ACCIDENT

Aircraft Type and Registration:	Bell 206B Jet Ranger II, G-RAMY	
No & Type of Engines:	1 Allison 250-C20 turboshaft engine	
Year of Manufacture:	1974 (Serial no: 1401)	
Date & Time (UTC):	6 June 2015 at 0805 hrs	
Location:	Near Creg-ny-Baa, Isle of Man	
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 (Helicopter)	
Commander's Age:	48 years	
Commander's Flying Experience:	786 hours (of which 71 hours were on type) Last 90 days - approximately 6 hours Last 28 days - approximately 6 hours	
Information Source:	AAIB Field Investigation	

Summary

The pilot of G-RAMY, a Bell 206B Jet Ranger II, had disembarked his two passengers and lifted off for the return flight, in an area of mountainous terrain. The wind was from 220-230°, gusting to 46 kt and the aircraft was seen to head initially into the wind. It was then seen to turn right onto a north-easterly track and the fuselage was seen to oscillate in roll. The fuselage then rotated in yaw beneath the rotor disc, more than once, and the nose of the helicopter pitched up into the rotor disc, being destroyed as it did so. The fuselage of the helicopter, its rotors and many fragments then fell separately to the ground, where the fuselage impact was not survivable for the pilot.

Examination of the wreckage showed that there had been a catastrophic failure of the helicopter's main rotor mast in flight and there was clear evidence that this had been due to heavy 'mast bumping' contact between the teeter ('static') stops on the main rotor head and the main rotor mast. This was consistent with the observed behaviour of the helicopter, where the pilot appears to have been attempting to control the aircraft in turbulent conditions.

History of the flight

Only limited witness information, and some recorded data, provided evidence relating to the accident flight. The helicopter had flown from a private landing site in Bedfordshire and landed on an unprepared private landing site close to the 'Creg-Ny-Baa'; the engine had been shut down and two passengers disembarked. The Creg-Ny-Baa is a public house on the Mountain Road north-west of Douglas, approximately 2 nm inside the northern edge of the Class D Control Zone surrounding Ronaldsway Airport.

The engine was re-started and the aircraft lifted off at around 0804 and flew on a south-westerly heading for a short distance before turning right onto a north-easterly track towards Windy Corner. No communications from the aircraft were received by Ronaldsway ATC.

One eyewitness gave the most detailed account of the final moments of the flight. He was on his motorcycle driving south along the Mountain Road (A18), north of the accident site (Figure 1). He described seeing the helicopter flying relatively low towards him, at moderate speed, before the fuselage began to oscillate in roll, pendulously, through ‘a few tens of degrees’ each way. The fuselage then completely rotated in yaw beneath the rotor disc, more than once. The nose of the helicopter then pitched up into the rotor disc, being destroyed as it did so. Another witness described that *‘[the helicopter] had a sudden change of direction that occurred in a split second’* just prior to its descent. Other witnesses’ recollections differed in detail but were broadly similar. Witnesses estimated the height of the helicopter at between 100 and 300 ft agl prior to the described oscillations.

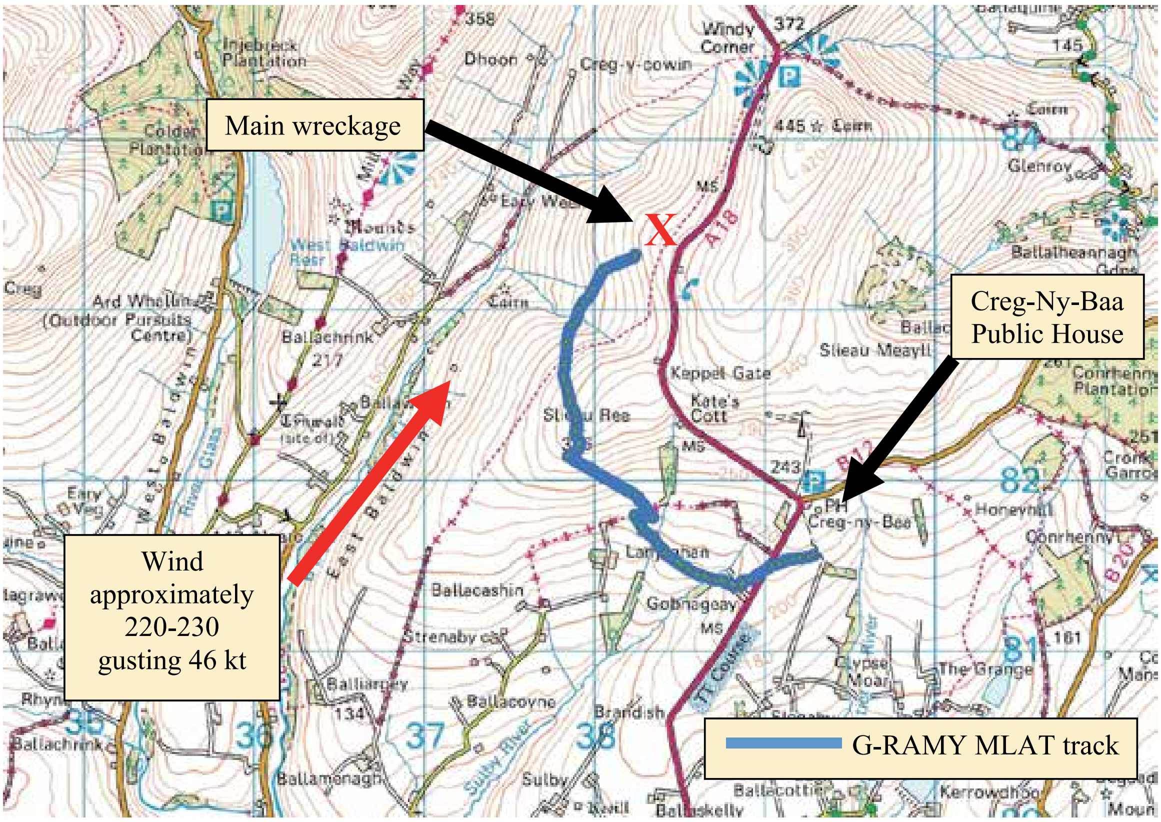

Figure 1

The accident location and recorded multilateration track

The fuselage of the helicopter, its rotors and many fragments then fell separately to the ground, where the fuselage impact was not survivable for the pilot.

Previous flight

The helicopter had departed from a private landing site at Woburn, Bedfordshire, around 0530 hrs with the pilot and two passengers on board and flew towards the Isle of Man, where it then routed towards the Creg-Ny-Baa.

At 0744 hrs, the pilot reported that he had his destination in sight, and the controller passed the Ronaldsway surface wind, which was from 230° at 22 kt, gusting to 33 kt.

The pilot flew an orbit north of Douglas and then carried out a reconnaissance of the landing site. He made an approach into wind and landed the helicopter. The final position of the helicopter recorded by radar was at 0746 hrs as it approached its landing site. The pilot shut the helicopter down and the passengers disembarked. He telephoned the manager at the flying school from which he had hired the helicopter and left a voice message informing her that he had arrived at the Creg-Ny-Baa, before starting the helicopter and lifting off on the accident flight.

Meteorology and terrain

On the day of the accident, weather conditions in England were relatively benign but those affecting the Isle of Man were more challenging.

The Ronaldsway TAF, issued at 0400 hrs, forecast surface wind from 230° at 28 kt gusting to 38 kt, visibility 10 km or more and one or two octas of cloud with a base 2,500 ft aal. The southernmost part of the Isle of Man is relatively flat and low-lying, but complex terrain further north rises to a peak of 2,037 ft amsl approximately 2 nm north of the accident site. The terrain south-west of Creg-Ny-Baa is a valley, which appeared to funnel the wind towards the accident site and the turn in the road (Figure 1) known as Windy Corner.

Data from two anemometer sites elsewhere on the Isle of Man was obtained, which showed stronger winds inland. At one site, Brandywell, 1.5 nm north-north-east of the accident site, the recorded wind direction remained relatively constant around the time of the accident, at around 220-230°, but the speed and gusts were more variable, with the highest gust, 46 kt, recorded at about the time of the accident (Figure 2).

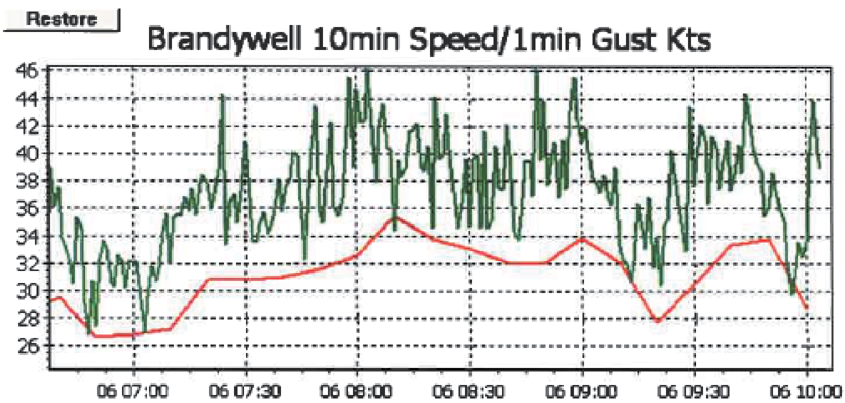

Figure 2

Wind speed and gusts recorded at Brandywell (timeline is 6 June 0630 hrs to 1010 hrs)

An air ambulance pilot landed an Airbus Helicopters AS355 Ecureuil 2 helicopter close to the accident site shortly after the event. His experience, gained over 25 years including seven years flying air ambulance operations on the Isle of Man, amounted to approximately 8,500 hrs. He commented on the conditions in the area at the time he landed, stating that the visibility was "excellent" and the cloud base was "quite high", but the wind was "extreme" with a speed of 40 kt or higher and associated turbulence. He opined that the conditions were entirely unsuitable for a private pilot with the accident pilot's flying hours.

The pilot

The pilot learnt to fly fixed-wing aircraft before training for a PPL(H) on the Robinson R22 helicopter in 2005, after which he added a type rating on the B206 to his licence. He maintained his proficiency on two single-engined piston aeroplanes and the B206. The flying instructor who carried out his rotary-wing proficiency checks described that he had very good retention of his skills despite not flying very often, and that his general handling skills were "very good". She had discussed 'low-g' and 'mast bumping'[1] with him the day before the accident, mindful that he was an experienced fixed-wing pilot also flying a helicopter; instinctive reactions on the flying controls in fixed-wing aircraft may have undesirable results in rotary-winged aircraft.

The pilot had discussed his plan for the Isle of Man flight with the flying instructor, covering fuel planning, alternate landing sites, and other matters. She considered that he was "properly prepared" for the flight.

His total flying time was 786 hours, of which 126 hours was on helicopters. The pilot held a current Class 2 medical certificate.

Post-mortem examination

A post-mortem examination of the pilot was carried out by a consultant pathologist. He found that the pilot had died of multiple injuries. The pathologist's report noted that:

> *'the severity of the injuries to the left hand, and possibly also the right hand, are very suggestive of the pilot having his left hand, and also possibly his right hand, on the controls of the helicopter at the time of the accident. This implies that the pilot was conscious at the time the injuries were sustained. … There is no suggestion that natural disease played a part in the causation of the accident and the toxicological analyses are also essentially negative.'*

Mountain flying

'Mountain flying' is a term applied to flight operations in mountainous areas, and in the context of training refers to a range of skills which can be taught and learnt. Military rotary-wing pilots receive such training at the conclusion of their flying courses. The EU has made provision for the introduction of mountain ratings in civil helicopter licences, and

Footnote

1 'Mast bumping' is described further in this report, under '**Other information**'.

the EASA reflected on this in '*Additional ratings for Part-FCL licence holders RMT.0565 & RMT.0566 (FCL.016) — ISSUE 1— 25/09/2013*':

> *'When drafting the initial requirements for Part-FCL, Member States' representatives and industry licensing experts proposed to also develop a specific mountain rating for helicopters, but due to time constraints the Agency postponed this task and offered to launch a separate task on this at a later stage.'*

As far as the investigation was able to determine, the pilot of G-RAMY had not received training in mountain flying techniques.

Flight within controlled airspace

Prior to entering or lifting off into Class D controlled airspace, a pilot must obtain clearance from the relevant ATC unit. If radio contact from the landing site was not possible (on account of terrain and the line-of-sight nature of VHF radio communications), a pilot in the circumstances in which G-RAMY lifted off could have obtained permission for his departure before losing contact with the controller on arrival, or telephoned while on the ground for permission to lift off and then established contact with the controller when a suitable height was achieved.

Published advice concerning flight in strong winds and potential 'low-g' conditions

'Allowable wind'

The Bell 206 flight manual states:

> *'OPERATION VS ALLOWABLE WIND*
>
> *Satisfactory stability and control in rearward and sideward flight has been demonstrated for speeds up to and including 20 MPH (17 knots) at all loading conditions; however, this is not to be considered a limiting value as maximum operating wind velocities have not been established.*

'Mountainous terrain'

The EASA published a document on its website entitled *'Techniques for Helicopter Operations in Hilly and Mountainous Terrain'* which stated:

> *'2.5 Turbulence*
>
> *In mountainous areas turbulence is often encountered. This can either be mechanical turbulence (due to the friction of the air over uneven ground at low levels), or thermal turbulence (due an air temperature instability at mid levels). Turbulence affects the behaviour of the aircraft in flight and increases the threat of retreating blade stall, vortex ring and LTE (loss-of-tail-rotor-effectiveness) as the ground and air speed fluctuates. For helicopters equipped with teetering rotor systems there is the additional danger of main rotor mast bumping and rotor / tail strike.'*

'Low-g' conditions and 'mast bumping'

In the USA the FAA publishes the *'Helicopter Flying Handbook'*. In *'Helicopter Emergencies and Hazards'*, in a section titled '*Low-g Conditions and Mast Bumping',* it states:

> *'Low acceleration of gravity (low-g or weightless) maneuvers create specific hazards for helicopters, especially those with semi-rigid main rotor systems because helicopters are primarily designed to be suspended from the main rotor in normal flight with only small variations for positive-g load maneuvers. Since a helicopter low-g maneuver departs from normal flight conditions, it may allow the airframe to exceed the manufacturer's design criteria. A low-g condition could have disastrous results, the best way to prevent it from happening is to avoid the conditions in which it might occur.*
>
> *Low-g conditions are not about the loss of thrust, rather the imbalance of forces. Helicopters are mostly designed to have weight (gravity pulling down to the earth) and lift opposing that force of gravity. Low-g maneuvers occur when this balance is disturbed. An example of this would be placing the helicopter into a very steep dive. At the moment of pushover, the lift and thrust of the rotor is forward, whereas gravity is now vertical or straight down. Since the lift vector is no longer vertical and opposing the gravity (or weight) vector, the fuselage is now affected by the tail rotor thrust below the plane of the main rotor. This tail rotor thrust moment tends to make the helicopter fuselage tilt to the left. Pilots then apply right cyclic inputs to try to correct for the left. Since the main rotor system does not fully support the fuselage at this point, the fuselage continues to roll and the pilot applies more right cyclic until the rotor system strikes the mast (mast bumping), often ending with unnecessary fatal results. In mast bumping, the rotor blade exceeds its flapping limits, causing the main rotor hub to "bump" into the rotor shaft. The main rotor hub's contact with the mast usually becomes more violent with each successive flapping motion. This creates a greater flapping displacement and leads to structural failure of the rotor shaft. Since the mast is hollow, the structural failure manifests itself either as shaft failure with complete separation of the main rotor system from the helicopter or a severely damaged rotor mast.'*

Recorded information

The air navigation service provider on the Isle of Man was in the process of commissioning a new multilateration surveillance system, which records aircraft position approximately every second using the aircraft's transponder. Their staff stated that because the system was not yet commissioned, the accuracy of this recorded data could not be assured.

Position data for G-RAMY's reported takeoff time was provided from this system and is shown in Figure 1. The track began near the Creg-Ny-Baa at 0804:01 hrs. The track then broadly followed that described by eyewitnesses and ended at 0805:18 hrs, approximately 120 m from the location of the main wreckage.

Engineering

Aircraft history

The helicopter was constructed in 1974 and was first registered in the UK in September 1995, having previously been registered in the USA. There were three registered owners before the current one, who acquired the aircraft in November 2000.

Documentation relating to the aircraft included engine and airframe logbooks. The Airworthiness Review Certificate (ARC) was due to expire on 11 February 2016. The most recent maintenance was an Annual Inspection, carried out on 22 May 2015 at 3,067.6 airframe and engine hours, 4,880 engine cycles; this represented the final logbook record. The Technical Log was recovered from the wreckage and recorded three flights since the last inspection, totalling 2.1 hours up to the 5 June, the day before the accident. No technical defects had been recorded.

Accident site details

The helicopter had come down onto a heather and grass covered hillside. The main rotors were found approximately 120 m northwest of the main wreckage, with no other wreckage items in the area in between; it was thus immediately apparent that separation had occurred whilst airborne. A trail of light debris items extended for approximately 500 m from the main wreckage in a north-easterly direction. The items included pieces of transparency from the windscreen and other windows, fragments of cabin interior trim and light pieces of structure from the nose and air intake area. Closer to, and slightly downwind of, the main wreckage were two deep holes in the ground, at the bottom of which were found the battery and a ballast weight; both these items had been in the helicopter nose and the depth to which they had penetrated the earth indicated they had been ejected at altitude.

The fuselage had landed in an inverted attitude with the tail boom almost detached. The tail rotor blades had sustained crushing damage as a result of ground contact but showed little evidence of rotation. The tail rotor driveshaft had separated close to the point where the tail boom joined the fuselage, with evidence of a torsional failure that indicated the shaft was being driven at impact. Despite the fact that the main rotor blades had departed in flight, there was no evidence that they had struck any part of the tail boom.

The top of the cabin, the flying control components on the transmission deck, together with the engine, sustained severe crushing damage as a result of the inverted impact attitude. The engine oil tank had burst open and the filler cap had come off despite the rim of the filler neck appearing un-deformed. Residual oil was present around the tank and an oil film was noted on the horizontal stabiliser.

Examination of the main rotors and rotor head revealed that the rotor mast had failed approximately 3 inches below the rotor head lower surface. It was evident that the mast had failed as a result of bending overload after coming into violent contact with one of the teeter, or static stops; see Figure 3. A deep cut in the ground close to where the rotors were found indicated that the rotor disc had struck the earth in a near-vertical attitude and one blade had broken under the sudden bending and compressive load. Both blades had been extensively scuffed over an area around their mid-span points, with the most severe damage being on the leading edges and undersides.

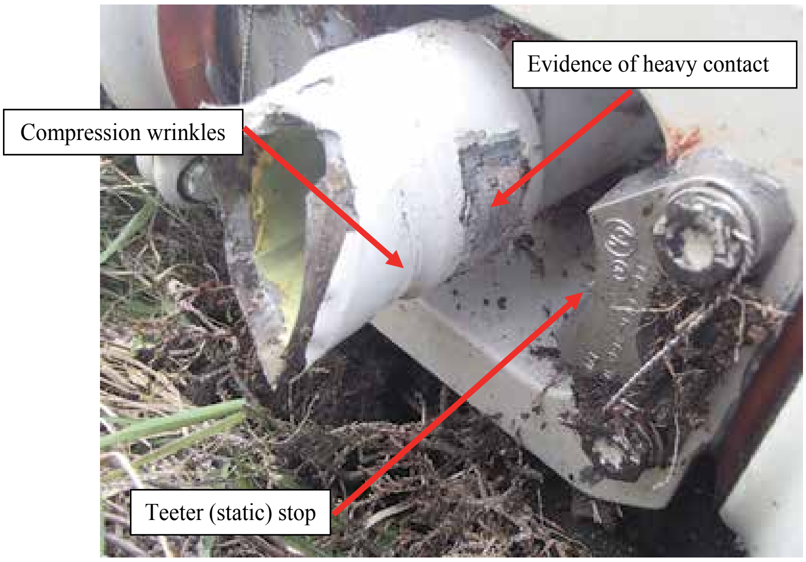

Figure 3

View of fractured mast, showing evidence of contact between mast and teeter ('static') stop

The wreckage was gathered together before being removed from the site; it was then transported to the AAIB's facility at Farnborough for additional examination.

Detailed examination of the wreckage

Airframe – general

The flying control system on the Bell 206 consists of bellcranks, rods and levers, hydraulically boosted by three hydraulic actuators; these 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 on most aircraft, including G-RAMY. The hydraulic power is provided by a pump mounted on the front of the main rotor gearbox. The pump has an integral fluid reservoir. However, during the detailed wreckage examination the reservoir was not identified, so it was not possible to confirm fluid contents at the time of the accident.

The flying controls were all accounted for and the fractures were attributed to overload. These had occurred during the impact with the ground and the yaw pedals on the left side had been disconnected from the rest of the system. The flight control components located on the cabin roof, forward of the main gearbox, had sustained particularly severe damage as a result of the inverted impact. The piston tubes of the hydraulic servos, also located in this area, had been severely distorted in the impact and there were numerous failures of the associated hydraulic lines, all consistent with overload. The control rods between the servos and the swashplate assembly, which controlled the cyclic and collective main-rotor blade pitch, had broken into a number of sections, again, as a result of the inverted impact. The pitch-change links that had connected the rotating swashplate with the rotor blade pitch horns had each failed at the approximate mid-point; the fractures were attributed to overload and were consistent with the in-flight departure of the rotor blades.

The tail rotor blades had sustained bending damage but were not fractured; the lack of chordwise scuffing suggested low rpm at impact. It was found that an overload failure had occurred in the tail rotor mast (the output shaft from the tail rotor gearbox), close to its junction with the tail rotor hub.

Main rotor blades

As already noted, there were areas of scuffing and paint transfer on the underside of both blades. These areas started approximately 90 and 104 inches from the centre of the hub and were not symmetrical. The paint marks were consistent with the blades having struck the right side of the nose of the helicopter, this conclusion being supported by the observed damage to the structure and that fragments from the nose were recovered from the furthest downwind part of the debris trail. Additional confirmation was provided by the VOR instrument, which had been located in the upper right area of the instrument binnacle but was found some distance from the main wreckage as a result of being struck by a blade, leaving a characteristic indentation in the casing. One blade exhibited a scuffed region that began a relatively short distance, 42 inches, from the hub centre, the result of the blade underside coming into contact with the front of the glassfibre fairing on the cabin roof. The combined information enabled a precise assessment of where the rotor blades had struck the airframe, illustrated in Figure 4.

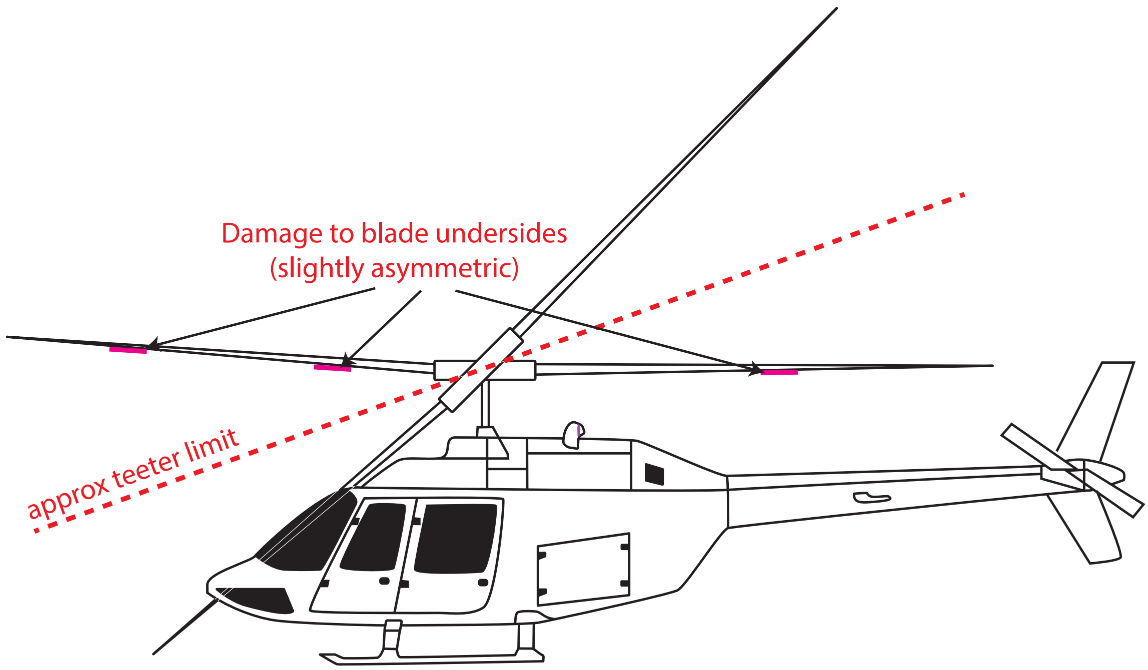

Figure 4

Showing blade strike location on fuselage

The hub assembly had remained intact although it was clear that the static (teeter) stops had come into heavy contact with the mast, such that they applied severe, reverse bending loads in the spanwise plane of the blades. Figure 5 shows the relative angular motion that occurred between the mast and hub.

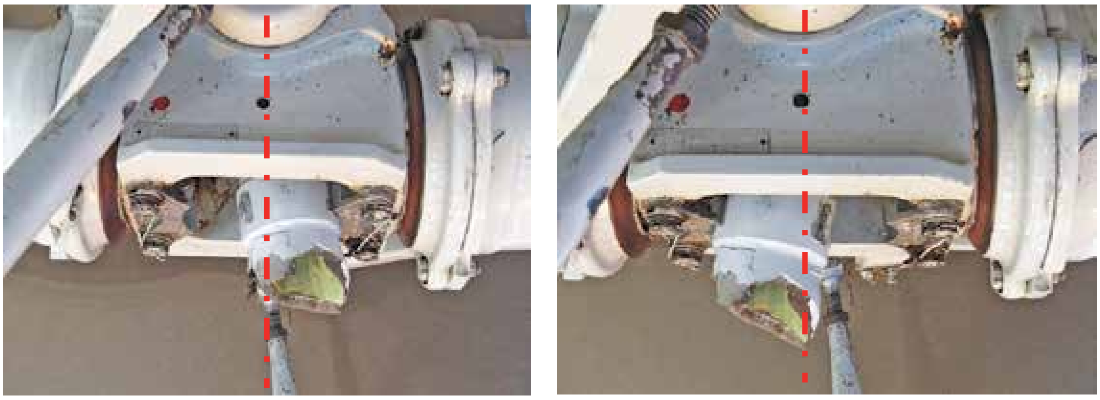

Figure 5

View of hub showing angular movement between hub and mast, resulting in heavy mast contact with teeter stops

The bending loads had been higher in one direction, as can be seen in Figure 5, where the surface of the mast adjacent to the static stop contact displayed compression wrinkles. The mast had become permanently bent in that direction, although the final failure was probably closer to the opposite direction, as evidenced by a shear lip, also visible in Figure 5. This feature, together with the permanent deformation of the mast and the 45° shear plane of most of the fracture face, indicated that the mast failure was the result of bending overload, which, in itself, was characteristic of 'mast bumping'. Such events can involve a large number of bending reversals within a short time. However, in this case, the relatively clean nature of the fracture face, in conjunction with the rotor blades being intact when they separated from the airframe, suggested that the bending failure occurred within one or two revolutions.

Transmission system

The main rotor gearbox had remained attached to the transmission deck although it had been rotated aft as a result of the mast contacting the ground during the inverted impact. Despite this the gearbox was intact with superficial damage to the casing. Manually rotating the input driveshaft caused corresponding rotation of the mast and subsequent removal of the top case revealed the internal components to be in good condition. The gears had remained in mesh and rotated smoothly and freely. No debris was apparent on the magnetic chip detector.

The driveshaft from the engine was in several pieces, as were the drive couplings, parts of which were not recovered. The damage was consistent with shaft misalignment that would have occurred during the impact with the ground. Despite this impact, the freewheel unit was found to function correctly.

A number of fractures were observed in the tail rotor driveshaft, all consistent with impact damage. All the coupling assembly between the shaft segments had remained intact, although there was considerable distortion as a result of shaft misalignment that would have occurred as a result of impact damage to the tailboom. It was also noted that the hanger bearings on the driveshaft rotated freely.

The tail rotor gearbox had remained intact, although the splined connection with the final tailboom driveshaft segment had become disconnected during the impact. The gearbox input shaft could be rotated by hand, which smoothly turned the fractured output shaft (the tail rotor mast). The chip detector was clear of debris, although the gearbox contained very little oil. No reason was established for this.

Engine

The inverted impact had resulted in severe damage to the engine and its controls; however there was no evidence of a pre-impact disconnect of the controls.

The engine was removed from the airframe and taken to a UK overhaul facility and was disassembled in the presence of representatives from the AAIB, engine and helicopter manufacturers.

The external fuel lines had remained secure, with one exception, which was considered the result of impact forces on the fuel pipe. The fuel filter bypass button was found extended but examination of the filter element revealed no contamination and the low-pressure filter was also clear, with the filter bowl full of fuel.

The compressor had sustained severe crushing damage. The first rows of blades in the axial stage were bent against the direction of rotation from contact with the compressor shroud. The impeller stage had been in heavy contact with the shroud, which had sustained significant abrasion damage. It is likely that this resulted in the metal spatter found on the first-stage nozzle shield and there were impact marks, consistent with compressor blade debris, present on all the turbine wheels and nozzles.

There was no evidence of pre-impact damage in any bearings or accessory gears and there was evidence of adequate lubrication. Similarly, there was no evidence of pre-impact damage in the power turbine governor, fuel pump or fuel control unit and the fuel nozzle, when flow-tested, was within the specified requirements.

In summary, the damage observed within the engine was consistent with normal operation, with the evidence of metal spatter and rotational damage indicating that the engine was operating at the time of impact.

Other information

'Mast bumping'

'Mast bumping' occurs when a helicopter's teetering ('static') stops, within the main rotor hub, make contact with the mast, such that it deforms and, in certain circumstances, results in complete failure. The phenomenon is peculiar to two-bladed, teetering head systems, such as fitted to the B206 helicopter. The manufacturer states that:

> *'Mast bumping is a phenomenon that is extremely rare and is associated with 'low-g' manoeuvers or excessive manoeuvring either intentionally or from over-controlling the helicopter.'*

Excessive flapping is required in order for the hub to contact the mast and, according to textbooks on the subject[2], flapping amplitude is increased by:

- Gusty wind conditions
- Sudden attitude changes caused by abrupt cyclic inputs
- Sideways flight at or near the helicopter's maximum allowable speed
- Flight under 'low, zero or negative g' conditions

Of these, 'low-g' is considered to be the most dangerous for mast bumping and can occur as a result of applying forward cyclic control, such as in a push-over manoeuvre or reacting to a sudden up-draught. This results in reduced blade angle of attack and increased induced flow into the rotor disc, which in turn leads to significantly reduced thrust being produced by the main rotor and, as a consequence, can result in low, zero or even negative 'g'. In a zero-thrust condition, the fuselage is no longer directed by the rotor disc and is free to move in any direction. The most significant force acting on it is the tail rotor thrust, generally to the right. Because the thrust line is above the centre of gravity there will be a roll to the right, irrespective of the disc attitude, accompanied by a yaw to the left. On its own, the right roll will reduce the clearance between the hub and the mast and, if left cyclic control is then used in an attempt at correction, it will produce upward flapping in the right side of the disc such that the clearance further reduces to the point that mast-bumping contact occurs. Under normal, 'positive-g', conditions the left cyclic input would have produced a horizontal component of total rotor thrust to the left, creating a moment that would have brought the helicopter back to the required attitude.

Previous 'mast-bumping' event investigated by AAIB

A similar pattern of structural damage was seen in a fatal accident which occurred to an Agusta Bell B206 Jet Ranger, G-SHRR, on 11 August 1997 at Nether Kellet, Lancashire. The helicopter was engaged on a gas pipeline inspection and was cruising at a height of around 600 ft agl at a speed of 80 kt. It was observed to perform an abrupt turn to the right, described as flat or only slightly banked. Shortly afterwards it was seen to roll

Footnote

[2] '*Principles of Helicopter Flight'* by W J Wagtendonk and '*The Helicopter Pilot's Guide'* by Steven P Sparrow were referred to in the compilation of this Bulletin report.

rapidly to the left and pitch down. One main rotor blade struck the nose and the aircraft fell to the ground. The weather conditions were generally benign, with a variable surface wind of 5 kt or less. The full report was published in AAIB Bulletin No 4/99, File Reference EW/C97/8/6.

Examination of the wreckage indicated that the aircraft had suffered a severe mast bumping incident, although there was no clear technical reason for the cause. There was evidence of multiple bending load reversals on the mast prior to failure, probably more than had occurred on G-RAMY. However the position of the main rotor blade strikes on the fuselage was virtually identical.

Analysis

The pilot held a valid licence, medical, and type rating, and the aircraft was serviceable for the flight. Although the weather conditions affecting the previous flight, until it neared the Isle of Man, had been benign, conditions on the island were not and strong gusty winds up to 46 kt were affecting the Creg-ny-Baa area. As the aircraft flight manual, FAA handbook, and EASA document stated, strong winds pose a challenge to helicopter operations. In turbulence, mast bumping is a particular hazard. However, there was no wind limit published in the flight manual.

The lift-off occurred within the controlled airspace around Ronaldsway, but without clearance. The choice of a downwind flight path, following the first moments of the flight, might have reflected a desire on the pilot's part to fly out of the controlled airspace promptly.

There was no evidence of pre-impact failure of the flying controls and the examination of the engine indicated that it was operating at the time of the impact with the ground. It is noteworthy that one of the eyewitnesses described the aircraft oscillating from side to side shortly before the main rotor blade sliced into the nose. This is likely to have been an indication of the pilot's control inputs in his attempts to cope with the gusty conditions. A control system failure, such as a disconnect, would be more likely to cause a steady divergence in one direction. The observed oscillatory motion therefore suggests that the system was intact. Thus, the available evidence indicates clearly that the accident occurred as a result of mast bumping, leading to structural failure of the main rotor mast.

The multilateration surveillance system recorded the helicopter travelling approximately downwind, although it was not possible to derive an accurate groundspeed. This agreed with the available witness information. The location of the main wreckage, a short distance upwind from the battery and ballast weight, which had become detached from the aircraft whilst airborne, suggests that there may have been an abrupt change of heading immediately before, or perhaps during, the break-up; this accords with one eyewitness account of the flight. Similar behaviour was observed prior to a similar mast bumping event that occurred, in benign weather conditions, in 1997. The strong wind conditions that prevailed on the day of the G-RAMY accident, which may have intensified as the aircraft progressed higher up the valley, is likely to have caused the pilot to make large control inputs in his attempts to maintain a stable flight path in the turbulent conditions. The strongest recorded gusts of wind coincided with the time of the lift-off and this coincidence may have contributed to the accident. The relatively lighter winds at Rondaldsway, which were passed to the pilot, would not have alerted him to the much stronger winds near the Creg-Ny-Baa.

Appropriate training in mountain flying techniques and the associated hazards could have assisted the pilot in executing the flight successfully, or making a decision not to fly in the challenging wind conditions which prevailed.