

Why did the helicopter collide with trees? Approach the causes from analysis of images and sounds.

Japan Transport Safety Board

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Currently, 75 helicopters are operated by 55 local governments in Japan for the purpose of firefighting and disaster prevention. For similar purposes, there are other services such as Emergency Medical Service (EMS), Police, Coast Guard, and the Self Defense Force. As a feature of the firefighting disaster prevention helicopter, they are operated by guidelines made by each local government independently, though they are instructed by the Fire Department. They were single pilot operation even though they are medium-sized helicopters of about 5 tons. The pilots are not required instrument flight licenses. And crew are no transfer between another local government team. This case is an example of a firefighting and disaster prevention helicopter accident in which all 9 people killed.

Despite the attention of the media that many victims came out, the helicopter was not equipped with a recording device such as a black box, so the investigation was forced to take considerable effort.

In the video taken on the aircraft, there was a mysterious video that it collided with the trees without avoidance even when approaching the trees.

In order to get a real of the accident, it was required to conduct a drone investigation, and analyze the images and sounds recorded in the video in various ways. I would like to introduce this actual investigation.

1 Summary of the accident

On Sunday, March 5th, 2017, a mid-size rescue helicopter, Bell 412, operated by the Nagano Fire and Disaster Prevention Aviation Center took off Matsumoto Airport to go rescue training and collided with trees and crashed onto the mountain's slope while flying toward the training site near the summit at 13:33. There were nine persons on board the helicopter, consisting of a captain, eight others and all of them suffered fatal injuries. The Helicopter was destroyed, but there was no outbreak of fire.

2 On site investigation

The three investigators went to the site the next day. The accident site was in a snowy mountain, and the roads leading to the site were not cleared. The large rescue vehicle has reached near the site. Our rental car also had stud-less tires, so I thought it was fine, but it was useless. I had to push the car many times on a road like an inclined ice rink that was hard to walk.

- Lesson 1: Select a 4WD car on snowy roads. Not enough with stud-less tires.

3 Drone Investigation

This accident investigation was the first investigation using drone for JTSB. The drone is not only for taking photographs from sky but also possible to create one fine 2D image (Ortho Mosaic) or 3D image by analyzing the image data taken continuously and the data of the position and the altitude of the drone.

- Lesson 2: The effectiveness of the drone is not only aerial photo.

4 Location survey (Laser range finder & GPS receiver)

The position and height of the cut trees could be measured easily and clearly by using a laser range finder (TruePulse 360, Laser Technology) and a GPS receiver (MMCX: Mobile Mapper CX, Magellan Navigation). They are described in the report. It led to the detailed situation of the accident site more than drone investigation.

- Lesson 3: Easy location survey with laser and GPS. (Of course you need tools and training.)

5 Image analysis of video taken on the helicopter

Since the helicopter was not equipped with a recording device such as a black box, it was difficult to find fact information. However, the video camera attached to the rescuer's helmet was taking a video of the situation from the middle of flight until the accident. The video showed that the weather at the time did not interfere with the flight.

The helicopter gradually approached the mountain surface covered with trees with constant attitude and speed, and crashed into trees and crashed. It was an unnatural situation that a helicopter was flying normally and collided with trees as it gradually approached without being avoided. What happened, nothing happened, why they didn't avoid? It was a shocking to investigate the cause, and it was a question that I had to keep asking until the end.

It was possible to estimate the position and altitude of the helicopter over time by analyzing still image with video stopped, and estimate the flight path by linking them.

It is certain that the helicopter took off from the Airport, headed northeast while climbing above the city, entered the airspace above the mountains, and turned right. It is highly probable that it headed toward Mt. Hachibuse in continuing roughly level flight at a speed of about 100 kt. It is certain that although the helicopter's altitude above the ground level (AGL) became lower gradually, and the tree-covered mountainside was looming ahead, the helicopter collided with trees while maintaining attitude and speed.

The helicopter leveled off at about 1,740 m. It is somewhat likely that this was because the helicopter was trying to ensure the safety altitude of 150 m or higher from the destination, the Helipad, with an elevation of about 1,580 m. It is highly probable that while maintaining the maximum safety altitude, the helicopter took neither the avoidance route at a constant altitude by directly heading for the Helipad nor the avoidance route by climbing, instead, it continued to fly toward Mt. Hachibuse at a constant altitude after turning right, its AGL became lower as flying into over the mountains region, and the helicopter approached the ground. It is highly probable that the helicopter fell into an uncontrollable condition as it crashed its fuselage and MRB into trees over a distance of approximately 40 m. It is highly probable that the helicopter turned upside-down and collided with an approximately 40-degree slope from its nose. It is also highly probable that it was four seconds later after the helicopter collided with trees when the video recording stopped by the impact of the helicopter crashing into the ground.

- Lesson 4: Analysis of flight tracks from video taken on the helicopter.

6 Detailed investigation of the helicopter

From the scattering of debris from the accident site, it was estimated that the helicopter crashed into a tree and became uncontrollable and crashed. The investigation of the details of the airframe was conducted in June when the snow melted and the debris was salvaged from the mountain, and no anomalies of the airframe and engine were found from the debris.

7 Voice analysis of video taken on the helicopter

Alarm sound and abnormal sound indicating abnormality of the helicopter were not recorded until it collided with trees.

A sheet recorded by a mechanic sitting in the left seat was found, which revealed that the crew of the helicopter had been performing engine performance tests after takeoff. Furthermore, by combining and analyzing this one sheet and the in-flight video and audio, the in-flight situation became clearer. At first, I had no idea what the crew was talking about, but it became clear that they were checking the engine, and the contents of the conversation became clear. Furthermore, by analyzing the engine noise, it was possible to estimate the throttle and engine N2 governor operation status during engine check, which supported the fact that an engine check was performed.

An analysis of the audio recorded by the video camera found that a spectrum of approximately 22 Hz was recorded at a constant frequency from the beginning of the video until 4.0 seconds before audio recording stopped. Assuming that the sound was generated by the MR, this would be equivalent to approximately 330 rpm. The 100% number of MR revolutions is 324 rpm.

An audio spectrum of approximately 3,300 Hz and an audio spectrum of approximately 3,400 Hz, which were transmitted at a constant frequency respectively. However, immediately after the voice of "minus two", in the former case, the frequency increased by approximately 200 Hz, while in the latter, the frequency decreased by approximately 200 Hz. Those frequencies returned to original frequencies and they were constantly transmitted again, immediately after the voice saying "I return it."

It is highly probable that there were no abnormalities in the helicopter's engines from the time of takeoff until transition to level flight. As the engine had been operating when the helicopter crashed, it is highly probable that the MR had been rotating at constant rpm until the helicopter collided with trees.

It is highly probable that the helicopter was conducting engine data checks en route from takeoff. When the helicopter commenced turning right above the mountains, it is probable that engine checks had been completed until then. It is highly probable that the mechanic was conducting engine checks, concentrating on the flight instruments, and hardly watched outside. And it is somewhat likely that his attention was focused on addressing the engine data check records even after the engine checks completed, but this could not be specified.

Since the engine check was finished two minutes before the collision with trees, it was difficult to link the relationship with the collision.

- Lesson 5: Analysis of human voices requires understanding what the person is doing.
- Lesson 6: We can understand the situation of the engine by analyzing the sound.

8 Captain's helmet visor

From the fact that the captain's helmet visor had an impact mark near the center and approximately half of its right side was missing, although the visor cover was not broken, it is probable that the visor received an impact from the right side while in a lowered state. From the fact that the captain's visor was raised at the time of takeoff, it is probable that the captain lowered his visor while in flight. The captain right upper arm moved 1'30" before the collision with trees, it is somewhat likely that it was because turning right at that time would have the helicopter face to the direction close to the sun, and the captain lowered his helmet visor to ward off the glare of the sun; however, this could not be specified.

With the visor lowered, the outside view was clear and not too bright, and the instrument indicators were readable. Therefore, it is probable that the use of visor had no effect on flying the helicopter. However, with the visor lowered, the opening state of eyes and the facial expressions were not recognized from outside.

9 Verification by same type helicopter

i) Position of the mechanic's right hand

When the CP Lever was moved up to the same position as at the time of climbing, and the right hand was extended to the ITT trim switch, almost the same composition as in the image of video camera (-4'5") was reproduced.

ii) View from the cockpit

The inspection was conducted after parking the helicopter with a magnetic heading of 150 degrees, the same heading as at the time of accident. It was conducted at about 13:40 on April 10, 2018, however, the pilot's face was not exposed to direct sunshine. The pilot's view was not blocked and it was possible for him to recognize visually the obstacles lying ahead in keeping the piloting posture, when either only sliding a glance to the instruments without moving his head or facing to the instruments and looking at them. However, when the body was bent forward and the head was lowered a little, the glare shield blocked the forward view (the horizon). Therefore, it seems that when the obstacles lying ahead is approaching, the approaching obstacles may not be recognized visually. In the posture of the mechanic mentioned as above i), the forward view was blocked because the position of the head lowered.

When looking at the pilot's face with the visor lowered, the opening state of eyes and his facial expressions were not recognized.

iii) Different Views with and without Visor

The different views with and without the visor that is attached to the helmet was confirmed. Without the visor, the contrast between outside and inside the helicopter was clear and when looking outside, it seemed that the view was too bright. Immediately looking at the instruments inside the helicopter, it was not to say that anything could not be seen but eyes seemed tired. With the visor lowered, the outside view was clear and not too bright. Immediately looking at the instruments inside the helicopter, it seemed a little dim, but the instrument indicators were readable.

- Lesson 7: Verification will be new discoveries or proofs of certainty.

10 ELT

The helicopter was equipped with an emergency locator transmitter (ELT) with switches (G switches) designed to automatically activate with impact from six directions. When an examination was conducted by agent of the manufacturer following the accident, it was found that the ELT had not activated in this accident. The examination after the accident revealed that the G switches that should activate with impact from the front, left, above, and rear were stuck because the bulb-shaped parts inside the ELT were firmly fixed.

Because the ELT is an important piece of equipment whose activation or non-activation when an accident occurs can affect human survival, inspection of items established by the manufacturer must be carried out and certainly within the time period set by the manufacturer. Therefore, the contents contained in the manufacturer's maintenance manual, including that pertaining to functional inspection of G switches, must be clearly stated in the ELT system maintenance manual of the certified workplace, and the person who conducts an inspection or maintenance must leave records of that inspection or maintenance. Especially, even when a G switch satisfies technical requirements at the time of its manufacture, it may deviate from those requirements by becoming stuck or degraded with the passage of time. Therefore, it is important to make periodic inspections of ELT G switches mandatory.

With regard to ELT, because there are many accidents in which ELT signal was not transmitted due

to the problems of ELT and installation and operation methods of antenna, and ELT problems hinder early detection of survivors, JTSB recognize as an important issue.

- Lesson 8: ELT is important for saving lives.

11 Flight recorder

For aircraft that are required to fly within small safety margins in activities involving life-saving and the like, the installation and utilization of a flight recorder can prove useful in better understanding of the characteristics and flight operations of a helicopter for special flight services by regularly analyzing and evaluating the flight conditions in ordinary flight operations, and if an incident or an accident occurs, it will contribute significantly to precisely identifying its causes and developing recurrence prevention measures. Accordingly, equipping such helicopter with flight recorders is considered as high priority and it is desired to study for its realization and promotion with the cooperation of relevant parties.

- Lesson 9: Flight recorder is important for accident investigation.

12 Factors of the Helicopter's Not Taking Avoidance Maneuver Even Getting Close to the Ground

It is somewhat likely that there were no abnormalities in the helicopter until it collided with trees. It is somewhat likely that during the time from when the helicopter turned right above the mountains until when captain's right upper arm moved, at least there was nothing wrong with the captain's condition like loss of consciousness.

Any voices were not recorded after a rescuer said, "Right rear clear" until the helicopter collided with trees. From this fact, it is somewhat likely that all members on board had not responded to the approaching danger, however, as there is a possibility that the extension microphone of the video camera might have come off the helmet, this could not be specified.

It is certain that the captain was under treatment for a certain disease, and he was taking the prescribed medicines. However, it could not be clarified whether the captain was subject to influence of those previous diseases, which would hinder the performance of aviation duties, or not, and whether the captain took those prescribed medicines during the flight and he was affected by those medicines or not.

Regarding the helicopter's not taking avoidance maneuver, it is somewhat likely that the captain could not recognize the dangerous situation and did not take any avoidance maneuver because he was in a state where the arousal level was lowered with micro-sleep, and so on, due to the effects of fatigue and time difference. However, it was not possible to clarify whether he actually fell into such a state.

The captain should keep watch so as not to collide with other objects. If, for some reason, he could not keep watch, it is highly probable that it was necessary for him to have instructed mechanic to temporarily keep watch for him.

If the mechanic did not question the captain about the flight route and the altitude, it is somewhat likely that his attention was focused on the instruments and the log papers, and therefore he did not keep sufficient outside watch; however, this could not be specified, as the mechanic died.

If the rescuers in the cabin did not question the captain about the flight route and the altitude, it is somewhat likely that they thought that the highly experienced captain and the mechanic, who should have been grasping the outside situation and keeping watch forward; that they got used to low-altitude flight so much that their sensitivity to the danger became lower due to rescue mission and training; however, this could not be specified, as all of the rescuers aboard the helicopter died.

It is important for conducting safe helicopter operations that all crew members display CRM skills under the appropriate leadership of the captain. It is probable that the mechanics can be actively used as cooperative resources in order to realize safe helicopter operations in the flight operations at the

Center. Therefore, it is desired that the Center will endeavor to establish the CRM appropriately based on the Center's flight operations.

● Lesson 10: Safety of CRM and two-person operation.

13 Probable Causes

It is highly probable that in the accident occurred, while flying in a mountainous region, the helicopter collided with trees and crashed, because the helicopter did not take avoidance maneuver even getting closer to the ground.

Regarding the helicopter's not taking avoidance maneuver even getting closer to the ground while flying in a mountainous region, it is somewhat likely that the captain could not recognize the dangerous situation because the captain was in a state where the arousal level was lowered, however, it was not possible to clarify whether he actually fell into such a state.

14 Other Identified Matters concerning Safety

i) It is highly probable that the captain had a past medical history and a surgical history and he was under treatment with medication. However, it is certain that he had obtained the aviation medical certificate without making a self-report on those medical information. In the examination for the Aviation Medical Certificate, it is difficult to make an appropriate judgment on whether to conform to the standards of Aviation Medical Examination unless applicants declare their medical history and information accurately. Applicants for the aviation medical examinations must accurately make a self-report on their medical information to apply for the aviation medical certification.

Regarding this matter, JTSB said opinion to the Ministry of Land, Infrastructure, Transport and Tourism, it is necessary that the Civil Aviation Bureau thoroughly instruct aircrews to accurately make a self-report on their medical information to apply for the aviation medical certification, and if non-conformity is suspected, they must not engage in the performance of aviation duties, and must receive instructions from the designated aviation medical examiners and others, even if his/her aviation medical certificate is still within validity period.

ii) In this accident, the captain of the helicopter in operation by one pilot was taking photos during the flight at such a low altitude that shall not be allowable from the aspect of safety, and it is probable that there might have some cases where keeping outside watch was not conducted appropriately.

iii) The Center conducts flight operations by one pilot (the captain) in accordance with the regulations. However, it is desired that the Center study using a two-pilot crew when possible.

16 Lesson

Lesson 1: Select a 4WD car on snowy roads. Not enough with stud-less tires.

Lesson 2: The effectiveness of the drone is not only aerial photo.

Lesson 3: Easy location survey with laser and GPS. (Of course you need tools and training.)

Lesson 4: Analysis of flight tracks from video taken on the helicopter.

Lesson 5: Analysis of human voices requires understanding what the person is doing.

Lesson 6: We can understand the situation of the engine by analyzing the sound.

Lesson 7: Verification will be new discoveries or proofs of certainty.

Lesson 8: ELT is important for saving lives.

Lesson 9: Flight recorder is important for accident investigation.

Lesson 10: Safety of CRM and two-person operation.

17 Summary

The incident occurred in March 2017, but in August 2018, one and a half years passed, an accident of a firefighting and disaster prevention helicopter occurred and also killed 9 people in the neighboring prefecture. This is still under investigation, but it has become a major social problem in Japan due to the large number of victims appearing for two consecutive years. I do not yet know whether the two accidents had something in common, but it would be disappointing to think that if the 2017 accident investigation report was published in July instead of October, it would have been a deterrent effect.

Last Lesson: Report should be published as soon as possible.