AIRCRAFT ACCIDENT INVESTIGATION REPORT

CRASH
PRIVATELY OWNED
ROBINSON R22 BETA, JA7975
HADANO CITY, KANAGAWA PREFECTURE
AT ABOUT 06:48 JST, OCTOBER 7, 2021

December 20, 2024

Adopted by the Japan Transport Safety Board

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

SYNOPSIS

<Summary of the Serious Incident>

On Thursday, October 7, 2021, a privately owned Robinson R22 Beta, JA7975, took off from Akada Heliport Operation Site in Oi-town Ashigarakami-gun, Kanagawa Prefecture. While flying toward Kisarazu Operation Site in Kisarazu City in Chiba Prefecture, the helicopter crashed into a field in Hadano City in Kanagawa Prefecture. The only person on board the helicopter was the pilot, who sustained a fatal injury. The helicopter was destroyed but no fire broke out.

<Probable Causes>

The JTSB concludes that the probable cause of this accident was that while the helicopter was climbing through clouds at an altitude where it was unable to maintain VMC, when the number of rotor speed decreased, and the pilot most likely made abrupt control inputs to the flight controls when the pilot heard LOW RPM HORN, which the helicopter continued an unstable low "G" flight condition, resulting in catastrophic mast bumping, rendering the helicopter uncontrollable and leading to the crash.

It is more likely that the number of rotor speed decreased by a lack of engine power because the pilot continued climbing through the clouds without proper using carburetor heat.

Additionally, the helicopter continued to fly in clouds was probably because it departed without considering the cruise altitude where the VMC could be maintained prior to departure, and because no corrections were made during the flight based on proper understanding of altitude information.

The major abbreviations and acronyms used in this report are as follows:

ELT : Emergency Location Transmitter
FDM : Flight Data Monitoring
GCA : Ground Controlled Approach
GPS : Global Positioning System
IMC : Instrument Meteorological Conditions
MAP : Manifold Pressure
MCP : Maximum Continuous Power
NR : Number of Rotor speed
OAT : Outside Air Temperature
QNH : Altimeter sub-scale setting to obtain elevation when on the ground
RPM : Revolutions Per Minute
SNS : Social Networking Service
TOP : Take Off Power
TWR : Tower
VFR : Visual Flight Rules
VHF : Very High Frequency
VMC : Visual Meteorological Conditions

Unit Conversion Table

1ft : 0.3048 m
1kt : 1.852 km/h (0.5144 m/s)
1in : 25.40 mm
1lb : 0.4536 kg
1inHg : 33.8639 mb (hPa)

Table of Contents

1 PROCESS AND PROGRESS OF THE AIRCRAFT ACCIDENT

1.1 Summary of the Accident

On Thursday, October 7, 2021, a privately owned Robinson R22 Beta, JA7975, took off from Akada Heliport Operation Site in Oi-town Ashigarakami-gun, Kanagawa Prefecture. While flying toward Kisarazu Operation Site in Kisarazu City in Chiba Prefecture, the helicopter crashed into a field in Hadano City in Kanagawa Prefecture. The only person on board the helicopter was the pilot, who sustained a fatal injury. The helicopter was destroyed but no fire broke out.

1.2 Outline of the Accident Investigation

1.2.1 Investigation Organization

On October 7, 2021, the Japan Transport Safety Board (JTSB) designated an investigator-in-charge and an investigator to investigate this accident.

1.2.2 Representatives of the Relevant State

An accredited representative and an advisor of the United States of America, as the State of Design and Manufacture of the aircraft involved in this accident, participated in the investigation.

1.2.3 Implementation of the Investigation

October 7 to 9, 2021	On-site investigation (Wreckage investigation and interviews)
October 12 to 13, 2021	Detailed examination of the helicopter
July 29, 2022	Re-examination of the helicopter
February 21, 2024	Re-examination of the helicopter

1.2.4 Progress report

On September 29, 2022, a progress report was submitted to the Minister of Land, Infrastructure, Transport and Tourism and made public based on the results of the fact-finding investigation up to that point.

1.2.5 Comments from Parties Relevant to the Cause

Comments were not invited from the person relevant to the cause of the accident because the pilot sustained a fatal injury in this accident.

1.2.6 Comments from the Relevant State

Comments on the draft Final Report were invited from the Relevant State.

2 FACTUAL INFORMATION

2.1 History of the Flight

A privately owned Robinson R22 Beta, JA7975, took off from Akada Heliport Operation Site (hereinafter referred to as "Akada Site") for a familiarization flight, which also served as a movement flight, with only the pilot on the right pilot seat, towards Kisarazu Operation Site (hereinafter referred to as "Kisarazu Site"). (See Figure 1)

The helicopter's flight plan reported at 06:26 Japan Standard Time (JST: UTC + 9hrs, unless otherwise stated all times are indicated in JST on a 24-hour clock) was as follows:

Flight rules: Visual Flight Rules, Departure aerodrome: Akada Site,
Estimated off-block time: 06:40, Cruising speed: 75 kt, Cruising altitude: VFR[*1],
Route: Yokosuka, Destination aerodrome: Kisarazu Site,
Total estimated elapsed time: 1 hour 00 minutes, Purpose of flight: Leisure flight,
Fuel load expressed in endurance: 3 hours 30 minutes, Persons on board: 1 person.

After that, the history of the flight up to the time of the accident is outlined below, based on the records of the GoPro MAX HERO action camera (hereinafter referred to as "GoPro") brought in the helicopter and the communications record between the helicopter and Atsugi Aerodrome Traffic Control Tower of the Ministry of Defense (hereinafter referred to as "Atsugi Tower"). (See Figure 1 and Figure 2)

06:31:36	The pilot established communication with Atsugi Tower before taking off from Akada Site and obtained the information on the wind direction and velocity, QNH and air traffic information.
06:34:37	The helicopter took off from Akada Site.
06:37:00	The helicopter leveled off at approximately 2,000 ft after climbing from the take-off.
06:37:20	The pilot reported the take-off time to the Area/En-route Information

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[*1] "VFR" stands for Visual Flight Rules, and when flying without specifying a cruising altitude, the altitude shall be stated as VFR in the flight plan.

Station *2.

06:40:28 The pilot reported the position to Atsugi Tower and confirmed the air traffic information again.

06:41:00 The helicopter initiated a 180° turn and set a course for Akada Site.

06:44:41 The helicopter began making a right turn in the north-northwest direction intersecting to the Tomei Expressway at a right angle.

06:45:36 As the helicopter was flying in clouds, the pilot requested Atsugi Tower to provide radar vector to Akada Site.

06:46:08 Atsugi Tower instructed the helicopter to establish communication with Yokota Approach.

06:46:54 Atsugi Tower provided the helicopter with the communication frequency of Yokota Approach, but there was no response from the helicopter.

06:47:29 to 33 After the NR decreased and “LOW PRM HORN” *3 was activated, the helicopter rolled sharply to the left and inverted.

06:47:34 The main rotor blades were broken, the tail cone was severed, and the fuselage broke up in mid-air.

06:48:03 The helicopter crashed into a field in Hadano City. (The GoPro, which had fallen away from the crash site, recorded the sound of the engine stopping at the time of the crash as audio information, from which the time of the crash was determined.)

Figure 1: Flight Plan and Estimated Flight Route of the Helicopter

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*2 The “Area/En-route Information Station” assists aircraft in flight in the position report, flight plan changes and others, and provides aircraft such as meteorological Information, aeronautical information and others responding to requests from aircraft.

*3 “LOW RPM HORN” is activated simultaneously with the LOW RPM caution light to warn the pilot of low NR when the NR of the R22 Beta is below 495 RPM (97% RPM).

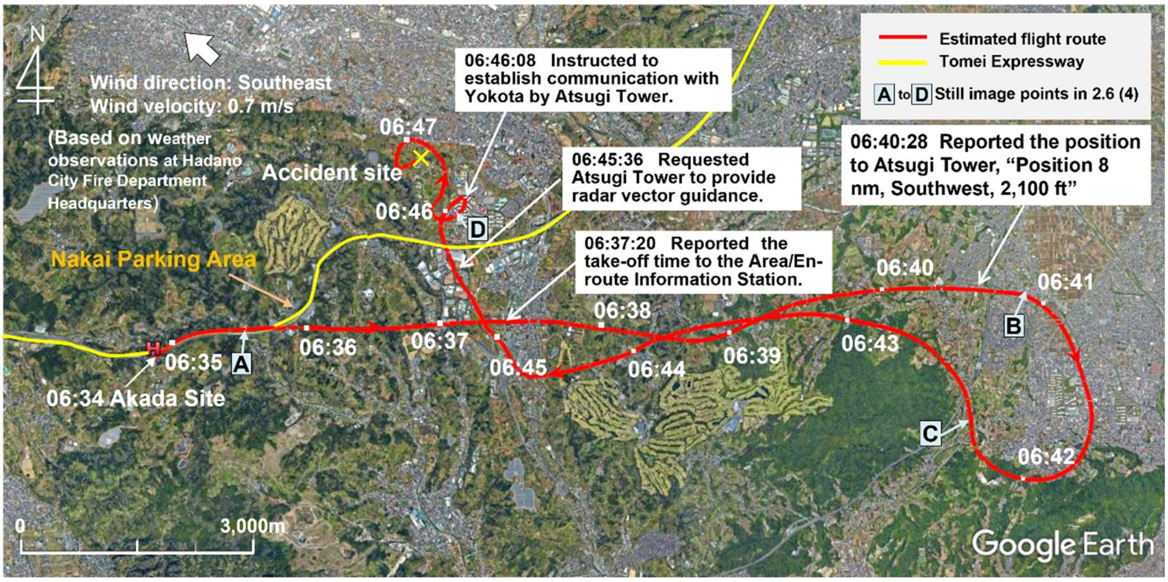

Figure 2: Estimated Flight Route of the Helicopter

The accident occurred at about 06:48:03 on October 7, 2021, in approximately 23 km west-southwest of Atsugi Aerodrome of the Ministry of Defense, (35° 21’ 35” N, 139° 13’ 05” E).

2.2 Injuries to Persons

The pilot sustained a fatal injury.

2.3 Damage to the Aircraft

2.3.1 Extent of Damage

Destroyed

2.3.2 Damage to the Aircraft Components

Fuselage : Damaged, cockpit and airframe of the helicopter were significantly deformed, and the tail cone was separated.

Main rotor system : Broken, deformed, partially scattered.

Engine : Damaged (partially deformed)

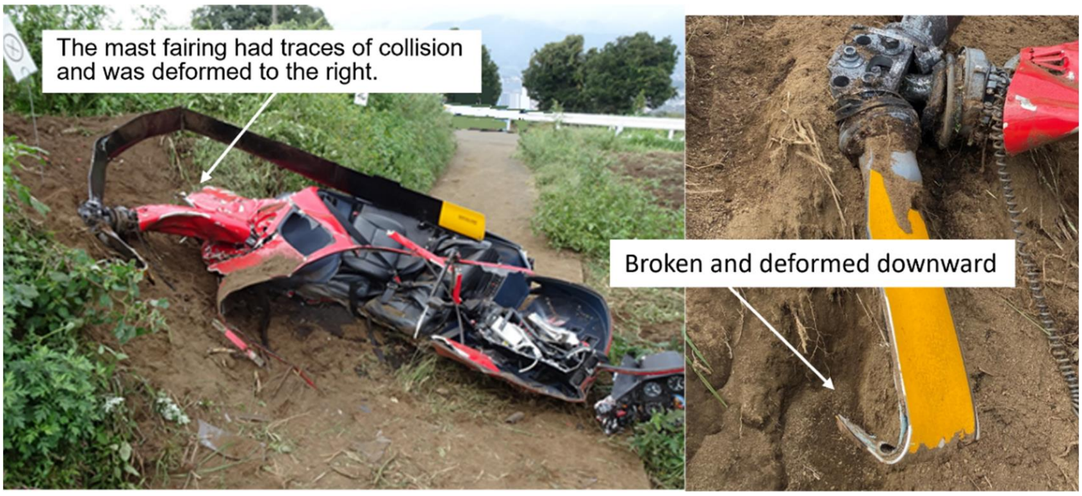

Figure 3: Crashed Helicopter Lying at the Accident Site

2.4 Personnel Information

Pilot: Age 28

Private pilot certificate (Rotorcraft)	March 2, 2021
Specific pilot competence	
Expiry of practicable period for flight	March 1, 2023
Type rating for single-piston engine (Land)	March 2, 2021
Class 2 aviation medical certificate	Validity: March 14, 2022
Total flight time	88 hours 51 minutes
Total flight time in the last 30 days	11 hours 06 minutes
Flight time on the same type of rotorcraft	88 hours 51 minutes
Total flight time in the last 30 days	11 hours 06 minutes
Instrument flight training with the hood	2 hours 10 minutes

2.5 Aircraft Information

2.5.1 Aircraft

Type	Robinson R22 Beta
Serial number	3795
Date of manufacture	March 10, 2005
Certificate of airworthiness	No. Toh-2020-401
Validity	December 10, 2021
Total flight time	4,008 hours 37 minutes
Flight time since last periodical check (100-hr check on April 9, 2021):	65 hours 44 minutes

2.5.2 Weight and Balance

Immediately before the accident occurred, the weight of the helicopter is estimated to have been 1,288 lb and the position of the center of gravity is estimated to have been 99.8 in, both of which are estimated to have been within the allowable range (the maximum take-off weight of 1,370 lb, and the center of gravity was within the range of 96.3 to 100.3 in corresponding to the weight at the time of the accident).

2.6 Meteorological Information

(1) General Weather Conditions

According to the Japan Meteorological Agency, as shown in Figure 4, the main island of Japan and its vicinity was covered by a moving high-pressure system off the Sanriku coast, and it was clear mainly over western Japan, but it was cloudy on the Pacific side from eastern Japan to the Tohoku region where moist air was flowing in from the northeast.

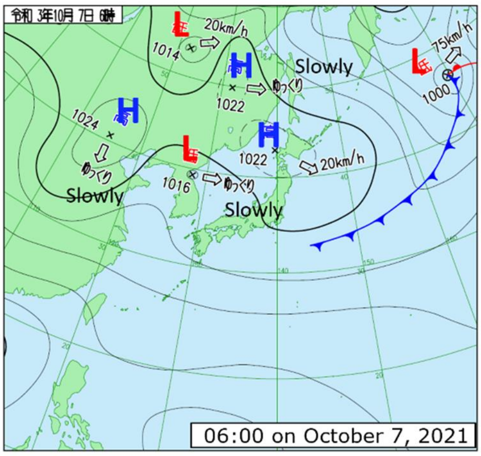

Figure 4: Surface Analysis Chart

(2) Aeronautical Weather for Atsugi Aerodrome of the Ministry of Defense

Aeronautical weather observations for Atsugi Aerodrome of the Ministry of Defense (Elevation 205 ft), located approximately 23 km east-northeast of the accident site, around the time of the accident were as follows:

07:00 Wind direction: 360°, Wind velocity: 7 kt, Prevailing visibility: 10 km or more
Current weather: Light rain,
Cloud: Amount 1/8 to 2/8, Cloud base 1,000 ft, Type Stratus,
Cloud: Amount 3/8 to 4/8, Cloud base 1,500 ft, Type Cumulus,
Cloud: Amount 5/8 to 7/8, Cloud base 2,000 ft, Type Stratocumulus,
Temperature: 19°C, Dew point: 17°C,
Altimeter setting (QNH): 30.17 inHg.

(3) Weather observations at Hadano City Fire Department Headquarters

Weather observations at Hadano City Fire Department Headquarters, located approximately 2.3 km north-northwest of the accident site, around the time of the accident were as follows:

06:40 Wind direction: Southeast, Wind velocity: 0.7 m/s,
Weather: Cloudy, Temperature: 17.8 °C, Humidity: 98.3 %

(4) Clouds Conditions as Seen from the Cockpit and Visibility during the Flight (Still image points: see Figure 2)

From the GoPro video, described in 2.8, four points were clipped as still images to confirm the cloud conditions as seen from the cockpit and the changes in visibility during the flight.

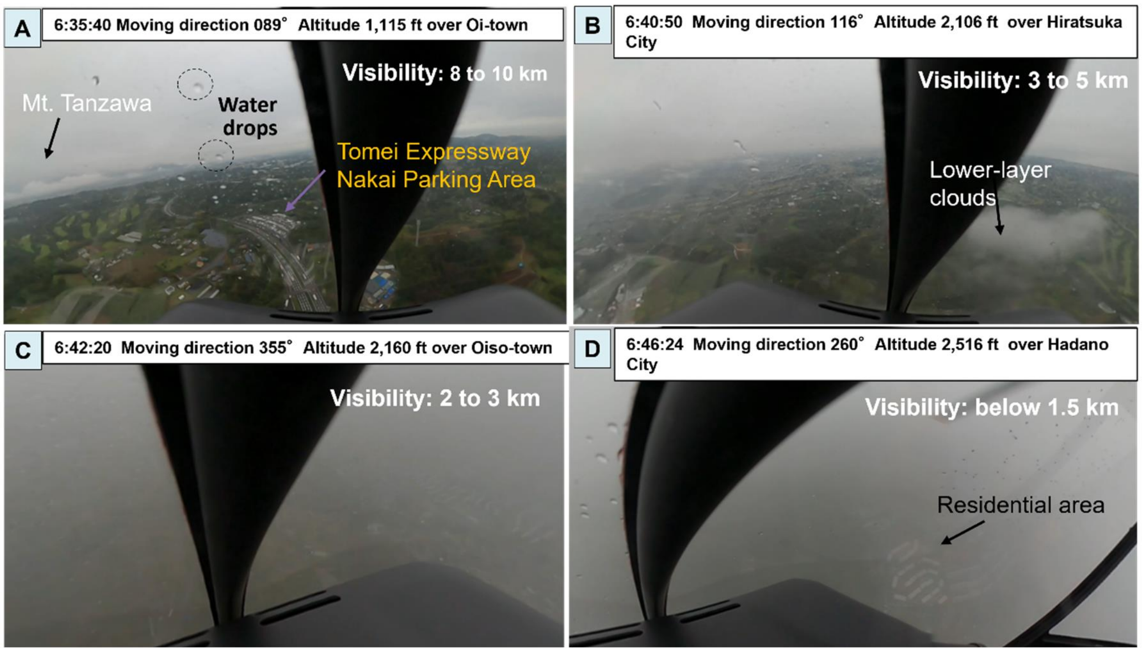

Figure 5: Clouds Conditions as Seen from the Cockpit and Estimated Flight Visibility during the Flight (created from GoPro video)

A: It was cloudy at about 1,100 ft over Oi-town, visibility was 8 to 10 km and there were drops of water on the cockpit window.

B: There were clouds scattered in the lower layer at about 2,100 ft over Hiratsuka City, and visibility was 3 to 5 km. It was difficult to determine the upper cloud base.

C: The ground surface was slightly visible at about 2,200 ft over Oiso-town with a visibility of 2 to 3 km.

D: The ground surface was slightly visible at about 2,500 ft over Hadano City with a visibility of less than 1.5 km.

2.7 Information on Communications

2.7.1 Communications Equipment of the Helicopter

The helicopter was equipped with one VHF radio.

2.7.2 Communication Records with Atsugi Tower

The communication records between the helicopter and Atsugi Tower were as shown in Table 1.

Table 1: Communication Content between the Helicopter and Atsugi Tower

Time	FROM	TO	Communication Content
06:31:36	JA7975	ATSUGI TWR	JA7975 NOW POSITION HADANO, WE ARE GOING TO TAKE OFF FROM AKADA HELIPORT, REQUEST TRAFFIC INFORMATION.
06:31:46	ATSUGI TWR	JA7975	JA7975 NO TRAFFIC AROUND HELIPORT, AH, VISIBILI..., WIND 360 AT 8 VISIBILITY 20 KM QNH 3016 CLEAR CONTROL ZONE REPORT LEAVING CONTROL ZONE
06:32:02	JA7975	ATSUGI TWR	ROGER AH...、WE AH...、DO NOT AH...、CROSS TO CONTROL ZONE, BREAK NO PLAN TO CROSS YOUR CONTROL ZONE, JA7975
06:32:15	ATSUGI TWR	JA7975	JA7975 ROGER.
06:35:51	ATSUGI TWR	JA7975	JA7975 ATSUGI TWR. (JA7975 did not respond to the call)
06:40:28	JA7975	ATSUGI TWR	JA7975 NOW POSITION EH..., 8 NM SAU..., NOW POSITION 8 NM SOUTHWEST EH..., 2,100 BOUND FOR KISARAZU EAST BOUND.
06:40:50	ATSUGI TWR	JA7975	JA7975 THIS IS ATSUGI TWR. DID YOU CALL?
06:40:55	JA7975	ATSUGI TWR	EH..., ALTITUDE 2,000 JA7975
06:41:00	ATSUGI TWR	JA7975	JA7975 ROGER BREAK, DO YOU CROSS CONTROL ZONE?
06:41:08	JA7975	ATSUGI TWR	WILL NOT CROSS CONTROL ZONE, JA7975
06:41:11	ATSUGI TWR	JA7975	7975 ROGER, NO TRAFFIC REPORTED SOUTH SIDE
06:45:36	JA7975	ATSUGI TWR	AH..., REQUEST RADAR VECTOR TO AKADA HELIPORT.
06:45:46	JA7975	ATSUGI TWR	ATSUGI TOWER EH..., I HAVE ENTERED IN THE CLOUDS. REQUEST RADAR VECTOR.
06:46:00	ATSUGI TWR	JA7975	JA7975 ATSUGI TWR BREAK, ARE YOU CALLING ATSUGI TOWER?
06:46:05	JA7975	ATSUGI TWR	CALLING ATSUGI TWR.
06:46:08	ATSUGI TWR	JA7975	JA7975. ATSUGI, WE ONLY PROVIDE TOWER AND GCA SERVICES, SO CANNOT PROVIDE RADAR VECTOR. IF YOU REQUEST RADAR VECTOR, PLEASE CONTACT YOKOTA.
06:46:39	ATSUGI TWR	JA7975	JA7975 CONTACT YOKOTA 12. CORRECTION
06:46:54	ATSUGI TWR	JA7975	JA7975 CONTACT YOKOTA 123.8
06:46:58	JA7975	ATSUGI TWR	975. (The communication was not received due to double transmission.)

06:47:00	ATSUGI TWR	JA7975	JA7975 CONTACT YOKOTA 123.8
06:47:04	JA7975	_____	ROGER, RADAR SERVICE IS NOT SERVICE (This record was obtained from the cockpit voice record including noise, the content of which was not recorded at Atsugi Tower.)

2.8 Information on In-flight Recordings

2.8.1 Overview of the Content Recorded on the Flight Data Recorder

The helicopter was equipped with a GoPro MAX HERO action camera mounted on the instrument panel in front of the cockpit, and the device recorded video and audio information using the 360° lens from before the helicopter took off to after it came off from the helicopter in mid-air at 06:47:42 and fell to the ground. The recorded content included the surrounding weather phenomenon, the pilot's facial expression, the collective[*4] and cyclic[*5] pitch control operations, and the helicopter's damage status. In addition, metadata[*6] attached to the video included information on GPS positions, altitudes, speed, as well as device’s angular rate, acceleration, and camera settings. (See Appended Figure 2: Summary of Records Used for Analysis, and Appended Figure 3: Analysis Based on the Metadata on the GoPro)

2.8.2 Changes in Altitude and Speed from Take-off to the Crash, and the Pilot’s Line of Sight and Characteristics of Control operations

According to the records on the GoPro, the changes in altitude and speed from take-off to the crash were as shown in Figure 6. The pilot did not adjust the carburetor heat control lever from just before takeoff until the helicopter broke up in mid-air. In these records, from 06:42:20 to 06:47:31, the pilot's eyes were mainly around the instrument panel. In addition, there was one point where the pilot's eyes briefly focused on the vicinity of the altimeter, and then the pilot lowered a collective lever to reduce the altitude. Furthermore, just before the helicopter broke apart in mid-air, it had been climbing at approximately 2,000 ft/min from 06:47:17, and by 06:47:29, when the "LOW RPM warning" was activated, it was climbing at approximately 2,300 ft/min and had reached an altitude of approximately 3,400 ft when bringing apart in midair.

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*4“Collective” is an abbreviation for collective pitch control, and is one of the control devices for helicopters. It is a system that controls vertical movement, and by operating a lever up and down, it increases or decreases the thrust of the main rotor.

*5 “Cyclic” is an abbreviation for cyclic pitch control and is one of the control devices used in helicopters. It is a device that is mainly operated to the direction to tilt the helicopter's attitude to control it.

*6 “Metadata” refers to data that describes additional information related to the data on the camera itself. In the case of GoPro, recording GPS position, altitude, and speed, as well as the device's angular rate, acceleration, and camera settings.

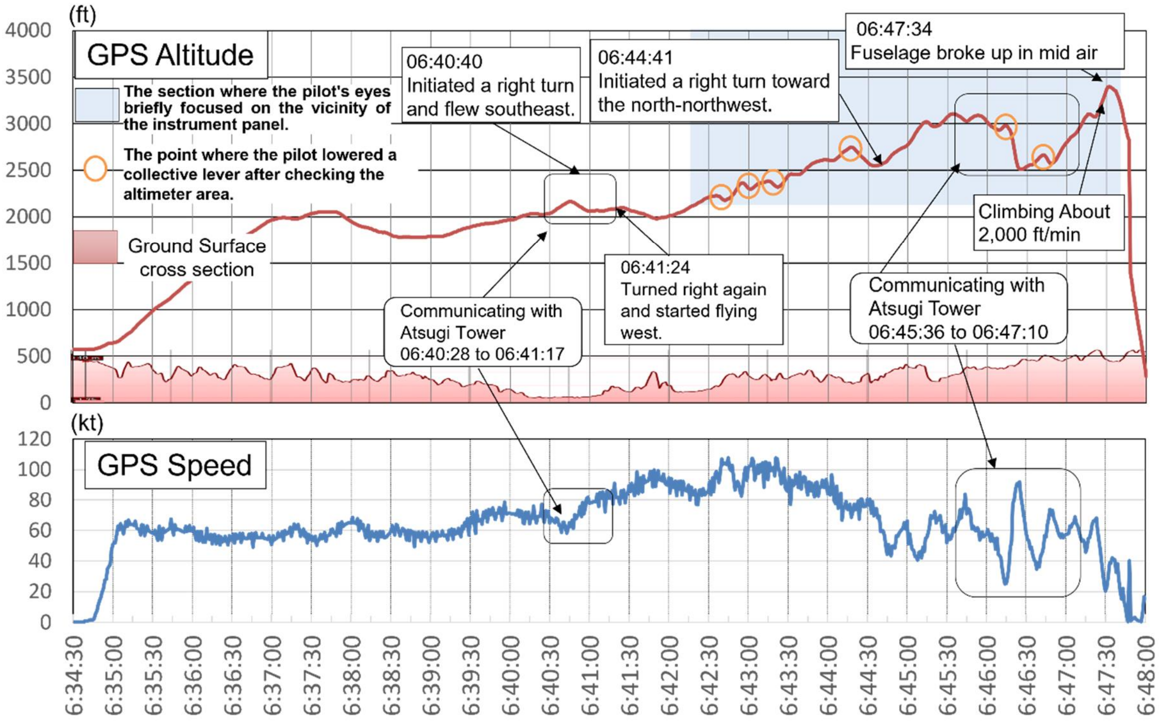

Figure 6: Changes in Altitude and Speed, and the Pilot's Line of Sight and Control Operations (based on the records on GoPro)

2.9 Accident Site and Wreckage Information

2.9.1 Situation at the Accident Site

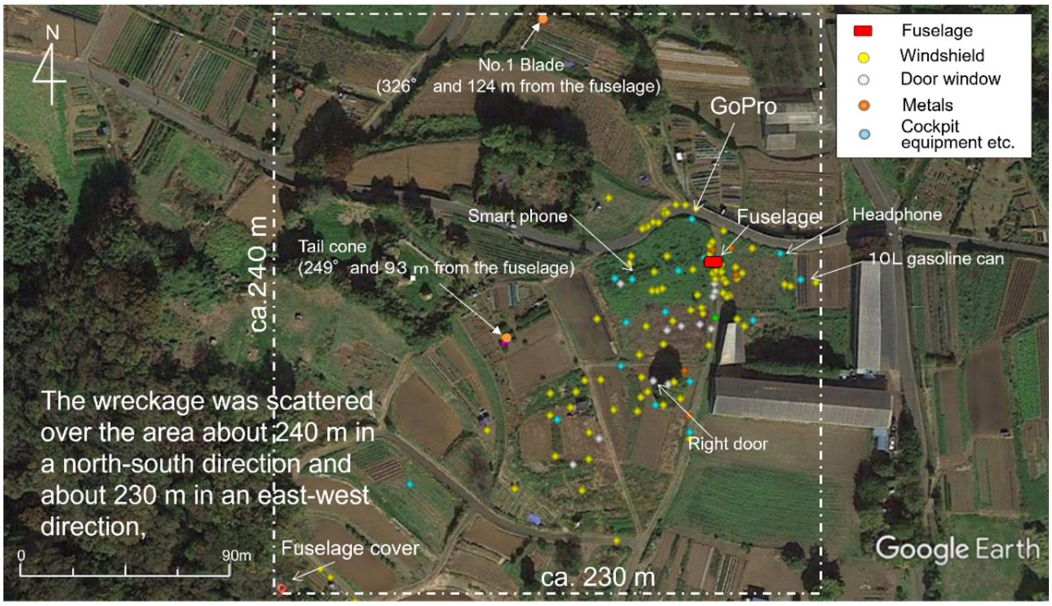

Figure 7: Scattered Wreckage near the Accident Site

The helicopter crashed into a field extending over a small hill at an altitude of 175 m (574 ft), about 300 m south of the residential area.

As shown in Figure 7, its wreckage was scattered over the area about 240 m in a north-south direction and about 230 m in an east-west direction, and most of the windshields and door windows fell from the fuselage concentratedly in a south-west direction. The tail cone dropped at 249° and 93 m from the fuselage, and the broken No.1 main rotor blades (hereinafter referred to as “No. 1 Blade” (The same goes for “No.2 Blade”)) dropped at 326° and 124 m from the fuselage.

2.9.2 Details of the Damage

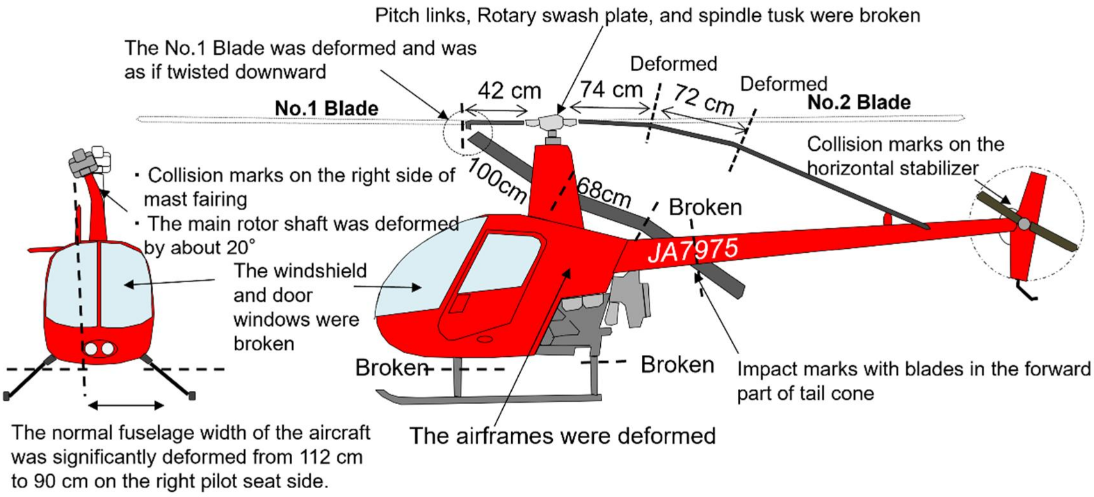

Figure 8: Overview of Helicopter Damage

(1) Fuselage

a. The mast fairing had traces of collision with the main rotor blades.

b. The fuselage width of the aircraft was compressed and deformed from 112 cm to 90 cm.

c. The frame of the cockpit was deformed, and the windshield and door windows were broken and scattered.

d. The tail cone broke off at the location of the impact mark with the main rotor blades in the forward part. In addition, the horizontal stabilizers had traces of collision with the main rotor blades.

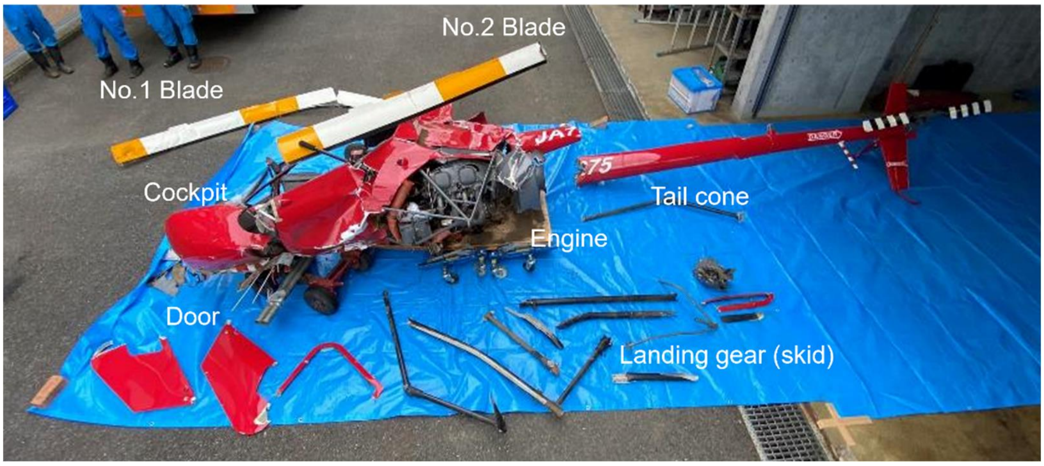

Figure 9: Damage Condition of the Helicopter after Wreckage Repositioning

(2) Main Rotor System

a. Two main rotor blades were deformed at several places, and the No.1 Blade was deformed and broken at about 42 cm from the spindle as if twisted downward and scattered. (See Figure 8 to Figure 10, and Figure 12)

b. The main rotor shaft was deformed by about 20° near the swashplate. (See Figure 13)

c. No significant impact marks were confirmed on the surface of the main rotor shaft, but the teeter stop had impact marks and the surface in contact with the spindle tusk in the lower part of the droop stop[*7] was deformed. (See Figure 13)

d. The rotary swashplate on the No.1 Blade side were broken at the overhanging root. (See Figure 11, Figure 12, Figure 15, and Figure 16)

e. The No.1 Blade pitch link was broken at the joint of swashplate and the No.2 Blade pitch link was broken at the joint of blade. (See Figure 11, Figure 12, and Figure 15)

f. The spindle tusk of the No. 1 Blade had its tip scraped off and rotated in the direction of the underside of the No. 1 Blade, which was partially compressed and deformed. (See Figure 11 and Figure 14)

[*7] "Droop stop" is a device that keeps the main rotor blades from drooping down when rotor RPM is low during engine starting up or shut down.

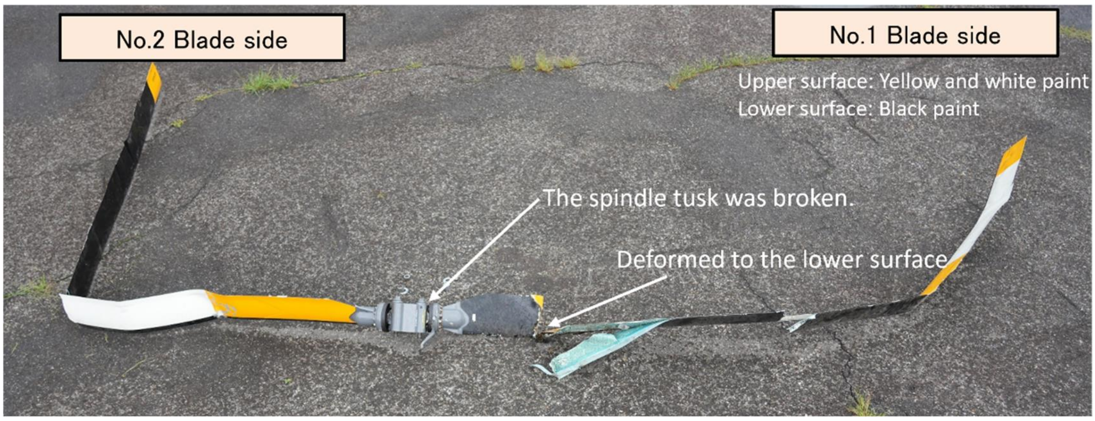

Figure 10: Broken and Deformed Main Rotor

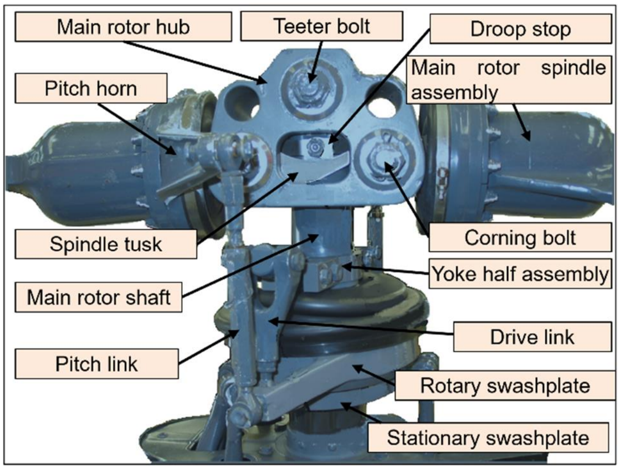

Figure 11: Properly Installed Equipment around the Main Rotor Hub

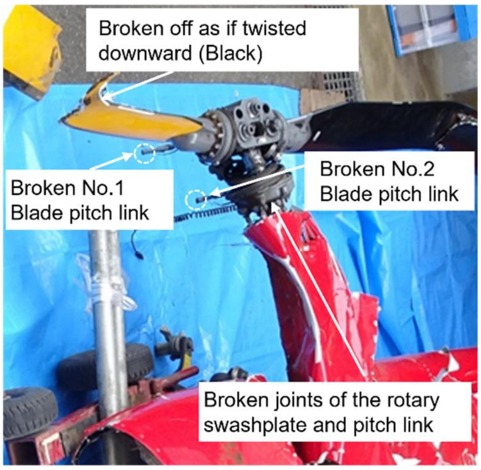

Figure 12: Fracture around the Main Rotor Hub

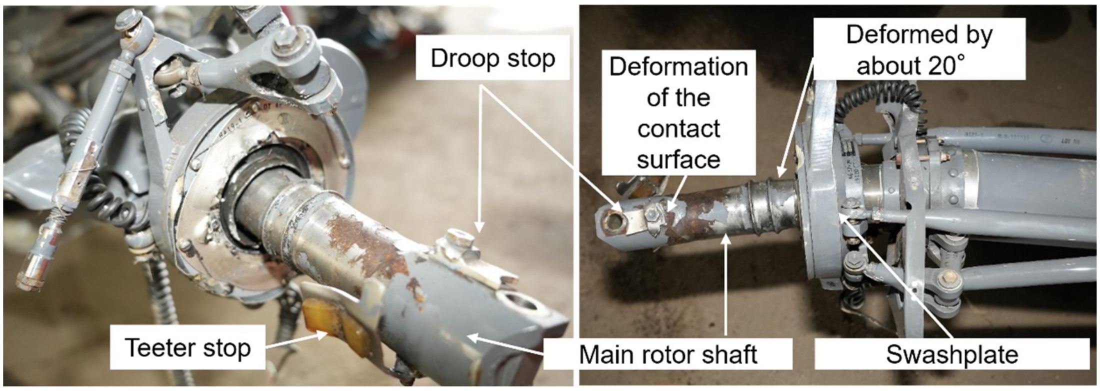

Figure 13: Deformation of the Main Rotor Shaft and Droop Stop

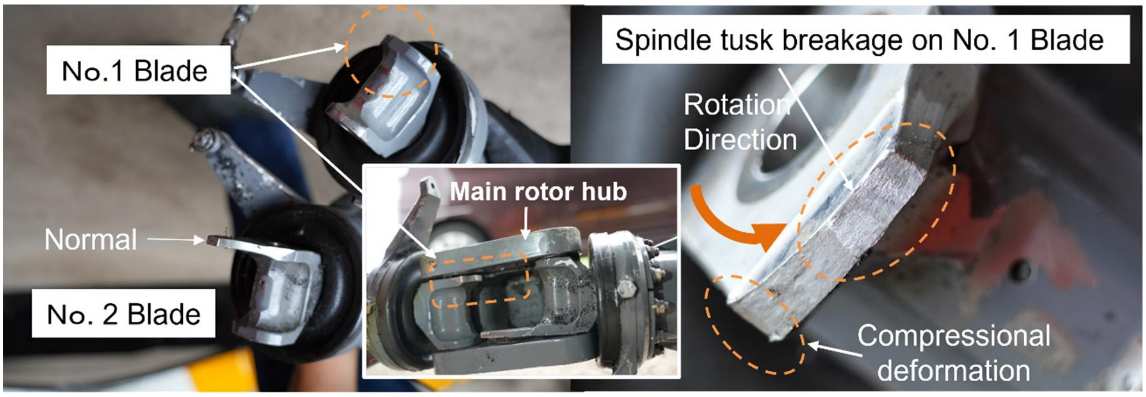

Figure14: Damage to the Spindle Tusk

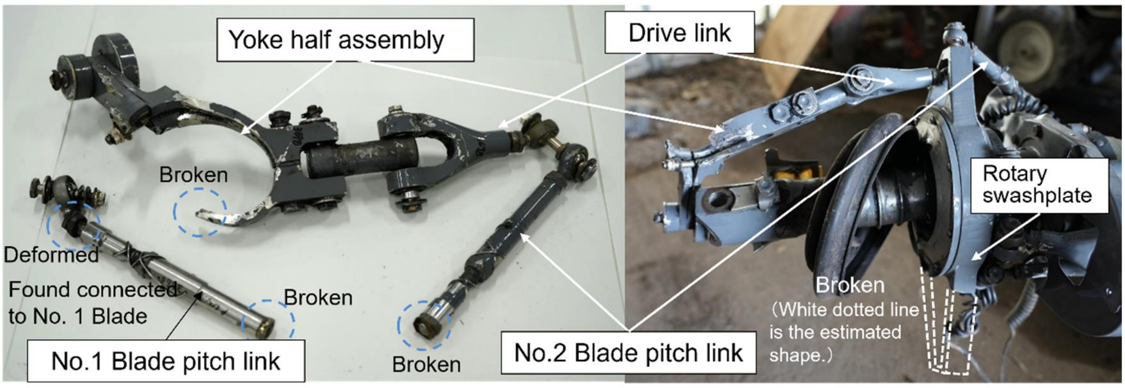

Figure 15: Damage to the Pitch Links and Rotary Swashplate

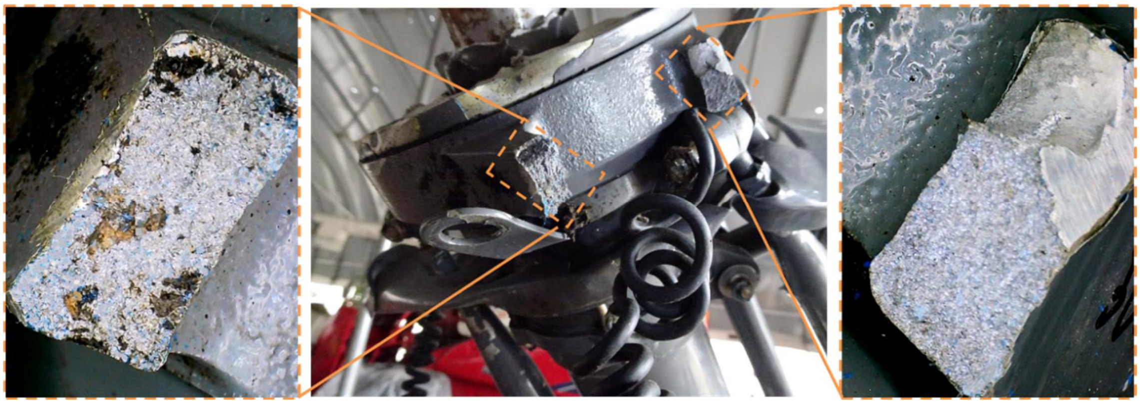

Figure 16: Enlarged Damaged Position of the Rotary Swashplate

(3) Engine

a. There was no anomaly in the engine, and GoPro audio information recorded the sound of the engine running at the time of the crash.

b. The latch of the carburetor heat control lever was unlatched but in the off position. (Figure 17, Left)

c. The slider valve inside the airbox, which is attached to the lower part of the engine had been opened for the fresh air side but closed for the hot side. (Figure 17, Right)

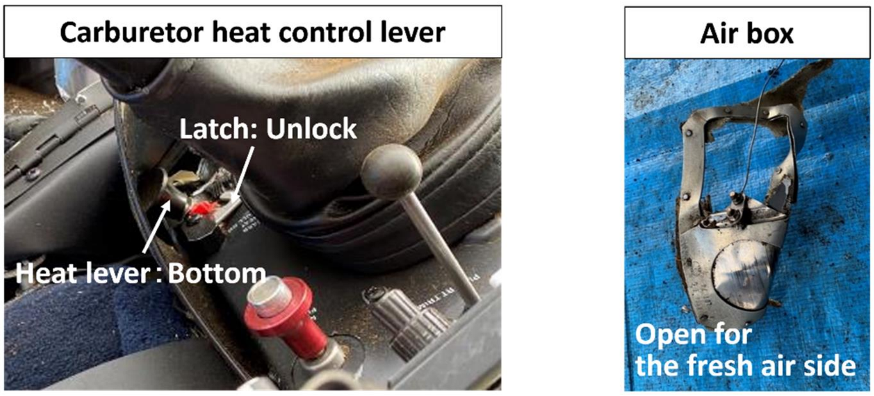

Figure 17: Carburetor Heat in Use

(4) Others

The helicopter's Emergency Location Transmitter (ELT) was a Kannad AP-H INTEGRA(ER), which was installed near the center of the aft fuselage and designed to be activated by an impact from 45° below the helicopter. As the helicopter's ELT did not transmit any signals at the time of the crash, an investigation was carried out and found that the partition inside the main body case was broken, causing the transmission circuit to fail, and the acceleration sensor was impacted from the opposite direction.

2.10 Injuries to Persons

The pilot seated on the right pilot seat sustained a fatal injury by the impact of the crash with deformation of the cockpit.

2.11 Additional Information

2.11.1 Statements of Acquaintances and the Instructor in Charge

(1) Statement of Acquaintance A

Acquaintance A had a dinner with the pilot after the pilot had finished the work on the day before the accident. Acquaintance A heard the pilot say "Akada Site was easy to find, because it is near the Oi-Matsuda Interchange on the Tomei Expressway." And the next day, Acquaintance A was told that the pilot would be going to fly to Kisarazu for the first time, then Acquaintance A advised the pilot, "In case of crossing over the Tokyo Bay, it would be better to choose the route enable to fly while seeing visual reference of landmarks on the ground, and not to try too hard when in bad weather."

(2) Statement of Acquaintance B

A few days before the accident, the pilot consulted on several issues. Regarding the first consultation, the pilot said, “I want to make a night flight from Akada Site to Kisarazu Site on October 6 (the day before the accident).” However, as the pilot did not have an experience in a night flight, Acquaintance B advised the pilot not to do that because over the sea flight could be dangerous. The second consultation came on October 5, two days before the accident, and was about how to fly from an operation site in Utsunomiya City to Akada Site. The pilot said, “The flight route is planned to be on a straight course passing through the control zones of Iruma Aerodrome, Yokota Aerodrome, and Tachikawa Aerodrome.” However, as this would be difficult for an inexperienced pilot to fly alone, Acquaintance B advised the pilot that it would be better to fly through the control zone of southernmost Tachikawa Aerodrome. After the helicopter arrived at Akada Site, Acquaintance B received a report via SNS from the pilot saying that the pilot was “Scared by thick clouds around Okegawa”, and that the pilot had “Responded to a call to another aircraft from the control tower at Yokota Aerodrome and got a warning.”

(3) Statement of the Instructor in Charge of the Course up to Obtaining the Competence Certificate

The instrument flight training was conducted by flying basic pattern with a hood*[8], and the radar vector training was provided by the neighboring instructor who conducted a simulated communication. Besides, regarding how to use the carburetor heat, the instructor used to instruct to use when it was humid. Furthermore, the flight altitude during the training was maintained at a ground altitude of 1,000 ft or more, usually, altitudes between 2,000 ft and 3,000 ft were used.

2.11.2 Attitude Control using Instruments.

2.11.2.1 Control System and Approved Operating Method Limitation for the R22 Beta

The R22 Beta is not equipped with an autopilot system capable of controlling attitude and maintaining altitude. The cyclic does not have a cyclic beep trim*[9] function, therefore, it will move if it is not held in position and pilots would not be able to take their hand off the cyclic. Additionally, although it is certified for instrument navigation*[10] flights, it is not certified for

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*8 The “Hood” means an easily removable device worn to shield the pilot from the forward horizon and approach targets during flight training relying solely on instruments.

*9 “Cyclic beep trim” is a switch that allows fine adjustments of pitch or roll attitude.

*10 “Instrument navigation” means flight that relies solely on instruments to determine the aircraft's position and heading other than by instrument flight and that exceeds 110 km or 30 minutes.

instrument flights*11 and may only be flown in visual meteorological conditions (VMC) *12.

2.11.2.2 Cross-check with the Instrument Panel of the R22 Beta

As shown in Figure 18, the set of instruments required to obtain attitude and performance information is installed in the center of the right and left pilot seats. The instruments are not arranged in a T-shape centered on the attitude indicator, but the attitude indicator and directional gyro are arranged vertically in a straight line when viewed from the right pilot seat, and other instruments are arranged to the right and left of the attitude indicator.

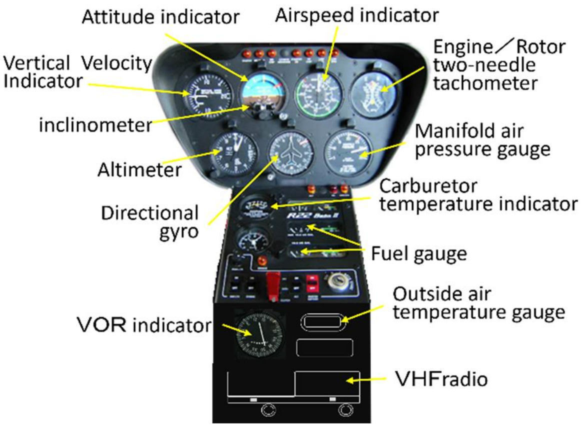

Figure 18: Instrument Panel of Robinson R22 Series Helicopter

To obtain information required to maneuver, pilots need to control attitude with the control system by frequently moving their eyes up, down, left, and right to cross-check with the instruments.

2.11.3 Flight in Unintended Instrument Meteorological Conditions *13 (IMC) *14

During an unintended IMC encounter, a pilot may not be prepared to lose visual reference, thereby reducing their ability to continue safe flight. Flying in unintentional IMC is a life-threatening emergency for the pilot. Pilots who have not been trained to be Instrument Certification*15 or proficient in flight solely by reference to instruments tend to attempt to maintain flight by visual ground reference, which tends to result in flying at lower altitudes, just above the trees or by following roads. The thought process is, “as long as I can see what is below me, I can continue to my destination.”

Below are some basic guidelines to assist a pilot to remain in VMC throughout a flight:

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*11 “Instrument flight" means flight using only the instruments to determine the aircraft attitude, altitude, position and heading.

*12 “Visual Meteorological Conditions (VMC)” refers to the weather conditions in the airspace in which the helicopter was flying that meet the following three flight conditions:
1. that flight visibility is over than 5,000 m.
2. that no cloud is within the vertical distance of 150 m above and 300 m below the helicopter.
3. that no cloud is within the horizontal distance of 600 m from the helicopter.

*13 “Instrument Meteorological Conditions (IMC)” are meteorological conditions other than visual meteorological conditions (VMC).

*14 U.S. DEPARTMENT OF TRANSPORTSTION FEDERAL AVIATION ADMINISTRATION Flight Standards Service “Helicopter Flying Handbook” 2019, pp. 11-24

*15 “Instrument certification” means the qualifications required to fly instruments, fly by instrument navigation, and fly using instrument flight procedures.

(1) Slowly turn around if threatened by deteriorating visual cues and proceed back to VMC or to the first safe landing area if the weather ahead becomes questionable. Remember that prevention is paramount.

(2) Do not proceed further on a course when the terrain ahead is not clearly discernible.

(3) Delay or consider cancelling the flight if weather conditions are already questionable, could deteriorate significantly based on forecasts, or if you are uncertain whether the flight can be conducted safely.

(4) Always have a safe landing area (such as large open areas or airports) in mind for every route of flight.

2.11.4 Carburetor Ice

2.11.4.1 Characteristic of Carburetor Ice *16

A carburetor is a device that delivers vaporized fuel to the engine. Inside the carburetor, the temperature drops rapidly due to the vaporization of fuel and the Venturi effect*17. If the air contains a lot of moisture and the temperature inside the carburetor drops below the freezing point, ice will form on the inside of the carburetor and on the throttle valve, as shown in Figure 19. Icing is likely to occur when the air temperature is below 21°C and the relative humidity is above 80%.

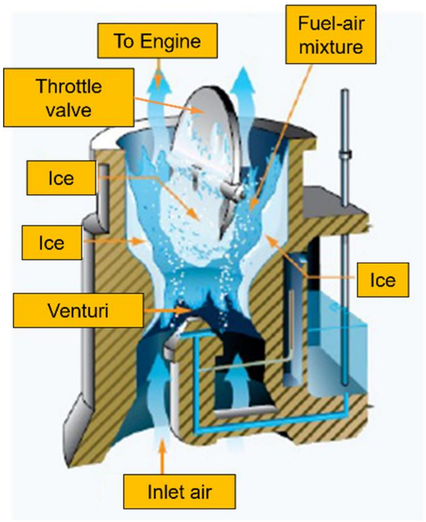
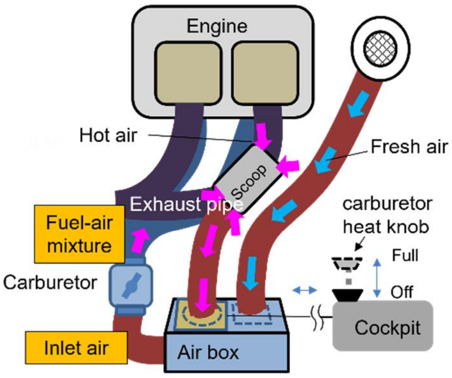


Figure 19: Carburetor Ice



When carburetor heat is activated:
It uses the heat around the exhaust pipe to draw in hot air.

Figure 20: Anti-icing with Carburetor Heat

When carburetor ice occurs, the mixture of air and fuel supplied to the engine is reduced,

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*16 U.S. DEPARTMENT OF TRANSPORTASTION FEDERAL AVIATION ADMINISTRATION Flight Standards Service “Rotorcraft Flying Handbook” 2000, pp. 5-7

*17 “Venturi effect” refers to a phenomenon in which narrowing the cross-sectional area of a fluid increases the flow velocity, creating areas with lower pressure than areas with lower flow velocity.

resulting in a drop in power. As shown in Figure 20, when the carburetor heat is turned on, the fresh air intake is closed, and hot air that has passed through the scoop and the exhaust pipe and has been heated flows into the carburetor, preventing ice formation.

2.11.4.2 Flight Manual Description of Carburetor ICE

To prevent the occurrence of carburetor ice, how to use Cab Heat Assist (SECTION 4 NORMAL PROCEDURES) and Safety Notice SN-25 (revised June 2012) in the R22 Beta Flight Manual states as follow:

SECTION 4 NORMAL PROCEDURES

USE OF CARBURETOR HEAT ASSIST

A carburetor heat assist device is installed on R22s with O-360 engines. The carb heat assist correlates application of carburetor heat with changes in collective setting to reduce pilot work load. Lowering collective mechanically adds heat and raising collective reduces heat. A friction clutch allows the pilot to override the system and increase or decrease heat as required.

A latch is provided at the control knob to lock carburetor heat off. The knob should be left unlatched unless it is obvious that conditions are not conducive to carburetor ice. Apply carburetor heat as required if carburetor ice is a possibility. Monitor CAT gage and readjust as necessary following lift to hover or any power change.

Safety Notice SN-25

CARBURETOR ICE

Avoidable accidents have been attributed to engine stoppage due to carburetor ice. When used properly, the carburetor heat and carb heat assist systems on the R22 and R44 will prevent carburetor ice.

Pressure drops and fuel evaporation inside the carburetor cause significant cooling. Therefore, carburetor ice can occur at OATs as high as 30℃ (86°F) Even in generally dry air, local conditions such as a nearby body of water can be conductive to carburetor ice. When in doubt, assume conditions are conductive to carburetor ice and apply carb heat as required.

For the R22 and R44, carburetor heat may be necessary during takeoff. Unlike airplanes which take off at full throttle, helicopters take off using power as required, making them *vulnerable to carburetor ice. Also use full carb heat during run-up to preheat the induction system.*

On aircraft equipped with the carb heat assist system, the control knob should be left unlatched unless it is obvious that conditions are not conductive to carburetor ice.

Carburetor heat reduces engine power output for a given manifold pressure. Approximately 1.5 in.Hg additional MAP is required to generate maximum continuous power (MCP) or take off power (TOP) with full heat applied. The additional MAP with carb heat does not overstress the engine or helicopter because power limits are still being observed. Since the engine is derated, it will produce TOP at lower altitudes even with full heat. However, avoid using more heat than required at high altitudes as the engine may reach full throttle at less than MCP or TOP.

2.11.4.3 Ceiling of Out-of-Ground-Effect Hovering for the R22 Beta II

The helicopter was equipped with a Lycoming O-360-J2A engine. According to the graph used to confirm the altitude at which hovering is possible using takeoff power in the air where there is no interference between the ground and air currents, as described in the flight manual for the R22 Beta II, the limit of the out of ground effect hovering altitude for the helicopter under ideal conditions when there is no wind is as shown in Figure 21. When the carburetor heat is fully used, the maximum hovering altitude is reduced by a maximum of approximately 2,000 ft.

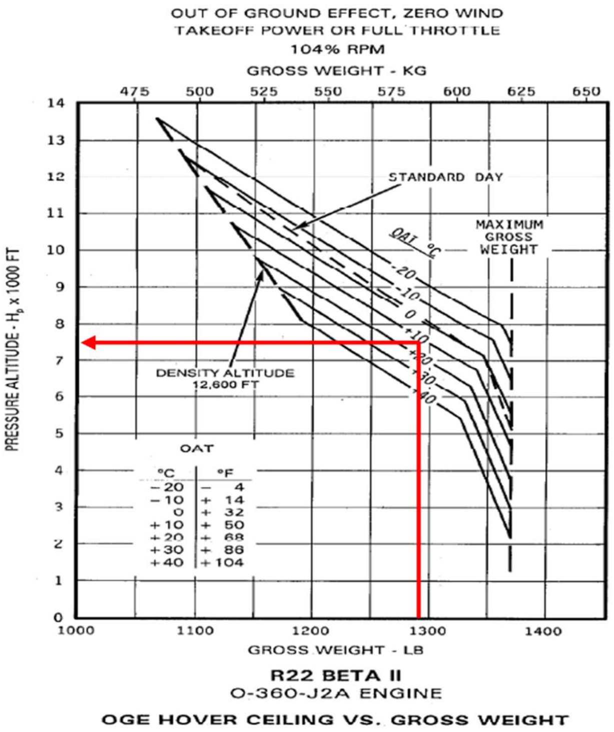


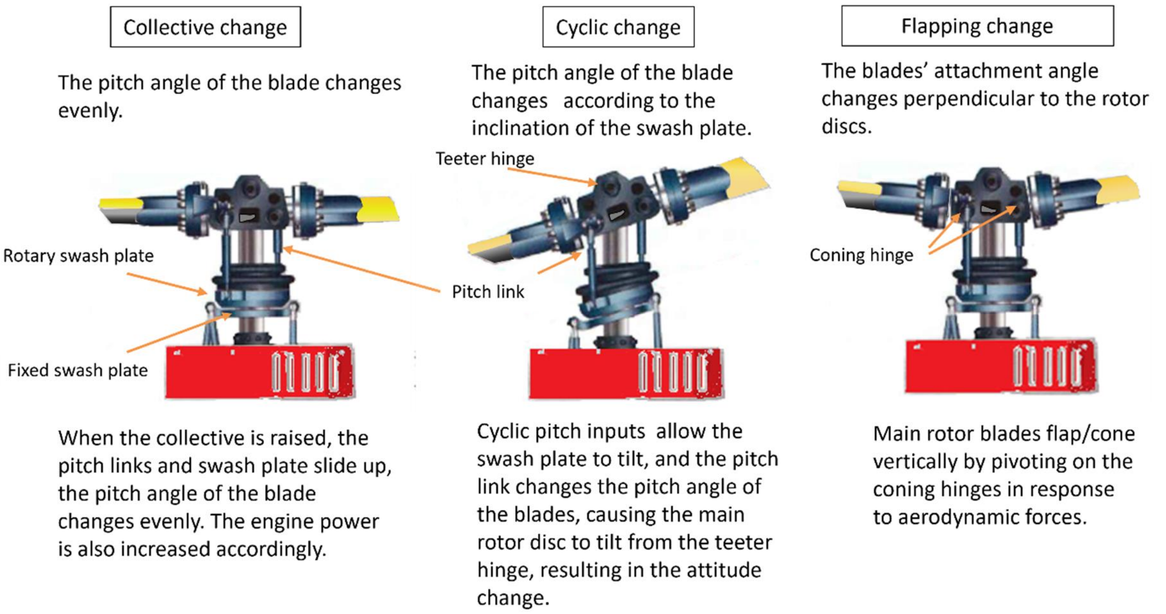
Figure 21: Ceiling of the Out-of-Ground-Effect Hovering Altitude for the R22 BETA II

Based on the estimated weight of the Aircraft at the time of the accident (1,288 lb) and the estimated outside air temperature (12°C), ceiling of the OGE hovering under ideal hovering conditions was approximately 7,500 ft.

2.11.5 Characteristics of the R22 Beta Rotor System, and Mast Bumping

2.11.5.1 Movement of the R22 Beta Rotor System and Swashplate

The Rotor type of the R22 Beta is a semi-rigid and underslung, and the names of main components around the main rotor hub are as shown in Figure 11. The changes in response to the flight controls system and blade flapping are as shown in Figure 22, and the aircraft ascends, descends, and changes in attitude through the combined action of these three movements.



Collective change

The pitch angle of the blade changes evenly.

When the collective is raised, the pitch links and swash plate slide up, the pitch angle of the blade changes evenly. The engine power is also increased accordingly.

Cyclic change

The pitch angle of the blade changes according to the inclination of the swash plate.

Cyclic pitch inputs allow the swash plate to tilt, and the pitch link changes the pitch angle of the blades, causing the main rotor disc to tilt from the teeter hinge, resulting in the attitude change.

Flapping change

The blades' attachment angle changes perpendicular to the rotor discs.

Main rotor blades flap/cone vertically by pivoting on the coning hinges in response to aerodynamic forces.

Figure 22: Swashplate and Main Rotor Blades Changes

(1) Collective change

When the collective is raised or lowered, the swashplate moves up and down via three push-pull rods, and the pitch links connected to the rotary swashplate slide up and down evenly, which changes the pitch angle of the blades evenly. At the same time, the engine power also changes.

(2) Cyclic change

Cyclic pitch inputs are transmitted via push-pull rods, allowing the swashplate to tilt and the main rotor disc to tilt in the cyclic direction, resulting in the attitude change.

(3) Flapping change

The two blades are attached via a coning hinge, offsetting the length from the main rotor shaft to the hinge to improve maneuverability, counter aerodynamic forces, and reduce vibration. The main rotor blades flap/cone vertically by pivoting on the coning hinges in response to aerodynamic forces.

2.11.5.2 Characteristics of Catastrophic Mast Bumping*18*19

Mast bumping occurs in underslung, or teetering, rotor systems only, and refers to a phenomenon that is often initiated by inappropriate cyclic control inputs by the pilot, it means a phenomenon that results in the main rotor spindle or hub coming into strong contact with the main rotor shaft typically at the time of a low G flight condition (less than 0.5 "G" flight conditions (Weightlessness) *20). Catastrophic mast bumping occurs when the main rotor teetering angle exceeds the design limit (approximately 12 degrees) during flight. If the entire weight of the helicopter is supported by the main rotor, when the main rotor thrust vector tilts, a control moment (rotational force) is generated due to the misalignment between the center of gravity and the point of application, and the helicopter follows the movement of the main rotor. When flying in low G, the weight of the helicopter is no longer applied to the main rotor via the main rotor shaft, and the control moment (rotational force) is lost, so the aircraft is no longer able to follow the movement of the main rotor. Therefore, when the pilot increases the large of cyclic or collective input during low-G flight or near-low-G flight, only the main rotor plane tilts and the helicopter movement does not follow, which encourages excessive teetering and results in mast bumping.

The following operations may result in catastrophic mast bumping.

1. Radical lateral cyclic input at steep bank angles
2. Abrupt control movements such as rapid roll or pitch reversals
3. Exceeding the flight envelope (altitude/speed and lateral speed)
4. Low main rotor RPM
5. The pilot's reaction to sudden mechanical failures (sudden failure of the engine or loss of tail rotor drive and others)

2.11.5.3 Description in Flight Manual of Mast Bumping

To prevent mast bumping in low G flight conditions, Section 2 Limitations and Section 3 Emergency Procedures of the R22 Beta Flight Manual stipulate as follows:

Section 2 Limitations

Aerobatic flight prohibited.

CAUTION

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*18 International Civil Aviation Organization Doc9756-AN/965"Manual of Aircraft Accident and Incident Investigation PartⅢ-Investigation"2011, Chapter 15. Helicopter Investigation, pp. Ⅲ-15-23-24

*19 "Helicopter Pilot Training Manual Vol. 5" (edited and published by the Helicopter Pilot Training Manual Revision Working Group in the Japan Aircraft Pilot Association in 2021, pp.273 - 274)

*20 "Low-G flight conditions (Weightlessness)" refers to the flight condition in which the load factor is below 1.0 G that is a normal load.

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

Flight and maneuver limitations

Low-G cyclic pushovers prohibited.

CAUTION

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

Section 3 Emergency Procedures

LOW RPM Horn

Horn is provided by a speaker in the side of the instrument console on earlier aircraft or through the audio system on later aircraft. The horn activates simultaneously with the LOW RPM caution light and indicates rotor speed below 97% RPM. To restore RPM, lower collective, roll throttle on and, in forward flight, apply aft cyclic. Horn and Light are disabled when collective is full down.

2.12 Effective Investigation Techniques

The helicopter was recorded with metadata, in addition to video and audio taken with a GoPro that was brought on board, which enabled a detailed analysis to be conducted by matching these records with the condition of the wreckage and determining how the helicopter was destroyed during flight.

3 ANALYSIS

3.1 Qualification of Personnel

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

3.2 Airworthiness Certificate

The helicopter had a valid airworthiness certificate and had been maintained and inspected as prescribed.

3.3 Influence of Weather

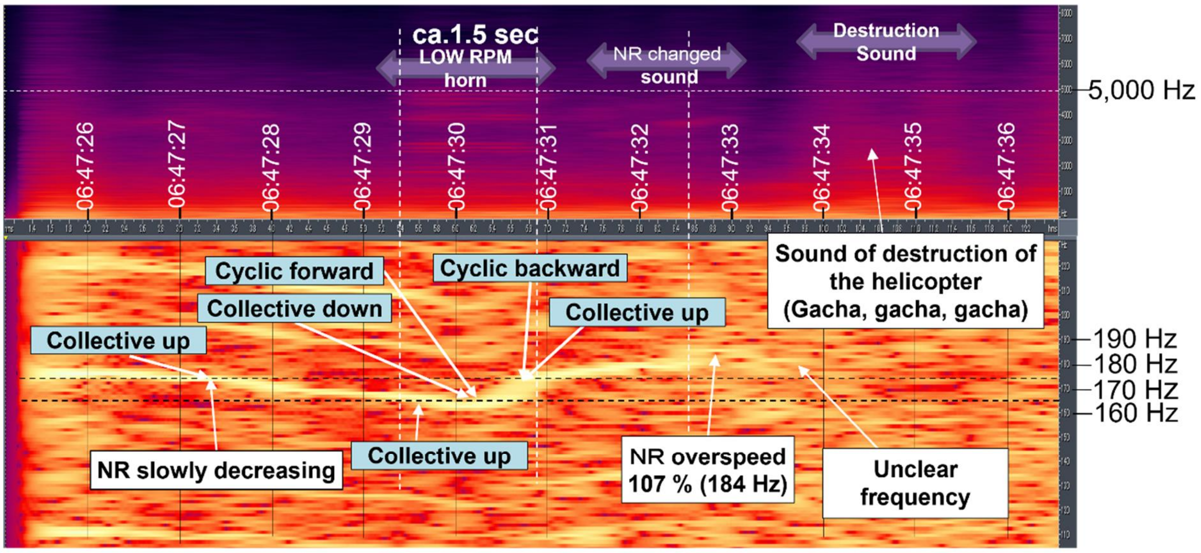
The JTSB concludes as follows:

As described in 2.6, it is probably that clouds were to form due to the high humidity of the air on the day of the accident. Based on the aeronautical weather observations at 07:00 for Atsugi Aerodrome at an elevation of 205 ft, clouds were observed at 1,000 ft, 1,500 ft and 2,000 ft, and the cloud base of stratocumulus was 2,000 ft, the pressure altitude of the cloud base was probably about 2,200 ft. And according to the GoPro video, the closer you got to the cloud base, the worse the visibility became, and between 2,000 ft and 2,500 ft, the flight visibility was 2 to 5 km, and at a flight altitude of 2,500 ft or more, the flight visibility was less than 1.5 km. It is certain that the helicopter needed to fly approximately 150 m (500 ft) below the cloud base in its flight airspace where the helicopter was flying and thus at a flight altitude of 1,700 ft and above, as being unable to maintain the VMC, the helicopter flew in IMC.

3.4 Analysis of the Factors Leading from Engine Power Drop to Crash

3.4.1 Acoustic and Video Analysis for the Number of Rotor Speed (NR)

※ Analysis using 10th harmonic



102.5% : 523rpm=523/60*2=17.4Hz
100% : 510rpm =510/60*2=17Hz
97% : 495rpm =495/60*2=16.5Hz

※1 the normal NR of the R22 Beta was 101 to 104 % RPM
2 The LOW RPM horn is activated when the NR dropped below 97 % RPM.

Figure 23: Acoustic Analysis for the NR

Based on the acoustic frequency that can be generated when the main rotors turn and the movement of the control system operation which can be confirmed in the video, as shown in Figure 23, frequency analysis was made according to the change of events.

In this graph, the vertical axis represents frequency, and the horizontal axis represents time, with stronger signal levels being represented by a whiter spectrum (continuum).

At NR of 510 rpm (100%) for the R22 Beta type, 8.5 Hz (one blade) or 17 Hz (two blades) are generated depending on the number of main rotor blades. As the normal NR is between 101-104%, the center frequency was set at 102.5% (17.4 Hz with two blades), assuming that engine power is normal. As the acoustic frequency of the LOW RPM HORN for the R22 Beta is 500 Hz, the upper row is expressed as the warning sound and other sound changes, and the lower row as the change in NR frequency. Taking advantage of the characteristic of sound vibrating at integer multiples, a comparison was made at 10 times the frequency where a noticeable change can be confirmed.

The LOW RPM HORN was activated at 06:47:29 when the NR dropped below 97 % RPM and continued to sound for approximately 1.5 seconds. At 06:47:30, when the pilot pulled down the collective while moving the cyclic forward, 0.5 seconds later, the NR increased to 102.5% RPM or more and continued to increase, reaching 107% RPM or more, resulting in overspeed. And at 06:47:31, while the NR increased, the pilot moved the cyclic aft while pulling up the collective, and then at 06:47:33, the NR frequency became unclear, and at 06:47:34 the sound of the helicopter being destroyed was recorded.

3.4.2 Decrease in NR due to insufficient Engine Power

The JTSB concludes as follows:

(1) As shown in Figure 23, the collective was upped and the NR slowly dropped below 102.5% from approximately 2 seconds before the LOW RPM HORN was activated. It is probable that the engine power could not be maintained, and the engine entered a LOW RPM condition.

(2) Normally, the RPM governor[21] automatically adjusts the engine power to maintain the adjusted value of NR, 102 to 104 % RPM. As described in 2.11.4, if carburetor ice occurs, the RPM governor will automatically open the throttle to compensate for the buildup of ice in the early stages of development, thus typical symptoms of carburetor icing are not noticeable to the pilot. As the ice gets worse, the throttle will reach fully open and engine power cannot be increased, by the governor or the pilot, therefore, the NR will decrease

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[21] The “RPM governor” is a device that senses changes in the engine RPM and is used to maintain the engine RPM by calibrating throttle via a friction clutch.

unless the collective position is lowered.

As described in 2.8.2, the carburetor heat control lever was unlatched but not adjusted during flight. Carburetor ice is an engine failure that does not leave a trace, but the environmental and equipment operating conditions at the time the LOW RPM was activated were as follows:

a. Environment when LOW RPM is activated.

- At about 06:47:29, when LOW RPM of the helicopter occurred, the helicopter was flying in clouds at a flight altitude of 3,400 ft. Estimating from the ground temperature (observation values at Hadano City Fire Department Headquarters) described in 2.6 (3), it is probable that the outside air temperature in the upper air was about 12°C, and the humidity was 100% as the helicopter was in the clouds.
- The conditions for carburetor ice to form are below 21°C and humidity above 80%, and the environment around the helicopter was highly probable within these ranges.
- As described in 2.11.4.3, the ceiling of OGE hovering was 7,500 ft, and climb was possible under ideal conditions with no wind.

b. The operating condition of the equipment when LOW RPM is activated.

- At 06:47:27 the collective was upped, and the helicopter was climbing at approximately 2,300 ft/min with NR slowly decreasing.
- The carburetor heat control lever was unlatched, which was linked to the collective setting, a certain amount of hot air flowed into the carburetor.

It is probable that NR of the helicopter decreased due to a decrease in engine power caused by carburetor ice, or due to insufficient engine power for the rapid climb caused by upped the collective, or due to both occurring simultaneously, resulting in a lack of engine power required to rotate the main rotors.

As described in 2.11.4, at high humidity and when in doubt, assuming conditions conducive to carburetor ice, carburetor heat should be applied as required. In addition, full carburetor heat should be used during run-up to preheat the induction system and as shown in the picture in Figure 5A, it is important to re-confirm that carburetor heat has been applied when it is confirmed that there are drops of water on the cockpit window in flight.

3.4.3 Occurrence of Catastrophic Mast Bumping due to Abrupt Control Movement

3.4.3.1 Damage to Main Rotor System

The JTSB concludes as follows:

According to the wreckage status and the GoPro video, the damage to the main rotor system highly probable occurred as follows:

As described in 2.3.2 and 2.9.2, two main rotor blades were broken off to the lower surface side, and, in particular, as to the tip of the No. 1 Blade spindle tusk, the blades were compressed and deformed in the rotation direction to the underside at the contact surface with the droop stop and were scraped off. Besides, the rotary swashplate was broken from the overhanging root of the No. 1 Blade, and the No.1 Blade pitch link was broken at the swashplate joint, and the No.2 Blade pitch link was broken on the blade pitch horn side. Furthermore, the main rotor shaft was deformed by approximately 20° near the swashplate, it is probable that excessive loads had been applied.

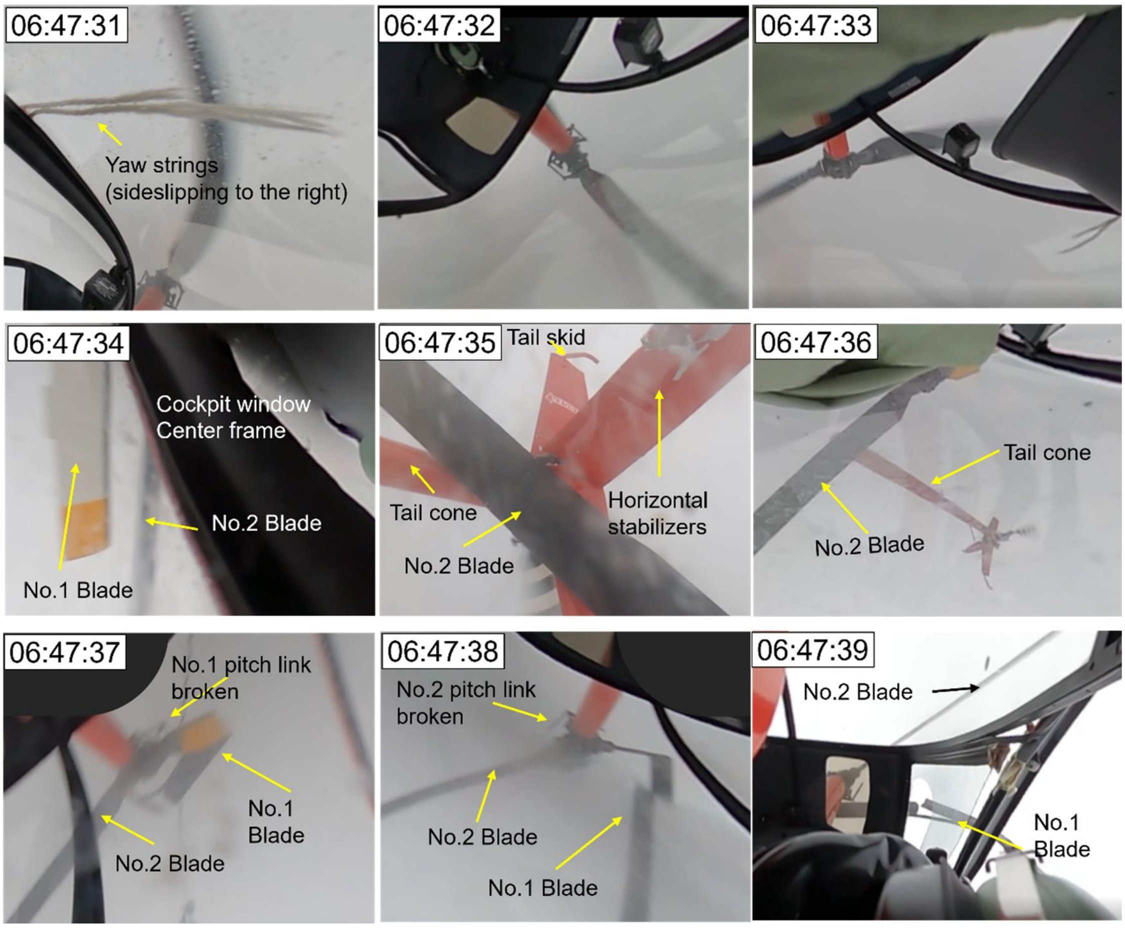


Figure 24: How the Helicopter Ended up with the Catastrophic Mast Bumping
(edited from GoPro video)

The GoPro had recorded video showing the main rotor blades were broken off while the helicopter was continuing to roll to the left between 06:47:31 and 06:47:34, leading to the catastrophic mast bumping, as shown in Figure 24. On the image in the video recorded at 06:47:34, the No.1 Blade is reversed, with the two blades in a parallel position. And from the damage state and direction of deformation of each component, as described in 2.11.5, that the main rotor teetering angle exceeded the design limit, and excessive loads were applied to the pitch links and swashplate while the No.1 Blade spindle tusk came into hard contact with the droop stop, and it is highly probable that the catastrophic mast bumping occurred, resulting in damage to the main rotor system.

3.4.3.2 Reasons Led to Catastrophic Mast Bumping

Figure 1 of the Appended Figure 3 shows the metadata recorded on the GoPro graphically, synthesizing the characteristics of the pilot's flight operation confirmed by the video and the peculiar points from the acoustic analysis. In addition, Figure 25 shows the superimposition of the wreckage positions described in 2.9.1 and the events confirmed by the video on the estimated flight route of the helicopter.

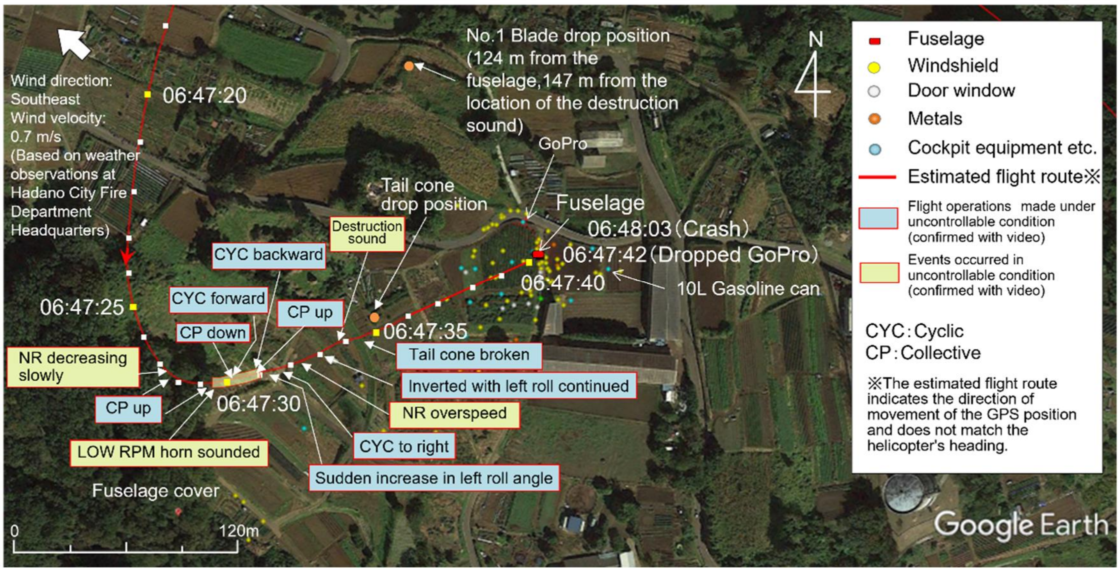
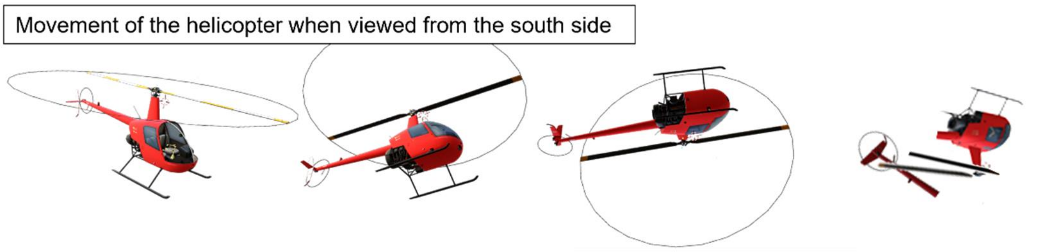


Figure 25: Comparison between the Helicopter's Estimated Flight Route before the Crash and the Wreckage Positions



A. LOW RPM horn sounded
B. Sideslipping to the right/Left roll
C. Continued a left roll
D. Catastrophic mast bumping occurred

Figure26: Condition of the Helicopter from LOW RPM HORN to Mid-air Breakup

Figure 26 is the visualization of the helicopter's condition from the LOW RPM HORN to mid-air breakup based on the video and metadata, showing the process leading up to catastrophic mast bumping in four phases.

A. While the helicopter was climbing turn to the left through about 2,300 ft/min vicinity of about 3,400 ft, to lack of engine power, NR dropped below 97 % RPM, and at 06:47:29, the LOW RPM HORN was activated. At this time, the helicopter was put into an unstable low G flight condition, which caused the helicopter to roll to the right. The pilot heard the LOW RPM HORN, up to collective slightly, and approximately 0.5 seconds after the warning sound, the pilot abruptly pulled down the collective and moved the cyclic forward, as shown on the left in Figure 27. As a result of these operations, NR recovered but the low G flight condition worsened, resulting in a gravity acceleration of approximately 0 G condition. As shown on the right in Figure 27, at 06:47:30.8 seconds, as if surprised by the change in gravity acceleration, the pilot abruptly pulled up the collective and simultaneously moved the cyclic aft.

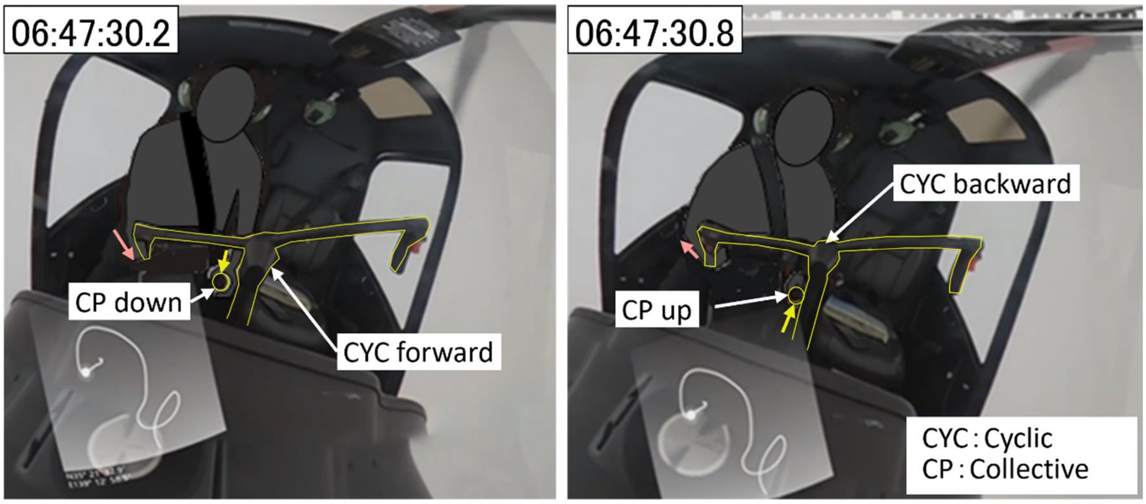


Figure 27: Abrupt Collective and Cyclic Control Movements
(created from GoPro video)

B. After the collective was abruptly pulled up and the cyclic was moved aft at the same time, the helicopter began to roll to the left and entered a sideslip state to the right with the yaw strings[*22] flowing directly to the side, as shown in the still image recorded at 06:47:31 in Figure 24. In addition, the collective was moved again during the left roll, the helicopter was continuously in a low G flight condition at about 0.5 G, flying

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[*22] "Yaw strings" are pieces of string used to confirm the flow of air over the aircraft. The R22 Beta has some yaw strings attached to the outside of the windshield, whose motion can be observed to check the helicopter's sideslip conditions.

towards about 70 degrees. The pilot applied the cyclic to the right during the left roll but was unable to stop the left roll. This was probably due to the resultant force, the combination of three forces created from the relationship between thrust and drag acting on the helicopter, such as parasite drag[*23] from the side of the helicopter due to skidding, main rotor thrust increased by abruptly raising the collective, and tail rotor thrust, which resulted in the helicopter continuing to roll to the left.

C. The helicopter continued to roll to the left, and at 06:47:33, the NR increased to 107 % RPM, and then the NR acoustic frequency became unclear.

D. The helicopter continued to roll to the left, and while the No. 1 Blade spindle tusk was in contact with the droop stop, the swashplate continue to be tilting, and at 06:47:33.6 seconds, the control system near the swashplate was broken, the swashplate connection side of the No.1 pitch link was severed, and the No.1 Blade was broken off as if twisted to downward, it is probable that the catastrophic mast bumping occurred. Afterwards, the helicopter was then in an uncontrollable situation due to the damage to the main rotor blades. In addition, it is highly probable that the broken main rotor blades came into contact with the fuselage, and the tail cone was broken, resulting in the crash.

Given the situation where these events occurred in a short period of time, it is most likely that the helicopter was climbing through the clouds, the NR dropped below 97% and the pilot made sudden abrupt control inputs when the pilot heard the LOW RPM HORN, which led to an unstable low-G flight condition that continued, the catastrophic mast bumping occurred, rendering the helicopter uncontrollable and leading to the crash.

As described in 2.11.5.3, abrupt control inputs may cause catastrophic failure of a critical component due to mast bumping, therefore it is important to fly a helicopter by maintaining a flight environment in which abrupt evasive operation is not required.

3.5 Pilot's Judgement regarding the Flight of the Helicopter

The JTSB concludes that based on the circumstances of the helicopter from take-off to the crash, the accident's contributing factors involving the pilot's judgement and flight skills are probably as follows:

3.5.1 Continued Instrument Meteorological Conditions (IMC)

[*23] "Parasite drag", which is made up of all types of drag that acts on any aircraft to retard its movement, is defined as all drag that is not associated with the production of lift.

As described in 2.1, the helicopter took off from Akada Site, climbed, and then leveled off at an altitude of about 2,000 ft, heading east. It is highly probable that after making a position report to Atsugi Tower at 06:40:28, the pilot judged that the weather was bad, as visibility was degraded due to the helicopter's temporary climb and began to turn right to follow the flight course to Akada Site. (See Figure 2) After completing the right turn, the pilot accelerated to a ground speed of about 100 kt and the helicopter flew towards Akada Site, but the helicopter continued to climb without maintaining altitude, thus from about 06:42:00 until the uncontrollable condition, it is certain that the helicopter was continuing in clouds and continued to fly in IMC. (See Figure 6C)

As described in 2.4, out of the total flight time of approximately 89 hours, the pilot had completed 2 hours and 10 minutes of instrument flight training, using the hood, to obtain a private pilot certificate, but had not completed the training to obtain an instrument flight certificate. As described in 2.11.2.1, the R22 Beta is not equipped with an autopilot system and instrument flights are not approved, therefore it is highly probable that the pilot was difficult to fly in IMC.

The helicopter took off from Akada Site, climbed to an altitude of approximately 2,000 ft, where the VMC could not be maintained, and levelled off to head east. The pilot chose to fly at an altitude of 2,000 ft because as described in 2.11.1 (3), the flight altitude during the training to obtain the certificate was at an altitude of 2,000 to 3,000 ft. Therefore, it is probable that the pilot also chose the altitudes during normal flights. As described in 3.3, the cloud base of stratocumulus was 2,200 ft, and as on the still image in Figure 5, the closer the clouds, the worse the visibility gradually becomes, thus when an altitude of 2,000 ft was chosen, the height difference from the clouds would be 200 ft, therefore, it is probable that the pilot flew the helicopter with the degraded visibility from when the level flight began.

Regarding the fact that the helicopter climbed without maintaining altitude, confirmation of the pilot's line of sight with the video revealed the following the pilot's eye was directed around the instrument panel after visibility deteriorated and the horizon could not be visually confirmed, as shown in Figure 6. The speed and course were almost maintained, so it is probable that the pilot cross-checked the attitude indicator, the airspeed indicator and the directional gyro. In addition, the altitude correction points were checked by comparing the movement of the pilot's line of sight and the collective control lever down operation, which showed that there were several altitude corrections made by the collective control lever down operation, but these corrections were not fully made, thus it is probable that the change of information from the altimeter and vertical velocity indicator, located to the left of the attitude indicator, had not been properly understood.

As described in 2.11.3, in order to avoid unintended flight in IMC, it is important to turn around slowly and proceed back to the first safe landing area while maintaining VMC if threatened by deteriorating visual cues and if the weather ahead becomes questionable. It is also important for pilots who have not been trained to obtain an instrument flight certificate to fly with VMC maintained, bearing in mind that they will not be able to fly adequately by instrument only.

3.5.2 Flight to the North-Northwest and Request for Radar Vector

As described in 2.1 and 2.8, after making a 180° turn, the pilot flew towards Akada Site, and after slowing down approximately at 06:44:10, the pilot initiated a right turn at 06:44:41 and flew towards the north-northwest. It is more likely that the flight altitude continued to increase for about four minutes until 06:44:35, but as the course was generally maintained, the pilot deliberately flew the helicopter in a north-northwesterly direction, looking at the directional gyro. Akada Site is located along the Tomei Expressway, which is usually referred to as a visual cue on the ground at the time of take-off and landing. As described in 2.11.1 (1), according to the statement of Acquaintance A, the pilot landed the helicopter using the Oi-Matsuda Interchange as a visual cue on two days before the accident, therefore, it is possible that while flying along the Tomei Expressway in a reduced visibility condition, the pilot turned in a north-northwest direction so as to be able to find Akada Site.

As described in 2.1, 2.7.2 and 2.8, in the section between 06:45:36 and 06:47:10, when the helicopter was communicating with Atsugi Tower to request the radar vector, the changes in course, altitude and speed were large, therefore it is probable that it was difficult for the pilot to maintain the attitude in the clouds while making communication.

In order to fly by receiving radar vector, while performing a basic instrument flight, the helicopter should have maintained a precise attitude, re-established communication, and climbed to the altitude which safe radar vector was possible. With the unstable attitude maintained by the pilot, it is probable that it was extremely difficult for the pilot to fly the helicopter by receiving radar vectors while making communication.

3.5.3 Judgement on Flight based on Skills

The JTSB concludes as follows:

The helicopter took off from Akada Site at 06:34, and after climbing, leveled off at an altitude 2,000 ft. The helicopter then generally maintained an altitude of around 2,000 ft and reported that it was at 2,000 ft at the time of the position report to Atsugi Tower, therefore, 2,000 ft was probably the cruising altitude intended by the pilot. As described in 3.3, in the airspace in which the helicopter was flying, it would probably have been necessary to maintain a flight altitude below 1,700 ft in order to maintain VMC. Therefore, it is possible that the pilot decided to depart without considering the cruising altitude where the VMC could be maintained by checking the aeronautical weather for Atsugi Aerodrome prior to departure.

It is important for a safe flight to maintain VMC. In order to do this, first of all, it is important to confirm the actual weather conditions of the flight route, and based on this confirmation, consider the cruising altitude at which a safe flight is possible, and whether or not to depart based on the pilot's individual skills, prior to departure. It is also important to make flight decisions by checking the weather conditions even during the flight.

4 CONCLUSIONS

4.1 Summary of the Analysis

(1) It is certain that at an altitude of 1,700 ft and above, where the helicopter was flying, as being unable to fly with VMC maintained, the helicopter flew in IMC. (3.3)

(2) It is probable that NR of the helicopter decreased due to a decrease in engine power caused by carburetor ice, or due to insufficient engine power for the rapid climb caused by upped the collective, or due to both occurring simultaneously, resulting in a lack of engine power required to rotate the main rotors. (3.4.2)

(3) From the video and the deformation direction and damage condition of each component, the helicopter is highly probable that the main rotor teetering angle exceeded the design limit, and excessive loads were applied to the pitch links and swashplate while the spindle tusk came into hard contact with the droop stop, resulting in the catastrophic mast bumping, leading to the damage to the main rotor system. (3.4.3.1)

(4) It is most likely that the helicopter was climbing through the clouds, the pilot made sudden abrupt control inputs when the pilot heard the LOW RPM HORN, which led to an unstable low-G flight condition that continued, the catastrophic mast bumping occurred, rendering the helicopter uncontrollable and leading to the crash. (3.4.3.2)

(5) Judging that the weather was bad, the pilot made a 180° turn to fly towards Akada Site, however, it is certain that as the helicopter climbed without maintaining altitude, the helicopter flew in IMC. As to the reason the helicopter climbed without maintaining altitude, confirmation of the pilot's line of sight with the video revealed that altitude corrections were not fully made, thus it is probable that the pilot did not properly grasp the change of information on the altimeter and vertical velocity indicator. (3.5.1)

(6) As the helicopter got to be flying in clouds, the pilot requested the radar vector, however, in order to fly by receiving radar vector, while performing a basic instrument flight, the helicopter should have re-established communication, maintain a precise attitude, and climb to the altitude which safe radar vector was possible. With such an unstable attitude that the helicopter was maintaining, it would probably have been extremely difficult for the pilot to fly the helicopter by receiving radar vector while making communication. (3.5.2)

(7) It is more likely that the pilot decided to depart without checking the aeronautical weather for Atsugi Aerodrome and considering the cruising altitude where the VMC could be maintained prior to departure. (3.5.3)

4.2 Probable Causes

The JTSB concludes that the probable cause of this accident was that while the helicopter was climbing through clouds at an altitude where it was unable to maintain VMC, when the number of rotor speed decreased, and the pilot most likely made abrupt control inputs to the flight controls when the pilot heard LOW RPM HORN, which the helicopter continued an unstable low "G" flight condition, resulting in catastrophic mast bumping, rendering the helicopter uncontrollable and leading to the crash.

It is more likely that the number of rotor speed decreased by a lack of engine power because the pilot continued climbing through the clouds without proper using carburetor heat.

Additionally, the helicopter continued to fly in clouds was probably because it departed without considering the cruise altitude where the VMC could be maintained prior to departure, and because no corrections were made during the flight based on proper understanding of altitude information.

5 SAFETY ACTIONS

5.1 Safety Actions Considered Necessary

(1) Maintaining Visual Meteorological Conditions (VMC)

To avoid flying unintended IMC, it is necessary to confirm the aeronautical weather for the nearest airport and based on this confirmation, consider cruising altitude at which it would be possible to maintain VMC, and then whether or not to depart based on the pilot's individual skills, prior to departure. It is also important to make flight decisions by always checking the weather conditions even during the flight.

(2) Proper Use of Carburetor Heat

At high humidity and when in doubt, assuming conditions conducive to carburetor ice, carburetor heat should be applied suitably. In addition, full carburetor heat should also be used during run-up to preheat the carburetor heat and, it is important to re-confirm that carburetor heat has been applied when drops of water are confirmed.

(3) Prevention of Mast Bumping

Abrupt control inputs may cause the catastrophic mast bumping leading to catastrophic failure of a critical component, therefore it is important to maintain a flight environment that does not enter for abrupt maneuvers that would result in low-G conditions.

(4) Installation of Flight Data Monitoring (FDM)[*24]

In this accident, the metadata and video from the GoPro that is in the category same as Flight Data Monitoring (FDM), installed in the cockpit of the helicopter allowed for a detailed analysis. For small aircraft, which are difficult to equip with a flight recorder, the installation of a Flight Data Monitoring (FDM) system could make it possible to analyze in detail the timing of the operation of the control system, the movement of pilot's line of sight, the flight route, acceleration and others, which is useful not only for preventing the recurrence of similar accidents, but also for the post-analysis of flight training, and for the flight operation records. Therefore, it is desirable to install Flight Data Monitoring (FDM) in aircraft that are not equipped with a flight recorder. For more information on the effectiveness of FDM, see the Japan Transport Safety Board Digest No. 42 "Prevention of Accidents Involving Small Aircraft": Are you aware of the Flight Data Monitoring (FDR)?"

(https://jtsb.mlit.go.jp/bunseki-kankoubutu/jtsbdigests/jtsbdigests_No42.html)

(only available in Japanese)

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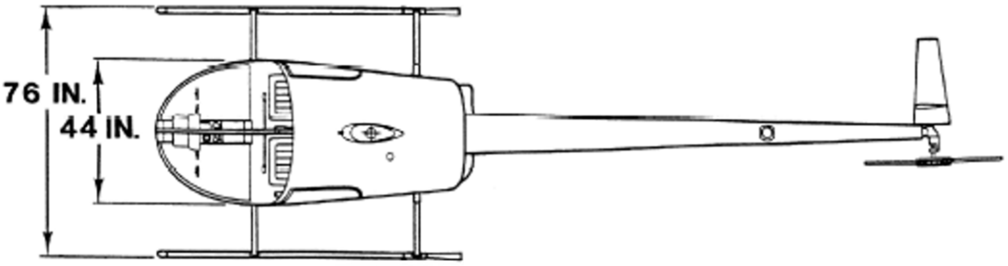
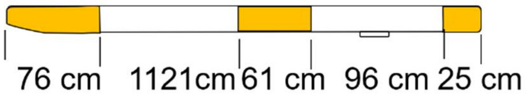
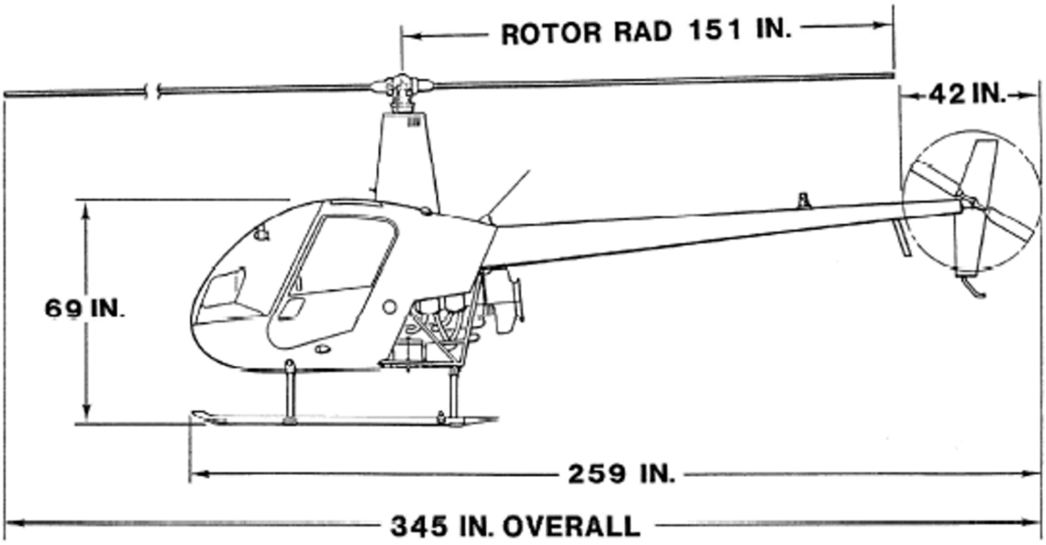
*24 "Flight Data Monitoring (FDM)" refers to a simplified type of the Flight Data Recorder, which can record aircraft position, altitude, cockpit voice and video information in flight for the purpose of Flight Data Monitoring.

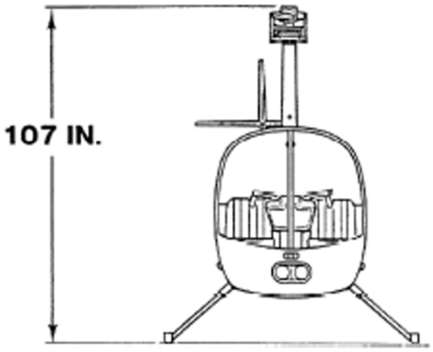
Appended Figure 1: Three Angle View of Robinson R22 Beta and Range of Main Rotor Blade Upper Surface Paint Colors





Range of Main Rotor Blade Upper Surface Paint Colors





R22

EXTERNAL DIMENSIONS

Appended Figure 2: Summary of Records Used for Analysis

Device used in the investigation:	GoPro MAX HERO action camera
Applications:	Telemetry Extractor

Table 1: Analysis Items

Records		Content of analysis
Items	Sampling rate	
GPS	20 Hz	• Position • Speed (2D and 3D) • Altitude
Angular rate	200 Hz	• Pitch • Roll • Yaw
Acceleration	200 Hz	• Longitudinal • Lateral • Vertical
Acoustics	Audible sound (6 Ch)	• The communication status was ascertained by matching the pilot's voice with the communication with the ATC. • LOW RPM horn • Sound of destruction of the helicopter
	Frequency	• Number of main rotor speed • LOW RPM horn • Sound of destruction of the helicopter
Video	60 Hz 3 K 360° angle of view	• Changes in weather conditions • Movement of control system • State of yaw strings (side slipping) • Rotating state of main rotor blades • Damage to blades and the helicopter • Movement of pilot's line of sight

The occurrence of catastrophic mast bumping was analyzed by coordinating each record with the time from the video and comparing them. The 360° video is highly distorted when displayed in its entirety, therefore it was necessary to zoom on each frame to check the feature points. Metadata is sensitive and has a high sampling rate, thus excessive amplitude of the data was excluded by using the smoothing filter value of the application software, which was set at 20 %, and the feature points were compared. However, as for the metadata, the installation angle of the GoPro was not aligned with the axis of the helicopter, thus it was necessary to correct it by checking it against the video, but it was possible to identify a dynamic change trend.

Appended Figure 3: Analysis Based on the Metadata on the GoPro

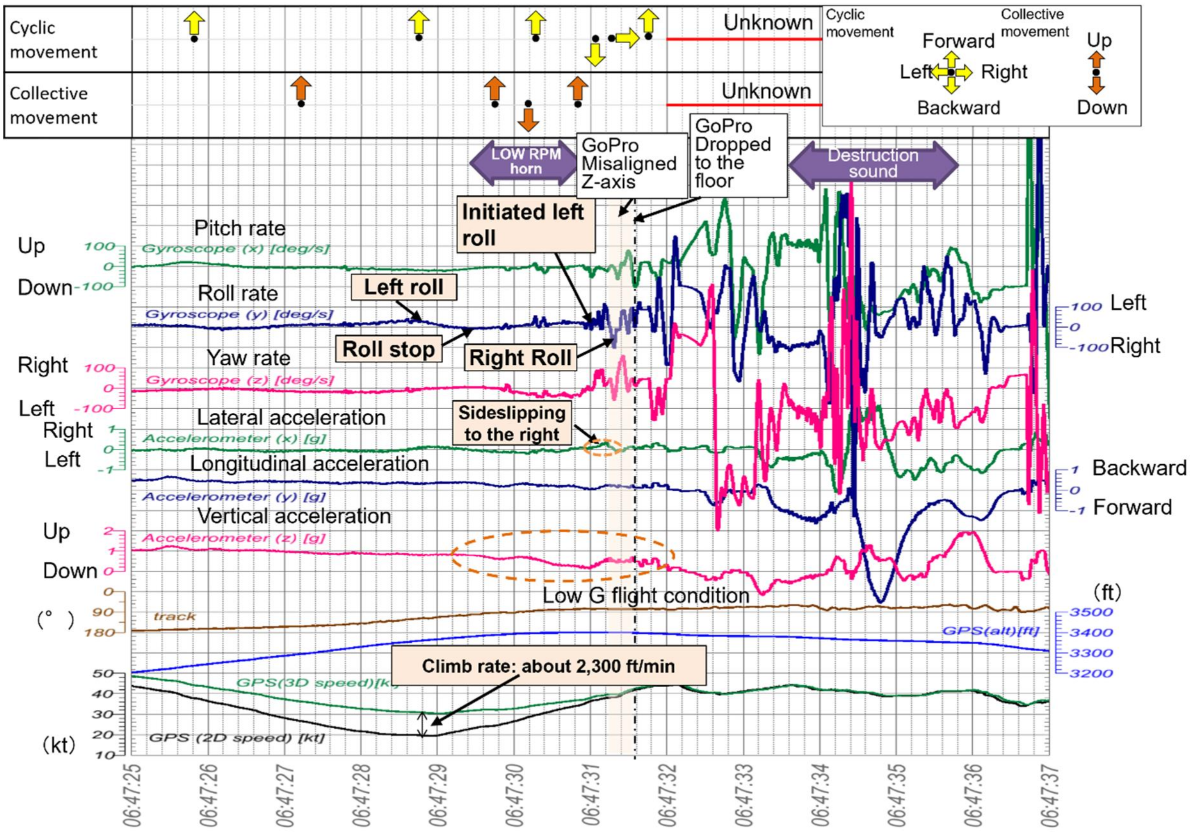


Figure 1: Analysis of the Metadata on the GoPro

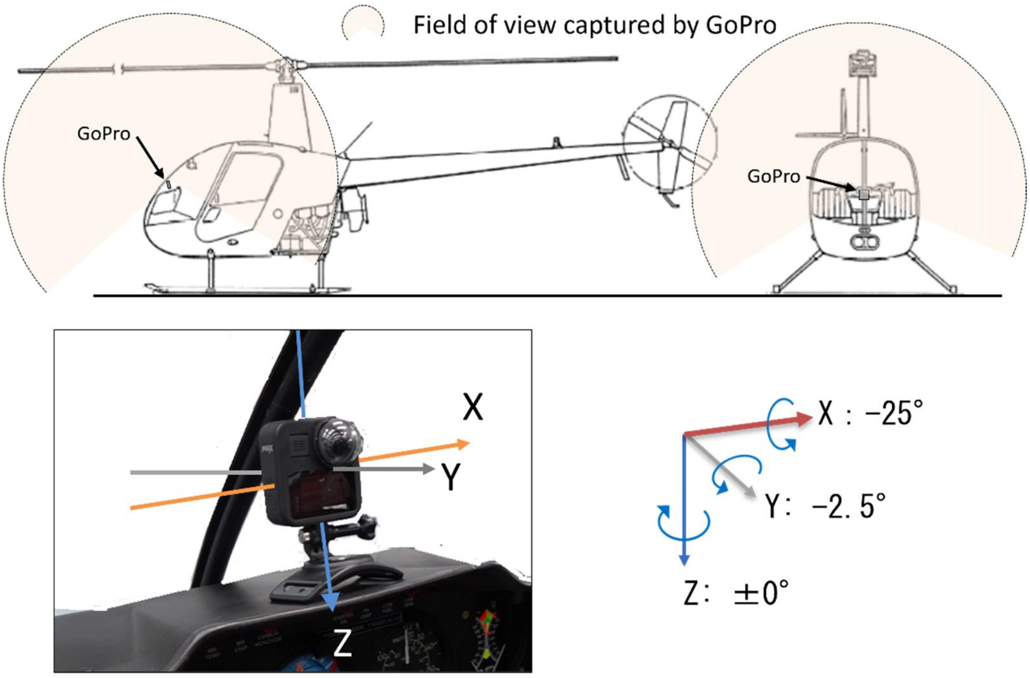


Figure 2: Installation Position of the GoPro (estimated) and Field of View