ACCIDENT

Aircraft Type and Registration:	CAP 222 (Modified), G-GZOZ
No & Type of Engines:	1 Lycoming AEIO-360-A1E piston engine
Year of Manufacture:	1998
Date & Time (UTC):	8 July 2005 at 1415 hrs
Location:	White Waltham Airfield, near Maidenhead, Berkshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Fatal) Passengers - N/A
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Airline Transport Pilot's Licence with Flying Instructor Rating
Commander's Age:	43 years
Commander's Flying Experience:	10,149 hours (of which 115 were on type) Last 90 days - 221 hours Last 28 days - 49 hours
Information Source:	AAIB Field Investigation

Synopsis

The experienced aerobatic pilot had briefed to fly four different unlimited aerobatic manoeuvres, practising three of each whilst being watched by his aerobatics instructor. When practising the fourth manoeuvre, a knife-edge spin[1], for the third time, the aircraft entered an inverted spin which was not part of the planned sequence. The aircraft continued spinning until it impacted the ground. It struck the ground in an inverted attitude, with a high vertical rate of descent and with an anti-clock-wise rotational movement when viewed from above. The pilot was fatally injured on impact.

Pilot's flying experience

The pilot was a current Boeing 747 commander. In addition to his UK Airline Transport Pilot's Licence, he held an FAA Commercial Pilot's Licence and a New Zealand Private Pilot's Licence. He started flying competition aerobatics in about 1995, winning the Standard Nationals aerobatic competition in 1997, in a Pitts S1D. He then moved on to advanced aerobatics in 1999 and became the National Aerobatic Champion at this level in 2002. He had been flying 'unlimited

Footnote

[1] A knife-edge spin is not a true spin because the wings are not stalled. Instead, the aeroplane is deliberately yawed and it rapidly rotates in pitch about its lateral axis, under the influence of elevator and gyroscopic forces.

aerobatics'[2] in G-GZOZ since 2003 but he continued to compete at the advanced level. He also held a Flying Instructor rating and a Display Authorisation to perform aerobatics down to a base height of 500 ft agl.

Nine months before the accident the pilot frequently practised aerobatics. He then stopped flying aerobatics on a regular basis whilst he completed, with his airline employer, an aircraft type conversion course followed by a command course. One month before the accident, the pilot resumed his previous aerobatic continuity and was again flying aerobatics frequently.

Other aerobatic types he had flown included the Chipmunk, CAP 10, Tiger Moth, Harvard, Extra 200, Sukhoi 29, Yak 52, various types of Pitts, and the Cessna 150 Aerobat.

History of flight

On the day of the accident, the pilot flew one flight in G-GZOZ prior to the accident flight. He had first flown in the morning to practise some other unlimited aerobatic manoeuvres. On both occasions he was provided with a ground based radio critique, on a quiet frequency, by the part-owner of the aircraft who was a very experienced aerobatic flying instructor and international aerobatic competitor. The instructor was positioned outside the flying club house, about 1 km from the crash site.

Both flights were flown overhead White Waltham Airfield, in pre-booked slots of 20 minutes. White Waltham flying orders state that aerobatics overhead the airfield are to be confined to that part of the aerodrome traffic zone that is to the west of the Heathrow Control Zone. The maximum and minimum heights for aerobatics in the overhead are 2,300 ft agl and 500 ft agl respectively. The weather minima required are 2,500 ft cloud base and 5 km visibility.

The weather was good with a surface wind from 020° at 08 to 12 kt, a visibility of 10 km or more and broken cloud at 3,200 ft and 4,500 ft agl. In accordance with normal practice, the flight was 'booked out' on a 'Waltham Based Aircraft' sheet, showing a planned departure time of 1400 hrs.

The pilot was described as looking fit and well that morning. People who had lunch with him said he was in good spirits and in a happy mood. In the afternoon, the pilot briefed with his instructor, for his second flight of the day. This flight was to practice four different manoeuvres, flying three of each, all of which he had flown before on various occasions. The last manoeuvre was to be a knife-edge spin.

The first three manoeuvres were flown without any problems. He then planned to fly the knife-edge spins, in order to practise the correct amount of aileron to use during the manoeuvre. He intended to complete only one rotation in pitch during each knife-edge spin. The first repetition was not balanced and progressed into a positive flick roll, (sometimes called a snap roll) from which the aircraft recovered normally. The second was flown satisfactorily, with good balance, but the rotation rate was a little slow. His instructor thought this was because he was not putting in full-forward control column. His instructor passed this advice to him by radio. He stated that he accepted the advice and set up to try one more knife-edge spin.

The set up and entry to the third knife-edge spin was flown correctly, at a height of approximately 2,300 ft agl. After one complete rotation in pitch, no recovery action

Footnote

[2] The most proficient aerobatic skill level of the class sequence: standard, intermediate, advanced and unlimited.

was evident. After a further half a rotation in pitch, the instructor called "recover" over the radio. He expected the aircraft to enter a vertical dive from which it would then recover. The pilot did not reply to this call.

The aircraft then continued for a further half to three-quarters of a rotation in pitch, before going onto its back and entering an inverted spin at approximately 1,800 ft agl. The aircraft continued to spin inverted until it impacted the ground. Because this inverted spin initially had a slow rate of descent with a 'flat' pitch attitude, it appeared to the instructor to be one in which right rudder was applied. (A right-rudder inverted spin is generally flatter than a left-rudder inverted spin.) Being aware of the manoeuvre the aircraft was then in, the instructor transmitted over the radio "change feet and stick back". He may have said this twice but there was no reply. The aircraft was by then at a height of approximately 1,500 ft agl. If recovery action was initiated without delay, this should have been enough height to recover from this inverted spin.

The aircraft continued to spin inverted until it went out of sight to the instructor behind a small rise on the airfield, where it impacted the ground. Whilst the aircraft was in the inverted spin, the instructor did not see any change in aircraft attitude or rate of rotation to indicate that there was any input to the flying controls. He also did not hear any radio transmission from the pilot but he also stated that his own transmission could have blocked those of the pilot.

The airfield's emergency services were quickly in attendance and they confirmed that the pilot had not survived the accident. Paramedics from the resident air ambulance, attended soon afterwards. In addition, fire vehicles from Maidenhead attended the scene.

Other witnesses

Many other eye witnesses saw the accident. The majority of them were outside the flying club at White Waltham, near the instructor. They reported seeing the aircraft doing aerobatics and then saw it enter a spin. Most identified the spin as inverted. They also stated that there was no change in attitude or rate of rotation, after the first few turns of the spin, before the aircraft went out of sight and impacted the ground. Another witness was flying into White Waltham while the aerobatics were taking place. He stated that he saw the aircraft at a height of approximately 1,000 to 1,500 ft in a spin. After observing it for a few turns, he soon became aware that if it did not recover soon, it would crash. He added that "it continued spinning with no visible attempt to alter the attitude of the 'plane." He did not notice if the spin was erect or inverted.

Another witness was taxiing his aircraft out to Runway 03, at White Waltham. He stated that, as he was approaching the end of a line of parked aircraft, he suddenly became aware of an aircraft spinning inverted and rotating to the left. At the time he estimated the aircraft's height to be approximately 600 to 800 ft agl. The aircraft appeared to be approximately 45º nose down with the propeller blades rotating slowly. He continued to watch the aircraft until it impacted the ground.

The knife-edge spin

A knife-edge spin is not a true spin, because it is not a 'classic' autorotation; for a successful knife-edge spin, the angle of attack at the wings must remain negligible. During the manoeuvre the aeroplane falls vertically and rotates in pitch about its lateral axis, (a motion sometimes described as tumbling), as it descends. The aircraft will lose about 200 ft of height in the first turn but this height loss per turn tends to increase with successive turns.

In an aircraft with a clockwise turning propeller, a knife-edge spin is usually entered from a stall turn to the left. Initially, a stall turn is flown until, when entering the descent, the moment arises when the pilot should apply opposite rudder to stop the yaw. Instead, left rudder is maintained. This makes the aircraft's nose swing through the vertical to about 45° past the vertical. With the nose in this 45° nose-up attitude, full forward control column is then smoothly applied to start the pitching motion. With high engine rpm, this pitch-down generates a large gyroscopic force which will assist the applied left rudder in holding the nose up against gravity. The forces involved are illustrated at Figure 1.

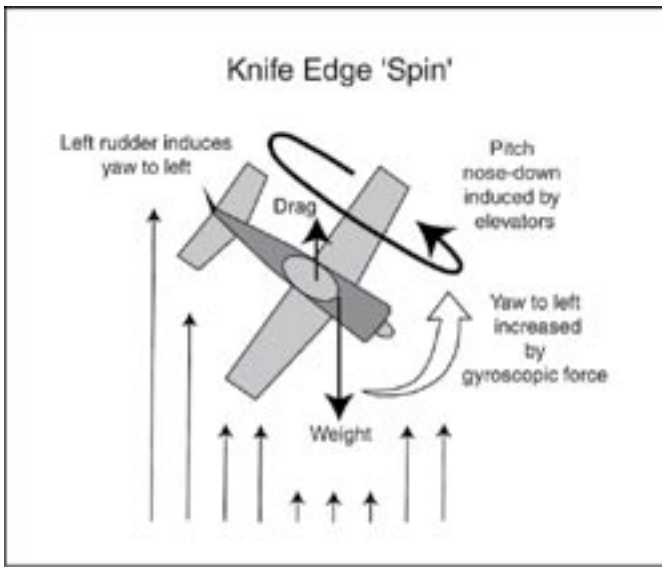

Figure 1
Knife Edge Spin illustration

The control column does not need to be pushed aggressively. However, if there is a delay before pushing whilst on the knife edge, the aircraft's forward speed will accelerate and the aircraft will straighten due to the effect of the stabilising effect of the fin. The pilot will then be exposed to an increased amount of negative g and the manoeuvre could become a descending outside turn. If the control column is pushed too slowly, the aircraft will accelerate with the same result. When the control column is pushed forward, the pilot must apply aileron to keep the wings in the vertical plane. The task with the ailerons is to balance the aircraft so that it falls straight downwards with the wings at right angles to the ground. If an angle of attack is generated by using too much aileron, the aircraft may enter a flick roll. Too much left aileron may lead to a positive flick roll; too much right aileron may lead to a negative flick roll.

The recovery procedure is always the same; apply opposite rudder and move the control column centrally back. It is possible to reduce the power initially, to reduce the gyroscopic effects, before applying the recovery controls but this will also reduce the effectiveness of the rudder in cancelling the yaw.

It is possible to enter an inverted spin from a knife-edge spin if right rudder is applied while full forward elevator is maintained.

Aerobatic limitations

The aircraft was cleared for aerobatic manoeuvres, including unlimited aerobatics, when complying with the limitations prescribed under the Aerobatics Category, up to its MTWA. Calculations show that the aircraft's weight was below the MTOW and the CG position was within the required limits.

Spin recovery technique

The following information was included in the '*Approved Airplane Flight Manual and Operating Handbook*' for the aircraft (See Figure 2):

3.5 Recovery from unintentional spins

The lost of altitude is about 330 ft (100 m) per turn, and 1000 ft (330 m) for the recovery.

WARNING

Before applying the recovery procedure, it is necessary to identify the nature of the spin, UPRIGHT or INVERTED.

The spins are very predictable and the recovery procedure is conventional:

Power .....idle

Ailerons .....neutral

Rudder .....full opposite to the spin

Elevator .....neutral for upright spins slightly backward for inverted spins

Figure 2

Excerpt from Approved Airplane Flight Manual and Operating Handbook

Medical information

The pilot held a current JAA Class 1 medical certificate with a limitation requiring him to wear distant vision lenses while flying and he was wearing a pair of spectacles at the time of the accident. The post mortem examination carried out by a consultant aviation pathologist, revealed that the pilot had died instantly from multiple injuries resulting from a severe vertical force. The pathologist concluded that there was no evidence of any medical condition or toxic substance that may have caused or contributed to the accident.

Aircraft information

The aircraft type was derived from the Giles G202. The French aircraft company, CAP Aviation, undertook to take on the design as a CAP project and obtain JAR 23 certification, renaming it the CAP 222. The accident aircraft, constructor's number C03, was built in 1998 and delivered as an uncertified aircraft but with JAR certification expected within 12 months. However, this did not happen due to funding issues. As delivered, the aircraft was registered in France as F-WWMX. In May 2005 it was transferred to the UK register as G-GZOZ, operating on a CAA Permit to Fly. It was registered as a CAP 222 (Modified) because it would probably vary from any subsequently certificated CAP 222 should JAR 23 type certification be obtained.

The aircraft had accumulated 475.3 hours at the time of the accident. It was fitted with a three-bladed propeller with a constant speed unit and a microprocessor based engine management system. This system displayed engine rpm, exhaust gas temperature, manifold pressure, fuel pressure and cylinder head temperature on a flat panel display. In addition to displaying these parameters, it was able to store the values in non-volatile memory and alert the pilot to significant variations.

Engineering investigation

The aircraft had struck the ground inverted in a fully developed inverted spin to the left, ie to the right relative to the aircraft's vertical axis. The wings were approximately level at impact, and there was very little travel over the ground. The impact was substantially nose down, after which the top of the fin struck the ground and, due to the rotation of the aircraft, there was some sideways movement of the rear fuselage and empennage. The pilot's harness had been fastened at impact but the accident was not survivable.

Evidence of engine speed and power was obtained from the damage to the propeller. This showed that at ground impact, the engine had been turning at low power, consistent with idle, and had stopped in less than one third of a rotation. The non-volatile memory, in the electronic engine management system fitted to the aircraft, was returned to its manufacturer in order for the data to be recovered. The manufacturer confirmed that prior to impact, the engine was working normally and operating at idle rpm.

The aircraft was recovered to the AAIB facility at Farnborough for a more detailed investigation. No pre-impact discontinuity was found in any of the primary flight control systems, much of which could still be functioned. All the breaks identified had been caused in the impact or were deliberate cuts made when the wreckage was recovered.

The aircraft was well constructed (it was a factory-built demonstrator) and the control runs were well laid out. They did not appear particularly vulnerable to interference from foreign objects. No extraneous objects were found in the wreckage and the front seat harness was adequately stowed. The possibility of a control jam could not be entirely ruled out but no evidence of a jam or restriction was found. In brief, no evidence of any flying control system problem was found.

There were no obvious witness marks identifying the position of the ailerons or elevators. However, clear marks were found on the rudder pedal linkage which indicated that full right rudder had been applied at ground impact.

Analysis

Inverted spin recognition and recovery

The accident pilot's aerobatics instructor commented that he had seen the pilot practise planned inverted spins before, but he had not seen him enter an unplanned inverted spin from any other aerobatic manoeuvre.

Because the inverted spin was inadvertently entered at a low height, the pilot only had a few turns to identify that he was in an inverted spin, identify the direction of the spin and apply the correct recovery technique in time to recover from the ensuing dive and avoid the ground. In this case, it is estimated that he had no more than three turns in which to commence the recovery. The elapsed time between spin entry and initiating a successful recovery was, perhaps, as little as 5 seconds. This was a very short time in which to resolve any unexpected confusion.

A turn indicator is the only instrument that can be used to identify the direction of an erect or an inverted spin. There was no turn indicator fitted to G-GZOZ and there was no requirement for one to be fitted because it was only cleared for VFR flight. In addition, a turn indicator would not necessarily be fitted to an aerobatic aircraft because the instrument panel might not have sufficient installation space. Also, the delicate gyro assembly in the turn indicator would be susceptible to failure whilst flying high-performance aerobatics.

If the direction of an inverted spin needed to be identified in an aircraft with no turn indicator fitted, the pilot would have to look over the nose of the aircraft and use visual cues alone. This introduces the possibility of confusion, particularly if the entry was sudden and unexpected. Another generic technique to identify turn direction is to remove any foot pressure from the rudder pedals, press each pedal in turn, determine which pedal requires more effort, and then push the 'heavy' pedal. However, the CAP 222 Flight Manual states that during spins, there is no aerodynamic pressure on the controls, so the technique could have been ineffective on this aircraft type.

Pilot incapacitation

The accident occurred because the pilot did not recover from the inverted spin. In the absence of evidence for a mechanical problem, this suggests he may have been confused or incapacitated. Entry to the inverted spin was unintentional and the pilot's intention was to complete only one rotation in the knife-edge spin. In fact, he did between one and a half and two and a quarter rotations. This suggests that the pilot's difficulties may have started during the knife-edge spin.

After his previous attempt, the pilot had been advised to increase the rate of rotation in the knife-edge spin. The rotation rate he achieved on his third attempt is estimated at about one turn in less than a second. The pilot's head was about 1.2 m from the axis of rotation, which passed through or close to his body. At 1 second per rotation, the acceleration at his head would have been minus 4.8g.

At 0.8 seconds per rotation, his head would have been subjected to a negative acceleration of 7.5g whilst his feet would have been close to the axis of rotation; see Figure 3 below:

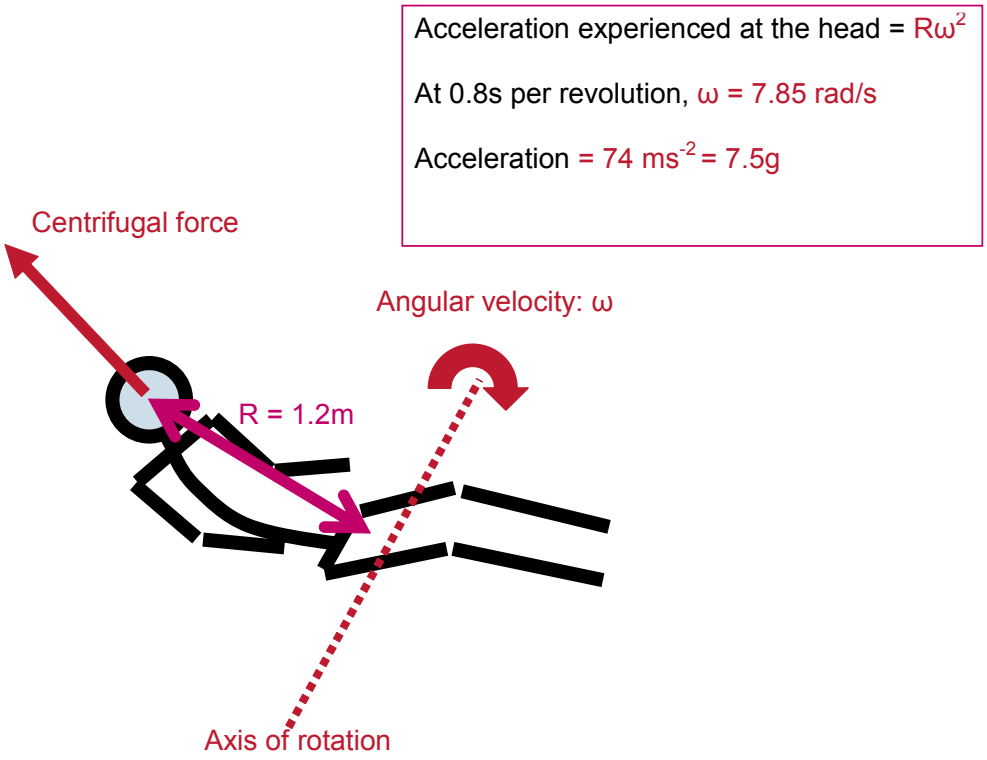

Figure 3

Forces acting on pilot's head

Positive g sends a pilot's blood towards the lower body; negative g sends the blood upwards towards the head. The equations above illustrate that a small increase in the speed of rotation would have brought about a significant increase in the acceleration experienced.

Negative g is uncomfortable and less well tolerated than positive g. Exposure for more than six seconds to between minus 4g and minus 5g is reported to cause confusion and unconsciousness[3].

As an experienced aerobatic pilot, the accident pilot might have been expected to tolerate minus 4g relatively well, at least for a few seconds. If he was unused to higher levels of negative acceleration, a sudden and unexpected exposure to minus 7.5g could have been very disturbing and painful, delaying his attempt to recover, making that attempt inaccurate and, perhaps, provoking an unthinking retardation of the throttle.

After possibly as long as 1.5 seconds at minus 7.5g, the pilot may then have experienced even higher levels of negative g, very briefly, as the aircraft transitioned to the inverted spin, due to the sudden increase in drag from the wings. Once stabilised in the inverted spin, the pilot would then have been exposed to a lower level of negative g which might have had continued effects on his cardiac efficiency and, therefore, on cerebral blood flow and cognitive function.

The unintentional entry into the inverted spin would, of itself, have presented the pilot with a challenge in terms of determining the direction of the manoeuvre and the correct recovery action. A response time of a few seconds would not have been unlikely even in the absence of the acceleration-induced physiological effects. In addition, the transition from the knife-edge spin to the inverted flat spin is likely to have been accompanied by vestibular overload; the pilot may have experienced illusory feelings of rolling in addition to the actual gyrations involved in the transition. This sensation is familiar to the competitive aerobatic community. They refer to this feeling as "wobbly head".

If the pilot did have normal levels of cognitive function during the inverted spin, he would have been faced with an increasingly alarming situation. Given that he was a fairly experienced aerobatic pilot, it is unlikely that he panicked. But the preceding few seconds would have been confusing as well as painful and disturbing, and he would have been presented with a dilemma: Should he persevere with a control strategy that is failing or change a strategy that might be about to work? In such a situation, unless there is a clear, positive, indication that the strategy is wrong, perseverance may persist by default – even if it appears clearly inappropriate to an observer who has the benefits of distance, hindsight, and a comfortable 1g, upright viewpoint.

In summary, the pilot may have been exposed to an unexpected, disturbing and painful level of negative acceleration by his attempt to make the knife-edge spin slightly brisker in terms of speed of rotation. As a result, his exit from the manoeuvre was delayed and the aircraft entered an inverted spin. His cognitive efficiency was likely to have been impaired by: the initial negative acceleration, any transient accelerations experienced in the transition from the knife-edge spin to the inverted spin, and by the continued exposure to negative acceleration during the inverted spin. The entry to the inverted spin was likely to have been confusing, in terms of both visual and vestibular sensations, so that a rapid

Footnote

[3] Aviation Medicine (third edition) by Air Vice Marshall J Ernsting, Air Commodore A N Nicholson and Air Commodore D J Rainford (eds). Butterworth-Heinemann, Oxford, 1999.

corrective reaction was not likely. If the pilot did recover normal levels of cognitive function as the inverted spin progressed, he would have faced an increasingly alarming situation with no clear options for recovery.

Conclusion

During a practice session of unlimited aerobatic manoeuvres at low altitude, the aircraft entered an unplanned inverted spin. The aircraft did not exhibit any indications of recovery consistent with application of the control movements required to effect recovery. Moreover, pro-spin rudder was still applied at ground impact. No reason for this failure to recover could be positively identified. However, the circumstances of the accident could be explained by some form of brief and temporary pilot incapacitation. Alternatively, confusion, disorientation and lack of time may have been contributory factors.