ACCIDENT

Aircraft Type and Registration:	Sud-Aviation SE-313B Alouette II, HA-PPC
No & Type of Engines:	1 Turbomeca Artouste II C6 turboshaft engine
Year of Manufacture:	1960 (s/n 1500)
Date & Time (UTC):	17 July 2016 at 1700 hrs
Location:	Breighton Aerodrome, Yorkshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 4
Injuries:	Crew - 1 (Fatal) Passengers - 4 (Serious)
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Private Pilot's Licence (H)
Commander's Age:	36 years
Commander's Flying Experience:	708 hours (of which more than 164 were on type) Last 90 days - 18 hours Last 28 days - 8 hours
Information Source:	AAIB Field Investigation

Synopsis

The helicopter flew along the runway at about 30 ft agl and carried out a quick stop. Witnesses reported a nose-up pitch attitude of around 45° was attained as the helicopter flared, then, as it levelled, the rotor blades struck the tail boom. The helicopter rotated to the right through 180° and dropped vertically to the ground. Everyone on board was taken to hospital; the pilot died subsequently. No technical failure was found which could explain the accident.

History of the flight

Previous flights

The pilot kept the helicopter at a private site located 27 nm to the east of Breighton Aerodrome. On the day of the accident he flew it to Breighton, where a vintage aircraft fly-in event was taking place. From there he flew several trips in the helicopter, taking friends and acquaintances for short flights. At 1636 hrs, following a local flight with three male passengers, the helicopter returned to Breighton. The pilot flew along Runway 28 and reduced speed above the runway, before flying towards the parking area in a steep nose-down attitude at a height of 30 ft to 50 ft. Approaching the fuel pumps the helicopter levelled and taxied forwards, however it pitched nose-down momentarily a couple of times, bringing the tail boom into close proximity to the rotor disc. It landed without incident in front of the fuel pumps; photographs taken from outside the helicopter showed a steady nose-down pitch attitude of 3° in the hover and at touchdown. The helicopter was refuelled with 112 litres of fuel.

Accident flight

The passenger who subsequently occupied the left front seat of the helicopter for the accident flight had flown an aircraft as part of a display formation earlier in the day. He had just finished putting it away when he met the pilot outside the hangar. The pilot offered him a flight in HA-PPC, which he accepted, and he went into the clubhouse to advise his partner. He then went to the helicopter, where he discovered there was a passenger who he knew seated in the back. Not knowing how much fuel was on board he asked the pilot if it was still alright for him to join the flight and whether there was room for anyone else. The pilot said it was fine and the passenger returned to the clubhouse to see if anyone else wanted to come. One person agreed and then a second asked if they could join as well. The passenger escorted them both out to the helicopter and checked with the pilot to see if they could join the flight. The pilot accepted them and they boarded in to the rear cabin.

The passenger who had invited the persons from the clubhouse, who was also a qualified helicopter pilot and instructor on another type of helicopter, occupied the left front seat; dual controls were fitted. Both front seat occupants wore full four-point harnesses. The other three passengers were seated on the bench seat in the rear of the helicopter, which was equipped with lap straps only. All persons on board were wearing headsets connected to the intercom system. A pre-flight safety briefing was not given to the passengers.

At 1648 hrs, with five persons on board, the pilot started up, lifted to a hover, turned 30° to the right and took off in a north-westerly direction. The helicopter was photographed in a 3° nose-down attitude in the hover. During the climb, the pilot offered control to the front seat passenger and a formal control handover took place. The passenger flew the helicopter to the west and then around to the south, performing some general handling manoeuvres at heights of between 1,000 ft and 2,000 ft amsl, before returning towards the airfield. He then flew along the runway at a height of around 100 ft, whereupon the pilot asked if he would like to do a zoom climb and a pushover at the end of the runway; the passenger declined.

The pilot resumed control, again with a formal handover, and suggested the passenger follow him through on the controls. He zoom-climbed to around 700 ft agl, pushed over into a steep descent before levelling at 400 ft to 500 ft agl and turning into a left-hand circuit pattern. He turned onto final approach at about 100 ft agl flew along the runway at a speed of around 55 kt before carrying out a quick stop. The front seat passenger reported that the quick stop was smooth and progressive with no perceptible yaw.

The onlookers described a nose-up pitch attitude of between 45° and 55° during the quick stop. As the helicopter pitched nose-down towards a more level attitude there was an audible “crack” and a “very loud bang”. One witness described seeing the tail lifting into the rotor disc. The main rotor blades struck the tail boom and the engine exhaust cowling; the tail rotor assembly separated from the helicopter. The helicopter rotated through 180° to the right as it dropped vertically to the ground.

Several bystanders ran across to assist. The helicopter was substantially upright but leaning to the right. The engine had detached from its mounting and was lying on the ground a few metres away; the sound of it spooling down could still be heard. Both doors had come open in the accident sequence. The pilot unfastened his harness and fell sideways out of his side door, his feet were trapped under the yaw pedals and he could not escape further without assistance. The passenger in the right rear seat unfastened his lap strap and managed to get himself clear of the helicopter before collapsing to the ground; the other occupants all had to be assisted out of the wreckage. Emergency services attended the scene and the five persons on board were transferred to hospital, either by road or by air ambulance. The pilot died a few days later in hospital.

Accident site and wreckage

Actions by airfield staff

An immediate response was carried out by the airfield staff and emergency services followed by methodical post-crash management action taken by the Chief Engineer at Breighton.

Shortly after the accident, the wreckage and detached items were moved away from the main runway and covered to protect them from the elements. CCTV footage and witness detail had been retained at the airfield and passed into AAIB custody. Figure 1 shows the helicopter shortly after the accident on the airfield.

Figure 1

Helicopter wreckage

After an initial examination of the wreckage, the main rotor blades were removed and the wreckage was transported to the AAIB HQ in Farnborough for a detailed examination.

Pilot information

The pilot's full logbook records were not available for the investigation. He qualified initially for a Private Pilot's Licence (Helicopter) in 2002 with a Hughes 269 type rating, in July 2002 he added a SA341G, Gazelle, type rating and in 2007 an endorsement for a SA318/SE313, Alouette. At the time of the accident the pilot held a valid EASA PPL(H) and a Hungarian National PPL(H).

Following his purchase of HA-PPC in 2007 the aircraft logbooks recorded that 163:25 hours had been flown on the helicopter. The pilot's 'on type' experience is based on this data.

Recorded information

Recorded radar data for the period around the time of the accident was examined. Great Dun Fell radar head, 72 nm to the north-west, showed primary returns, identified as HA-PPC, manoeuvring to the west and south of the airfield. The final contact was recorded at 1656:22 hrs, 2 nm south-east of the airfield.

A rear-seat passenger took some pictures with his mobile phone during the flight and these included several taken during the first low flypast but none closer to the time of the accident.

Video evidence was obtained from two security cameras mounted on a hangar to the south of the runway which showed the helicopter manoeuvring on the previous flight and during the accident flight. The cameras covered the east and west ends of the runway, but not the centre portion where the accident occurred and therefore the accident sequence was not recorded.

A spectator who had been photographing aircraft throughout the day took a number of pictures of HA-PPC during the afternoon. He captured two sequential photographs, at 0.2 second intervals, showing disruption of the rotor head and main body of the helicopter, while it was still airborne.

Aircraft description

The SE-313B Alouette II is a lightweight utility helicopter originally designed for a variety of military and State roles. Examples of the type were used by armed forces including the British Army and although a few remain in State usage, many are now owned and flown privately.

HA-PPC first came into service in 1960 as XP967, operated by the British Army. It was transferred to the UK civil register in 1990. The pilot purchased the helicopter in 2007 and transferred it to the Hungarian register, although it continued to be based in the UK. He had flown approximately 160 hours in HA-PPC.

The helicopter airframe is made up of a tubular steel frame through which all of the major engine and transmission components can be seen. It has an enclosed cabin but the majority of its panels, including the roof, are of clear Perspex giving the pilot and passengers very good all round visibility. The helicopter can carry up to five people including the pilot and co-pilot. The helicopter is powered by a Turbomeca Artouste II single shaft gas turbine engine driving a three-blade main rotor and two-blade tail rotor via a conventional transmission system. There is a centrifugal clutch and freewheel coupling assembly between the engine and main rotor gearbox input. The tail rotor output shaft is fitted with a hydraulic rotor brake consisting of disc and caliper assembly.

The cyclic and collective flying controls consist of a system of rods, levers and bell cranks routed under the cabin floor and up behind the cabin to the fixed and rotating star assembly attached to the main rotor gearbox. The lateral and longitudinal control systems are fitted with servo units powered by a simple hydraulic system. Flying control servo assistance was an optional extra in the Alouette series of helicopters. The system consists of a main rotor gearbox-driven pump, reservoir and filters. Hydraulic pressure can be controlled by a pilot operated SERVO ON/OFF valve situated on the cabin floor alongside the co-pilot's seat.

System pressure is displayed on a gauge on the side of the instrument binnacle. The Flight Manual states that the hydraulic servo system requires the main rotor head to be fitted with hydraulic blade dampers.

The tail rotor control is transmitted via the yaw pedals into cables and pulleys running along the tail pylon into a pitch change actuation mechanism which operates through the tail rotor gearbox.

The main rotor blades consist of an extruded aluminium alloy main spar which forms the leading edge of the blade. The aerofoil section and trailing edge of the spar is constructed of thin gauge aluminium alloy, packed with a synthetic resin foam filler to give rigidity to the skin. Tip balance weights are fitted to the blades and covered by light alloy tip fairings. The blades are attached to the rotor head blade sleeves by two tapered steel bolts. The main rotor head is fitted with hydraulic piston drag dampers. In addition to the drag dampers, there are cables attached between each blade at the outer end of the blade sleeve, held in place by small articulated links. These cables are known as the blade spacing equaliser system.

Tie bars are fitted within the blade sleeve which take the centripetal loads from the main rotor blades onto the flapping hinge trunnion alleviating those loads from the blade sleeve pitch change bearings.

Fuel is held in a single 580 litre (153 US gallon/464 kg) cubic tank within the helicopter framework under the main rotor gearbox and supplied to the engine via an electrical booster pump. Of the 580 litres of fuel, 15 litres (12 kg) is considered unusable and is shown by a red marker on the fuel contents gauge scale. Low fuel is indicated by a red warning light within the fuel gauge which illuminates when there is 60 litres (48 kg) remaining. It should be noted that the fuel gauge is calibrated in US gallons and both metric and imperial weights and quantities are used in the Flight Manual performance charts.

The Alouette series of helicopters are fitted with either skids, floats or wheeled landing gear. HA-PPC was fitted with skids.

The cockpit instruments are of a conventional electro-mechanical and pneumatic design. HA-PPC was also fitted with a transponder and radio along with a Skyforce GPS. The front seats and passenger bench seat in the rear, are of a lightweight tubular construction with leather covered cushion facings on top of the original cord and canvas facings.

Flight Manual

The Operating Limitations section of the Flight Manual for the SE-313B Alouette II helicopter includes, under the title '*Manoeuvring limits',* the information:

> *'The following recommendations should be observed:*
>
> - *Over 3,000 lb* (1,361 kg) *gross weight, approach should be made at a shallow angle*
> - *Handle the aircraft gently near limit speed and reduce speed before attempting sharp manoeuvres'*

Weight and balance

The maximum all-up weight (MAUW) of the helicopter is 1,588 kg (3,500 lb) with a CG range of 274 cm to 307 cm, measured from a datum forward of the aircraft nose. The design and mechanical layout of the helicopter are such that fuel quantity is the balancing factor when flights are being planned. If a pilot is planning to carry passengers they must take into account that all persons and items in the cabin will bring the CG forward. The addition of fuel will bring the CG aft.

Table 1 shows the last two weight and balance checks recorded for HA-PPC. Following the most recent helicopter overhaul, there was in an increase in weight of 46 kg. It also shows the basic CG moving forward from 320.5 cm to 317 cm. The reason for this is discussed later in this report.

Date	Inclusions	Empty Weight	CG position (from datum)
6 Aug 12	Fire extinguisher, first aid kit, 5x seat harnesses, 5x headsets, Skyforce GPS, transponder, unusable fuel	994 kg (Note - does not include fuel tank at red warning level of 48 kg)	320.5 cm
10 Mar 16	Standard cockpit, 4x headsets, first aid kit, battery, systems filled with oils and fuel at red warning level 48kg	1,088 kg	317 cm

Table 1

Weighing record details

It was not possible to determine the precise quantity of fuel on board at the time of the accident therefore a series of weight and balance calculations were completed (Table 2). The fuel consumption at maximum weight and a cruise speed of 90 kt is approximately 175 litre/hr (140 kg/hr) and the V_{NE} at sea level is 100 kt.

	Fuel on 'red' warning	**Fuel at takeoff - assuming uplift quantity of 90 kg added to 'red' level in the tank**	**Minimum possible fuel remaining at the time of the accident - assuming previous shutdown fuel above red warning level**
Empty Weight	1,088 kg	1,088 kg	1,088 kg
Fuel	0 kg	90 kg	64 kg
Passengers & items in the cabin	424 kg	424 kg	424 kg
Total	1,512 kg	1,602 kg	1,576 kg
CG (Range 274-307 cm)	276.6 cm	278.2 cm	277.7 cm

Table 2

Weight and balance figures[1]
(Red font shows a total exceeding the maximum allowable 1,588 kg)

The CG position figures in the table shows the CG moving forward as fuel is used. The range of its movement brings it close to but does not exceed the forward CG limit.

Aircraft examination

Aircraft structure

The helicopter had landed upright on its landing skids which had left deep indentations in the surface of the grass runway. The landing skids cross bars and inclined shock absorbers had bent, bringing cabin structure into close proximity with the ground. The cabin structure was distorted, the doors had detached and the majority of the cabin Perspex transparency had fragmented.

The structure supporting the main rotor gearbox had retained its basic shape over the fuel tank but the gearbox itself had partially detached, tilted forward and leaning over to the left.

The tubular framework around and beneath the main rotor gearbox had suffered bending and fractures to the various struts and ties. The fuel tank was distorted and had split allowing the fuel to drain out on to the ground. The structures around the transmission

Footnote

[1] The figures presented for the fuel load are based on the assumption that the pilot refuelled with 90 kg at the point when the red fuel low warning light illuminated at 48 kg. It is possible that there was more than 48 kg of fuel already in the tank, therefore the takeoff weight could have been more than 1,602 kg.

deck were covered in a film of oil and spattered with grease. The oil had escaped from the lubricating oil tank and its associated supply and return pipes which had been damaged during the accident.

The tubular frame tail boom was in a highly disrupted state. All three tubes which make up the triangular section of the framework had been distorted and severed approximately half way up the tail boom. The tail rotor gearbox and associated framework had detached as had the tail rotor protective skid. There was no evidence that the underside of the tail rotor skid contacted the ground during the accident sequence. The stabiliser aerofoils and cross tube were severely damaged and had also detached. The centre section of the cross tube was heavily scuffed and flattened and the inboard face of the stabiliser was badly crushed at its trailing edge.

Rotor head, blades and dampers

For identification during maintenance, the main rotor head, blades and associated components are colour coded (red, blue and yellow) and marked with tape or painted bands. All three main rotor blades had exhibited varying degrees of damage to their aerofoil skin surfaces and their tip fairings had detached. The yellow blade had suffered the worst damage and had lost the outermost upper section of aerofoil skin. One of the pieces of skin material had a scuffed transfer of grey paint on to its outer surface. The yellow blade main spar had taken on a permanent curved bend upwards and rearwards along its entire length. The red and blue blade main spars were also damaged but not to the same extent. The upper and lower skin surfaces of all three blades, from the blade root outwards, showed evidence of multi-strand steel cable strikes. The hydraulic blade damper trunnions had failed on all three blades. The yellow blade had undergone an extreme lag or 'retardation' and the blue and red blades suffered an equally extreme lead or 'advance' over-travel.

The blade spacing cables had detached between the red and yellow blades and between the red and blue blades. In each case, the articulated links which connect the eye-end to the cuff joint had broken across their attachment bolt hole. Laboratory analysis of the broken cable links show that they all failed in overload.

The rotor head assembly had witness marks at various points on the articulated joints (ie flapping and drag hinges) of all three arms and on the head boss due to over-travel about the joints. The droop restrainer ring was in place and free to move within its location slot but was compressed and misshapen in several areas around its circumference.

Cockpit controls and instruments

Despite severe distortion to the instrument binnacle, the helicopter instrumentation, switches and controls were undamaged. The barometric altimeter was set at 1020 hPa which matched the local QNH at the time of the accident. Apart from this setting no meaningful data could be gathered from any of the other instruments which had decayed to zero or null readings when electrical power was lost after the accident. The fuel shut-off cock, flow control lever and governor control lever were all in the forward MAX or OPEN positions. The adjustable stop on the governor control lever quadrant was set forward of the mid position.

Tail rotor

The two-blade tail rotor had lost the outer half of both of its blades but was still attached by its hub to the tail rotor gearbox. The pitch change links were intact and responded to a manual input to the pitch change actuation mechanism with full range and in the correct sense.

Flying controls

The flying control rods and linkages from the cyclic and collective were bent and in many cases broken behind the cabin leading up to the main rotor gearbox. Despite the damage to these control runs, continuity and operation in the correct sense could be demonstrated in the collective and cyclic control systems via the servos. The control rods mounted on the main rotor gearbox between the bell crank pivot shaft and fixed star of the swash plate assembly, through to the rotating star and into the red, yellow and blue pitch control rods were relatively intact except for a slight bend. However, the lateral control rod had fractured at the waisted portion above the eye-end adjustment thread. There was also evidence of ferrous corrosion on the eye-end thread in the same area.

The yaw pedals were intact and free to move. The control rod between the yaw pedals and control quadrant was distorted. The cables between the quadrant and the tail rotor pitch change input helix on the tail rotor gearbox had broken near to the tail boom structure disruption. However, continuity and operation in the correct sense could be demonstrated.

The hydraulic system pipes had been damaged but the majority of other system components were intact. There was fluid present in the system but there had been some leakage from the damaged pipes. Although the servo selector valve hand wheel had broken in two and was not attached to its valve, examination found the valve spindle to be fully clockwise in its open SERVO ON position.

Engine and transmission

The engine had fully detached and had come to rest next to the helicopter on the ground. The output clutch assembly was free to rotate but the core of the engine was jammed. The exhaust and its insulation cowl had also detached and there was crush damage to the diffuser. There was also a perforation to the combustion chamber. Removal of the diffuser released the tension on the rear bearing and the compressor and turbine assembly became free to rotate. Despite the accident, the engine and its ancillary equipment were in good condition. There was no evidence of foreign object debris within the engine.

Notwithstanding the detachment of the tail rotor gearbox and dislocation of the main rotor gearbox, both assemblies were undamaged, free to rotate and contained lubricating oil. The main rotor gearbox magnetic particle detection plug was free of debris. The tail rotor drive shaft, inclined shaft (tubular tail rotor drive shaft which runs beneath the engine) and freewheel unit had detached from the helicopter. The inclined shaft head had been pulled from its universal joint and the shaft which runs along the top of the tail boom had been bent and showed evidence of a torque-twist failure at the outer end. The freewheel unit worked correctly and was intact except for a small amount of distortion to its engagement splines.

The photographs taken by chance during the accident sequence show the engine and transmission shafts undergoing serious disruption and separation whilst the helicopter was still airborne.

Crashworthiness

Although the design of this helicopter predates many of the crashworthiness requirements of EASA Certification Specification 27, this helicopter absorbed most of the impact forces. The skid cross tubes deformed uniformly and the seat frames and faces absorbed the shock. The straps and harnesses retained the occupants and reduced the possibility of them being ejected from the cabin during the accident. The fuel tank split in the impact but did not burst open thereby reducing the possibility of fuel spillage as well as the likelihood of a post-crash fire.

Meteorology

Meteorological data for Breighton is not recorded but reports from persons at the airfield suggested that the weather was fine and clear with a west-south-west wind of 10 kt to 15 kt. Photographs and video recordings taken at the time of the accident showed clear skies at low level, with good visibility; the surface wind was gusty from a westerly direction.

Airfield information

Breighton is an unlicensed aerodrome situated at the south-west corner of a disused military airfield. The field elevation is 20 ft amsl. The single grass runway, orientated 10/28, is 850 m in length and 45 m in width; all circuits are to the south. A parallel tarmac taxiway is located on the south side of the runway, alongside which are various hangars and buildings, including a clubhouse. A refuelling facility is positioned in front of the clubhouse.

Organisational information

Overall condition and maintenance

Despite the damage to the helicopter the examination found it to be in good condition. The Hungarian based Continued Airworthiness Management Organisation (CAMO) had carried out a major overhaul of the helicopter and issued a Certificate of Airworthiness and Release to Service on 11 March 2016. This included the helicopter check-weigh and CG calculation. It was reported that during the major overhaul the cabin structure was replaced due to an unacceptable level of degradation of the light alloy skin in the cabin floor due to corrosion. The AAIB was informed that the replacement cabin was of German origin and this is supported by the cabin specification plate fitted on the cabin floor.

The Artouste C6 engine fitted to HA-PPC is recorded as having annual servicing and although not recorded in its Engine Log Book, a Release to Service Certificate showed that it had been overhauled in October 2005. It was due its next calendar based overhaul in October 2020. The engine manufacturer has no record of this work being carried out by any of their approved organisations.

Other information

Handling of flight controls

A non-qualified person on board an aircraft handling the flight controls for a short duration is common practice but whether it is allowable under existing regulation is not clearly specified. HA-PPC is an Annex II aircraft and is subject to national regulation in Hungary, not to EASA regulation. The Hungarian Ministry of National Development advised that a passenger cannot operate a helicopter without holding the appropriate type rating.

For EASA aircraft, Regulation (EC) No 216/2008, Article 7, states:

> *'Except when under training, a person may only act as a pilot if he or she holds a licence and a medical certificate appropriate to the operation to be performed.'*

The EASA interpretation of the phrase '*act as a pilot*' is equivalent to that defined by ICAO where '*to pilot*' is:

> *'To manipulate the flight controls of an aircraft during flight time[2].'*

EASA states:

> *'outside of a training context, a helicopter pilot without the required type-rating, and travelling as a passenger, is prohibited from manipulating the flight controls of the aircraft during flight time.'*

In the UK the interpretation for an Annex II aircraft is similar to that for an EASA aircraft.

CAA Flight safety information publication[3]

CAA Safety Sense Leaflet 02 – '*Care of Passengers*' states:

> *'The Commander of an aircraft is responsible for the safety and well-being of his passengers and the law requires a pre-flight safety briefing in any UK registered aircraft.*
>
> *This applies to ALL aircraft, including gliders, balloons, microlights and helicopters, as well as 'conventional' aeroplanes.'*

Footnote

2 P12 of Part 1 'Definitions' in ICAO Doc 9713 'International Civil Aviation Vocabulary'.
3 Available at: http://publicapps.caa.co.uk/modalapplication.aspx?appid=11&mode=list&type=sercat&id=21 [Accessed 13 September 2016]

Advice on the importance of the correct distribution of weight in a helicopter is provided in the FAA '*Helicopter Flying Manual, Chapter 06: Weight and Balance*[4]. For forward CG it states:

> *'This condition is easily recognized when coming to a hover following a vertical takeoff. The helicopter has a nose-low attitude, and excessive rearward displacement of the cyclic control is needed to maintain a hover in a no-wind condition. Do not continue flight in this condition, since a pilot could rapidly lose rearward cyclic control as fuel is consumed.'*

However this indicator can be disguised in strong wind conditions:

> *'A forward CG is not as obvious when hovering into a strong wind, since less rearward cyclic displacement is required than when hovering with no wind. When determining whether a critical balance condition exists, it is essential to consider the wind velocity and its relation to the rearward displacement of the cyclic control.'*

An illustration of the effect of the CG on pitch attitude is included and shown at Figure 2.

Figure 2

Illustration of the effect of CG on helicopter handling[5]

Analysis

The pilot had been inviting different people for flights during the course of the day. On this occasion, although he hadn't originally planned to, he accepted four passengers on board. The helicopter, with these four passengers and an uplifted fuel load of 90 kg, exceeded the Flight Manual limitation for maximum weight. The helicopter was also operating towards the forward limit of its CG range.

Footnote

4 Available at: https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/helicopter_flying_handbook/

5 Shown in: https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/helicopter_flying_handbook/

A safety briefing is a required part of every flight and gives the pilot an opportunity to advise the passengers of features specific to the aircraft type and indicate the emergency escape procedures. The absence of a briefing did not affect the outcome of this flight.

Weight and balance

In 2012 the helicopter empty weight was 994 kg including 12 kg (26.7 lb) unusable fuel, ie an empty fuel tank. In 2016, after a major overhaul, the helicopter was reweighed and recorded as having a weight of 1,088 kg. Taking into account this figure includes 48 kg of fuel, the resultant empty weight was 1,040 kg. The revised empty weight was 46 kg greater than the previous weighing record. This increase is likely to have been as a result of the cabin change and explains the movement of the basic CG forward from 320.5 cm to 317 cm. It is possible that the pilot overlooked these changes when he considered how many passengers he could take on a flight.

For the accident flight, the weight of the helicopter with its fitted equipment, an assumed minimum reserve (red light) fuel of 48 kg and just the pilot on board was calculated at 1,227 kg. The MAUW is 1,588 kg, thus the available payload for fuel and passengers would be 361 kg. The pilot had loaded 90 kg of fuel, giving a maximum possible available payload of 271 kg. The combined weight of the passengers and other non-essential items on board was 285 kg, an exceedence of 14 kg or greater[6]. This degree of weight exceedence was probably not significant for gentle flight manoeuvres but may have been relevant for some more dynamic manoeuvres. The information provided in the Flight Manual for operation at weights above 1,361 kg (3,000 lb) recommends a reduction in speed before '*attempting sharp manoeuvres*'. During the accident flight a zoom climb and a bunt were observed and on the previous flight the helicopter was flown towards the parking area in a steep nose-down pitch attitude before levelling.

The Flight Manual weight of 1,361 kg (3,000 lb), above which the helicopter must be handled 'gently' at higher speeds and shallow approach angles are required, for HA-PPC represents the pilot plus one hour of fuel on board with no passengers, or 30 minutes fuel with one passenger.

Effect on handling characteristics

All weight in the helicopter cabin acts to move the CG forward whereas fuel moves the CG aft. For the flight preceding the accident flight there were three male passengers on board, and less fuel than on the accident flight. The CG is likely to have been towards the forward edge of the range, leading to a nose-low attitude and rearward stick position in a zero wind hover, a situation which brings the rotor disc closer to the tail boom. Cyclic control authority is reduced, making it more difficult to reduce speed and decreasing manoeuvrability. The CCTV recordings showed that at the end of this flight the rotor disc twice came close to contacting the tail boom as the helicopter flew towards the fuel pumps.

Footnote

[6] The figures presented for the fuel load are based on the assumption that the pilot refuelled with 90 kg of fuel at the point when the red fuel low warning light illuminated at 48 kg. It is possible that there was more than 48 kg of fuel already in the tank, therefore the exceedence may have been greater than 14 kg.

The helicopter was refuelled after this flight, moving the CG further aft. However, the additional load in the cabin would have brought the CG forward. The observed nose-down attitude in the hover suggests that the helicopter was operating with a forward CG which would have brought the rotor disc closer to the tail boom in flight, increasing the possibility of its contacting the tail boom.

Accident sequence

The helicopter component examination clearly shows that the main rotor disc came into contact with the tail boom structure. It is evident from the damage to the main rotor blades and their tips, along with the damage to the stabiliser and its cross tube, that the first impact was from the yellow blade closely followed by blue and the red blades in succession. The yellow blade tip missed the right stabiliser aerofoil but collided with the cross tube and on into the inboard trailing edge corner of the left stabiliser aerofoil. Figure 3 shows the damage to the stabiliser cross tube and path of the blade impact.

Figure 3

Damage to the stabiliser cross tube and path of the blade impact

This was the probable source of the “loud crack” described by the passengers and many of the witnesses. The tip fairing was crushed and detached and its deformation precisely matched the profile of the stabiliser trailing edge. In this initial impact, the cross tube was flattened and there is evidence that the yellow blade, whilst in contact with the cross tube, travelled underneath the tail rotor drive shaft and it is possible that it momentarily restricted its rotation to the extent that it twisted under torque and failed. It is also possible that the torque-twist occurred when the shaft bent as the tail rotor gearbox and its associated structure bent and separated from the tail boom. Photographic evidence shows a long section of tail rotor drive shaft, still rotating, detached from the helicopter whilst it was airborne and the torque-twist could only have happened prior to this event.

The tail structure suffered a number of main rotor blade strikes leading to complete loss of structural integrity. With an N_R[7] at approximately 360 rpm, there could have been up to 18 blade passes and potential impacts per second.

With an Alouette II helicopter at rest, it can be shown that the most likely blade tip impact point will be in the area where the stabiliser is fitted. However, it is very difficult to pull a main rotor blade down to contact this area by hand against the anti-droop ring. Nevertheless, in flight the aerodynamic and inertial forces have a large effect on the disc path and can, under extreme circumstances, allow the tip of the main rotor to come into contact with the tail structure. Potential blade impact may be exacerbated by a forward CG, which reduces the distance between the blade tip path and tail boom.

The damage to the hydraulic dampers and blade spacing cables is likely to have occurred at the first impact of the yellow blade leading to an inertial shock through the rotor head when it momentarily slowed as the yellow blade transited through the structure. Then, as this structure disintegrated, the head, which was still being driven, caused the red and blue blades to accelerate under their own inertia to over-travel with enough energy to break through the damper trunnions. The lead and lag of the damaged blades would then not be damped or controlled; the effect would be for the blades to fly out of track leading to a worsening out of phase situation between the blades. It is possible that it was during this early sequence of events that the pitch rods were damaged.

It is also early in the sequence that the inter blade cables and drag dampers suffer significant shock loading as the blades and head, still being driven from the main rotor gearbox, collided with the tail structure. The two sequential photographs show the latter stages of the sequence, by which time the disruption and deflection of the blades from their normal track and phase was so great that one of the blades collided with the engine with such force that it detached from the helicopter. This was probably the source of the “bang” described by witnesses.

The tail rotor appears to have departed the helicopter and flown upwards and forwards, suffering secondary damage after collision with the main rotor blades. This resulted in the torque rotation of the helicopter through 180º as it dropped to the ground.

The sudden deceleration when the helicopter hit the ground resulted in all three main rotor blades undergoing a violent droop whilst still rotating. The blades collided with the remains of the tail boom structure severing the already damaged tubing to leave a distinctive angular cut. It was also likely at this point that the droop restrainer ring was misshapen.

Footnote

[7] N_R – Abbreviation used to represent rotor rpm in rotary wing aviation.

Finally whilst still in a drooped condition, a main rotor blade struck the cabin structure. The impact caused severe distortion to the left side door frame, instrument binnacle and fragmented the cockpit transparencies and brought the main rotor to a stop. Based on the witness evidence and the helicopter's proximity to the ground, it is estimated that this whole sequence took less than five seconds.

Observations

It was suggested by outside observers that it was possible that the accident resulted from the tail skid striking the ground. However, there is no evidence that the tail skid came into contact with the ground prior to or during the accident.

The engine manufacturer could find no records that the overhaul had been carried out by one of their approved organisations. However, the engine performance or condition was not a causal or contributory factor.

Conclusion

The helicopter was well maintained, serviceable and in good condition prior to the accident. All the damage to the helicopter's structure, its components and systems is attributable to the main rotor disc striking the tail boom structure in the vicinity of the stabiliser cross tube. There was no evidence of pre-accident defects of the flying controls or transmission system which could have led to the rotor disc colliding with the tail boom, therefore it probably occurred as result of control inputs.

The helicopter was close to or above the MAUW of 1,588 kg (3,500 lb). Also, the CG was towards the forward limit of the allowable range detailed in the Flight Manual, thus the margin of clearance of the rotor disc from the tail boom in flight may have been reduced, increasing the risk of the disc striking the tail boom.

It is probable that whilst a quick stop was carried out, coarse control inputs associated with the dynamic manoeuver caused the main rotor disc to contact the tail boom.