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Bureau d'Enquêtes et d'Analyses
pour la sécurité de l'aviation civile

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SAFETY INVESTIGATION REPORT

Accident to the BELL 47G-2 registered F-BIFN on Wednesday 12 July 2023 at Arles

Time	Around 10:05[1]
Operator	GIRAGRI 17
Type of flight	Spraying
Persons on board	Pilot
Consequences and damage	Pilot severely injured, aircraft substantially damaged
This is a courtesy translation by the BEA of the Final Report on the Safety Investigation. As accurate as the translation may be, the original text in French is the work of reference.	

Loss of yaw control during a spraying flight

1 HISTORY OF THE FLIGHT

Note: The following information is principally based on statements and data transmitted by Giragri 17 from the PCMCIA card of the helicopter's GNSS computer.

At around 07:40, the pilot took off from the trailer to start fertiliser spraying operations by helicopter over an area of rice fields to the south of the town of Arles (see **Figure 1**). He was assisted by a staff member responsible for ground operations.

Between 08:00 and 09:40, he carried out 33 spraying rotations. At 09:53, after refuelling for 12 min, the pilot resumed the spraying operation, at the end of which he initiated a return leg to the fertiliser supply area. During this phase, the pilot lost yaw control of the helicopter, which started yawing to the left, fell some 20 m and ended up in the submerged part of a rice field.

The pilot managed to extricate himself from the helicopter and reach the dyke by his own means.

[1] Except where otherwise indicated, the times in this report are in local time.

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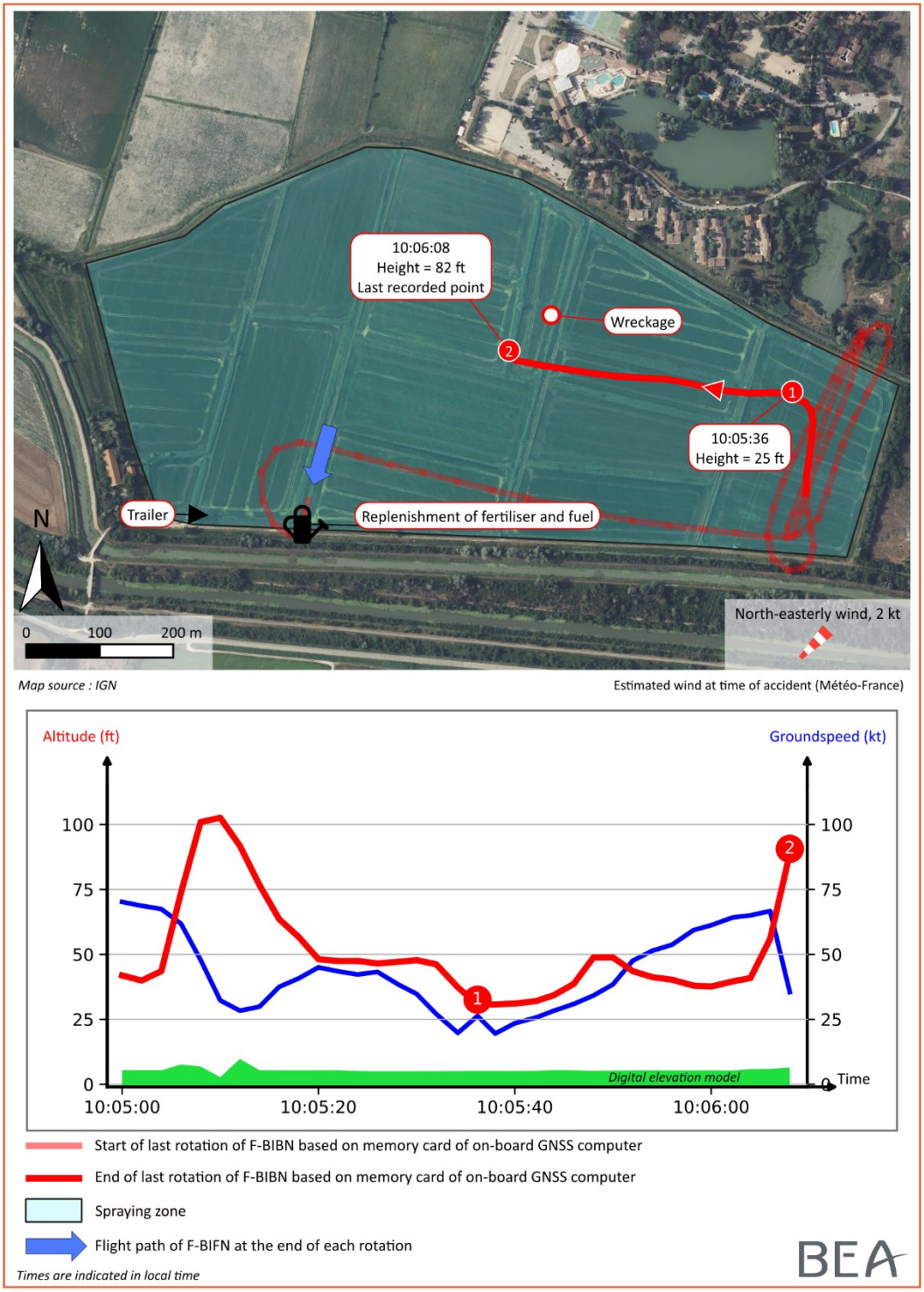

Figure 1: paths before the accident

Note: the end of the flight was not recorded in the memory card of the computer. This lack of data is probably linked to the setting of the GNSS computer, which recorded a point every two seconds, and to a recording failure of the computer at the time of the collision with the ground.

2 ADDITIONAL INFORMATION

2.1 Examination of site and wreckage

The accident site was a field covered by a few centimetres of water located to the south of the town of Arles (Bouches-du-Rhône). The helicopter was intact and tipped over onto its left side on the ground.

All of the damage observed on the helicopter's entire structure was caused by the collision with the ground. The left skid initially hit the ground, causing the helicopter to tilt onto its left side. The distortions observed, particularly on the tail boom, are consistent with a moderate-energy impact while the helicopter was rotating about its yaw axis in a counter-clockwise direction, with an attitude close to zero.

The fertiliser tank was found filled to a third of its capacity.

2.1.1 Examination of mechanical drives

A detailed examination of the main gearbox (MGB) did not find any particular anomaly. The free wheel had no damage. It was operational.

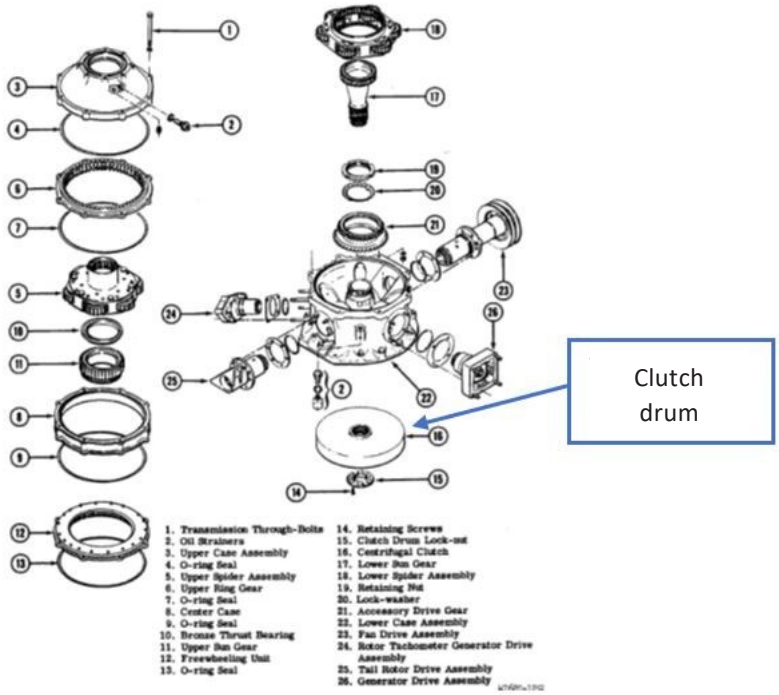

Figure 2: MGB and junction with the engine (main rotor drive)
(Source: manufacturer, Bell 47 Maintenance Manual)

The clutch was visually examined. The thickness of the linings was greater than the minimum required[2]. Significant discolouration, consistent with local heating, was observed at the bottom of the drum. It was not possible to determine whether this discolouration was normal. On the day of the accident, the clutch had logged 1,555 flight hours. The manufacturer prescribes an intermediate visual inspection of the clutch every 600 hours and an overhaul every 1,200 hours. The last overhaul was carried out on 15 December 2021. Since then, the helicopter had logged 306 flight hours.

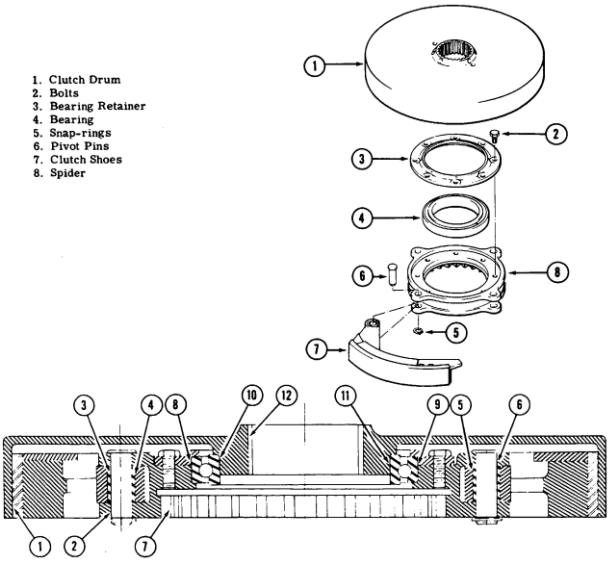

Figure 3: clutch parts (Source: manufacturer, Bell 47 Maintenance Manual)

The tail rotor drive was ruptured in torsion, in line with the junction between the MGB and the short front shaft of the tail rotor drive. The observed distortion was consistent with a drive shaft still being driven by the engine. After this rupture, the entire tail rotor drive rotated freely. Both blades of the tail rotor (T/R) were damaged at the tip. Combined with the rupture in the tail rotor drive shaft, this observation indicates that the T/R blades struck the ground, in the presence of power transmission from the MGB to the T/R.

All of the ruptures observed on the rotor mast was caused by the collision with the ground. One of the two main rotor blades had multiple distortions (blade distortion lengthwise under compression, distortions locally under torsion, warped coating). This blade most likely touched the ground first, with the helicopter being in an tilted position. The other blade is only slightly damaged.

2.1.2 Examination of the flight controls

The cyclic and collective pitch control linkages were continuous from the stick/lever to the rotating star at the bottom of the rotor mast. The ruptures in the control linkages observed at the top of the rotor mast were caused by the collision with the ground. The control linkages were continuous at the time of the collision with the ground.

[2] Based on the information provided by the operator, the clutch installed is a reinforced clutch based on Bell Helicopter Textron Service Instruction No 373 of 22/03/1965 amended on 16/09/1966 for pages 1 to 3 and on 07/03/1979 for pages 4 to 8, with P/N 47-620-690-1.
The reference measurements used to assess the condition of the clutch are therefore consistent with pages 4 to 8 of aforementioned SI 373.

2.1.3 Examination of engine and fuel system

The fuel tanks were partially filled with a mixture of water and fuel. The water probably came from the rice field on which the helicopter tipped over at the time of the impact with the ground. The fuel system control linkage was continuous from the red handle to the inlet on the fuel shut-off valve. From here, the fuel system was continuous from the tanks to the fuel filter and then to the carburettor.

The carburettor components were contaminated by an orange-coloured liquid. A smell of fuel was detected in the liquid drained from the bowl. This contamination is most likely the result of the carburettor being immersed in muddy water. As a consequence, it was not possible to test the carburettor as part of a test bench examination. Moreover, no internal damage was observed.

The engine control linkages were continuous, with reduced functionality for the throttle control. The air system had no damage. The carburettor heat control was operational. The continuity of the oil system was confirmed. The engine rotated freely without any restrictions. The borescope inspection of the cylinders did not reveal any internal damage. The ignition system was continuous. The magnetos and spark plugs were operational.

2.1.4 Clutch engagement conditions

In its section on starting and ground tests, the Bell 47 Flight Manual indicates that the engine speed must be increased up to a value between 2,200 and 2,300 rpm to prevent the clutch from slipping. The recommended engine speed during operation is between 3,000 and 3,200 rpm, and the recommended rotor speed is between 333 and 370 rpm.

As a general rule, increasing the main rotor pitch also increases the lift, and consequently, the drag coefficient that the main rotor has to overcome. This places a greater load on the clutch, which must transmit a higher torque from the engine to the main rotor. If the engine speed is not sufficient or is decreasing, this reduces the clutch's ability to transmit power efficiently to the main rotor. The torque transmitted by the clutch may not be sufficient to maintain engagement, which may cause clutch slip, or even increased clutch wear and overheating.

2.2 Meteorological information

The meteorological conditions estimated by Météo-France were as follows: north-easterly wind of 2 kt, gusts up to 8 kt, visibility greater than 10 km,clear sky, temperature 26°C, dew point temperature 21°C, QNH 1,015 hPa.

The pilot and the ground staff member reported that the wind was light.

2.3 Pilot information

The 56-year-old pilot held a Commercial Pilot Licence - Helicopters (CPL(H)) issued in 2014, replacing a CPL(H) issued in 2003. He held a Private Pilot Licence - Helicopters (PPL(H)) issued in 2001. He revalidated his rating on Bell 47s the day before the accident. His instructor stated that all the exercises were carried out correctly and that it seemed to him that the pilot had a good knowledge of the Bell 47 and how to fly it. He added that he drew the pilot's attention to the risks associated with high heat.

The pilot also obtained the following ratings:

- Robinson R22, issued in 2001;
- Hugues 300, issued in 2003;
- SA318/SE313 (Alouette II), issued in 2008 and valid until 2009;
- Bell 47, issued in 2001;
- Airbus Helicopters AS350/EC130 (Écureuil), issued in 2001 and valid until 2016.

He was registered as a civil aviation professional crew member since 2012. He held a Declaration of proficiency for aerial work in the agricultural, wine and forestry sectors.

He had logged 860 flight hours on helicopters, 720 hours of which on Bell 47s, 116 hours of which on R22s, 15 hours of which on Hugues 300s and 6 hours of which on Écureuils. He had logged 93 flight hours in the previous three months and 28 flight hours in the previous month, all of which on Bell 47s.

The pilot had been working for Giragri 17 as a helicopter pilot since 15 March 2023. He had previously worked for two other companies in Martinique and Senegal. As a consequence, he had already flown in very hot conditions.

2.4 Statements

2.4.1 Pilot's statement

He stated that, on the day of the accident, F-BIFN enabled him to change engine and rotor speed with quick and smooth transitions. He was seated in the left seat. The pilot reported that he felt a sudden yaw movement to the left, described as "a short sharp shock", while flying in a straight line at a stable altitude, approximately two rotations before the accident. He immediately corrected the movement. The rest of the flight went on normally.

As he was returning (empty) to the supply area, in forward flight at a speed of around 40 to 50 kt, with the power required (gas pressure of approximately 21 in) to maintain the height he estimated to be around 20 m, the helicopter suddenly began to yaw to the left at a relatively slow angular velocity. He specified that, at that moment, he was not applying any pressure on the left rudder pedal and was not making any input on either the collective pitch or the throttle controls. While the helicopter's yaw angle was less than 20° to the left, he tried to counter the movement by pressing the right rudder pedal, but it seemed "very soft" to him, and the input had no effect. He added that the helicopter suddenly began to spin very quickly to the left as soon as he pressed the right rudder pedal. He had the feeling that something had broken, because this second movement was not gradual. He no longer had any yaw control over the helicopter.

The pilot reported that the helicopter descended vertically, spinning very quickly, with a flat attitude and no bank angle. He was disorientated, lost track of time and waited for the impact with the ground.

He remembered that the helicopter was tilted on its left side and that the water from the rice field was entering the cockpit. He had his four-point harness fastened and his left arm trapped under the door jamb (he was flying without a door). He explained that he had difficulty unfastening his harness, which was taut. He finally extricated himself from the helicopter through a hole in the canopy after managing to free his arm by removing his watch, as the soil in the rice field was loose.

2.4.2 Ground staff member's statement

The staff member indicated that he has been working for Giragri 17 since August 2022. His main function consists in bringing the helicopter to the worksites and in ensuring it is supplied with oil, fuel and spraying products. He added that he had planned to take the Bell 47 rating during the week following the accident and that he held a CPL (H) and an Airline Transport Pilot Licence - Helicopters (ATPL (H)) as well as a Part 66 licence for aircraft mechanics and a French higher technician's licence (BTS) in aeronautics. He had previously been working at Airbus Helicopters in Marignane, where he performed maintenance tasks on Tigers and NH90s.

The ground staff member reported that when he arrived at the site at around 07:00, he prepared the Bell 47 and he did the greasing operation and the pre-flight inspection. Spraying operations began at around 07:30. He was in charge of topping up the helicopter with oil every ten rotations. He remembered adding the quantity of one oil can only once. He also added one hundred litres of fuel every time the helicopter was refilled with fertiliser. There were generally fifty litres of fuel remaining when he topped up.

According to him, the operations took place normally. The wind was calm.

He explained that the accident happened at the end of a fertiliser filling operation. The pilot usually turned at reduced speed and level off, with a flat attitude, yawing to the left. He saw the helicopter at a height of approximately 20 m, level off and at low speed, make a quarter turn with a flat attitude to the left. He thought at that moment that the pilot was making a U-turn. Then the helicopter began to spin very quickly to the left, like a top. He estimated that the helicopter made at least five spins with a flat attitude before hitting the ground. He heard the engine accelerate sharply approximately 5 m above the ground.

He called the fire brigade and went to the scene of the accident, where he found the pilot already out of the wreckage and around 20 m from it.

He explained that, after the accident, he removed the memory card from the GNSS computer that equipped the helicopter and that he took it back to the company's headquarters.

3 CONCLUSIONS

The conclusions are solely based on the information which came to the knowledge of the BEA during the investigation.

Scenario

At the end of a helicopter spraying sequence over a rice field, the pilot flew to the supply area to refill the helicopter with fertiliser. Flying forward at a speed of around 40 to 50 kt, with an intake pressure of 21 in and at a height of approximately 20 m, the helicopter suddenly began to yaw to the left. Initially, the angular velocity was relatively slow, but as soon as the pilot made an input on the right rudder pedal, the helicopter suddenly began to spin very quickly to the left and to lose height. The pilot was unable to maintain yaw control of the helicopter, which ended up in a partially submerged rice field after making at least five full spins.

The rupture in the tail rotor drive indicates that the MGB was delivering energy when the T/R made contact with the ground. The motion transferred from the engine to the MGB and rotor drives may have been effective, although the examinations carried out were unable to quantify its power.

When the rotor receives engine power, it generates a reaction torque which tends to make the helicopter spin in the opposite direction, i.e. to the right in the case of the Bell 47[3]. To counter this effect, the T/R produces an opposite force applied to the aft end of the fuselage. In hover flight, the pilot therefore applies pressure on the left rudder pedal to stabilise the helicopter in yaw. In the event of an engine power reduction in forward flight, if the pilot maintains the rudder pedals' position, the helicopter will begin to spin more or less rapidly to the left about the yaw axis, depending on the extent of the reduction.

The pilot reported that he felt a sudden yaw movement to the left, described as "a short sharp shock", while flying in a straight line at a stable altitude, approximately two rotations before the accident. He did not report any other similar events during the 25 spraying sequences that preceded the accident. Apart from a discolouration of the clutch drum, nothing unusual was observed on the helicopter prior to the collision with the ground. A clutch slip may cause disconnection between the engine and the main gearbox. As the rotor is

[3] The main rotor of the Bell 47 rotates counter-clockwise when viewed from above.

no longer receiving full power from the engine, the reaction torque decreases and the helicopter begins to yaw to the left. A clutch slip may result from a substantial reduction in engine revolutions, combined with an increase in the main rotor collective pitch.

In rapid yawing rotation situations, pilots may be subjected to high centrifugal forces, which may disorientate them and lead to a loss of control. In this event, when the helicopter yawed rapidly to the left, the pilot was centrifuged to the left, making it difficult to use the right rudder pedal. Using the rudder when the helicopter started to yaw would have made it possible to slow down and stop the rotation.