ACCIDENT

Aircraft Type and Registration:	Bell 206B3 Jet Ranger III, G-OPEN
No & Type of Engines:	1 Allison 250-C20J turboshaft engine
Year of Manufacture:	1994 (Serial no: 4300)
Date & Time (UTC):	30 May 2018 at 1223 hrs
Location:	Near Aldborough, North Yorkshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Fatal) Passengers - N/A
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Private Pilot's Licence
Commander's Age:	70 years
Commander's Flying Experience:	255 hours (of which 224 were on type) Last 90 days - 0.5 hours Last 28 days - 0 hours
Information Source:	AAIB Field Investigation

Synopsis

The pilot was flying G-OPEN from Husthwaite to Walton Wood Airfield for its annual maintenance check. The weather conditions en route were challenging with low cloud and reduced visibility. The helicopter was seen by several witnesses to be flying normally before climbing steeply into cloud. It was then seen to emerge from the cloud, rotate through 540°, then descend rapidly, striking the ground in an approximately level attitude. The helicopter became inverted and caught fire. The pilot was fatally injured.

The investigation did not find any evidence of pre-existing defects with the helicopter or its engine. It could not be determined why the helicopter entered cloud but it is probable that the pilot was distracted or became disorientated in the poor weather conditions. Having entered cloud it is likely that the pilot became spatially disorientated and was unable to maintain control of the helicopter.

History of the flight

The pilot was planning to fly G-OPEN from Husthwaite in North Yorkshire, where the helicopter was kept, to Walton Wood airfield for its annual maintenance check which was due the following day. This was a route the pilot had flown many times. The normal routing was to fly initially west-southwest through the gap between RAF Linton-on-Ouse and RAF Topcliffe MATZ[1] then turn left following the A1(M) south towards Walton Wood (Figure 1).

Footnote

[1] Military Air Traffic Zone.

The helicopter's co-owner pulled the helicopter out of the hangar at approximately 0700 hrs and left it on the helipad. The pilot arrived at the property at 0830 hrs but, after completing pre-flight checks, decided the weather was not suitable for the flight and left the property at 0906 hrs. He returned at 1150 hrs and lifted off at 1216 hrs. The cloud base en route was forecast to be between 300 ft and 700 ft with a possibility of visibility below the cloud reducing to 3,000 m.

At 1218 hrs the pilot contacted RAF Linton-on-Ouse ATC and requested a Basic Service. He reported he had just lifted from a private site at Husthwaite, destination Walton Wood, and was routing via Boroughbridge flying through "the gap". He reported he was at an altitude of 700 ft. Linton ATC issued a squawk and provided a Basic Service. The radar track of the route flown (Figure 1) shows that the helicopter flew slightly left of the planned track and penetrated the Linton-on-Ouse MATZ.

Witnesses saw G-OPEN passing above Humberton Farm (approximately 1.2 nm from the accident site) at low level. They reported the helicopter appeared and sounded to be flying normally.

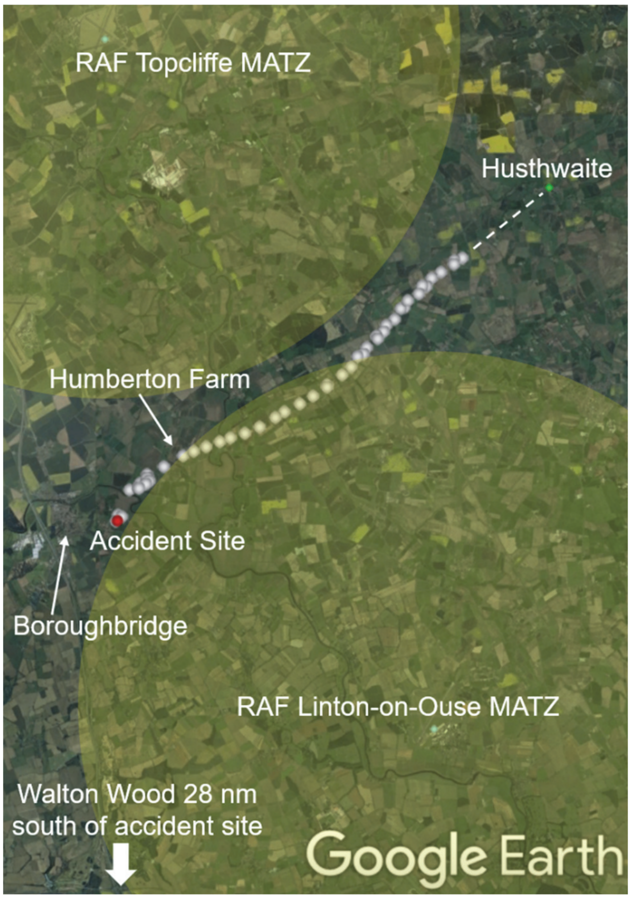

Figure 1

Radar track of G-OPEN
(Map data: Google, Landsat / Copernicus)

At 1223 hrs ATC heard a brief carrier wave transmission, which the controller thought had come from G-OPEN, and seconds later radar contact was lost. At about the same time the accident was reported to the emergency services by several witnesses.

Several witnesses near the accident site reported seeing and hearing the helicopter before the accident. Witnesses reported initially seeing G-OPEN flying normally before it pitched up into a steep climb and entered cloud. The helicopter could still be heard in the cloud and witnesses described it as sounding very loud. One witness described seeing the helicopter emerging from "the mist" and track across the sky at 100 to 150 ft. He described it as "not flying straight but was moving from left to right". As the helicopter moved away from him he described seeing it "spin around anticlockwise [cockpit turning to the left] one and half times before correcting itself". He then described seeing the nose coming up, banking to the left, the nose dropping and the helicopter descending to the ground. The witness recalled it taking approximately 15 seconds from first seeing the helicopter emerge from the mist to the impact. Several witnesses saw the helicopter enter a steep nose-down attitude and descend rapidly. Just before hitting the ground they described seeing the helicopter coming to a level attitude but the rate of descent continuing until impact.

Several witnesses heard the helicopter before the accident. They all described the sounds as very loud, louder than the helicopters they normally hear. Some witnesses described a constant beating sound which sounded like a large military helicopter. Others suggested that it sounded like the engine was struggling and that something was wrong.

Witnesses described the aircraft catching fire as soon as it hit the ground. Several people ran to the accident site, but the fire was too intense to get close to the scene. Emergency services arrived on site at 1233 hrs. An air ambulance attended the scene, landing at 1241 hrs, but the pilot of G-OPEN had suffered fatal injuries. A Coastguard helicopter also attended the scene, landing approximately 40 minutes after the accident.

Recorded information

There was no onboard recorded data available from the aircraft following the accident.

Secondary surveillance radar (SSR) returns from the helicopter were recorded for the flight starting 1.5 nm from the takeoff point and ending in the vicinity of the accident site. The returns included Mode C altitude information (rounded to the nearest 100 ft, ±50 ft) and indicated that the helicopter flew between 520 and 720 ft amsl at an average groundspeed of 97 kt until approximately 1 nm from accident site (Figure 2).

At this point, just over one minute before the last recorded data point, the helicopter was at 520 ft amsl, before climbing to 1,020 ft amsl 16 seconds later. This equates to a climb rate of between 1,500 and 2,250 ft/min, given the ±50 ft resolution of the altitude data. It then descended at a similar rate before climbing to over 800 ft amsl and descending again. The average groundspeed during these climbs and descents was approximately 60 kt. For the period the helicopter was above 920 ft amsl during the first climb the average groundspeed was 30 kt (these groundspeeds are highlighted in Figure 2).

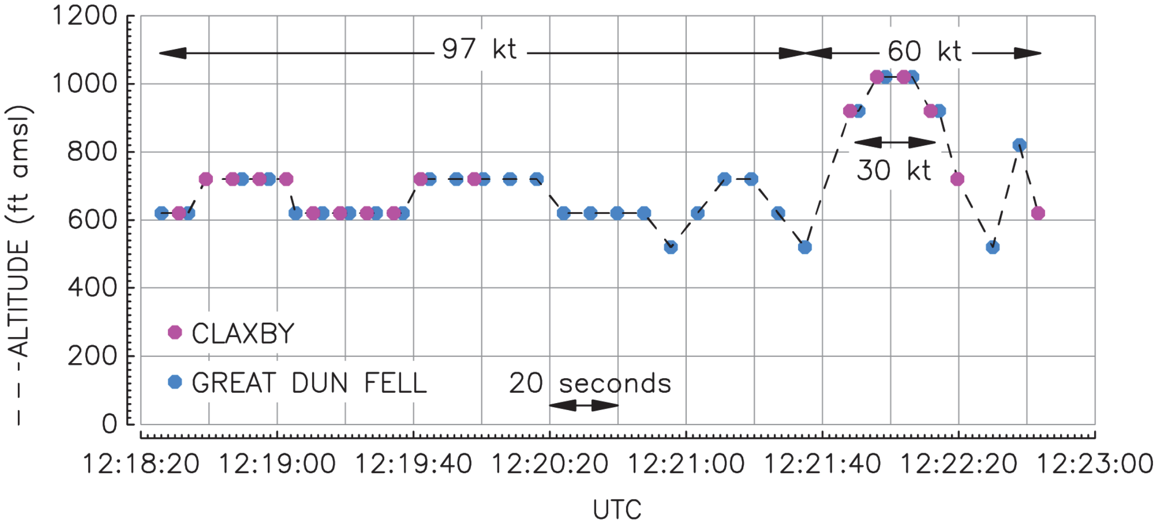

Figure 2

SSR Mode C altitudes for accident flight with average groundspeed indicated (note that the ground height along the route varied from 130 ft at the start to 40 ft near the accident site)

Helicopter information

G-OPEN (Figure 3) was a Bell 206B3, a single-engine light helicopter, powered by a Rolls-Royce (Allison) 250-C20J reverse-flow gas turbine engine, driving a two-bladed main rotor system through the main gearbox (MGB).

Figure 3

G-OPEN

The flying control system on the Bell 206B3 consists of control rods, bellcranks and levers, hydraulically boosted by three hydraulic actuators which transmit the cyclic and collective pitch inputs from the pilot. The tail rotor pitch inputs are operated via control tubes, but with no hydraulic assistance. In the event of a hydraulic system failure, the helicopter can continue to fly in response to the pilot's control inputs.

G-OPEN was fitted with analogue flight instruments and a two-axis Bendix King KAP 150-H autopilot, capable of controlling the helicopter's desired flight path by inputs from mechanical actuators mounted to the pitch and roll flight control linkages. The autopilot was controlled by an autopilot mode control/annunciator panel, mounted on the centre instrument console.

G-OPEN was constructed in 1994 and was first registered in the UK in January 2005 when it was acquired by the current owners, having previously been registered in the USA. The helicopter was being maintained in accordance with an approved maintenance programme and its Airworthiness Review Certificate (ARC) was valid until 12 April 2019. The last scheduled maintenance was a six-months inspection carried out on 13 March 2018 and included a compressor case inspection, an engine oil change and rectification of other minor defects. An engine ground run was carried out following the inspection. Since then, the helicopter had flown for a total of 1 hour 45 minutes on four flights, the most recent of which had been on 3 May 2018. The next scheduled maintenance was an annual inspection due on 31 May 2018. The helicopter was en route to the maintenance facility for this inspection when the accident occurred. G-OPEN had accrued a total of 4,038 flight hours at the time of the accident.

Accident site

The helicopter had come down in an approximately level attitude on flat ground in a crop field, on an heading of about 270°, striking the ground with a high vertical rate of descent and some forward speed (Figure 4). The distribution of wreckage and ground marks indicated that the tail was the first part of the helicopter to strike the ground, followed by the landing gear and main rotor. The helicopter became inverted and caught fire.

The landing gear skids and cross-tubes had separated from the airframe, such that the lower fuselage struck the ground causing the fuel cell to rupture.

Cut marks in the standing crop provided evidence that both the main and tail rotors had been rotating at impact. One of the main rotor blades struck the ground, causing the main rotor assembly to separate from the airframe and the helicopter to become inverted. Both blades were found still attached to the rotor head, approximately 31 m beyond the main wreckage. One blade was largely intact. The other blade exhibited extensive damage and a 75 cm section at the blade tip was absent; this was found approximately 70 m from the main wreckage, having detached and travelled opposite to the helicopter's direction of flight when the blade struck the ground.

The post-impact fire consumed much of the fuselage, cockpit, flight controls and fuel system. The top of the cabin, the flying control components on the transmission deck, together with the engine, sustained crushing damage as a result of the helicopter becoming inverted.

The engine oil tank had burst open; residual oil was present around the tank and an oil film was noted on a number of panels and the vertical fin.

A trail of light debris items was present on both sides of the main wreckage trail. These items included fuselage and engine cowling panels, doors and cabin interior trim.

Figure 4
Aerial view of the accident site

Detailed examination of the wreckage

Airframe – general

The fuselage had suffered extensive fragmentation during the impact, but there were no indications of pre-impact anomalies. The landing gear had splayed and separated from the airframe following the ground impact and both skids were broken in a number of locations. The aft cross-tube exhibited a slight spread but remained close to its normal shape; however, the forward cross-tube was flattened and broken on the left side, indicating that when the landing gear contacted the ground the helicopter was banked left, in a nose-down attitude and had a high rate of descent. All fractures were consistent with overload forces at impact.

Flying controls

All the damage observed in the mechanical elements of the flying controls was consistent with accident forces and exposure to the post-impact fire. All except one of the cyclic control rod connections were recovered from the wreckage and observed to be properly secured. However, the cyclic control bellcrank, to which the missing control connection normally attaches, exhibited an overload fracture similar to that observed at the other control connection locations. It was therefore concluded it had been connected at impact.

The hydraulic fluid reservoir was found empty and the hydraulic oil filter was destroyed in the post-impact fire. The hydraulic servos appeared intact and all hydraulic lines were connected or exhibited fractures consistent with overload forces at impact.

Fuel system

No fuel was recovered from the helicopter due to the post-impact fire and all damage to the fuel system was consistent with impact forces or fire damage.

Main rotor, tail rotor and transmission system

The blade which struck the ground exhibited downwards bending, had a spanwise deflection opposite to the direction of rotation and showed multiple impact damages including skin tears and gouges. This blade also exhibited a chordwise tear, approximately 1.5 m outboard of the mast and the outer portion of the blade remained attached only by a small section of trailing-edge blade skin. The released blade tip exhibited evidence of ground contact. All of these observations are consistent with overload forces experienced at impact.

The other blade was almost completely intact except for some creasing and deformation and the absence of the inboard trim tab, which was found in a different location. This was consistent with damage caused when the blade assembly came to rest after departing the helicopter.

The main rotor mast had severed just below the main rotor hub teeter (static) stops, and the failure was consistent with overload forces from excessive flapping following the ground strike. The teeter stops had made light impressions on the painted surface of the mast. These could be considered consistent with normal operation, or alternatively, could have occurred during the impact sequence. However, there was no indication of heavy 'mast-bumping[2]' contact between the teeter stops and the mast.

The main rotor gearbox was largely intact; however, the casing suffered impact and heat damage exposing the internal gears, which appeared to be in good condition and correctly meshed. The bottom chip detector was found clean while the top one for the mast could not be examined.

The driveshaft from the engine was intact but was disconnected at both ends; however, rotation marks on the isolation mount indicated that the shaft was rotating when it disconnected at impact. Despite impact and heat damage, the freewheel unit operated freely when rotated by hand.

The tail rotor hub and blades remained attached to the tail rotor gearbox assembly. Both blades sustained impact damage and broke chordwise at the root end. The tail rotor driveshaft exhibited torsional twisting and one of the 'Thomas coupling' assemblies was

Footnote

2 Mast bumping is a phenomenon that is associated with low-G manoeuvres or excessive manoeuvring, either intentionally or from over-controlling the helicopter. Mast bumping can cause the main rotor mast to fail due to excessive bending loads, leading to inflight separation of the main rotor.

torn; this was consistent with torsional overload caused by a stoppage from the tail rotor section while power was still being produced by the engine. No chips were present on the tail rotor gearbox chip detector.

Flight instruments

All the helicopter's flight instruments had been severely damaged during the impact and ensuing fire and no useful information could be drawn from them.

Autopilot system and caution and warning panel

The autopilot mode control/annunciator panel on G-OPEN featured six push-button switches to select autopilot operating modes and illuminated captions to annunciate if the autopilot is engaged and which modes are active. Each caption was illuminated by a single incandescent-filament light bulb.

The Caution and Warning Panel (CWP), located on the top of the instrument panel, comprised 20 caution lights, each illuminated by two incandescent-filament light bulbs. On G-OPEN the CWP was configured to display 12 different cautions, and the remaining light positions were spare.

Both the autopilot mode control and CWP panels were disassembled and the light bulbs removed for examination. Although largely intact the bulbs were extensively heat-damaged, which precluded visual examination. They were therefore imaged in a Computed Tomography (CT) scanner. Examination of the images did not show any evidence of filament hot-stretching, which can occur when a lit bulb is subject to very large deceleration forces. While this suggests that none of the bulbs examined were lit at impact, it could not be stated with certainty as it not known whether the impact deceleration forces experienced were sufficiently high to cause hot-stretching.

Engine examination

General

The engine was disassembled at an approved overhaul facility in the presence of representatives from the AAIB, engine and helicopter manufacturers.

The engine and its controls sustained substantial damage when the helicopter became inverted and it was therefore not possible to inspect the integrity of the engine control linkages.

The engine oil reservoir had split open so it was not possible to determine the oil level. The bypass indicator button on the scavenge oil filter was found extended but examination of the filter revealed that residual oil was present, with no debris noted within the filter element.

No cracks or abnormalities were observed on the fuel lines. The power turbine governor, fuel control unit and fuel pump could not be tested due to the extent of the damage sustained but each unit was disassembled. All damage appeared consistent with impact forces and thermal degradation due to the post-impact fire and fire damage. The fuel nozzle, when flow-tested was within the specified limits. The low-pressure fuel filter element displayed thermal damage and no fuel was present within the filter bowl.

The compressor front support exhibited crushing damage and the axial portion of the compressor had separated from the centrifugal impeller shroud, remaining attached to the engine only by the oil and anti-ice supply and scavenge lines (Figure 5). None of the 16attachment bolts were found at the accident site or recovered from the wreckage.

Figure 5
Axial compressor detached from impeller shroud

However, disassembly of the axial compressor showed distinct evidence of rotational damage; the rotor blades from the first three stages of the axial compressor were bent opposite the direction of travel (Figure 6) and all the stator vane stages were bent in the direction of travel (Figure 7). Additionally, the tie bolt was fractured into two pieces.

The centrifugal impeller displayed leading-edge damage consistent with hard-body impact damage and there was evidence of rotational contact between the impeller and the impeller shroud.

Disassembly of the turbine confirmed that the turbine shaft and all blades and nozzle guide vanes were intact. Some circumferential rub marks and scoring were noted on the third and fourth stage turbine wheels.

The magnesium accessory gearbox housing exhibited thermal degradation as a result of the post-impact fire; however, no missing gear teeth or mechanical damage were noted. Both magnetic chip detectors were clear and there was no debris in the pressure oil filter element.

Figure 6
Axial compressor rotor blades

Figure 7
Axial compressor case halves and stator vanes

The starter-generator cooling blades were uniformly fractured at the blade roots and the driveshaft was fractured at the manufactured shear point.

Small fragments of metallic debris were collected from the outer combustion case and compressor discharge tubes. Subsequent laboratory analysis determined that the material was a close match to 17-4PH grade precipitation-hardened stainless steel, consistent with the impeller shroud material, which exhibited scoring damage.

The compressor bleed valve was tested and while the action of the valve appeared satisfactory, the results were out of limits because the internal diaphragm had melted as a result of the fire.

Examination of axial compressor to impeller shroud attachment flange

The helicopter had undergone a six-monthly compressor case inspection in March 2018, during which the 16 axial compressor attachment bolts would have been removed. However, the helicopter had operated four flights totalling 1 hour 45 minutes of flight time since then without any reported issues. The engine manufacturer advised that the compressor would not operate for any length of time if the axial case halves were not securely attached to the front diffuser. The rotor would not be correctly located, either radially or axially and rotor/stator interference would be immediately evident, along with a significant air leak.

Laboratory examination of the axial compressor and impeller shroud attachment flanges identified bending deformation. The location and direction of this deformation indicated that it most likely resulted from the impact damage sustained at the forward end of the axial compressor. Mechanical damage adjacent to a number of the fastener holes, an example of which is shown in Figure 8, was consistent with fasteners being present in those holes at the time of impact.

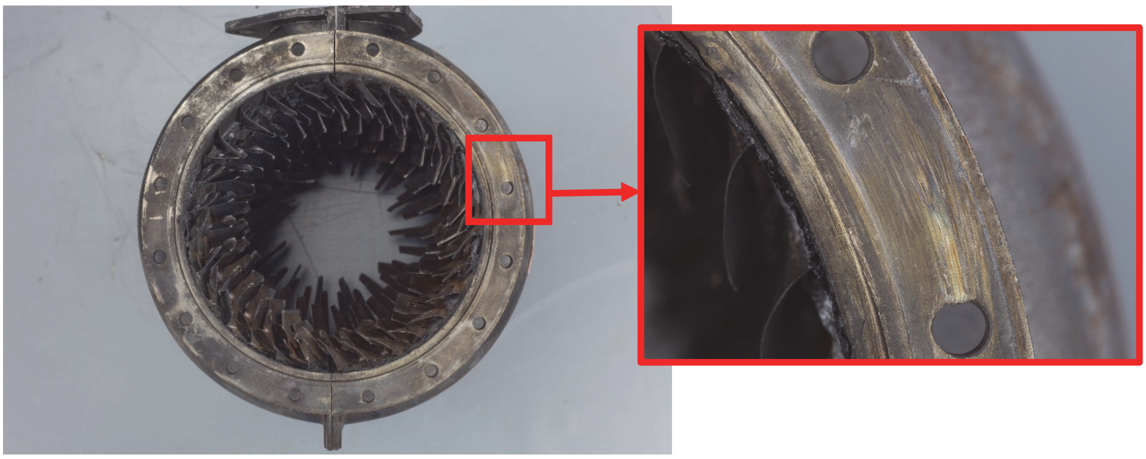

Figure 8

Axial compressor case flange showing mechanical damage at one of the fastener locations

The engine manufacturer indicated that it was aware of one previous Bell 206B3 accident in which the axial compressor had separated from the impeller in a similar manner. The helicopter had departed from controlled flight and struck the ground inverted, after striking electrical power transmission lines during a survey flight. The investigation into that accident[3] determined that the engine had been operating normally at the time the helicopter collided with the power lines and the engine manufacturer considered that the compressor damage was sustained during the impact with the ground.

Footnote

[3] Accident to Bell 206B, registration N5016U on 1 May 2010. National Transportation Safety Board (NTSB) report reference WPR10GA097.

Weight and balance

The helicopter was within weight and balance limits throughout the flight and sufficient fuel was loaded for the flight.

Meteorology

Forecast

Forecast information was available from the meteorological office for RAF Linton-on-Ouse and RAF Topcliffe which are close to the initial planned route. RAF Linton-on-Ouse forecast issued at 1053 hrs gave visibility greater than 10 km, cloud base broken[4] at 700 ft, temporarily[5] between 1200 and 1300 hrs cloud base scattered[6] at 500 ft with a 30% probability of visibility reducing to 3,000 m in light rain. RAF Topcliffe forecast issued at 1053 hrs gave visibility greater than 10 km, cloud base broken at 700 ft, temporarily between 1200 and 1500 hrs cloud base scattered at 500 ft with a 30% probability of visibility reducing to 3,000 m in light rain.

Walton Wood airfield, where G-OPEN was intending to land, does not provide weather forecasts. The closest airfield which has meteorological forecasts is Doncaster Sheffield Airport which is 12.5 nm SE of Walton Wood. The forecast for the time of G-OPEN's flight showed cloud base broken at 1,000 ft and visibility greater than 10 km, temporarily reducing to broken cloud at 600 ft and visibility 6,000 m with a 40% probability of broken cloud at 300 ft, visibility 3,000 m in light rain and mist.

It is not known what weather information was reviewed by the pilot prior to undertaking the flight. The pilot had a SkyDemon account, but this had not been accessed for several months. However, there are many other sources of meteorological information which he may have consulted.

Actual weather

A witness reported the visibility at Husthwaite was approximately 3 km when G-OPEN lifted off.

The accident site is located between RAF Linton-on-Ouse (5 nm SE) and RAF Topcliffe (6 nm N). At the time of the accident RAF Linton-on-Ouse was reporting cloud scattered at 500 to 600 ft and overcast between 800 and 1,500 ft with visibility below the cloud greater than 4 km. RAF Topcliffe reported cloud overcast at 300 ft and visibility between 3 and 8 km.

Surface winds reported at RAF Linton-on-Ouse and RAF Topcliffe just before the time of the accident were 330° at 10 kt and 360° at 11 kt respectively.

Footnote

4 Broken cloud is defined as 5 to 7 eighths cloud cover.
5 'Temporarily' means the conditions will not occur for more than one hour at a time and for less than half of the total time indicated.
6 Scattered cloud is defined as 3 to 4 eighths cloud cover.

The air ambulance pilot that landed at the accident site 17 minutes after the accident reported cloud base at 400 to 500 ft with visibility 3 to 5 km on scene. The air ambulance had been operating near Wetherby (south of the accident site) when tasked with attending the accident. They routed to the accident site following the A1(M) north, the same route G-OPEN would have flown in the opposite direction. The air ambulance pilot reported challenging weather conditions which required his local knowledge and air ambulance exemptions to operate.

The air ambulance pilot also commented that the weather at Husthwaite, where G-OPEN departed, may have been better than the accident site as his experience was that weather tended to be better in that area.

A Coastguard helicopter was also tasked with attending the scene, landing approximately 40 minutes after the accident. The Coastguard helicopter pilot confirmed the weather on scene as cloud base 500 to 600 ft with visibility 4 to 5 km.

Pilot information

The pilot held a helicopter Private Pilot's Licence (PPL(H)) with a Bell 206 rating which was valid until 31 August 2018. He initially qualified in 2006.

The pilot's logbook was onboard the helicopter and was damaged in the accident; however, the last few entries were legible and recorded total flying hours of 254.5 hours including 126.1 hours as pilot in command. A statement given to the insurance company in August 2017 confirmed he had a total flying time of 250 hours with 224 hours on type.

The pilot's last flight before the accident was on 13 March 2018, lasting 30 minutes, flying the same route as the accident flight. Prior to this flight, the pilot had not flown since his licence skills test on 11 August 2017. Between 13 April 2017 and 11 August 2017, the pilot had undertaken 18.7 hours of refresher training following two years without flying. The pilot planned to fly on 27 October 2017 but this flight was abandoned due to a flat helicopter battery.

The pilot was not qualified to fly in instrument meteorological conditions. The PPL(H) training syllabus includes 'basic instrument awareness' in case of inadvertently entering into poor visibility or cloud. The pilot's basic instrument awareness was refreshed during the training undertaken in 2017.

Several people who had flown with the pilot commented that he was a "good pilot" who was very conscious of the weather. They described him as "very cautious" and "meticulous with his checks". They observed that he was the type of pilot who only flew in good weather and was "the last person who would fly in poor weather". Some people commented that they were very surprised that the pilot had decided to go ahead with the flight given the prevailing conditions. One of the pilot's previous instructors did note that, like many pilots, the accident pilot's skill levels did seem to drop with lack of flying practice.

On the day of the accident the pilot had arranged for a friend to collect him on arrival at Walton Wood. Several people also commented that the pilot had a busy diary and that it was difficult for him to fit helicopter flying around his other commitments.

Medical

The pilot held a Class 2 medical which was valid until 21 July 2018.

Witnesses who met or spoke to the pilot on the day of the accident reported that he appeared to be in good health. It was reported that he had been suffering from toothache on the day before the accident and had recently experienced a nose bleed. It was also reported that he had suffered a minor knock to the head when he slipped on the stairs on the evening before the accident. Advice from a CAA doctor suggested that these conditions are unlikely to been causal factors in the accident but could have caused a minor distraction during the flight.

Post-mortem report

The post-mortem report stated death was caused by multiple injuries. It also noted evidence of moderate coronary heart disease but indicated that the degree would not usually be expected to cause sudden death or incapacitation, however it might have been symptomatic. Toxicology showed no evidence of alcohol or any other significant drug. Carboxyhaemoglobin saturation was negative, confirming that the pilot died as a result of injuries sustained in the impact, rather than the effects of the post-impact fire.

Other information

Helicopter flight in reduced visual conditions

Helicopters are naturally unstable and require constant input from the pilot or an automatic stabilisation system (not fitted to G-OPEN) to maintain the correct attitude. When flying in visual conditions pilots primarily determine the helicopter attitude using the visual cues from the environment outside the helicopter. As visibility reduces it is much harder for the pilot to determine, and detect small changes in, the attitude and if the attitude is not controlled, control of the helicopter can be lost. Once a helicopter enters cloud no external visual cues are available and the pilot must transition to using the helicopter instruments to determine attitude.

Without adequate visual reference it is very easy for a pilot to become spatially disorientated. Spatial disorientation occurs when a pilot does not correctly sense the aircraft attitude relative to the Earth's surface. Without visual reference the human body uses senses in the ears, skin and muscles to determine 'which way is up'. However, these senses can give incorrect, conflicting or ambiguous information leading to disorientation. Spatial disorientation presents a danger to pilots and can often lead to incorrect control inputs and possible loss of aircraft control.

In 2007 the CAA published a study into the hazard of helicopter flight in degraded visual conditions[7]. The report highlights how challenging it can be for an average pilot to control a helicopter in poor visibility. The UK AIP Aeronautical Information Circular (AIC) P 067/2013 *'Helicopter Flight in Degraded Visual Conditions'*[8] also highlights the challenge of flying a helicopter in degraded visual conditions and how easily a pilot can become disorientated.

'Blade slap'

Witnesses reported hearing a constant loud beating sound from the helicopter. It is likely that this sound was 'blade slap', which can occur when a rotor blade passes through the trailing vortex of the preceding blade. It tends to occur during transient manoeuvres and is often associated with steep turns, with shallow descents and with flaring manoeuvres. It is particularly prevalent on helicopters with two main rotor blades. It creates a loud beating sound, consistent with that described by the witnesses.

Pre-flight risk assessment

A number of tools are available to assist pilots in assessing the risk involved in a particular flight. The use of pre-flight risk assessment is recommended in CAA Safety Notice SN-2017/003[9]. An example, which can be used for general aviation flights, is published by the European Helicopter Safety Team (EHEST)[10]. The tool consists of 27 questions and categories a flight as 'low risk', 'caution' or 'high risk'. The tool also highlights significant risk areas. These tools enable pilot to make decisions about whether to fly or to think how they could modify their plan to reduce the risk.

Analysis

Helicopter and engine

The helicopter's records showed that it had been maintained in accordance with its approved maintenance program and there were no recorded defects at the time of the accident.

The investigation did not identify any defects which would have prevented the helicopter from responding normally to the pilot's control inputs. The evidence found at the accident site showed that the helicopter struck the ground with a high descent rate. Examination of the wreckage and ground marks indicated that both the main and tail rotors were operating under power at the time of impact.

There was no evidence of pre-impact damage or a pre-existing defect which would have prevented the engine from responding normally to control inputs. The damage observed

Footnote

7 CAA Paper 2007/03 Helicopter Flight in Degraded Visual Conditions available at https://publicapps.caa.co.uk/docs/33/Paper200703.pdf (accessed February 2019).

8 UK AIP Aeronautical Information Circulars available at http://www.nats-uk.ead-it.com (accessed February 2019).

9 CAA Safety Notice SN-2017/003 - http://publicapps.caa.co.uk/docs/33/SafetyNotice2017003.pdf (accessed February 2019).

10 EHEST Pre-flight Risk Assessment Checklist - https://www.easa.europa.eu/document-library/general-publications/ehest-pre-departure-risk-assessment-checklist (accessed February 2019).

to the engine was consistent with it operating normally immediately prior to the impact, as evidenced by rotational damage to the axial compressor, the impeller and its shroud, the turbine and the starter-generator cooling blades.

The axial compressor had separated from the impeller. It was concluded that bending loads arising from the impact damage sustained to G-OPEN's compressor front support housing caused the attachment bolts to fail, leading to separation of the axial compressor.

The evidence provided by examination of the lightbulbs from the autopilot mode control panel and the CWP was not sufficiently conclusive to determine whether the autopilot was engaged or whether any warnings were illuminated on the CWP, at the time of impact.

Weather conditions

The forecast weather for the destination and airfields en route showed cloud ceiling between 700 ft and 1,000 ft and a probability of cloud base reducing to 300 ft. The visibility below the cloud was forecast to be 6,000 m or greater with a probability of visibility reducing to 3,000 m. The actual weather conditions on the intended route were described by an experienced pilot as "very challenging".

The route was typically flown at approximately 1,500 ft. These weather conditions meant that the pilot would have needed to fly much lower to remain clear of cloud. Flying lower increases workload because a pilot needs to be more aware of terrain and obstacles and it is harder to see a clear horizon, making it more difficult to hold the helicopter at the correct attitude. It is also more challenging to navigate as a pilot cannot see as far and landmarks are harder to locate.

Whilst these weather conditions were above the legal weather minimums for a VFR flight, the low cloud base and reduced visibility would have made the flying conditions challenging.

Pilot recency

The pilot had not flown for 77 days prior to the accident flight and had only flown for 30 minutes in the last 10 months. The weather conditions during this 30 minute flight had been good. Pilots who knew the accident pilot described him as a competent pilot; however, like most pilots, his flying skills would have deteriorated with lack of practice.

There are no recency requirements for pilots of privately-owned helicopters flying solo. To fly with passengers, EASA regulations require the pilot to have completed three takeoffs and landings within the preceding 90 days. If an aircraft is hired from a commercial organisation, recency requirements are normally specified. Although these vary between organisations, a typical recency requirement would be to have flown within the last 28 days.

The pilot's lack of recency is likely to have made the flight more challenging and increased his workload.

Decision to fly

The purpose of the flight was to take the helicopter for its annual maintenance check, which was due the following day. This may have created a perception that the flight needed to go ahead on this day. However, the maintenance company stated that an extension could have been obtained and that this had been done in the past and the co-owner indicated that he would have been able to operate the flight at another time.

The pilot reportedly had a busy diary. He had arranged for a friend to collect him from Walton Wood and if he had not undertaken the flight it is likely that it would have been many days before he could find another opportunity to fly. These factors may have contributed to his decision to go ahead with the flight.

It is not known what meteorological information the pilot consulted prior to the flight, however, forecasts suggested a cloud base en route of between 300 ft and 700 ft. Without being qualified to fly on instruments, a pilot would need to fly below this altitude.

The combination of poor weather, low recency and perceived need to undertake the flight on this day would have contributed to the risk involved in this flight. The pilot was described as someone who only flew in good weather. A number of people who knew the pilot were very surprised he had decided to go ahead with the flight given the prevailing conditions.

The EHEST flight risk assessment tool was later used by the AAIB to assess the accident flight. Although the answers were not known for some of the questions, the tool would likely have categorised this flight as 'caution'. It is not known whether the pilot was aware of this pre-flight risk assessment tool or if he had used it before. Routine use of such a tool may cause a pilot to reconsider undertaking a flight that is categorised as 'caution' or 'high risk' or to take steps to mitigate some of the risks.

Accident flight

The pilot contacted RAF Linton-on-Ouse ATC at 1218 hrs to request a Basic Service. At this time the pilot did not report any problems. The helicopter was seen 1.2 nm from the accident scene and appeared to the witnesses to be flying normally although lower than they were used to seeing helicopters. The initial flight is recorded on radar at an altitude of 520 to 720 ft and a groundspeed of approximately 100 kt.

In the last minute before the accident, radar shows the aircraft descending to 520 ft, climbing to 1,020 ft and then descending back to 520 ft and the ground speed reducing to below 30 kt. It is not known whether these were intentional or unintentional climbs and descents. These were not observed by any witnesses, so it is not known whether the helicopter entered cloud at this time. It is possible the pilot was experiencing a varying cloud base and was changing height to remain clear of cloud. If the pilot was experiencing reducing visibility it would be logical to reduce speed, so this may have been the reason for the reducing ground speed. Alternatively, the pilot may have been becoming disorientated in the challenging weather conditions and was not aware of the change in altitude. The radar trace shows the helicopter flew left of his intended route and entered RAF Linton-on-Ouse MATZ (Figure 1).

ATC reported that it is not unusual for aircraft to enter the MATZ whilst transiting the gap, but the slight deviation from the planned track is a possible further indication that the pilot was disorientated.

As the helicopter approached Boroughbridge witnesses saw the helicopter pitch up and climb into cloud. The last radar point also shows the helicopter was at a height above the base of the cloud. The pilot was not qualified to fly in cloud, so it is unlikely that this was intentional. There are several possible explanations for the climb into cloud;

a) Spatial disorientation – It is possible that the pilot experienced a degraded visual environment and had become disorientated. Without a clear view it is difficult for a pilot who is not experienced in instrument flying to maintain the correct attitude. It is possible that the pitch up into cloud was the pilot attempting to maintain what he perceived as the correct attitude.

b) Distraction – It is possible that the pilot made an inadvertent control input which caused the helicopter to climb into cloud. This could occur if the pilot was distracted or was reaching to retrieve something in the cockpit.

c) Avoiding action – ATC confirmed that there was no other traffic shown on radar in the area at the time of the accident. However, it is possible that the pilot saw a bird which caused him to take avoiding action. Birds are a significant hazard for helicopters and it would be normal for pilots to avoid a collision.

d) Medical – The post-mortem did not reveal any condition which would explain the sudden pitch up into cloud. The pilot was suffering from a few minor conditions which could have caused a distraction.

e) Technical failure – There was no evidence of any malfunction that would account for the pitch up and climb into cloud. It is possible that a minor malfunction occurred which caused a distraction resulting in an inadvertent climb, however, there was no evidence of this.

Having entered cloud, it is challenging to continue to control a helicopter without experience and training in instrument flying. It is likely that the pilot would have experienced spatial disorientation when deprived of the normal visual cues. The pilot was not qualified to fly in instrument conditions; he would have received training in how to manage inadvertent entry into cloud but this is normally practiced from level flight. Having entered cloud in a steep climb it would be much more challenging to regain control.

Numerous witnesses reported hearing the helicopter whilst in cloud and it was reported as sounding very loud. No evidence was found of a mechanical failure of the helicopter which would account for the noise reported by the witnesses. It is likely that the noise was caused by a combination of 'blade slap', by the helicopter being at low altitude and the pilot making large control inputs whilst trying to control the helicopter.

The helicopter was seen by one witness to emerge from cloud and track across the sky before spinning one and half times and then rapidly descending. Numerous witnesses saw the helicopter in its final descent. With a cloud base of 400 to 500 ft over the accident site the pilot would have had very little time to regain control of the helicopter having exited the cloud. It is likely that the pilot was unable to regain control before the impact with the ground.

Conclusion

The investigation did not identify any evidence of pre-existing technical defects with the helicopter or its engine.

It could not be determined why the pilot decided to undertake the flight on this day. The combination of poor weather, low recency and perceived need to complete the flight would have contributed to the risk.

The helicopter was seen to climb into cloud prior to the accident. It could not be determined why the helicopter entered cloud but it is probable that the pilot was distracted or became disorientated and entered cloud inadvertently.

Having entered cloud it is likely that the pilot became spatially disorientated and was unable to maintain control of the helicopter. Having exited the cloud with a low cloud base it is likely the pilot did not have sufficient time to regain control before impact with the ground.

This accident highlights the importance of adequate pre-flight risk assessment and the hazard of flying helicopters in poor weather without adequate recency and experience.