BULLETIN RE-ISSUED

In its September 2004 Bulletin, the AAIB published a report into a fatal gyroplane accident. Between publication and completion of the Inquest into the pilot's death, new and significant facts emerged. Principal amongst these facts was that after it was issued with a Permit to Fly, the machine was fitted with a rotor of larger diameter than that specified in the Permit. This change to the machine's configuration had implications relevant to its weight, balance and performance; it also had potential but unquantifiable effects on its handling qualities. Consequently, the Chief Inspector decided that the report should be updated and re-issued in full to incorporate new and revised information.

ACCIDENT

Aircraft Type and Registration:	Ponsford Bensen B8MR (modified), G-BIGU
No & Type of Engines:	1 Rotax 532 piston engine
Year of Manufacture:	2001
Date & Time (UTC):	29 June 2003 at 1250 hrs
Location:	Shipdham Airfield, near Dereham, Norfolk
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:	Private Pilot's Licence (Aeroplanes) and qualifications for the issue of a Private Pilot's Licence (Gyroplanes)[1]
Commander's Age:	44 years
Commander's Flying Experience:	324 hours (of which 43 were on gyroplanes) Last 90 days - 27 hours Last 28 days - 5 hours
Information Source:	AAIB Field Investigation

Synopsis

The accident occurred on the first unsupervised flight following the pilot's completion of his Private Pilot's Licence (Gyroplanes) course. It resulted from the rotor blades striking the rudder, which rendered the gyroplane uncontrollable. Witness accounts indicated that G-BIGU was flying straight and level at a reasonable speed just before this event, although there were reports of possible 'over-controlling' during the flight. The specific reason for the rotor blades striking the rudder could not be determined but a pilot-induced oscillation appeared to be the probable cause. An examination of the aircraft, and subsequent computer modelling by the University of Glasgow, indicated that the aircraft could have poor longitudinal stability characteristics. The investigation also highlighted the poor safety record of gyroplanes in general compared to other types of recreational aircraft. Accordingly, recommendations have been made concerning the approval of gyroplanes and the training and licensing of gyroplane pilots.

Footnote

[1] The pilot had completed an approved course for the issue of a PPL (Gyroplanes) and had submitted his licence application to the CAA. At the time of the accident the CAA had not processed the application and so had not issued the licence. However, the Authority subsequently confirmed that the pilot met all the requirements for the issue of a PPL (Gyroplanes).

Factual Information

Background to the flight

The pilot had been the holder of a Private Pilot's Licence (PPL) (Aeroplanes) since July 1992 and had started a PPL (Gyroplanes) course in August 2002 at a recognised flight training school. He had bought G-BIGU from the original builder of the aircraft.

He subsequently passed his General Flight Test (GFT) on 17 April 2003 in a twin seat VPM. After a final flight in G-BIGU under supervision at the training school on 21 June 2003, the flight examiner endorsed the pilot's flying logbook with a clearance to fly "*single seat gyroplanes and VPM twin seat*". The pilot then transported his aircraft by road to his home. His intention was to keep the aircraft in a hangar at Shipdham Airfield and to enable him to do so he joined the Shipdham Aero Club.

On 22 June, he brought G-BIGU by trailer to the airfield, parked it in a hangar and was seen to attach the rotor blades to the body of the machine. During the subsequent week, he did not go to Shipdham Airfield but did complete a dual flight in a fixed wing aircraft at another airfield on 23 June.

History of the flight

On the morning of 29 June, the pilot went to Shipdham Airfield with the intention of flying in his gyroplane. One club member spoke to him as he was preparing G-BIGU for flight. During the conversation, the club member informed the pilot that there would be some glider flying using Runway 20 with a right hand circuit, and that powered aircraft normally used a left-hand circuit on that runway. At the time, the surface wind was calm and the pilot asked if there would be any problem with him doing some ground runs in both directions along the runway. The pilot also commented that he had "something to try out". The club member's impression was that the pilot seemed in "good spirits". The weather was good with no cloud and a light and variable surface wind.

Sometime later, the gyroplane was seen taxiing out to a position just short of the threshold of Runway 20. It stopped there for a time with the rotors turning before entering and taxiing along the runway. No other aircraft from Shipdham were airborne at the time and various club members were preparing aircraft for flight. No witness watched G-BIGU during its entire flight so it was not possible to determine exactly what manoeuvres were completed. However, most members were aware of the engine noise remaining constant in the background. G-BIGU appeared to take off from Runway 02 and fly a short distance to the north before turning back towards the airfield. The aircraft was seen to fly along the runway in each direction and some witnesses were aware of G-BIGU gently "porpoising" as it flew along. Estimates of the height of the gyroplane during this time varied between 10 and 20 feet above the runway and also between 400 and 500 feet but displaced to one side of the runway. With the variation in height estimates from the witnesses, who were both pilots, it was possible that this "porpoising" occurred at different times. None of the witnesses were concerned by the manoeuvres. One witness, who saw the last moments of flight, was standing by the airfield hangar looking towards the east. He saw G-BIGU in a downwind position for Runway 20 at about 250 to 300 feet agl and at an estimated speed of about 45 kt. The gyroplane appeared to be stable and in level flight when the witness heard a single "bang" and saw an immediate change in attitude. The aircraft pitched nose down and fell vertically to the ground. This witness also commented that he had heard a "broken" radio transmission sometime prior to the accident sequence; with no other club aircraft flying, he assumed that the pilot of G-BIGU had made this transmission.

One other witness, who was cycling in the local area, stopped to look at the aircraft to the east of the runway, as it flew apparently straight and level in a northerly direction. The gyroplane passed close to him and its pilot waved to him. There was a constant noise from the engine until this witness heard a "clunk" and the engine noise stopped. He watched the aircraft tip nose down and fall to the ground with the rotors stopped; his impression was that the rotors were hanging vertically down each side of the aircraft. This witness was approximately 500 metres away from the crash location.

No other witnesses were watching the aircraft just prior to the unusual noise although all considered that the engine noise was constant up to that point. They were attracted to the location by a noise, variously described as a "pop" or a "bang" and a change in engine noise. The aircraft was seen to pitch slightly nose down but it remained in an upright attitude as it descended rapidly to the ground. The rotors were variously described as turning slowly or stopped and two witnesses had an impression that one rotor blade was bent about halfway along its span. One witness thought that the aircraft turned through about 180° on its longitudinal axis as it descended.

Emergency '999' calls were made while two vehicles set out to locate the crash site. One other club member had already prepared an aircraft for flight and he taxiied this aircraft, G-BPWL onto Runway 20 and took off. Once airborne, he contacted Norwich ATC on 119.35 MHz, declared an emergency and requested assistance for a gyroplane that had crashed near Shipdham Airfield. Norwich ATC recorded the call at 1253 hrs and the controller initiated his emergency procedures. As he was doing so, the crew of an air ambulance helicopter, G-EYNL, called on the frequency and, when informed of the accident, elected to proceed direct to the accident site. The pilot of G-BPWL reported that he would remain over the crash site and did so until the air ambulance reached the crash site at 1303 hrs. Just before then, two club members had reached the accident scene and had found the aircraft lying on its side with the pilot still in his seat. They could not detect any signs of life and this was confirmed when the air ambulance personnel arrived, moved the aircraft clear and checked the pilot.

Aircraft description and history

The aircraft was a light single seat gyroplane with a pusher engine configuration and an open cockpit (see Figure 1). When constructed and flight tested, the aircraft was fitted with 22-foot diameter 'Dragon Wing' rotor blades and a Rotax 532 engine with a three-bladed composite propeller. The engine was not fitted with a carburettor heat system. In common with other Bensen-type

Figure 1

Aircraft prior to the accident (G-BIGU)

gyroplanes, the control stick was of the pump-action type which pivots at a point below the seat and moves vertically during forward and aft movements. This differs from a keel mounted stick that has no significant vertical movement during pitch control changes. The movement of a keel mounted stick would be similar to that encountered in conventional fixed wing aircraft.

During the investigation two people reported that the accident pilot had attempted some wheel balancing on his aircraft without supervision at sometime during the latter half of 2002. During this attempt the aircraft had suffered a 'blade flap' incident on the ground[2] resulting in a rollover and damage to the propeller and rotor. These accounts are supported by the fact that the pilot purchased new rotor blades and a new propeller blade in October 2002. The new rotor blades were of the same type but, at 23 ft diameter, one foot larger than the authorised rotor diameter specified in the machine's Permit to Fly. However, there is no evidence to suggest that any aircraft damage from that accident led to the pilot's subsequent fatal accident.

Other modifications to the B8MR design included the addition of a modified nosecone fairing from the Air Command gyroplane design, the addition of side pod tanks and a seat incorporating a fuel tank, also from the Air Command design. The nosecone fairing and seat tank modifications had been approved by the PFA. The side pod tank modification had not yet been approved due to its potential adverse effect on vertical CG. However, a weight and balance study by the University of Glasgow had determined that the tanks had little effect on the vertical CG. From weight measurements taken with the 23 ft rotor fitted, the vertical position of the CG was calculated to be 4.8 ±1.2 inches below the thrust line. The aircraft's mass with the accident pilot on board and with the seat tank half full was measured at 252 kg. The maximum total authorised weight of the aircraft was 280 kg.

The flight instruments on G-BIGU consisted of an airspeed indicator calibrated in knots, an altimeter and a compass. The instrument panel also included an analogue engine rpm gauge, an analogue engine water temperature gauge, a digital rotor rpm indicator and an ignition ON/OFF switch. At the left side of the pilot's seat there was a short, Air Command-style throttle lever and on the right side there was an engine choke control. The fuel supply could be selected from one of three fuel tanks by means of a fuel selector located behind the pilot's seat.

Accident site examination

The aircraft struck the ground in a wheat field approximately half a mile east of the airfield. The lack of disturbed wheat surrounding the aircraft indicated a near vertical impact with very little forward speed. The aircraft had struck on its left side in a steep left bank. There was no indication of any appreciable rotor speed at impact. One rotor blade had buckled on impact and forced the rotor mast to bend to the right. A large section of the upper portion of the rudder had detached and could not be found near the main wreckage. The missing section of rudder was found in pieces two months later by a farmer harvesting the field. The pieces were located 60 to 120 feet from the main wreckage. The rotor blades had red marks along their leading edge and underside between 4.6 and 6.2 feet from the rotor hub. The location of these marks was consistent with the rotor having struck the red rudder and the distant location of the rudder pieces indicated that the rudder was struck in flight rather than at ground impact.

Footnote

2 Accelerating the gyroplane too rapidly along the ground for the current rotor speed causes this form of blade flap.

The rotor blades also had curved red marks on their underside nearer the root. These marks were consistent with the rotor having made contact with the red propeller tips. One of the three propeller blades had separated at its root and one blade had separated at mid-span; both separated blades were found within 15 feet of the wreckage. The close proximity of the propeller blades to the wreckage indicated that the blades had probably separated at ground impact rather than in flight as a result of a rotor blade strike. The close proximity of the propeller blades also suggested that the propeller shaft was rotating at low power at impact.

The side pod fuel tanks were found empty and had not been punctured. The seat tank was also nearly empty but its fuel cap had been dislodged and any fuel remaining would have drained out whilst the aircraft was lying on its side. The fuel selector was set to the seat tank position. The accident site had a distinct smell of fuel and there was fuel remaining in the carburettor bowl.

Detailed wreckage examination

After the on-site examination the wreckage was recovered to the AAIB facility at Farnborough for a more detailed examination.

The flight controls were checked for continuity and no disconnects were found. The aircraft was fitted with a pre-rotator mechanism which was still operable and there was no evidence to suggest any interference between the pre-rotator mechanism and the rotor. The teeter stop plate was bent downwards on both sides which was consistent with a hard impact between the rotor blades and the teeter stops. This evidence suggested a violent vertical motion of the rotor blades which was consistent with the motion required for the rotor blades to strike the rudder.

The engine was taken to an approved overhaul agency to be tested. A few repairs were required including replacement of the damaged starter casing, exhaust manifold and propeller as well as removal of the damaged radiator. It was then mounted on a test stand and the engine started and operated normally.

All the structural failures were consistent with the rotor blade strikes and ground impact damage. No anomalies or defects that might have contributed to the accident were found in the aircraft's construction.

Aircraft approval process

Most gyroplanes are now built from kits but G-BIGU was built from the plans for a Bensen B8MR with additional modifications. The Popular Flying Association (PFA) was delegated by the CAA to investigate and make recommendations concerning new applications for approval of this gyroplane type. Following build completion, G-BIGU was inspected and then test flown by a pilot accepted by the PFA for this task. Seven test flights were carried out during a period between 29 June and 1 July 2002. These tests were conducted with the 22 ft rotor fitted. After the test flights the pilot submitted a declaration to the PFA stating that he considered that the aircraft complied with the British Civil Airworthiness Requirements (BCAR) Section T. The PFA then recommended to the CAA that G-BIGU be issued with a Permit to Fly. The CAA issued G-BIGU with a Permit to Fly on 19 September 2002. The Permit was concurrently issued with a Certificate of Validity that maintained its currency until 18 September 2003. Before the Permit was issued, the builder sold the aircraft to the accident pilot.

Stability characteristics of gyroplanes

In the same way that a fixed wing aircraft has longitudinal static stability when the CG is forward of the aircraft's lift vector, a gyroplane has longitudinal static stability when the CG is forward of the Rotor Thrust Vector. In this configuration, when a gust causes the gyroplane to pitch up the rotor thrust will increase causing a restoring nose-down pitching moment. A large factor in determining the balance of moments which affects the location of the RTV in steady flight is the vertical location of the propeller thrust line relative to the vertical CG. A simplified diagram showing the two dominant forces, propeller thrust (T_{prop}) and RTV, is shown in Figure 2 (the aerodynamic drag is assumed to be closely in line with the vertical CG). For Case A, the thrust line is below the CG and therefore to establish equilibrium in flight, the RTV lines up aft of the CG (to balance the nose-up pitching moment of the thrust line). When a disturbance such as an upwards gust causes the aircraft to pitch up the RTV will increase and tilt aft (flap back), the net effect being to pitch the aircraft nose-down – a restoring moment. For Case B, the thrust line is above the CG and therefore to establish equilibrium in flight, the RTV lines up forward of the CG. When a disturbance causes the aircraft to pitch up, the RTV will increase and tilt aft, the net effect being to pitch the aircraft nose-up even further – an unstable configuration.

In addition to static longitudinal stability it is also desirable that a gyroplane possesses dynamic longitudinal stability. A gyroplane that has static stability does not necessarily possess dynamic stability. A gyroplane with positive longitudinal static stability but negative longitudinal dynamic stability would pitch down in response to an upwards gust but the restoring moment would be excessive and without pilot input the nose-down pitch attitude would increase with each subsequent overshoot.

The University of Glasgow conducted a study into the stability characteristics of gyroplanes using a simulation model based on both wind tunnel data and flight test data. The computer model verified that aligning the thrust line close to the vertical CG had a favourable

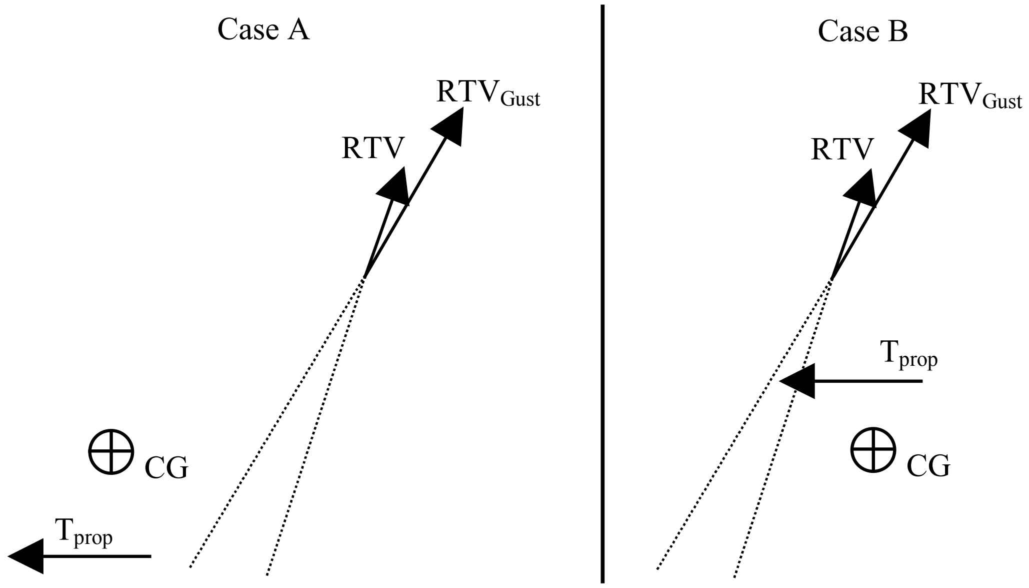

Figure 2

Diagram of Rotor Thrust Vector (RTV) change due to an upwards gust.
Case A: Propeller thrust line passes below CG.
Case B: Propeller thrust line passes above CG

effect on both static and dynamic longitudinal stability characteristics. The study recommended that the CAA revise BCAR Section T to include a limit for vertical CG position that was within ±2 inches of the propeller thrust line. A small amount of instability with a thrust line slightly above the CG was deemed acceptable but a thrust line at or below the CG was deemed desirable. The CAA plans to implement the recommendation by requiring a more rigorous demonstration of acceptable handling qualities if the ±2 inches thrust line to CG relationship is not met. It should be noted, however, that aligning the thrustline close to the vertical CG would be advantageous but will not in itself guarantee that a gyroplane will have good longitudinal stability characteristics.

The aerodynamic drag vector can also affect the stability of a gyroplane if it is not closely aligned with the vertical CG. In this situation, changes in speed will cause drag changes and resulting pitch changes. A drag vector below the vertical CG will result in a speed-unstable configuration because an increase in speed will pitch the aircraft nose-down.

Theoretically the addition of a properly sized and properly located horizontal tail can improve both speed stability and pitch stability. A horizontal tail can provide a restoring pitching moment and it can also act as a pitch damper, reducing the number of overshoots during a pitch oscillation which improves dynamic stability.

The more longitudinally unstable gyroplanes are, the more difficult they are to fly and the more likely the pilot is to enter a pilot-induced-oscillation (PIO) in pitch. In a PIO, the pilot's control inputs are out of phase with the response of the aircraft. A PIO in a gyroplane, if not recognised and stopped immediately by the pilot, can have fatal consequences. The study on gyroplane stability by the University of Glasgow demonstrated that when a gyroplane is pitching up and down, the rotor speed is also oscillating up and down. If a rotor slows down too much, retreating blade stall can occur, also known as in-flight blade flap. During in-flight blade flap the rotor blade becomes unstable and usually strikes some part of the airframe, tail or propeller.

Blade flap can also result from a deliberate unloading of the rotor. If the pilot pushes forward too rapidly on the control stick (bunting) the rotor disk's angle of attack will reduce and the ensuing lift loss will unload the rotor (ie less than 1g). Unloading the rotor causes the rotor to slow down and if it slows down excessively, retreating blade stall can occur and blade flap will follow. The situation is aggravated by a thrust line located above the vertical CG, because as the RTV reduces, the propeller thrust causes the aircraft to pitch further nose-down, further unloading the rotor. For this reason the phenomenon is often referred to as a 'power pushover'.

An additional factor that can affect the aircraft's PIO susceptibility is the type of control stick employed. The pump-action type control stick translates up and down during forward and aft stick movements. In theory, with this type of stick a PIO could be aggravated due to the vertical motion of the aircraft coupling with the vertical motion of the stick as the pilot tries to control the pitch. The keel-mounted stick does not translate up and down and therefore is less likely to couple with the aircraft motion.

In summary, gyroplanes can be designed with inherent longitudinal stability. Aligning the propeller thrust line at or slightly below the vertical CG improves longitudinal stability as may a properly sized and located horizontal tail. Aligning the drag vector with the vertical CG also improves speed stability. The use of a keel-mounted stick as opposed to a pump-action stick may also help alleviate PIO susceptibility.

BCAR Section T requirements

Section T of BCAR covers light gyroplanes. At the time of the accident the current version of Section T was Issue 1, Amendment 1, of August 2001. All new designs of gyroplanes must comply with Section T but G-BIGU did not need to comply with Section T because it was built from the plans of an existing design. Nevertheless, the flight test for the permit issue for G-BIGU was conducted against certain performance and handling criteria from Section T (Issue 1).

Section T includes requirements for static longitudinal stability (T173) and dynamic stability (T181). The static longitudinal stability requirements specify criteria relating to stick force as a function of speed and load factor. The dynamic stability criteria relate to the damping and frequency of any oscillations – important criteria when assessing an aircraft's susceptibility to PIO. The requirement and interpretative material concerning oscillations were as follows:

Requirement: *'Any short-period oscillations occurring under any permissible flight condition must be heavily damped with the primary controls fixed or free.'*

Interpretative Material: *'Longitudinal, lateral or directional oscillations with controls fixed or free and following a single disturbance in smooth air, should at least meet the following criteria:*

(a) Any oscillation having a period of less than 5 seconds should damp to one half amplitude in not more than one cycle. There should be no tendency for undamped small amplitude oscillations to persist.

(b) Any oscillation having a period between 5 and 10 seconds should damp to one half amplitude in not more than two cycles. There should be no tendency for undamped oscillations to persist.

(c) Any oscillation having a period between 10 and 20 seconds should be damped, and in no circumstances should an oscillation having a period greater than 20 seconds achieve more than double amplitude in less than 20 seconds.'

The interpretative material states that any oscillation with a period of less than 20 seconds must be stable, ie damped. Oscillations with a period of more than 20 seconds are more controllable and therefore a certain degree of instability is permitted. These tests can be a challenge to perform as the oscillations can make it difficult to hold the stick fixed.

Stability characteristics of G-BIGU

G-BIGU had a number of characteristics that indicated that it probably would not have met the longitudinal dynamic stability criteria of Section T. The thrust line on G-BIGU was 4.8 ±1.2 inches above the vertical CG. This is in the unstable direction and is outside the 2 inch limit recommended by the University of Glasgow. G-BIGU was not equipped with a horizontal tail designed to improve stability and it was modified with the addition of a nosecone fairing - the drag acting on this fairing could have had a destabilising effect. Moreover, the aircraft had a pump-action stick as opposed to a keel-mounted stick that could have increased the aircraft's susceptibility to PIO. All these features indicate that the aircraft would probably have been difficult to fly, particularly for an inexperienced gyroplane pilot.

G-BIGU was test flown by a very experienced gyroplane pilot as part of the process for the issue of a Permit. The pilot thought that the aircraft flew well and met the criteria of Section T. The flight test report was written in subjective terms and did not contain any data to compare against the longitudinal dynamic stability criteria of Section T. The report stated that the aircraft *"can be flown hands and feet off at cruise speeds of 45 to 50 mph for short periods of time before gently deviating from straight and level flight"*. The phrase "*short periods of time*" was not qualified in the report but the pilot later stated that it was about 5 seconds. The stick-free stability of a gyroplane is generally considerably better than the stick-fixed stability because leaving the stick free allows the rotor hub to move independently of the aircraft, adding a degree of auto-stabilisation.

The University of Glasgow was asked to model the stability of G-BIGU using their RASCAL simulator that had been developed to model gyroplanes. The pod, tailplane and vertical tail aerodynamics were those estimated from a similar looking single-seat Air Command gyroplane. The mass properties, CG, thrust line and geometric data used were those specific to G-BIGU with the 23 ft diameter rotor fitted. The results showed that when the aircraft was excited by a fore and aft stick input, the response was a stable and lightly damped pitch oscillation (see Figure 3) at 45 mph. However, when the speed was increased to 65 mph the model predicted that G-BIGU would have an unstable rapidly divergent pitch response shown by the rapidly increasing pitch angle in Figure 3. The control stick was assumed to be held fixed following

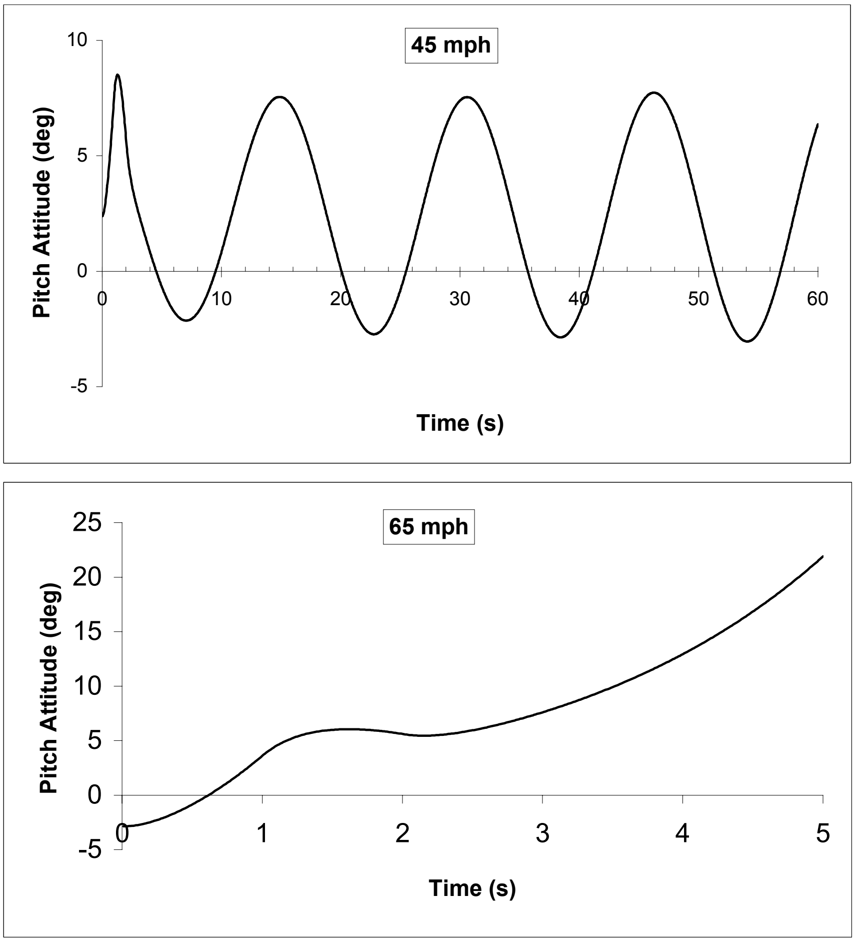

Figure 3

Modelled pitch response of accident aircraft at 45 mph and 65 mph following a fore and aft stick input the initial input. Similar stability results were obtained from the RASCAL simulator when a 22 ft diameter rotor was substituted although the predicted rotor speed was increased by 6%.

Unfortunately, this simulator model for G-BIGU cannot be validated against the real aircraft and therefore these results must be treated with some caution. However, taken together with the design characteristics of G-BIGU, the results indicate that the aircraft could have had an unstable mode in pitch and probably did not meet all the longitudinal stability criteria of BCAR Section T.

The reason for the discrepancy between the flight test assessment and the modelled results could be due to the change in rotor size after the flight tests, the flight test technique, or a combination of both factors. The flight test studies conducted by the University of Glasgow with instrumented gyroplanes revealed that very experienced gyroplane pilots, who have not been trained as test pilots, have a subconscious tendency to correct for instabilities in the aircraft with small stick inputs. The true stability characteristics of an aircraft need to be assessed objectively both stick fixed and stick free.

An additional factor that could have induced or aggravated a PIO in pitch in G-BIGU was the short throttle lever coupled with the 'peaky' nature of the Rotax 532 engine. At high rpm the Rotax 532 engine has a non-linear relationship between power output and throttle position. In the high rpm region small movements of the throttle lever can result in large power changes. Any power changes will affect the pitch response of the aircraft due to the high thrust line above the CG. The Montgomerie B8MR kit-build gyroplane has a longer throttle lever, which partly alleviates this problem.

Finally, the instructor at the training school considered that the high seating position of G-BIGU, coupled with the location of the nosecone, would have resulted in a less favourable airframe reference relative to the horizon.

Stability Characteristics of the VPM M-16

The accident pilot underwent the majority of his flight training on a VPM M-16. The VPM M-16 (shown in Figure 4) is a very different aircraft from G-BIGU. The VPM is a two seat aircraft and has a lower thrust-to-weight ratio than G-BIGU. Unlike G-BIGU, the VPM has a stabilising horizontal tail, a keel mounted stick and its thrust line is closer to the vertical CG than on G-BIGU (between 2.4 and 3.4 inches above CG). The University of Glasgow carried out a flight test programme on an instrumented VPM M-16 with a former military test pilot. Various longitudinal stability tests were carried out, including stick fixed pitch oscillations. The recorded flight test

Figure 4

In foreground, VPM M-16 used by accident pilot for majority of training data was analysed and showed that the aircraft met the longitudinal dynamic stability criteria of Section T. Those who have flown the VPM confirm that the aircraft is considerably more stable and easier to fly than most other gyroplanes.

Operational information

Medical information

A post-mortem examination was carried out on the pilot. He died from severe multiple injuries resulting from a severe vertical force; death would have been instantaneous. There was no evidence of any disease, alcohol, drugs or any toxic substance, which may have caused or contributed to the accident.

Pilot training and licensing

The current requirement for the issue of a UK PPL(G) licence is for the applicant to have completed a course of training to a syllabus recognised by the CAA. The flight training must be completed on an approved 2-seat gyroplane. However, a single seat gyroplane may also be used after specified dual flight instruction. A minimum of 40 hours flying experience as a pilot in a flying machine was required for licence issue, of which 5 hours must be dual flying training, 10 hours must be dual or supervised in gyroplanes and 10 hours must be as pilot-in-command of gyroplanes.

During the gyroplane course, the pilot flew 17 hrs 15 minutes dual instruction in a twin-seat VPM gyroplane before his first training flight in G-BIGU on 16 December 2002. His first three flights in G-BIGU were recorded as 'wheel balancing'. ('Wheel balancing' is one of the early exercises on gyroplanes when the student accelerates the aircraft to a point where the nosewheel is clear of the ground and the machine is balanced on the main wheels.) Thereafter on his course, he flew the VPM, G-BIGU and another B8MR (with a smaller engine than on G-BIGU). All his flights in G-BIGU were recorded in his flying logbook as 'wheel balancing' until 9 April 2003 when he recorded some 'straight and level' flying. Then, on 15 April, his training record showed that he was overcontrolling on G-BIGU and he reverted to 'wheel balancing'. He passed his General Flying Test on the VPM on 17 April. On 18 April, his 'wheel balancing' on G-BIGU was assessed as "*much more confident*" and he was ready for "*high hops and circuits*". After a further 2.5 hours flying in G-BIGU, the flight examiner endorsed his flying logbook with a clearance to fly "*single seat gyroplanes and VPM twin-seat*".

Towards the end of his course, his instructors considered that the pilot appeared more confident. However, comments made by the pilot's partner indicated that he remained somewhat apprehensive of gyroplanes. The pilot had mentioned instances of PIO during the course that had alarmed him and he expressed some anxiety about flying G-BIGU.

Pilot's notes

In common with many other types of gyroplane, G-BIGU did not have any accompanying pilot's handling notes. However, numerous books have been published dealing with the theory and practice of gyroplane flying. In general, specific flight training organisations would recommend publications and provide classroom instruction during a training course. Subsequent to the accident involving G-BIGU, written notes were found belonging to the pilot. These covered subjects such as gyroplane theory, gyroplane safety checks and actions following an engine failure. The current Section T requirement was for type specific handling notes to be available for any new gyroplane build; this requirement was not retrospective.

Safety record of gyroplanes

The safety record for gyroplanes was very poor compared to other types of aircraft. Between 1989 and 2004 there were 15 fatal gyroplane accidents in the UK. In that period there were between 200 and 265 gyroplanes on the UK register. Based on CAA estimates of hours flown, this placed the fatal accident rate for gyroplanes at 27.1 per 100,000 flight hours. This rate compared to just 2 fatal accidents per 100,000 flight hours for microlight aircraft and only 1.1 fatal accidents per 100,000 flight hours for light fixed-wing general aviation aircraft. The fact that the fatal gyroplane accident rate was more than 13 times greater than that for similar weight microlight aircraft raised serious questions over the design of gyroplanes and the training of gyroplane pilots.

A review of the 15 fatal accidents showed that 13 of the pilots involved held a licence for fixed wing aircraft or helicopters. One of the 15 fatalities had a total flying experience on gyroplanes of 170 hours but none of the others had more than 50 hours and 6 had less than 10 hours.

A study of gyroplane accidents in the USA during the 3 year period between 1999 and 2002 by the American Popular Rotorcraft Association revealed that of the 17 fatal gyroplane accidents, 8 listed pitch instability as the primary cause. In these accidents the aircraft was considered to have entered an unstable mode. In 4 of these fatal accidents the rotor had struck the tail in flight. The aircraft in the study were of varying types but it was noted that the fatal accidents as a result of pitch instability all occurred in aircraft without a horizontal tail. Information on each aircraft's thrust line versus CG location was not available. "Deficient Pilot Proficiency" was considered a shared cause when pitch instability was involved.

Previous AAIB investigations and recommendations

An investigation into the fatal accident of G-BXEM, a Cricket Mk IV, on 1 June 2001 (reported in AAIB Bulletin 5/2002) highlighted the possibility that the pilot was experiencing difficulties flying a machine different from that in which he had trained. The CAA addressed this matter in revised requirements for the grant of a UK PPL (Gyroplanes). The revised requirement was to complete differences training so that:

> *'Pilots wishing to fly gyroplanes different from the specific manufactured type that they received flight training on, shall receive appropriate differences training from a gyroplane assistant flight instructor or flight instructor and have their log books endorsed by the instructor.'*

Another investigation involved the fatal accident of G-CBAG, a RAF 2000 GTX-SE, on 17 May 2002 (reported in AAIB Bulletin 9/2003). This investigation highlighted the possibility that the aircraft's stability characteristics contributed to the accident. As a result, the AAIB made the following recommendations to the CAA (listed together with the CAA response):

Recommendation 2003-01: It is recommended that the CAA should review the pitch stability requirements of BCAR Section T in the light of current research, and amend the Requirement as necessary. The CAA should consider the need for an independent qualified pilot assessment of the handling qualities of different gyroplane types currently approved for the issue of a Permit-to-Fly against the standards of BCAR Section T, as amended.

Recommendation 2003-02: It is recommended that the CAA should consider retrospectively assessing all gyroplane types currently on the UK register for acceptable pitch stability characteristics.

CAA Response: The CAA accepted both recommendations and published its proposed response to them in CAA FACTOR F31/2004. This FACTOR is available on the Internet.

Analysis

It was evident from the wreckage examination that the rotor blades had struck the rudder in flight. This evidence is consistent with the loud 'bang' that witnesses reported hearing before they saw the aircraft descend vertically into the field. Following such a rotor to rudder strike, the reduced energy in the rotors would have made a recovery virtually impossible.

There have been other fatal gyroplane accidents that have resulted from the rotor blades striking some part of the airframe - usually the tail or rudder. The cause of these strikes is usually associated with in-flight blade flap following a PIO or a bunt (pushing the nose over and reducing the g appreciably below 1g). Both witnesses who saw G-BIGU at the moment of the 'bang' reported that the aircraft was flying straight and level which suggests that the aircraft was not performing a bunt. The witness evidence would also seem to rule out a PIO but it is possible that a PIO, perhaps leading to a 'power pushover', developed quite rapidly and the distance of the witnesses from the aircraft could have made the oscillation difficult to detect.

The fact that the aircraft was seen to be 'porpoising' earlier in the flight suggests that the pilot was having some difficulty controlling the aircraft in pitch. The aircraft had a number of features that indicated that it could have had poor longitudinal stability characteristics: it did not have a horizontal tail; it had a thrust line to CG relationship outside the ±2 inches recommended by the University of Glasgow; it had a nosecone fairing that could have reduced longitudinal stability; and it had a pump-action control stick. In addition, the aircraft's short throttle lever coupled with the Rotax 532 power characteristics could have induced or aggravated a PIO in pitch. A simplified computer model developed by the University of Glasgow showed that the aircraft might have an unstable mode at 65 mph. Furthermore, the pilot was inexperienced on this aircraft type and had conducted the majority of his flight training on a VPM aircraft, which is reportedly easier to fly and exhibits good longitudinal stability characteristics. For these reasons, it was concluded that a PIO was the most probable cause of the rotor striking the rudder.

No evidence of a technical malfunction was found that might have contributed to the onset of a PIO. The engine was tested and operated normally. There was evidence of fuel at the accident site and all the defects and failures found in the wreckage were related to either rotor blade flapping or to ground impact damage.

Furthermore, there was no evidence of any medical factor which may have resulted in the pilot becoming incapacitated. He was also qualified to fly fixed wing aircraft and he had completed his gyroplane training in accordance with the current CAA requirements. However, there was some indication that he was somewhat apprehensive regarding gyroplane flying in general and G-BIGU in particular.

Throughout the pilot's training, occurrences of overcontrolling had been noted and attempts made to rectify the tendency. At the end of his course, his instructors were satisfied that he had reached an appropriate standard for the issue of a PPL (Gyroplanes).

One aspect that may have been relevant, particularly involving an inexperienced gyroplane pilot, was that he had a dual flight in a fixed wing aircraft in the period between finishing his gyroplane course and the fatal flight. This would have involved different handling techniques in a machine with radically different flying qualities. The accident occurred on the pilot's first unsupervised flight in G-BIGU following completion of his course.

Regardless of the specific cause of the accident to G-BIGU, the investigation highlighted two aspects that were considered highly relevant. Firstly, the current training requirements and secondly compliance with the standards required by BCAR Section T. These were particularly important when associated with the accident rate of gyroplanes.

Safety recommendations

Training requirements

At the time of the accident the requirements for differences training had evolved following a recommendation by the AAIB. It arose from an accident where there was a possibility that the pilot was experiencing difficulties in flying an aircraft different from the one on which he trained. The accident involving G-BIGU had similar indications. Although the pilot of G-BIGU had completed differences training as required by the CAA, his aircraft had a greater power to weight ratio and was less stable than that of the VPM on which he had initially trained. He converted to his own aircraft under supervision but there was evidence that he remained somewhat apprehensive about G-BIGU. The pilot's logbook and training records indicated that a large proportion of his 'flying' on G-BIGU had involved wheel balancing. A review of the training requirements also revealed that there was no minimum hours requirement for the differences training. It was considered appropriate for the CAA to review the training requirements with the aim of establishing a minimum number of supervised flying hours before being qualified for a type of gyroplane different from that on which the preliminary training was completed. Additionally, a minimum number of these required hours should be airborne exercises as opposed to wheel balancing. It was therefore recommended that:

Safety Recommendation 2004-42

The Civil Aviation Authority should differentiate between wheel balancing and airborne exercises when detailing the flying hours required for the issue of a Private Pilot's Licence (Gyroplanes).

Safety Recommendation 2004-43

The Civil Aviation Authority should review the present gyroplane training requirements with the aim of establishing a minimum number of supervised flying hours, discounting wheel balancing, when undertaking differences training on gyroplanes.

CAA Response The CAA accepted these recommendations and published its proposed response to them in CAA FACTOR F31/2004. This FACTOR is available on the Internet.

Assessment of gyroplanes against BCAR Section T

Following the investigation into the fatal accident of the RAF 2000 gyroplane G-CBAG, the AAIB recommended that the CAA should consider retrospectively assessing all gyroplane types currently on the UK register for acceptable pitch stability characteristics (Recommendation 2003-02). Following the accident to G-BIGU in which poor stability characteristics were probably a contributory factor, the AAIB reiterated the importance of carrying out this recommendation. The Civil Aviation Authority has accepted this recommendation and planned to carry out the assessments giving priority to gyroplanes with a poor safety record.

The test flight of G-BIGU that was carried out on behalf of the Popular Flying Association did not appear to have been flown in accordance with the interpretative material of the stability requirements of British Civil Airworthiness Regulations Section T. The flight test report did not include any data to support the opinion that the aircraft met the dynamic stability criteria of Section T. The format of the form used for the flight test report was poor in that it did not include fields for recording the data required by British Civil Airworthiness Regulations Section T. The AAIB therefore made the following recommendations:

Safety Recommendation 2004-44

It is recommended that the Civil Aviation Authority in conjunction with the Popular Flying Association (PFA) ensures that test pilots evaluating the handling qualities of gyroplanes against British Civil Airworthiness Regulations Section T are appropriately trained to make such evaluations.

Safety Recommendation 2004-45

It is recommended that the Popular Flying Association (PFA) in conjunction with the Civil Aviation Authority revises the format of the PFA Gyroplane Flight Test Schedule such that a completed form contains all the data required by British Civil Airworthiness Regulations Section T.

Safety actions taken

On 24 June 2004, the Civil Aviation Authority confirmed that all the recommendations arising from the investigation into the accident to G-BIGU had been accepted.

In respect of recommendation 2004-42 the CAA would make the necessary amendments to the Private Pilot's Licence (Gyroplanes) requirements in the LASORS (Licensing, Adminstration, Standardisation, Operating Requirements and Procedures) publication in time for the next re-print, which was scheduled for January 2005 and completed in 2005.

With regard to Safety Recommendation 2004-43, following a review of the gyroplane training requirements, the CAA would introduce a specified minimum number of supervised flying hours, discounting wheel balancing, for differences training on gyroplanes. The necessary amendments to the Private Pilot's Licence (Gyroplanes) requirements in the LASORS (Licensing, Adminstration, Standardisation, Operating Requirements and Procedures) publication would be made in time for the next re-print, which was scheduled for January 2005. In the meantime, all Gyroplane Flying Instructors would be instructed, by letter, to implement the change to flight training with immediate effect.

In respect of Safety Recommendation 2004-44 the CAA was working with the PFA to define a process which ensures that test pilots evaluating the handling qualities of gryoplanes against BCAR Section T requirements are appropriately trained to make such an evaluation. This work was to be completed by the end of 2004.

In respect of Safety Recommendation 2004-45 the CAA was working with the PFA to define a process which ensures gyroplane flight test schedules include fields for recording all the data required by BCAR Section T. This work was to be completed by the end of 2004.

The Popular Flying Association also endorsed the recommendations and stated: "We are now working with the CAA Projects Department and Flight Department to develop a new gyroplane flight test schedule specifically to investigate ultralight gyroplanes against the Section T handling requirements, and to train selected experienced gyroplane pilots in the test methods and reporting procedures. We are, of course, working with the CAA on the re-evaluation of existing types of gyroplanes against Section T handling requirements which we see as a very positive step towards addressing the high accident rate on this class of aircraft."