McDonnell Douglas Hughes 369E, G-LOGO

AAIB Bulletin No: 11/2004	Ref: EW/C2003/12/02	Category: 2.3
Aircraft Type and Registration:	McDonnell Douglas Hughes 369E, G-LOGO	
No & Type of Engines:	1 Allison 250-C20B turboshaft engine	
Year of Manufacture:	1991 (Manufacturer's Serial No 0454E)	
Date & Time (UTC):	2 December 2003 at 1428 hrs	
Location:	Near Kensworth, Bedfordshire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Aircraft destroyed	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	40 years	
Commander's Flying Experience:	4,900 hours (of which 1,100 were on type)	
	Last 90 days - 68 hours	
	Last 28 days - 24 hours	
Information Source:	AAIB Field Investigation	

Synopsis

Whilst on a cross-country flight the helicopter encountered severe turbulence followed by heavy vibration. The pilot carried out a forced landing in a field during which the helicopter rolled over and was destroyed. The pilot escaped without injury. One and a half minutes before the turbulence event an Airbus A319 aircraft had passed 300 feet above the position where the helicopter encountered the turbulence.

History of the flight

The flight was undertaken to position the helicopter from Shoreham Airport in Sussex, to Cheshire where it was to be demonstrated to a prospective customer. During the morning a different customer asked the pilot if, during his flight north, he would be able to take him to a helicopter landing site near Hemel Hempstead. The pilot agreed to do this.

After the helicopter was refuelled during the morning, the pilot carried out a pre-flight inspection. Departure from Shoreham was at 1354 hrs with the pilot seated in the left seat and the passenger seated in the right front seat. Dual controls were fitted.

The flight to Hemel Hempstead was uneventful and the pilot did not observe any problems with the helicopter en-route. Approaching Luton Control Zone he made two-way contact with Luton Radar and received a Visual Flight Rules (VFR) clearance into the zone to the landing site. The approach to the site was made into an open field before the helicopter was hover taxied to the landing pad. The pilot described the landing area as being clear and free from obstructions. Before the passenger disembarked, the pilot briefed him to be sure that both the passenger door and the rear right side door, which he would need to open to collect his baggage, were properly closed and secured afterwards. The helicopter was on the ground for one minute with the rotors kept running throughout.

The pilot lifted off from the site and contacted Luton Radar again who issued a VFR clearance for the helicopter to route north-west not above 1,500 feet amsl. A minute later Luton Radar advised the pilot that there was an "EASYJET SEVEN THREE SEVEN JUST CROSSING YOUR NOSE INTO YOUR ONE O'CLOCK POSITION BE LANDING ON YOUR RIGHT". The pilot acknowledged this information.

About a minute later the pilot described feeling a 'severe vertical bump' causing a descent followed by an ascent and, at the same time, he heard a mechanical noise. His immediate thought was that the rear door had opened and something had flown up into the main rotor. However, he looked back over his shoulder and could see that the door was still closed. The helicopter was now suffering significant vibration and so he lowered the collective and entered autorotation. The aircraft's response to the flying controls appeared normal and the pilot recalled that the instrument indications appeared to be "in the green". He selected a field to his left that he thought would be suitable for landing.

As soon as the event happened the pilot broadcast a 'PAN' call containing the following information "SEVERE TURBULENCE GOING DOWN IN A FIELD". The Luton Radar controller's response to the call was as follows: "ROGER SQUAWK MAYDAY". Unable to reach the transponder, the pilot could not comply with this request but concentrated on landing in the field he had selected. He made a turn to the left into the field and, as he approached what he judged to be a power on recovery height, he raised the collective lever. The helicopter did not respond as he expected so he lowered the lever again and decided to commit to an engine-off run-on landing. Afterwards he noted that his perception at the time was that there was a loss of rotor RPM, although he did not hear the low RPM warning horn.

Approaching the ground he flared the helicopter, reducing the speed to around 30 kt, and then cushioned the run-on landing. After a ground run of some eight metres the helicopter pitched forward and, despite the use of aft cyclic, he could not prevent it from pitching towards the inverted and then rolling sideways. The helicopter eventually came to rest lying on its right side. The pilot stated that the engine was still running so he closed the throttle, shut off the fuel and switched off the battery master switch before climbing out.

Once out of the machine the pilot was able to locate a flight guide from the helicopter and his mobile telephone, which he used to inform Luton Air Traffic Control (ATC) of his situation. Bystanders in the vicinity of the accident were able to direct the emergency services to the scene.

Damage to the aircraft

Examination of the accident site revealed that the aircraft had touched down, with significant forward speed, in a field with a smooth, soft surface. The ground markings indicated that after a short ground slide, the skids started to penetrate the surface, creating a drag force which caused the aircraft to pitch forward. This resulted in the forward ends of the skids digging into the ground and ultimately fracturing at their forward attachments. This effect further contributed to pitching the aircraft down until the nose firmly contacted the earth. During this process the main rotor blades also contacted the ground and the forces applied, in conjunction with the blade damage inflicted, caused at least one of them to leave the normal plane of rotation and pass through the tail-boom. Thereafter, the outboard sections of all the main rotor blades separated and the aircraft became almost inverted before coming to rest on its right side. Extensive damage occurred to the area of the aircraft normally occupied by the front right seat occupant; the pilot's occupied volume suffered no intrusion.

Pilot Experience

The pilot held a United Kingdom Private Pilot's Licence and a Federal Aviation Administration Commercial Pilot's Licence with Instructor Rating. He was familiar with the helicopter and had recent flying experience on the type. Moreover, during the week preceding the accident he had practised a number of engine-off and run-on landings.

Meteorological and surface conditions

The weather in the central and southern United Kingdom area was being influenced by a generally unstable air mass with a light easterly airflow. There was good visibility in most areas with cloud layers at 2,000 feet agl and above. The forecast wind at 2,000 feet amsl was easterly at 5 to 10 kt; the surface wind at Luton Airport (5 nm to the east) around the time of the accident was from 050º at 5 kt.

A young crop was established in the chosen landing field which had been cultivated and seeded. The surface was reasonably level but sticky following recent rain.

Aircraft description

The aircraft type has its origins in a US Army competition for a light observation helicopter in 1961 which was fulfilled by the Hughes Helicopters Inc Model 369. As development of the military version proceeded, Hughes also developed a commercial version.

Figure 1 - G-LOGO

Figure 1 – G-LOGO

During 1984 Hughes Helicopters became a subsidiary of the McDonnell Douglas Corporation and the generic type is now more commonly known as the Hughes 500 or the MD 500. By the end of 1991 almost 4,000 examples had been constructed. Some variants have a four-bladed main rotor and some, like G-LOGO have a five-bladed main rotor. The flight controls are mechanical with no hydraulic assistance. G-LOGO was equipped with two pilot seats and a range-extension fuel tank in the rear passenger compartment beneath two passenger seats.

Significant main rotor features

Each main rotor blade is attached to the hub via a pair of quick release pins engaging in steel mounting lugs. A third generally similar pin secures the lead-lag damper to its bracket at the trailing edge of the blade. Each of the blade pins consists of a central spindle passing through a series of split colletts, each having internally tapered ends. A nut threaded onto the lower end of the spindle retains the colletts and a series of conical inserts that engage in the corresponding tapered recesses in the ends of the collets. An over-centring lock lever is attached to the top end of the pin by means of a lateral shaft into which the top of the spindle is threaded. The locking lever incorporates an eccentric section which reacts against a washer at the top of the collet stack and draws the lateral shaft and hence the spindle upwards as the lever is rotated downwards in a plane parallel to the spindle centre-line. This action compresses the stack of collets and conical inserts between the top washer and the bottom nut and forces the inserts into the internally tapered ends of each of the split collets, causing the latter to increase in diameter and to create an interference fit in the blade mounting lugs. A spring steel extension on each locking lever incorporates a hexagonal cut-out which engages with the bottom nut when the lever is in the fully over-centred position parallel with the spindle axis. A quick release pin in both the open and closed positions is illustrated in Figures 2 and 3.

Figures 2 and 3 Pin Open and Closed

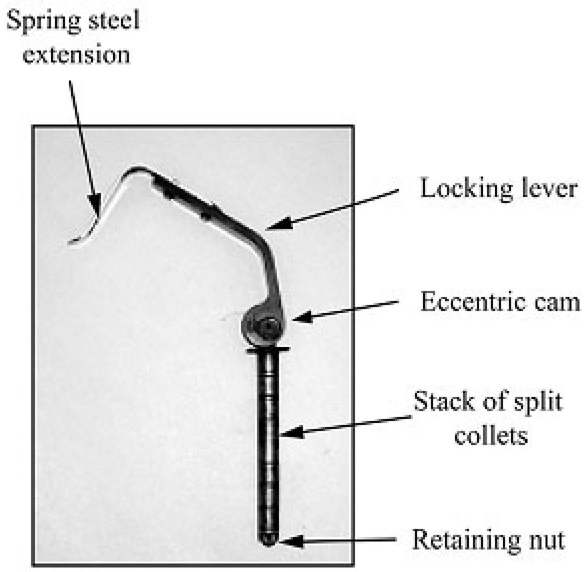

Figure 2 - Pin Open

Figure 3 - Pin Closed

The aircraft manufacturer stated that, in-flight, the centrifugal load on the pin would have been in excess of 19,000 lbf.

Detailed helicopter examination

Detailed examination of the aircraft confirmed that four of the five main rotor blades had failed approximately in the plane of the section at identical span-wise stations close to the blade roots. In each case the attachment between the blade and the lead-lag damper had failed. The failure of the remaining blade, however, took a very different form. The forward of the two blade pins was absent, whilst the lugs through which it normally passed were entirely undamaged. The blade cuff had rotated backward in the plane of rotor rotation about the rear blade attachment pin, the attachment of the lead-lag damper being totally destroyed. A substantial length of blade remained attached with the tension bearing element at the leading edge of the section being wrapped around the rotor mast.

A visual search of the accident site revealed no evidence of the absent retaining pin. Two separate searches in the immediate area, using a metal detector, also failed to find the pin. An analysis of the helicopter flight path, utilising recorded data extracted from the hand-held GPS in use in G-LOGO, combined with the radar recording which showed the passing Luton bound airliner, isolated a ground area over which the event is presumed to have begun, on the assumption that a wake encounter was the initiating event. Calculations were carried out to establish the extent of possible 'throw' of the pin either side of the flight path. Using this data, an area of possible fall of a quick release pin was established, again assuming it separated in the region of the point where the helicopter may have entered wake turbulence from the airliner. This area was then subjected to an extensive search using metal detectors. Neither the pin nor any of its constituent parts were found.

A thorough examination of the controls and mechanical systems of the aircraft was carried out at the AAIB headquarters in conjunction with an accident investigation specialist supplied by the aircraft manufacturer. No evidence of pre-impact failure was found.

Recorded information

The aircraft was not equipped with a flight data recorder (FDR) or a cockpit voice recorder (CVR) nor was either required by regulation. However, it carried a Bendix/King 'Skymap II' GPS (Global Positioning System) receiver. The GPS data log was successfully recovered from the unit. The following parameters were recorded every thirty seconds: date, time, latitude, longitude, ground speed, track and GPS altitude.

The time reference for the GPS was obtained from a master clock linked to the satellite system. Seven GPS data points were recorded for the accident flight. The first point was recorded at 1425:46 hrs, just after takeoff and the final data point was recorded at 1428:47 hrs. At the final data point the ground speed was 115 kt, track 315 degrees and GPS altitude 978 feet.

All the Luton ATC communications with the helicopter were recorded. The time reference for these is considered accurate to within a few seconds. The information passed to the helicopter about the Boeing 737 aircraft crossing ahead was incorrect in so much that the aircraft was actually an Airbus A319. This aircraft was on an Instrument Landing System approach to Runway 08 at Luton.

Recorded radar information was available and was analysed. The time reference is considered accurate to within a few seconds. There was data for the Airbus A319 aircraft, including altitude information, on the approach to Luton Airport. The helicopter track data was also recorded but without an altitude readout.

When combined the data showed that at 14:27:02 (radar time) the A319 was descending on the approach to Runway 08 at Luton Airport passing 1,800 feet amsl and decelerating through 140 kt groundspeed. At 14:28:30 (GPS time) the helicopter passed immediately under the same location at a height of 1,500 feet amsl and with a groundspeed of 125 kt. At 14:28:39 (ATC time) the helicopter made a PAN call to Luton ATC. (See Figure 4)

G-LOGO Final GPS log

The pilot reported, following the event, that he had noticed a vibration which started after lift off from the site at Hemel Hempstead and continued throughout the short flight. A total of 14 radio transmissions from G-LOGO to Luton ATC, both before and after the intermediate landing, were analysed for background sound. The first transmission occurred at 1418:20 hrs and the final transmission, the PAN call, occurred at 1428:40 hrs. The longest transmission lasted for 15 seconds.

Four of these transmissions were after the landing at Hemel Hempstead. In these it was noticed that there was a signal of between 36 and 40 hertz recorded. This signal was not evident in any of the earlier transmissions but was much stronger in the final transmission. The exact frequency of the signal could not be determined due to voice audio masking and the short duration of the transmissions; the longest of which was five seconds starting at 1428:40. Although the exact origin of the signal could not be confirmed it would have been consistent with a main rotor speed in the region of 450 to 490 RPM.

Wake vortex

General information

There are a number of publications and guidance documents available that highlight the dangers to aircraft associated with wake vortices generated by other aircraft. The greatest hazard to light fixed wing aircraft is the induced roll and yaw which can be extreme. There is less information about how vortices may affect control of rotorcraft but for both types of aircraft there is also a risk of structural damage in a severe encounter, either from the initial event or from a pilot's subsequent attempt to maintain control.

The most severe vortices are generated by heavy aircraft flying slowly and the recommended strategy is to avoid the area behind and below such aircraft. The amount of time during which a vortex will persist varies with wind and atmospheric conditions. The CAA publication General Aviation Safety Sense Leaflet 15B contains information about wake vortices including the following:

> *'For each nautical mile behind an aircraft, the vortex the aircraft generates will typically have descended between 100 and 200 ft',*

and from Aeronautical Information Circular (AIC) 17/1999 'Wake Turbulence':

'Avoid flight below and behind a large aircraft's flight path.'

Air Traffic Control service providers in the United Kingdom use specific wake vortex spacing criteria which broadly conform to the International Civil Aviation Organisation (ICAO) specification. The A319 aircraft is classified in the 'medium' weight category. Aircraft operating in accordance with Visual Flight Rules (VFR) are required to maintain their own separation from other aircraft although, if on an approach, ATC will pass advice about the recommended distance.

Previous occurrences

There have been a number of accidents and serious incidents to aircraft that were attributed to wake vortices generated by heavy aircraft and some have been the subject of previous AAIB reports. In the United Kingdom, National Air Traffic Services (NATS) operates a voluntary wake vortex reporting scheme and maintains a database of events extending back to 1972. There were three reported vortex encounters by helicopters in the period but the information on each event was limited.

Analysis

At the time of the initial event the helicopter had just climbed to reach level cruise flight at close to 1,500 feet amsl with a groundspeed of 125 kt. Prevailing winds at this altitude were across the track so it is reasonable to assume the airspeed was approximately equal to the groundspeed. The A319 was heading directly into the wind so it would be expected that the trailing vortices would remain approximately along the line of its track. The intersection point of the two aircraft tracks was at a distance of 5 nm from the touchdown zone of Runway 08, thus the A319 at 1,800 feet was on or close to the glideslope. (Luton Airport's elevation is 526 feet amsl.)

Although there may be differences between the time references used for the different data sources it is considered that these will not be more than +/- 2 seconds. The helicopter crossed about a minute and a half behind the Airbus A319 and some 300 feet below its flightpath. The known characteristics of wake vortices are that, unless disturbed, they will persist for several minutes and drift downwards at about 100 to 200 ft/min. Wind conditions were light and, although the meteorological forecast indicated that the airmass was somewhat unstable, it is in just such circumstances that a wake vortex encounter seems likely.

The pilot was advised by ATC of the traffic ahead. The nature of most helicopter operations is such that they will not often be in a location where a wake vortex encounter is likely. It may be that the level of the awareness of the hazard associated with wake vortices is less amongst helicopter pilots than fixed-wing pilots. The general advice given to pilots in AIC 17/1999 is however the same for all:

'The wake of a large aircraft deserves the respect of all pilots. The area up to 1,000 feet below and behind such an aircraft should be avoided.'

The pilot described experiencing a "severe vertical bump", which was possibly the effect of turbulence caused by a wake vortex. Although information about wake vortex characteristics and how they affect fixed wing aircraft is plentiful, there is much less anecdotal evidence or data available of the effects upon a helicopter. Any physical evidence of damage sustained by the helicopter during the turbulence encounter would have been disguised by the subsequent accident damage and so was not available.

The pilot remembered that after the transit stop at Hemel Hempstead he had noticed an increase in noise from the rotor head, which he had thought to be evidence of a tracking problem. A recorded signal, which was probably rotor RPM, was observed in the background of his transmissions from this time, however there are a number of possible different explanations for this. For instance, all the transmissions made after the transit stop were during the climb phase and a different rotor noise might thus be expected. This signal was, however, much stronger during the PAN call than before it.

A reason for the lack of collective pitch control effectiveness described by the pilot could not be determined, again because of the damage. During the run-on landing the sticky ground conditions probably caused a rapid deceleration and subsequent pitch forward. The pilot remembered using aft cyclic input to try to prevent it nosing over. Whether the tail boom was severed as result of these inputs or as a consequence of the main rotor disruption following ground contact could not be positively established.

The only obvious features found during wreckage examination judged not to be consistent solely with the aircraft impact parameters were the absence of one blade retaining pin, coupled with the condition of the associated blade and the undamaged state of its attachment lugs. The unusual blade damage was not only entirely different from the damage to the remaining four blades, but it was judged to be consistent with the presumed effect of the aircraft overturning with the pin not being located in the lugs. Although a search was made of the likely area of fall of the pin, had it separated whilst in flight close to the point where the wake encounter probably occurred, the inability to find it was not conclusive evidence of its absence from that area. Similarly, failure to find it at the accident site was not conclusive evidence that it was missing at the time the aircraft overturned. Moreover, the manufacturer stated that the centrifugal load on in the pin, in conjunction with the in-built interference fit, would have ensured that the pin could not migrate upwards during flight.

A brief study of the geometry of the blade root attachment and the effect of the lead-lag damper confirmed that loss of the blade attachment pin in flight would have resulted in overall imbalance of the main rotor disk. The extent of this imbalance was not known and it was initially decided to carry out an analysis to determine the new geometric position of the blade during rotation and to establish whether continued flight was possible after loss of a pin from the relevant attachment lug. Subsequent reflection, however, lead to the conclusion that the extent and magnitude of the assumptions required to carry out such an analysis would cast doubt on the validity of the results. In addition, the failure to locate the missing pin, or any parts thereof, lead to an inability to comment usefully on any possible serviceability issues with this component. However, a representative of the helicopter manufacturer stated that this design of blade pin and variants of it have been in use for 40 years and have accumulated millions of flight hours with no recorded in-flight failures.

It could not, therefore, be positively determined whether damage sustained as a result of wake turbulence alone, or the loss of a blade pin, or a combination of both, or indeed other factors were responsible for the vibration experienced by the helicopter and its pilot.