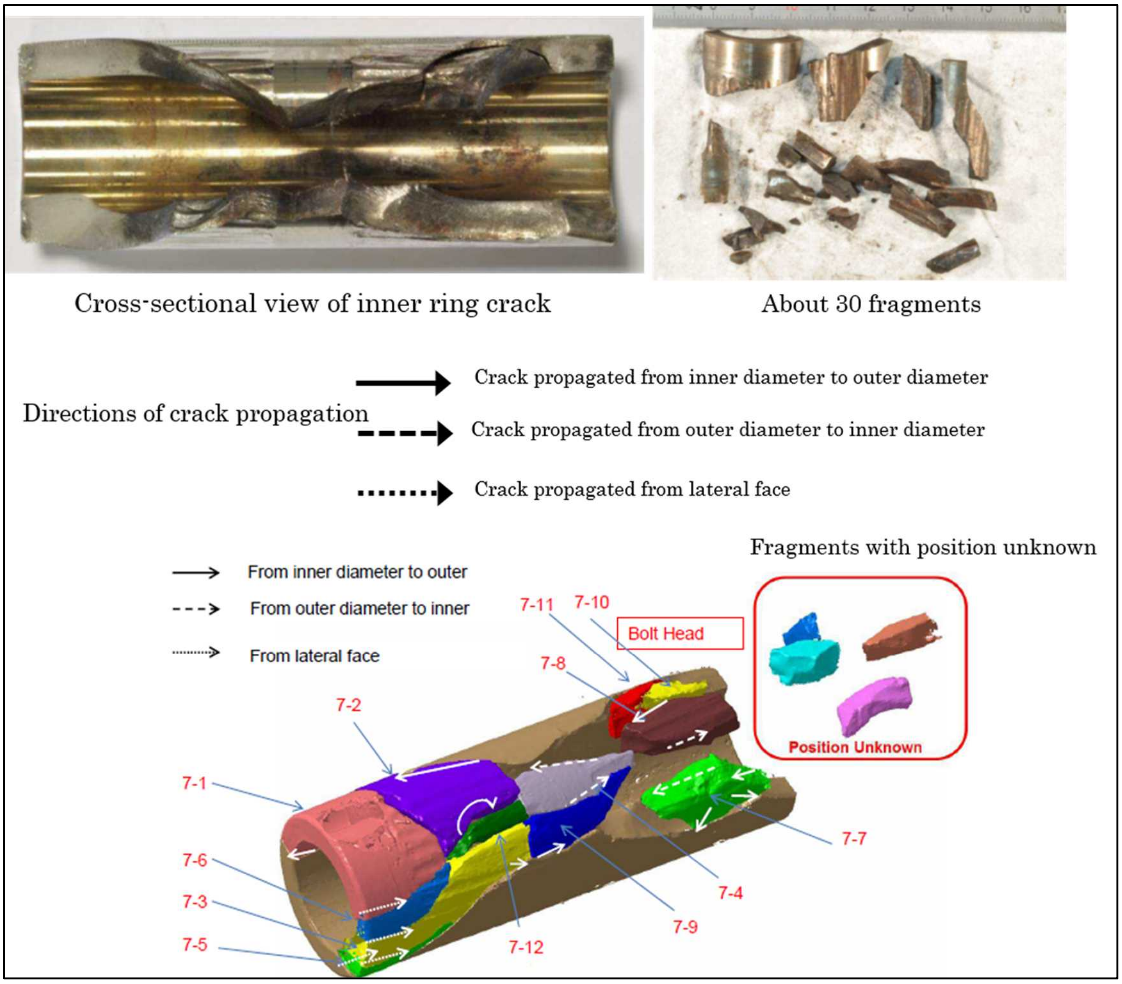

Figure 21: Damaged inner ring

(3) Outer Bearings

The outer bearings, consisting of the needle bearings and the outer ring, of the White Blade, contained a smaller amount of the grease than the outer bearings of other blades. However, it could not be determined whether the grease amount had been smaller or not before the spindle bolt fractured because it was found that a large amount of the grease had been dispersed by centrifugal force (CF) when the spindle bolt fractured. Each needle bearing was observed fretting and wear at different levels of damage as shown in Figure 22, and several pieces in fracture had spalling. In measuring the weight of the needle bearings, 10% of the needle bearings (equivalent to at least six needle bearings in weight) were not found.

The highest damaged area of the outer bearings received damage from false brinelling wear and spalling peeling. Examinations of the bearings did not allow to characterize their state when the Old Inner Ring was replaced by a new one. Inner diameter faces of the outer bearings showed both damage of indicating the needle bearings tilted axis, and pushing out of the needle bearings in axial direction.

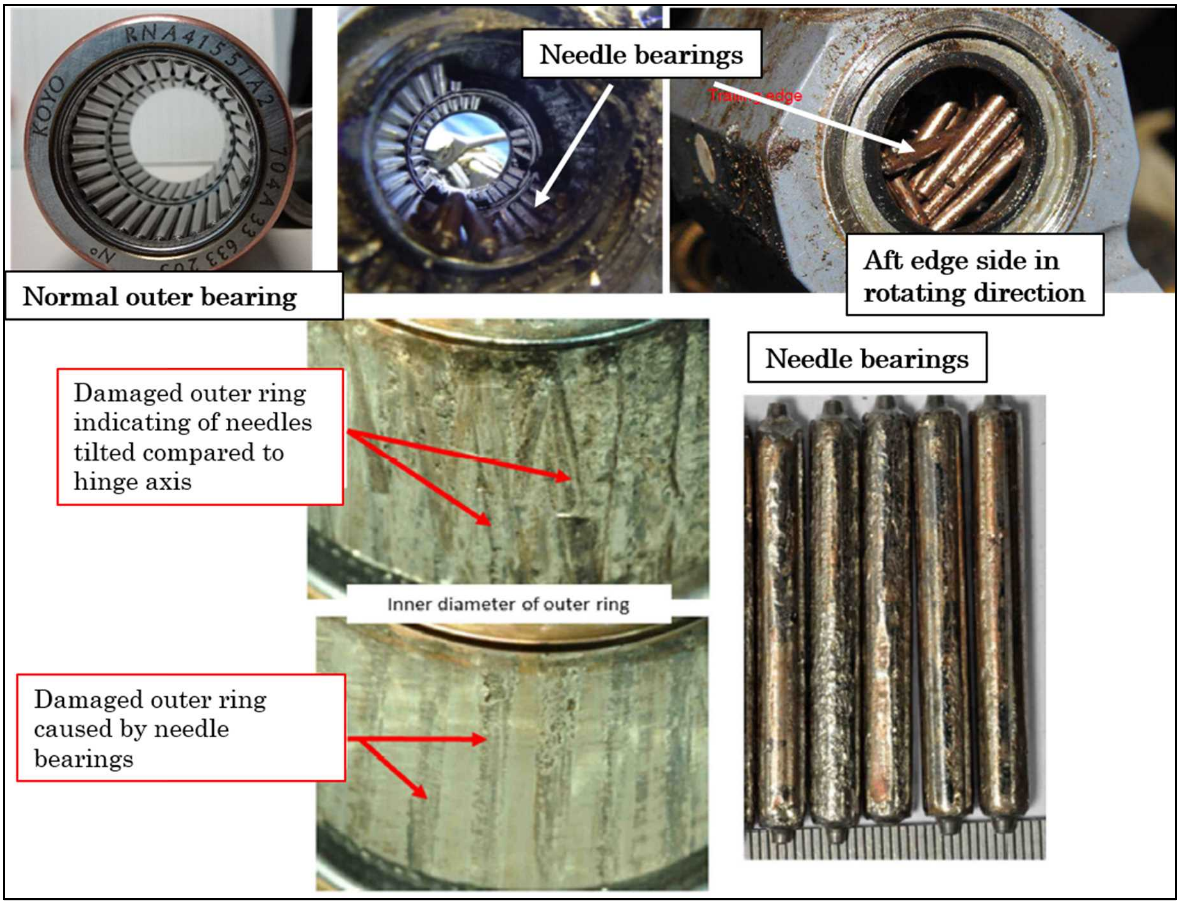

Figure 22: Damaged outer ring (white blade)

2.14.4 Investigation Results of Other Tail Rotor Flapping Hinge

Parts of the flapping hinge of blades other than the White Blade of the Helicopter showed deteriorations caused by normal usage (slight false brinelling of the inner ring and a slight fretting of the spindle bolts) or by the impact of the crash.

2.14.5 Analysis Results of Grease

Ingredient analysis was performed on the grease of the flapping hinge of all tail rotor blades of the Helicopter. Although satisfactory analysis result was not obtained due to small sample size or deterioration of the grease, the grease adhered to the tail rotor head, the fractured face of the inner ring, and the stop washer met the grease designated by the maintenance manual, and no abnormal grease was found from any part of the five blades.

2.14.6 Detailed Investigation on Parts Based on Flapping Hinge Emergency Inspection

After the accident, Airbus Helicopters published an Emergency Alert Service Bulletin (EASB No. AS332-64. 00. 43) to users of the same type and same series of aircraft requesting to perform an emergency inspection of the flapping hinge of the tail rotor. Inspection results of EASB were reported to Airbus Helicopters, and analysis of the flapping hinge parts was performed based on the inspection results.

(1) Spindle bolt

There occurred corrosion and fretting in several cases but no crack occurred.

(2) Inner ring

There occurred false brinelling, spalling and cracks in several cases, and occurrence of false brinelling was prominent among them.

(3) Tightening torque

Some of the loss of tightening torque were also reported, while a few cases of the spindle bolts exceeded tightening bolt torque range; however, none of them related to the cracked inner ring.

(4) Dent on the flapping hinge

There was no flapping hinge with dent.

2.14.7 Measures Taken by Airbus Helicopters Based on Emergency Inspection First

Based on the analysis results of the malfunctioning parts, Airbus Helicopters published an Alert Service Bulletin (ASB No. AS332-05. 01. 10 2018-10-25) on October 25, 2018, that requires that flapping hinge inspection, which had been performed in 1,000-hour inspection, be performed at time intervals not exceeding 250 hours and the components of the flapping hinge, except for the spindle, be replaced and be discarded.

This came as a result of the analysis of the flapping hinge damage reported to Airbus Helicopters which revealed that the former inspection procedures were identified to be not sufficient to maintain airworthiness. Accordingly, it was decided that the inspection interval needed to be shortened to 250 hours. It was decided that the attached parts were not only to be inspected as additional precautionary measures to consider human factor during maintenance.

2.14.8 Airworthiness of Flapping Hinge Parts of Tail Rotor

The European Aviation Safety Agency (EASA) issued on 21 November 2017, an Airworthiness Directive (AD) to cover the Airbus Helicopters EASB requesting an emergency inspection of the flapping hinge of the tail rotor to users of some type and some series of aircraft. On November 15, 2018, the EASA issued an AD to those users based on the results of the emergency inspection on the flapping hinge of the tail rotor performed by Airbus Helicopters on November 21, 2017. According to the AD, this condition, if not detected and corrected, could lead to failure of flapping hinge link and unbalance of the tail rotor, possibly resulting in detachment of tail rotor gearbox and tail rotor hub, with consequent loss of control of the helicopter. It was judged that repetitive replacements (shortened service life) of parts were necessary in order to prevent damage from the repetitive load that was supposed to be added to the parts during the service life.

Required Action:

Inspection of the flapping hinge is to be performed at time intervals not exceeding 250 hours, and the affected parts, except for the spindle, are to be replaced with new ones and to be discarded.

The discarded parts have to be inspected and the inspection results have to be reported to Airbus Helicopters.

2.15 Information On Organization and Management of the Company

2.15.1 Maintenance Control System of the Company Pointed Out by Civil Aviation Bureau

Based on the occurrence of the accident, the Tokyo Regional Civil Aviation Bureau of Ministry of Land, Infrastructure, Transport and Tourism performed on-sight inspection at the facilities of the Company from December 25 until December 27, 2017, and from January 17 until January 18, 2018, and issued an Order for Business Improvement (Tokuun No. 12681, Tokuan No. 7 and Tokushin No. 120 on February 2, 2018).

According to the Order for Business Improvement against the Company, it was confirmed that maintenance work not in compliance with the authorized maintenance manual had been performed, and items that were required to be filled out in the flight logbook (items affecting safety of flight of aircraft) had not been described. In addition, it was confirmed that maintenance control division, which controls and supervises maintenance work to be performed on-site in an appropriate manner, failed to fulfill its organizational responsibility in the context of giving necessary instructions to mechanics on-site.

2.15.2 Malfunction Reporting Prescribed by the Company

The maintenance manual of the Company incorporates the system that, in the event that aircraft has malfunctioned and has to have the maintenance work outside a principal base, a mechanic initiates malfunction report, reports to the manager of operation maintenance section at the principal base and takes measures for the malfunction with support from maintenance control division, and simultaneously fills out the flight logbook. However, malfunction of the Lateral Vibrations occurred in the Helicopter as described in 2.1.3 and the condition of the removed inner rings as described in 2.13.3 (6) were not noted in the onboard flight logbook (flight record) against the maintenance manual, the malfunction report was not initiated, and the malfunction was not reported to manager of operation maintenance section.

2.15.3 Maintenance of the Helicopter confirmed by Certifying Mechanic A

A total flight time of the Helicopter during the last one year was about 600 hours, most of which were for cargo transport and ferry flight associated with cargo transport. The CM A, who was on board the accident Helicopter, had been on board all flights during the last one year and none of other mechanics were on board. Every maintenance work performed during the last one year including the most recent maintenance work before airworthiness certificate inspection was confirmed by the CM A.

2.16 Additional Information

2.16.1 Tail Rotor Flapping Hinge Inspections of the Helicopter

Inspections of the tail rotor flapping hinge of the Helicopter were performed in accordance with the maintenance manual; post-flight inspection, 10-hour inspection, 50-hour inspection, 500FH/2Y*[5] and 1,000-hour inspection. The maintenance manual of the designer and manufacturer of the aircraft contains following descriptions:

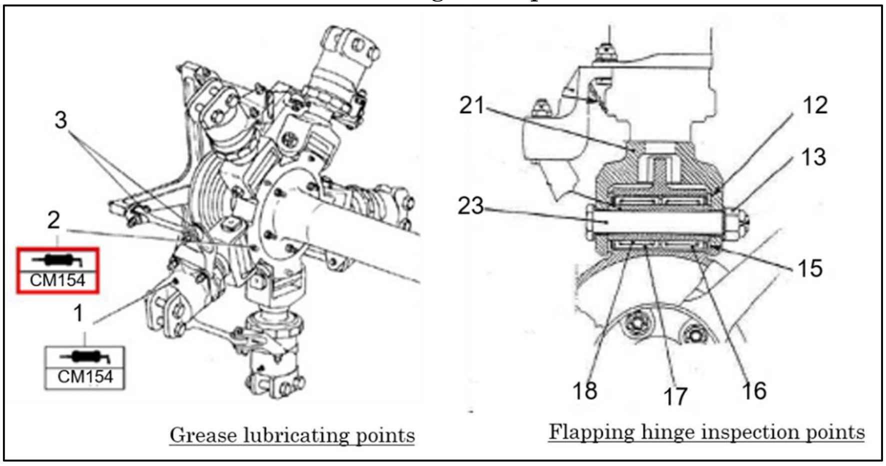

Figure 23: Flapping hinge inspection points

(1) Post-Flight Inspection

Post-flight inspection (Chapter 05 20 of MSM REV 005) stipulates that following task are to be performed:

(3) Tail rotor hub	*: General condition. When the tail rotor blades rotate, check the following for unusual noise: blades, blade horns and pitch-change links and pitch-change spider. Grease CM 154*[6] the hinges*

*5 "500FH/2Y" denotes an inspection performed at 500 flight hours or in two years, whichever comes first.

*6 "CM154" denotes No. 154 of Consumable Materials and falls under the category of the grease with specification code of G-366 (as described in MTC 20-01-01-102).

(a) Regreasing the hinges	*as per MET 64-20-00-301 paragraph On Spindle/Sleeve Assembly and On Flapping Axis.* *: Apply Grease CM 154 as per MTC, move the blade flapwise until clean Grease CM 154 comes out. If metal particles are found, remove and replace the bearing stack.*

(See Figure 23: Flapping hinge inspection points)

Lubrication procedures (MET 64-20-00-301) stipulate following:
(See Figure 23)

Lubrication *(2) On Flapping Axis* *(a) Clean grease nipples (2) as per MTC* *(b) Inject 30 g (.066lb) of Graisse CM 154 in grease nipples (2) with a grease pump.* *(c) Move the spindle/sleeve assembly about the flapping axis every 5 pump operations.* *(d) Remove the existing grease at the drain seals.* *(e) Clean the grease nipples (1) and (2) with a Cloth as per MTC.* *(f) Connect pitch-change links as per 64-20-00-402.* *NOTE* *Make sure that there is a label next to each grease nipple indicating the type of grease used.*

(See Figure 23: Flapping hinge inspection points)

(2) 10-Hour Inspection

10-hour inspection on the flapping hinge (Chapter 04 20 of ALS REV 005) is incorporated in the Company's post-flight inspection table, which stipulates that greasing up of the tail rotor head is to be performed and existence of cracks in the flapping hinge rotor head is to be checked after flight.

(3) 50-Hour Inspection

50-hour inspection (Chapter 04 20 of ALS REV 005) stipulates that following inspections are to be performed:

ITEM-COMPONENTS-METHODS	*ACTION CRITERIA*	*ACTION*
- Feel check the hinge.	*- Excessive binding points*	*- Replace bearings and inner rings (lubrication highly recommended as per intervals specified in MSM)*
- Check for correct condition of spindle (21): cracks and corrosion.	*- Excessive play in drag plane (for reference, play less than or equal to 0.6mm(0.23 in))*	*- Inspection of the spindle wear as per paragraph F.5 a2 "Spindle".*
- Check for correct condition and safetying (cotter pin (14)) of flapping hinge pins (spindle bolt) (23).		*Before connecting the pitch change link, rotate the sleeve a few turns.*
- Check the spindle lateral stops and the blade flapping stop (no deformation nor bead)		

(See Figure 23: Flapping hinge inspection points)

(4) 500FH/2Y Inspection

500-hour inspection (Chapter 05 20 of MSM REV 005) stipulates the following:

ITEM-COMPONENTS-METHODS	*ACTION CRITERIA*	*ACTION*
External visual inspection: *- pin (23)* *- sealing.*	 *- No locking* *- Leak*	 *- Torque nut (13) as per paragraph H. "Installation of spindle-sleeve assembly" of MET 64-20-00-403 and lock nut (13) with pin (14) as per MTC* *- Replace bearings and inner races (inner rings).*

(See Figure 23: Flapping hinge inspection points)

(5) 1,000-Hour Inspection on Flapping Hinge

1,000-hour inspection on the flapping hinge stipulates that following inspections are to be performed:

ITEM-COMPONENTS-METHODS	*ACTION CRITERIA*	*ACTION*
- Check needles and inner race (inner rings) (18) of bearing (16) and (17). *- Plastic lateral thrust washers (15).* *- Bearing race (18)*	*- Spalling* *- Brinelling*	*Replace bearings (16) and (17) and inner races (18) as per MRM 64-20-00-703.* *Replace plastic lateral thrust washers if their thickness is less than 1.5mm (.060in) as per MRM 64-20-00-728.* *Turn bearing race (18) through 180°*

(See Figure 23: Flapping hinge inspection points)

(6) 1,000-Hour Inspection on Spindle

1,000-hour inspection on the spindle (Chapter 05 20 of MSM REV 005) stipulates that following inspections are to be performed:

ITEM-COMPONENTS-METHODS	*ACTION CRITERIA*	*ACTION*
- When checking the flapping hinge bearings, check seating of the lateral thrust washers (15) on the spindles."	*- Wear on inner faces of yokes (12)* *if there is wear on the inner faces measure the wear depth with a Dial indicator in according with Figure 7.*	

(See Figure 23: Flapping hinge inspection points)

(7) Spindle Bolt Removal - Installation Procedures

Spindle bolt removal - installation procedures (MET 64-20-00-403) stipulate as follows:

Sleeve-spindle assy. removal MET 64-20-00-403 *1. Remove and discard split pin.* *2. Remove nut and bolt.* *3. Remove sleeve-spindle assy from hub.* *4. Remove stop washers and seals.* *5. Discard seals.*

(8) Tools Dedicated for Use in Replacing Outer Bearing

In the event that there has occurred an excessive binding in the feel check of the flapping hinge performed in 50-hour inspection, the inner ring and the outer bearings must be replaced. Besides, replacement work of the outer bearings requires use of a dedicated tool. Because the Company did not own such a dedicated tool, they needed to borrow it from the manufacturing company or other company.

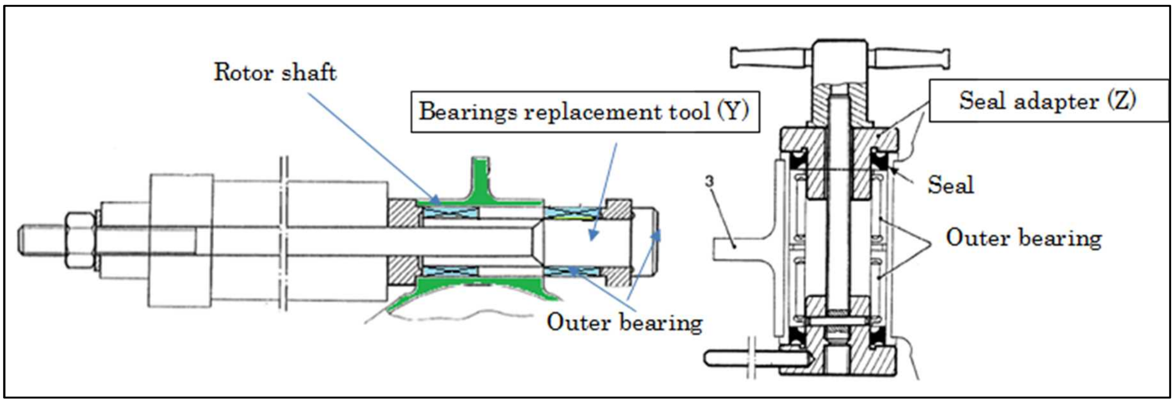

Figure 24: Part of dedicated tool

Figure 25: Outer bearing removed with a dedicated tool

2.16.2 Information on Use of the Grease

(1) Specified Operating Temperature Range for the Grease Used in the Flapping Hinge of the Same Type of Aircraft

Specified operating temperature range for the grease used in the flapping hinge of the same type of aircraft is as shown in Table 2 below:

Table 2: Operational temperatures of Aeroshell 14 grease

Air Specification	NATO Symbol	Specification DATA		Supplier	Trade name
		Operating T (℃)	Drop Point (℃)		
Mineral grease for helicopter rotors	G-366	– 54 to +93	148	SHELL	Aeroshell grease 14

(2) Information on the Grease Used in the Same Type of Aircraft

Information on the grease used in the same type of aircraft is notified as in Table 3 below:

Table 3: Information on the grease used in the same type of aircraft

No.	Type, No. and Date of issue	Issued by	Title and Outline
1	Service Bulletin No. 64. 51 R1 May 28, 1991	Eurocopter	"Tail rotor: Lubricating flapping hinge with MOBIPLEX 47 grease" Recommended applicable range of the grease ● MOBIPLEX 47: –30 ℃ to +50 ℃ ● AEROSHELL 14: –30 ℃ or below MOBIPLEX 47 is recommended for use at 0 ℃ or higher and grease replacement procedures are stipulated.
2	Information Notice No. 2017-I-64 December 20, 2008	Eurocopter	"Tail rotor: Lubricating pitch change and flapping hinge" ● Notifying use of Aeroshell 14 grease only ● Cautioning when using Aeroshell 14 grease at high temperature and high humidity*7.
3	Safety Information Notice No. 2919-S-64 July 9, 2015	Airbus Helicopters	"Tail rotor: Fractured pitch change spider arm in flight" ● Re-cautioning when using Aeroshell 14 grease ● Cautioning on maintenance procedures of tail rotor head
4	Safety Information Notice No. 2987-I-64 January 19, 2016	Airbus Helicopters	"Tail rotor: Lubricating flapping hinge" ● Re-cautioning when using Aeroshell 14 grease from the information on corroded flapping hinge inner ring

(3) Caution Issued by the Designer and Manufacturer for the Use of Aeroshell 14 Grease

In December 2008, then-Eurocopter notified their users of following information (Information Notice No. 2017-I-64, Revision 0 2008-12-20) on the grease related to the pitch change and the flapping hinge bearings.

In the past, EUROCOPTER had noted on tail rotor hub pitch change hinge bearing stacks, lubricated with Aeroshell 14 grease, increased proneness to the false Brinelling phenomenon. To improve this behavior, recommended Service Bulletin No. 64.15 R1, enabling operators to lubricate the tail rotor hub pitch change bearing stacks of AS332 MK1 helicopters with MOBILPLEX 47 grease, was issued in 1991. The results with this grease proved to be excellent and a considerably improved in-service behavior was noted (this history is covered in Telex Information T.F.S. No. 00000255 dated July 26, 2005). As the supplier no longer produces this product, Aeroshell 14 grease is currently the only grease available to ensure tail rotor hub lubrication.

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*7 Airbus Helicopters defines the environmental conditions of high temperature and high humidity as 28 °C and 75%, respectively. (AIRBUS ALS AS332L 5.11 Specific and severe atmospheric operating conditions)

Since the return to lubrication with Aeroshell 14 grease, EUROCOPTER has noted a significant decrease in the reliability of the tail rotor hub bearings, in particular within the scope of helicopter operation in hot and damp conditions.

*Compliance with the checks defined in the Maintenance Program (maintenance A scheduled at 50 FH**) enables operators to detect any deterioration of the condition of the pitch change and flapping hinges before it results in the loss of the function concerned.*

However, to improve the in-service behavior, EUROCOPTER is searching jointly with the oil companies for an alternative grease. Pending the availability of this new grease, EUROCOPTER draws your attention to the greasing of the TRH, which is currently the only means to ensure its correct behavior.

This lubrication is required as part of the ALF check as well as at the 10 FH** time limit. However, if the aircraft has been parked and has not been used for more than one day, in particular in a hot atmosphere, we advise you to grease the TRH before resuming flights.*

(4) Response Taken by the Company Related to the Information in Table 3

According to the Company, they revised the work card in August 2008 because MOBIPLEX 47 grease was discontinued and was not available to purchase, and commenced to use Aeroshell 14 grease around October when the inventory of MOBIPLEX 47 was used up. Thereafter, they obtained the cautionary information of No. 2 to No. 4 in Table 3; however, it was not disseminated to mechanics on-site, and re-lubrication was not performed prior to flight even after parking at high temperature and high humidity for 24 hours or more.

2.16.3 Emergency Operating Procedures for the Same Type of Aircraft

According to the flight manual of the Helicopter, procedures for the tail rotor-related failure and emergency landing are as follows:

(1) *Tail Rotor Failure*

- *Symptom:*
  - *Sudden major rotational movement on yaw axis.*
- *Actions:*
  - *Enter autorotation immediately.*
  - *Accomplish a full autorotative landing with engines shut down, at the highest possible roll-on speed compatible with terrain.*

  Immediately on touchdown:
  - *Control yawing by using wheel brakes.*
  - *Pull the GENERAL CUT-OUT handle.*

(2) *Tail Rotor Control Failure*

- *Symptom:*
  - *Hardover and stabilized sideslip more or less significant.*
- *Failure Analysis:*
  - *Tail rotor control cable failure.*

    Note: A device brings the tail rotor blades to a safe pitch to permit yaw control within certain limits.

  Failure in Cruising in Flight
- *Immediately reduce collective pitch to about 13° to limit or cancel the sideslip.*
- *Continue level flight under these conditions until a site suitable for run-on landing is found.*
- *Carry out an approach far enough to provide sufficient time to find a suitable collective pitch / airspeed / rate-of- descent combination that following conditions : 50 to 60 kt (93 to 110 km/h) IAS, 9 to 11° collective pitch and about 500 ft/min (2.5 m/s) rate-of-descent.*
- *Control sideslip via the roll axis.*

- *Maintain this attitude until the aircraft is close to the ground;*
  touch down will be achieved without increasing collective pitch;
  however the impact will be dampened by slightly moving the cyclic stick rearward.
- *Immediately on touchdown, pull the GENERAL CUT-OUT handle and control steering with the differential wheel brakes.*

(3) *Emergency Landing*

- *Actions:*
  When immediate landing is unavoidable:
  - *Attempt to reach the best sink rate / forward speed combination for the planned touchdown area.*
- *On impact*
  - *Pull the GENERAL CUT-OUT handle.*

2.16.4 Vibrations at Low Frequency less than 4.4 Hz and the Same Originating from Tail Rotor

According to the maintenance manual in relation to vibrations that the manufacturer of the Helicopter stipulated in relation to vibrations, vibrations at low frequency less than 4.4 Hz and the same originating from the tail rotor are as described in Table 4.
Excerpt from MET 05-53-00-612

Table 4: Vibrations at low frequency less than 4.4 Hz and the same related to tail rotor system

VIBRATION MEASURED	*POSSIBLE CAUSES*	*CHECK AND CORRECTIVE ACTIONS*
Vibrations less than 1 OMEGA, main rotor (Less than 4.4 Hz at nominal 265 r.p.m) *Vibrating roll phenomena on the ground, called padding (frequency close to Omega/2)* *Vibrations less than 1 OMEGA, main rotor (Less than 4.4 Hz at nominal 265 r.p.m)*	*Condition of the frequency adapters*	*Remove the frequency adapters. Check the adapters and their hinges for correct condition.*
	1. Incorrect operation of auto-pilot	*Check by disengaging the various channels in level flight.*
	2. Frequency adapter operating up to limit travel	*Check the frequency adapters for correct condition, if these vibrations are experienced during turns (of less than 45° bank (frequency close to: Omega/2))* *If in doubt, replace them.*
	3. Incorrect balancing of tail rotor	*Check the tail rotor for correct balance, if these vibrations are experienced in climbing flight. (Frequency close to : Omega/2)*
	4.End play in large ball joint of frequency adapter.	*Check and re-rig if applicable.*
1 OMEGA Tail rotor (21.3 Hz at nominal = 1,279 r.p.m)	*1.Tail rotor unbalance*	*Check and correct the unbalance, using the kit, if applicable.*
	2.Condition of tail rotor blades	*Check the condition of each blade, make the repairs if they are authorized, if not, replace the damaged blade.*

2.16.5 Reporting When Critical Damage Not Described in Maintenance Manual Has Been Found

(1) Airbus Helicopters' Reporting Procedure when Repair Criteria Are Exceeded

The maintenance manual (MET AS332 CC1LL1) of the same type of aircraft contains the following general information:

General Information About Technical Manuals

Purpose

The purpose of the Maintenance Manuals is to provide helicopter operators with the information required to ensure the maintenance of the helicopter.

They only contain the maintenance, inspection and repair information for the Operational and Intermediate levels.

When the repair criteria described in the Maintenance Manuals are exceeded, please contact the Airbus Helicopters network for the definition of a repair, if applicable, or the decision to discard the component.

(2) Reporting When Critical Malfunction Has Been Found

In order to promptly, accurately and thoroughly exchange information related to the occurrence of every phenomenon that could affect safety of flight, Airbus Helicopters (including Eurocopter) is asking operators to report occurrence as described in Table 5.

Table 5: Notice of occurrence report by the manufacturer

No.	Type, No. and Date of issue	Issued by	Title and Outline
1	Information Notice No.2046-I-00 June 19, 2009	Euro-copter	<Occurrence reporting> Defined purport of the occurrence report and format of the incident report with EASA AMC20-8 Occurrence Reporting attached.
2	Safety Information Notice No. 2739-S-00 October 22, 2014	Airbus Helicop-ters	<General> Reminder concerning compliance with the maintenance and operating conditions of aircraft of Airbus Helicopters and occurrence reporting.
3	Safety Information Notice No. 3242-S-00 April 25, 2018 (after the occurrence of this accident)	Airbus Helicop-ters	<General> Report of in-service events • Airbus Helicopters request to operators for providing information on all events considered as abnormal, occurring within the scope of aircraft operation or maintenance, with 2 working days.

3. ANALYSIS

3.1 Qualification of Personnel

The captain held both a valid airman competence certificate and a valid aviation medical certificate.

3.2 Airworthiness Certificate of the Helicopter

The aircraft had a valid airworthiness certificate and had been maintained and inspected as prescribed. However, as described in 3.5, it is highly probable that some of maintenance work was not properly performed.

3.3 Relations to Meteorological Conditions

As described in 2.7.1, it is highly probable that meteorological conditions in the vicinity of the accident site in terms of wind, prevailing visibility and cloud base did not adversely affect the flight.

3.4 Flight Situations of the Helicopter until Just Before the Accident

3.4.1 Situations of Lateral Vibrations during Goods Transport

As described in 2.1.3 (1), vibrations like precessions were felt by pilots since October 31, 2017, and then, there occurred no change in the level of the vibrations until November 2. It is probable that same level of vibrations as before lasted during cargo transport because the Helicopter continued flight for a total of about eight hours from November 3, 2017 until the accident day as shown in Figure 19 in 2.13.4, and there was no report of malfunction with the Helicopter as described in 2.15.2.

3.4.2 First Deceleration after Taking Off from Arakura Temporary Helipad

As described in 2.1, 2.1.1 and 2.1.5, the Helicopter was flying for Tochigi heliport via Nirasaki City, Yamanashi Prefecture after taking off from Arakura temporary helipad around 14:04. According to the radar track records from 14:22:21 until 14:27:02, the Helicopter climbed to a pressure altitude of 7,000 ft at a mean ground speed of 130 kt, and then moved to the level flight at a mean ground speed of 150 kt, which indicates that it is probable that there occurred no vibrations that adversely affected the flight during the period. Around 14:25:52, the first abrupt deceleration from a mean ground speed of about 150 kt to 100 kt occurred, followed by the flight at a mean ground speed of about 100 kt lasting for about 40 seconds while gradually descending. At that time, it is probable that rotation of the tail rotor became imbalanced, there occurred unusual events such as abnormal noise and increased level of vibrations, and the captain was coping with them.

3.4.3 Abrupt Descending while Left Turning from the Second Deceleration

From the statement of the witness A described in 2.1.4 (1) and the radar track records described in 2.1.5, the Helicopter commenced abrupt descending at a mean ground speed of about 80 kt and a mean descent rate of about 3,800 ft/minute while turning to the left around 14:26:40 after the second abrupt deceleration. Synthesizing the location of the Helicopter computed from the photos taken by the witness B as described in 2.1.4 (2), information from the witnesses as described in 2.1.4 and the radar track records reaches that the estimated flight route immediately before the accident was such as the one shown in Figure 5 and 6 and Appended Figure 6.

It is probable that the condition of the tail rotor was further worsened because the witness B heard an abnormal noise of "clapping". Besides, from the enlarged photo of Figure 3-2 in 2.1.4 (2), the Helicopter's landing gear was down at this time.

From these, it is highly probable that the abrupt descending flight with a left turn along the estimated flight route shown in Figure 5 and 6 indicates that the Helicopter commenced approach for emergency landing.

Besides, there is a riverside of about 300 m long and about 30 - 50 m wide in the vicinity of about 200 m east side from the accident site as shown in Appended Figure 6, and it is probable that the riverside was selected as an emergency landing site and the Helicopter was in an attempt to approach the selected emergency landing site while going around after descending at a low altitude.

3.4.4 Crash from Approaching for Emergency Landing

It is probable that the Helicopter commenced approaching the riverside along the Kanna River selected as the emergency landing site along the flight route in Figure 5 and 6 as described in the preceding subsection. It is highly probable from the statements of the witnesses C and D described in 2.1.4 (3) and (4) that the tail rotor separated from the airframe after the Helicopter made a noise of explosion while turning to the right about 200 m short of the riverside, thereafter the Helicopter became uncontrollable, and there occurred left whirling and a significant nose down as shown in Appended Figure 6 and Figure 26. It is probable that the Helicopter at that time performed nose up maneuvering in response to the nose down, and it is highly probable that the maneuvering caused the main rotor to lean backward that resulted in cutting the tail boom, and the pylon and the horizontal stabilizer dropped. It is highly probable that the Helicopter immediately, crashed with the nose firstly while cutting electric wires, and was destroyed, and the fuel caught fire causing the outbreak of fire.

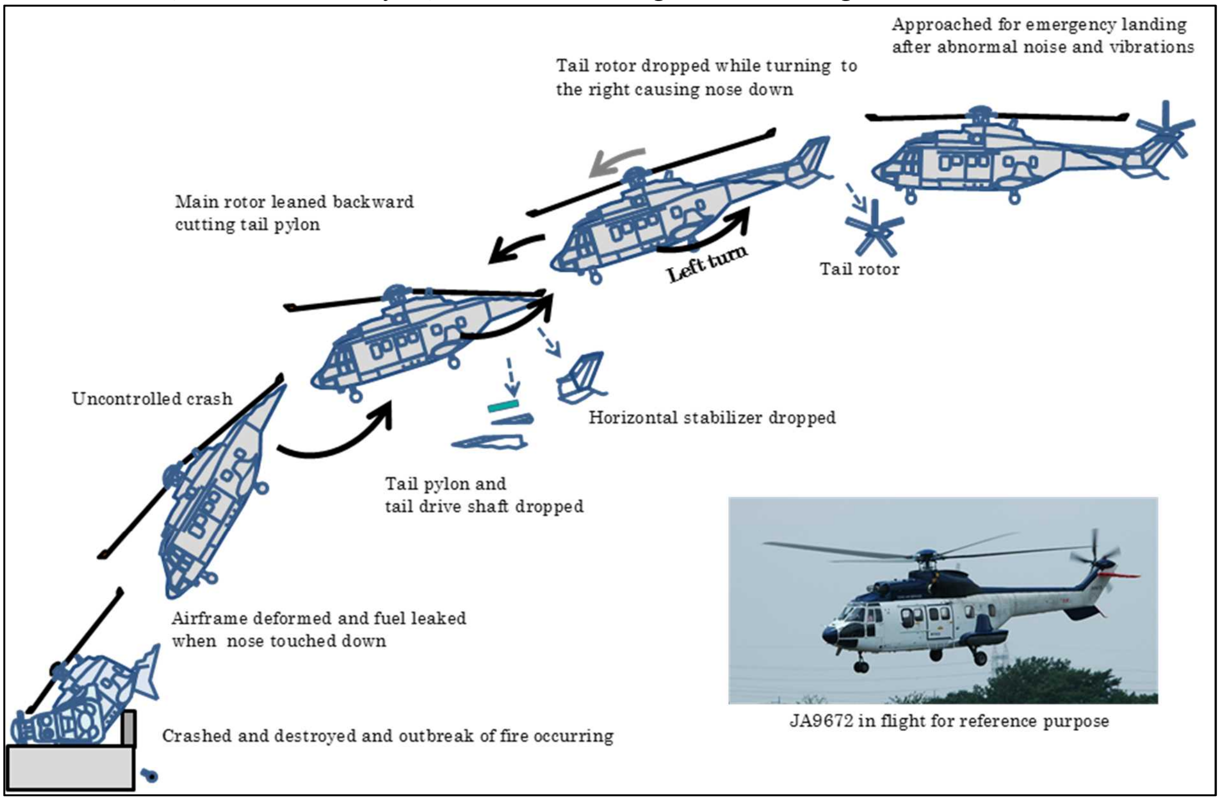


Figure 26: Changing flight attitude before the crash

3.5 Maintenance Work Performed on the Helicopter

3.5.1 Maintenance Work before September 19, 2017

3.5.1.1 Maintenance Situations at the Previous 1,000-Hour Inspections

As described in 2.13.3 (1), the Helicopter received the 500-hour and 1,000-hour flapping hinge inspections and spindle inspections described in 2.16.1 (4), (5) and (6) from March 21 until May 16, 2017. In this work, all spindle bolts were pulled out. The spindle bolts were pulled out smoothly, and some of the bolts had corrosion generating, which was removed for reinstallation after removing their corrosion. It is highly probable from the statement of Mechanic A described in 2.1.2 (1) that the inner ring and the outer bearings were not removed in this work. It is considered that spalling inspection of the needle bearings and brinelling inspection of the inner ring described in 2.16.1 (5) were feasible to perform by sliding the inner ring without completely disassembling it; however, it could not be confirmed how the inspections were actually performed. The stop washers of all spindle bolts were replaced with new ones due to deterioration. However, because the seal was not replaced against the spindle bolt assembly and removal procedures described in 2.16.1 (7), it is somewhat likely that this affected subsequent sealing performance of the bearings.

Maintenance record for 1,000-hour inspection noted nothing about the condition of the inner ring and the outer bearings as described in 2.13.3 (1); however, when considering that the grease of the flapping hinge of the White Blade became darkening about one month after the 1,000-hour inspection and the inner ring was found smashed in the inspection performed 243 hours later, it is somewhat likely that some kind of malfunction had already occurred at this time in the bearing's inner parts such as the needle bearings.

3.5.1.2 10-Hour Inspection Performed in the Middle of June 2017

As described in 2.13.3 (2), 2.16.1 (1) and (2), when greasing up the flapping hinge in a 10-hour inspection performed in the middle of June 2017, it was found that the old grease of the White Blade only was darkened. From this, it is somewhat likely that malfunction had occurred at this time in the flapping hinge of the White Blade.

3.5.1.3 Situations of White Blade from Early July until Late August 2017

As described in 2.13.3 (3) and (4), the White Blade only had the drag play in drag plane around the middle of July 2017, and the black grease was discharged compared to other blades from. Although some of the flapping hinges of other blades also had the black grease discharged when flying after rainfall or for five hours or more, it was not as contaminated as the White Blade. From this, it is somewhat likely that the environment of usage affected the grease condition, and the degree of malfunction of the flapping hinge of the White Blade further was progressed than the other four blades.

3.5.1.4 50-Hour Inspection Performed on August 30 and September 19, 2017

As described in 2.13.3 (5) and 2.16.1 (3), the measured value of play of the White Blade in drag plane was 0.4 mm against the maximum acceptable play of 0.6mm or less in the 50-hour inspection performed on August 30 and September 19, 2017. Besides, the black and contaminated grease was discharged. Furthermore, the motion of the White Blade was not smooth in the 50-hour inspection performed on September 19. From these and the inner ring's damaged condition that was found out by the investigation as described in 2.13.3, it is somewhat likely that deterioration of the inner ring had been progressed and the flapping hinge of the White Blade had stuck at this time.

3.5.2 Maintenance Work since September 20, 2017

3.5.2.1 Maintenance Work Performed from September 20 until September 23, 2017

As described in 2.13.3 (6), the spindle bolt was removed from the flapping hinge for maintenance work simultaneously with the 250-hour inspection performed from September 20 until September 23, 2017. Inspection of the flapping hinge by removing the spindle bolt requires visual checking of the condition of the needle bearings and the inner ring, and in the event of spalling was found, both the inner ring and the outer bearings must be replaced as described in 2.16.1 (5). In this maintenance work, cracks were found in the inner ring fully installed, and the measures to cope with this were set to replace the inner ring and the stop washer only. It is probable that the rapid deterioration of the stop washer leads to play in the drag plane. However, as described in 2.1.2 (2), the stop washer was not much shaved off but the contact surface of the yoke was shaved off. So it is probable that the contaminated grease deteriorated the yoke of the flapping hinge of the white blade, which caused play. The stop washer was replaced in line with the procedures; however, the condition of the outer bearings was not confirmed and the seal was not replaced against the spindle removal - installation procedures described in 2.16.1 (7), which requires the seal replacement. As described in 2.13.3 (6), a new inner ring was attached in a way to push out the Old Inner Ring, which was smashed. The Company should have reported this damaged condition of this Old Inner Ring to the designer and manufacturer of Airbus Helicopters to ask for their engineering judgment the measures like as repair as described in 2.16.5 (1) because the damaged condition was far progressing than the criteria for 1,000-hour inspection on the flapping described in 2.16.1 (5).

It is probable that the needle bearings in contact with the inner ring were also damaged because the Old Inner Ring was in the smashed condition as described in 2.13.3 (6) and tiny fragments possibly remained in the outer bearings. Besides, it is probable that the maintenance control division in charge of quality control of the Company had no way of recognizing the condition of the fragments of the Old Inner Ring because the fragments were discarded as kept in the vinyl bag. Accordingly, there was no reporting made to Airbus Helicopters.

3.5.2.2 Maintenance for Lateral Vibrations

As described in 2.1.3 (1) and 2.13.3 (8), there occurred the Lateral Vibrations at a low frequency in a cycle shorter than a second like precession that could be felt in the pilot's seat from around October 31, 2017. As the vibrations level was so small and such an extent as not to affect the flight, and the vibrations were considered to be caused by a small amount of oil leakage from lip seal of the sleeve of the MRB, the Lateral Vibrations were set to be treated in the regular maintenance planned for December.

According to Table 4 in 2.16.4, it is somewhat likely that the low-frequency vibrations in a short cycle of less than a second that Pilot A felt were identical to 2.2 Hz vibrations that occur when the tail rotor blades have a malfunction in balancing. Although it is difficult to determine the source of the vibrations of a helicopter, it is desirable that probable sources of vibrations be determined using vibration measuring devices as needed when unusual vibrations are felt by the feeling of the human body in many cases because it is generally difficult to identify the sources of such vibrations. It is somewhat likely that malfunction occurred in the flapping hinge of the Helicopter that could have been detected if the cause of the vibrations was searched for.

3.6 Factor of the Tail Rotor Separation and Influence on the Operation

3.6.1 Fractured Spindle Bolt

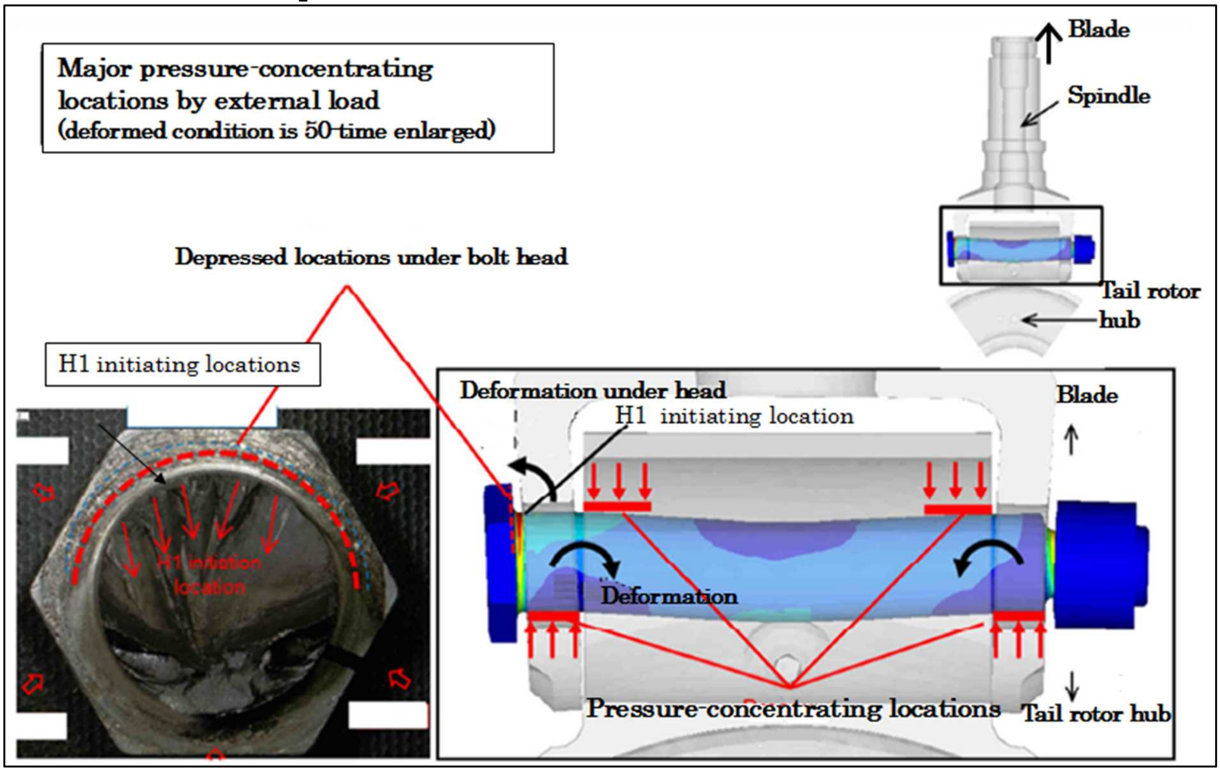


Figure 27: Pressure added to spindle bolt

As described in 2.14.3 (1), cracks were propagating from the bolt head of the spindle bolt of the White Blade of the Helicopter. The spindle bolt under normal condition with normal bearings receives load in axial direction initiating from CF and lead-lag moment and some shearing load as shown in Figure 27; however, flapping moment is as low as negligible and the spindle bolt does not receive the torsional load.

Propagation of the cracks of the spindle bolt of the Helicopter shows torsional condition, which indicates that it received unexpected fatigue load. In the event that torsional load occurs on the bolt head, flow of the torsional load propagates in the spindle, and load is generated by occurs on the boundary between the spindle bolt head and the spindle as shown in Figure 28. It is highly probable that the cracks were generated on the contact face between the spindle bush and the bolt head, which was added by the torsional load leading to the fracture of the spindle bolt.

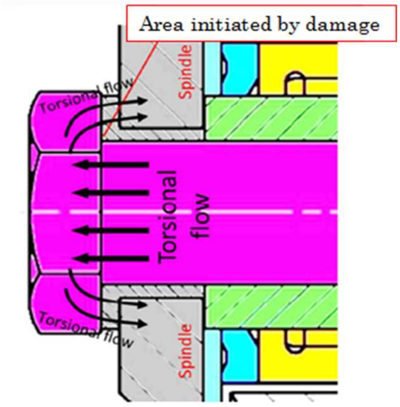


Figure 28: Torsional load flow of bolt

3.6.2 Factors Causing Torsional Load in the Spindle Bolt

The following are probable factors causing the torsional load in the spindle bolt. As seen in Figure 29 (1), there occurs no torsional load when the spindle bolt is under normal condition because the needle bearings in the outer bearings in red smoothly move. With regard to the principle that the torsional load is generated in the spindle bolt, in the event that the needle bearings stick due to damage or some other factor, the inner ring is fixed to the needle bearings causing the spindle bolt to slide on the inner diameter of the inner ring as seen in Figure 29 (2). Furthermore, in the event that the outer bearings, the inner ring and the spindle bolt stick, load concentrates on contact face while the spindle bush and the spindle bolt are sliding as seen in Figure 29 (3). The spindle bolt is added by three different pressures of tightening pressure, spindle pressure and inner ring pressure as seen in the left picture of Figure 30. In the event that the bearing sticks, the inner ring receives load in the circumferential direction by flapping of the blade as seen in the right picture of Figure 30. This load is added to the bolt as tangential force passing through the boundary between the inner ring and the bolt. Torsional load added to the spindle bolt is generated, by friction or burning between the spindle bolt head and the spindle bush.

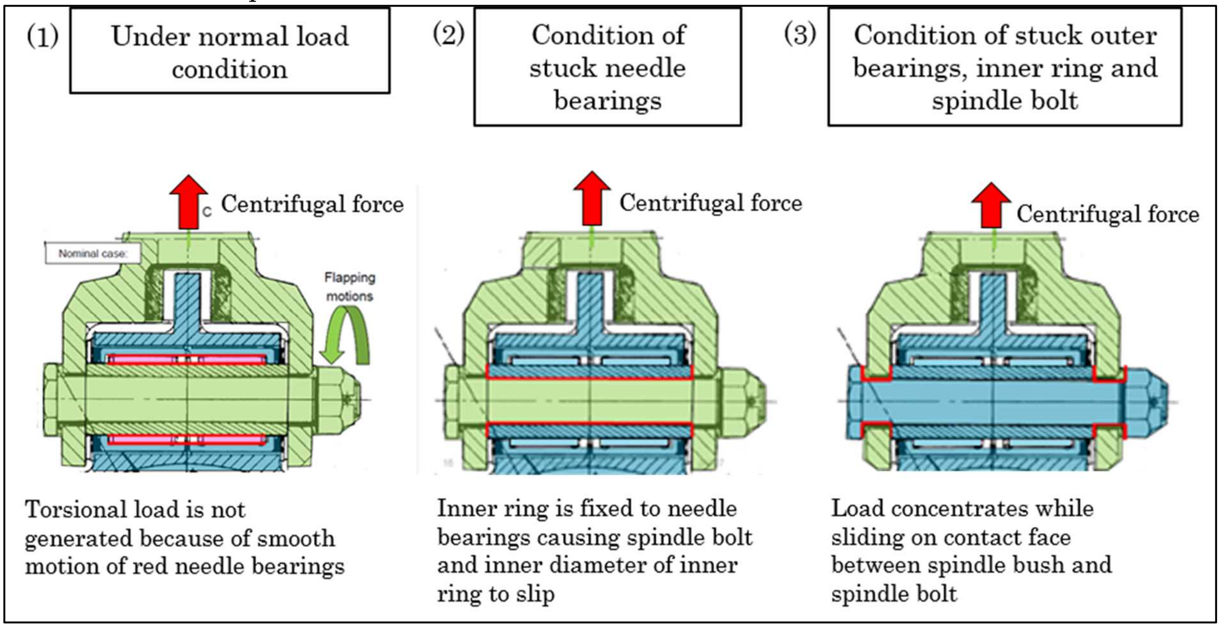


Figure 29: Stuck flapping hinge

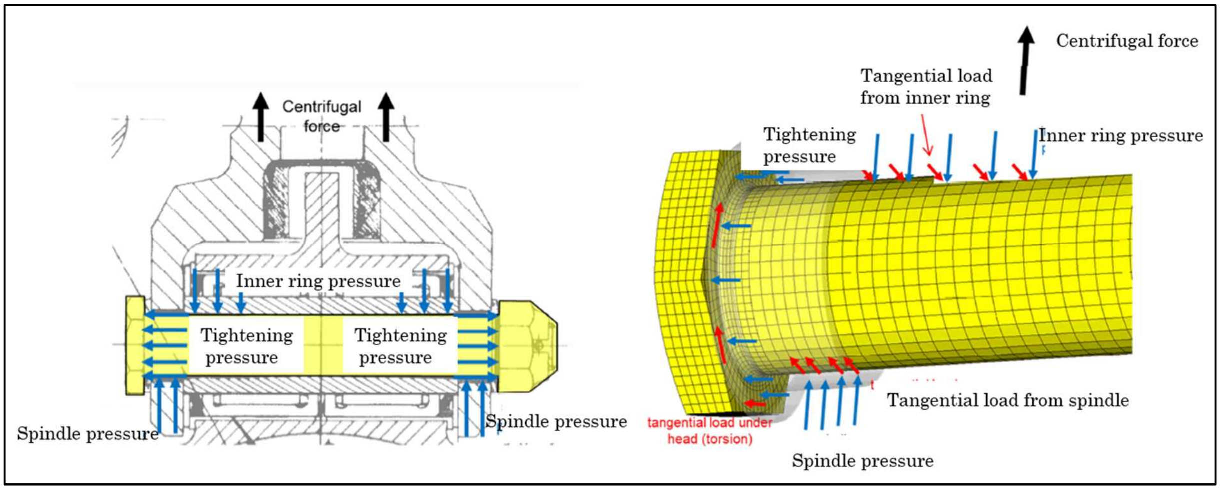


Figure 30: Pressures acting on spindle bolt

3.6.3 Damaged Inner Ring and Fractured Spindle Bolt

As described in 2.14.3 (2), the inner ring was fractured by propagating cracks accompanied by false brinelling wear. In the maintenance on September 23, 2017, the Helicopter had the inner ring replaced with a new one, and flight time after the replacement until the accident was 94 hours. Compared with the malfunction condition of the inner ring obtained by the emergency inspection of the flapping hinge of the same type of aircraft described in 2.14.6, it is probable that the malfunction was progressed considerably rapidly. It is probable that factors of the rapid progress of the malfunction of the inner ring compared to same type of aircraft were that the fragments of the Old Inner Ring remained in the outer ring when replaced with new one on September 23, 2017, as described in 3.5.2.1, and damage had already occurred in the needle bearings and the outer bearings at that time. It is highly probable that this caused the needle bearings to stick described in 3.6.2, which developed to the condition seen in Figure 29 (2) and (3), accelerated the propagation of the cracks of the inner ring, and the spindle bolt fractured added by the torsional load.

3.6.4 Needle Bearings Sticking in Outer Bearings

As described in 2.14.3 (3), the needle bearings in the outer bearings were damaged from fretting and wear. Furthermore, it is probable that there occurred a position sliding under off-aligned condition in the needle bearings because marks of the false brinelling wear of the outer rings caused by the needle bearings leaned off the outer bearings axis. When considering the deformed needle bearings, deep brinelling and the position sliding, it is highly probable that the needle bearings stuck, not properly rolling.

3.6.5 Time When the Old Inner Ring Got Fractured

Deteriorations of parts consisting of the flapping hinge include corrosion, spalling, fretting, brinelling, deformation, wearing and cracks. Because occurrence of these deteriorations is prone to be affected by environment and condition of usage, it is set to maintain airworthiness by regular inspection and maintenance work.

The maintenance work of the flapping hinge of the same type of aircraft is set to maintain lubrication of parts by greasing in post-flight inspection and in 10-hour inspection described in 2.16.1 (1) and (2), and to find malfunction by measuring blade play and by conducting the feel check of the motion without disassembling the hinge in 50-hour inspection described in 6.1 (3). Furthermore, tightening torque and seal are confirmed to check normal condition and leakage of grease in 500-hour inspection described in 2.16.1 (4). In the 1,000-hour inspection of the flapping hinge described in 2.16.1 (5), the hinge was to be disassembled to detect possible deterioration of the spindle bolt and bearings.

However, as described in 2.13.3 (2) through (6), the Helicopter had a black grease discharging from the White Blade about one month after 1,000-hour inspection performed in

May 2017, followed by occurrence of the drag play that stayed within the criteria, and the inner ring was found fractured in such a short period of 243 hours after the Previous 1,000-Hour Inspections. It is probable that these indicate that some kind of malfunction occurred in the bearings of the flapping hinge of the White Blade accelerated the progress of the malfunction.

From these, as described in 2.14.7 and 2.14.8, the measures taken by the designer and manufacturer after this accident to replace systematically the flapping hinge components in 250 hours are deemed effectual to prevent similar occurrence beforehand.

3.6.6 Influence of Grease

As described in 2.16.2 (3), Aeroshell 14 grease, which is the grease only available and has been used since February 2008, has less reliability when used at high temperature and high humidity, and accordingly requires a sufficient amount of the grease to be lubricated. It is somewhat likely that insufficient lubricating condition of the grease hinders a smooth motion of the hinge and causes sticking of parts due to lack of sufficient lubrication. Particularly, it is recommended that the grease be re-lubricated prior to flight in the event of parking for 24 hours or more at high temperature of 28℃ or higher and high humidity of 75% or higher. As described in 2.16.2 (4), according to the Company, the grease was lubricated in post-flight inspection, and it was not re-lubricated prior to flight after parking for 24 hours or more in high temperature and high humidity. In addition, as described in 2.13.1 and 2.13.2, in two inspections of 1000-hour since June 2014, there was no record of seal replacement that is required for removal and installation of the spindle bolt. Therefore, it is somewhat likely that the bearings had a deteriorated sealing performance.

The Helicopter had the drag play from around the middle of July, and as described in 3.5.1.3, the play was found to be at 0.4 mm in 50-hour inspections performed on August 30 and September 19, 2017. Besides, as seen in Appended Figure 2, comparing the parking situations of the Helicopter and the meteorological changes during the period from May 30 until September 19, 2017, when flight was resumed after completion of 1,000-hour inspection revealed that the number of days when the Helicopter parked at high temperature and high humidity for 24 hours or more inside a hanger was 10 days and outside a hanger was 5 days during the period from late June until middle September 2017. Among these days, the number of applicable days when the Helicopter should have been lubricated by grease prior to flight were 10 days. It is somewhat likely that insufficient grease lubrication made the malfunction progress and caused damage to the parts because the applicable days generally coincide with the time when the black grease of the White Blade was generated. Taking into account the play of the White Blade and the generating situations of the black grease, it is probable that failure to maintain lubrication caused damage and sticking of the parts in the Old Inner Ring to occur and generated cracks leading to the fracture. However, it could not be determined why the damage to the White Blade progressed far rapidly compared to the other blades.

As described in 3.6.5, replacing all parts consisting of the flapping hinge in every 250 hours is deemed effectual to prevent occurrence of malfunction beforehand. Besides, it is considered necessary to determine appropriate time for lubrication, considering environmental conditions in usage based on the characteristics of Aeroshell 14 grease. Furthermore, it is considered necessary to closely watch a possible mixing in of metal fragments through monitoring changes in grease condition and, in the event of detecting abnormality, to perform disassembly maintenance of the flapping hinge for early replacement of parts.

3.6.7 Relationship between Lateral Vibrations and Tail Rotor Imbalance

As stated in 2.1.3 (1), the Lateral Vibrations that occurred on or around October 31, 2017 was considered to be caused by a small amount of oil leakage from the sleeve of MRB. As described in 2.12.1 (2), it is unlikely that the small amount of oil leakage was a sign of malfunction causing vibrations because a sufficient amount of oil was supplied to the main rotor head from the reservoir tank all the time. The position of the CG of the same type of aircraft is normally located directly under the main rotor mast as seen in Figure 31, and the motion of the airframe occurs with the position of the CG in the center. Because the tail rotor rotating vertically at the aft airframe is located higher than X axis of the airframe, it causes balancing malfunction of the tail rotor blade, and in the event that thrust of the tail rotor is altered, motion in yaw direction around the vertical Z axis and the same in roll direction around X axis are generated. In the event of ASE mode, it is probable that precession is felt in pilot's seat affected by flight control to make attitude, direction and altitude reverted to the standard position.

Figure 31: Unstable relation between lateral vibrations and rotating face of tail rotor

It is probable that rotating face of the White Blade and other four blades was largely slid because the Helicopter had the spindle bolt of the White Blade fractured in flight, and further larger vibrations occurred.

3.6.8 Tail Rotor Separation from Airframe

As described in 2.1.4 (4) and 2.9.2, the probable causes of separation of the tail rotor from the airframe immediately before the accident are probable as follows:

Following phenomena are probable to have occurred from the fracture of the spindle bolt of the White Blade:

It is probable that the fracture of the spindle bolt of the White Blade occurred firstly, followed by significant change in the position of the tailor blades due to CF and aerodynamic force on the tail rotor blades, which results in the imbalance of rotating face of the White Blade. It is probable that this increased stress on the tail rotor hub, generated abrupt motion in the yaw axis, stress was increased by vibrations to parts of the airframe, and the tail rotor separated from the pylon by further imbalanced tail rotor. (See Appended Figure 4 and 5)

It is probable that excessive load was imposed on the structure parts that led to the separation of the tail rotor because the frame of the section where the lower side of the tail rotor was fractured had marks of the load, cracks were generated in some part of the frame, and the rivets were damaged as seen in Figure 32. Besides, from the damaged condition of the tail rotor drive shaft and the pylon, it is probable that contact marks on attaching side of TGB in the inclined drive shaft within the pylon as seen in Appended Figure 5 was left when the tail rotor was separated together with TGB.

Figure 32: Fractured face of tail rotor lower side separated from airframe

3.6.9 Altered Position of CG and Abrupt Left Whirling Due to Tail Rotor Separation

As described in 2.9.2 and 3.4.3, influence on maneuver due to the separation of the tail rotor was computed.

In the event that the tail rotor has been separated from the pylon, it is probable that there occurs a remarkable change in the position of the CG and a change in thrust. It is estimated that the weight of the Helicopter was approximately 6,418 kg and the position of the CG was 4.53 m immediately before the accident, and it is probable that the total weight of the separated tail rotor was about 110 kg locating 14.09 m from the CG base line. Because the weight of the Helicopter becomes approximately 6,308 kg and the position of the CG becomes 4.36 m after the separation of the tail rotor, it is probable that the Helicopter was in forward position exceeding allowable longitudinal CG, and there occurred a large nose down moment. Accordingly, it is probable that the CG exceeded the forward limit line, and the pilot maneuvered to pull the cyclic stick backward in an attempt to revert to the previous attitude under the situations of being lack of affordable maneuvering in the directions of back and forward. It is highly probable that this caused the main rotor to lean backward leading to cutting the tail boom. It is probable that this caused the pylon and the horizontal stabilizer attached to it to drop.

Besides, computing whirl rate generated by reduced thrust of the tail rotor by separation of the tail rotor indicates that it is probable that there occurred a left whirling at 120 °/second or more due to abrupt reduction of the antitorque.

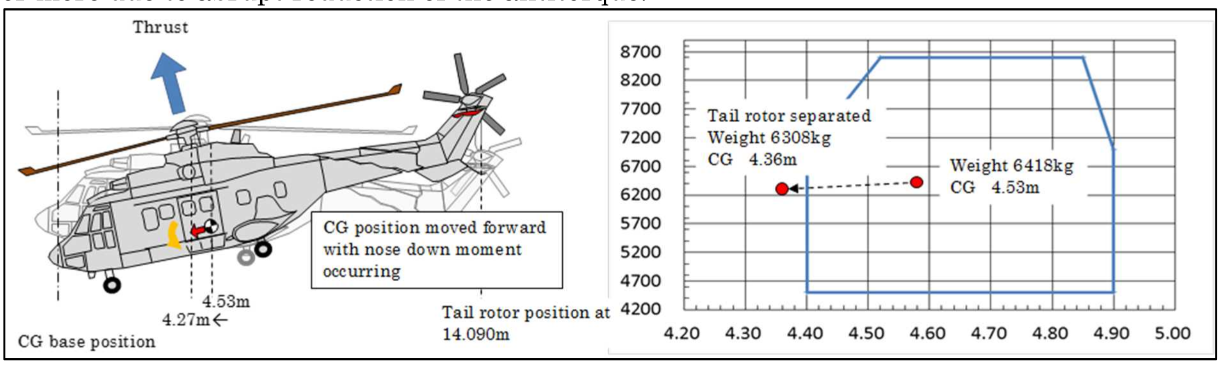


Figure 33: Change in center of gravity immediately before crash of aircraft

3.7 Judgments by Captain and Certifying Mechanic A

3.7.1 Judgment and Operation by Captain

(1) Recognition of the Lateral Vibrations during Cargo Transport

As described in 2.1.3 (1) and 3.5.2.2, the captain heard from Pilot A on November 2 about the situation of the Lateral Vibrations occurring since October 31, 2017. It is probable that there occurred no significant increase in the level of the Lateral Vibrations in cargo transport from then until November 8 because a CM A who grasped the situations of the vibrations was on board and there was no malfunction report.

(2) Deceleration and Descent to Cope with Increased Vibrations

As described in 3.4.2, it is probable that there occurred no significant change in the level of the Lateral Vibrations during the flight because the captain climbed to a pressure altitude of 7,000 ft after take-off from Arakura temporary helipad around 14:04, accelerated to a ground speed of about 150 kt after shifting to level flight and continued the high speed flight. It is probable that the captain reduced the power by lowering the collective pitch lever because the ground speed was decelerated from 150 kt to 100 kt and the pressure altitude descended from 7,000 ft to about 5,600 ft around 14:25:52. From the remarkable change in the flight condition, it is probable that the captain felt and coped with a worsened level of the Lateral Vibrations. As described in 2.16.3, the same type of aircraft has emergency operation procedures for the cases of the tail rotor failure when thrust is lost, and the tail rotor control failure when the tail rotor control cable is fractured. Although emergency operation procedures for vibrations is not set forth, it is probable that the captain's judgment to decelerate and descend by lowering the collective pitch lever was to mitigate the aerodynamic influence and load of the tail rotor.

(3) Emergency Landing Operation and Selecting Landing Site

As described in 3.4.3, it is highly probable that the captain judged that emergency landing was needed, and headed toward the Kanna River while handling the altitude by autorotation because he commenced descending at the descent rate of 3,800 ft/minute performing gear down operation around 14:26:40. It is probable that the condition of the tail rotor was further worsened because the witness B heard the abnormal noise of "clapping" while the Helicopter was approaching going round as described in 2.1.4 (2) and (4). The riverside inferred to have been selected as the emergency landing site was not bulldozed with river gravels and a little difficult to land on, and the witness D was at construction work there. It is probable that the riverside accommodated space for landing if it was made at a low speed even without hovering.

(4) Operation to cope with the situation immediately before the Accident

The location where the tail rotor was separated was where the Helicopter commenced a direct approach toward the selected emergency landing site near 200 m short of the landing site according to the flight route in Appended Figure 6. It is highly probable that the captain was unable to maneuver to cope with the left turn exceeding 120 °/second and the abrupt nose down because it is probable that there occurred the alteration of the CG and the abrupt left turn caused by the separation of the tail rotor described in 3.6.9 immediately after the pilot commenced the direct approach for landing maneuvering.

3.7.2 Judgment and Coping by Certifying Mechanic A

(1) Judgment to Replace Inner Ring and Outer Bearings

As described in 3.5.2.1, the CM A confirmed cracks in the Old Inner Ring after disassembling the spindle bolt in replacement work of the inner ring performed from September 20 until September 23, 2017 and judged to replace the inner ring and the washer. At this time, as described in 2.1.2 (3), (4) and (5), the CM A confirmed repair instruction and parts ordering with maintenance control division, and explained the situations of the malfunction to person in charge for ordering parts in response to his inquiry. Because the malfunction report in line with the maintenance manual of the Company was not developed, he could not receive advice from maintenance control division. Besides, replacement of the outer bearings requires the special tools described in 2.16.1 (8); however, when the CM A requested to order the parts described in 2.1.2 (5), the inner ring only was ordered and borrowing the dedicated tool was not taken into consideration.

The CM A judged to replace the inner ring and the washers only; however, as described in 3.5.2.1, it is probable that he should have reported to maintenance control division for their technical review when he found cracks in the inner ring because the cracks were considered to have propagated more than spalling condition.

(2) Judgment on Lateral Vibrations

As described in 3.5.2.2, measures to deal with the Lateral Vibrations that occurred from around October 31, 2017 were postponed until the regular maintenance based on presumption that they might be caused by a small amount of oil leakage from the sleeve of the main rotor. According to Table 4 in 2.16.4, it is unlikely that the vibrations the Pilot A felt as described in 2.1.3. (1) may be caused by the leaked oil from the sleeve of the main rotor; however, it is somewhat likely that he judged that the vibrations were not caused by the tail rotor because he finished maintenance work of the flapping hinge of the tail rotor on September 23.

3.8 Handling by Maintenance Control Division of the Company

(1) Management System at the Occurrence Malfunction during maintenance

As described in 2.1.2 (3), (4) and (5), aircraft status chart and aircraft malfunction report were not developed for the malfunction of the Helicopter. This was based on the recognition that the malfunction was corrected by replacement of general parts during the inspection work; however, inter-office email describing "cracks in the inner ring" was sent although the email did not contain detailed report. The inner ring is defined as one of the general parts by the Company manual because of unlimited time of use. In view of significant influence on airworthiness by malfunction of parts used in rotation equipment of helicopters, it is probable that maintenance control division should have actively confirmed details of the malfunction in order to prevent similar malfunctions of the same type of aircraft beforehand, and should have reported to the designer and manufacturer as a serious malfunction case of smashed Old Inner Ring as described in 2.16.5.

As described in 2.16.2 (4), the Company received the information notice from the manufacturer with regard to cautions of use of Aeroshell 14 grease requiring re-lubrication prior to flight after parking for 24 hours or more at high temperature and high humidity; however, the information in question was not made public to mechanics on-site and the information notice was kept stored in engineering section. It is somewhat likely that this was responsible for the damage to the parts of the flapping hinge of the Helicopter. It is required that information relating to cautions on maintenance notified by designer and manufacturer be promptly reviewed from engineering point of view and necessary information be disseminated to mechanics on-site.

(2) Inspection System by Multi-Mechanics

As described in 2.15.3, the Company had the CM A, who was on board the accident flight, on board all the flights during the last one year, and all the inspections performed during the said period were confirmed by the CM A alone. Under the system, it is probable that when an erroneous decision was made, it tends to be difficult to detect and modify compared to inspection system performed by multi-mechanics. Besides, it is somewhat likely that allowing a single mechanic alone to perform all inspections for a long period of time led to the lack of consciousness to report and share information.

3.9 Recurrence Prevention of Similar Cases

Based on the situations described in up to the preceding sections, following are considered to prevent recurrence of similar accidents.

(1) In the event that malfunction is suspicious with airframe, mechanics engaged in the inspection must report to maintenance control division for thorough consideration to fly or not.

In the event of the airframe to which the maintenance manual (or maintenance standard) is applied, mechanics engaged in the inspection should report to maintenance control division in accordance with the procedures stipulated in the maintenance manual to ask for their instructions on measures to take. Besides, maintenance control division is required to review the measures from engineering point of view, to report to the manufacturer as needed, and to provide the mechanics engaged in the inspection with appropriate instructions. Besides, in the event that such malfunction including damage, which is not listed on manual or the like of the manufacturer, is found, maintenance control division is required to report to the manufacturer asking for their technical review and to take corrective measures for the malfunction in accordance with the instruction from the designer and manufacturer.

(2) In the event that vibrations that differ from normal ones are felt, it is desirable that source of the vibrations be identified by measuring the vibrations, if needed, in order to properly perform maintenance work.

4 CONCLUSIONS

4.1 Findings

(1) It could not be determined how spalling inspection of the needle bearings and brinelling inspection of the inner ring were actually performed in the Previous 1,000-Hour Inspection of the Helicopter. The stop washers of all spindle bolts were replaced; however, it is somewhat likely that the seals that were not replaced affected subsequent sealing performance of the bearing. (3.5.1.1)

(2) When greasing up the flapping hinge in 10-hour inspection of the Helicopter in the middle of June 2017, the White Blade only had the darkened old grease. From this, it is somewhat likely that malfunction started to occur in the flapping hinge of the White Blade at this time. (3.5.1.2)

(3) It is somewhat likely that the deterioration of the inner ring progressed and the flapping hinge of the White Blade stuck because the Helicopter had the drag play of the White Blade, and the black and contaminated grease discharged in 50-hour inspection performed on August 30 and September 19, 2017, and from the damaged condition of the inner ring turned out by the investigation. (3.5.1.4)

(4) In the disassembly maintenance work of the flapping hinge of the Helicopter performed from September 20 until September 23, 2017, cracks were found in the inner ring and only the inner ring and the stop washers were replaced. Besides, the condition of the outer rings was not confirmed and the seals were not replaced. The new inner ring was assembled in a way to push out the Old Inner Ring, which was found to be smashed. It is probable that the Company shuould have reported the damaged condition to the designer and manufacturer of Airbus Helicopters, and asked Airbus Helicopters for their engineering judgment of the measures such as repair. (3.5.2.1)

(5) It is somewhat likely that the Lateral Vibrations at a low frequency in a cycle shorter than a second like precession felt in the pilot's seat from around October 31, 2017 were identical to 2.2 Hz vibrations that occur when the tail rotor blades have malfunction in balancing. It is somewhat likely that malfunction of the flapping hinge could have been detected if the cause of the vibrations was searched for. (3.5.2.2)

(6) With regard to the first deceleration from a mean ground speed of about 150 kt to 100 kt after the Helicopter took off from Arakura temporary helipad, it is probable that rotation of the tail rotor became imbalanced and there occurred abnormalities such as abnormal noise and increased level of vibrations, and the captain was coping with them. (3.4.2)

(7) It is highly probable that, while approaching to the riverside of the Kanna River selected as an emergency landing site, the tail rotor separated from the airframe and there occurred the left turn and the significant nose down after the Helicopter made the noise of explosion while turning to the right about 200 m short of the riverside. It is highly probable that the

Helicopter crashed with the nose first as losing control, cutting electric wires, and was destroyed, and the fuel caught fire causing the outbreak of fire. (3.4.4)

(8) It is highly probable that the damage generated in the needle bearings and the outer bearing caused the needle bearings to stick and accelerated the propagation of cracks of the inner ring, and the spindle bolt fractured added by the torsional load. (3.6.3)

(9) It is probable that some kind of malfunction occurring in the flapping hinge of the White Blade indicates that the progress of the malfunction was accelerated because the fracture of the inner ring was found in such a short period of time of 243 hours after the Previous 1,000-Hour Inspection.

As described in 2.14.7 and 2.14.8, the measures taken by the designer and manufacturer after this accident to replace systematically the flapping hinge component in 250 hours are deemed effectual to prevent occurrence of similar malfunctions beforehand. (3.6.5)

(10) It is probable that diligently checking of possible mixing of metal pieces through monitoring change in the condition of grease, and early replacement of parts by performing disassembly maintenance of the flapping hinge, in the event of detecting abnormality, are necessary. (3.6.6)

(11) It is probable that the Lateral Vibrations occurred in the Helicopter indicated the malfunction in balance occurring in the tail rotor blade which were felt as precession in the pilot's seat. Furthermore, it is probable that rotating face of the White Blade and other four blades largely slid due to the fractured spindle bolt of the White Blade in flight leading to occurrence of further larger vibrations. (3.6.7)

(12) It is probable that, from the fractured spindle bolt of the White Blade, the cause of separation of the tail rotor from the airframe immediately before the occurrence of the accident was the imbalance occurring in the rotating face of the White Blade. Due to that, it is probable that the stress against the tail rotor hub was increased, there occurred an abrupt motion of yaw axis increasing stress by vibrations to parts, and a greater imbalance of the tail rotor caused it to separate from the pylon. (3.6.8)

(13) The altered position of the CG of the Helicopter caused the forward position exceeding allowable longitudinal range due to the separation of the tail rotor. It is highly probable that generation of a large nose down moment caused the main rotor to lean backward, and the tail boom was cut. Besides, it is probable that reduced thrust of the tail rotor caused by the separation of the tail rotor indicates that abrupt reduction of antitorque caused the left turn over 120 ° /second to occur. (3.6.8)

(14) The CM A judged to replace the inner ring and the washer only in the replacement work from September 20 until September 23, 2017. It is probable that the CM A needed to report to maintenance control division for their engineering review in the event of finding cracks in the inner ring because the cracks were considered to have propagated, compared with the condition of spalling. (3.7.2 (1))

(15) It is somewhat likely that the CM A judged that the Lateral Vibrations were not caused by the tail rotor because he completed the maintenance work of the flapping hinge of the tail rotor on September 23. (3.7.2 (2))

(16) It is probable that maintenance control division of the Company should have actively confirmed details of the malfunction in order to prevent similar cases of malfunction beforehand, and should have reported the fractured inner ring as a serious malfunction case to the designer and manufacturer.

The information with regard to cautions of usage of Aeroshell 14 grease that requires re-lubrication prior to flight after parking for 24 hours or more at high temperature and high humidity was not disseminated to mechanics on-site at the Company. It is somewhat likely that this was responsible for in the damage to the parts of the flapping hinge of the Helicopter. It is required that information relating to cautions on maintenance notified by designer and manufacturer be promptly reviewed from engineering point of view and necessary information be disseminated to mechanics on-site. (3.8. (1))

(17) The Company had the CM A alone perform all maintenance work and had him on board all flights during the last one year. Under the system, it is probable that when an erroneous

decision was made, it tends to be difficult to detect and modify compared to inspection system performed by multi-mechanics. Besides, it is somewhat likely that allowing a single mechanic alone to perform all inspections for a long period of time led to the lack of consciousness to report and share information. (3.8. (2))

4.2 Probable Causes

In this accident, it is highly probable that, when the Helicopter attempted an emergency landing due to abnormal vibrations occurring in the airframe in flight, the tail rotor was separated leading to loss of control and subsequent crash.

It is highly probable that the separation of the tail rotor from the airframe was caused by imbalanced rotation of the tail rotor due to the fracture of the spindle bolt of the flapping hinge of the White Blade, which generated excessive vibrations and damaged the section attached to the tail rotor.

It is highly probable that the fractured spindle bolt was caused by damaged and stuck bearings of the flapping hinge. Besides, it is highly probable that this resulted from the fact that the damaged condition of the bearings was not grasped in inspections and maintenance work performed on the Helicopter and the appropriate measures were not taken.

5 SAFETY ACTIONS

On November 21, 2017, as a result of the investigation, the JTSB published the factual information of “Spindle bolt fractured at the attached section of tail rotor blade”. In response to the factual information provided and the Airworthiness Directive (AD) issued by EASA, Ministry of Land, Infrastructure, Transport and Tourism published their AD instructing users of the same type of aircraft across the nation to perform an emergency inspection.

Besides, Ministry of Land, Infrastructure, Transport and Tourism performed on-site inspection after the accident at the facilities of the Company, and issued the Order for Business Improvement on February 2, 2018.

5.1 Safety Actions Taken by Airbus Helicopters after the Accident

Airbus Helicopters published following engineering circulars to users of the same type and similar types of the aircraft.

(1) Emergency Alert Service Bulletin (EASB) No. AS332-64. 00. 43 on November 21, 2017, calling on to perform an emergency inspection of the flapping hinge of the tail rotor and to report the inspection results.

(2) Alert Service Bulletin (ASB) No. AS332-05. 01. 09 on May 3, 2018, based on the intermediate analysis results of the flapping hinge emergency inspection requesting to perform inspection of the flapping hinge every 250 hours, which had previously been inspected every 1,000 hours.

(3) Alert Service Bulletin (ASB) No. AS332-05. 01. 10, based on the final analysis results of the flapping hinge emergency inspection, requesting to perform inspection of the flapping hinge within the time interval not exceeding 250 hours and to replace all the flapping hinge components with new ones excepting spindle.

5.2 Safety Actions Taken by European Aviation Safety Agency (EASA) after the Accident

EASA published the following Airworthiness Directive (AD) to users of the same type and same series of aircraft.

(1) Emergency Airworthiness Directive (EAD) No. 2017-023 2-E on November 21, 2017, based on Airbus Helicopters EASB No. AS332-64. 00. 43.

(2) Airworthiness Directive (AD) No. 2018-0248 on November 15, 2018, based on Airbus Helicopters ASB No. AS332-05. 01. 10.

5.3 Safety Actions Taken by Ministry of Land, Infrastructure, Transport and Tourism after the Accident

(1) Published Airworthiness Directive (Kokukuki No. 1749 TCD-9063-2017) on November 21, 2017 based on Emergency AD (EAD No. 2017-0232-E) by EASA.

(2) Performed on-site investigations at the facilities of the Company from December 25 until December 27, 2017 and from January 17 until 18, 2018, and issued to the Company the Order for Business Improvement in relation to ensuring safety of air transport on February 2, 2018.

(3) Published Airworthiness Directive (Kokukuki No. 938 TCD-9063B-2018) on November 29, 2018 based on AD (AD No. 2018-0248) by EASA.

5.4 Safety Actions Taken by the Company after the Accident

In response to the Order for Business Improvement issued by Ministry of Land, Infrastructure, Transport and Tourism on February 2, 2018, the Company implemented following safety actions.

(1) Thorough Re-enhancement of Safety Awareness and Implementation of Compliance Education

The Company reviewed the safety control manual and implemented education on safety control manual for all employees. Education and test were conducted as preventive measures to address the lack of safety consciousness and compliance consciousness of maintenance division. Degree of their awareness is to be regularly assessed in future. Education on safety-first and compliance was performed to correct lack of safety consciousness and compliance consciousness within the entire company, and seminar on human factor by outside-company lecturers were held six times.

(2) Restructuring Safety Control System

As corrective measures in relation to insufficient manuals, safety control office was newly established for restructuring safety control system, where safety control manual and information sharing method were reviewed.

(3) Restructuring Maintenance System

Operating aircraft maintenance support team and Operation control office were newly established to provide maintenance support at any time. Besides, to cover short-staffed maintenance mechanics, the Company increased a number of new employees, introduced maintenance control system and reviewed work methods of engineering section, and as part of strengthening maintenance control system, it restructured maintenance system by entirely reviewing all manuals and rules and introduction of assertion education system.

(4) Reviewing Manuals and Rules Related to Descriptions on Flight Logbook

As corrective measures for the failure to note necessary information on flight logbook, the flight logbook description procedures were newly established and amended the flight operational implementation rules, the operation standard and the operation manual.

6 RECOMMENDATIONS

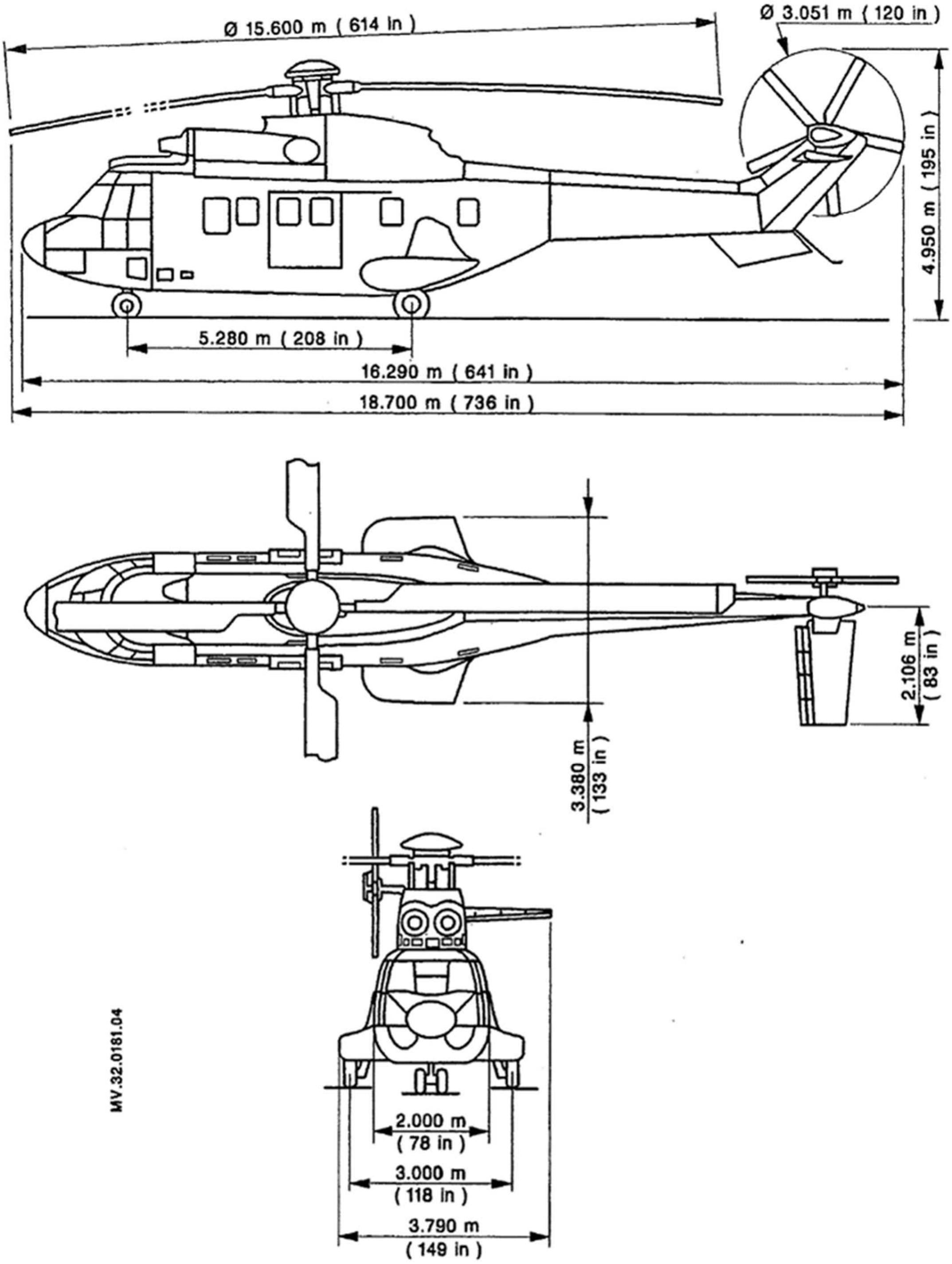
6.1 Recommendations to Toho Air Service Co., Ltd.

In this accident, the information on the malfunction of the flapping hinge of the white blade was not reported and appropriate maintenance was not performed in the disassembly maintenance work for the flapping hinge of the White Blade. Besides, the information issued by Airbus Helicopters with regard to the usage of the grease was not disseminated, and maintenance work in the event of parking at high temperature and high humidity was not thoroughly performed. It is probable that either case was related to the factors of the accident.

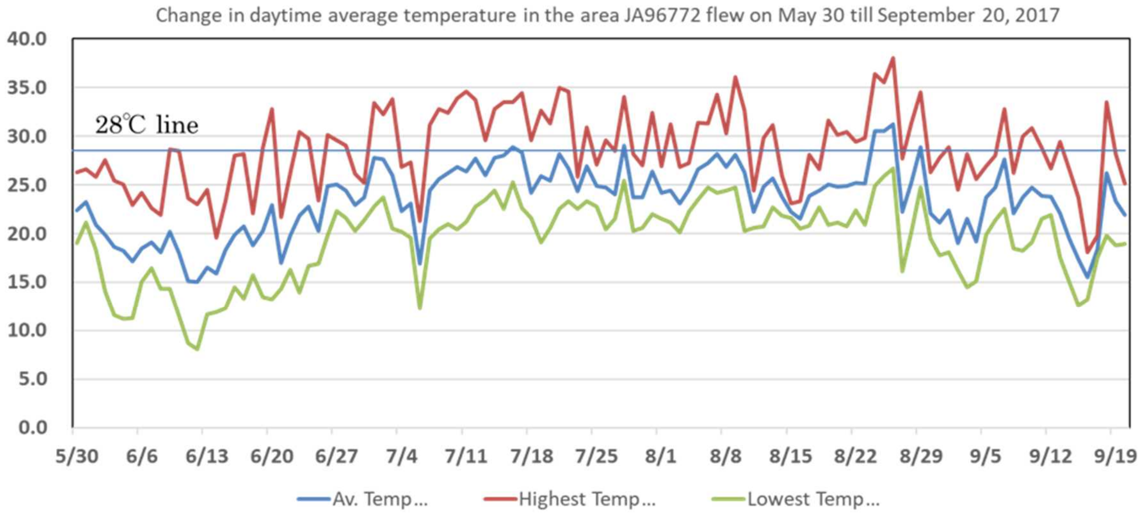
In the view of this accident investigation, in order to contribute to the prevention of recurrence of similar cases of accident, the Japan Transport Safety Board submits recommendations pursuant to the provision of the Article 27, paragraph (1) of the Act for Establishment of the Japan Transport Safety Board to Toho Airlines Co., Ltd. as follows:

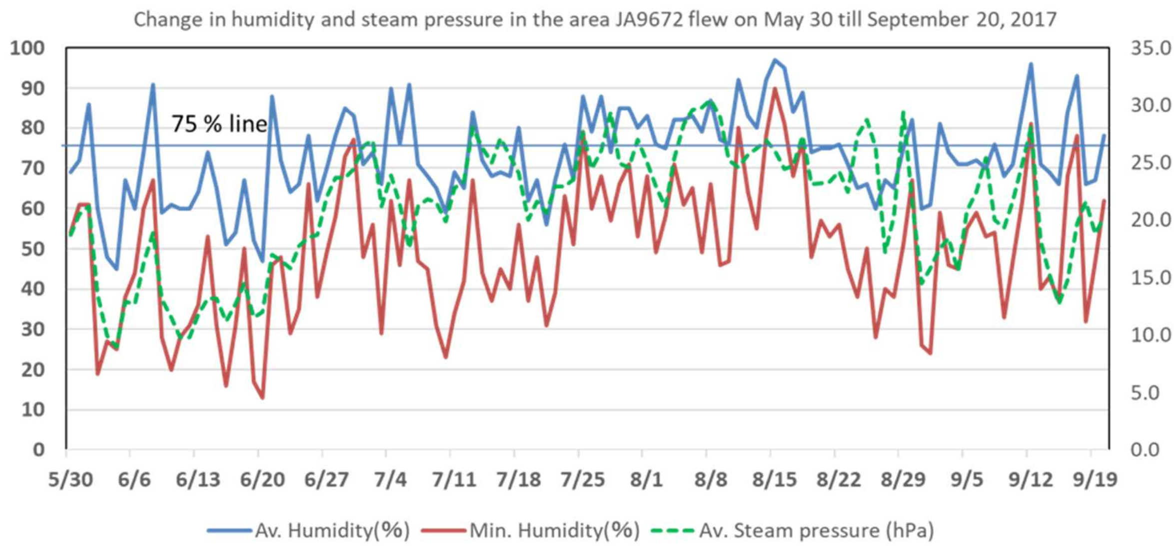
1) In the event that malfunction including damage, which is not described in manual or the like of the designer and manufacturer, is found during maintenance inspection work, report to the designer and the manufacturer for their technical review, and take necessary measures for the malfunction in accordance with their instructions.
2) From technical point of the view, promptly review the malfunction information, notified in relation to caution in maintenance work that was notified by the designer and the manufacturer, and disseminate such information to mechanics on-site.

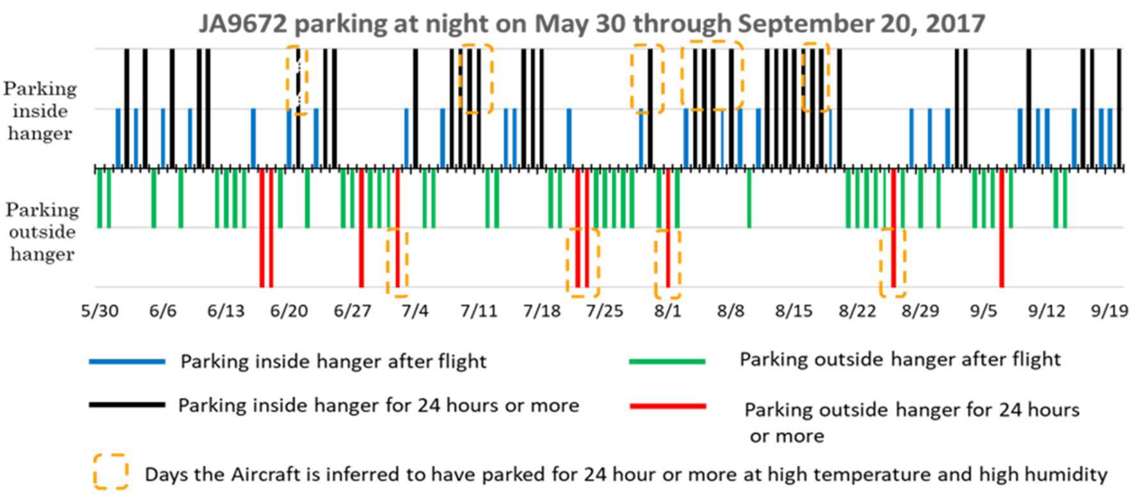
Appended Figure 1: Three-view Drawing of Aerospatial AS332L



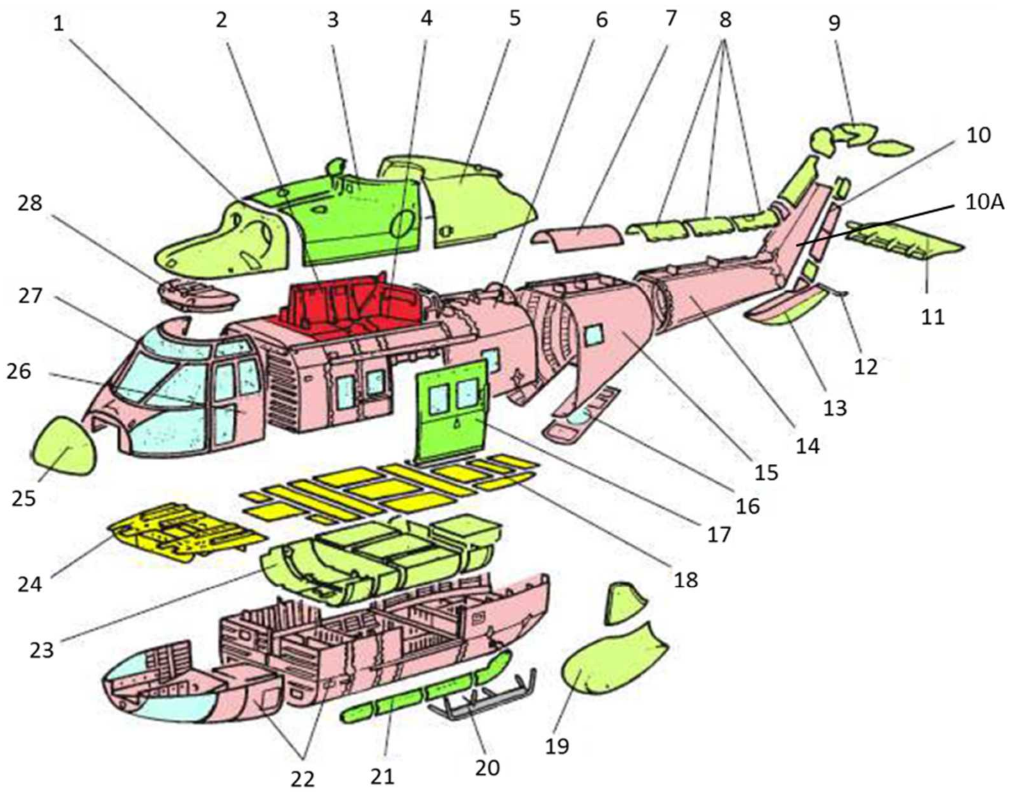
Appended Figure 2: Weather Change in the Area Where the Helicopter Flew







Appended Figure 3: AS332L Structure of Airframe and Materials



Light alloy 軽合金

Kevlar ケブラー

Titanium チタニウム

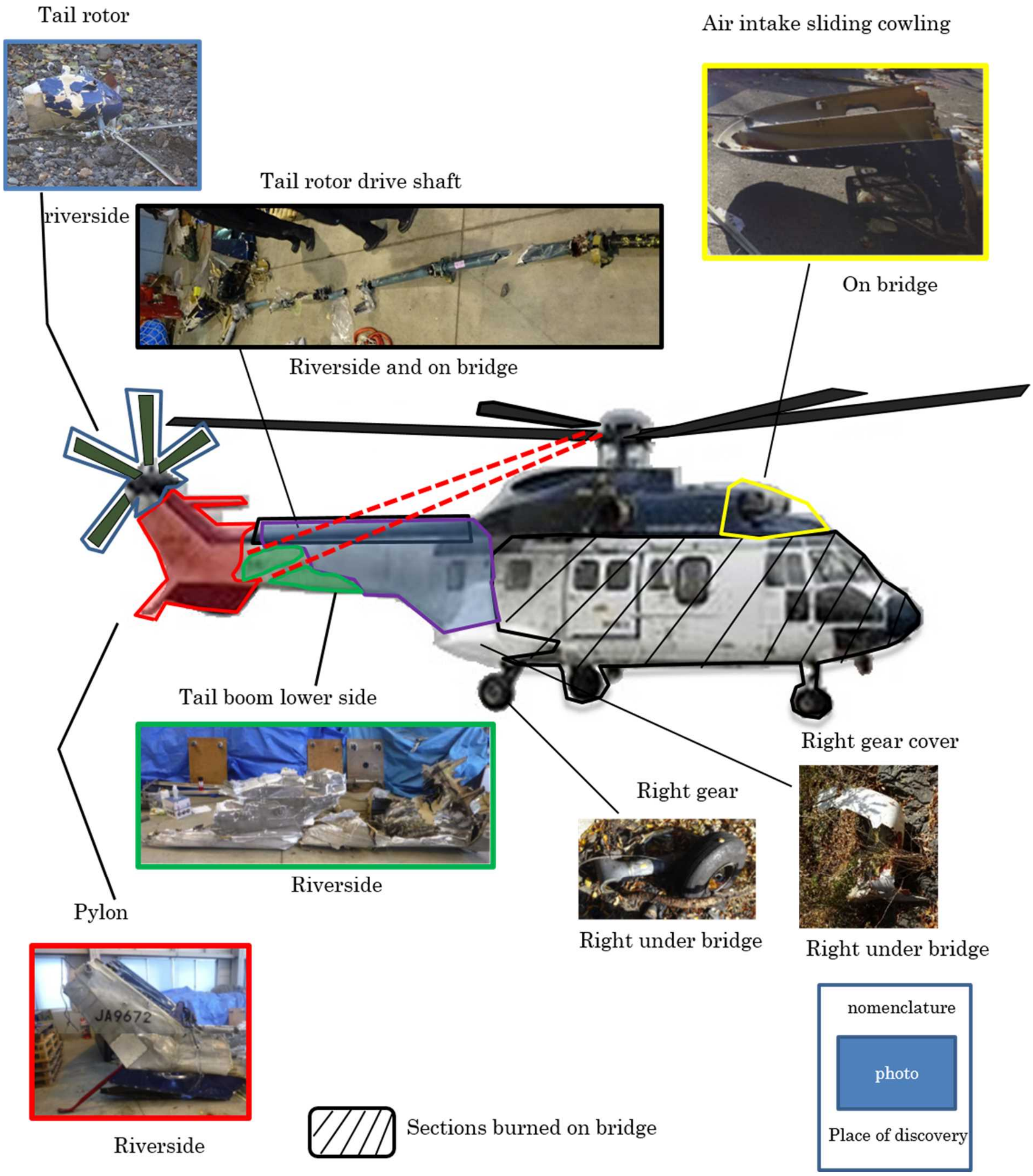
Altuglass(Triplex glass for the pilot's and copilot's windshield panels) アクリル樹脂

Sandwich structure : metal honeycomb/metal skin サンドイッチ構造

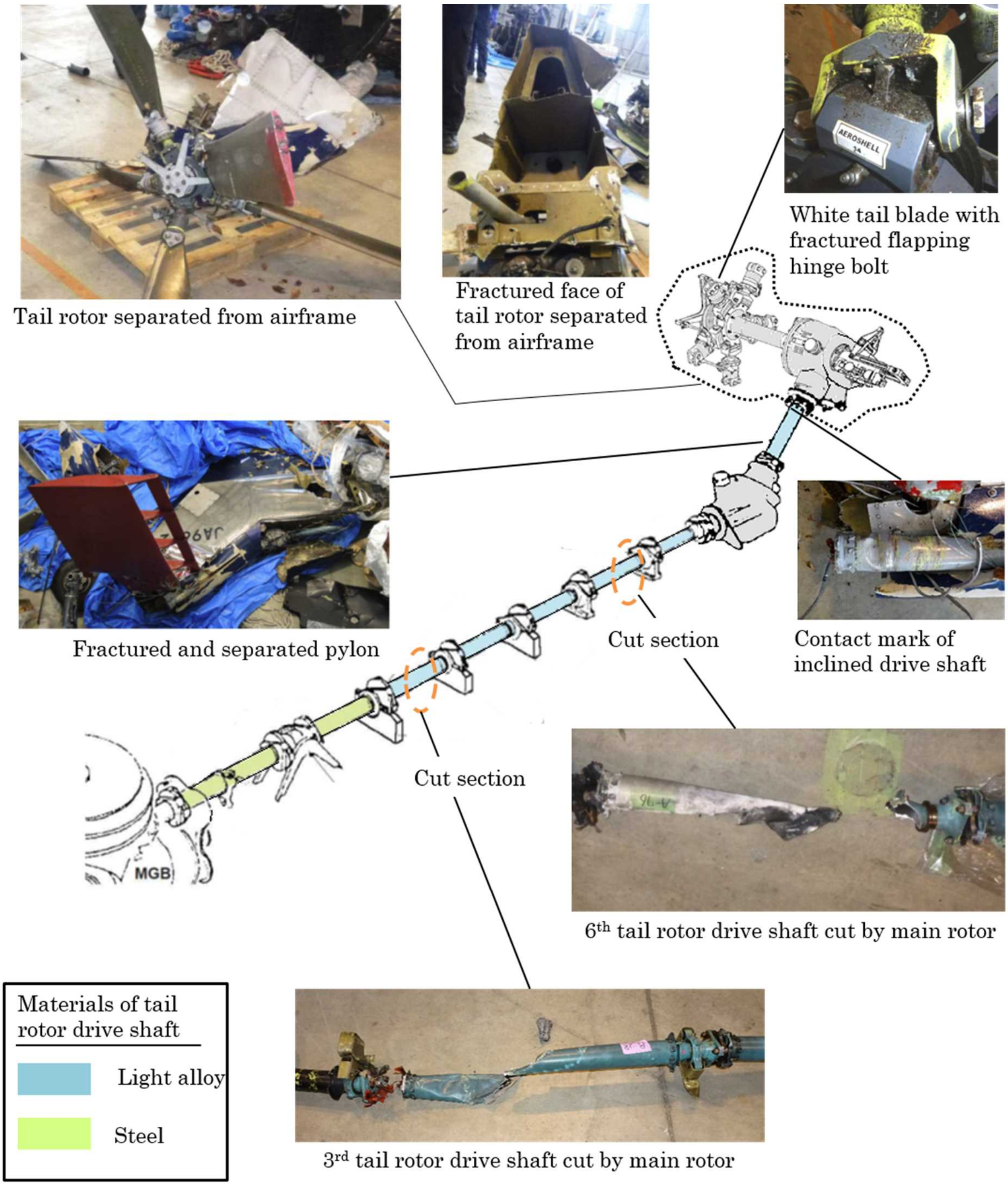
Composite, honeycomb-glass cloth 複合材

1-Air intake sliding cowling	15-Intermediate structure
2-Firewalls	16-Loading hatch
3-Engine cowling	17-Cabin door
4-Transmission deck	18-Cabin floor
5-MGB sliding cowling	19-Landing gear fairing
6-Upper structure	20-Footstep
7-Tail rotor drive shaft fixed cowling	21-Fuel lines protective channel
8-Tail rotor drive shaft opening fairings	22-Bottom structure
9-TGB fairing	23-Fuel tank compartment trimming
10-Pylon fairing	24-Cockpit floor
10A-Pylon	25-Radome
11-Horizontal stabilizer	26-Copilot's door
12-Tail skid(steel)	27-Canopy
13-Lower fin	28-Forward fixed fairing(Cockpit roof)
14-Tail boom	

Appended Figure 4: Detailed Conditions of Wreckage



Appended Figure 5: Tail Rotor drive shafts had contact marks



Appended Figure 6: The flight track of the Helicopter before crashed