Aircraft Type and Registration:	Eurocopter EC 120B, EI-IZO
No & Type of Engines:	1 Turbomeca Arrius 2F turboshaft engine
Year of Manufacture:	2001
Date & Time (UTC):	7 November 2003 at 1431 hrs
Location:	Swansea Airport, West Glamorgan, Wales
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 4
Injuries:	Crew - None Passengers - None
Nature of Damage:	Substantial
Commander's Licence:	Private Pilot's Licence
Commander's Age:	36 years
Commander's Flying Experience:	Estimated 350 hours Last 90 days - not supplied Last 28 days - not supplied
Information Source:	AAIB Field Investigation

Synopsis

The helicopter was stationary in the hover over the apron area at Swansea Airport when it unexpectedly yawed left and pitched nose down. The surface wind was a gusting crosswind, varying in direction, from the right and slightly behind the helicopter at 15 to 20 kt. The pilot attempted to recover but the cyclic control reached its aft limit of travel and he was unable to prevent the forward fuselage and front of the right skid contacting the paved surface, followed by the main rotor blades. The helicopter rolled over and slid along the ground for some distance before coming to rest against a vehicle. All persons on board escaped uninjured.

History of flight

The helicopter was operating in the local Swansea area in connection with the Wales Rally Great Britain 2003. It departed from Cardiff Heliport at 0735 hours and, during the course of the day, visited a number of the designated landing sites. On board were the pilot, who was also a co-owner of the helicopter, and four passengers.

The pilot was flying from the right seat with a safety pilot seated in the left who was operating the radio and assisting with the navigation. Dual controls were fitted. Early in the afternoon the helicopter was flown to Swansea Airport to refuel and stop for lunch. After approaching from the east the helicopter carried out a descending right turn to a hover into wind on the south side of the airfield. It was then cleared to cross the active Runway 10 to park on the apron area. The pilot hover taxied in a north-easterly direction, with a crosswind of 090º to 120º at 15 to 20 kt, and came to a stationary hover over the apron. The safety pilot contacted the tower and sought clearance to park in their present position. The tower controller agreed and advised them that they could turn into wind if they wished. The safety pilot pointed out to the pilot an area to their right that he thought suitable for parking.

Before the pilot was able to initiate the right turn the helicopter yawed approximately 20º to the left and pitched nose down. It accelerated forwards a short distance and then the nose and right skid contacted the ground. Both pilots in the front seats attempted to recover from the pitch down by applying full aft cyclic control but they were unable to prevent the ground contact. The passenger seated immediately behind the pilot recollected being able to see the ground through the canopy above the pilot's head, indicating that a steep nose down pitch attitude was attained. The main rotor blades struck the ground and the helicopter slewed round and slid along the ground on its right side.

The tower controller had a clear view of the apron area and was watching the helicopter while it was in the hover. He saw what he thought was a turn to the left, a pitch down and a move forward. Initially he thought that the helicopter was transitioning into forward flight but then realised that control had been lost. He saw the helicopter roll over and slide towards the base of the tower, at which point he moved away from the window, activated the crash alarm and took cover.

The helicopter came to rest lying on its right side against a small airport tractor. The fire service arrived at the scene and assisted the pilot and passengers in evacuating from the left rear entry door. There were no injuries.

Meteorological information

The south-western United Kingdom was under the influence of an unstable airmass with an easterly airflow. The Swansea Airport weather observation at 1309 hrs recorded a surface wind of 110º/20 kt, in CAVOK conditions with a temperature of 12ºC and a dewpoint of 6ºC. At 1537 hrs, 66 minutes after the accident, the surface wind was 090º/14 kt.

There were two surface wind reports passed to operating aircraft just before the accident and recorded on the Air Traffic Control (ATC) tape. These gave the surface wind as 100º/20 kt and 120º/15 kt, one minute and 30 seconds respectively, before the accident.

A pilot operating another helicopter on the south side of the airfield at the time of the accident reported that the wind was gusty, varying in direction and strength up to a maximum of 25 kt.

Pilot experience

The pilot bought a half share in the helicopter when it was new, two and a half years earlier, and had flown it approximately twice a week since then. His type conversion course was carried out by a qualified instructor independent of the manufacturer or distributor. The pilot had flown the helicopter in a variety of wind conditions either solo or with up to a total of five persons on board. He also often flew with a safety pilot and on the accident flight the safety pilot held a Commercial Pilot's Licence (Helicopter) and was a qualified instructor on type.

Impact and ground slide

The surface markings indicated that the initial ground contact point of the helicopter was on the paved apron some 60 metres south of the control tower. The final resting point of the helicopter was approximately 15 metres from the tower. Light ground markings suggest that extremities of the helicopter and/or rotor system were in contact with the paved surface for most of the distance between these points.

Examination of the helicopter, the wreckage distribution and the ground markings revealed evidence consistent with the helicopter fuselage having initially contacted the paved surface with light force whilst in a steep nose-down attitude, banked slightly to the right, with a low rate of descent and limited forward speed. Immediately thereafter, the main rotor blades struck the ground. The combination of the inclined main rotor disc and the reaction of the blades striking the surface is assumed to have caused the helicopter to accelerate in an approximately northerly direction, (parallel with the initial longitudinal axis of the fuselage) and for the fuselage initially to rotate about the main rotor axis such that the helicopter motion then became tail-first.

Damage to the tail-boom indicated that at some stage during this process, the tip trajectory of one or more of the damaged main rotor blades passed through that structure, severing the fenestron. The helicopter also began rolling to the right. The backward motion was arrested when the lower rear area of the fuselage collided with the exposed edge of a vertically orientated steel plate forming the ballast weight and radiator grill of a small tractor. Ground evidence showed that this impact displaced the tractor sideways. The impact and cutting action inflicted by the edge of the steel plate severed the aft central attachment of the aircraft skid system, allowing the whole skid assembly to rotate in a forward direction through some 270° about its forward cross member mounting. This permitted the helicopter to slide to a halt lying on the skin of its starboard side.

The main rotor blades, reduced to root sections less than one metre in length, were still attached to the rotor head. Dense items of main rotor blade debris (ie sections of tip weights and fragments of erosion strips) were found to have been projected in a number of directions up to a maximum distance of approximately 150 metres. The bulk of the lengths of each of the main blades, being of GRP composite material, were shredded and spread over a wide area of grass and paved surface. The overall distribution was consistent with these items being shed during the initial impact and continuing rotation of the blades in ground contact.

Slight damage, resulting from dense rotor debris impact, was sustained by two vehicles, three parked aircraft, a fuel installation and a hangar. One of these damaged vehicles was in a car park outside the airport perimeter fence. There was no evidence to indicate that any items separated from the helicopter before the initial ground impact.

A small spillage of hydraulic fluid was noted at the final resting place of the helicopter the day after the accident and a headset cover was found in the tail boom after the accident although it was believed to have become lodged there during the ground slide.

Helicopter examination

Examination of the cabin confirmed that the shell was structurally complete. It had not suffered any permanent distortion or any intrusion and the transparencies were only slightly damaged. There was no damage to the seating or any other items within the occupied volume. The flying control system was examined and no evidence of pre or post impact damage was noted. Functioning of the cyclic and collective controls confirmed that the control systems from the pilot inputs to the hydraulic servos were correctly connected and capable of functioning appropriately

The hydraulic pump/reservoir unit was unbolted from the main rotor gearbox without disconnecting the flexible hoses between the unit and the three main rotor servos. The main rotor head was turned by hand and corresponding rotation of the output drive to the hydraulic unit was noted. Both the drive connection within the gearbox and the corresponding drive connection on the hydraulic unit shaft were examined and found to be undamaged and serviceable.

The aircraft battery was re-installed and an attempt was made to drive the exposed input shaft of the hydraulic unit with an auxiliary power source. With the battery selected 'ON' it was noted that appropriate pitch change movement of the blade roots took place when the cyclic and collective controls were operated. Initially however, the low hydraulic pressure caption on the instrument panel warning system remained illuminated. The reservoir fluid level, being slightly depleted, was replenished and the hydraulic unit operated again. Again the hydraulic low pressure caption remained illuminated and it was not until a more effective drive for the hydraulic unit input shaft was obtained, to rotate the shaft with sufficient speed, that low pressure caption extinguished. At the same time, full and simultaneous movement of cyclic and collective controls could be made and full and appropriate pitch range movement of the main rotor blade roots was noted. No hydraulic leakage was evident.

The helicopter

Certification

The EC 120B is a multipurpose five place helicopter certified in accordance with JAR 27 requirements. The manufacturer supplied the following information regarding certification and the flight test programme:

> *'Personnel weight used during certification testing was 80 kg (JAR minimum requirement 77 kg).*
>
> *At the most critical Centre of Gravity (CG) position the most critical wind condition is considered to be a left tailwind.*
>
> *The maximum demonstrated wind at the most critical CG position was 30 kt (JAR certification requirement 17 kt), this was not considered limiting'.*

The Approved Flight Manual (AFM) does not contain specific information regarding wind limitations and neither is it required to do so. It does include a statement that the helicopter complies with JAR 27 requirements.

Weight and balance

The specific weight and CG limitations for EI-IZO are provided in the AFM. The maximum authorised weight for takeoff and landing is 1,715 kg. The datum for the CG is defined as 4 metres forward of the mast centroid.

The Equipped Empty Weight (EEW) of EI-IZO was 1,058.5 kg, measured on 21 May 2001, with a CG at 4.183 metres aft of the datum. The two front seats are at a station 2.35 metres aft of datum and the rear seat row is 3.25 meters aft. There is a single load space for the baggage or cargo, accessed by a door on the starboard side, within which there is a net fitted to enable items to be easily secured. The centre of this load space is 4.10 metres aft of the datum. Fuel (4.09 metres aft of datum) has a negligible effect on the CG position but the forward limit of the CG envelope changes with a corresponding change in weight. From these figures it can be seen that all persons on board and any cargo loaded forward of the mid position each contribute a forward moment.

There are two methods provided in the AFM for calculation of the CG, either numerical or graphical. The baggage in the hold area was not secured and had moved in the accident so it was not possible to determine its exact position during flight. However, as the baggage was of a fairly light and bulky nature it was assumed that it was evenly distributed within the area. The fuel on board was recovered following the accident and measured at 40 litres (32 kg).

The CG position, utilising the best available data, was calculated as shown in Table 1 below:

	Mass (kg)	**Arm (metres)**	**Moment (mkg)**
EEW	1058.5	4.183	4428
CREW	155	2.35	364
PASSENGERS	240	3.25	780
CARGO/BAGS	10	4.1	41.0
FUEL	32	4.09	131
TOTAL	**1495.5**	**3.84**	**5744**

Calculated Weight and CG for EI-IZO

Table 1

The graphical method provided a result that was similar although less accurate. Both of these methods were found to be time consuming and somewhat difficult to interpret. However, both results when plotted showed that the CG was 5 mm forward of the forward limit of the CG envelope.

The distributor of the EC120B in the United Kingdom provides customer training courses when supplying new helicopters; information regarding the loading limitations is taught on the course. A computerised load calculation spreadsheet programme can be supplied for customers but it is not intended to replace either of the methods from the AFM and is only to assist pilots with loading calculations. The spreadsheet method gave the same result when using the above data. For the accident flight however, the pilot did not complete a specific weight and balance calculation for the load carried.

The following warning is included at the top of the spreadsheet:

> *'It shall be the pilot's responsibility to verify that all cargo is stowed and tied down properly so that in-flight shifting is impossible'*

The AFM similarly requires the pilot to ensure that there are no loose items in the cargo area during the pre-flight inspection.

There have been a number of Service Bulletins issued with reference to weight and balance. Details of these are shown in Table 2 below:

NUMBER DATE AC/STATUS	TITLE	REASON	PRINCIPLE MODIFICATIONS
SB 24-001 Mar 1999 EI-IZO At build	Relocating the battery aft	Improving weight balance by relocating its centre of gravity aft	Relocation of the battery and the addition of weights below the battery shelf
SB53-001 Sept 1999 EI-IZO At build	Provision for installation of ballast in the fenestron	To provide provisions on the helicopter for the installation of ballast aft of the fenestron to improve aircraft balance and increase the payload	Removal of the ballast plates below the battery shelf and the addition of ballast plates (8 kg) secured to the fenestron aft frame
SB53-005 Oct 2000 Optional (EI-IZO not inc)	Increased possibilities for adjusting the CG	To allow the operator to re-adjust the CG when the ballast installed in the fenestron is not sufficient	Installation of one to four ballast plates under the battery tray
SB 53-009 May 2003 (EI-IZO not inc)	Fenestron ballast increased to 19 kg		

History of Service Bulletins

Table 2

Flight controls

After the accident the left crew seat was found to be locked in the fully forward position. With a person seated in the seat, of the same height and weight as the safety pilot, it was found that full aft cyclic pitch control movement could be achieved. It was noted, however, that it was not possible in this seating position to obtain full right cyclic, because the left seat pilot's right knee impinged against the centre instrument pedestal preventing more than approximately half right cyclic stick being achieved.

A check of the 'full and free' movement of the flight controls forms part of the 50 hour or 62 day maintenance inspection but is not performed as part of a pre-flight check. This is because of the possibility of causing damage to the rotor head assembly.

Other incidents

During the investigation it was reported to the AAIB by another pilot of an EC 120 helicopter that he too had experienced a similar uncommanded pitch down in the hover from which he considered himself fortunate to have recovered. He described the wind conditions as gusty at up to 25 kt from behind and as he slowed the helicopter to a hover he found that the cyclic pitch control lever was at the aft limit of its travel. The helicopter pitched down but he was able to recover by using the collective lever to gain height and recovered into a climb. He discovered on subsequent calculation that the helicopter had been loaded outside the forward CG envelope.

Analysis

Impact dynamics and survivability

The light scour markings of the fuselage lower nose indicate that the aircraft initially contacted the ground gently, confirming that it had been at a low height and low, or zero, forward speed when the event began. The low forward speed at first ground contact indicated that the pitch-down must have occurred rapidly.

The geometry of the nose and skids dictates that at the time of initial blade contact, the nose-down angle would have been such as to cause the horizontal component of main rotor force to have been high and therefore to have imparted a rapid acceleration along the fuselage axis, once the full nose-down angle was approached. This would account for the motion of the aircraft in a northerly direction, immediately after first ground contact. The complex motion thereafter appears to be partly as a consequence of the reaction to the blades repeatedly striking the paved surface. Both the degree of destruction of the blades and the distribution of composite debris is consistent with them continuing to rotate under power sustaining many sequential strikes during the period between the first ground contact and the final impact with the tractor. It is thus clear that the engine continued to deliver power during this period.

The separation of the rear of the tail-boom as a result of one or more blade strikes was to be expected given the modified blade path relative to the fuselage as a consequence of ground strikes, physical blade damage and complex motion of the aircraft after the initial ground contact.

The fact that the main rotor blades were under power at a time subsequent to the initial ground contact and the main rotor gearbox drive to the hydraulic unit was found to be intact and to turn in unison with the rotor head, indicates that the hydraulic pump must have been rotating correctly at the time of the initial event. The tests showed that under such circumstances the pump operated correctly and the control system produced the appropriate pitch changes to the main rotor blades. Hence there was no evidence to indicate incorrect rotor system response to pilot inputs.

Although the sequence of post initial impact motion was complex, the considerable distance the aircraft travelled indicates that the occupants were subjected to only relatively low accelerations until the helicopter struck the tractor. The unusual (rearward) direction of that final, more severe impact ensured that full support was provided by the seats and the headrests/restraints minimising the possibility of deceleration injuries. Lack of intrusion into the occupied volume and absence of major damage to transparencies also contributed to lack of occupant injury.

Operational factors

The wind conditions at the time of the accident were moderate to strong with significant gusts, making the task of hovering and manoeuvering the helicopter close to the ground a demanding one. The left yaw observed both by the pilots and ATC prior to the pitch down, and the pitch down itself, was probably the result of the effect of a gust or lull in the wind acting on the helicopter. As it became destabilised in pitch, the pilot then found there was insufficient cyclic control authority to recover.

It was considered whether the safety pilot could have inadvertently interfered with the cyclic control during the hover. He reported however, that after asking ATC where to park he had pointed with his right hand to suggest to the pilot where he thought they should set down. Therefore this hand must have been free of the cyclic control.

The manufacturer initially suggested that the cause of the pitch down could have been due to one or both of the flight crew seats having been at the full forward position together with the position of a crew member causing physical interference and limiting the aft travel of the cyclic stick. The left crew seat was indeed found to have been fully forward, but when tested full aft cyclic authority was available. Whether or not there was inadvertent interference from either pilot however, could not be ascertained.

It was noted during the investigation that, with dual controls fitted and the left seat occupied, only about half right lateral cyclic control movement was possible but in normal operation this may not be apparent to the pilot as he cannot conduct a 'full and free' control check prior to flight. This fact was drawn to the attention of the manufacturer who responded that the whole of the 'stick aft and stick right' area is never used. The manufacturer also provided information issued by their flight test department concerning the areas in which the cyclic stick moves under different flight conditions. This showed that full right cyclic was not required for certification purposes or for any of the various recorded flight test conditions.

The estimated weight of the helicopter at the time of the accident was 1,495.5 kg, some 220 kg less than the 1,715 kg maximum. The two separate approved methods of CG calculation and the computer spreadsheet all showed that the CG was 5 millimetres forward of the CG envelope. The manufacturer advised that there would be a reduction of aft cyclic authority of 1% for a CG position 10 millimetres forward, thus there could have been a reduction of around 0.5% of aft cyclic authority. It was considered therefore that this degree of loading forward of the limit, although undesirable, would have had only a marginal effect upon the control of the helicopter.

There is a series of service bulletins relating to weight and balance for the EC 120. Each modification has effectively increased the aft moment to prevent operators encountering forward CG limits. EI-IZO had been built in accordance with SB24-001 and SB53-001 but not had any subsequent modifications added. While there was no requirement for these to be done they would have improved its capability to carry a full load of passengers.

Both the graphical and calculation methods for determining the CG are time consuming and it is not surprising that they could be overlooked for what was thought to be a routine load. The UK distributor has provided, for its customers, a simpler method of checking CG and, on their own training course, offers advice on avoidance of CG problems. However, this pilot did not have the benefit of this information. His perception was probably that the five occupants were of average weight and may have been unaware of the potential for a CG problem. The fact that he had operated the helicopter on a number of previous occasions in a similar configuration without difficulty would have reinforced this view.

It was considered by the AAIB that the present method for calculating the CG was unduly complicated for routine use and that a simpler method would be desirable. This was proposed to the manufacturer who responded that they did not consider that a simpler method was practicable but that with correct ballasting and use of customer options, as per the various service bulletins, the aircraft could be configured to remain within its CG envelope regardless of the fuel load within the following range:

> *'either with a light-weight pilot of 60 kg or with 5 persons weighing 80 kg.*
> *In this case the pilot would not need to check the center of gravity as long as he is sure that he weighs more than 60 kg or that he and his passengers do not each weigh more than 80 kg.'*

The forward CG and associated reduction of aft cyclic control authority do not seem sufficient explanation alone for the loss of control of the helicopter. The wind conditions were gusting and varying in direction from across to behind. Control authority for wind speeds of up to 30 kt have been demonstrated during flight test, but these would have been in steady wind conditions. Variations in direction and strength of the wind will give rise to longitudinal trim changes, and once a pitch rate has developed there may then not be enough control authority to counter it, especially at heavier weights with a forward CG. The manufacturer's assessment was that the conditions of forward flight at very low speed with a tailwind were the main cause with the heavy aircraft weight and forward CG as aggravating factors. The report of one other apparently similar incident of uncommanded pitch down shows that prevention of this problem may warrant further safety action.

The cargo net was not in use on this occasion and from its condition it appeared that it had not been used regularly. It is interesting to note that the space aft of the cargo area leading into the tail boom is not separated by any partition and it may be possible for loose objects to migrate into the tail boom during flight. Indeed a headset cover was found in the tail boom after the accident although it was believed to have become lodged during the ground slide and did not affect the control of the helicopter.

The following safety recommendations are made:

Safety Recommendation 2005-033

It is recommended that Eurocopter highlight the circumstances of this accident to EC 120 operators, with a view to emphasising the importance of correct loading and the possible adverse effects a gusting tail wind can have on a hovering helicopter with a centre of gravity (CG) close to or on the forward CG limit.

Safety Recommendation 2005-034

It is recommended that Eurocopter include information, in the EC 120 Approved Flight Manual (AFM), concerning the locus of the cyclic control and the possibility that restriction in its movement, brought about by the morphology of either of the front seat occupants, may not be apparent prior to flight, when dual controls are fitted, because a pre-flight 'full and free' control check by the pilot is not routinely performed.