MOUNTAIN HELICOPTER ACCIDENT

(AW139 JA139F, main rotors severed tail drive shaft) [1]

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Abstract

On Saturday, February 1, 2020, while flying an Agusta AW139, JA139F, over mountainous terrain, the main rotor blades severed the tail drive shaft and controlling the helicopter became difficult while flying. Therefore, the helicopter attempted a forced landing in a paddy field in the town but made a hard landing and rolled over. There were seven people on board the helicopter, four of whom sustained serious injuries and three others sustained minor injuries. The helicopter was destroyed, but no outbreak fire.

The Japan Transport Safety Board (JTSB) concluded that the probable cause of the accident was that the main rotor blades severed the tail drive shaft during flight, making it difficult to control the helicopter, and that the helicopter attempted a forced landing, but made a hard landing, injuring the occupants and damaging the helicopter. The reason why the main rotor blades severed the tail drive shaft when the helicopter encountered a strong downdraft while flying at high speed over mountainous areas in strong winds. It started a right rolling motion exceedingly more than 360 degrees, and the main rotor blades were largely flapping toward the fuselage. It was probably affected by the captain's excessive control input when encountering the downdraft.

In this study, we will introduce accident cases and explain how we deepened the analysis.

1. Summary of the Accident

On Saturday, February 1, 2020, when an Agusta, AW139, JA139F, operated by the Fukushima Prefectural Police Aviation Unit, took off from the prefectural police heliport at 07:09 to transport organs for transplantation. Passing over Koriyama City to check the weather in advance and heading to the Aizu Central Hospital heliport in Aizu-Wakamatsu City, Fukushima Prefecture.(See Figure 1 and 2) The captain, about 3,000 ft southeast of Lake Inawashiro, confirmed that the wind was blowing from the northwest at about 50 kt, and after consulting with the co-pilot, decided to fly at a higher altitude on the return flight than on the outbound flight. The helicopter then landed at the Aizu Central Hospital heliport at 07:40. After the organs for transplantation and two passengers were seated, the helicopter took off from the Aizu Central Hospital heliport at 08:00 and headed for Fukushima Airport, the destination of the transfer. After climbing to an altitude of 5,700 ft over Lake Inawashiro, the helicopter gradually began to descend. During the descent, the captain recognized that the ground speed had increased from 193 kt to 200 kt due to the tailwind. After passing over the Ou Mountains, at 08:08, at an altitude of about 4,300 ft above Mihoda-machi, Koriyama City, Fukushima Prefecture, the helicopter's indicating airspeed (IAS) rapidly increased to 188 kt, causing the helicopter started rolling to the right. During the right rolling, the main rotor blades severed the tail drive shaft, making it difficult to control. The captain attempted a forced landing in a paddy field in the town, but the helicopter made a hard landing while rotating to the right and rolled over to the right. After the rollover, all crew members escaped through the captain's seat window. There were seven people on board the helicopter, including the captain, the co-pilot, two mechanics, and three passengers, of whom four were seriously injured and three minor injured. The helicopter was destroyed, but no outbreak fire. (See Figure 3)

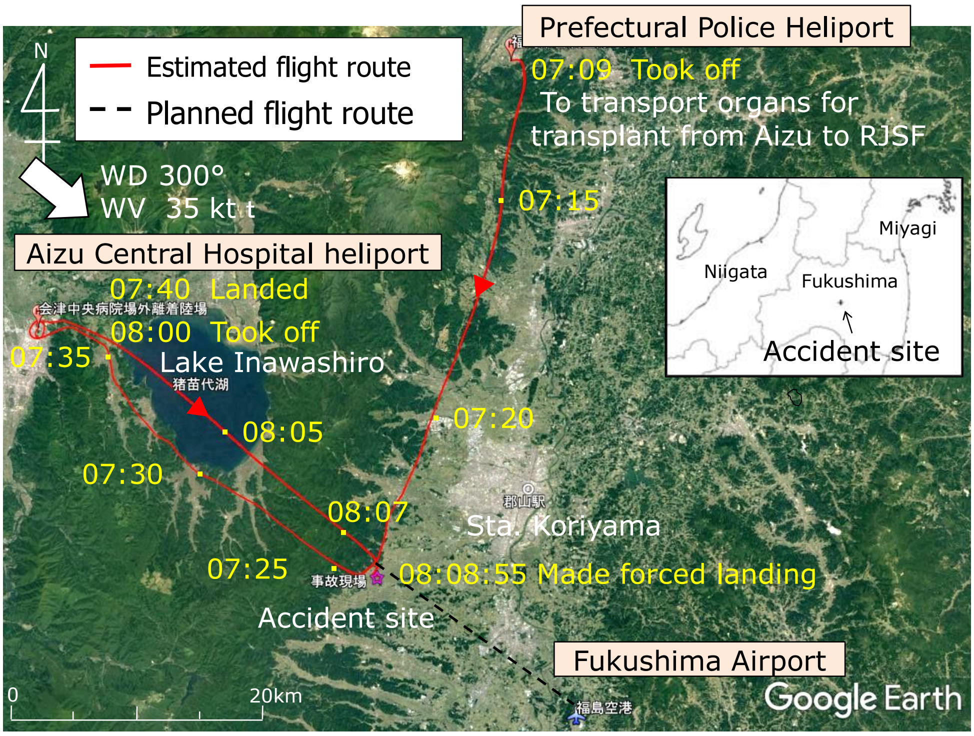

Figure 1 Estimated flight route of the helicopter

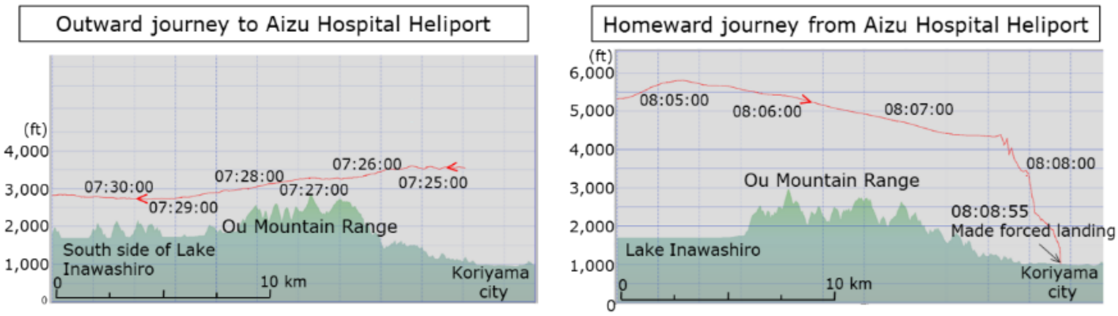

Figure 2 Cross sectional view during the helicopter's flight over the Ou Mountain

Figure 3 Rollover of the Accident Helicopter

2. Situation when the tail drive shaft is the cut off

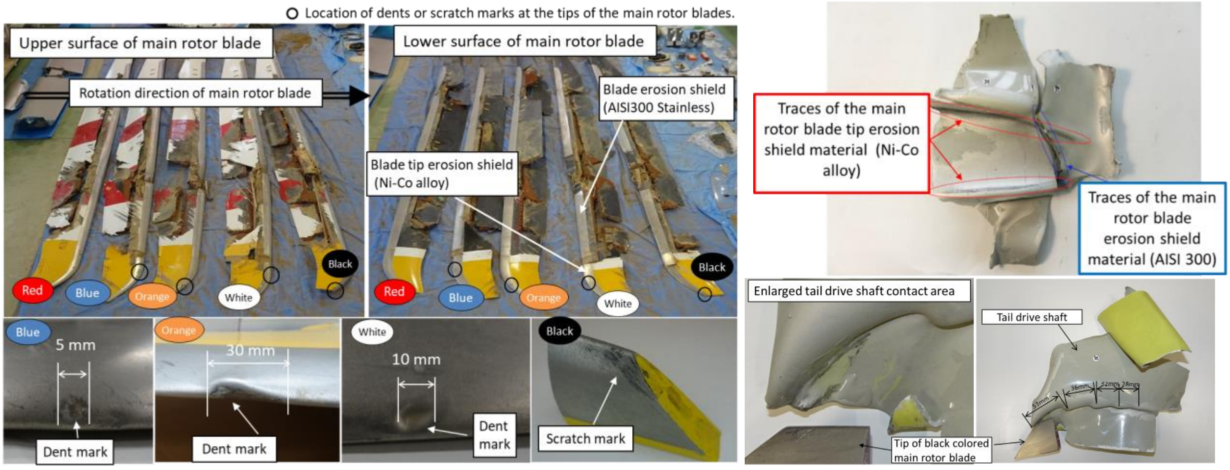

Figure 4 Wreckage of main rotor blades and tail drive shaft

From the condition of the wreckage of tail drive shaft and main rotor blade, it was clear that the tail drive shaft had been the cut by the main rotor blade. (See Figure 4) To identify the part of the main rotor blade that had encounter it, the ANSV, Leonardo Co. and JTSB investigated the material composition and deformation of the contact surface. The two pieces of the tail drive shaft with matching cut surfaces had dents with shapes that matched the shapes of the main rotor blade tip erosion shields, and on the outside, they showed signs of friction of compatible materials.

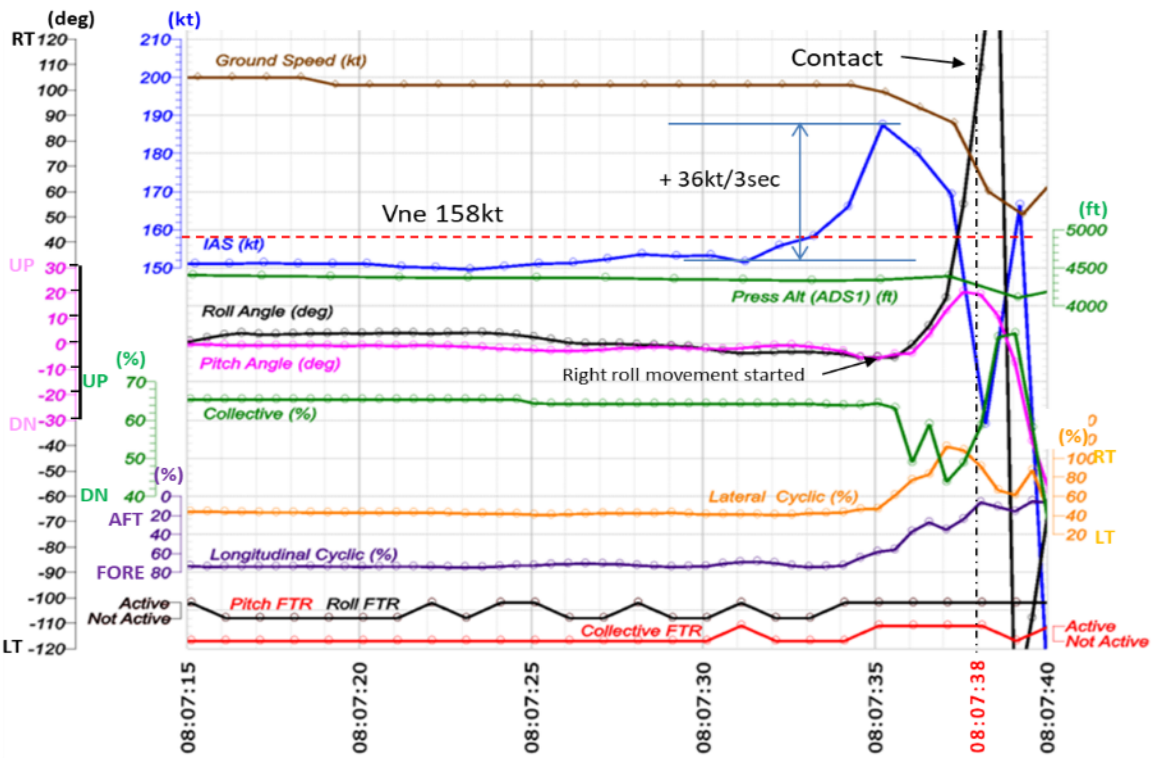

Figure 5 The record of MPFR when the IAS increased rapidly

Next, the time when the main rotor blade contacted the tail rotor blade during a right rolling identified using the Multi -Purpose Flight Recorder (MPFR) contact sound data. The helicopter was in a pitch attitude of +19°, right bank of 108°, with a right roll rate of 100°/sec, and the captain was being operated the collective upward from a vertical acceleration of -1.4G. As a result, it was highly probable that the main rotor blade was subjected to an excessive load, and the main rotor blade flapped toward the fuselage, and contacted the tail drive shaft. (See Figure 5 and 6)

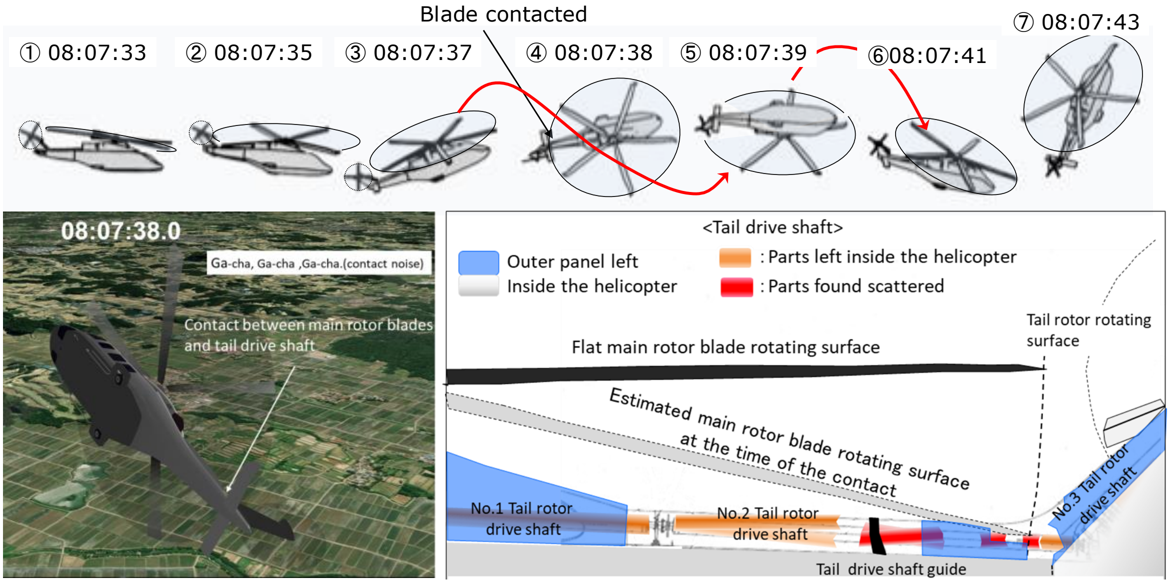

Figure 6 Changes in helicopter attitude and blades when the tail drive shaft was severed by the main rotor blades

3. Why did the IAS rapidly increase and then start right rolling movement?

Regarding the rapidly increase in IAS and the start of the right rolling movement, while flying in a northwesterly tailwind of about 50 kt on the east side of the Ou Mountains, the helicopter encountered a strong downdraft, at which point the horizontal wind speed of the tailwind suddenly decreased. Due to the inertial force of the helicopter, the ground speed gradually changes, causing the IAS to temporarily increase. When the IAS suddenly increased, the captain pressed the Force Trim Release (FTR), which caused the attitude control function (ATT MODE) to Stability augmentation system (SAS MODE), resulting in a slightly left roll attitude and a nose-down attitude. It is probable that the cyclic was operated significantly to the right rear to counter this attitude change, which triggered the start of the right roll of over 360°.

4. Analyzing the effects of local winds in mountainous areas through meteorological simulations

It is known that roll winds blow downwind of mountainous areas, but the rapidly increase in IAS was especially and it was thought that it was not just a roll wind, so a local weather simulation was performed using a Supercomputer. Two types of weather simulation resolution were performed, 1km and 100 m, and the generation area of vertical flow was confirmed at the 1km resolution, and the change in air pressure and wind speed along the flight route was analyzed using a cross-sectional diagram at 100 m resolution.

Based on the results of the weather simulation analysis, it is probable that in the skies above Aizu-Wakamatsu to Koriyama, general winds of 20 m/s (40 kt) to 30 m/s (60 kt) were blowing from the northwest, and that a vertical current running in a southwest to northeast direction was occurring in the skies above the lee side of the Ou Mountains.(See Figure 7)

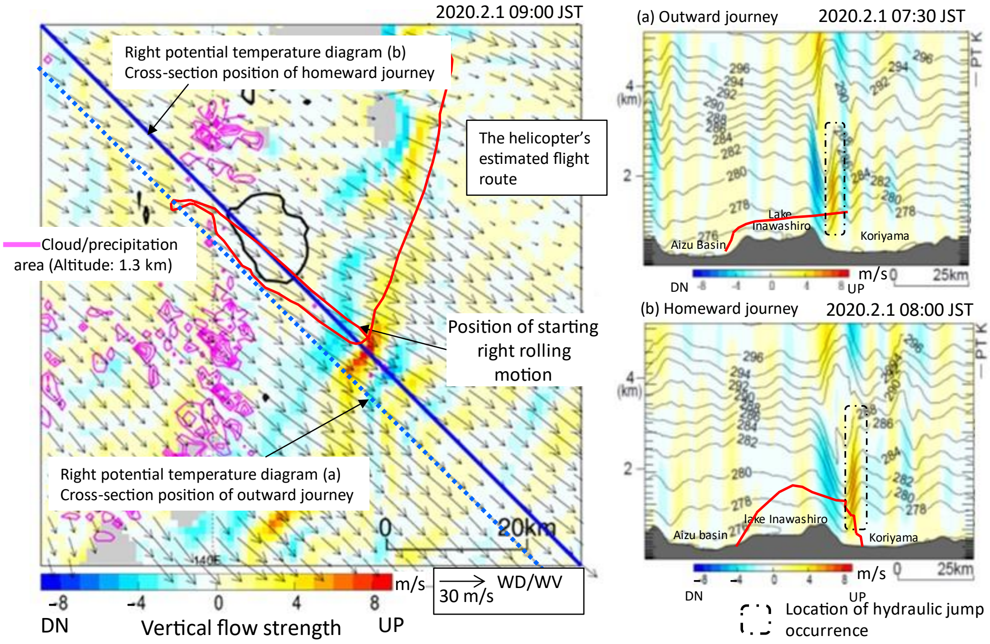

Figure 7 Horizontal distribution of vertical and horizontal flow s at an altitude of 1.3 km (Left) and Cross section of potential temperature and vertical flow according to the blue dotted line / the blue solid line in the left (Right (a) / (b))

In particular, it is probable that in the mountainous area on the southeast side of Lake Inawashiro where the helicopter passed, a strong updraft, which resulted in a hydraulic jump [2], occurred. The area in which the air currents changed in a short period of time, and on the windward side of the strong updraft, there were weak updrafts and strong downdrafts, and it is probable that the horizontal wind speed rapidly decreased in the area where the air currents switched.

It is probable that the helicopter encountered an area where air currents changed drastically and locally in a short period of time, and because the horizontal wind speed at the altitude where the helicopter was flying had dropped sharply from 25 m/s (50 kt) or more to less than 15 m/s (30 kt), it is probable that in this area, the helicopter experienced a rapidly increase in IAS, which had a strong effect on flight control.(See Figure 8 and 9)

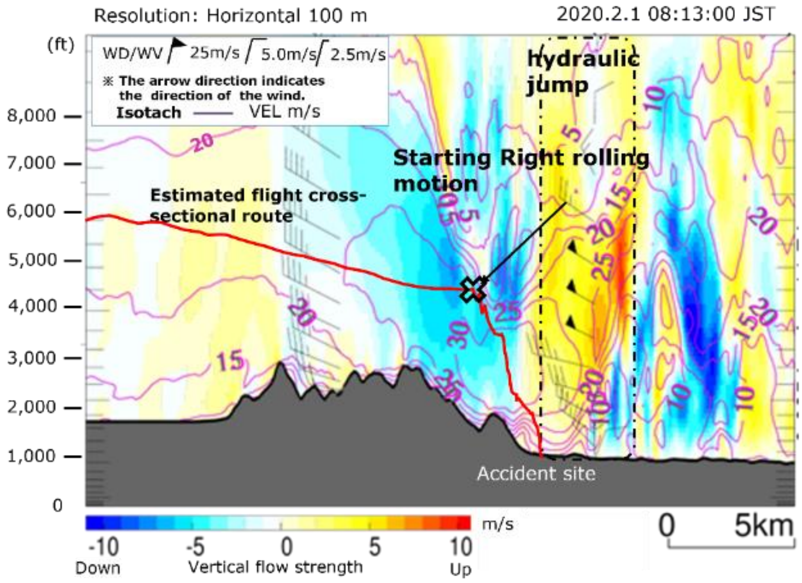

Figure 8 Vertical cross section of horizontal wind velocity and vertical flow

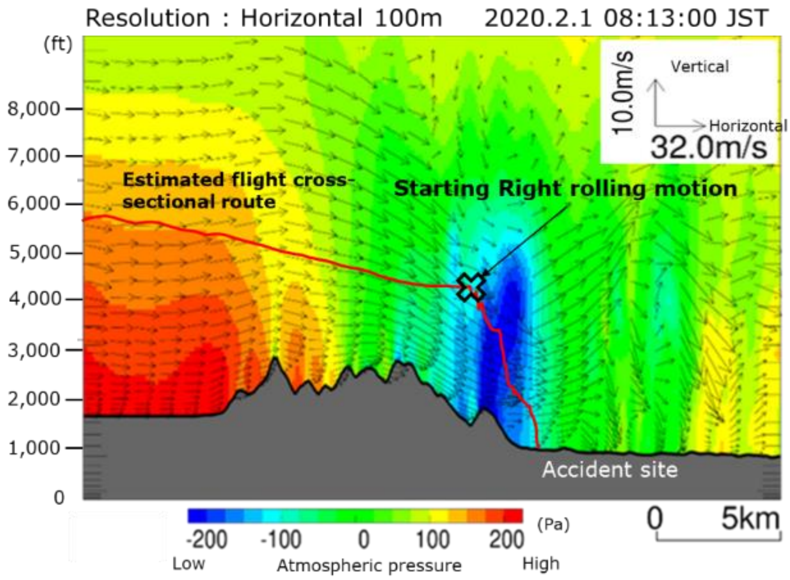

Figure 9 Distribution map of wind and Atmospheric pressure deviation along the cross section

5. Why did the pilot make such large control movements?

When the main rotor cut off the tail drive shaft, the captain fully operated the cyclic to the right rear position and operated the collective from down to up. The captain stated that when the IAS rapidly increased, he thought the helicopter would somersault forward. In addition, according to the flight control data on the MPFR, the FTR SW was frequently pressed throughout the entire flight. When we asked the captain about the timing of pressing the FTR SW in response to turbulence, he seemed to think that pressing the FTR SW and making corrections in SAS mode would allow for faster corrections than making corrections in ATT mode.

The FTR SW is a function that releases the steering reaction force applied according to the amount of operation of the flight control device, and while a pilot is pressing the FTR SW, the mode is changed from ATT mode (attitude maintenance function) to SAS mode (stability augmentation function). During this time, the SAS function is working, but since operating the FTR SW while pressing it makes the steering force constant and no steering reaction force is obtained, it is probable that the captain operated it to the maximum operable position.

6. Safety Actions

(1) Important notes when flying over mountainous regions in strong winds

Although it is difficult to accurately predict the location of strong vertical winds as in this accident, especially when general wind orthogonal to mountainous areas blows, large-amplitude mountain waves are generated and rapid change in horizontal wind velocity is expected to occur. Therefore, it is necessary to constantly monitor the weather conditions outside the aircraft and changes in flight specifications, and to fully consider the flight control capability of the aircraft so as to be able to respond to sudden weather changes, and to select appropriate flight control mode during flight.

When flying with a tailwind, if there is a significant difference between airspeed and ground speed, it is necessary for pilots to decelerate in advance above the areas where mountain waves would occur and fly selecting the appropriate altitude and flight route.

(2) Implementation of recurrent trainings using the FFS and others

Pilots need to judge flight objectives and environmental conditions in order to select a proper flight control mode during the flight. In order to fully understand and properly use the flight control modes, it is necessary for them to read carefully the flight manuals and other related documents and learn the differences of flight control by using the FFS and others.

With normal flight training and ground training only, it is difficult to respond quickly and calmly between two pilots in the event of an emergency operation. Therefore, as much as possible, it is desirable to conduct trainings using the FFS and others that are corresponding to each boarding aircraft type and including the coordination of two pilots.

7. Investigation Difficulty

(1) Confirming reasons for the rapidly increase in IAS

We described that the law of inertia is why IAS increases rapidly when horizontal wind speed decreases rapidly. According to the JTSB report, there were three accidents involving large aircraft that have occurred in Japan in the past, in which IAS increased rapidly. These occurred when the aircraft past a front passed or over mountainous areas, but their final reports did not describe the reason for the increase being due to the law of inertia.

To confirm why IAS increased due to inertial forces, the wind speed was rapidly decreased in the flight simulator by inputting from 50 kt to 0 kt and checking the increase in IAS. We confirmed that Ground Speed decreased slowly, and that IAS increased with the rapidly decrease in wind speed.

(2) An analysis of why the pilot is probable to have operated the cyclic to the rear right.

From the pilot's statement that he was trying to loop forward, it was easy to imagine that he operated the cyclic backward. In addition, as for operating the cyclic to the right, it was easy to imagine that he operated it to the right, since the helicopter had tilted to the left before operating it to the right. However, to understand the slightly tilt to the left when the pilot pressed the FTR, it was necessary to fully understand the shape of the helicopter and the flight control system.

(3) Challenging weather simulation

The data used in the weather simulation was an analysis of observation data every three hours, and according to the meteorological researcher who requested the weather simulation, they said that the observation accuracy includes an error of one hour. When we initially performed the analysis with a resolution of 1 km, we confirmed the approximate location of the change in airflow, but it did not lead to the reason for the increase in IAS. However, after continuing discussions with the meteorological researcher, we performed the simulation with a resolution of 100 m, and we found that the location of the decrease in wind speed coincided with the estimated flight path with an error of a few minutes. In addition, when we created a distribution map of air pressure and air currents with a resolution of 100 m, we clarified the location of the downdraft. The researcher said that this was the first time that such a fine resolution meteorological analysis was compared with a flight recorder, and that he would like to use it in future research.

[1] AIRCRAFT ACCIDENT INVESTIGATION REPORT, Fukushima Prefectural Police Aviation Unit, JA139F, https://www.mlit.go.jp/jtsb/eng-air_report/JA139F.pdf

[2] A “hydraulic jump” is a phenomenon which is observed in a fluid where airflow passing over obstacles including mountains increases the speed rapidly, and a sudden updraft (jump) occurs on the leeward side of the obstacle.