ACCIDENT

Aircraft Type and Registration:	Pegasus Quantum 15, G-BZJF
No & Type of Engines:	1 Rotax 582-40 piston engine
Year of Manufacture:	2000
Date & Time (UTC):	26 August 2007 at 1920 hrs
Location:	Knotting Wood, near A6 Northamptonshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - 1 (Fatal) Passengers - 1 (Fatal)
Nature of Damage:	Aircraft destroyed
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	38 Years
Commander's Flying Experience:	37 hours (all of which were on type) Last 90 days - 8 hours Last 28 days - 2 hours
Information Source:	AAIB Field Investigation

Synopsis

The microlight aircraft suffered an in-flight break-up, causing fatal injuries to the two occupants. Examination of the wreckage revealed damage consistent with the aircraft having entered a tumble; a rapid, uncontrolled pitch rotation usually resulting in structural failure. Insufficient evidence was available to allow the cause of the tumble to be determined, although mechanical failure could be ruled out as a contributory factor.

History of the flight

The pilot arrived at Sackville Farm Airstrip at approximately 1600 hrs with three acquaintances. With their assistance he moved G-BZJF from its hangar, where it was kept fully rigged, and prepared it for flight, including refuelling the fuel tank to full. He then flew three flights, one with each of his acquaintances. The accident flight departed Sackville Farm at 1850 hrs with approximately half a tank of fuel remaining. The passenger on this flight knew the pilot well and had flown with him before. At 1920 hrs the aircraft was seen manoeuvring approximately two miles west of the airfield. This series of manoeuvres ended in a turn during which the wing and trike separated and the pilot was ejected from the trike. Several witnesses to the accident went immediately to the scene and called the emergency services. Both occupants were fatally injured in the accident.

Previous flights

The passengers from the flights conducted on the day of the accident were interviewed. They believed the pilot of G-BZJF carried out thorough checks of the microlight before departure. During both previous flights the pilot conducted a series of manoeuvres including steep turns, climbs and dives. The overriding impression of the passengers was that the pilot was confident and enjoying his flying.

Witnesses to the accident flight

An eyewitness in the village of Sharnbrook, two miles south of the accident site, saw G-BZJF executing pitching and turning manoeuvres that appeared well controlled. As it turned towards the witness it seemed to be descending and then pulled up into a climbing left turn. This turn continued through 360° and as G-BZJF began a second turn, the microlight trike and the wing separated. The trike and the pilot were seen to fall to the ground with the wing descending separately in a porpoising motion.

Other witnesses described hearing a loud bang similar to a gunshot which attracted their attention to the microlight. They saw a black object falling vertically to the ground followed by the wing. The wing was described as "folding a couple of times" before spiralling downwards. Further witnesses report the wing spiralling down separately from the trike.

Weather

Several pilots who flew from Sackville Farm that evening described the weather conditions as excellent visibility and light winds. The weather report for Luton Airport (approximately 20 miles to the south) at 1920 hrs was a wind of 210º/6 kt, no cloud below 5000 ft, greater than 10 km visibility and a temperature of 23ºC.

Pathology

Post-mortem examination confirmed that the occupants died of multiple injuries sustained on impact. The accident was considered non-survivable and it is unlikely that any additional or alternative restraint would have saved the occupants' lives.

Pilot history

The pilot commenced NPPL (M) training at Sackville Farm in November 2006. He completed the training in May 2007 having achieved a consistently high standard throughout. As part of his training he had conducted turns of up to 60º angle of bank with an instructor on 21 April 2007 and "unusual and dangerous attitudes training" on 22 April 2007 . He was cleared for solo practice of steep turns although there is no record of him doing so during the remainder of his training. He again demonstrated both steep turns and unusual attitude recovery as part of his General Skills Test (GST) for issue of his licence on 22 May 2007 . The instructor who had conducted his training was also qualified as an examiner and carried out the GST on the pilot. The GST requires turns with 60º bank in both directions and recovery from two unusual attitudes. The first unusual attitude was nose-high with some bank applied and the second was a spiral dive. During the pilot's training, the tumble condition was briefed as part of unusual and dangerous attitude training. The pilot's licence was issued on 7 June 2007 and he had flown 10 flights since, all of which were on the accident aircraft. The owner of the flying school had been impressed with his ability during training and had suggested to the pilot that when he gained sufficient experience he should consider becoming an instructor.

Training notes

Students at the pilot's training school are provided with a copy of "*Briefing Notes – Flexwing*". Exercise 14

'Advanced Turning', states:

> *'Significant wake turbulence is produced in a steep turn – above 45 degrees of bank in a level turn limit the heading change to 270 degrees.'*

Exercise 15 lists a range of general flexwing limitations and the likely consequences of exceeding these. It also mentions the likely causes of unusual/dangerous attitudes. These include wake turbulence, mishandling of controls during stall recovery or a steep turn, and deliberately attempting manoeuvres outside the limits of the aircraft and/or pilot.

Pegasus Quantum flight manual

The Pegasus Quantum flight manual states that the aircraft must be operated in compliance with the following limitations:

> *'Do not exceed more than 60° of bank.*
> *Do not pitch nose up or nose down more than 45° from the horizontal.*
> *ALL aerobatic manoeuvres... are prohibited.'*

Aircraft information

Background information

The aircraft was a Pegasus Quantum 15 microlight aircraft, serial number 7696, manufactured in July 2000. It held a current Permit to Fly, valid until 20 July 2008 and had completed approximately 1,060 flying hours since new.

Aircraft description

General

The Pegasus Quantum 15 is a two-seat, weight shift controlled flexwing microlight aircraft (Figure 1). It consists of a wing, constructed of fabric and aluminium alloy tubing and braced by steel cables, and a 'trike' unit incorporating a tricycle undercarriage, rear-mounted engine and seating for two occupants in tandem configuration. The aircraft is normally flown from the front seat. The limitations placard on the aircraft states that the aircraft is non-aerobatic and that positive 'G' loading must be maintained at all times.

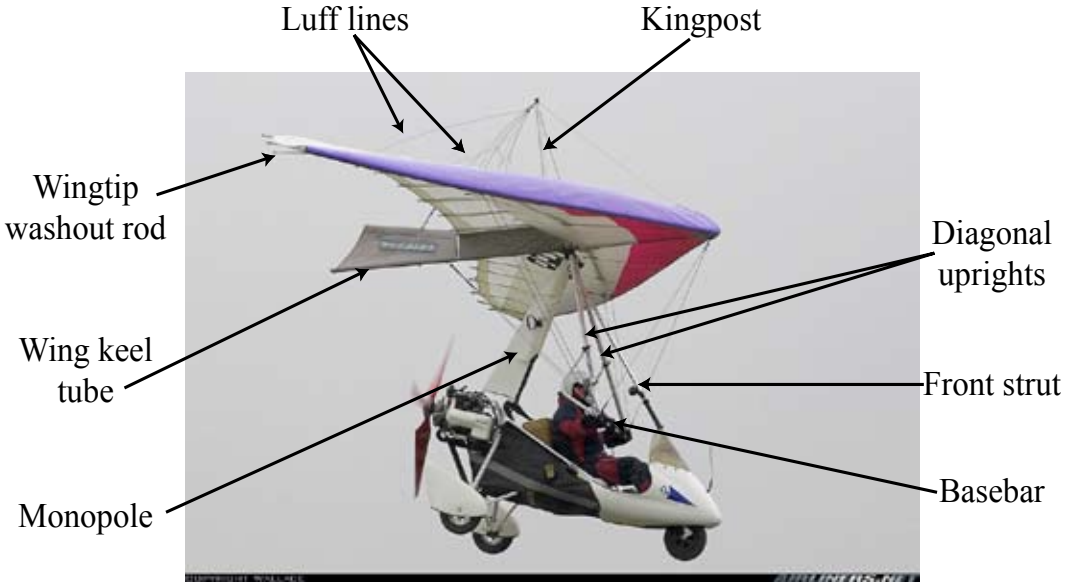

Figure 1

Pegasus Quantum 15 Microlight

Trike construction

The trike is constructed of extruded aluminium alloy box sections, with a fabricated steel engine mounting frame and undercarriage. The main structural elements comprise the keel tube, to which the major components are attached and the monopole, which is enclosed within an aerodynamic fairing. The keel tube and monopole are braced by a tubular aluminium alloy front strut, which is made up of inner and outer tubes. An instrument panel is incorporated in a moulded fibreglass fairing at the front of the trike. The pilot is secured by a three-point harness and the rear occupant by a four-point static harness.

The wing is attached to the top of the monopole by a U-shaped 'hang' bracket, which allows the wing to articulate in pitch and roll. A safety strap running inside the monopole further connects the wing to the trike and is intended to prevent the two from separating if the monopole fails. The monopole can be folded down for transport and it is locked in the upright position by an overcentre clamp incorporating a nylon roller which bears on the front face of the monopole.

Wing construction

The primary structure consists of a series of aluminium alloy tubes, the main elements being the central keel tube and the leading edge tubes, with bracing provided by cross tubes. The leading edge and keel tubes are attached to an aluminium alloy noseplate fitting at the apex of the wing. Upward loads are opposed by steel cables attached between the wing tubes and the ends of the basebar of the 'A' frame below the wing. Downward loads are opposed by cables between the wing tubes and a kingpost above the wing. The wing skin is formed from polyester fabric stretched over the tubes and obtains its curved profile from pre-shaped fibreglass and tubular aluminium alloy battens inserted into pockets in the fabric. A vertical fabric 'fin' extends aft of the wing.

Aircraft controls

The pilot controls the aircraft via the 'A' frame, which comprises a horizontal basebar and two diagonal uprights attached to the hang bracket. Steel cables are attached between the ends of the basebar and the front and rear of the wing keel tube, so that moving the basebar fore and aft causes the wing to tilt up and down, changing the amount of lift produced. The aircraft is turned by moving the basebar to the left or right. The range of forward movement of the basebar and thus the degree of upward tilt of the wing is limited by the presence of the front strut. The geometry is such that even with the basebar fully forward and in contact with the front strut, the rear of the wing keel tube remains clear of the propeller arc.

The engine speed is controlled via a foot operated throttle pedal. A hand throttle on the left side of the trike allows a constant throttle setting to be selected without the need to maintain pressure on the throttle pedal.

The pilot can adjust the trimmed speed of the aircraft via a trim wheel on the right-hand 'A' frame diagonal upright. This varies the length of steel cables or 'luff lines' attached to the trailing edge of the wing, thus changing the wing's aerodynamic characteristics. The luff lines are routed through a group of pulleys attached to the top of the wing kingpost.

Wreckage and impact information

Accident site location

The aircraft wreckage was located in a partly ploughed field just to the east of the A6, approximately two miles southeast of the town of Rushden in Northamptonshire. From the wide separation of the wing, trike and pilot's body, it was evident that the aircraft had broken up in flight.

On-site wreckage examination

The trike came to rest approximately 93 m to the east of the pilot's body. The passenger was still securely strapped in the rear seat. The trike had impacted the ground inverted and tail first, with a high vertical speed, causing the engine to become deeply embedded in the soil. The contents of the fuel tank had leaked out, but a strong smell of fuel at the site suggested that there had been a significant quantity of fuel on board. The wing, which was largely intact with the 'A' frame and a large section of the monopole still attached to it, came to rest inverted, partly folded up, approximately 289 m to the south of the trike. The basebar and right-hand upright of the 'A' frame had failed. The trim control was at the 'TAKE OFF' (mid-range) setting.

Most of the damage to the aircraft was ground impact related, although other damage was found which, given the wide spread of the wreckage, could only have occurred in the air.

The front strut had failed, with the upper and lower portions remaining attached to the wing and the trike, respectively. The pilot had sustained a wound to the front of his head, consistent with having struck the fractured end of the upper portion of the strut. The monopole had failed at the locking clamp location, leaving an approximately 150 cm long section of it attached to the wing; the rest of the monopole was still attached to the trike. Multiple paint transfer marks, indentations on the rear of the wing keel tube and cuts in the fabric of the fin were indicative of the propeller blades having struck the rear of the wing whilst the propeller was turning (Figure 2).

All of the major components of the aircraft were accounted for and the aircraft appeared to have been correctly assembled.

Figure 2

Propeller strike marks on wing keel tube

Detailed wreckage examination

Trike examination

The aircraft wreckage was recovered to the AAIB's facility for more detailed examination. It was reconstructed to enable the in-flight damage to be correlated with the aim of determining the sequence of the break-up.

Examination of the 'A' frame basebar revealed that it had failed in bending after having struck the rear of the front strut with considerable energy. The force of this impact was sufficient to bend the front strut tubing. The failure of the right-hand upright of the 'A' frame was consistent with ground impact damage. The front strut had failed in compressive overload in the middle of the strut, some distance above the bend caused by the basebar impact.

From the deformation of the material in the area of the failure (Figure 3), it was evident that the monopole had been exposed to large bending loads in the fore and aft directions prior to failure. The stitching in the upper loop of the safety strap had subsequently failed in overload, causing the wing and trike to separate in the air.

The right-hand lap-strap of the pilot's harness had failed in overload where it passed through the seat pan. The buckle was still fastened and operated correctly when tested. The pilot had not worn the shoulder strap; this was found stowed inside the trike.

Wing examination

Distortion and fractures of the noseplate fitting indicated that the wing folded upwards following the failure of the basebar. It was also apparent that the wing had been exposed to very high negative (ie downward) loading at some point in the break-up sequence. This was indicated by downward distortion of the tip washout rods and 'kinking' of the luff line cables where they passed through the pulley wheels. The aft sections of the No 6 wing battens (left and right) were also bent upwards due to the rear of the battens having been restrained by the outer luff lines as the rest of the wing deflected downwards under the negative loading.

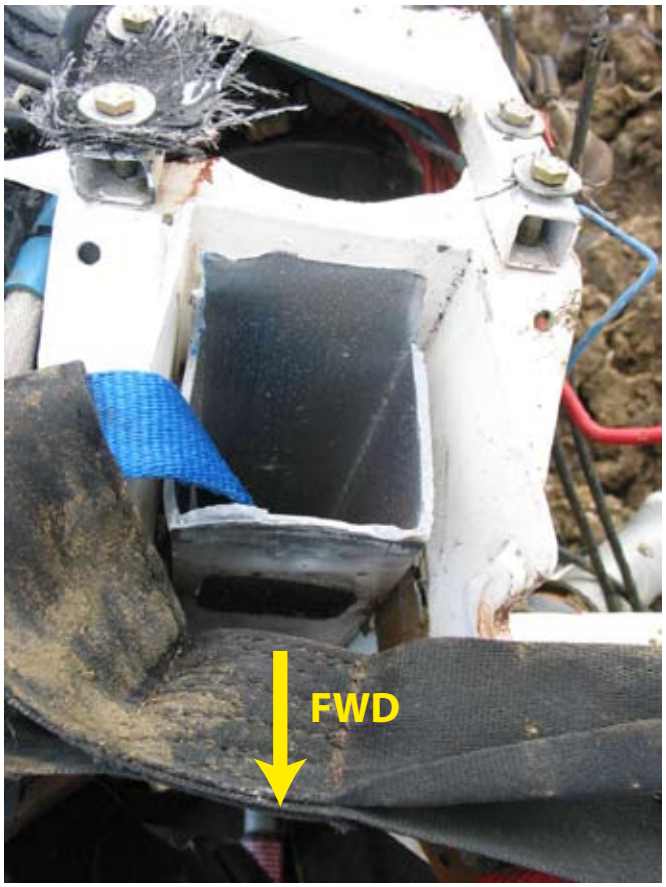

Figure 3
Monopole failure

Engine and propeller examination

The damage suffered by the engine in the ground impact was such that it could not be run. It was therefore stripped as necessary to evaluate its mechanical condition.

Both the engine and gearbox rotated freely and both cylinders produced good compression. The spark plug electrodes were in good condition and their colour indicated that the air/fuel mixture was correct. No mechanical failures, evidence of excessive wear,

overheating or seizure was found on the engine internal components. Significant quantities of clean oil were found in both the engine and the reduction gearbox. A small amount of residual fuel remained in the carburettor bowls and the inlet filters were clean. One propeller blade was completely severed at the blade root and another was almost completely severed. Two blades exhibited localised leading edge damage and deformation consistent with having struck the wing keel tube.

All the damage to the engine was consistent with ground impact and it appeared otherwise capable of running.

Metallurgy

The fractures of the monopole, front strut, basebar and right 'A' frame upright were examined. The failures were found to be consistent with rapid overloading of the structure. No pre-existing defects, such as fatigue, were found that could have contributed to the failure of these components.

Material properties tests were performed on samples taken from the basebar, monopole, front strut and right diagonal upright, all of which are manufactured of aluminium alloy equivalent to specification 6082-T6. The results showed that the material composition of the samples was consistent with that of a 6082-series alloy; however the 0.2% proof stress values for the monopole and inner front strut were slightly deficient, being 1.2% and 2.0% lower than the minimum specified value of 250 MPa. The results for the control bar and front strut outer tube were above the minimum specified value.

Aircraft maintenance history

A review of the airframe and engine logbooks showed that detailed, up-to-date maintenance records were kept by the owner. There were no recorded outstanding defects at the time of the accident. The aircraft was inspected and check flown on 13 July 2007 by a BMAA Inspector for the purposes of renewal of the Permit to Fly. No anomalies were noted during this inspection and the check flight was completed satisfactorily. The flight check included evaluation of the aircraft's handling characteristics at high and low speeds, its behaviour in wings level power-off stalls and in stalls in 30 degree banked turns to the left and right.

On 2 August 2007, the engine suffered a loss of power on climb out due to crankshaft and big end bearing damage, following which the engine was replaced. At the time of the accident, the aircraft had completed several flights since the engine replacement with no reported engine problems.

Microlight tumbling

The tumble is a departure from controlled flight whereby the angular momentum of the aircraft causes the microlight to rotate about its pitch axis with a very high angular velocity and acceleration; pitch rates of over 360° per second and transient accelerations of 8g are not unknown. During the tumble the forces are so great that the basebar normally hits the front strut with sufficient force to cause either the basebar or front strut to fail. A tumble normally results in the break up of the aircraft and the occupants to be fatally injured. There is no known recovery technique from a tumble. Mechanical failure aside, there are believed to be four ways of inducing a tumble:

- The whip-stall
- Spiral instability combined with loss of visual horizon
- Failed aerobatic manoeuvre
- Flight through severe turbulence or wake vortex

Previous events

The only other tumble event to a Pegasus Quantum is known to have occurred in Michigan USA in 2000. Approximately 800 Quantum aircraft have been produced to date.

Analysis

Wreckage evidence

From the site and wreckage examination it was determined that the aircraft had been correctly assembled, was structurally intact and that the engine was running at the time of the accident. Examination of the failed components did not identify any pre-existing defects that could account for the apparently sudden and violent break up of the aircraft in flight and there were no current defects recorded in the aircraft technical documentation.

Assessment of the in-flight damage suggested that the first event leading to the break up was the failure of the 'A' frame basebar due to impact with the front strut, which damaged the basebar tube and precipitated its failure in bending. This would have immediately rendered the aircraft uncontrollable and also have allowed the wing to tilt sufficiently nose-up to cause the rear of the keel tube to come into contact with the propeller. The multiple impact marks on the keel tube indicate that the propeller was turning at the time. To cause a compressive overload failure of the front strut, the wing must have experienced a high negative loading during the failure sequence and the monopole must have been intact in order to transfer the compression load into the front strut. The failure of the monopole must therefore have occurred after the failure of the front strut. The wound on the pilot's head caused by contact with the upper part of the front strut shows that he remained in the aircraft well into the breakup sequence. The subsequent overload failures of the pilot's lap strap, the monopole and the safety strap are further indications that the aircraft had entered an uncontrolled flight regime as it was being subjected to loads well in excess of those for which it had been designed.

The nature of the failures of the basebar, front strut and monopole and the distortion of the No 6 wing battens, washout rods and luff lines indicate that the aircraft was subjected to violent alternating upward and downward loading during the break-up sequence. These failures are characteristic of those produced in a tumble.

The basebar material strength was above the minimum specification value and given that this was the first component to fail, material deficiency could be ruled out as an initiating factor of the in-flight break-up. Although the strengths of the monopole and front strut inner tube were very slightly below the minimum specification, no evidence was found in either component of any pre-existing failures, such as fatigue. The slight deficiency is not thought to have been significant as the loads encountered during the break-up sequence were clearly grossly in excess of the design loads for these components.

There is insufficient evidence to ascertain what led to the tumble although there is no evidence of mechanical failure being the cause. The current BMAA syllabus covers unusual and dangerous attitudes and conditions which could lead to tumble entry and the pilot had received training in accordance with this syllabus. Witness evidence suggests that he may have turned through more than 270° and placed the aircraft in its own wake turbulence but the angle of bank used in that turn is not known and therefore the degree of turbulence cannot be assessed. However, the witness may have observed what was intended to be a spiral

climb, which is an accepted method of gaining height. Flying through significant turbulence or wake vortex is though, one way of inducing a tumble. Training of the pilot and awareness of what can cause a tumble remain the primary means of defence against this condition.