ACCIDENT

Aircraft Type and Registration:	Gippsland GA8 Airvan, G-CDYA
No & Type of Engines:	1 Lycoming IO-540-K1A5 piston engine
Year of Manufacture:	2006
Date & Time (UTC):	28 November 2010 at 1015 hrs
Location:	Near Redland Airfield, Swindon, Wiltshire
Type of Flight:	Aerial work
Persons on Board:	Crew - 1 Passengers - 8
Injuries:	Crew - 1 (Serious) Passengers - None
Nature of Damage:	Landing gear and left wing damaged
Commander's Licence:	UK Private Pilot's Licence
Commander's Age:	61 years
Commander's Flying Experience:	2,686 hours (of which 1,057 were on type) Last 90 days - 75 hours Last 28 days - 13 hours
Information Source:	AAIB Field Investigation

Synopsis

Shortly after takeoff the aircraft stalled at a height that was too low to allow a recovery. There was probably frost on the wing, which caused the aircraft to stall at a speed that was higher than expected.

History of the flight

The pilot arrived at the aircraft at approximately 0900 hrs to prepare it for a flight to drop parachutists. The aircraft had been outside overnight and there had been a heavy frost. The pilot removed a cover from the windscreen and began his pre-flight check during which he noticed no ice or frost on the upper surface of the wings. He returned to the operations building to complete his pre-flight planning and went back to the aircraft in time to start the engine at 1000 hrs. There was a very light wind from the north-west across the grass Runway 06L, the temperature was -4°C and the QNH was 1004 mb. While the engine was warming up, eight parachutists boarded the aircraft and sat down in the cabin. There were three parachute instructors, who were connected to three students, and two other parachutists with video cameras, one of whom was the jump supervisor.

After the pilot judged that the engine had warmed up, he carried out a power check and the before takeoff checks, during which he selected the flaps to TAKEOFF. All indications appeared normal to the pilot and he taxied onto the runway and selected takeoff power, which was 29 inches of Manifold Air Pressure (MAP) and 2,500 rpm. The acceleration seemed, to the pilot, to be normal but, although V_R was 60 kt, he delayed the rotation until 65 kt. At about the time the aircraft rotated, the pilot selected the flaps to FULL.

As the aircraft crossed the hedge at the upwind end of the runway, the pilot began a left turn, which was the usual noise abatement manoeuvre to avoid flying over buildings situated on the runway's extended centreline. During the turn, he realised the aircraft was descending and checked the engine instruments, observing that the MAP, fuel pressure and rpm were indicating correctly. He called "BRACE, BRACE, BRACE" and the aircraft hit the ground immediately afterwards in a left wing low attitude. After crossing a ditch, during which the landing gear detached, the aircraft skidded to a halt in the next field. The pilot was able to exit the aircraft through the door on his left but found that he could not stand up because of an injury to his leg. The sliding door on the rear left side of the cabin was jammed and the parachutists were unable to use it to leave the aircraft and so they exited through the same door as the pilot. One parachutist received a whiplash injury but the rest were unhurt. The pilot was subsequently airlifted to hospital.

Witness evidence

Five of the parachutists had flown in G-CDYA many times from the same runway and they commented that the takeoff seemed to take longer than normal. Shortly after the aircraft entered the turn, it started to lose altitude and one parachutist recalled it "shaking a bit" as it started to descend. When the aircraft came to rest following the impact sequence, the jump supervisor tried to open the sliding door but was unable to do so. The occupants decided to follow the pilot and they climbed over his seat and left the aircraft by the front left door.

A witness on the ground thought that the aircraft seemed to stop climbing when it started its turn and did not climb above about 100 ft agl. He also thought that it started to lose altitude about half way into the turn.

Accident site details

The aircraft had contacted the ground on a track of around 340ºM immediately in front of a 1.5 m high hedge, which formed the boundary between two fields. On the far side of the hedge, and running parallel to it, were a ditch and an agricultural concrete track. Marks on the ground indicated that there had been heavy contacts from the outboard left wing and the left landing gear. The nose and right landing gears had also left marks on the ground as the aircraft passed through the hedge, with all the landing gears having been torn off as a result of striking the ditch; the nose wheel was found embedded on the far side of the ditch. The aircraft then slid along on its belly on the stubble surface of the field, slewing to the left before coming to rest on a heading of 240ºM, approximately 25 m beyond the hedge.

The aircraft geometry in relation to the observed ground marks indicated that the aircraft had struck the ground with a bank angle in excess of 25º to the left and approximately level in pitch.

On-site examination of the aircraft

The initial AAIB examination commenced approximately four hours after the accident. The air temperature had remained below freezing all day and it was noted that there was a layer of frost, similar to that which typically accumulates overnight on a car windscreen, on the wing upper surface. The layer, which was difficult to discern against the white paint on the wing, was approximately 1 mm thick and had a texture similar to medium grade sandpaper. There was no evidence of frost on the windscreen; in consequence it was concluded that the frost on the wing had likely been present all day, rather than having formed after the accident.

The flap lever, which was located on the floor to the right of the pilot's seat, was found to be in the middle of its three detented positions, ie at the TAKEOFF setting. This corresponded to the observed position of the flap on the right wing, although the position of the left flap had been affected by the relatively severe damage arising from the impact with the ground. As a consequence, the inboard trailing edge of the wing, including the flap, had been deflected downwards so that it impinged on the front edge of the sliding door in the cabin, preventing it from being opened.

Some scuff marks were observed on the concrete track; these were attributed to the stub of the nose leg and the propeller blades. The latter would have struck the ground following the removal of the landing gear, and it is probable that the blade pitch change mechanism was broken at this stage. The blades had then twisted, allowing their flat surfaces to contact the frozen ground, resulting in both blade tips curling over. It was considered that the observed damage was indicative of a considerable amount of power being developed by the engine at impact.

The aircraft had a simple fuel system, whereby the engine was supplied simultaneously from the wing tanks via a collector tank located in the forward lower fuselage. A small sample was taken from the fuel drain on each tank; the appearance was consistent with Avgas, with no evidence of water droplets, cloudiness or debris. There was no evidence of a fuel spillage resulting from the accident. The fuel selector was a simple ON-OFF 'T' handle on the instrument panel, which was found in its forward, ON, position. It was considered prudent to move the selector to the OFF position prior to leaving the accident site for the evening. However, on the following morning it was apparent that fuel had been leaking from beneath the nose, in the area of the collector tank. Approximately 20 litres of fuel were drained from the left tank, with only a small amount being found in the right tank. This was attributed to the attitude in which the aircraft had come to rest; the right wing was at a slight wingtip-high angle, with the left wing being almost level. As a consequence, most of the fuel in the right tank had drained inboard and was lost via the leak around the collector tank, with the possibility of a lower volume being lost from the left tank. The refuelling records suggested there should have been approximately 70 litres of fuel on board at the time of the accident, out of a total capacity of 350 litres. Thus, although it was not possible to assess the quantity of fuel that had leaked into the ground, the amount that was recovered was in excess of that required to sustain the engine.

Following the on-site examination, the wings were removed from the fuselage and the wreckage was recovered to the AAIB facility at Farnborough, where it was subjected to a more detailed examination.

Detailed examination of the wreckage

Airframe

The fuel tank drain valves were located on the underside of the forward fuselage immediately aft of the collector tank, which was also equipped with a drain valve. All had some degree of damage where they had been in contact with the ground. The fuel ON-OFF selector valve was downstream of the drain valves. It was considered that fuel was lost, principally from the right tank, through the drain valves, which were probably partially opened by being pressed against the ground as a result of activity at the aircraft following the accident.

As noted earlier, the sliding door could not be opened after the accident due to the left wing trailing edge being in contact with the front edge of the door. However, even with the wing removed the door could be slid along its rails only with difficulty. This was subsequently found to be due to distortion in the lower fuselage frames, causing misalignment of the upper and lower rails.

In the absence of the front right hand seat, the instrument panel and control columns were protected from potential interference from passengers by an upright panel, in the approximate shape of a seat back, which was attached to a frame and mounted on the floor in place of the co-pilot's seat. This item, which had been designed and built by the aircraft manufacturer, served to partially obstruct access to the right forward door from the passenger cabin, although the obstruction was less than that with the seat left in place. The panel had been deflected forwards as a result of one of the parachutists leaning against it during the accident although this had had the effect of improving access to the door.

Stall warning system

The stall warning device fitted to G-CDYA consisted of a small vane fitted below and slightly aft of the leading edge of the main wing. An electrical continuity check of the system revealed no faults, and the associated warning horn was found to be operational.

Engine

The engine had been installed in the aircraft from new and had achieved 1,535 operating hours and more than 3,400 flights at the time of the accident. The most recent maintenance was a scheduled 50 hour inspection, which was conducted on 20 September 2010 when the aircraft had logged 1,485 operating hours.

The engine had suffered little visible damage apart from some scuffing of the oil cooler on the underside. However, after removing the cowlings it was apparent that the upper fitting of the nose landing gear had been deflected during the impact with the result that it had penetrated the oil filter mounted on the rear of the engine, causing a small oil spillage.

The engine was taken to an overhaul agent, where, after conducting a detailed inspection and fitting a new oil filter, it was mounted in a test cell that was equipped with an eddy current dynamometer. A pre-oiling operation conducted at this time revealed that the oil pressure was satisfactory. Some difficulty was experienced in starting the engine; this was attributed to the test cell installation not utilising the engine's priming system. The engine ran normally after starting and, after warming, was run to full power. This was found to be around 250 bhp at 2,700 rpm, which was somewhat short of the 300 bhp specified for a new engine. The overhaul agent commented that the value observed was, in their experience, typical for an engine of this type that was three quarters through its 2,000 hour overhaul life.

After testing the engine, the fuel injection servo unit was removed and subjected to a separate bench check. Fuel metering in this type of unit is a function of air mass flow, its associated suction and throttle position. Fuel flows were measured at a number of test points specified in the manufacturer's test schedule; all were found to comply with the specified values apart from a minor deviation in a 'mid range' setting. According to the overhaul agent, this was observed regularly on this type of unit and would have had no effect on engine operation.

Recorded evidence

There were two video recordings of the flight taken from within the cabin and information was available from the GPS unit fitted to the aircraft, which provided data at 10 second intervals. Using this evidence, it was possible to establish to a reasonable degree of accuracy the sequence of events leading up to the accident. The results are shown in Table 1, where the times shown are relative to the time the aircraft passed a recognisable dip in the runway during takeoff.

Interview with the pilot

The pilot stated that the rpm lever could be moved forward through a gate, which would increase the propeller speed from 2,500 to 2,700 rpm and increase engine power from 275 to 300 bhp. He did not recall selecting 2,700 rpm when he realised the aircraft was descending and he did not recall hearing the stall warning horn.

The pilot also stated that he sometimes selected flaps to FULL after passing the dip in the runway, selecting them back to TAKEOFF shortly after lift-off. He would then accelerate to the takeoff safety speed before selecting the flaps to UP. He did not recall when, on this occasion, he selected flaps back to TAKEOFF following lift-off.

Aircraft performance

The aircraft's takeoff performance was calculated using the manufacturer's performance tables, which assume the use of full throttle and 2,500 rpm. The calculation was made using no headwind, an airfield pressure altitude of 580 ft, no runway slope and a takeoff mass of 1,738 kg. V_R was 59 kt and the takeoff safety speed was 70 kt. The distance calculated to lift off was 340 m, and the distance to a height of 50 ft was 520 m, using performance figures for a takeoff on short dry grass. There were no performance figures available

Time (seconds)	Video evidence	GPS evidence
- 2		Groundspeed 47 kt Track 060° T
0	Aircraft crossed a dip in the runway.	
6	Last point where the flaps were seen to be at TAKEOFF.	
8	Lift off. Flaps at FULL.	Groundspeed 63 kt Track 060° T
13	Aircraft at upwind hedge boundary. Left turn started. Flaps at FULL.	
18		Groundspeed 58 kt Track 027° T
24	Impact. Flaps subsequently found at TAKEOFF.	

Table 1

Sequence of events

for takeoff on a grass surface following a heavy frost, but the takeoff distances were adjusted using factors recommended by the CAA to generate estimated values for takeoff on short wet grass. The values obtained were 368 m and 563 m respectively. Using video evidence, it was established that the aircraft actually left the ground after approximately 560 m. The runway is 640 m long.

Stall warning

The Civil Aviation Authority's *Safety Sense Leaflet 3: Winter Flying* discusses some of the problems that pilots might encounter when flying in winter. It states:

> *'Tests have shown that frost, ice or snow with the thickness and surface roughness of medium or course sandpaper reduces lift by as much as 30% and increases drag by 40%. Even a small area can significantly affect the airflow, particularly on a laminar flow wing.'*

The GA8 Aircraft Flight Manual states that the stall is preceded by slight aerodynamic buffet. In addition, the GA8 is equipped with a stall warning system. If the angle of attack increases towards a set value – which corresponds to a speed of five to seven knots above the stalling speed for a given configuration with an uncontaminated wing – it causes the stall warning vane to move, resulting in a warning horn sounding in the cockpit. The horn, therefore, is triggered by angle of attack and is not a direct indication of an aerodynamic stall. If a wing's lifting performance is reduced by frost, the wing will stall at a lower angle of attack and a higher speed than usual and the angle of attack might not be high enough to trigger the warning horn.

The aircraft's takeoff mass was 76 kg below the maximum takeoff mass of 1,814 kg. The stalling speed of a GA8 at idle power and maximum mass is 57 kt with flap at FULL (38°) and 60 kt with flap at TAKEOFF (14°). The stalling speed would be expected to be slightly lower at takeoff power due to slipstream effects from the propeller. If the lift of the wing was reduced by 30%, which was a possibility according to *Safety Sense Leaflet 3*, the 60 kt level flight stalling speed with takeoff flap selected would increase to 72 kt[1].

Information from Table 1 suggested that the aircraft heading changed by 33° in the five seconds after the turn began at the upwind hedge of the airfield, corresponding to approximately 20° angle of bank at 60 kt IAS. If it is assumed that the track at impact was approximately 338°T[2], the heading changed by approximately 49° in the six seconds before impact, corresponding to approximately 24° angle of bank. A level flight stalling speed of 60 kt would increase to approximately 63 kt with a bank angle of 24°[3]. A level flight, contaminated wing, stalling speed of 72 kt might increase to approximately 75 kt.

Survivability

G-CDYA had been modified to carry parachutists and all seats had been removed apart from the pilot's seat on the left side of the cabin. Five parachutists sat on the right side of the aircraft and three on the left. Six of the occupants faced rearwards but the parachutist at the rear on each side faced forward and carried a video camera. The occupants sat on rectangular cushions on the floor and secured themselves in the cabin using straps attached to hard points on the cabin floor, which they passed through their own parachute harnesses.

Footnote

1 See Appedix.
2 340° M adjusted for variation, which was 2° W.
3 The stalling speed increases with the load factor in the turn. The load factor is given by the secant of the bank angle.

The GA8 has two forward opening cockpit doors, one on each side of the aircraft, which act as emergency exits. There is a sliding door on the left side of the main cabin, which may be opened in flight but the GA8 flight manual does not specify this door as an emergency exit. The accident was, self-evidently, survivable, and during the impact sequence the aircraft remained upright with the occupants remaining close to where they were seated at impact. During the evacuation, after finding that the sliding cabin door was jammed, all the occupants left the aircraft by the exit to the left of the pilot's seat; none of the occupants considered leaving the aircraft by the exit to the right of the co-pilot's seat.

British Parachutists Association

Pilot qualifications

The British Parachutists Association (BPA) Operations Manual states that, in order to act as pilot in command (PIC) of an aircraft for a flight during which parachutists are to be dropped, a pilot must hold a valid pilot's licence for the type or class of aircraft to be flown and must have at least 100 hrs PIC. Pilots also undergo ground training, at least four lifts supervised by a BPA Pilot Examiner or Club Chief Pilot, and a written examination and flight test. Pilots must complete a proficiency check at least every twelve months. The pilot in this accident was in compliance with the requirements.

Risks other than the parachute jump itself

The BPA website contains a section on managing the risks associated with parachuting. It discusses the risk associated with the airfield environment and the flight leading to a jump and states:

> *'These risks are…..numerically less significant than those of the jump itself. Major international airlines maintain their aircraft and conduct their flights in accordance with 'Public Transport' Requirements. However, many parachute clubs may maintain their aircraft and conduct their flights in accordance with the less demanding requirements of the 'Private Category' Schedules.'*

Air Navigation Order

Schedule 7 to Section 1 of the Air Navigation Order (ANO) details the privileges given to pilots holding a Private Pilot's Licence (PPL). Holders of a UK PPL may not fly for the purpose of aerial work except:

> *'for the purpose of aerial work which consists of…. a flight for the purpose of dropping persons by parachute.'*

Analysis

The aircraft was parked outside overnight prior to the accident and the windscreen, which had been covered, was clear of ice and frost when the cover was removed. Four hours after the accident, the windscreen was still clear, which suggested that ice and frost were not actively forming during that period. However, since frost was found on the upper surface of the wing, it was concluded that the frost would have been present prior to and during the takeoff.

The maximum engine power was found to be approximately 50 bhp less than the rated value. This was attributed to the state of wear expected of an engine approximately 75% through its normal overhaul life rather than as a result of a failure experienced on this particular takeoff.

The distance to lift off, calculated using the manufacturer's performance information, should have been between 340 m and approximately 368 m and yet the aircraft actually left the ground after approximately 560 m. The extra distance used by the aircraft was probably a combination of two factors: the engine was not producing the power assumed in the performance calculation and the aircraft was rotated approximately three to five knots above V_R. It is possible that takeoff performance was reduced due to the effects of frost on the wings but it was not possible to quantify these effects.

As the aircraft began its left turn, the flaps were at FULL and yet the flap selector handle and the flaps were found in the TAKEOFF position following the accident. At some point in the turn, therefore, the flaps were raised by one stage. This would have had the effect of increasing the stalling speed by approximately three knots (in the case of an uncontaminated wing).

The groundspeed of the aircraft, recorded by the GPS approximately six seconds before impact, was 58 kt. The aircraft was turning into a light wind and so the IAS might have been slightly higher. The stalling speed of the aircraft during the turn, with the flaps in the TAKEOFF position and with an uncontaminated wing, would have been approximately 63 kt. The effect of the frost would have been to increase the stalling speed, in the worst case, to 75 kt. The CAA *Safety Sense Leaflet 3* suggests that the maximum reduction of lift might occur with frost that has a surface roughness of course sandpaper, whereas the frost found on G-CDYA was similar to medium sandpaper. Nevertheless, it was clear that the lifting ability of the wing would have been compromised and the stalling speed would have been higher than 63 kt. It seemed probable, therefore, that the aircraft stalled in the turn as a result of frost on the wing. Furthermore, the angle of attack at the stall was probably lower than that required to activate the stall warning horn.

Appendix

Estimation of the stalling speed of the frost-covered wing

The lift of a wing, L, is given by:

$$L = \frac{1}{2}\rho V^2 S C_L$$

Where:

ρ = the density of the air (which is assumed to be constant for the purpose of this comparison).

V = the velocity of the aircraft (knots will be used as the units because, as a ratio of speeds is to be found, the units merely need to be consistent).

S = the representative area of the wing (which is constant).

C_L = the lift coefficient of the wing immediately before the stall (which is assumed in this comparison to reduce by 30% if the wing is covered in frost).

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For a given aircraft, let L represents the lift of its uncontaminated wing in level flight, and L' represent the lift of its frost-covered wing in level flight. As the wings in each case are supporting the aircraft in level flight, $L = L'$. If the lifting ability of the wing, C_L, is reduced by 30% on a frost-covered wing, as suggested in *Safety Sense Leaflet 3*, then the aircraft will have to fly faster to generate the same amount of lift. In order to calculate by how much the speed will have to increase, assume:

$C'_L = 0.7\ C_L$

V = the level flight stalling speed of the aircraft with an uncontaminated wing = 60 kt

V' = the level flight stalling speed of the aircraft with a frost-covered wing

$\frac{1}{2}\rho S$ = a constant, k

Then:

$\frac{L}{L'} = \frac{kV^2C_L}{kV'^2C'_L} = 1$ and $\frac{V^2C_L}{0.7V'^2C_L} = 1$ and $V^2 = 0.7V'^2$

If V = 60 kt, then V' = 71.7 kt