
AAIB Bulletin

12/2024



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01252 512299

Air Accidents Investigation Branch
Farnborough House
Berkshire Copse Road
Aldershot
Hampshire
GU11 2HH
United Kingdom

Tel: 01252 510300

Media enquiries: 01932 440015 (office hours) / 0300 777 7878 (out of hours)

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AAIB Field Investigation Reports

A Field Investigation is an independent investigation in which AAIB investigators collect, record and analyse evidence.

The process may include, attending the scene of the accident or serious incident; interviewing witnesses; reviewing documents, procedures and practices; examining aircraft wreckage or components; and analysing recorded data.

The investigation, which can take a number of months to complete, will conclude with a published report.

Serious Incident

Aircraft Type and Registration:	Boeing 737-8K5, G-TAWD
No & Type of Engines:	2 CFM56-7B27E turbofan engines
Year of Manufacture:	2011 (Serial no: 37265)
Date & Time (UTC):	20 October 2023 at 1153 hrs
Location:	Leeds Bradford Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 6 Passengers - 195
Injuries:	Crew - None Passengers - None
Nature of Damage:	Main landing gear tyres and nosewheel tyres damaged. Left nosewheel inner axle bearing destroyed
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	41 years
Commander's Flying Experience:	14,250 hours (2,800 hours on type) Last 90 days - not known Last 28 days - 88 hours
Information Source:	AAIB Field Investigation

Synopsis

After touching down at Leeds Bradford Airport (LBA) in stormy weather, the aircraft began to yaw left of the runway centreline. When the pilot flying increased the right rudder input to correct the deviation, both pilots reported feeling a significant judder from the nose gear. This prompted the pilot flying to reduce the right rudder input and, although there were repeated brief right pedal inputs, the aircraft continued to deviate from the centreline and left the runway. The aircraft sustained minor damage and there were no injuries.

The investigation found that one of the aircraft's nosewheel bearings had failed, likely during the rollout at LBA. The resultant juddering was unexpected and led the PF to limit his rudder input. However, there was, in fact, no mechanical impediment to the use of additional rudder, and differential braking was also available to maintain directional control.

History of the flight

The crew reported for duty at 0400 hrs for a scheduled passenger flight from Manchester to Corfu, followed by a return flight to Leeds Bradford Airport (LBA). The outbound flight to Corfu was uneventful and the crew did not experience any issues with directional control of the aircraft during landing or take off from Corfu.

The commander was PF for the flight to Leeds. There was inclement weather forecast at the time of their arrival, with high winds expected as part of Storm Babet which was passing

through the north of the UK. The crew conducted a comprehensive briefing during the cruise and discussed the increased likelihood of a diversion to Manchester, where the wind direction was forecast to be more favourable.

As the aircraft was in the descent towards Leeds, the crew calculated landing performance using the manufacturer's performance tool and used the wind of 060° at 19 kt that was passed to them. However, they recall that the results of the calculation were outside the aircraft landing performance limits and so requested to enter a holding pattern at the LBA NDB. As they approached the holding pattern, the approach ATCO passed the current wind to be 070° at 21 kt gusting 33 kt and advised the crew that a Boeing 737-800 had just landed at Leeds.

The crew confirmed this wind was in limits and commenced an ILS approach for Runway 14. They were expecting turbulent conditions and reported that they were 'go-around minded'. Both crew members recalled that the conditions were smoother than expected and that the approach was stable with minimal speed fluctuations. The PF configured the aircraft for landing earlier than normal and autobrake MAX was selected. The tower ATCO cleared the aircraft to land as it was descending through approximately 2,000 ft and passed a final wind check of 070° at 23 kt gusting 37 kt, indicating a maximum crosswind component of 35 kt from the left.

The PF de-crabbed the aircraft using right rudder and landed in the touchdown zone. The landing was described by the crew and tower ATCO as smooth. The autobrake engaged one second later, reverse thrust was commanded and deployed as normal, and the target deceleration rate was achieved. There was left control wheel input after touchdown for 5.5 seconds. The PF reduced the right rudder pedal to neutral five seconds after landing and the aircraft began to yaw to the left. In response, the PF made a right rudder input which reduced the rate of yaw to the left. The PF then disconnected the autobrake whilst decelerating through 107 kt, following which there was a period of eight seconds where there was no wheel braking. The reverse thrust was cancelled at approximately 86 kt and there was an increase in right rudder pedal input to 2.5°. The rudder was periodically reduced to 0° and the aircraft continued to yaw to the left.

The crew reported feeling a significant 'judder' when right pedal pressure was applied. The PF reported that the judder was accompanied by an un-commanded yaw to the left. He stated that subsequent right rudder inputs were effective initially but then there was a return to left yaw beyond mid-deflection of the rudder. This repeatedly led the PF to reduce the rudder input and meant that the full range of rudder application was not used to correct the aircraft's drift to the left of the runway centreline. Asymmetric braking was used momentarily, and the crew reported attempting to regain control using the tiller as the aircraft approached the runway edge. Maximum manual symmetric braking was applied three seconds prior to the aircraft reaching the runway edge. The PF recalled using nosewheel steering in an attempt to correct the deviation, but control of the aircraft was not regained, and the aircraft left the runway at a groundspeed of approximately 55 kt.

The aircraft came to a stop six seconds later in muddy ground approximately 150 m beyond the D taxiway exit (Figures 1 and 2). The crew followed normal shutdown procedures to secure the aircraft. There were no injuries reported by passengers or crew.



Figure 1
Aircraft final position



Figure 2
Aircraft ground track

On-site examination

The mainwheel and nosewheel tyres left light 'cleaned' marks on the runway surface which became visible after the surface had dried (Figures 3 and 4). The marks began approximately level with taxiway Lima, and continued until G-TAWD left the runway. The nosewheel track changed from two clear tyre marks to a single tyre mark at approximately 840 m after touchdown, where it continued for more than 200 m until the aircraft left the runway. The change in mark indicates that the nosewheels were turned to one side instead of in the direction of the aircraft's travel.

'Steam-cleaned' tyre marks can indicate the presence of reverted rubber hydroplaning.



Figure 3
Runway tyre marks in direction of travel

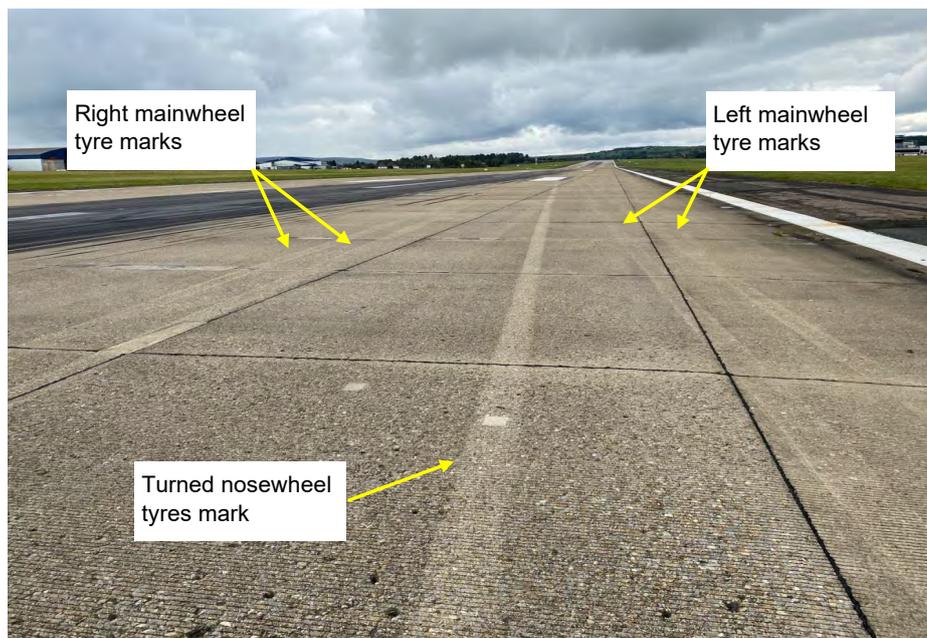


Figure 4
Runway tyre marks facing direction of travel

Aircraft information

Nosewheel steering

Nosewheel steering on ground is linked to the rudder pedals and a steering tiller on the commander's side. When the rudder pedals are moved to full travel, the nosewheels turn a maximum of 7° in the left or right direction. Rudder pedal steering is used during the takeoff and landing roll, whilst for slow speed manoeuvring, the tiller is used. When the tiller is moved to full travel, the nosewheels turn a maximum of 78° in the left or right direction. Both the tiller and rudder pedals provide input to the same system of cables that control the nosewheels, but tiller input will override any rudder pedal steering input. There is no physical mechanism to prevent use of the tiller at higher speeds, however, the manufacturer's Flight Crew Training Manual (FCTM) and the operator's Operations Manual Part B Volume 1 states that for directional control and braking during landing roll:

'Do not use the nose wheel steering wheel until reaching taxi speed.'

Further guidance is stated that for unusual events:

'Upon landing and rollout, if direction control cannot be maintained by normal control inputs, careful use of nose wheel steering control wheel may be necessary.'

Note: *Use of nose wheel steering control wheel is not recommended until reaching taxi speed.'*

Braking system

The left and right main gear wheel brakes are independently controlled by brake pedals mounted on top of the rudder pedals, using toe pressure. The nosewheels do not have a braking system. Each main gear wheel has individual antiskid protection which, when triggered, releases brake pressure until the wheel starts to rotate again. This system provides protection in the event of a skid, a locked wheel, and hydroplaning.

The autobrake system has five settings (OFF, 1, 2, 3 and MAX) that can be used during landing to achieve a pre-selected deceleration rate. Each setting applies an increased amount of braking system pressure up to the MAX setting of 3,000 psi. The setting required is calculated by the manufacturer's Onboard Performance Tool which determines operational landing distance at each setting compared to available landing distance and also takes into account figures input for the runway and weather conditions. Applying manual braking during the landing roll will disable any pre-set autobraking. The maximum pressure available from manual braking is 3,000 psi.

Recorded information

The aircraft was fitted with a FDR and CVR, both of which were downloaded and captured the landing at Leeds Bradford Airport.

Prior to takeoff in Corfu, the flight crew performed a 'full and free' control surface check which included the rudder and control wheel. During this check, the rudder pedals were moved to their full travel which was recorded as 13.4° left to 11.9° right. The recorded rudder surface position followed the pedal demand to a deflection of 30.4° to 30° respectively. Full control wheel travel was to 95° left and 92° right.

At 1252:10 hrs, whilst on the final approach at approximately 1.6 nm from the Runway 14 threshold, the autopilot and autothrottle were disconnected. The approach continued with touchdown at 1252:55 hrs at a recorded vertical acceleration of 1.3 g and Computed Airspeed (CAS) of approximately 140 kt (point A, Figure 5). During the flare, rudder inputs were recorded which reduced the drift on touchdown.

The speedbrakes deployed and autobrake system engaged with the recorded brake pressure rising to approximately 1,600 psi¹ leading to an increase in the longitudinal deceleration² to -0.45 g. Additionally, the throttles were moved to the reverse 2 position, and the thrust reversers operated as expected. The aircraft decelerated, during which right rudder pedal inputs were recorded.

Seven seconds after touchdown at a CAS of 107 kt, the autobrake was disengaged and brake pressure reduced (point B, Figure 5). Six seconds later at a CAS of 86 kt, the throttles were returned to the 'Forward Idle' position and the thrust reversers were stowed. Throughout this time, up to 1.8° right rudder pedal continued to be applied (point C, Figure 5) and the Cockpit Area Mic (CAM) recorded what could be described as a juddering/rattling sound. This was more pronounced from point C onwards.

Once the thrust reversers were stowed, the recorded right rudder pedal deflection periodically returned to zero and the control wheel was progressively increased up to 42° to the right. Three seconds after the reversers were stowed, pedal braking was applied which was the same time the CVR recording captured the commander vocalising concerns (point D, Figure 5). Braking application was briefly asymmetric with a demand for full right braking after which the pedal demand for left braking increased to maximum to match that of the right brake pedal (point D, Figure 5). The aircraft deviated to the left of the runway and the recorded longitudinal and vertical acceleration deviations showed it departed the left side of the runway (point E, Figure 5) at approximately 64 kt CAS (groundspeed 55 kt), stopping six seconds later. Nosewheel steering position was not recorded.

Footnote

¹ Recorded brake pressure is upstream of the antiskid system.

² The target deceleration for autobrake MAX is -0.435 g.

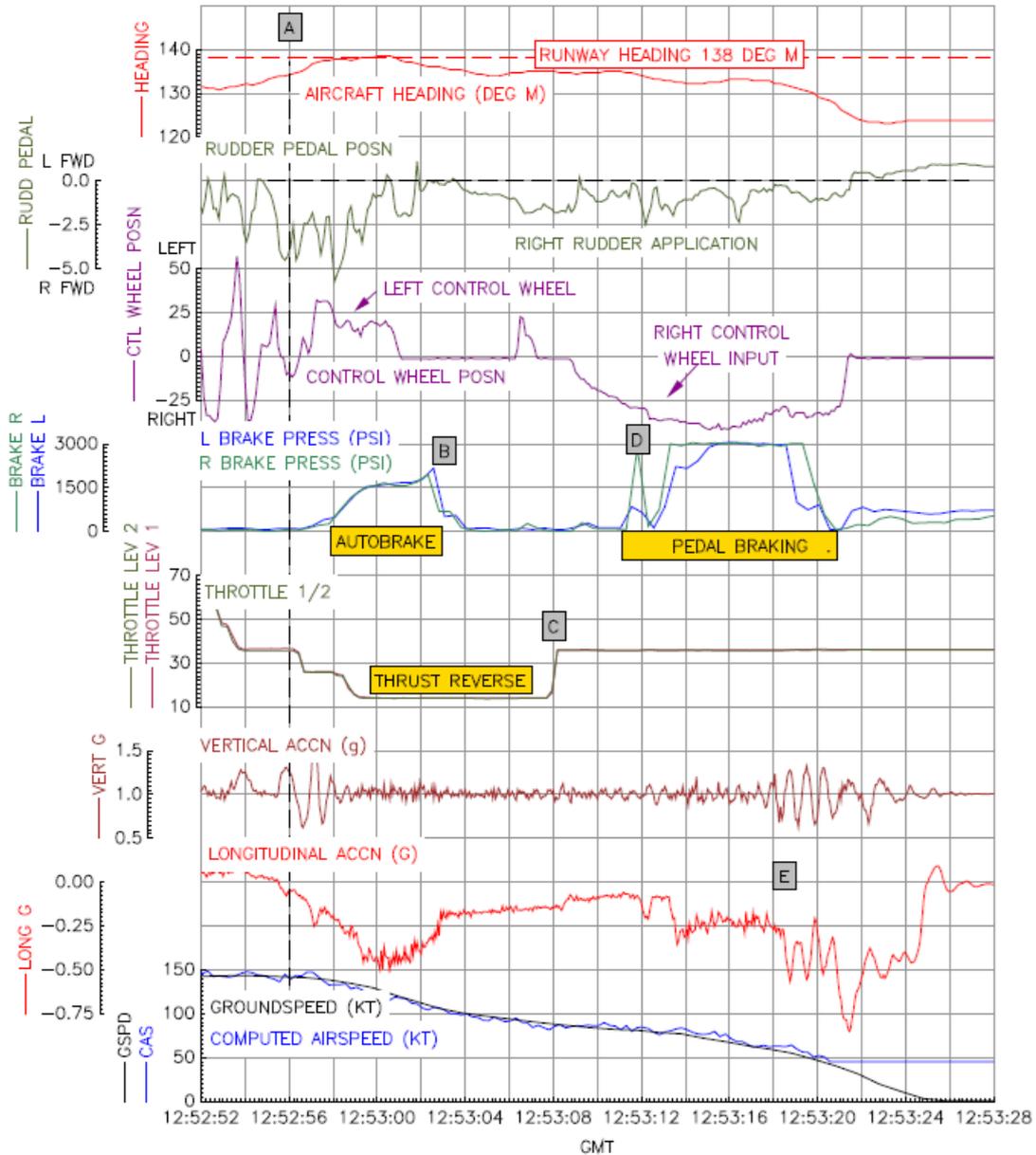


Figure 5

FDR parameters during landing

Manufacturer's data analysis

Ground track analysis

The aircraft manufacturer carried out a ground track analysis of the flight data using a combination of inertial data, localiser deviation and airfield information, cross-referenced against gear marks on the runway and final resting location of the aircraft. This provided a baseline against which further results could be compared.

Calculated airplane braking coefficient

The airplane braking coefficient was calculated for the landing. The coefficient is the ratio of the deceleration force from the wheel brakes (calculated from total aircraft deceleration,

minus aerodynamic drag and thrust components) to the normal force acting on the main gear wheels (aircraft weight minus lift). It is an all-inclusive term that incorporates effects due to the runway surface, contaminants, and aircraft braking system (e.g. anti-skid efficiency, brake wear, tyre condition etc.). It is not equivalent to the tyre-to-ground friction coefficient and does not rely on METAR information or reported runway conditions. If the surface friction level reduces to the point that the tyre begins to lock up, the antiskid system should detect this and release the brake to prevent the skid. In such circumstances, the tyre/runway interface is described as being 'friction-limited'.

The manufacturer found that the measured deceleration while maximum autobrakes were selected (0.45 g) was consistent with the expected deceleration (0.435 g). They stated that braking was not friction-limited at any point during the landing.

Landing simulation

A desktop engineering simulation was used to recreate the landing rollout. The simulation was a six-degrees-of-freedom non-linear model updated to match flight data, and it was driven by recorded control positions from the actual landing, along with the METAR data nearest to the time of the event and a runway surface condition of wet. The simulation was used to assess aircraft lateral performance during the landing, and the simulated results were a reasonable match to the aircraft's actual track over the ground (Figure 6).

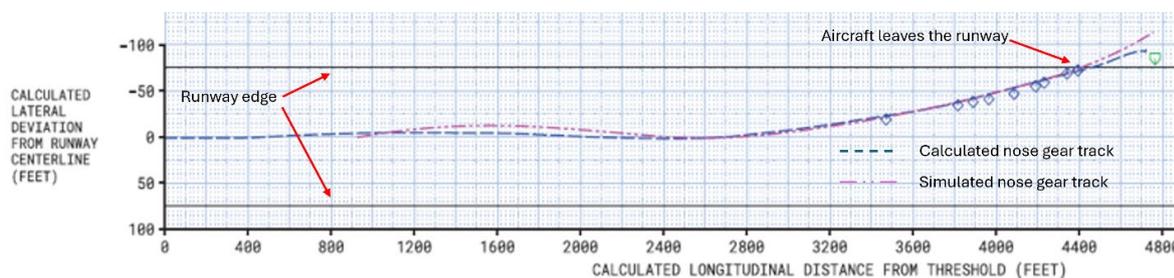


Figure 6

Landing simulation (The Boeing Company)

The model was also used to estimate the magnitude of rudder pedal application during landing that would have kept the aircraft on the runway centreline. The manufacturer stated that:

'Under similar crosswind/headwind conditions as indicated in the provided METAR and with the braking assumptions listed, it is expected that approximately 2-3 degrees of right rudder pedal, increasing to 4 degrees by the time that the airplane comes to a stop, would be required to maintain the airplane on the runway centerline.'

The 2° to 3° of right rudder pedal used in the simulation was a continuous pedal application (rather than application followed by a periodic return to the zero position), increasing to 4°.

The manufacturer commented that:

'Throughout the ground roll, there was additional directional control authority at the flight crew's disposal, via rudder and asymmetric wheel braking, that was not utilised.'

Initially after touchdown, there was left control wheel input, which is normal for landing with a crosswind from the left. As the aircraft decelerated through 86 kt, there was application of right control wheel. These inputs were considered in the simulations and the manufacturer stated that the contribution of this control wheel input to the loss of lateral control was negligible. They also stated that they had observed such control wheel inputs during previous lateral runway excursion events and commented that such inputs may have been instinctive responses.

Aircraft examination

General

The aircraft was examined once it had been recovered to hardstanding. A significant amount of mud had accumulated within all landing gear bays, underneath the wings including flap surfaces, and over the fuselage towards the tail. There was mud within the engine bypass and engine cowlings. The main and nose landing gear appeared to be undamaged and no further apparent structural damage had occurred.

Tyres

The mainwheel tyres all showed some form of damage, comprising either light flat-spotting or from cuts and deep gouges. The latter type of damage typically requires contact with a foreign object to occur and was likely incurred during the recovery process. The No 1 mainwheel tyre had deflated. None of the mainwheel tyres showed damage corresponding to a locked wheel condition or rubber reversion as a result of hydroplaning.

Both nosewheel tyres had abrasion surface damage around their entire circumference. The type, direction and quantity of damage indicates it occurred when the nosewheels were turned nearly perpendicular to the direction of travel (to the right), and that the wheels were still rotating (Figure 7). Neither nosewheel tyre showed damage corresponding to a locked wheel condition or rubber reversion in the un-abraded sections of their surface.



Figure 7
Nosewheel tyre damage

Nosewheel bearing

The left nosewheel was removed which revealed that the inner axle bearing had failed (Figure 7), while the outer axle bearing was undamaged. Each nosewheel has an inner and an outer axle bearing which are replaced on condition and do not have a fixed service life. This bearing was fitted during a routine wheel overhaul in September 2022.

Prior to removal, the left nosewheel had significant play on the axle but was free to rotate. It is probable that the play of the nosewheel on the axle occurred during the recovery process as, had it been present during the landing roll, significant damage to the outer bearing and further damage to the wheel and axle would have been expected.



Figure 8

Left inner nosewheel bearing components

Operator maintenance

The aircraft was subject to inspection and rectification maintenance by the operator prior to its return to service. No further evidence was identified of any system or component failure that could have been contributory to the event.

Meteorology

The weather at Leeds Bradford at 1250 hrs reported a visibility of 4,000 m with light rain and mist at the airfield. The cloud base was at 600 ft with some scattered cloud at 400 ft. The temperature was 10°C. The wind was from 070° at 17 kt with gusts of 32 kt. The final wind check received by the crew from ATC prior to landing was reported at 070° at 23 kt gusting to 37 kt.

The weather forecasts which were available to the pilots (published at 0500 hrs and 1100 hrs) were consistent with these conditions.

Airfield information

Leeds Bradford Airport (Figure 9) has one concrete runway (14/32) which is 2,250 m long. The landing distance available for Runway 14 is 1,801 m and the threshold elevation is 674 ft.

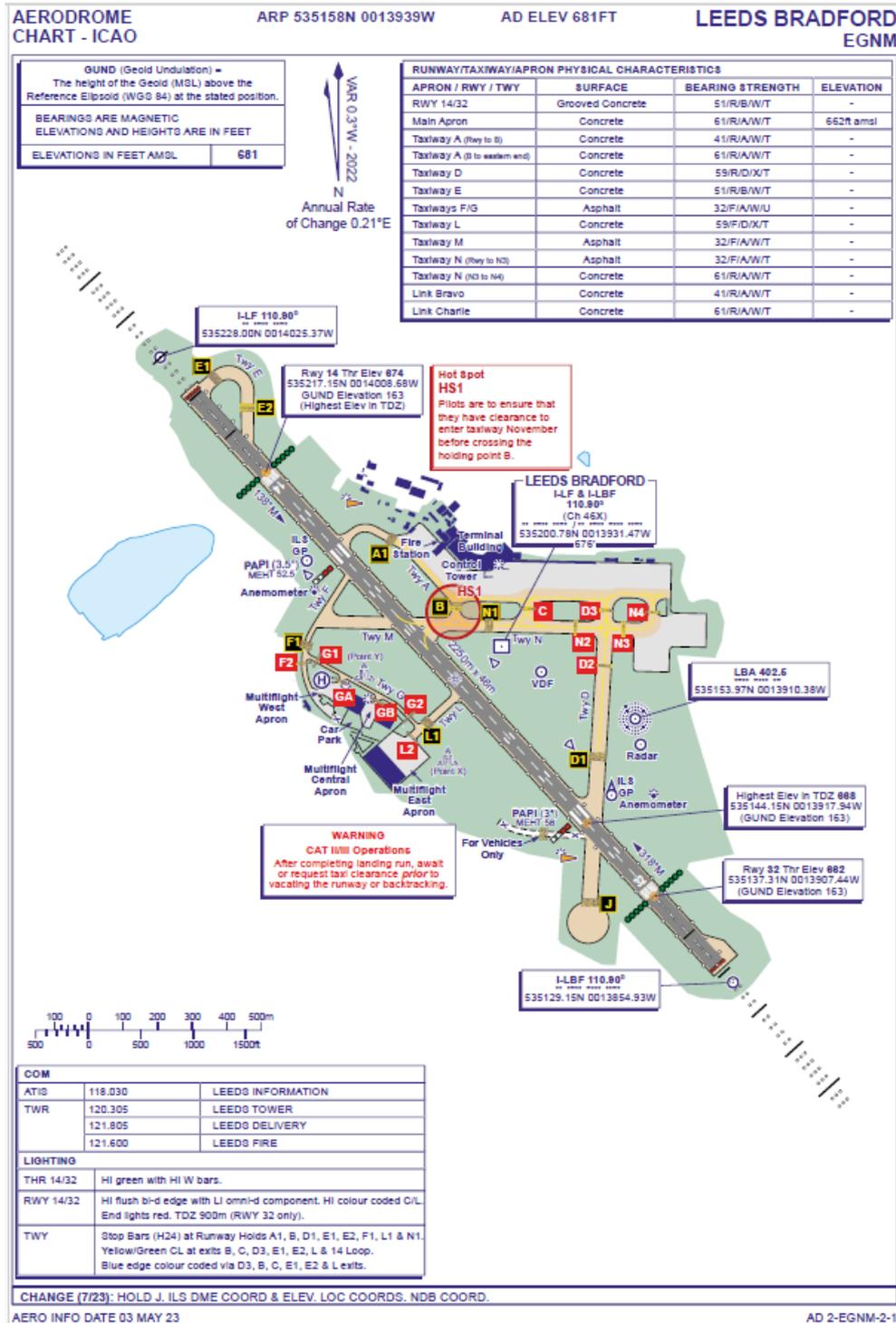


Figure 9

AIP Leeds Bradford Aerodrome chart

Runway type and friction measurement

Runway 14/32 is constructed from concrete with a grooved surface to help disperse water and improve aircraft tyre grip.

A runway surface friction assessment³ was conducted by airfield operations personnel on 11 October 2023, and again on 21 October 2023 following the incident. Both tests showed some isolated 10 m interval measurements fell below the minimum friction level (MFL) required but concluded that the average values of each section of the runway were above the MFL.

Runway condition

About 30 minutes before touchdown there was a runway inspection (1221 hrs on 20 October 2023) after which the condition was assessed to be WET WET WET over the whole surface (5/5/5). Airport personnel who carried out the inspection were aware of increased risk of runway contamination due to weather conditions. The personnel who carried out the inspection were confident in their assessment that the runway was not contaminated and noted that the rainwater could be seen draining away. This was consistent with other witness descriptions that the runway was wet, although no significant standing water was present. This investigation found no evidence to suggest the reported runway condition was not reflective of the actual runway condition.

Operator manuals

Braking

The Operations Manual Part B (OMB) Vol. 1 'Landing Roll Procedure' details the standard calls to be made by the pilots during the rollout with regard to aircraft braking:

Pilot Flying	Pilot Monitoring
Verify correct autobrake operation.	
By 60 knots, start movement of the reverse thrust levers to reach the reverse idle detent before taxi speed.	Call "60 KNOTS."
Before taxi speed, disarm the autobrake. Use manual braking as needed.	Call "AUTOBRAKE DISARM" when the advisory light illuminates.

The OMB Vol. 1 provides the following description of the braking technique for the aircraft:

'Use an appropriate autobrake setting or manually apply wheel brakes smoothly with steadily increasing pedal pressure as required for runway condition and runway length available. Maintain deceleration rate with constant or increasing brake pressure as required until stopped or desired taxi speed is reached⁴.'

Footnote

³ Using a Douglas Mu-Meter, conducting ten adjacent runs along the runway's length measuring surface friction in 10 metre intervals. The values are averaged for inner and outer sections of the runway.

⁴ FCTM 6.44 Landing roll.

The manufacturer FCTM provides additional guidance:

'Rudder control effective until approximately 60 kt. Rudder pedal steering is sufficient for maintaining directional control during the rollout.'

'Use a combination of rudder, differential braking, and control wheel input to maintain runway centreline during strong crosswinds, gusty wind conditions or other situations. Maintain these control input(s) until reaching taxi speeds.'

The FCTM recommends that autobrake is used when the runway is limited or when landing in a crosswind and that the speed at which manual braking is made will depend on the deceleration rate of the aircraft, runway conditions and stopping requirements.

Guidance on manual braking states:

'Immediately after main gear touchdown, smoothly apply a constant brake pedal pressure for the desired braking. For short or slippery runways, use full brake pedal pressure.'

- *do not attempt to modulate, pump or improve the braking by any other special techniques*
- *do not release the brake pedal pressure until the airplane speed has been reduced to a safe taxi speed.'*

Crosswind limits

It is the operator's policy not to include wind gusts in performance calculations. The maximum crosswind component permitted for landing a B737-800 on a wet runway is 37 kt (Figure 10).

737-800			
Runway Surface Condition	RWYCC	Maximum Crosswind Component	
		Takeoff	Landing
Dry	6	33	37
Wet	5	25 / 33*	

Maximum crosswind component can be increased to 33 knots with the following conditions:

- Braking action 'GOOD' or better / RWYCC 5 or better
- Flaps 5 or greater is used
- MACTOW is 25% or less
- Minimum runway width 45 meter

Figure 10
Operator Operations Manual Limit

Reverse thrust operation

The operator OMB Vol. 1 contains the following information on reverse thrust use:

'After touchdown, with the thrust levers at idle, rapidly raise the reverse thrust levers up and aft to the interlock position, then to the number 2 reverse thrust detent. Conditions permitting, limit reverse thrust to the number 2 detent.'

'When stopping is assured and the airspeed approaches 60 KIAS start reducing the reverse thrust so that the reverse thrust levers are moving down at a rate commensurate with the deceleration rate of the airplane. The reverse thrust levers should be positioned to reverse idle by taxi speed, then to full down after the engines have decelerated to idle. Reverse thrust is reduced to idle between 60 KIAS and taxi speed to prevent engine exhaust re-ingestion and to reduce the risk of FOD.'

Figure 11 shows the lever position to select detent no. 2.

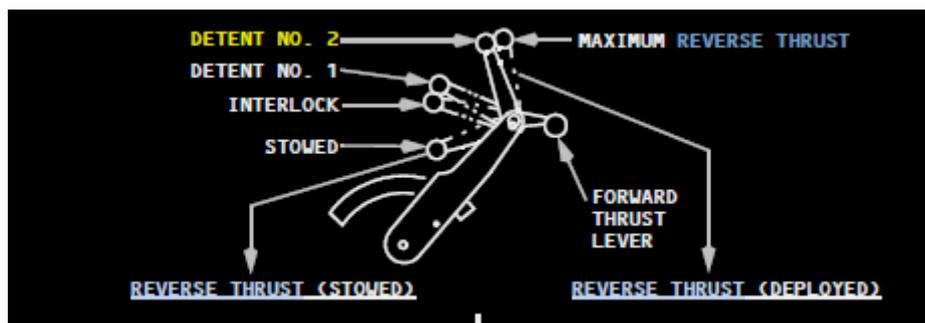


Figure 11

Thrust reverser lever positions

Use of reverse thrust in crosswinds on a slippery runway

Although the indications are that the LBA runway was not slippery, guidance in the manufacturer FCTM for landing in crosswinds on a slippery runway states that if deviation from the centreline occurs during strong crosswinds, pilots should release the brakes and reduce reverse thrust to IDLE to prevent the reverse thrust side force component adding to the crosswind (Figure 12). This guidance is to assist pilots in controlling the aircraft in a crosswind on slippery runways, where the aircraft is blown to the downwind side of the runway.

'Releasing the brakes increases the tire-cornering capability and contributes to maintaining or regaining directional control. Setting reverse idle reduces the reverse thrust side force component without the requirement to go through a full reverser actuation cycle.'

The guidance further advises pilots to use rudder pedal steering and differential braking as required. Once the centreline is regained, maximum braking and symmetrical reverse thrust should be reapplied. It states that using this technique will increase the landing distance required.

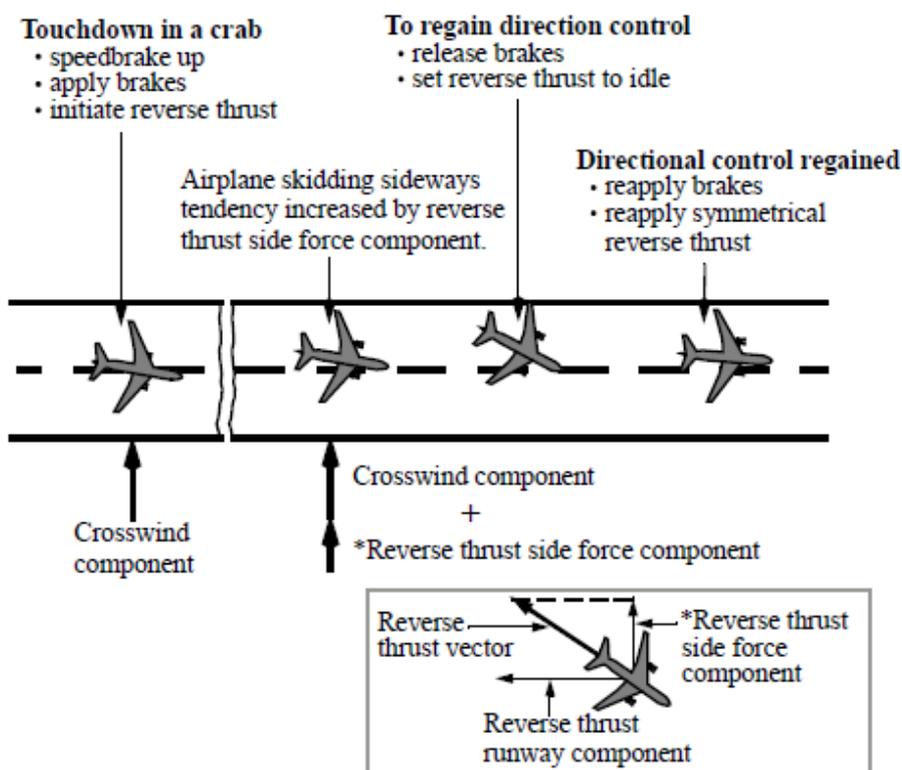


Figure 12

Use of reverse thrust in crosswinds on a slippery runway

Landing performance

Landing performance calculations were carried out by the investigation using the software available to the crew for in-flight performance. The landing distance required (LDR) was within the Runway 14 landing distance available (LDA) at Leeds for the prevailing conditions, using maximum autobrake or maximum manual braking. Landing performance was calculated (Table 1) for a Flap 40° landing and using reverse thrust. There was insufficient landing distance to use AUTO BRK 1, AUTO BRK 2 or AUTO BRK 3 but sufficient for MAX AUTO.

LDA Runway 14	1,800 m
LDR MAX AUTO	1,709 m
LDR MAX Manual	1,599 m

Table 1

Landing performance calculations

Startle and surprise

Pilots may experience unexpected events – such as an interruption from another crew member or unexpected interactions with ATC – on a daily basis, which do not result in a negative outcome. The startle reflex and surprise can play a part in how pilots respond to unexpected events.

Startle reflex is a short, involuntary physiological (heart rate, blinking, muscle tension, distraction) and emotional response to sudden and intense stimulus. The emotional reaction to startle largely dictates how a person will respond. Pilots experiencing the startle reflex can experience task disruption ranging from 100 ms to three seconds for simple tasks, and up to 10 seconds for more complex motor tasks⁵.

The physiological response to surprise can be similar to that of startle but onset does not involve an intense stimulus. Rather, surprise is a mismatch between expectation and reality. These effects of surprise are typically longer lasting than startle as the pilot must reassess their reality and their new expectations.

Startle and surprise are normal human reactions to non-normal events and do not normally result in adverse outcomes. Pilots are trained to react to unexpected events, some of which require immediate and accurate response to unexpected circumstances to ensure a safe outcome. Examples of this include responding to TCAS or EGPWS warnings.

Analysis

Approach preparation

The crew carried out a thorough briefing of the expected approach at Leeds, the weather conditions and were well prepared for a diversion to Manchester Airport.

The landing performance was calculated and within limits to land at Leeds with a margin of 91 m⁶ when using auto brake MAX.

Landing roll

The aircraft touched down in the touchdown zone and the initial phase of the rollout was normal, with the aircraft reaching the expected deceleration rate. After the PF cancelled the autobrake, there was a period of eight seconds with no wheel braking applied, during which the reverse thrust was also cancelled. The guidance on braking in the operator OMB and FCTM stated that pilots should '*maintain deceleration rate with constant or increasing brake pressure as required until stopped or desired taxi speed is reached*' and '*do not release the brake pedal pressure until the airplane speed has been reduced to a safe taxi speed*'. The reduction in deceleration rate caused by disconnecting the autobrake and cancelling reverse thrust on a wet runway, with a significant crosswind, invalidated

Footnote

⁵ Research Project: Startle Effect Management, EASA 2015, available at https://www.easa.europa.eu/sites/default/files/dfu/EASA_Research_Startle_Effect_Managements_Final_Report.pdf. [accessed 8 October 2024].

⁶ Calculations inclusive of the required legal safety margins.

the landing performance calculated by the crew. However, there is no evidence that, as a result, the aircraft did not have sufficient stopping distance available or that the crew assessed this to be the case.

Runway surface

The 'cleaned' runway tyre markings are typically only associated with reverted rubber hydroplaning. However, no evidence of reverted rubber was found on the mainwheel or nosewheel tyres, which requires locked wheels to occur, nor were there corresponding 'melted' rubber deposits on the runway. The runway marks suggest that the surface temperature underneath all the tyres was high enough to turn some of the water on the runway's surface into steam but not high enough, nor combined with locked wheels, to cause rubber reversion.

During the period after touchdown when maximum autobrake was used, actual deceleration was as expected. The eight second period after autobrake disengagement, during which there was no wheel braking applied, corresponded to a period when the aircraft's heading remained broadly constant (although slightly left of the runway centreline). This showed that there was sufficient friction for effective directional control during this period. In addition, the manufacturer assessed that the aircraft was not friction-limited at any point during the landing, so hydroplaning was not considered to be a contributory factor in this event.

The nosewheel tyre damage is consistent with abrasion scrubbing from being turned to an angle nearly perpendicular to the direction of travel whilst the tyres were rotating and in contact with the runway; also demonstrated by the runway marks left by the nosewheel tyres. The angle of the nosewheels could only be achieved by use of the tiller rather than rudder pedal steering alone, and this corresponds with the commander's account of events.

Nosewheel bearing

It was not confirmed when the nosewheel bearing began to fail, but it is likely that it occurred during the rollout at LBA and was contributory to the vibration through the rudder pedals, as felt by the crew. Both crew members recalled the "judder" as being significant and unusual, and the CVR recording contained a confirmatory sound during this period. The PF recalled the vibration increasing as he increased right rudder pedal input, effectively limiting the amount of rudder he felt he could apply. However, no evidence was found that the bearing failure did, in fact, limit rudder pedal or rudder movement.

Aircraft handling

After touchdown, the rudder pedal input reduced to zero at 12:53:02 (Figure 5) for two seconds and the aircraft heading began to turn into wind, as would be expected in a strong crosswind. The autobrake was disengaged, and the right rudder pedal input was increased to an average of about 2° over a period of about 10 seconds (from about 12:53:07 to 12:53:17), with a maximum of 2.5°. The increased rudder pedal input stabilised the aircraft's heading for about six seconds (until 12:53:11), although it was not sufficient to return the aircraft to runway heading. The manufacturer's report concluded that 2° to 3° of right rudder pedal would be required to maintain the runway centreline initially, increasing to

4° as the aircraft slowed and came to a stop. At 12:53:11, the aircraft had slowed to about 80 kt, the rudder was less effective, and, in the absence of an increase in rudder input to about 4°, the aircraft began to turn progressively into wind until it left the runway at 64 kt. The manufacturer commented that additional directional control was available by using increased rudder (which is effective down to 60 kt) and differential braking.

Differential braking was applied momentarily at 12:53:12, but it was not applied for long enough to have an effect.

The bearing failure was not considered to have physically prevented the application of further rudder. Nevertheless, the PF felt constrained not to apply more rudder than he did because of the vibration it caused and his perception that increasing right rudder pedal beyond mid-application led to left yaw. Had increasing right rudder input led directly to left yaw, it would have been an unexpected aerodynamic response and it is likely that the manufacturer's simulated landing data would have diverged from the recorded data (Figure 6). However, the manufacturer's modelling of the landing was closely correlated with the actual performance of the aircraft, and so the left yaw response reported by the PF was likely to have been an indication that even the increased rudder input was insufficient to counter the left yaw in the strong crosswind.

Landing distance

The guidance for pilots on handling deviations from the runway centreline in high crosswinds and on slippery runways is to release the wheel brakes and cancel reverse thrust, although this technique will increase the LDR. The runway was wet but there was no evidence that the aircraft skidded at any point, nor did the aircraft drift downwind of the runway centreline during the landing roll. It may have been that the pilot cancelled the reverse thrust earlier than normal SOP in an effort to apply a known procedure (Figure 11) in response to the nosewheel judder.

In this event, there was an adequate, but not significant, margin between the landing distance required and that which was available. The recorded data shows there was a significant amount of right rudder input available to the pilot that was not used. The simulation calculated by the manufacturer suggested that the extra rudder and differential braking available would have been sufficient to correct the deviation and prevent the runway excursion without cancelling the autobrake and cancelling reverse thrust.

Startle and surprise

It is possible that the pilot was startled by the sudden onset of vibration of the nosewheel and, as he perceived it, an adverse reaction to increased rudder pedal input. However, the use of rudder to steer an aircraft is an embedded skill for pilots, so any startle response was likely to have been short. Surprise – a mismatch between expectation and reality – can last longer and may have played a role in events. The PF's expectation was that increased right rudder input would correct the aircraft's deviation from the centreline, but it was actually met with vibration and a feeling of left yaw, and he was required to reassess his expectations related to directional control with limited time and in difficult conditions.

Conclusion

The initial phase of the landing roll was normal, with the aircraft touching down in the touchdown zone and meeting the target deceleration rate. The PF disconnected the autobrake and then stowed the reverse thrust early in the landing rollout and a constant deceleration was not maintained.

It was likely that a nosewheel bearing failed during the landing causing an unusual vibration that increased with rudder input. This, combined with the PF's perception that increased rudder input was causing an adverse yaw response, led him to consider that he was limited in the amount of right rudder he could apply. However, the bearing failure did not physically prevent the application of more rudder, and the manufacturer's modelling showed that increased rudder and differential braking would have been effective in maintaining directional control during the landing.

Published: 24 October 2024.

Note: the original report was amended online on 11 February 2026. The correction is included in AAIB Bulletin 3-2026.

Accident

Aircraft Type and Registration:	Rotorsport UK Cavalon, G-CKYT	
No & Type of Engines:	1 Rotax 914-UL piston engine	
Year of Manufacture:	2018 (Serial no: RSUK/CVLN/027)	
Date & Time (UTC):	12 November 2020 at 1250 hrs	
Location:	Farmland between Avoch and Munloch, Black Isle	
Type of Flight:	Solo training flight	
Persons on Board:	Crew - 1	Passengers - None
Injuries:	Crew - 1 (Fatal)	Passengers - N/A
Nature of Damage:	Aircraft destroyed	
Commander's Licence:	Student private pilot	
Commander's Age:	67 years	
Commander's Flying Experience:	117 hours (of which 46 were on type) Last 90 days - 20 hours Last 28 days - 6 hours	
Information Source:	AAIB Field investigation	

Synopsis

A solo student pilot was on a local general handling flight when the rotor head of the gyroplane he was flying, separated from the fuselage in flight. The separation was caused by a structural overload failure from exposure to dynamic flight loads, judged to be due to a specific sequence of aircraft manoeuvres.

The gyroplane was found to have been correctly released to service. There were no maintenance issues identified relevant to the accident. A number of operational factors were considered and it was likely that the pilot inadvertently allowed the aircraft to enter a low g flight regime close to, or potentially exceeding, that prohibited by the Cavalon Pilot's Operating Handbook.

The accident highlighted limitations in the design, testing, manufacture and operating limits for the Cavalon and Cavalon Pro gyroplane types. Based on an assessment of the requirements within BCAR Section T, these limitations could be relevant to other gyroplane types certified to this standard. The investigation also highlighted issues with gyroplane training material regarding the awareness of rotor load factor by pilots. Four Safety Recommendations have been made to address these issues.

History of the flight

The student pilot arrived at Inverness Airport at 0850 hrs on the morning of the accident to prepare for a dual check flight with his instructor, followed by a solo flight as part of his PPL training.

The student first completed a 20-minute check flight with his instructor, flying one circuit and a practice aborted takeoff, which the instructor considered were flown well. The instructor then briefed the student for a solo flight in the operator's training area over the Black Isle, 4 nm to the north of Inverness. The instructor reported that he had not given the student specific exercises to fly but had directed him to fly around the training area to gain more experience of handling the gyroplane. The student took a short break while staff from the training school refuelled the gyroplane and added ballast¹. The student then took off at 1020 hrs, returning to Inverness at 1140 hrs. The flight went without incident and the student was reported as being very pleased with his achievement. The student made no adverse comments about either the flight or the wind conditions encountered. He was scheduled to fly another solo flight on the following day, but the forecast winds were due to be out of limits for solo students. His instructor instead offered him the opportunity to fly a further solo exercise that afternoon as the weather conditions were assessed by him to remain suitable for a student solo.

After a short break, the student reported that he was not fatigued and was ready to fly again. He discussed the content of the sortie with his instructor, which was to repeat the previous flight around the Black Isle. The student then refuelled the gyroplane and booked out with ATC for the flight. The gyroplane took off from Runway 23 at Inverness Airport at 1237 hrs with a clearance to climb not above 2,000 ft until coordinated with radar. At 1240 hrs the student was instructed to contact Inverness Radar, which he did, reporting that he was at Chanonry Point at 1,800 ft and requested a Basic Service (Figure 1).

Footnote

¹ For a description of the ballast, refer to the Weight and Balance section.

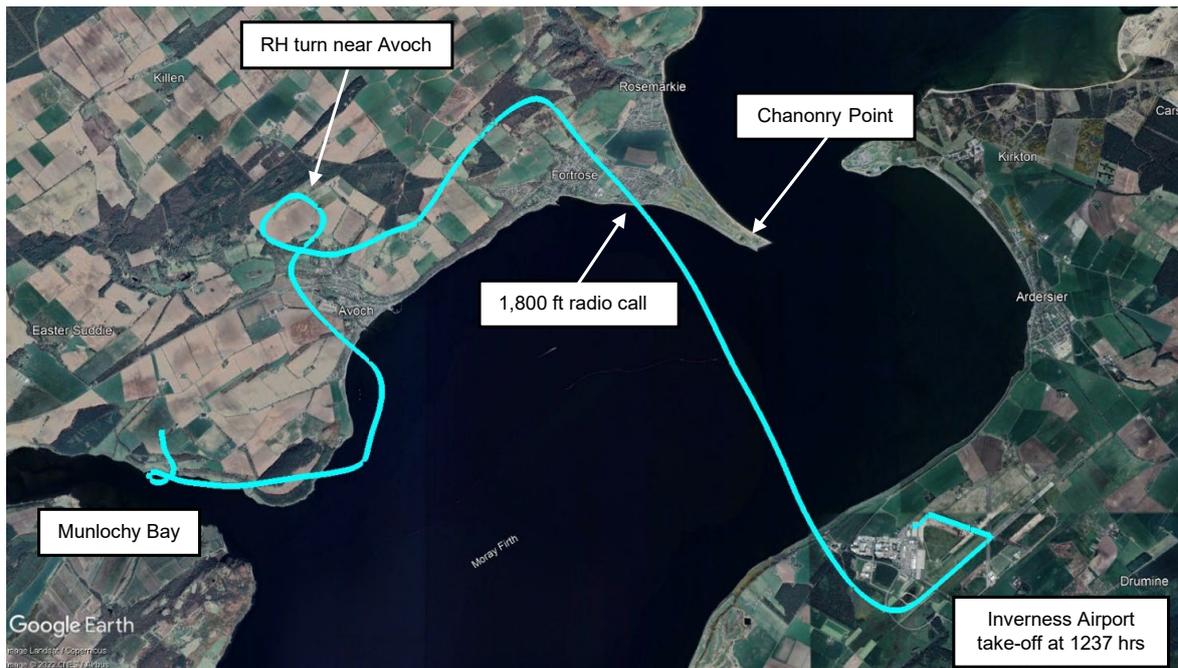


Figure 1
Accident flight track from GNSS

ATC confirmed the request for a Basic Service, informing the student that there were no level restrictions and passed him relevant traffic information. The gyroplane turned onto a westerly track towards Avoch and at 1243 hrs was informed of another aircraft to his west routing from Munloch Bay to Inverness Airport. The student reported that he was visual with the aircraft.

The gyroplane then completed an orbit to the north of Avoch before routing in a south-easterly direction towards the Moray Firth coastline. The first witness to see the gyroplane in the area (location 1 - Figure 2) described hearing a marked increase in engine noise that prompted him to look up. He reported seeing a gyroplane moving in a south-westerly direction. At approximately the same time, a witness at location 2 reported seeing a gyroplane flying in a similar direction but did not consider there was anything unusual about it. The gyroplane then flew parallel to the Black Isle coastline in a south-westerly direction before turning north-west to follow the Munloch Bay inlet. Two witnesses in this area (location 3 - Figure 2) reported hearing an engine alternating between high and low revving sounds, and “spluttering”, but neither reported seeing an unusual flightpath. As the gyroplane continued on a north-westerly track, witnesses at locations 4 to 8 reported hearing unusual sounds that drew their attention. They variously described the sounds as an engine “roaring as if at full revs” and “spluttering as if an engine was failing”. Witnesses at location 8 reported hearing a “very loud mechanical noise, which sounded like a metal crunch”, and a “loud mechanical cracking noise”.

The eyewitnesses at locations 2 and 3 reported seeing the gyroplane again a few minutes after they had initially seen it, describing it now in a fast, erratic and steep descent. This was a similar description to those given by witnesses 4 to 8 who had looked up at the gyroplane on hearing an unusual sound. One of the witnesses at location 3 reported seeing the rotor blades detach as the aircraft descended. The witnesses at location 8 also reported seeing the main rotor blades spinning off the gyroplane and landing about 30 m from where they were standing. Some of the witnesses then saw the gyroplane hit the ground and catch fire.

At about 1250 hrs, around the time the eyewitnesses reported seeing the gyroplane descending erratically, there was a short open mic transmission² on the Inverness approach frequency. At about the same time the controller lost radar contact with the gyroplane. The controller tried to establish radio communication but received no response. He alerted colleagues in the Tower and asked them to look in the direction of the last recorded contact to check if they could see the gyroplane. They reported seeing black smoke rising in the area but could not specifically identify which side of the Moray Firth it was coming from.

Several onlookers made calls to the emergency services, and local community emergency responders arrived on scene at approximately 1305 hrs, quickly followed by paramedics and a doctor. The first responders stated that they could not access the aircraft due to the intensity of the fire which was extinguished shortly afterwards on the arrival of the fire service.



Figure 2

Witness locations in relation to ground track of gyroplane

Footnote

- ² An open mic transmission happens when a press-to-transmit button is held, or the radio transmission unit is stuck on transmit, and no intentional communication is passed.

Accident site

The fuselage was located in a field approximately 150 m west of farm buildings and was surrounded by smaller items, which had been released when the fuselage initially struck the ground. The rotor head and blades had detached from the fuselage together and were located in an adjacent field to the fuselage, some 65 m south-south-east of the same farm buildings. Two ground marks from the leading edge of each blade striking the ground were positioned at an obtuse angle to each other. A trail of small items of wreckage stretched from the location of the detached rotor head east-north-east for approximately 500 m across farmland and into the garden of a private residence (Figure 3). These items of wreckage consisted of sections of the right door of the aircraft, along with the tip of one of the propeller blades.

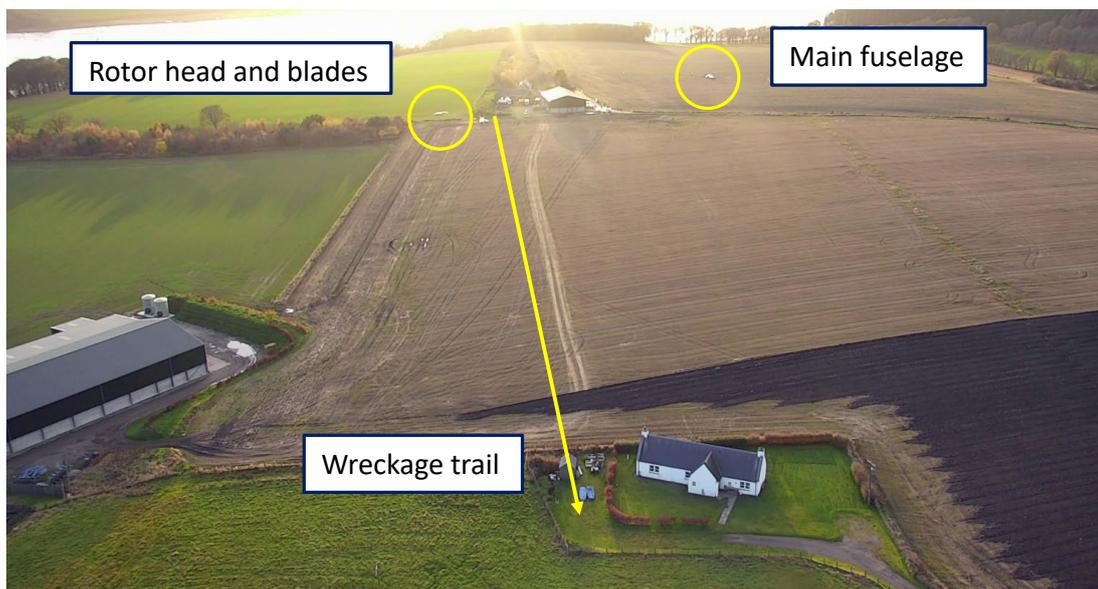


Figure 3
Wreckage location

Recorded information

The aircraft was captured by the Inverness radar head throughout the accident flight, recordings of which were made available by Inverness ATC. ATC also made available recordings of radio transmissions between ATC and the aircraft. The gyroplane was fitted with a transponder capable of transmitting Mode C altitude³, but this information was not recorded by the radar. Reasons for this could not be established, but it is possible to switch off Mode C altitude on this transponder. A review of the radar data from a previous flight of G-CKYT on 7 November 2020 also confirmed no Mode C altitude had been recorded. The gyroplane was fitted with a number of avionics components but, due to the impact and post-crash fire, they all sustained significant damage. The only onboard device from which data could be recovered was a Garmin GDL 50 portable ADS-B receiver. This device was fitted to receive traffic data via ADS-B which was then transmitted to the cockpit display to allow the pilot to view traffic information on a moving map.

Footnote

³ Mode C altitude is that sensed by the transponder and transmitted to the nearest 100 ft.

To determine aircraft position, the device included a GNSS receiver and a pressure altitude sensor. This information was recorded to the device as a track log, once per second, which was more accurate and at a higher sampling rate than the recorded radar data. Data in this track log included time, position, altitude, and a derived vertical speed, groundspeed and track. This device was positioned on the coaming above the instrument panel and attached to the aircraft's power supply.

Despite suffering impact damage, the device was successfully downloaded at the AAIB and contained a track log which was from the accident flight. There were no other flights recorded. The data recovered did not contain any GNSS accuracy information such as the number of satellites in view at the time.

G-CKYT previous flight

The flight prior to the accident flight lasted approximately 1 hour 20 minutes. Figure 4 shows the radar ground track of this flight in which the student took off from Inverness then travelled around the Black Isle in an anticlockwise direction.

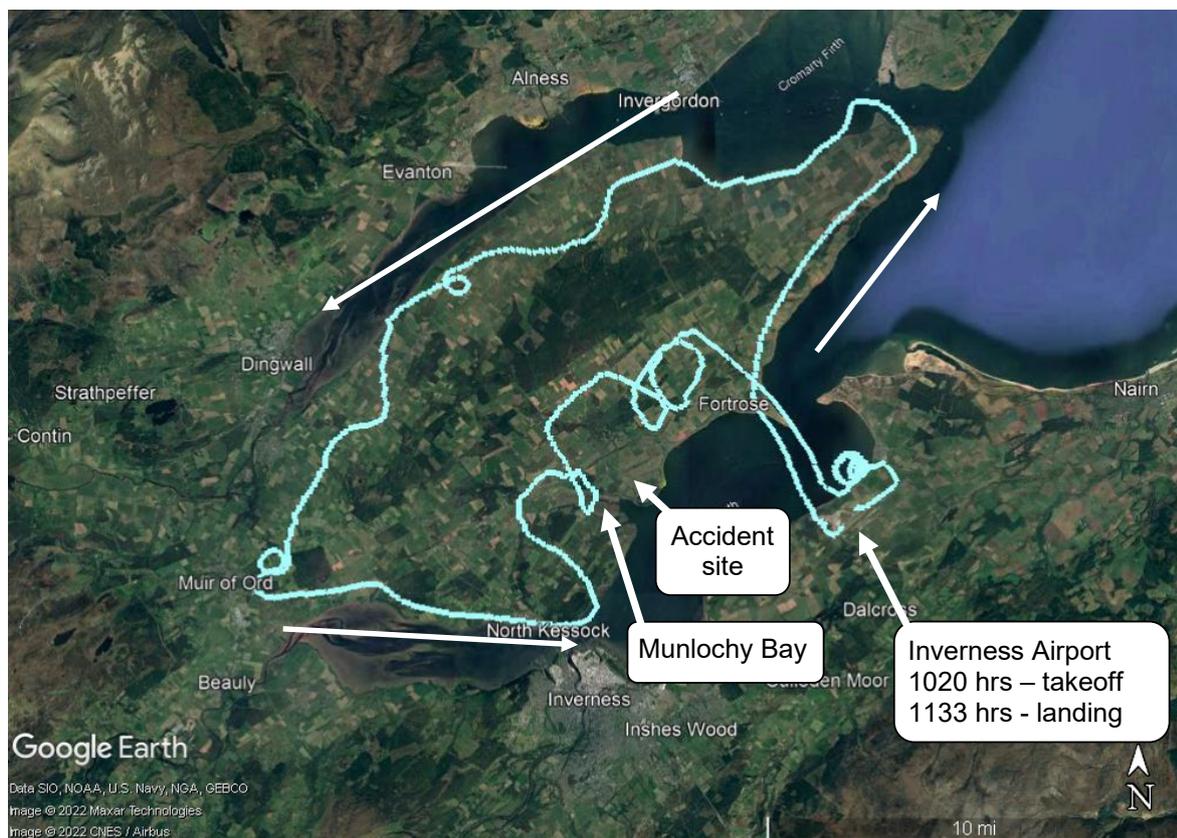


Figure 4

Radar data showing G-CKYT flight track prior to the accident flight

The radar was only recorded every four seconds and has a significantly lower position accuracy than the GNSS data. However, it was possible to show that a number of left and right orbits were performed throughout the flight, including one over Munloch Bay, two in the region of Avoch and four mid-downwind prior to landing.

Accident flight

The GNSS device only contained one recording which was for the accident flight and provided more detailed flight path information than the radar data. The pressure altitude recorded by this device used a reference pressure of 1013 hPa which was corrected to the Inverness QNH at the time of 1001 hPa. When comparing the recorded altitude to the elevation of the Inverness runway, the recorded pressure altitude was within 20 ft. GNSS altitude was also recorded and was within 30 ft of the airfield elevation. After takeoff, the GNSS altitude was consistently lower than the pressure altitude but within 13-95 ft.

Analysis of the recorded pressure altitude over time revealed that it was not smooth and fluctuated even when the aircraft was in level flight. The GNSS altitude was smoother than the pressure altitude and despite an offset, followed the same trend as the pressure altitude.

Radar data showed the presence of a light aircraft, a Grumman AA-5, transiting through the area of the accident a few minutes prior to G-CKYT. It was enroute to Inverness from the north and, when passing over Munloch Bay at 1244 hrs, was descending through an altitude of about 1,900 ft.

Derived parameters

An estimate of the airspeed was calculated using surface wind conditions at Inverness Airport and those at 1,000 ft and 2,000 ft amsl (see Meteorology section). The reported wind at 2,000 ft amsl was 30 kt from the south-west which had a notable effect on the difference between ground and airspeed. A simple estimate of bank angle was calculated using aircraft airspeed and rate of turn, assuming a level and coordinated turn.

The vertical speed parameter recorded on the GNSS device correlated well with the rate of change of GNSS altitude. The rate of change of this vertical speed provided an estimate of the vertical acceleration. This is only the acceleration in the vertical direction in m/s^2 which can also be expressed as a fraction of normal gravitational acceleration, or g (9.81 m/s^2).

Accident flight data

The recovered GNSS track (Figure 1) was similar to the recorded radar track. Figure 5 shows the GNSS data parameters with respect to time for the whole flight. Takeoff commenced at 1237:15 hrs followed by a right turn. Just over three minutes later, the pilot made a radio transmission to Inverness Radar for a Basic Service, stating he was at 1,800 ft. At the time, the data showed the aircraft climbing through a pressure altitude of 1,700 ft (GNSS altitude 1,624 ft) at an airspeed of 64 mph.

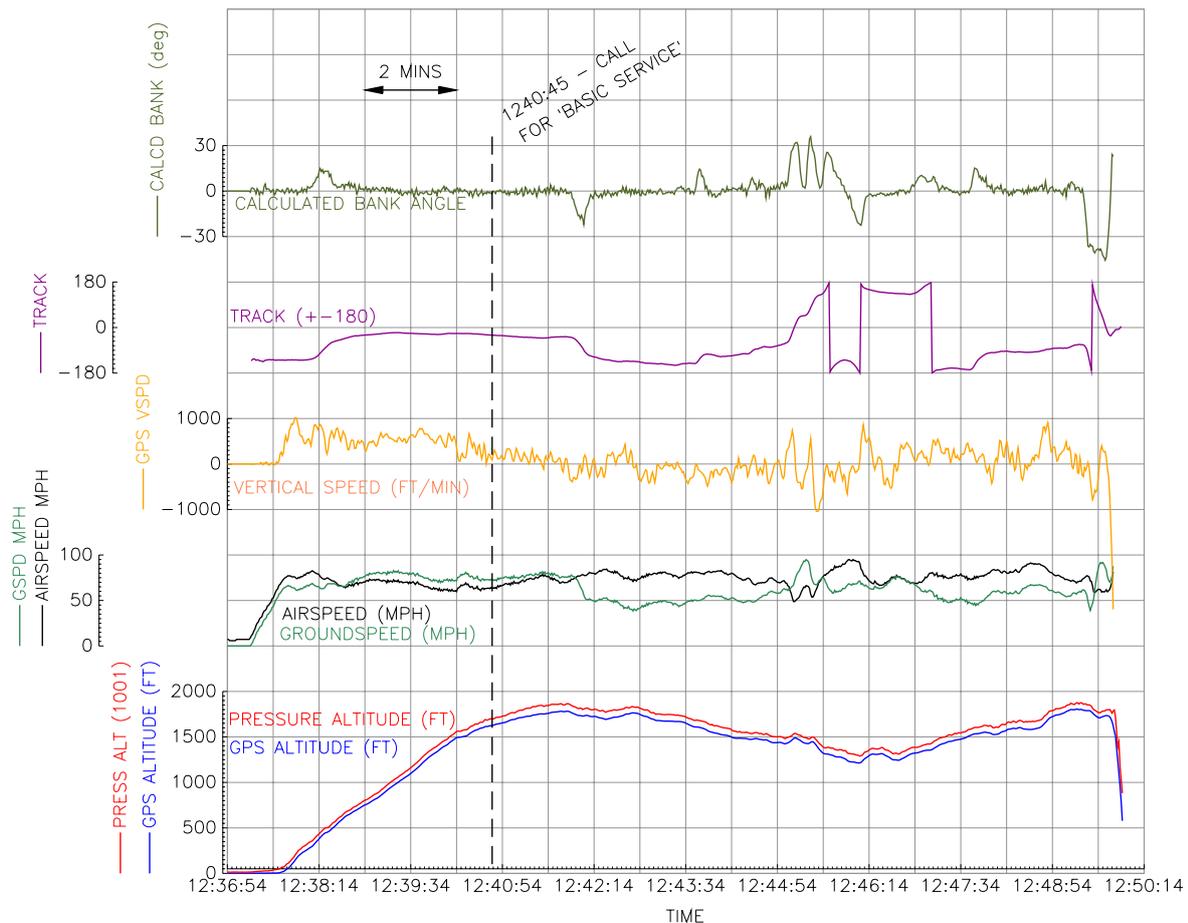


Figure 5

G-CKYT GNSS flight parameters

The aircraft continued towards the Black Isle, climbing to a maximum altitude of 1,860 ft before turning left to towards Avoch. When just under a mile from Avoch, ATC advised G-CKYT of another aircraft routing towards Munloch Bay, returning to Inverness Airport. The pilot replied that he was “VISUAL WITH THE LIGHT AIRCRAFT”.

Turn north of Avoch

One minute later, at 1244:30 hrs, G-CKYT was overhead Avoch and commenced a turn to the right at a pressure altitude of 1,540 ft and approximate airspeed of 73 mph. During the turn, bank angle was estimated at approximately 30° with the pressure altitude fluctuating and progressively decreasing over 1 minute 22 seconds to 1,347 ft at the end of the right turn. Airspeed during the turn reduced to approximately 50 mph before increasing to 92 mph by the end of the turn (a total loss in the turn of 193 ft and increase of 19 mph). Vertical speed fluctuated in the turn, reaching a descent rate of up to 1,000 ft/min and as the turn was completed, the aircraft was descending at approximately 500 ft/min with an increasing airspeed.

The aircraft then turned to the left and tracked towards the coast before turning into Munlochy Bay (Figure 1). Its airspeed reduced and the aircraft climbed progressively to approximately 1,900 ft amsl.

Remainder of the flight

At 1249:20 hrs, when overhead the northern shore of Munlochy Bay, the aircraft commenced a turn to the left (Figure 6).



Figure 6

G-CKYT final ground track (Google Earth)

The turn started at a pressure altitude of 1,870 ft (GNSS altitude 1,799 ft) and airspeed of 73 mph. For the first 16 seconds of the turn, the estimated bank angle increased and remained at between approximately 35-40° to the left. During this time, the vertical speed fluctuated, at one point reaching a descent of 782 ft/min (Points A to B, Figure 7).

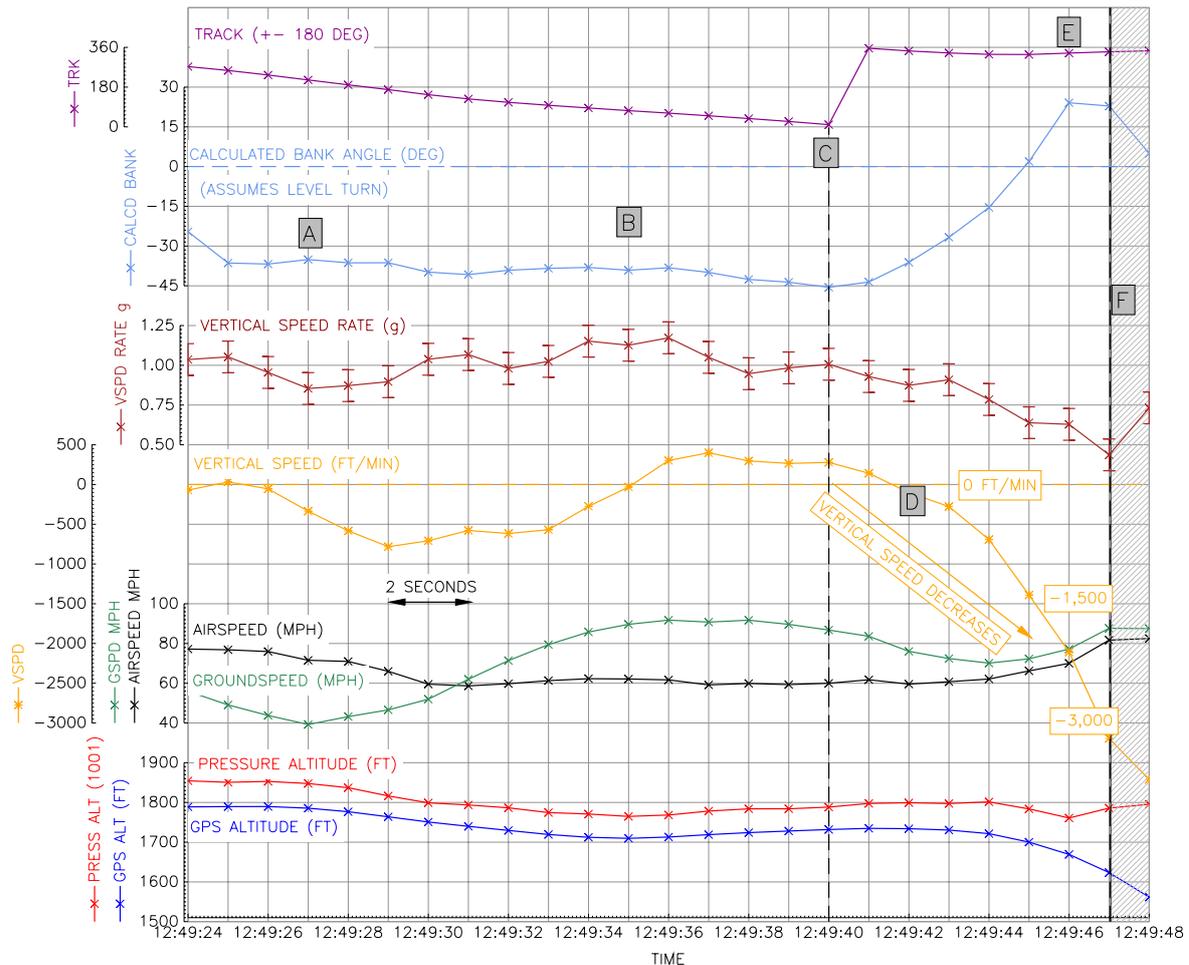


Figure 7
G-CKYT flight parameters

Towards the end of the left turn, at 1249:40 hrs, the estimated bank angle had increased to approximately 45° (point C). At this time, the aircraft was at a pressure altitude of 1,788 ft (GNSS altitude 1,732 ft), an airspeed of 60 mph and climbing at 278 ft/min. After this time, the vertical speed started to reduce. Over the next seven seconds, the vertical speed decreased progressively, from +278 ft/min to -3,195 ft/min.

From 1249:42 hrs (point D), the vertical speed became negative (-102 ft/min), signifying the start of a descent. Three seconds later, the calculated aircraft track showed completion of the left turn while at a pressure altitude of 1,783 ft (GNSS altitude 1,700 ft) and an airspeed of 66 mph, but was then descending at 1,390 ft/min.

At 1249:46 hrs, the calculated aircraft track showed the aircraft then entering a right turn (point E) while still descending, but now at a pressure altitude of 1,761 ft (GNSS altitude 1,669 ft), an airspeed of 70 mph and descending at 2,107 ft/min.

Radio transmission at 1249:46 hrs

At the same time, a transmission was recorded on the Inverness Approach frequency. The source of the transmission could not be confirmed as coming from G-CKYT, but appeared to be a radio transmission which lasted a fraction of a second. There were two further transmissions at 1249:48 hrs and 1249:49 hrs, lasting 0.5 seconds and 7 seconds respectively. The transmissions contained primarily a high-pitched frequency with no intelligible speech. An analysis was performed, comparing these transmissions with those from earlier in the flight. Previous recordings included clear audio signatures of the aircraft propeller, a lower level of background noise and clear speech. The transmissions from 1249:46 hrs differed, with no evidence of the propeller audio signature and a much higher level of background noise. No conclusive information could be drawn from these radio transmissions.

Last part of the recording

The GNSS and pressure altitudes had been similar throughout the flight, apart from GNSS altitude consistently being lower than the pressure altitude. In the final minute, the GNSS altitude was within between 48-92 ft of the pressure altitude with a similar trend.

At 1249:47 hrs (Point F, Figure 7, one second after the first of the radio transmissions), the recorded pressure and GNSS altitudes began to diverge. The derived rate of descent from the GNSS altitude at this time was 3,195 ft/min. The pressure altitude indicated a reversal from descent to climb within one second (a derived vertical speed change of -1,368 ft/min to +1,494 ft/min). Such a change is not possible in this aircraft so the pressure altitude from this point was considered to be inaccurate.

Low confidence in the accuracy of the data beyond this time meant detailed analysis of the recorded data after 1249:47 hrs was not considered reliable. At 1249:49 hrs, the recording of position and GNSS altitude was the same as that for one second later. Potential reasons for this are discussed below but it is indicative of a loss in accuracy of the device.

Despite the loss in accuracy of the device, the recording continued. Position and GNSS altitude data from 1249:47 hrs showed a continued descent towards the location of the aircraft wreckage. The final recorded data point was at 1249:55 hrs.

Vertical Acceleration

Between 1249:40 hrs and 1249:46 hrs, the aircraft vertical speed reduced. The rate at which this reduced is a measure of how fast the aircraft was accelerating vertically, with respect to the recorded GNSS altitude. Figure 7 shows the derived vertical acceleration (g) and that the trend towards the end of the valid data was for a decreasing vertical acceleration. As there were no accuracy metrics in the GNSS download, it is difficult to ascertain a tolerance on the calculated figures. However, using different calculation methods gives a difference of approximately ± 0.1 g.

GNSS accuracy

From 1249:47 hrs, inaccuracies were noted in the GNSS device recording. These included a divergence between the pressure and GNSS altitudes, significant reversal of the pressure altitude value and a double recording of position/GNSS altitude recording. There was no GNSS accuracy data recorded by the device which could help explain this.

The accuracy of the device in determining position and GNSS altitude depends on a number of factors. If the GNSS antenna is obscured, the number of satellites in view may be reduced and the accuracy of the recorded position and GNSS altitude will be affected. Sensing of pressure altitude is performed by a pressure sensor in the device which is affected by the location of the device. If there is a sudden pressure change, the pressure sensor reading (and recorded pressure altitude) will be affected.

In previous investigations, the AAIB has encountered erroneous position and altitude data recovered from GNSS devices when aircraft have been in unusual attitudes and, as a result, the aircraft has a shielding effect on the device antenna. Erroneous GNSS data is not unusual during an accident sequence.

For the GNSS device fitted to G-CKYT, if the number of satellites in view reduces, the track log will continue to be recorded, albeit with a lower position and altitude accuracy. This would be seen in the track log as either unusual positions, GNSS altitudes, or both.

If the GNSS signal is lost completely then the device used an algorithm to predict the ongoing position and GNSS altitude for a period of time. This prediction, based on its previous flightpath, allows a continuation of the position reporting and recording in the event of an intermittent signal loss. This predictive tracking is also known as 'coasting' and during testing of another Garmin GDL 50, this coasting function was confirmed and occurred for up to 20 seconds. As there were no accuracy measures recorded, the difference between an accurate track, coasted track and one affected by a reduced satellite count could not be distinguished.

Aircraft information

G-CKYT was a Rotorsport UK Cavalon gyroplane. This was a UK imported version of the AutoGyro Cavalon, manufactured in Germany.

The Cavalon is a side-by-side, two seat gyroplane, with an aerodynamically shaped composite fuselage and fully enclosed cockpit. It has a non-retractable, tricycle landing gear and a tailplane attached by a curved tail boom, which provides clearance for the propeller. The tailplane has a horizontal stabiliser and three vertical fins, of which the largest centre fin is equipped with a rudder. The aircraft is powered by a Rotax piston engine, which in the case of G-CKYT was a 914 UL fitted with a turbo. The engine is located at the rear of the fuselage and drives a three-blade composite IVO pusher propeller, which rotates anticlockwise (when viewed from the rear). The gyroplane has an 8.4 m diameter teetering rotor, located at the top of a mast to provide clearance from the propeller. The fuselage mass is approximately 529 kg at maximum weight⁴.

Footnote

⁴ The rotor head and rotor blades together weigh approximately 31 kg.

The top of the fuselage composite structure forms the lower half of the rotor mast. A stainless steel box section tube is bolted to this by two fixing bolts to form the top half of the mast. The steel section also provides the attachments to support the routing of the flying controls and pre-rotor drive shaft, which is then connected to the rotor head. This section of the mast is covered by an aerodynamic fairing (Figure 8).

The rotor head fitted to G-CKYT was a Mark III head (referred to as Rotorkopf III), which was the latest iteration of the design introduced in 2018, and was common to the AutoGyro MTO Sport, Calidus and Cavalon Pro models. The complete rotor head is formed by several individual components attached to an aluminium 'rotor bridge' structure. The rotor bridge locates the main rotor bearing to which the rotating components, namely the pre-rotator ring gear and the aluminium teeter tower and rotor pivot bolt, are fitted, secured by the main rotor bolt. The two rotor blades are joined together by a centre section and attached by the rotor pivot bolt to the teeter tower, with the main mass of the blades hanging below the pivot point formed by the rotor pivot bolt.

Bracket plates bolted on to either side of the rotor bridge are in turn secured to a gimbal block laterally by a single pitch pivot bolt and washers, allowing the rotor head to tilt up and down around the pitch axis, relative to the gimbal block. The gimbal block is bolted longitudinally to side plates welded to the front and back faces of the top of the rotor mast by a roll pivot bolt and washers. This allows the combined rotor bridge and gimbal block to rotate from side to side around the roll axis. Flying control and trim connections attach at the rear of the rotor bridge to control pitch and to a bracket which extends to the left side (viewed from the rear) of the rotor bridge to control roll (Figure 9).

The manufacturer's design drawing designates a 65 mm long, 10 mm diameter stainless steel bar is fitted into locating holes in the side plates on the mast below the roll bolt holes and is welded in place on the exterior surfaces of the plates. The manufacturer confirmed the thickness of these plates should nominally be 5 mm. Only the internal width dimension between the side plates ($52.0 + 0.5$ mm) is specified on the manufacturer's drawing. With a nominal plate thickness of 5 mm this would result in the bar extending between 1.5 and 1.25 mm beyond the external faces of the side plates on either side, though any variation in the thickness of the side plates could reduce this further. The drawing specifies an all-round fillet weld on the external face only. It does not give a dimension for the throat, but specifies the use of a 2 mm, 1.4576 steel electrode. The weld requirement is the same on both side plates of the mast. When the mast and gimbal block are assembled, the bar on the mast locates in a channel along the bottom of the gimbal block (Figure 10). When the gimbal block rotates in roll around the roll pivot bolt by approximately 8° in either direction, the respective side of the channel contacts the roll stop bar to act as a limit stop. The manufacturer advised this control stop feature was only intended for use on the ground.

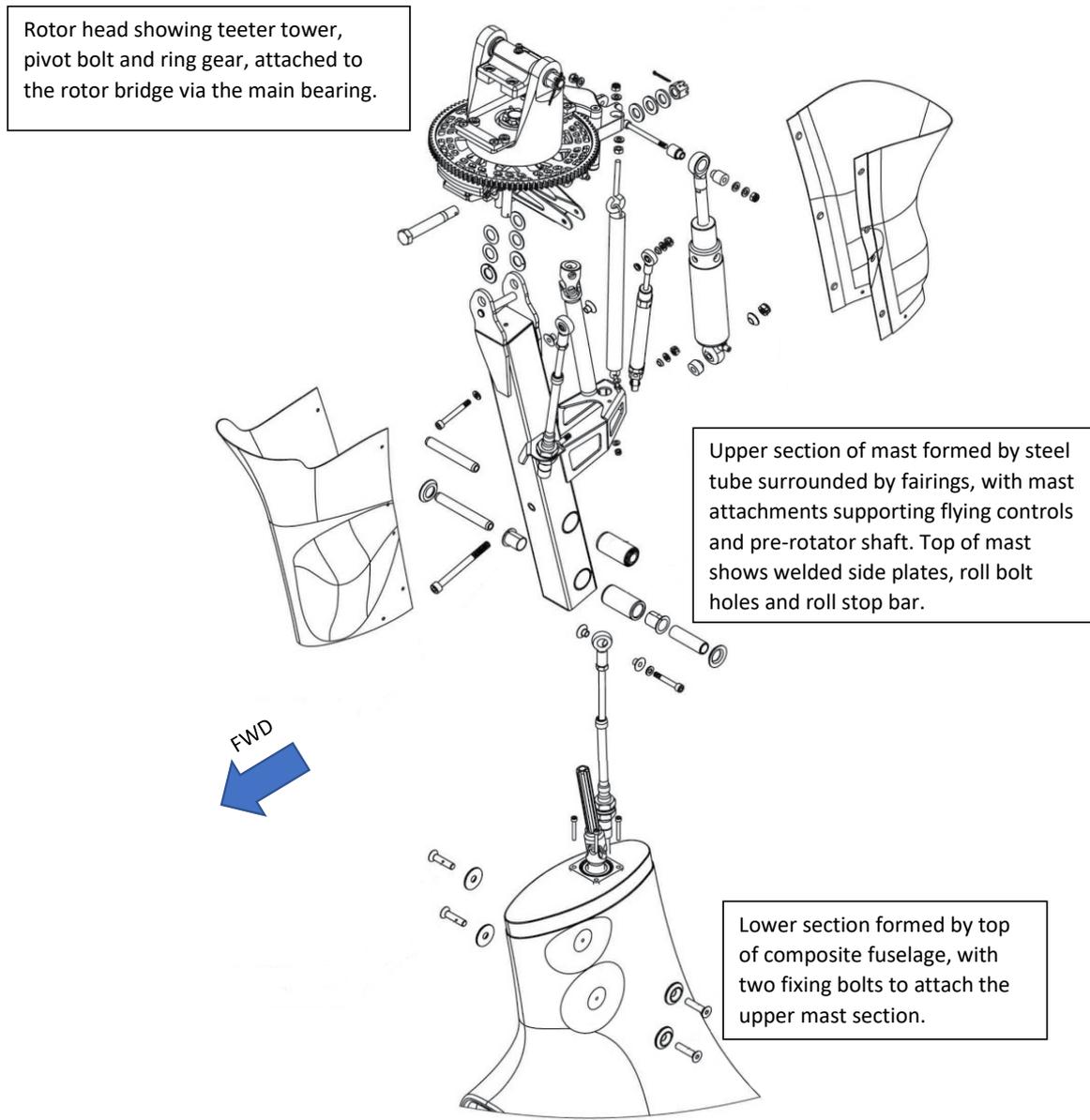


Figure 8

Mast and rotor head arrangement (original image courtesy of manufacturer)

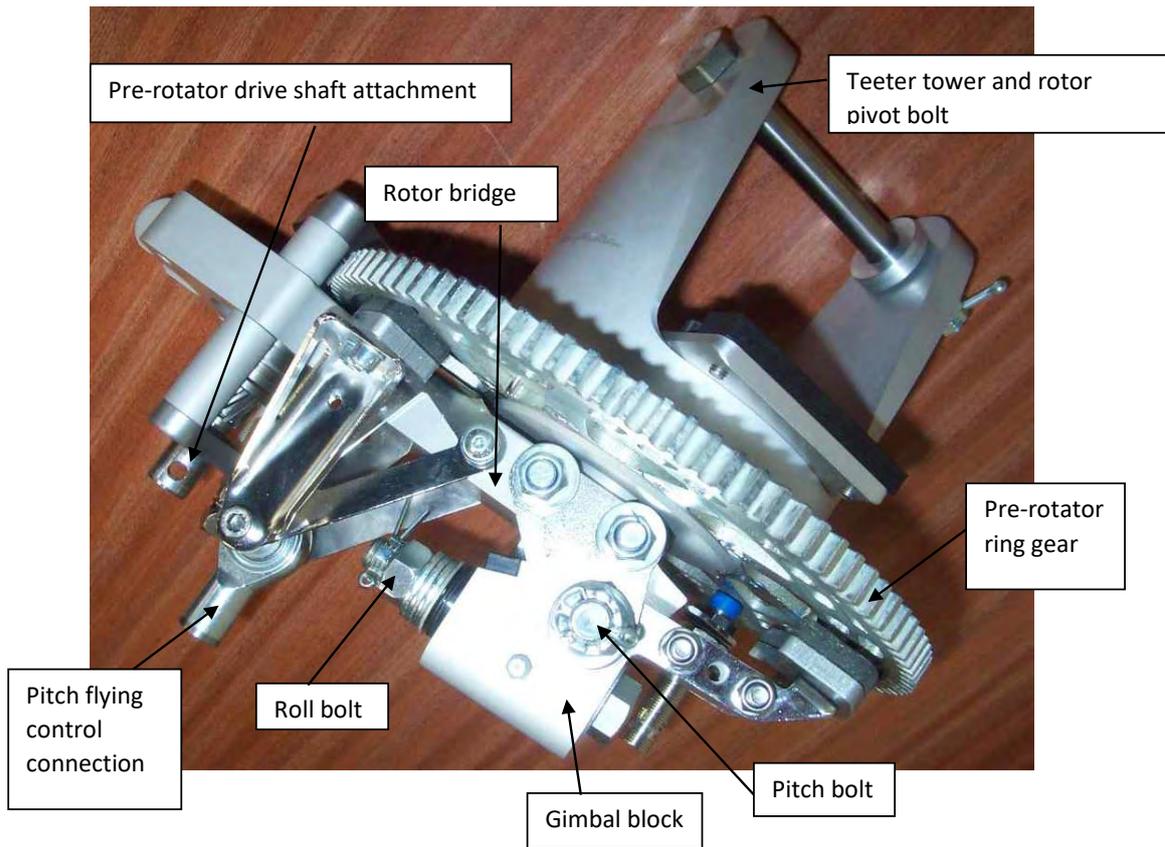


Figure 9

Rotor head components (original image courtesy of manufacturer)

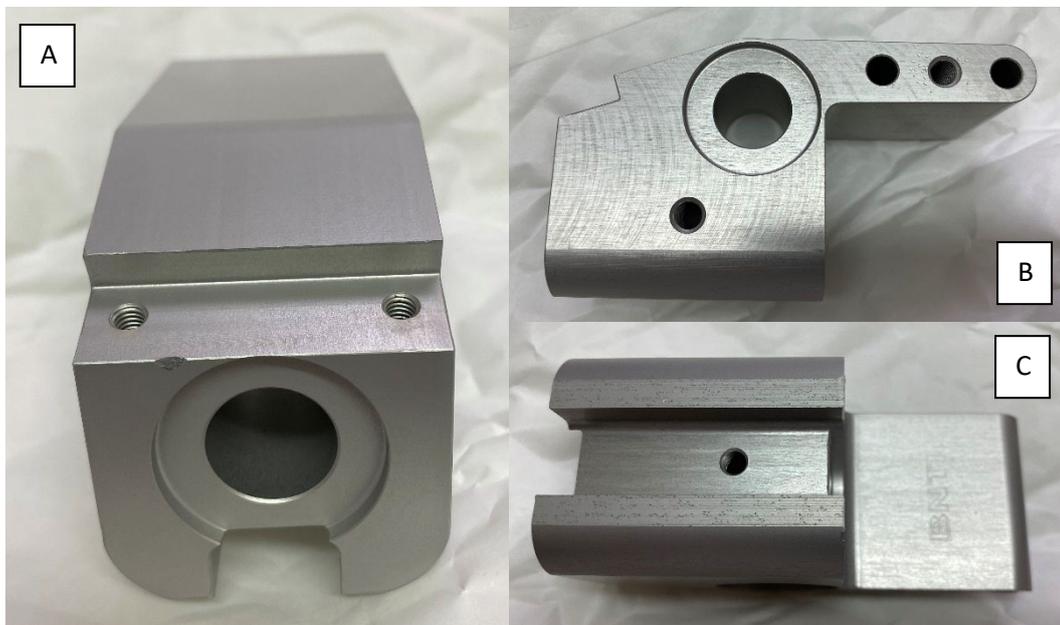


Figure 10

Gimbal block: A – rear, showing roll bolt hole and roll stop channel. B – right side, showing pitch bolt hole. C – bottom, showing roll stop channel and grub screw hole

Gyroplane Operation

A gyroplane achieves lift and directional control through a free turning rotor. The rotor operates in autorotation spinning freely as a result of air flowing up through the blades with the aircraft being propelled by an engine-driven propeller. This is in contrast to a helicopter which relies on an engine to turn the blades and draw air from above. Aerodynamic forces acting on the rotor blades during autorotation keep the rotor turning, as well as creating lift to keep the gyroplane airborne.

The forces acting on a gyroplane in flight are lift, weight, thrust and drag. Lift is derived from the rotor, which also produces a drag force. The lift component of rotor force acts vertically in straight and level flight whilst the drag component acts rearwards. Drag forces also act on the fuselage which, when combined with the rotor drag, give the total drag of the aircraft.

Thrust acts forward and is provided by an engine typically driving a pusher propeller. This acts directly through the airframe, rather than through the rotor system as on a helicopter. Changes in thrust are used to control airspeed and to compensate for changes in the lift and drag components of the rotor force caused by aircraft manoeuvring.

To manoeuvre the gyroplane in pitch and roll, the entire rotor is manually rotated about the pitch and roll pivot bolts respectively, with control connections from the pilot's control stick to the rotor bridge to enable this. Moving the control stick forwards and backwards rotates the rotor bridge around the pitch pivot bolt. Moving the stick from side to side rotates it around the roll pivot bolt.

In a banked turn, due to the angle of the rotor plane (relative to horizontal) a proportion of the rotor force generated acts horizontally resulting in a turn. The greater the bank angle, the greater the proportion that acts horizontally and the less there is acting vertically. Pulling back on the stick increases the total amount of lift force generated by the rotor, but this also increases drag. Increased drag is countered by the pilot increasing engine power to increase the thrust from the propeller.

During a turn, the pilot must use a combination of backstick and increased thrust to maintain airspeed and altitude. Increasing bank angle requires increasing thrust until a bank angle is potentially reached where all available power is required. Any further increase in bank would then result in either a loss of airspeed or altitude.

As a result of the control arrangement, the entire weight of the fuselage hangs directly from the roll pivot bolt and is free to rotate laterally like a pendulum. This rotation is not damped and there is no artificial control force system to moderate the pilot's control inputs. In a level turn, the centrifugal force acting horizontally outwards from the centre of the turn causes the fuselage to swing upwards, pivoting around the roll pivot bolt, until the mast is at approximately 90° to the plane of the rotor⁵. Reversing the roll angle, will cause it to rotate around the roll pivot bolt in the opposite direction.

Footnote

⁵ This reaction is actually the result of inertia but is perceived to be a force with respect to the fuselage.

Lift forces generated by the rotor disc during dynamic operation of the rotor effectively act through the rotor pivot bolt and teeter tower and down into the rotor head and gimbal block. The rotors do not contact the teeter stops when the rotor rpm remains within the normal operating rpm range. Movement of the rotor head bridge through flying control inputs changes the angle of the rotor disc without stop contact occurring. The roll control input is offset from the rotor bridge by a bracket, to reduce the control force magnitude required to overcome the aerodynamic and gyroscopic forces generated by the rotor in normal flight.

In the air, the lift force opposes the weight of the fuselage. Changes in the balance of these forces dictate whether the gyroplane climbs or descends and the rate at which this vertical speed varies.

Load factor

The load factor (n) is simply defined as lift divided by weight. For a gyroplane, this is the actual load on the rotor head and mast at any point, divided by the normal load or gross weight. When a gyroplane flies in a constant altitude turn, maintaining level flight, the load supported by the rotor blades is greater than the total weight of the gyroplane. The steeper the bank angle is, the greater the load supported by the rotor and the greater the load factor. Load factor is non-dimensional, but is often expressed relative to the perceived force (weight) under normal gravitational acceleration or 1 g. For example, a turn which results in a load factor of 2 might also be described as a 2 g turn.

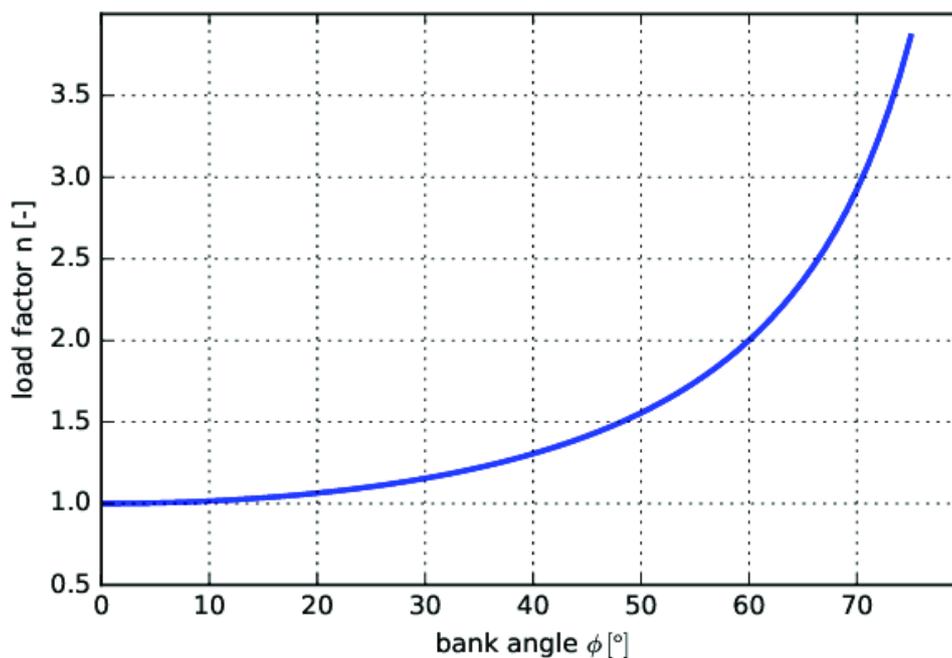


Figure 11

Load factor increase with bank angle

To overcome this additional load factor, the gyroplane must produce more lift by increasing the airflow through the rotor. If additional engine power is not available to achieve this, the gyroplane will descend. The load factor change is relatively small in turns up to 30° but increases more rapidly as the bank angle increases above this (Figure 11).

Load factor is also affected by the gyroplane climbing and descending. An increase in vertical acceleration results in a load factor greater than 1. Conversely if the vertical acceleration of the aircraft reduces below that normally experienced due to gravity, this can result in the load factor reducing below 1, reaching zero or even becoming negative (Figure 12). This reduction results in the gyroplane's rotor 'unloading' or creating a reduced force compared to normal flight at or above 1 g.

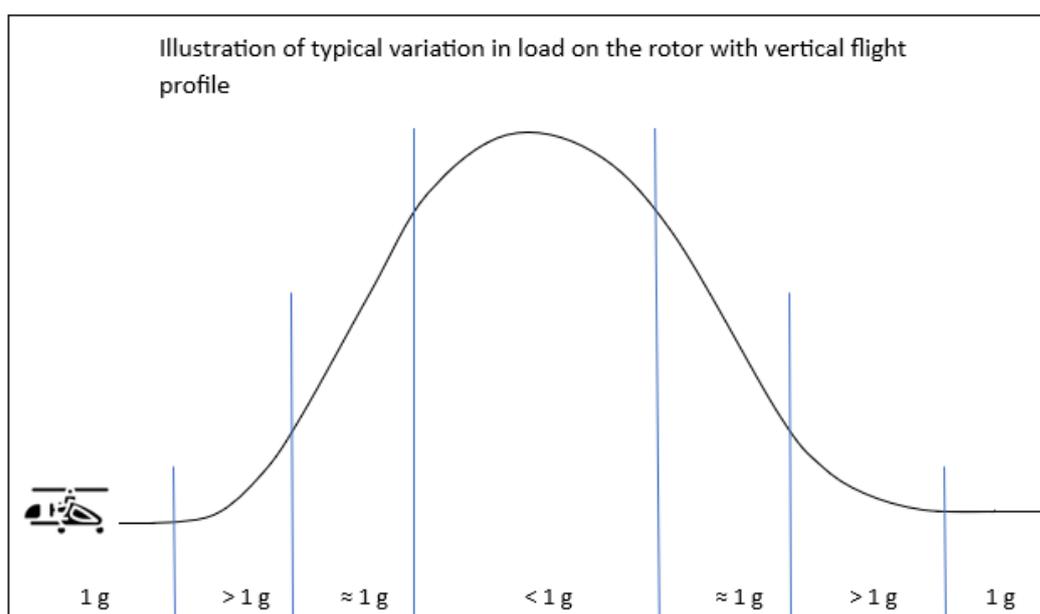


Figure 12

Load variation with vertical flight profile compared to 1 g flight

Reduction in rotor loading can result in a reduction in rotor rpm, altitude and directional control. With a teetering rotor head, if rotor rpm drops too low it can also cause the blade flap angle to increase to a level where the blades contact the teeter limit stops. The adverse effects of unloading the rotor become more pronounced the closer the load factor is to zero, when they can become catastrophic.

When calculating load factor, the flight profile of the gyroplane must be considered in all three dimensions as, for example, the load may reduce in the vertical plane due to a reduction in vertical acceleration but increase in the horizontal plane while flying a turn.

Footnote

⁶ Zero g or below is commonly referred to as 'weightlessness'.

Engine torque induced fuselage rotation (Torque Roll)

The force generated by an operating engine to turn the drive shaft and propeller also produces an equal and opposite force. If the engine and propeller rotate anticlockwise (viewed from the rear) this produces a clockwise torque on the engine body in operation. As the engine is fixed in the airframe on a gyroplane, this results in the fuselage rotating clockwise around the roll pivot bolt, which is perceived by the pilot as a right roll, even though the rotor may be horizontal and the control stick is initially centred. The engine manufacturer quotes the torque produced by the engine at various power settings. Typically, the highest torque is generated when the engine is at maximum power and rpm. This is the case for the Rotax engines fitted in the Cavalon. In normal operation the pilot can counter the induced rotation with an opposite roll control input.

Aircraft certification

The accident aircraft was a Cavalon model, approved as a Permit to Fly aircraft by the CAA. Permit annual checks and continued airworthiness were overseen by the Light Aircraft Association, under delegation from the CAA.

The Cavalon design was originally approved by the UK CAA as compliant with British Civil Airworthiness Requirements (BCAR) Section T (CAP643), issue 4. BCAR Section T, covering light gyroplanes, was introduced in 1995 and originally based on Section S (microlight design), with various amendments to address issues specific to gyroplanes. As such, it is a less complex set of requirements compared to those intended to support a full Type Design and Certificate of Airworthiness level of certification. Given the limited total operating hours and relatively small number of aircraft designed to BCAR Section T requirements, compared to other design regulations, they have not been revised as frequently or as extensively.

The CAA advised the investigation that BCAR Section T had been developed as a response to the very high accident rate seen on early gyroplane designs. They stated that it had continued to evolve since the original issue, drawing on other codes such as EASA CS-VLA, CS-VLR and CS-27. They highlighted that it was the first gyroplane design code in the world and is generally considered as the definitive standard for certification. The foreword for Section T states that gyroplanes which have been shown to comply with BCAR Section T will only be eligible for a Permit to Fly.

The manufacturer went on to develop the Cavalon Pro for use in a commercial capacity which required the individual aircraft to have a Certificate of Airworthiness. This was agreed by the CAA based on the original certification work for the Permit to Fly Cavalon, along with the demonstration of compliance to changes in issue 5 of Section T, and additional requirements detailed in Certification Review Item (CRI) E-01. Demonstration of compliance by the manufacturer with the additional requirements was subsequently confirmed by the CAA. This allows a Certificate of Airworthiness to be issued for individual aircraft, permitting them to be used for commercial aerial work in the UK. The manufacturer marketed the Cavalon Pro as being '*compliant with CAA requirements for a UK Standard Category Certificate of Airworthiness*', with which '*the aircraft is permitted to undertake any paid aerial*

work for which it is equipped and approved, and where a Certificate of Airworthiness is required, especially in Europe. Examples of such work include air taxi, carriage of goods, surveying, police and fire service duties, and much more.' The manufacturer then elected to comply with issue 5 and CRI E-01 for all Cavalon models to standardise manufacture.

BCAR Section T has several requirements regarding structural strength. These include T305, T307, T337, T339 and T547b. The wording of requirement T337 was amended by CRI E-01 to reduce the static strength requirements to:

'The gyroplane must be designed such that-

- a) i) The gyroplane's rotor must be designed for a positive limit manoeuvring load factor of +3.0, at all forward speeds from zero to the Maximum Design Speed VD.*
- ii) The rest of the gyroplane must be designed for positive and negative limit manoeuvring load factors of +3.0 and -0.5, respectively, at all forward speeds from zero to the Maximum Design Speed VD'.*

The means of compliance stated in the manufacturer's Certification Report for T337 was Calculation/Analysis and Laboratory Test. Along with compliance statements, this was the same for all the structural strength regulations. The laboratory test carried out to demonstrate compliance to T337 was a ground-based flight load simulation test, which statically loaded the airframe vertically to simulate the effective weight of the aircraft at 560 kg MTOW and +3⁷ load factor. For practical reasons the test did not simulate the negative part of the requirement. It was argued by the manufacturer that, as the structural strength of the components was the same in either direction, the positive load factor test adequately addressed a load factor of -0.5 as well. This was accepted by the CAA who agreed that the test demonstrated compliance with both parts of the regulation.

No flight test activity was conducted to formally demonstrate compliance with T337 or any of the other structural regulations⁸. Some flight testing was done to determine the highest g load likely to be achieved in operation by flying tight, steeply banked turns. This only explored the positive g load part of the envelope. Given the inherent risks associated with prolonged low to negative g flight, this area of the operating envelope was not intentionally explored during any of the general handling flight tests. The manufacturer advised that during the assessment of minimum airspeed for level flight (V_{min}), the gyroplane can momentarily experience less than 1 g as the gyroplane drops below V_{min} and descends. The actual g load, if measured, during this test was not provided to the investigation. The section of the Cavalon Certification Flight Test Summary report relating to general controllability requirements (T143) noted that in normal [≥ 1 g] flight *'the turbo engine produces some limited torque roll if suddenly engaged.'*

Footnote

⁷ The test was done to demonstrate the earlier requirement standard of 500 kg at +3.5 g which was a more severe test.

⁸ As stated in RSUK0405 Iss. 1 Cavalon Revised Certification Report.

⁹ The Rotax 914 and 915 engines are fitted with a turbo and are both engine options on the Cavalon.

Requirement T675 addresses the need for control system stops and states:

'a) Each control system must have stops that positively limit the range of motion of the pilot's controls.

...

Each stop must be able to withstand any loads corresponding to the design conditions for the control system.'

The Type Approval Data Sheet (TADS) issued by the CAA for the Cavalon identifies several prohibited manoeuvres for the gyroplane, it states:

*'(G) Prohibited Manoeuvres: Aerobatic manoeuvres are prohibited.
Manoeuvres involving a deliberate reduction in normal 'g' shall be avoided.
Flight in icing conditions is prohibited (not placarded).
Flight in strong gusty winds or wind velocities of more than 45 mph (40 kt) is prohibited (not placarded).'*

Product conformity and airworthiness

An aircraft design is defined by a set of controlled design drawings for every component or assembly which is bespoke to that aircraft. Collectively these represent the baseline standard which has been approved by the certification process of the overall aircraft. To maintain the same standard of airworthiness in production aircraft, each component or assembly manufactured must conform to its drawing for it to be installed on an operational aircraft. Minor quality lapses and variations can be accepted, providing these have been assessed as acceptable from a safety and functionality perspective and this is documented by an approved quality exemption.

If the components are fitted to a new aircraft on the manufacturer's assembly line, then a statement of conformity is issued to the customer for the aircraft as a whole, indicating that each of the individual components and assemblies making up the overall aircraft conform to their respective design drawings. For non-EASA or non-Part 21 aircraft in the UK, components must be supplied with a UK CAA Approved Certificate, which contains a statement of conformity by the manufacturer, that the part conforms to the approved design drawing or details any exemptions or variations. The maintenance provider must confirm this documentation is present before they can fit the component and declare the aircraft serviceable again.

Aircraft examination

A post-impact fire in the fuselage section resulted in severe fire damage to the structure, with only peripheral sections and components made from high melting point metals surviving. These items included most of the engine, the majority of the propeller blades, parts of the landing gear, the rotor mast and some of the flying control cables and connections. Loose ballast material and the remains of a ballast container were found in the main wreckage, however, the level of damage meant it was not possible to determine the position of the ballast at impact. The nose gear wheel and various small items of structure, such as broken plexiglass, were thrown clear of the fuselage and were not affected by the fire.

The rotor head and blades were located separately from the fuselage. One of the blades had been heavily bent and deformed at the blade root where it was bolted to the centre joining section. There were other small marks and distortions along the length of both blades. The most significant of these was a small puncture hole just over a centimetre long. The edges of the hole were pushed inwards from the outside surface of the blade. Adjacent to this, in a diagonal pattern between the hole and the blade leading edge, were many small marks with red and black colour transfer consistent with the paint on the propeller blades. The centre section exhibited impact marks on both sides from contact with the teeter stops (Figure 13). The mark was more significant on one side than the other, but both were superficial and there was no plastic deformation of the blade surface material or the stops.

On the rotor head itself, all the connections to the flying controls had failed at the 'eye end' connectors. The pre-rotator drive shaft was disconnected at a join in the drive shaft. The bracket connecting the roll controls to the rotor head was bent backwards and had failed along most of the weld line between the body of the bracket and its mounting plate.

The gimbal block had failed where two cracks joined. One ran vertically through the roll bolt hole and down the length of the block. The other fracture surface ran horizontally through the centre of the pitch bolt hole for half the width of the gimbal block until it met the vertical fracture surface. The pitch bolt was retained in place and secured the largest section of the gimbal block to the rotor head (Figure 13). The other smaller section of gimbal block was missing and despite an extensive search, could not be located on the accident site or the surrounding fields.



Figure 13

Rotor head showing gimbal block failure, rotor blade deformation and teeter stop contact mark

The roll bolt remained fitted to the top of the mast section. The roll stop bar in the mast had deformed to become curved, rather than straight (Figure 14).

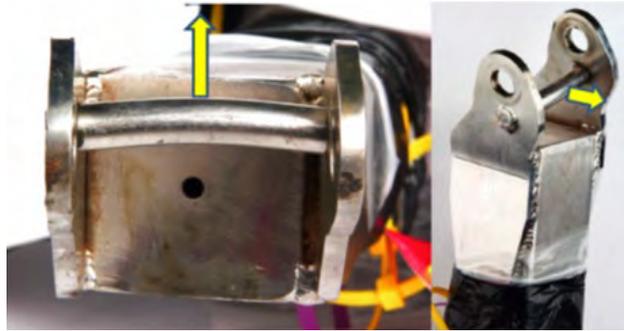


Figure 14

Deformation of mast roll stop bar (with roll pivot bolt removed)

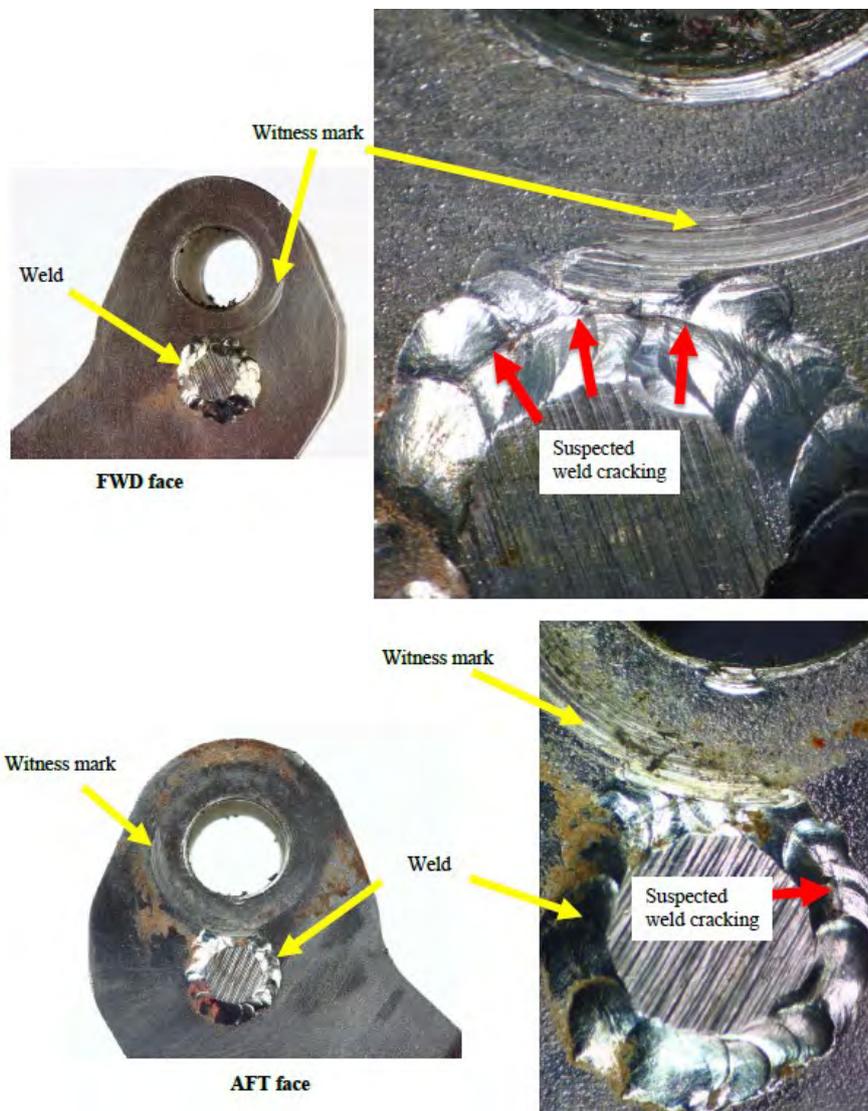


Figure 15

Detailed inspection of the roll stop bar end welds

Detailed inspection of the mast welds showed witness marks on both external faces of the mast. The manufacturer subsequently stated that these were machining marks, where a flat surface was machined during manufacture to accommodate the washers used in the assembly of the pivot bolt. The inspection also indicated that cracks were present in the weld on both sides (Figure 15).

Laboratory inspection

The rotor bridge, gimbal block and mast were removed from the wreckage and sent for metallurgical analysis. Detailed inspection of the gimbal block showed evidence of additional cracks at one end of the block. There was also a curved indentation in the side wall at each end of the channel that acted as a roll stop (Figure 16). The extent of the missing material is shown in Figure 17.

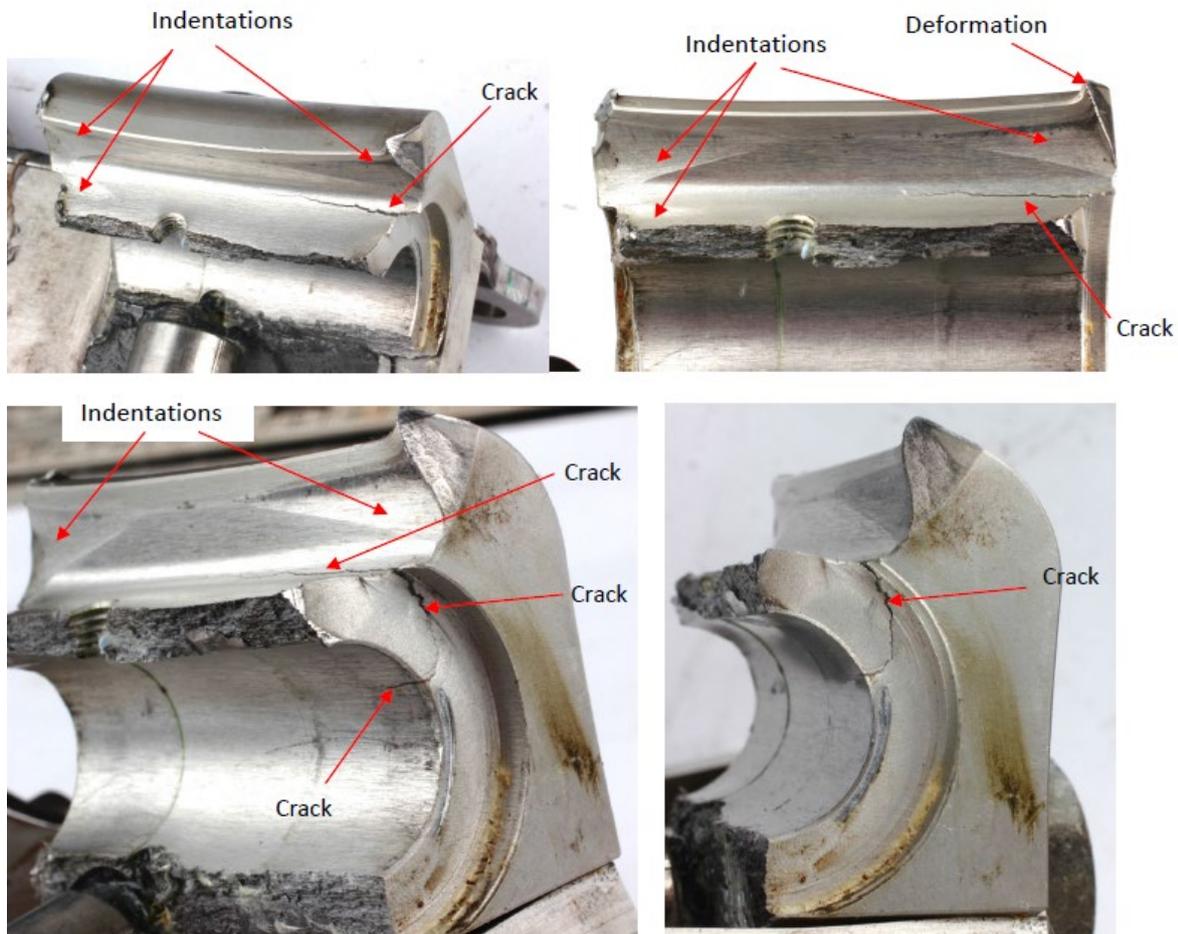


Figure 16

Additional cracks and deformation of the gimbal block

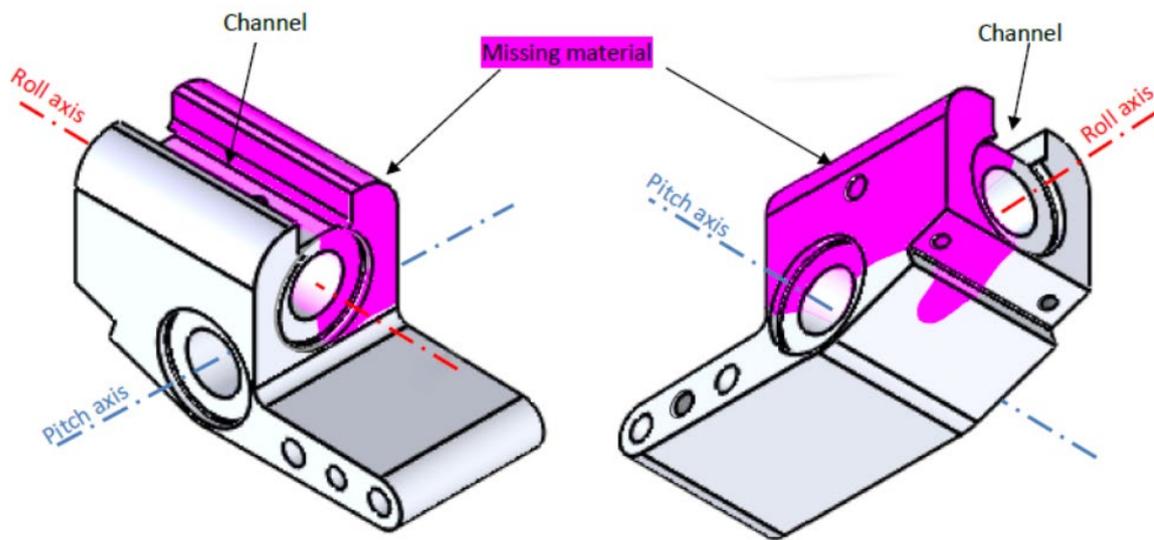


Figure 17

Extent of missing material from the gimbal block
(shown inverted relative to its installed orientation)

Analysis of the gimbal block material properties confirmed that it was machined from extruded T4 aluminium alloy, as specified by the component drawing. The direction of extrusion of the original material was along the roll axis (Figure 17), which was demonstrated by the elongated shape of the grains in this direction. Hardness testing conducted in a number of positions on the block all gave values consistent with the specification for this material. EDX spectrum analysis¹⁰ was carried out, which also confirmed that the alloy composition was within the tolerances of the specification.

Visual analysis of the fracture surfaces showed that the vertical fracture was the primary crack as it extended past the point where it was joined by the horizontal fracture surface (Figure 18). Inspection using a Scanning Electron Microscope (SEM) confirmed that all the fracture surfaces were the result of a single continuous overload, with no evidence of fatigue present. Analysis of the failed flight control attachments confirmed they had also failed in overload.

Footnote

¹⁰ Use of x-rays to determine which chemical elements are present and to what extent within the test sample.

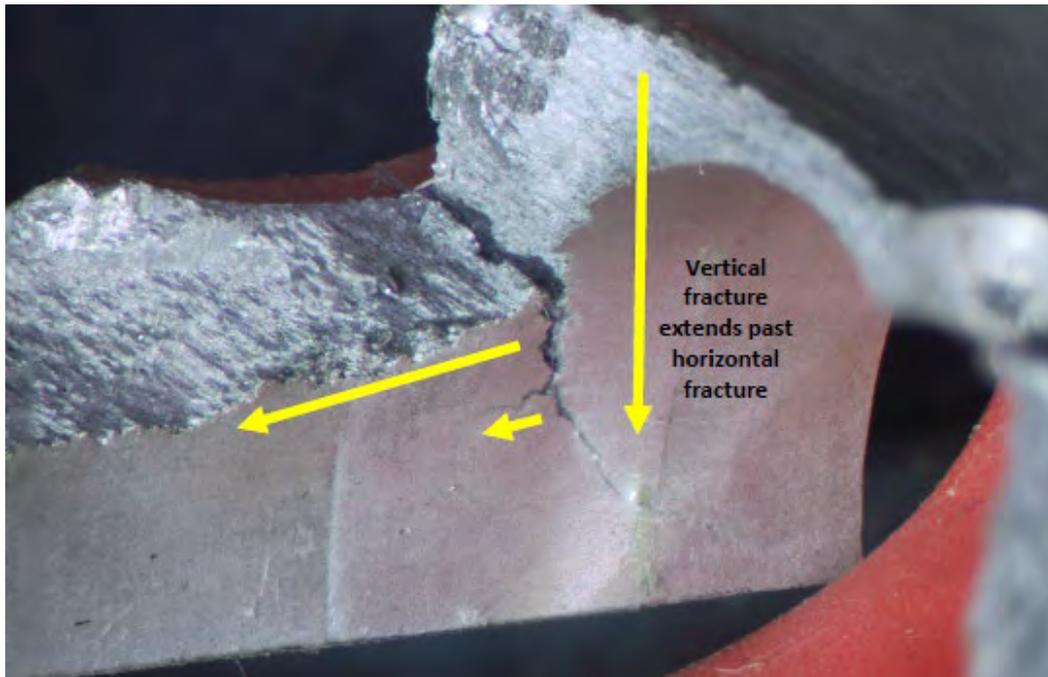


Figure 18

Image showing the vertical fracture surface extending past the horizontal fracture

The side plates which attached the gimbal block to the rotor bridge on both sides were significantly distorted and the bolt holes were elongated. The bolts and bracket attaching the front brake pad assembly to the gimbal block were also distorted, indicating a rotational force on the gimbal block (Figure 19).

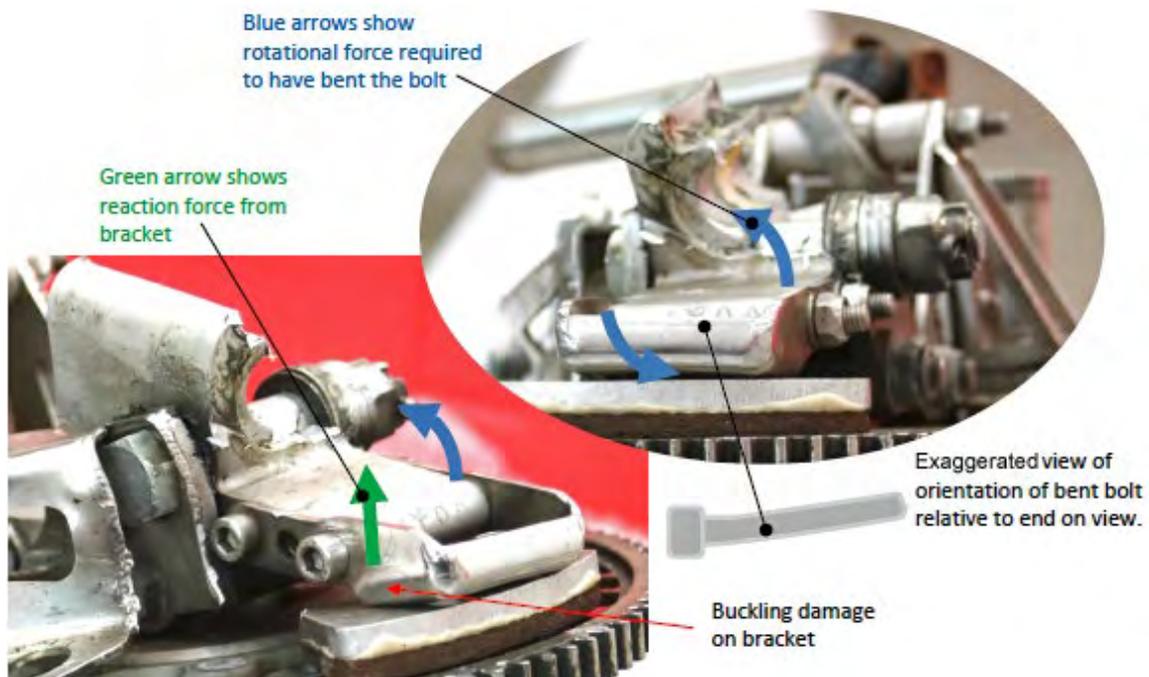


Figure 19

Images of the distorted brake pad bracket and bolts indicating a rotational force

A CT¹¹ scan was carried out on the mast, which confirmed the extent of the roll stop bar distortion and the distortion from vertical of the side plates which supported the bar and the roll pivot bolt. The orientation of the bend in the bar was consistent with the indent marks on the gimbal block. It also showed that the end welds fixing the roll stop bar in the side plates were surface welds on the exterior of the plates, with very little penetration into the plate material. The welds on both sides of the plate had failed or on one side the weld may not have extended across the hole in the plate originally (Figure 20).

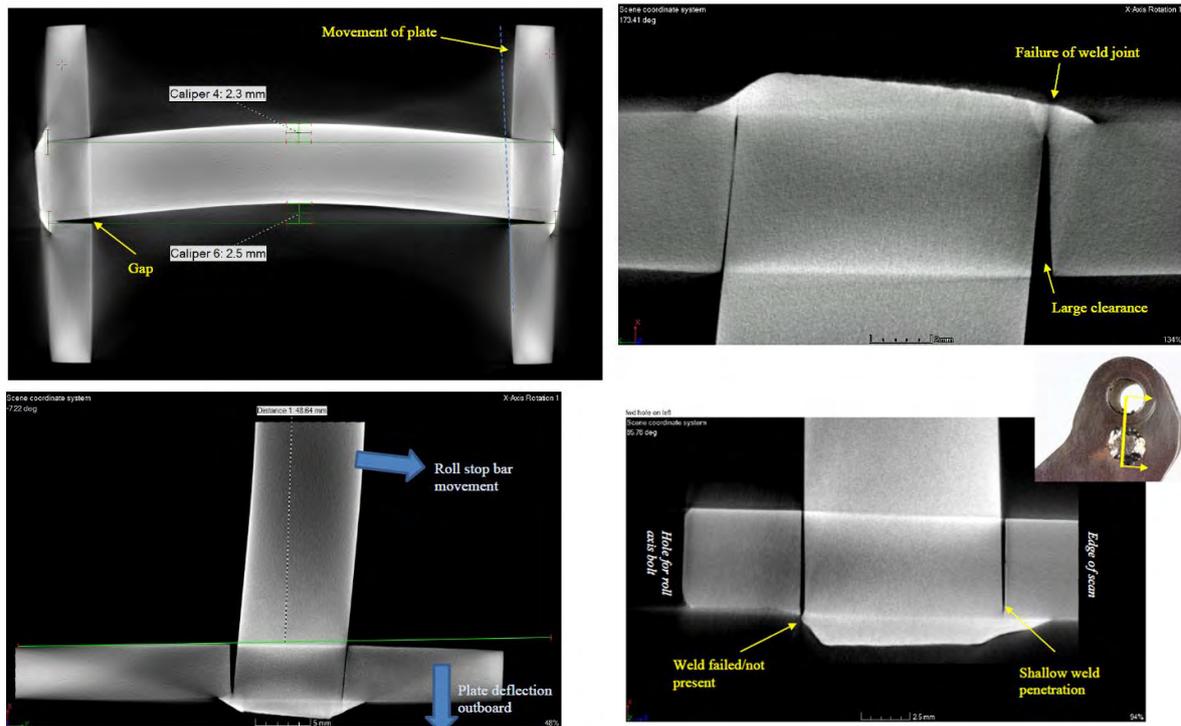


Figure 20

CT scan showing the distortion of the bar and side plates, the shallow weld size and weld failure on both sides

CT scans of the mast also showed the extent that the roll stop bar extended beyond the external face of the mast side plates. This was confirmed as 1.5 mm on the forward side and 1.3 mm on the aft (Figure 21).

Footnote

¹¹ Computerised Tomography combines multiple x-ray image 'slices' through a component to create a 3-D model of the interior of the structure.

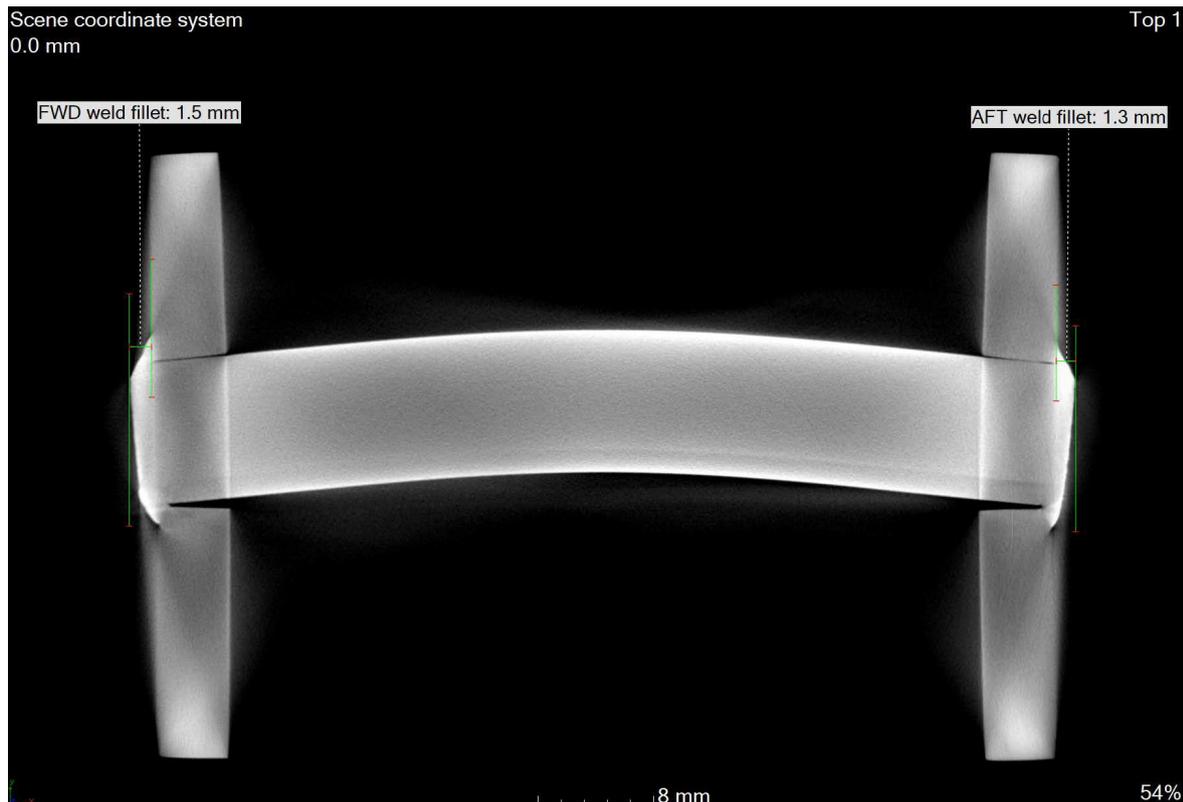


Figure 21

CT scan measurement of roll stop bar extension beyond the mast side plates

Previous incidents

The manufacturer confirmed that the distinctive conical indentations present on the side of the roll stop channel of the accident gimbal block and bending of the roll stop bar had been seen previously. The manufacturer provided samples of gimbal blocks from reported ground-based accidents which had resulted in similar deformation, but not the cracking or complete failure of the block. The manufacturer was not able to provide details of the gyroplanes from which these gimbal blocks had been removed, so it was not possible to determine if the accidents had been independently investigated or the specific circumstances of the incidents which caused the damage. However, as the manufacturer stated that they were ground-based events, it is most likely the damage had resulted from either dynamic rollover of the fuselage or low rotor rpm blade sailing issues during the takeoff roll.

Fuel

After the first flight of the day a member of the operator's staff refuelled G-CKYT with 40 l of motor gasoline, bringing the total to 60 l, providing an endurance of 3 hours of flight. Following the second flight of the day the student refuelled the gyroplane with a further 20 l. Based on the known history of the flights it is estimated that there were 50 l¹² of fuel onboard at departure for the accident flight. This was sufficient for an endurance of 2.5 hours.

Footnote

¹² 36kg at a specific gravity of 0.72 kg/m³.

Weight and balance

The Pilot's Operating Handbook (POH) contained the following note about the use of ballast:

'Pilots in the right hand seat weighing less than 65 kg must carry corresponding ballast during solo operation (which may be located in the baggage compartment, around the occupant in a form such as sheet lead under the seat cushion, or securely restrained on the second seat).'

The student weighed more than 65 kg, but the training school routinely used ballast to minimise the lateral attitude change of the aircraft when the left seat was not occupied on solo student flights.

Ballast was added to the gyroplane for both solo flights undertaken by the student on the day of the accident. This was described as a jerrycan filled with sand weighing 35 kg strapped onto the front left seat, and a sandbag weighing 15 kg, also filled with sand, placed on the cockpit floor in the space behind the left seat.

G-CKYT had a recorded basic empty mass of 326 kg. The calculated take off mass, including the mass of the pilot, fuel and ballast, was approximately 512 kg. The MTOM permitted is 560 kg.

The distribution of weight in the gyroplane was within the limits defined in the POH for weight and balance calculations.

Aircraft limitations

The Cavalon POH contains the following limitations:

Air Speed	Marking	
V_{NE} Never Exceed Speed	Red radial	 195km/h (120mph)
V_B 130km/h (max design speed for strong gusty conditions)	Yellow arc	130 – 195 km/h (80-120mph)
Recommended manoeuvring speed range	Green arc	30 - 130 km/h (20-80mph)
	Yellow arc	0 – 30 km/h (0-20mph)

Figure 22

Cavalon POH - Section 2.4 - Airspeed Limitations and Instrument Markings

In addition, the structural load factors were defined as:

'2.7.3 Demonstrated Structural Load Factors

Demonstrated positive load factor (500 kg)..... + 3.5 g

Demonstrated negative load factor (500 kg) – structural limit..... - 1 g

Demonstrated positive load factor (560 kg)..... + 3.0 g

Demonstrated negative load factor (560 kg) – structural limit..... - 0.5 g

Important note: *the indication of a demonstrated negative load factor represents a structural limit only. In flight, the limitations (see 2.9) have to be respected at all times.'*

The POH provides the following notes and warnings for manoeuvres:

'Section 2 - Limitations

2.1 General

WARNING

Positive G load on the rotor must be maintained during all flight manoeuvres. Do not perform any manoeuvres resulting in the sensation of feeling light or near weightless.

2.9 Kinds of Operation

Aerobatic flight is prohibited!

NOTE

Manoeuvres involving bank angles of more than 60° are considered to be aerobatic flight.

Low-G manoeuvres are prohibited!

WARNING

Any manoeuvre resulting in a low-G (near weightless) condition can result in a catastrophic loss of lateral/roll control in conjunction with rapid main rotor RPM decrease. Always maintain adequate load on the rotor and avoid aggressive forward control input performed from level flight or following a pull up.'

In a later section entitled 'Safety Tips', the following advice is provided:

'Low-G Avoidance

Never push the control stick forward to descend or to terminate a pull-up (as you would in an airplane). This may produce a low-G (near weightless) condition which can result in a situation with reduced or lost lateral roll control and significant loss of main rotor RPM. Always reduce power to initiate a descent.'

The manufacturer and the CAA were requested to clarify what specific 'g' represented a limit beyond which operation of the gyroplane was explicitly prohibited. They stated it was not possible to provide a specific figure.

Identifying low g

Despite these warnings in the POH describing the need to avoid situations where the rotor head becomes significantly unloaded, there was no qualifying information on what these terms represented. A number of phrases were used to describe this including '*low g*', '*near weightless*' and '*sensation of feeling light or near weightless*'. It also describes the need to maintain '*adequate load*' on the rotor.

Enquiries were made with the Royal Air Force Centre of Aviation Medicine (RAFCAM) about a pilot's ability to perceive low g. This revealed it is likely that a pilot could detect a change from + 1 g to + 0.5 g, and probably even a change from + 1 g to + 0.8 g. However, RAFCAM stated that there is no trial evidence to support this and there is no evidence in medical literature of studies having been conducted in this area. It was further suggested that if the change was from greater than 1 g, or occurring in turbulent conditions, then it is likely that it would be more difficult for a pilot to identify the transition point to less than 1 g.

Typical values of vertical acceleration during climbing and descending were not available from the aircraft flight tests.

Meteorology

On the morning of the accident, the forecast wind speed aloft was 20 kt at 1,000 ft and 30 kt at 2,000 ft from the south-west. The METARs at Inverness Airport recorded at 1020 hrs and 1250 hrs reported the surface wind as 220° at 8 kt and 230° at 7 kt respectively. Between these observations the maximum windspeed recorded was 11 kt. The TAF published at 1100 hrs reported that between 1200 hrs and 2100 hrs the surface wind would be from 220° at 12 kt, with a 30% probability from 1500 hrs of a temporary increase to 17 kt, gusting 27 kt.

With only light winds down the runway, the instructor assessed the weather to be suitable to send his student on solo sorties and regarded the wind speeds of 20 to 30 kt at height as acceptable and '*not challenging*'. The wind strength was below the Environmental Limitation in the POH of a maximum wind speed or gust intensity of 40 kt.

An aftercast of the area provided by the Met Office showed Inverness and the surrounding area to be in benign conditions between frontal systems at the time of the accident. From local observations, the wind conditions were shown to be as or lighter than those forecast. Local wind reports were of south to south-westerly with varying wind speeds from 4 to 11 kt at Inverness, 11 to 15 kt at Lossiemouth (46 km north-east) and 11 to 20 kt at Tain (30 km north). There was satellite evidence of mountain wave activity from the Grampian Hills with modest activity at 6,000 ft above the surface. Given the terrain and the forecast mountain wave activity, varying wind speeds were expected. There was no rainfall and visibility was good. Between the surface and 5,000 ft there were only FEW amounts of cloud, with any broken layers above 5,000 ft.

The pilot of the Grumman AA-5 flying in the area shortly before the time of accident reported that there were no gusts or turbulence when he transited the Black Isle and described the weather as '*suitable for normal flying*'.

Gyroplane licensing and training regulation

Responsibility for gyroplane operations had historically been delegated by the CAA to the British Rotorcraft Association (BRA). In 2012 the CAA appointed their first Flight Operations Inspector with specific responsibility for gyroplane operations. This was in response to a recognised lack of relevant in-house experience of gyroplane operations within the CAA.

In 2013 the CAA formed the gyroplane Panel of Examiners, consisting of established industry experts, taking over responsibility for gyroplane operations from the BRA. This included establishing the minimum skill levels for all aspects of PPL gyroplane training and ongoing training standardisation. It comprised three senior gyroplane flying instructors and examiners, meeting biannually chaired by the CAA. Additionally, the group hosted an annual conference of gyroplane instructors to discuss training standards.

Standards set by the Panel are reviewed by the CAA before approval is granted and they are included in CAA Standards Document 44: *Gyroplane Licensing*. This defines the standards to be applied for the training of UK licensed gyroplane pilots after 01 July 2012.

To obtain a Private Pilot's Licence for gyroplanes, PPL(G), a pilot must complete a training course with a CAA certified flight instructor entitled to instruct on gyroplanes. Training must follow the gyroplane syllabus published by the CAA in Standards Document 44.

Instructor information

The instructor gained his instructor's qualification, FI(G), with restricted privileges¹³ in 2015 and achieved an unrestricted status in April 2017. He had delivered over 1,000 hrs of dual instruction and became qualified to deliver training to flight instructors in August 2020.

He operated from a flying school, which was an Approved Training Organisation (ATO) for the delivery of fixed wing training, as the sole qualified gyroplane instructor. Oversight of his gyroplane training standards was achieved through the triennial revalidation of the instructor's training qualification, conducted by an examiner who sat on the Panel of Examiners.

The instructor managed and documented the progress of students by an online application. In the '*Pilot's Logbook*' section, students could view the objective of each lesson, including a list of key topics covered by the instructor. It also contained comments from instructors and provided an option for students to add their own comments.

Footnote

¹³ An instructor holding a FI(G) with restrictions requires the supervision of an individual holding an FI(G) without restriction.

Student pilot information

The student started training towards a PPL (aeroplane) in August 2014. He achieved 71 hours flying experience but in January 2018 stopped flying for medical reasons. He then decided to gain a PPL on a gyroplane and started his flying training in September 2019, undertaking all his instruction on G-CKYT.

The student was assessed as a confident, diligent, and able student, who presented no supervisory concerns to his instructor. He demonstrated transferable knowledge from his previous fixed wing experience which conferred benefits in the initial phase of the course. However, when developing the skills for takeoff and landing his progress was reported to be of a standard expected for most students. This was attributed to the significant differences in the flying techniques used in gyroplanes and fixed wing aircraft.

Following a period of consolidation of these gyroplane techniques, he undertook his first solo flight on 6 November 2020, six days prior to the accident, which was conducted without incident. He did not undertake any further flights until the day of the accident.

Gyroplane training syllabus

CAA Standards Document 44 included a training syllabus largely developed independently by one of the members of the Panel of Examiners and approved by the CAA. This was used by the operator in training the student and comprised 38 lessons arranged into eight phases.

The syllabus differs from fixed wing training in that the gyroplane student is not expected to be ready to fly solo until after lesson 31. This is attributed to the level of difficulty of gaining proficiency in the techniques for takeoff and landing. The licensing requirement for gyroplanes is a minimum of 40 hours of instruction of which 10 must be supervised solo. Up to the accident flight, the student had achieved 45 hours dual instruction and 1 hour 45 minutes solo.

Lesson 23: Higher bank angle level turns and turning in relation to ground reference features

The objective of this lesson was to teach a student how to maintain airspeed, height and balanced flight during turns using up to 45° angle of bank, and how to turn around a point on the ground maintaining a constant distance from it. The angle of bank is assessed visually by reference to a horizon reference line taped onto the windscreen. The manoeuvre requires the application of significant back pressure on the control stick to prevent the gyroplane's nose from dropping and up to near full power to maintain airspeed. For turns around a point on the ground, in order to maintain a constant distance from the point, the student has to compensate for drift caused by the wind. This is achieved by varying the angle of bank during the turn.

The student's instructor stated that in his experience bank angles of 45° or greater required '*application of full throttle (5,600 rpm) and significant back pressure on the control stick*'. He stated that in comparison to this, initiating a turn using approximately 30° angle of bank at 60 to 70 mph with 4,800 rpm set, would require an increase in engine power of approximately 200 rpm during the turn and some back pressure on the control stick to maintain height and speed.

The student conducted lesson 23 on 29 July 2020 and consolidated the technique on 5 November 2020 during pre-solo practice with his instructor. The instructor noted in the student's training record after the flight on 29 July that the student required '*more focus on the horizon reference line during the exercise, and less focus on the point we are turning around*' and cautioned him, '*Don't go too far on the high bank turns*'. The student added the comment: '*fun high bank turns, but easy to go too far*'. The training record contained no further entries regarding high bank angle turns.

The instructor reported that while turns using up to 45° angle of bank should be well within the skills of a pilot by solo stage, students would normally be expected to use a maximum of 30° angle of bank when flying solo unless specifically briefed.

The instructor reported that he had not given the student specific exercises to fly but had directed him to fly around the training area to gain more experience of handling the gyroplane. His expectation was that the student would not use more than 30° angle of bank, but this was not explicitly briefed to the student.

Lesson 24: avoiding, recognising and recovery from unusual attitudes

During this lesson students were taught to be able to understand why unusual attitudes¹⁴ occur, how to recognise them and how to safely recover the gyroplane back to controlled flight. A particular manoeuvre taught was the recovery from a descending steep banked turn, also referred to as a 'spiral dive'. This was taught by the operator in two forms: a 'slow' spiral dive at a manoeuvre entry speed of approximately 40 mph, and a 'fast' spiral dive at approximately 70 mph.

The instructor would place students into the manoeuvre using up to 30° angle of bank, with the student following through on the controls, then hand over control to the student to recover to straight and level flight using the following technique:

- Reduce power.
- Select a level attitude in the order of roll, pitch then yaw.
- Maintain a level attitude until the rotor rpm reduces back to the normal level for cruise conditions.
- Once rotor rpm is stable, increase power to a cruise setting and continue flight.

The student received training in this technique on 13 March 2020 and again on 29 July 2020. On both occasions they were flown over Munloch Bay. The instructor informed the AAIB that students were not permitted to practise this technique when flying solo before they gained their pilot's licence.

The instructor stated that he would not expect the descent rate to exceed about 1,000 ft/min when a student properly recognised and recovered from the unusual attitude as taught, before it developed into a spiral dive.

Footnote

¹⁴ An unusual attitude is an unintentional, unanticipated, or extreme aircraft attitude.

The instructor further commented that as part of the lesson on climbing and descending turns, the bank angle is incrementally increased which can result in a significant increase in descent rate up to 1,500 ft/min. He stated descent rates above 1,500 ft/min were in any case unusual in normal gyroplane operations but descent rates of up to about 2,000 ft/min may be achievable in a spiral dive if the nose is lowered to increase airspeed as part of the manoeuvre. He stated that 2,000 ft/min was considered safe and within the ability of most instructors but is *'pretty extreme'* and *'not something that would ever be performed by a student'*.

NPPL skills test accuracy

The instructor stated that for the NPPL skills test the relevant tolerances for flying accuracy during normal manoeuvres were:

- Airspeed: ± 5 kt.
- Altitude or height: ± 100 ft.

Training for avoiding low g

Standards Document 44

Standards Document 44 contains the syllabuses for all gyroplane licences, including instructors and examiners. In the section on the General Flying Test for the award of a PPL(G), it states:

'The syllabus lists all the items which should be covered during training and which may be examined during the Flight Test. The applicant will be required to demonstrate a satisfactory standard of knowledge and handling in all items included in the Flight Test.'

However, there was no guidance provided on the need to teach or examine recognising and avoiding low and negative g flight profiles.

In contrast, the awareness of the hazards of low g is included in the syllabus of theoretical knowledge for a PPL(H)¹⁵ and in the UK CAA *Helicopter Flight Examiner Manual*¹⁶.

The instructor

The instructor reported that he discussed the subject of low and negative g throughout the PPL(G) course, including reference to video footage of historic gyroplane accidents. Documentary evidence provided to the AAIB indicated that the emphasis during training was placed on avoiding pushing the control stick forward too quickly or abruptly during manoeuvres, and the avoidance of over-controlling. This reflected warnings and advice contained in the manufacturer's POH.

Footnote

¹⁵ CAP1340: Alternative Means of compliance 1 FCL210; FCL215 Syllabus of theoretical knowledge for the PPL(H), October 2015.

¹⁶ UK CAA Helicopter Flight Examiner Manual, Version 1, 23/04/2021.

Neither source covered the potential for a transient reduction in the load factor below 1, hence unloading of the rotor, during a turn-reversal manoeuvre.

Medical information

While undergoing training on aeroplanes, the student held an EASA Class Two medical. His last EASA Class Two medical examination was on 30 December 2016, at which he had an Operational Safety Pilot (OSL) restriction¹⁷ added due to a medical condition. This medical condition subsequently caused him to stop flying.

Medical records indicated that the student then received successful treatment for his condition. On 1 September 2020, on the commencement of his gyroplane training, the student presented a Pilot Medical Declaration of fitness to fly signed by his General Practitioner (GP) and dated 12 December 2019.

The Pilot Medical Declaration is appropriate for pilots flying an aircraft less than 2,000 kg MTOM. The student provided this declaration on CAA Form SRG 1204, although this went out of use after 25 August 2016 being replaced by an online declaration which does not require a doctor's countersignature. However, the declaration and GP's countersignature affirmed that the student met an appropriate medical fitness standard that was acceptable to the CAA.

Post-mortem examination did not reveal any evidence of medical incapacitation. The impact forces were assessed as not survivable.

Assessment of point of failure from the wreckage trail

The recorded GNSS path up to 1249:47 hrs, wreckage location and estimated wind conditions were used to help estimate the approximate point of the rotor head failure (Figure 23). The gyroplane had sufficient height that the lightweight, low inertia debris released during the failure sequence was blown downwind to form a long wreckage trail roughly half a kilometre long. The wind direction at 2,000 ft was estimated by the Met Office but corresponds well to the direction of the wreckage trail. The gyroplane had a groundspeed of at least 70 mph during this period, so the debris would have travelled diagonally forward¹⁸ from the point of release. This gives some indication of when the failure must have occurred and is consistent with the period immediately before the data became unreliable.

Once the rotor had departed the fuselage, physical evidence from the wreckage shows a rotor blade contacted the propeller, stopping the engine; there was now no other means of influencing the flight trajectory and the fuselage would have fallen ballistically. Given its significant weight and inertia compared to the small debris released at the same time as the rotor head, although it would have been affected by the prevailing wind, it would have maintained its forward speed and fallen faster, reducing the extent of the change in direction and distance it travelled.

Footnote

¹⁷ This limitation is added to a medical certificate when a pilot is considered to be at increased risk of incapacitation compared to his/her peer group. The holder of the medical certificate must always fly with a safety pilot.

¹⁸ Forward relative to the approximate direction of travel at the point of failure.

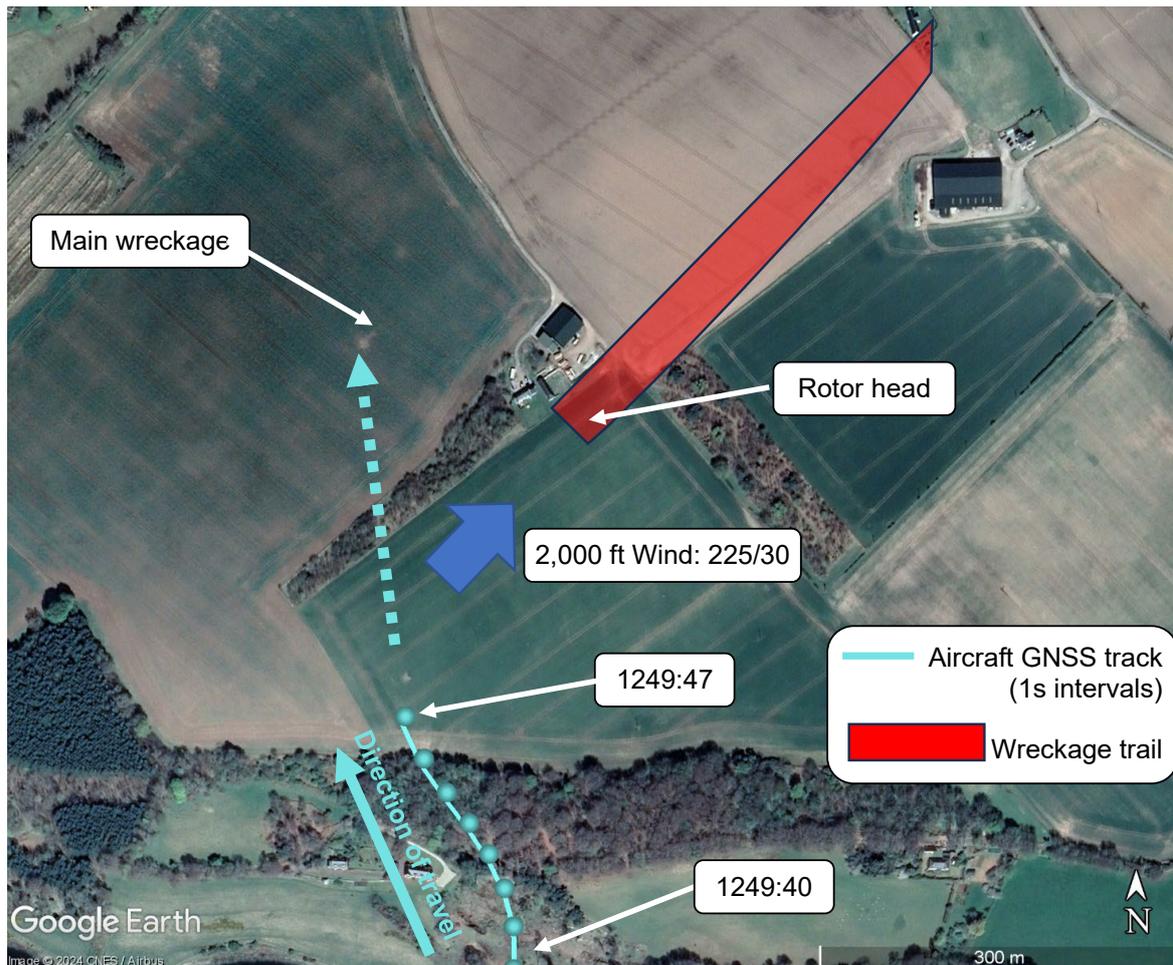


Figure 23

Image showing wreckage trail and prevailing wind direction relative to the GNSS flightpath

Tests and research

DLR gyroplane flight performance modelling

The German national aeronautics and space research centre (DLR) were contacted to assist the investigation based on their extensive knowledge of gyroplane performance modelling and flight testing.

The DLR have created an accurate data model of gyroplane flight characteristics, which has been validated by flight testing with an instrumented airframe. The gyroplane on which they based the model and which was subsequently used for flight test validation of the data was an AutoGyro Cavalon.

The DLR model was used to simulate a period of reduced g during a turn. This included a number of assumptions which were not taken from the accident flight data but considered a similar typical scenario.

The simulation used assumed parameters of an engine torque of 100 Nm (approximately 75% power), a rotor head roll control angle increasing above 4° and a reducing vertical acceleration (n_z) below 1 g. This resulted in a fuselage angle at the rotor head roll pivot bolt (ξ_{RH}) that reaches the maximum available (-8°) in the geometry of the rotor head control system at around 0.3 g. Practically this would result in the roll stop bar on the mast coming into contact with the left side of the gimbal block channel.

The time taken for the fuselage angle to reach the maximum available is proportional to the rate at which the vertical acceleration reduces and will vary with increased engine torque, as shown by the top graphs in Figure 24. A faster reduction in vertical acceleration, or a greater torque figure, would result in a faster response at the roll pivot bolt. The torque and rate of vertical acceleration change chosen for the modelling were arbitrary and not taken from the accident flight data, as was the resulting time of 8 secs to reach -8° limit.

The bottom left graph shows that although the rotor rpm reduces as the vertical acceleration reduces, it remains within the normal operating limits for the gyroplane, as stated in the POH, of 200-550 rpm.

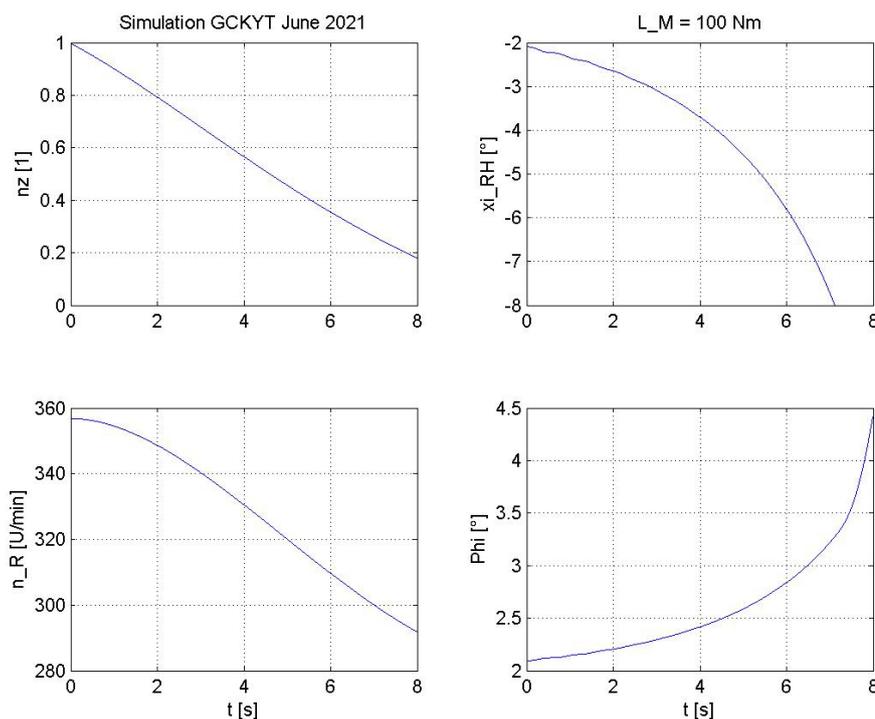


Figure 24

DLR modelling predicting an induced roll angle of the fuselage due to engine torque during flight conditions below 1 g

The DLR also provided a static calculation tool for the Cavalon. This allows an assessment, under static conditions, of approximately how much roll control angle input is required at the roll pivot bolt to counter the engine torque induced rotation. In normal 1 g or above flight,

where the vertical acceleration results in a force acting against that induced by the engine torque, this requires only a small amount of counter control input. However, as the vertical acceleration reduces, the effects of engine torque can become significant and result in the fuselage rotating clockwise (viewed from the rear) about the roll pivot bolt in the gimbal block.

Based on the calculation tool, for a Cavalon configured to the same assumed weight and balance as G-CKYT and the engine operating at full power, if the vertical acceleration drops to approximately 0.5 g, then the maximum available opposite roll input may be required to counter the torque of the engine, resulting in possible contact between the mast roll stop bar and the gimbal block. If the vertical acceleration drops below 0.5 g, there would be insufficient control authority to counter the induced rotation without increasing the contact force on the gimbal block.

In dynamic operation, if the fuselage is already rotating clockwise about the pivot bolt, reducing the clearance between the gimbal block and the roll stop bar, this could in theory lead to contact occurring at vertical accelerations above 0.5 g. For example, at 0.6 g, if just over one degree of fuselage rotation past the neutral position is present, the required control input to counter the engine torque may result in contact.

The DLR modelling and calculation tool only provide an approximate indicator of the likelihood of contact between the gimbal block and roll stop bar but highlight the significance of vertical acceleration, engine power and whether the aircraft is manoeuvring. The DLR calculations confirm that the vertical acceleration can theoretically be above the subjective POH limitations of '*near weightless*' or '*low g*' when contact with the roll stop bar occurs. However, the recorded data from the accident flight did not have sufficient parameters to allow the exact circumstances resulting in contact during the accident flight to be confirmed.

Mast interface

In order to assess the geometry of the mast interface found on G-CKYT, a new production mast was purchased directly from the manufacturer for comparison. This mast had not been used in operation. It was CT scanned to determine the interface dimensions and weld penetration on the roll stop bar. Figure 25 shows that the internal distance between the side plates is 52.2 mm, which was within the drawing tolerance. It also confirmed that the side plates were flat and aligned at 90° to the roll stop bar, which was straight, but the bar measured 62.5 mm, rather than the specified 65 mm.

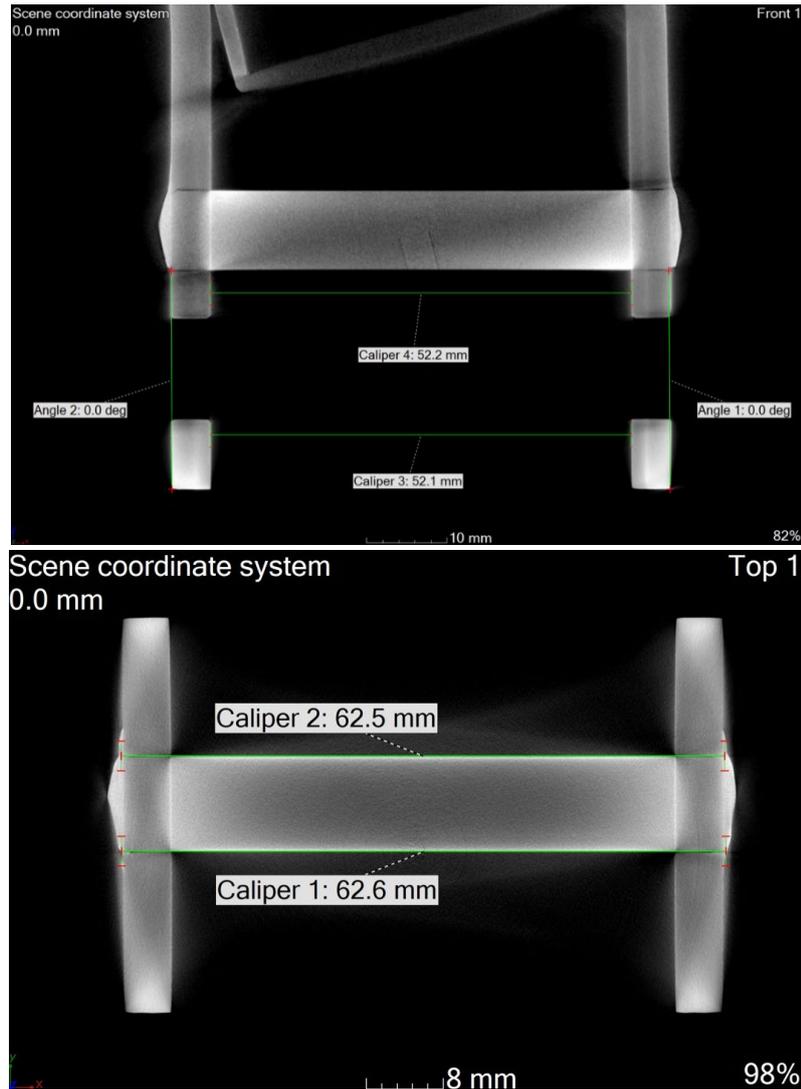


Figure 25

CT scan of new production mast top

Measurements taken from the scan showed that the roll stop bar at its highest points extended beyond the external face of the side plates by 1.4 mm on the aft side and 0.8 mm on the forward side, although the measurement dropped significantly away from the peak. The weld depth at its deepest penetration was 1.99 mm and 1.45 mm respectively on each side, but this also varied significantly across its diameter (Figure 26).

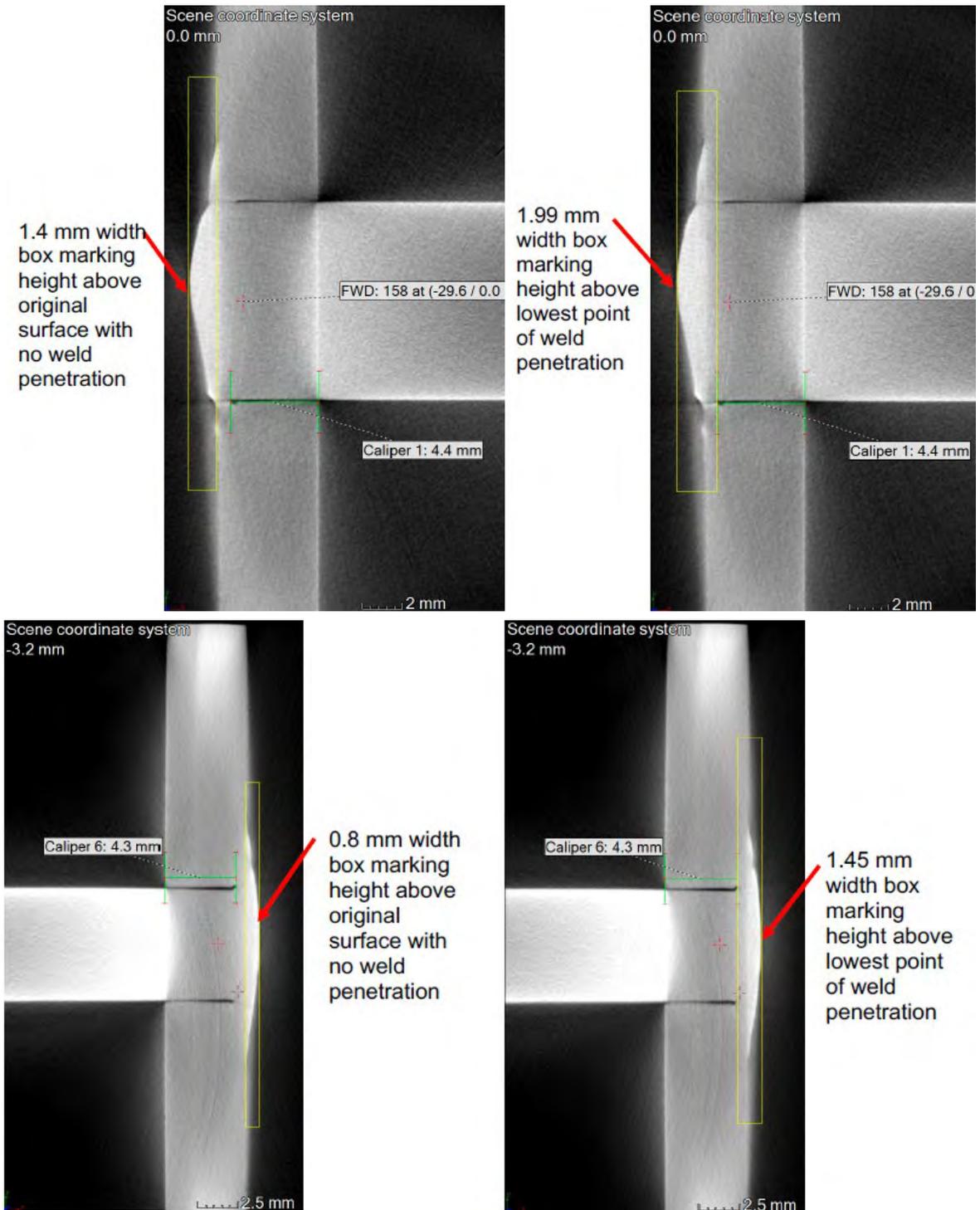


Figure 26

CT scan of new production mast top showing the roll stop bar weld (aft side - top images, forward side - bottom images)

According to the design drawing dimensions, for a nominal plate width of 5 mm, the roll stop bar should extend between 1.5 mm and 1.25 mm, depending on manufacturing tolerances.

The mast arrived with an existing witness mark on the side plates. The manufacturer confirmed that these were machine marks, where the faces and weld had been machined flat during manufacture to accommodate the washers fitted during assembly of the roll pivot bolt. (Figure 27).

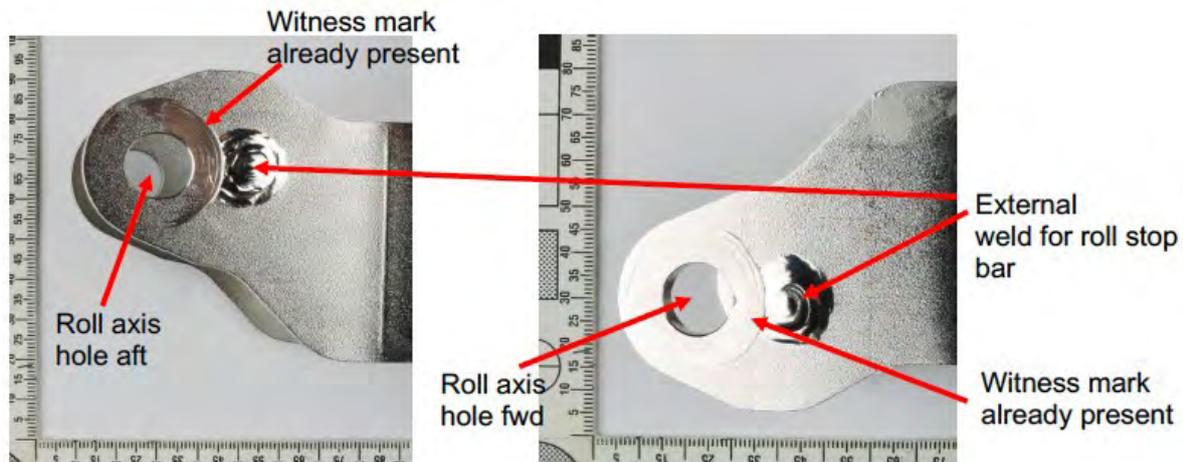


Figure 27

As received part showing damage to weld

Assessment of the roll stop bar welds

The strength of a fillet weld is based on the throat size (a), shown in Figure 28 as the distance between the two red arrows on the left. The strength can be increased by using a deep penetration weld shown on the right of Figure 28, which increases the size of the throat (a).

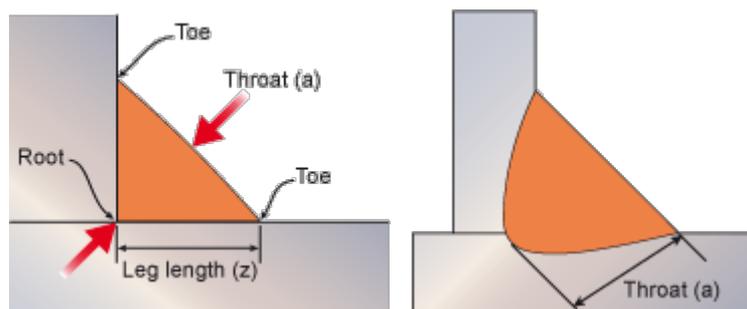


Figure 28

Weld definitions

The throat dimension can't be easily measured on a finished weld, but it can be estimated using the leg length (z) shown in Figure 28. For an isosceles triangle (equal leg lengths), the throat is approximately 0.7 of the leg length ($a \approx 0.7z$). European welding standards EN ISO15614-1 state that where the drawing doesn't specify weld size, for plate material between 3 and 30 mm thick, the minimum throat size should be 0.5t (where t = minimum plate material thickness) or at least 3 mm to achieve a full strength weld.

For the roll stop bar and side plate of thickness 5 mm this would give a minimum leg size of 4.3 mm. In order to measure this, the roll stop bar would need to extend at least 4.3 mm from the external face of the side plates. The CT scans show that on one side of the new production mast the bar only extended 0.8 mm at its highest point, this would give a theoretical best-case throat thickness of 0.6 mm. In reality, the height was not consistent across the width of the bar, tapering to less than half this height at the edges of the bar. The CT scans showed that the penetration of the weld reached 0.7 mm at its greatest, but as the extension height tapered across the radius of the bar, it did not significantly improve the throat size. As such, the weld was less than a third of the recommended size. The welds could, therefore, only be considered as 'tack' welds used to hold the bar in position, rather than full strength welds designed to carry load. As the mast on G-CKYT was the same, this was considered a consistent feature of production rather than a single quality lapse.

The manufacturer was requested to confirm whether they considered that the accident mast and the production mast supplied for testing conformed to the approved design drawing for the component and whether there was any intention to change the manufacturing process to address the findings of the investigation. In response, the manufacturer stated that the gimbal block channel was not expected to contact the roll stop bar in flight and was only intended to act as a control stop on the ground. As such, the welded joint was not anticipated to carry significant load and did not need to be a full strength weld. They considered that there was a lack of evidence, based on their experience gained from the large number of other aircraft currently in service, that a change was required. They did however state they will review the entire mast welding process as part of their product improvement programme.

Gimbal block testing to failure

A rig test of an assembled mast and gimbal block was commissioned using nC² engineering consultants at the University of Southampton. The test was designed to apply a load to the side of the gimbal block roll channel, by rotating the mast until the roll stop bar on the mast made contact with the block, then continuing to move the mast to increase the load until the gimbal block failed.

To achieve this a test rig was designed to attach the gimbal block to a high load hydraulic press, with a roller cradle to hold the mast and keep the point of load approximately in the same place as it moved (Figure 29). The new production, unused mast and gimbal block were configured with accessory components to be as representative to normal operation as possible. To understand how the loads were transferred through the gimbal block and mast assembly and how the structure responded, four rosette strain gauges were applied on the mast along the box section and two on either side of both of the side plates. One gauge was placed on the roll stop bar, thirteen were fitted to the gimbal block, including the roll channel. One rosette gauge was fitted to each of the brackets attaching the gimbal block to the test fixture. The output of these gauges was logged and also displayed on a screen in real time to identify when the various components started to deform and ultimately fail during the test. The applied force data from the hydraulic test machine was also recorded.

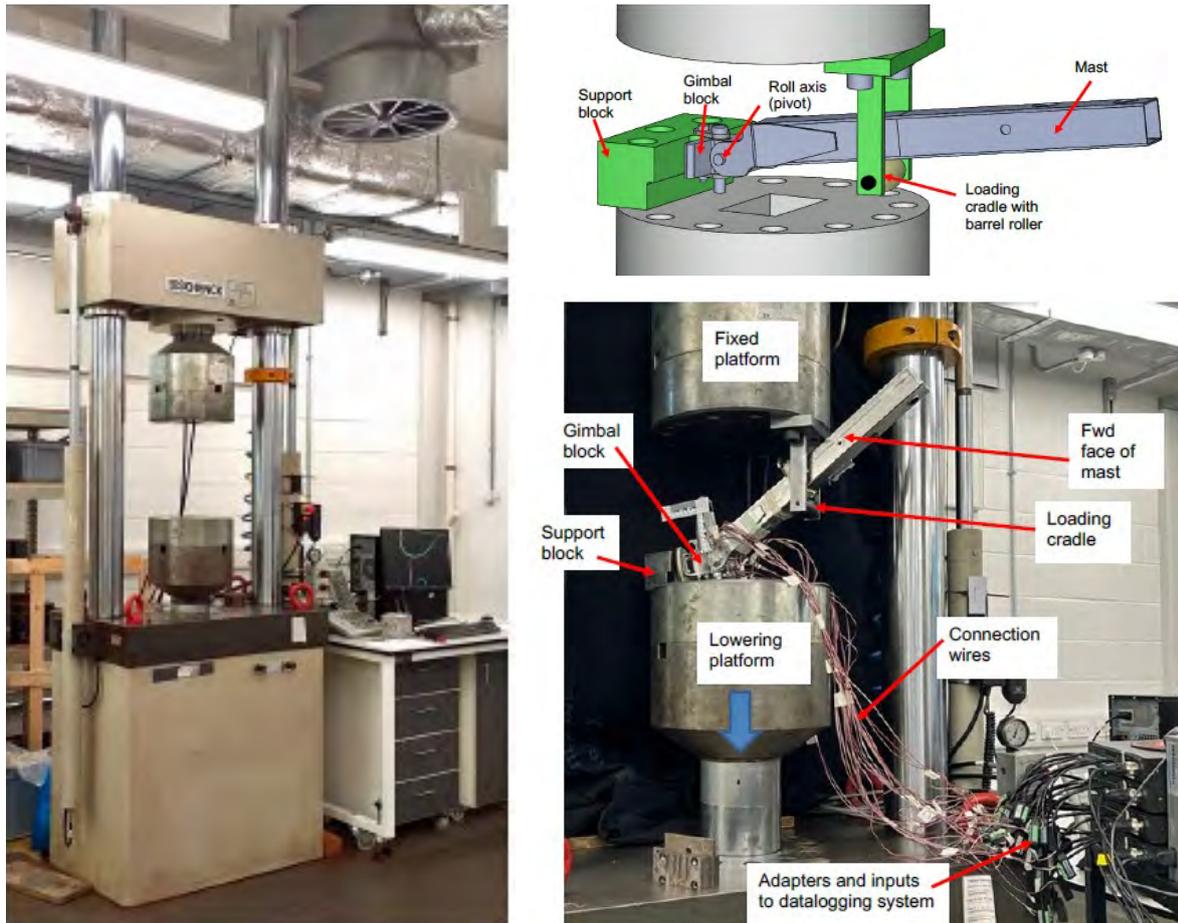


Figure 29

Images of the test machine, test configuration and installed test piece with instrumentation

Test conduct

Below explosive/ballistic levels, the speed at which the load is applied does not significantly change the way the material reacts. Whilst significantly slower than a flight manoeuvre would have occurred, a speed of 5 mm per minute was chosen to allow time to assess the response of the block and mast assembly during the test and stop if necessary. The force being applied by the hydraulic press was continuously monitored during the test to ensure the test was progressing to plan. At one point in the test, one of the side brackets on the mast (not associated with the test) came into contact with the loading cradle. The test was stopped while the mast was repositioned and then restarted at the same point. Further into the test a loud crack indicated that the gimbal block had started to fail and eventually the load dropped off significantly indicating that load shedding had occurred.

As the mast rotated around the roll bolt pivot continuously through the test, the vertical force readings from the test machine were resolved into a load and moment applied at the point of contact between the roll stop bar and the gimbal block. This raw data is shown in Figure 30.

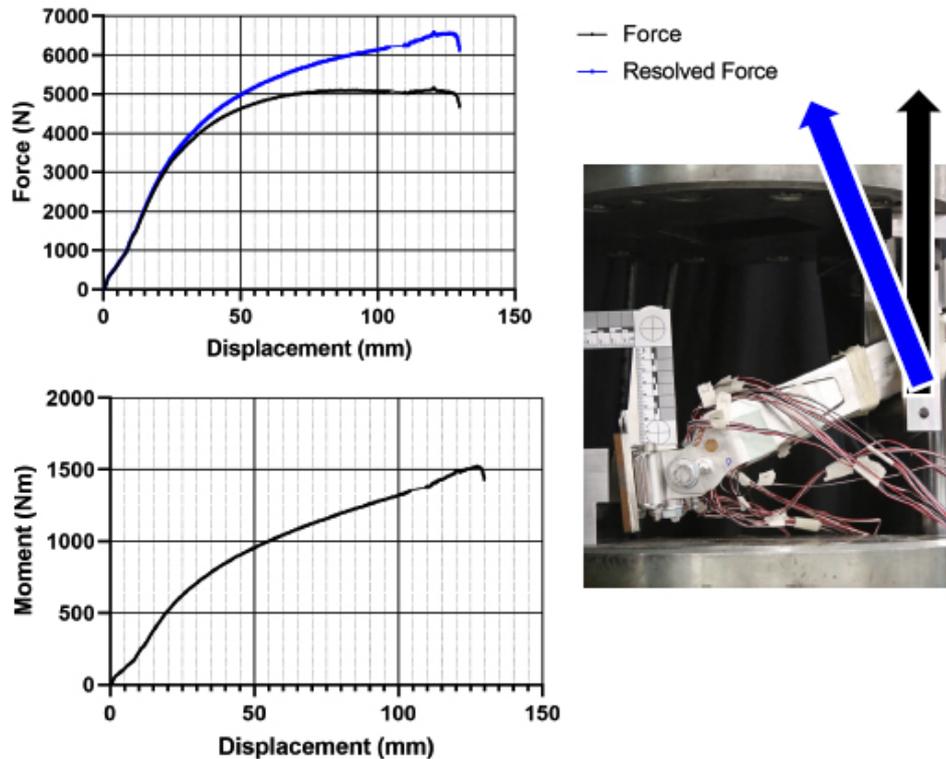


Figure 30

Raw data test results showing the resolved force (blue) and moment acting on the gimbal block (black)

The test showed that the gimbal block failed under a moment of 1,500 Nm.

Post-test inspection

Inspection of the components following the test showed that the roll stop bar had plastically deformed, matching the profile seen on the accident mast.

CT scans of the mast following the test confirmed that the bar had deformed slightly more than the accident mast, with the displacement from straight at the centre measuring 3.3 mm compared to 2.5 mm on the accident mast. The side plates were deformed outwards similar to the accident mast and the roll stop bar welds had failed on both sides, producing the same large gaps between the bar and the plate locating hole on the concave side of the bar (Figure 31).

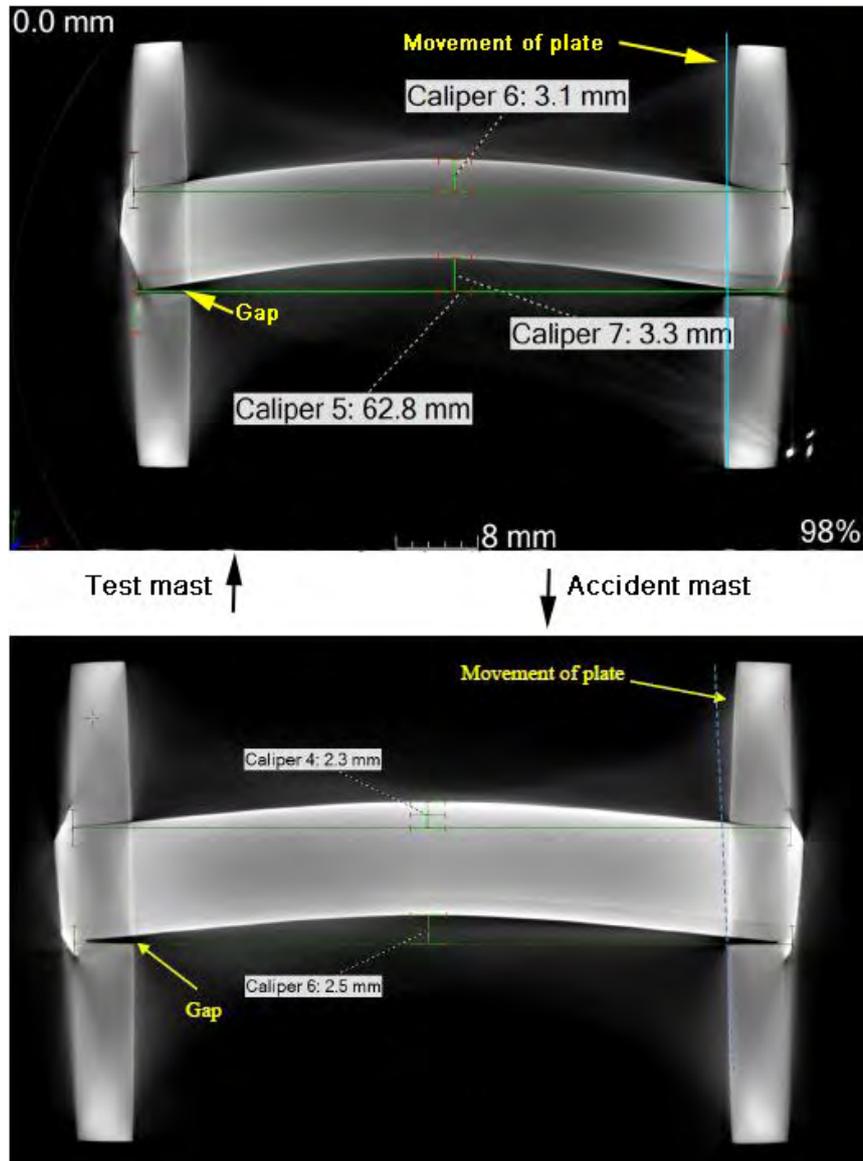


Figure 31

Plastic deformation of the roll stop bar post-test (top)
compared with the accident mast (bottom)

The gimbal block had also failed in a similar manner to the accident block, though as the force applied was only in the horizontal plane, only the vertical cracks were present. However, they were located in the same positions and had progressed to similar extents. Figure 32 shows this by highlighting the same cracks with the same-coloured arrows. It also shows the identical indentation marks and distortion left on the side of the channel by the roll stop bar.

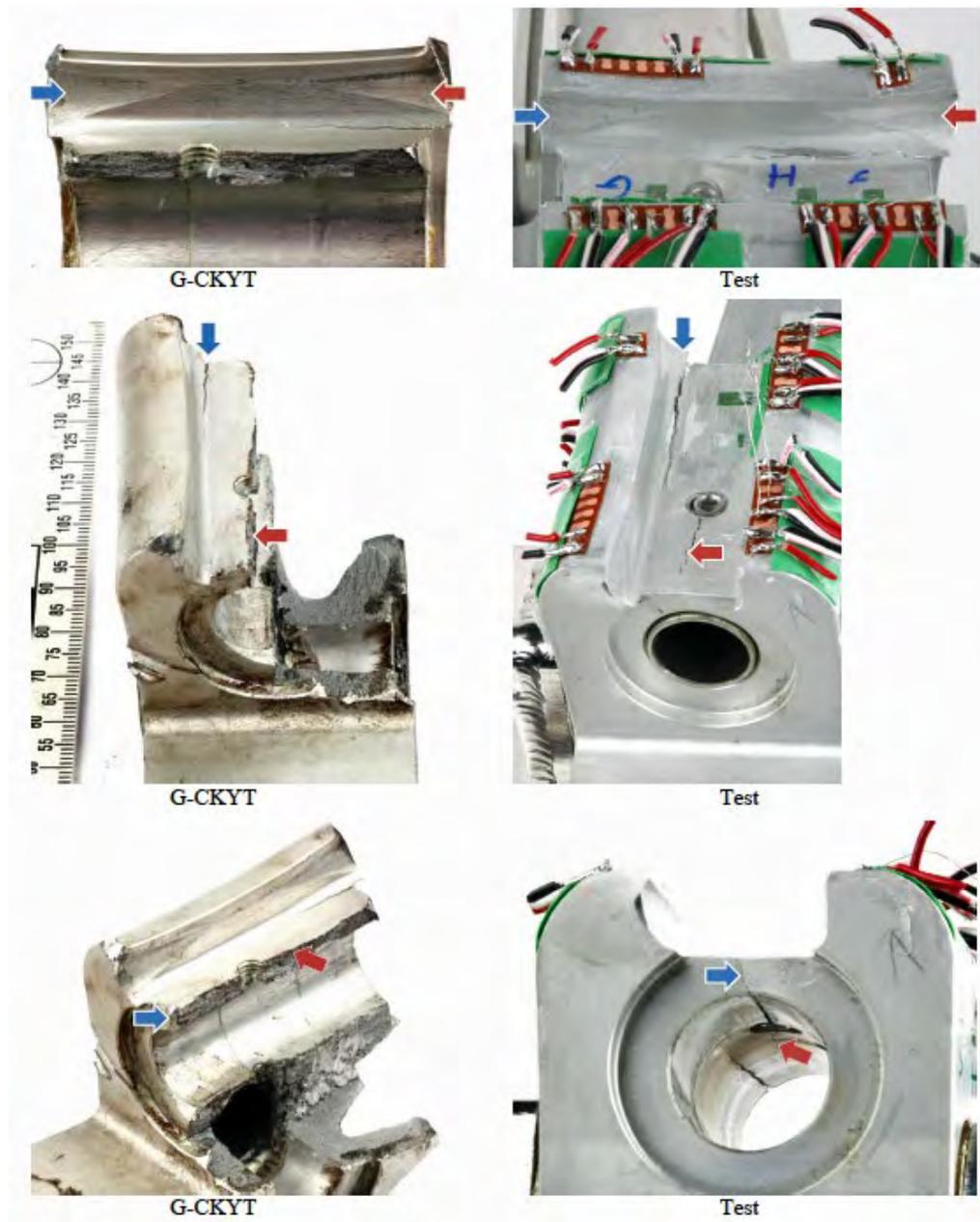


Figure 32

Cracks in the gimbal block post-test compared to the same cracks seen on the accident gimbal block

The brackets holding the gimbal block to the test rig had also deformed in a similar manner to the ones from the accident, with the same elongation of the bolt holes. The brake block assembly also showed the same rotational distortion.

Load analysis

Assessment of the load at which the damage occurred to each component was calculated based on the data from the strain gauges. The roll stop bar started to plastically deform under a moment or torque of 300 Nm. A theoretical calculation for the bar material shape

and strength indicated that a simply supported beam (not fixed at either end) would start to yield at a load of 7.7 kN or 140 Nm of torque in this application. This demonstrated that the welds restrained the bar to some extent. However, the theoretical calculation for a fully supported beam (completely held at both ends) shows it would have sustained 90 kN or 1,620 Nm before it yielded in plastic deformation.

The indentations formed on the side of the gimbal block channel where the roll stop bar was in contact with it, resulted from a torque of 1,500 Nm or an 83 kN load being applied. Due to the distortion of the bar, this was effectively transmitted as a point load of approximately 41.5 kN on each end of the roll stop bar. If this load was applied to the gimbal block material with a Brinell Hardness test indenter, it would result in spherical dents of diameter 7 mm. The sizes of the indentations on the gimbal block were 5 mm at the forward end and 6 mm at the aft end. This shows a similar order of magnitude. The difference in size can be explained by the fact that the bar was continuing to bend under load, resulting in the maximum point of stress continuously moving and the load increasingly acting tangentially to the block, unlike the indenter which applies a constant, perpendicular load. The widest parts of the indentations on the accident gimbal block were obscured by secondary damage, so it was not possible to do a direct comparison.

The gimbal block failed at an applied load of 83 kN during the test. A theoretical calculation based on the material thicknesses at the crack locations and the quoted Ultimate Tensile Strength (UTS) of the material, suggest that this load should have been 91 kN or 1,642 Nm. Possible reasons for the discrepancy are:

- Features of the gimbal block, such as the grub screw hole acting as a stress raiser.
- A reduction in the UTS due to the material grain orientation used in the gimbal block.¹⁹
- The radii of the gimbal block corners acting as stress raisers.

Test conclusion

The results from the test showed that the load transfer through the gimbal block was quite complex, but that the test closely replicated the damage to the gimbal block retrieved from the wreckage of G-CKYT. Although only torque loads transferred through contact between the mast roll stop bar and the gimbal block were applied during the test, the damage seen on the gimbal block, support plates and mast, demonstrated that this contact had also occurred during the accident sequence.

Footnote

¹⁹ The gimbal block is extruded aluminium, which gives a longitudinal grain orientation. The maximum UTS is achieved in this direction. In the transverse direction (90° to the grain) the UTS typically reduces by 15-20%.

Analysis

Physical and eyewitness evidence confirmed the rotor head of G-CKYT separated in flight, causing the fuselage to fall to the ground in a non-survivable accident. The impact resulted in a post-crash fire, following ignition of the highly flammable fuel released by the disruption of the fuselage structure. The investigation centred on determining the cause of the separation.

There was no evidence of the pilot suffering any in-flight incapacitation. He had already completed two flights that morning, the preceding flight lasting over an hour. Despite this, the student had rested between flights and had not displayed any signs of fatigue to his instructor.

The instructor assessed the weather conditions as suitable for the student's solo flights, with only light winds along the runway at Inverness Airport. The instructor regarded winds aloft to be 'not challenging' while the Met Office described the conditions as 'benign' in their aftercast. The possible temporary increase in wind speed reported in the TAF was not due to occur until after the student's return. The forecast wind speed aloft was not considered a problem by the instructor who had considerable experience operating in the area. The student had made no adverse comments on his return from his previous flight, not long before, and there was no evidence of the conditions causing him a problem. The pilot of the aircraft that had flown through the same area as the gyroplane over Black Isle only shortly before the accident, and at a similar altitude, had also reported smooth flying conditions.

Due to the disruption caused by the impact, it was not possible to determine whether the ballast had shifted during the flight. Equally, it was not possible to determine whether during the accident sequence the pilot had reverted to fixed wing flying techniques. Whilst both are possible, it is considered that these and the other operational factors are unlikely to have directly contributed to the accident.

The investigation determined the aircraft had been correctly released to service with no contributory maintenance issues identified.

Gimbal block failure sequence

A rig test conducted by the investigation applied a load to the left side of the gimbal block roll stop channel, by rotating the mast about the roll pivot bolt until the roll stop bar pressed against it. As the force with which the bar pressed against the gimbal block was increased, the welds locating the roll stop bar in the mast side plates failed. This allowed the ends of the bar to move, which meant the roll stop bar now started to bend. As a consequence of this change in shape, the loading on the gimbal block changed from being evenly distributed along the length of the roll stop bar, to being focussed on the two contact points at each end. This significantly concentrated the load, resulting in indentation marks forming in the aluminium of the gimbal block. As the load continued to increase, cracks started to form in the block and at a load of 83 kN (1,500 Nm torque applied at the mast) the block was no longer able to resist the applied force.

Laboratory analysis of the failed rotor head components identified very characteristic damage to the gimbal block, including indentations and distortion on the left side (looking forward) of the roll stop channel and vertical and horizontal fractures through the body of the block. Detailed inspection of these fracture surfaces confirmed they were caused by continuous overload from an applied force greater than the UTS of the material. The roll stop bar on the mast was also distorted and the welds attaching it to the mast side plates had failed on both sides. In addition, the support brackets between the block and bridge, and those which held the brake block, showed twisting deformation resulting from a torque load.

The damage to the gimbal block and mast from the test closely matched that seen on the accident gimbal block and mast. The differences were considered to be due to the fact that the test was stopped before complete fracture of the block (for safety reasons) and that only the torque (or rotational) load component from contact between the mast roll stop bar and the gimbal block was applied during the test.

The indentations, deformation and fracture damage seen on the gimbal block, the twisting deformation of the support plates, and the deformation of the mast support plates, welds and roll stop bar, all demonstrated that the same contact between the roll stop bar and the gimbal block had occurred during the accident sequence. The damage also demonstrated that the resulting loads had been the likely cause of the vertical crack features seen on both the accident and rig test blocks.

While there would almost certainly have been a difference in the rate at which the load was applied between the accident flight and the rig test, this would not have affected the response of the material and as such could be discounted.

In flight, the gyroplane fuselage hangs from the roll pivot bolt fitted to the gimbal block. This also applies a vertical component to the force on the gimbal block equal to the weight of the fuselage (Figure 33). The damage to the accident gimbal block showed both vertical and horizontal fracture surfaces, with the vertical cracks occurring first, as seen in the rig test. Analysis of the fracture surfaces confirmed the overload had occurred during a single continuous event. As the cross-sectional area of the block carrying the weight of the fuselage was reduced by the vertical cracks during the accident flight, the horizontal cracks also formed due to overload. These cracks joined together resulting in a section of the gimbal block breaking off (Figure 33), allowing the rotor to detach from the fuselage. The separation of the rotor head was therefore caused by a structural failure of the gimbal block from exposure to dynamic flight loads during a single event.

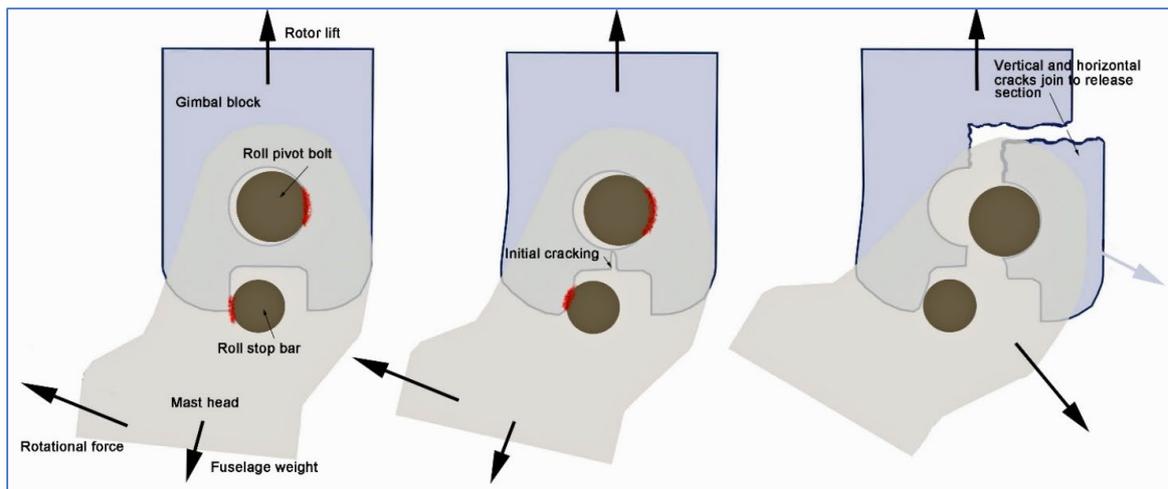


Figure 33

Simple illustration of the final failure sequence of the gimbal block

Flight sequence north of Avoch

The student performed a turn north of Avoch prior to tracking towards Munloch Bay. Radar data from the previous flight also shows that the student performed a number of orbits both to the left and right throughout the flight.

The turn north of Avoch was at an estimated bank angle of 30° which was considered by the instructor to be a 'normal' turn. However, during the turn, the airspeed fluctuated between approximately 50 and 92 mph and the altitude reduced by 193 ft. Vertical speed also fluctuated, reaching up to 1,000 ft/min and, as the turn was completed, the aircraft was descending at approximately 500 ft/min with an increasing airspeed.

This indicated that the student was having difficulty keeping the aircraft level and at a constant airspeed, which may not be considered unusual for a student pilot. However, his training record did not indicate that he had a history of issues with the accuracy of his flying, and it is possible that the student may not have been attempting to maintain specific parameters as closely as might be the case with an instructor on board.

Flight sequence leading to failure

The wreckage trail identified an approximate point by which time the rotor head must have already detached from the mast. This was around the time when the recorded data recovered from the GNSS became unreliable.

Immediately prior to this, the student pilot had performed a turn which started at an estimated bank angle of 35-40° to the left, but then increased up to approximately 45°. From the instructor's comments, 45° was considered to be a 'steep turn'. While the bank angle was an estimate, it confirms this turn ended steeper than the earlier turn to the right over Avoch and likely required the application of significant backstick to prevent the nose dropping. This would have increased drag, requiring more engine power to maintain height, probably close to full power. These inputs required coordination to achieve a level turn.

The instructor had not explicitly briefed the student to use only up to 30° angle of bank and had formed the expectation that he would limit himself to this. The instructor believed that this limitation was implicit in his briefings to '*fly around the Black Isle*' to gain more experience of handling the gyroplane.

During the final left turn, the recorded data shows that the student pilot had allowed a rate of descent to develop in the initial part of the turn, which was then reversed to a moderate climb. As the turn continued, the vertical speed in the climb reduced, possibly due to the student pilot relaxing the back pressure on the control stick in anticipation of rolling out of the turn.

Just before the structural failure, the aircraft rolled from a left turn directly into a right turn which would have resulted in the fuselage starting to swing from the right to the left (viewed from behind). By this stage, a recorded instantaneous rate of descent of nearly 1,500 ft/min had developed which was above the rate by which the student would have previously recovered during training and by which the instructor would have expected recovery action to have been taken.

The student's training record indicated that he actively participated in the training feedback process and demonstrated an awareness of the importance of flying within the POH guidance. A level turn, if flown accurately, should not in itself have been hazardous and there was no evidence to suggest the student would deliberately choose to enter a manoeuvre that would result in a high descent rate or low g. It is therefore considered likely that the sequence of manoeuvres inducing a high rate of descent was an inadvertent result of the pilot's difficulty in maintaining a level turn.

The recorded rate of descent continued to increase, reaching approximately 3,200 ft/min two seconds later; a higher descent rate than would be achievable in normal operation. Given the final position of the fuselage, the recorded track data and the limitations in rate of descent achievable for an intact Cavalon, the investigation determined that the very high rate of descent seen in the data, if accurate, most likely occurred after the rotor became detached.

Failure sequence

It was not possible to determine the exact point of failure of the rotor head but, based on the recorded data, from 1249:43 hrs onwards the vertical acceleration was decreasing below 1 g as the aircraft rolled from the left into the right turn. The combination of reducing bank angle and reducing vertical acceleration identified by this analysis suggests that the rotor head was unloaded enough for a few seconds as the pilot transitioned between left and right roll manoeuvres to initiate the sequence of reactions which likely resulted in critical contact between the gimbal block and the roll stop bar. Though not identical, given the variation in assumptions used, the accident sequence was consistent with the DLR's theoretical modelling. This demonstrated that even with vertical accelerations above '*near weightless*', the torque from an engine at high power causes an induced rotation of the fuselage clockwise about the roll pivot bolt to the extent that there is insufficient roll authority to correct it.

When the gyroplane transitioned between the left and right roll, the fuselage would have swung across with significant momentum. The torque induced rotation of the fuselage would probably have felt to the pilot like an uncommanded roll to the right, likely triggering an instinctive left roll input to counter it. This input would have changed the angle of the rotor relative to the horizontal. The lift and gyroscopic force and the weight of the rotor assembly opposing it effectively acts at the rotor pivot bolt which is a fixed distance away from the roll pivot bolt. The gyroscopic forces, the horizontal component of the lift and the weight vector would therefore create a moment around the roll pivot bolt and thus the contact point between the gimbal block and the roll stop bar. This would act to oppose the moment created by the fuselage rotating in the opposite direction, driven by the engine torque and inertia. This would likely have resulted in an impact between the bar and the gimbal block channel sufficient to generate the force required to cause the block to fracture, as confirmed during testing (Figure 34).

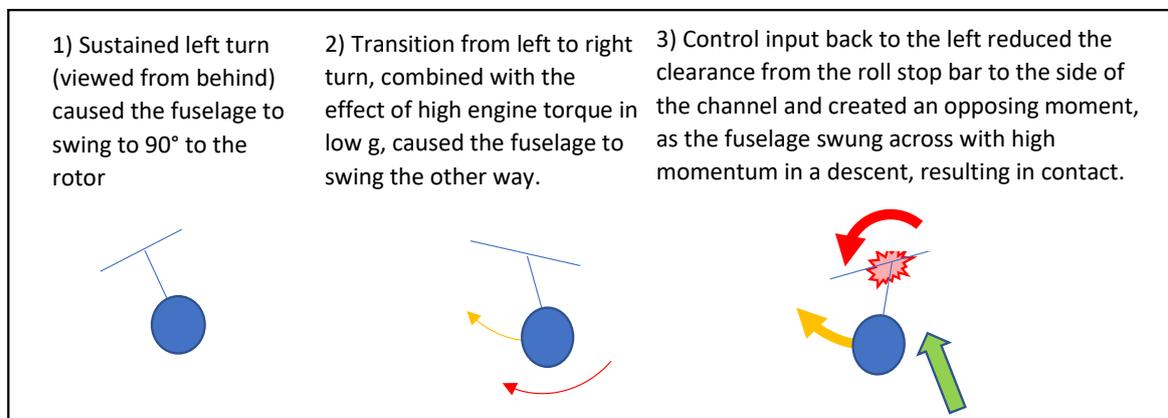


Figure 34

Response of the fuselage to the roll reversal inputs

Blade flapping

It is possible under very low to zero g conditions that the rotor rpm can reduce to the extent that blade flapping occurs leading to contact between the blades and the teeter stop as the blade flaps downwards on the retreating side. If this is allowed to continue it can reach the stage where loss of control of the rotor head occurs. However, this level of blade flapping is more typically experienced on the ground when the rotor rpm starts off low before decaying further.

There were superficial marks on the accident rotor blades showing that contact with the teeter stops had occurred, however they were different on each blade which is inconsistent with blade flapping and there was no plastic deformation of the blade surface, or the teeter stops. They were, however, consistent with other damage on the blades which occurred as they hit the ground following release from the gyroplane. Given that rotor rpm increases during a steeply banked turn, and the period of low g in question was very brief, it is also unlikely that it had reduced sufficiently as the rotor unloaded to make blade flapping a factor in this accident. This is reflected in the DLR modelling which shows that even over a period

of 8 seconds below 1 g and reducing to a minimum of 0.3 g, the rotor rpm does not drop outside of the normal operating range. As with normal operation the forces generated by the rotor react through the rotor pivot bolt without requiring contact of the teeter stops.

Roll stop bar welds

The manufacturer stated that the roll stop bar and gimbal block were not intended to come into contact in flight and as such the welds on the roll stop bar were not designed to carry any significant load. However, the welds inspected were generally of poor quality with regard to size, shape and consistency. The design drawing for the mast assembly specified a fillet weld, but did not specify the throat size of the weld required. As such, there was no consistency in the strength of the weld and no easily measurable quality inspection criteria which could be applied to the welds during production without conducting x-ray inspections²⁰. None of the welds inspected on the accident or test mast met the basic requirements for the definition of a fillet weld and could not meet the minimum fillet weld throat size recommended by the European welding standards, because the roll stop bar length was specified to be too short by the design. The roll stop bar on the mast supplied for testing did not meet the drawing requirements for the bar length and the production process required part of the weld to be intentionally machined away to accommodate the washers on the roll pivot bolt, further reducing its strength.

While not causal to the accident, a key element of the failure sequence of the gimbal block was the failure of the welds holding the roll stop bar in position. Rather than being structural welds, they effectively just located the bar in position and failed under a relatively low load. Theoretical analysis showed that had full strength welds been used, they would have remained intact under a much greater load, the roll stop bar would then not have started to deform at a low load, maintaining an even distribution in the load transferred to the gimbal block and allowing the combined structure to support a load greater than that which failed the block in the practical test. While it was not possible to determine the exact load that was experienced by the gimbal block and mast during the accident, it can be stated that had full strength welds been present, the capacity to withstand contact loads between the gimbal block and the roll stop bar would have been greater, providing an increased safety margin in the event of unintended contact.

Contact between roll stop bar and gimbal block in flight

The conical impressions on the side of the gimbal block channel resulting from contact with the roll stop bar seen on the accident block, had also been seen previously in several takeoff accidents on this gyroplane type. Although the reasons for contact in these scenarios were different from the accident flight, it appears the consequences of the contact were not investigated any further. The manufacturer stated that contact was not intended to occur in flight and as such there was no requirement to consider it or design the structure to be strong enough to resist it. This approach is supported by the wording of the relevant certification requirement T675, which only requires the control stop to withstand loads intentionally applied by the control system design.

Footnote

²⁰ X-ray inspections were not used as part of the production process.

Roll control inputs under normal circumstances are small and within the 8° of clearance available. Equally under normal rotor load factor (≥ 1) the fuselage would rotate perpendicular to the rotor in a turn, maintaining the clearance rather than being subject to engine torque induced rotation in the opposite direction. This investigation showed that there is a transition point where contact can result. The lack of any previous record of other complete failures of the gimbal block would suggest the degree of contact between the roll stop bar and gimbal block which resulted in the accident was unusual.

Contact between the gimbal block and roll stop bar whilst airborne was not considered during the design of this type of rotor head. A minimum threshold force is required to leave a permanent impression in the gimbal block material if contact does occur. There is no inspection requirement in place to capture in-flight contact events, and inspection of the gimbal block is only routinely conducted after a ground contact. Damage to the gimbal block, if found during generic maintenance, would likely result in the gimbal block being rejected. However, there are no specific inspection criteria in the maintenance programme, or as the result of an in-flight event, targeted at finding gimbal block damage, identifying and recording the fact it had occurred in flight. Thus, there is no record of the reason for replacement of damaged gimbal blocks that would provide supporting evidence on the frequency of in-flight occurrences. As such, there was no evidence available to the investigation, other than the accident flight, to confirm under what exact circumstances contact to any extent could occur in flight on gyroplanes fitted with the Rotorkopf III design. The small control angle range of 8° and the undamped, free rotation of the fuselage around the roll pivot bolt means that, other than through the actions of the pilot, there is nothing to prevent contact occurring. Yet there is no means of indicating to the pilot how much margin to contact remains, nor any warning for the pilot of when contact is occurring. The manufacturer stated that they did not design the mast and gimbal block interface to be able to withstand a specific contact force because they did not anticipate contact would occur in flight. However, there is no supporting data to assess what safety margin from contact (if any) is provided during flight within the approved envelope, what manoeuvres flown with what parameters could result in inadvertent contact, or what loads on the gimbal block could result from contact if it does occur. As such, it was not possible to assess whether the manufacturer's approach was reasonable.

Additionally, there is no specific requirement within BCAR Section T which addresses whether unintended control stop contact should be anticipated in flight nor what level of load the structure should withstand, if the possibility of unintended contact cannot be definitively excluded. Based on the evidence available to the investigation, it appears that the manufacturer's approach to the issue of contact has been accepted by the airworthiness authorities without comprehensive supporting evidence.

The investigation has determined that this accident likely resulted from a flight manoeuvre which was initially within the approved envelope of the gyroplane but then, likely inadvertently, resulted in a vertical acceleration of less than 1 g. This led to induced torque rotation from the engine which, combined with a reversal of the roll direction, resulted in catastrophic contact between the gimbal block and the roll stop bar.

The negative load factor element of the structural requirements was not demonstrated by test, but was based on a theoretical assessment of a simple assumed load path. Whilst the POH prohibits conducting low g manoeuvres, it doesn't specify the exact margin below 1 g where the risk of damage exists. The POH quotes structural limits of -1 g and -0.5 g but emphasises the need to respect the in-flight operating limits at all times. The in-flight limits are, however, not specific and refer only to 'low g' and 'near weightlessness'. This may lead a pilot to assume the stated structural limits provide a safe margin with regard to the risk of component failure. Operating within these limits also relies on the pilot's ability to assess g without reference to a suitable indication or warning system, neither of which are installed on the aircraft. The investigation found no supporting research data to determine how accurately a pilot can sense g values less than 1 g to support this approach.

Mitigation of risk of contact

There are typically three generic risk mitigation routes which are used within aviation, either individually or in combination. These are:

1. Operational limitations.
2. Structural design and testing.
3. A safety case based on probability of occurrence demonstrating a failsafe design.

Applying these to the specific issue of contact between the gimbal block and the roll stop bar would require the following:

- 1) Publishing evidence based, detailed and specific operational limitations, including an appropriate safety margin, which if observed will ensure damaging contact does not occur, and providing the necessary indication or warning system to ensure pilots can accurately operate within those limitations. This approach will also require a supporting training syllabus and guidance material to increase awareness of how to conduct approved manoeuvres within the published limits and the correct recovery techniques to avoid unintended exceedances.
- 2) Defining limit and ultimate loads for the gimbal block and mast, using an appropriate safety factor and based on the highest dynamic loads which can be encountered from any level of contact between the roll stop bar and gimbal block resulting from manoeuvres within the approved flight envelope. This should take account of inadvertent contact which can be reasonably foreseen from conducting approved flight manoeuvres with a defined margin of handling error or inaccuracy. All components should be designed and tested to demonstrate that they meet these defined load requirements without permanent deformation in the case of limit load or without failure for ultimate load.

- 3) Compilation of a system safety assessment which demonstrates that based on supporting evidence the probability of occurrence of catastrophic contact between the gimbal block and the roll stop bar is extremely improbable and does not result from a single cause, and that hazardous contact is extremely remote.

However, option three is based on the common certification regulation 1309 found across both EASA and FAA certification requirements for fixed and rotary wing aircraft. It is typically used for assessing the reliability of system operation but can take account of the structural implications of a failure of that system. Given that there is nothing in the control system or operating limitations to prevent contact with the control stops and no supporting evidence that contact cannot occur under normal operation, such contact cannot be considered a failure of the system. Requirement 1309 is also not included or referenced in BCAR Section T. This effectively precludes option 3 as an appropriate mitigation in this case.

When this accident was discussed with the CAA, they stated that their preference was to avoid pilots operating in any flight phase where contact with the roll stops could occur. This is a valid approach to mitigate the risk of structural failure, but as highlighted in paragraph 1) above, it requires limits to be well defined, identifiable by the pilot in flight with relevant training provided.

The investigation recognises that this issue may not be unique to the Rotorkopf III rotor head and may affect a number of other gyroplane designs with a simple roll pivot rotor head design. However, as the accident occurred to a gyroplane fitted with the Rotorkopf III rotor head, a recommendation relating to this specific rotor head is appropriate. To ensure that actions to mitigate the risk of contact are both independently assessed as adequate and mandated where appropriate, the following recommendation is made to the UK CAA as the regulator responsible for continued airworthiness of all models of gyroplanes fitted with the Rotorkopf III certified under BCAR Section T.

Safety Recommendation 2024-017

It is recommended that the Civil Aviation Authority introduces mitigations to reduce, as far as reasonably practicable, the risk of a catastrophic failure resulting from contact between the gimbal block and the roll stop bar on all gyroplanes fitted with the Rotorkopf III rotor head and those of similar design.

In order to address similar risks which may exist in other gyroplane designs submitted for certification in the future the following Safety Recommendations is made:

Safety Recommendation 2024-018

It is recommended that the Civil Aviation Authority reassess the requirements and acceptable means of compliance in BCAR Section T for issuing approvals to gyroplanes, in light of the failure mode identified from the dynamic loading of the gyroplane rotor head in flight, to ensure manufacturers demonstrate to an acceptable level, through appropriate test and/or analysis, mitigation of the risk of catastrophic structural failure from dynamic loads in flight.

Pilot training and awareness

The investigation highlighted the criticality of pilot awareness of the load factor being applied to the rotor during all flight manoeuvres. Training is an essential element of building this awareness, however, the investigation also identified that there was no relevant guidance for gyroplane instructors and examiners in Standards Document 44. Therefore, to ensure standardisation of training delivery and examination of the subject of low g manoeuvres in gyroplanes, the following Safety Recommendation is made to the CAA.

Safety Recommendation 2024-019

It is recommended that the Civil Aviation Authority publishes guidance on the subject of rotor load factor during flight manoeuvres for the theoretical training and testing of pilots undertaking the gyroplane PPL syllabus and the gyroplane instructor and examiner qualifications.

Certification

G-CKYT was certified as a permit aircraft, which has the lowest level of airworthiness design validation and as such is subject to commensurate limitations on its operation. Given historical issues around the safety of gyroplane designs, for use in the UK, the Cavalon was required to comply with certification requirements specified in BCAR Section T. The introduction to BCAR Section T is clear that it is only intended for use in certifying permit aircraft, and this is reflected in the relatively simple specification and compliance requirements it contains. This was typified by structural requirement T337, which only required the consideration of limited vertical static loads and the use of a simple static test to demonstrate compliance. This contrasts with the testing and analysis which models the more complex real-world dynamic response and associated complex structural loads necessary to obtain a full type design approval under EASA CS-23 or CS-27.

However, in the case of the Cavalon Pro, BCAR Section T was also used as the basis for issuing a Certificate of Airworthiness, which allows the aircraft to be used for commercial work. This change in purpose normally increases the analysis and testing requirements imposed on a design and would typically be associated with more stringent and demanding certification compliance requirements. For the Cavalon Pro this did result in some additional compliance requirements added through CRI E-01, but structurally the Cavalon Pro is the same design as the basic Cavalon, and no additional compliance testing was required to certify it.

The manufacturer stated that they extensively compared the requirements in BCAR Section T with those of EASA CS-VLR, which is used to issue Certificates of Airworthiness on very light helicopters. The CAA and the manufacturer presented a case that a comparison with the requirements of EASA CS-VLR is a more appropriate benchmark, given the size and weight of the gyroplane. However, EASA CS-VLR is also a simplified airworthiness code used for certifying light helicopters which are primarily used for leisure and pilot training activities only. As the Cavalon Pro is intended for commercial use, a comparison with EASA CS-27 or CS-23 is considered more appropriate.

This accident demonstrated that catastrophic structural failure could occur from flight loads which are encountered inadvertently by the pilot, because such scenarios were not adequately defined and analysed during the certification process, due to the simplified requirements of BCAR Section T. The investigation considered that this represents a safety concern for aircraft intended for commercial operations. As such, the following Safety Recommendation is made:

Safety Recommendation 2024-020

It is recommended that the Civil Aviation Authority reassess the certification and acceptable means of compliance requirements for issuing Certificates of Airworthiness to gyroplanes intended to be used for commercial operations, to ensure manufacturers demonstrate, through appropriate test and analysis, mitigation of the risk of catastrophic structural failure from dynamic loads to a level comparable with equivalent Certificate of Airworthiness aircraft certified to design regulations such as Certification Specifications 23 and 27.

Component conformity

The investigation identified differences between the approved design drawing and components released for service on both the accident mast and the mast supplied by the manufacturer for testing. These differences related to the roll stop bar length and installation welds.

It is a fundamental airworthiness requirement that production parts conform to the drawing which defines the approved certification standard. Non-conforming parts must either be rejected by a manufacturing quality control inspection or have an appropriate production permit or concession documented before they are released to service. There was no evidence identified that either was the case for these components inspected as part of the investigation. The manufacturer responded that they did not consider the issue to be an airworthiness concern.

As this finding was not determined to be causal to the accident, and was based on examination of only two masts, it was considered outside the scope of the investigation to assess whether non-conforming parts had been released to service and what airworthiness risk that may pose. Assessing the implications of this finding and any necessary mitigation falls within the oversight role of the relevant airworthiness authorities. For gyroplanes certified and manufactured to UK requirements, design and manufacturing oversight is the responsibility of the CAA.

Conclusion

The accident occurred when the gyroplane rotor head separated from the mast in flight. Forensic analysis of the failed gimbal block and mast confirmed that the separation was caused by a structural overload failure of the gimbal block from a single continuous exposure to dynamic flight loads.

Testing and analysis of a new production mast and gimbal block closely replicated damage seen on the accident mast and gimbal block, demonstrating that the same contact between the roll stop bar on the mast and the side of the channel on the gimbal block had occurred during the accident.

Factual evidence from the accident site and recorded data, together with engineering and operational analysis, allowed the investigation to identify that this contact sequence, and the loads resulting from it, most likely occurred because of the difficulty experienced by the student pilot in consistently flying a level turn to the left, followed by a reversal to the right. This inadvertently resulted in a vertical acceleration below 1 g, briefly unloading the rotor and allowing an unopposed rotation of the fuselage around the roll pivot bolt due to the torque of the engine.

Modelling and analysis have shown that contact with the roll stops can occur with this specific sequence of manoeuvres in a flight regime above the 'low g' or 'near weightlessness' limits defined in the POH.

The gyroplane was found to have been correctly released to service with no maintenance issues identified relevant to the accident. A number of operational factors were considered and it was likely that the pilot inadvertently allowed the aircraft to enter a low g flight regime close to, or potentially exceeding, that prohibited by the Cavalon POH.

Whilst fully compliant with BCAR Section T regulations, the accident highlighted limitations in the design, testing, manufacture and operating limitations for the Cavalon and Cavalon Pro gyroplane types. These limitations are also likely to be relevant to other gyroplane types certified to this standard. The investigation also highlighted issues with the gyroplane training material regarding the awareness of rotor load factor by pilots. Four Safety Recommendations have been made to address these issues.

Safety Recommendations

Safety Recommendation 2024-017

It is recommended that the Civil Aviation Authority introduces mitigations to reduce, as far as reasonably practicable, the risk of a catastrophic failure resulting from contact between the gimbal block and the roll stop bar on all gyroplanes fitted with the Rotorkopf III rotor head and those of similar design.

Safety Recommendation 2024-018

It is recommended that the Civil Aviation Authority reassess the requirements and acceptable means of compliance in BCAR Section T for issuing approvals to gyroplanes, in light of the failure mode identified from the dynamic loading of the gyroplane rotor head in flight, to ensure manufacturers demonstrate to an acceptable level, through appropriate test and/or analysis, mitigation of the risk of catastrophic structural failure from dynamic loads in flight.

Safety Recommendation 2024-019

It is recommended that the Civil Aviation Authority publishes guidance on the subject of rotor load factor during flight manoeuvres for the theoretical training and testing of pilots undertaking the gyroplane PPL syllabus and the gyroplane instructor and examiner qualifications.

Safety Recommendation 2024-020

It is recommended that the Civil Aviation Authority reassess the certification and acceptable means of compliance requirements for issuing Certificates of Airworthiness to gyroplanes intended to be used for commercial operations, to ensure manufacturers demonstrate, through appropriate test and analysis, mitigation of the risk of catastrophic structural failure from dynamic loads to a level comparable with equivalent Certificate of Airworthiness aircraft certified to design regulations such as Certification Specifications 23 and 27.

Bundesstelle für Flugunfalluntersuchung (BFU) comments

Standard 6.3 of Annex 13 to the Convention on International Civil Aviation provides that the State conducting the investigation shall send a copy of the draft Final Report to all States that participated in the investigation, inviting their significant and substantiated comments on the report as soon as possible. If the State conducting the investigation receives comments within the period stated in the transmittal letter, it shall either amend the draft Final Report to include the substance of the comments received or, if desired by the State that provided comments, append the comments to the Final Report.

The BFU, representing the state of design and manufacture, provided comment on the draft Final Report. The BFU Accredited Representative, stated that in their opinion the failure of the rotor was a direct consequence of a complete and unrecoverable loss of control of the gyroplane. As such, the flight loads which resulted in the failure were outside of the design requirements and neither the current design of the Cavalon nor the certification regulations require amendment as a result of this accident. They stated that in their opinion the loss of control of the gyroplane was a result of the actions of the pilot.

Several adjustments were made to the report as a result of comments received during the consultation process. However, the investigation did not find evidence indicating a complete and unrecoverable loss of control before the catastrophic failure of the rotorhead, and so this point of disagreement is appended to the Final Report.

Appendix - BFU statement

**Bundesstelle für
Flugunfalluntersuchung**
German Federal Bureau of Aircraft Accident Investigation



Braunschweig 11. May 2024

Appendix to the report:

Accident to Rotorsport UK Cavalon, G-CKYT, at Farm land between Avoch and Munloch, IV9 8RP on 12/11/2020 12:53 TRAK:0314001107

BFU File NO: 20-0979

The BFU sees its role as accredited representative for the German manufacturer of the same gyrocopter type (Cavalon) and rotorhead (Rotorkopf III) in question.

The BFU request to append the following sentences according ICAO Annex 13.

The BFU disagrees with the report title, analysis and conclusion of the causes that led to the accident involving the gyrocopter G-CKYT and the planned safety recommendations based on them.

Unlike the AAIB, the BFU sees the breakage of the rotor head as the result of uncontrolled flight attitudes and a loss of control over the gyrocopter as recorded by the accident flight data and the data evaluation.

The BFU sees its opinion supported by the described *flight sequence north of Avoch* and *flight sequence leading to failure*. The rotor head breakage was therefore the result of flight attitudes and flight dynamics outside the expected loads of authorised flight manoeuvres.

The BFU is the opinion that the breakage of the rotor head was a consequence and not the leading cause of the accident.

**Bundesstelle für
Flugunfalluntersuchung**
Hermann-Blenk-Straße 16
38108 Braunschweig

Published: 7 November 2024.

AAIB Correspondence Reports

These are reports on accidents and incidents which were not subject to a Field Investigation.

They are wholly, or largely, based on information provided by the aircraft commander in an Aircraft Accident Report Form (AARF) and in some cases additional information from other sources.

The accuracy of the information provided cannot be assured.

Accident

Aircraft Type and Registration:	Diamond DA 40 NG, G-LDGB	
No & Type of Engines:	1 Austro E4-A piston engine	
Year of Manufacture:	2015 (Serial no: 40.N296)	
Date & Time (UTC):	16 May 2023 at 1445 hrs	
Location:	3 nm north-west of Oxford Airport	
Type of Flight:	Training	
Persons on Board:	Crew - 2	Passengers - 1
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Rear passenger door detached from airframe	
Commander's Licence:	Commercial Pilot's Licence	
Commander's Age:	33 years	
Commander's Flying Experience:	1,700 hours (of which 500 were on type) Last 90 days - 52 hours Last 28 days - 32 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot and further AAIB enquiries	

Synopsis

Whilst conducting an instrument flying training lesson the rear door detached from the aircraft. The instructor inadvertently disengaged the primary locking mechanism whilst pressing the rear door handle to demonstrate to students how to secure it in the event of an in-flight Primary Flying Display (PFD) door warning. The aircraft landed safely and there were no injuries. The Operator undertook a number of safety actions following the event.

History of flight

The flight was an instrument flight training lesson, there was also a passenger, another student, who was to observe for local area familiarity and lesson content. Part of the Operator's checklist for the Diamond DA40 NG requires that the rear door is to be confirmed closed before engine start and before take-off. On both occasions the student pilot and the instructor observed the student in the rear seat check that the handle mechanism of the rear door was in place and apply pressure to the door; all crew members were content the rear door was locked. Furthermore, the door warning light was confirmed to be OFF on the PFD as required the aircraft checklist.

Following a successful take-off and initial departure by the student, control was handed over to the instructor during climb out to enable the student to don the instrument flying hood¹, control was then returned to the student.

Prompted by a routine altitude warning and call out by the student pilot during the climb out, a discussion commenced with the instructor about visual and audio warnings on the PFD. The instructor demonstrated how selecting the pitot heat on would be displayed on the PFD. There then followed a discussion about the most common occurrence being door warnings and how these can be triggered by the door handle being open a small amount. At this point the instructor reached back and pushed on the rear door handle to demonstrate to the students how to secure the door following an in-flight PFD warning that would indicate the door was not closed. As the instructor interacted with the door handle it unexpectedly opened fully.

With the student pilot still flying, the instructor and rear seat student assessed the situation. The rear seat passenger could not reach the door to close it due to the seat restraint harnesses and shortly afterwards the door fully detached from the airframe. The instructor took control of the aircraft, contacted ATC to advise of the situation and was given clearance to land. The return to the airfield, landing and taxi were uneventful and there were no injuries to the occupants. The aircraft is shown below (Figure 1).



Figure 1

G-LDGB with rear door missing (image used with permission)

Footnote

- ¹ IFR Hoods or View Limiting Devices are used by pilots during flight training to simulate flying in the clouds or in poor visibility. It restricts their view so the student can only see the flight instruments, forcing them to fly without any external references to the ground or horizon.

Rear door description and operation

The rear passenger door is a carbon fibre reinforced plastic moulding with inner and outer frames bonded together. The door has an acrylic glass window. Two hinges attach the door to the top of the fuselage near the centreline. A gas strut attaches to the rear of the door and the fuselage which holds the door open on the ground. A handle on the left of the door operates two locking bolts located at the bottom front and rear corners of the door.

An additional safety latch is fitted (Figure 2). The function of this red safety latch is to hold the unlocked passenger door in a near closed position, whilst the aircraft is parked on the ground, protecting the passenger door from wind gusts. It also helps reduce the risk of a passenger door separation in case of an inadvertent opening of the door locking mechanism by a passenger during flight. Although it should be noted that the original design intent of the red safety latch was not to prevent a passenger door from separating from the aircraft because of a failure to lock the passenger door before flight.

The passenger door hinge design provides a predetermined breaking point, strong enough to comply with the certification specification but allowing a passenger door, which was closed, but improperly locked, to separate cleanly from the airframe with minimal damage. If the passenger door swung open and did not separate from the fuselage, reduced controllability of the aircraft would be the consequence.



Figure 2

Rear passenger door handle configuration (image used with permission)

There is a DOOR OPEN warning that activates on the PFD if the primary locking mechanism is not properly located. However, there is no way of demonstrating this warning on the PFD without opening the doors. This warning can be demonstrated in the DA 40 simulator, but the operator did not have this facility.

Operators Investigation

The operator of the aircraft conducted an investigation into the occurrence. This concluded that the instructor wanted to show a common warning annunciation (door not fully closed) to the student whilst in-flight and to do this he intentionally manipulated the handle. The instructor refuted this conclusion and maintained that his intention had been to show the students how to deal with an erroneous door open warning by pushing the door handle to ensure it was secure. The operator's investigation also found that it was likely that the red safety latch was either not fully engaged or was not able to retain the door, resulting in the door opening into the airflow and detaching from the aircraft.

A check of the airframe and the recovered detached door was undertaken by the Continuing Airworthiness Management Organisation (CAMO) which concluded the following: there was no fault with the primary or secondary door locking mechanisms, the door hinges were damaged where the door had been torn away in-flight and there was no evidence of impact damage to the rest of the airframe from the door detaching in-flight.

The operator provided photographs and videos of the detached door and surrounding airframe which showed the locking mechanisms operating correctly and the safety latch retaining block intact. There were witness marks on the top of this block, although these were assessed by the Continuing Airworthiness Organisation as being due to normal wear and tear.

Tests and Research

Research conducted by the Design Organisation (DO) showed that since 2004, there were approximately 80 reports of DA 42 series and DA 40 series airplanes that experienced an in-flight passenger door separation. The investigations into these incidents could not establish a technical reason that would cause door separation. The possibility of pilots not correctly closing doors could not be discounted in many of these investigations and the DO concluded this to be the most likely cause of in-flight passenger door separations.

Nevertheless, over time the design of the involved components, such as the door locking mechanism, safety hook, retaining block on the fuselage, and the composite hinges have continued to be improved to minimize the risk of a technical failure. Although there was no proof that the red safety latch had ever disengaged spontaneously, the DO has also improved the design of the black retaining block on the fuselage, which was introduced to airplanes in the field under a Service Bulletin in July 2010², preventing the red safety latch from slipping past the black retaining block (Figure 3). Furthermore, the geometry of the red safety latch and the black retaining block on the fuselage was improved for aircraft in serial production. Built in 2015, G-LDGB would have benefitted from these improvements.

An investigation in 2011 conducted by the Dutch Safety Board into a rear door separation incident on a DA 40 found that excessive free play on the rear door forward hinge bracket combined with an unlocked door could move the door up at the top front position. This was

Footnote

² This Service Bulletin was covered by EASA Airworthiness Directive 2010-0235 and FAA Airworthiness Directive 2010-25-01 in November 2010.

causing a de-activation of the red safety latch and the door separated from the aircraft. The Aircraft Maintenance Manual now requires hinges to be inspected as part of a scheduled maintenance check and this was carried out on G-LDGB on 17 April 2023.



Figure 3

Red safety latch in engaged position (Image used with permission)

Analysis

Whilst this investigation could not determine the instructor's intent when interacting with the door handle during flight, the instructor's action inadvertently disengaged the primary locking mechanism for the rear door. This allowed the door leading edge to open sufficiently to be pulled open by the airflow and torn off its hinges. There was no evidence found on the recovered door of a technical fault with the primary door locking mechanism. From the evidence available it was also not possible to determine why the red safety latch did not retain the door once the primary locking mechanism was disengaged. The door hinges had been inspected recently so excessive free play of the forward hinge was unlikely to be a factor and the instructor and crew were confident the door was closed properly. However, the red safety latch is not the primary mechanism for securing the door.

Conclusion

The passenger door detached from the aircraft because the primary locking mechanism for the door was inadvertently disengaged by the instructor whilst demonstrating to the student pilot how to respond to potential door warnings in flight. The reason why the secondary mechanism that was designed to help prevent door opening in-flight did not retain the door could not be positively determined.

Safety actions

Following the accident, the operator undertook a number of safety actions:

- Providing clear guidance to crews on the use of the rear door and latches.
- Amendments to the pre-flight check list to include additional testing of the secondary latch during pre-flight checks and a reminder of the importance of reporting any faulty secondary latches as a defect.

Accident

Aircraft Type and Registration:	Rans S6-ES, G-BZKO	
No & Type of Engines:	1 Rotax 912-UL piston engine	
Year of Manufacture:	2000 (Serial no: PFA 204-13564)	
Date & Time (UTC):	26 February 2024 at 1400 hrs	
Location:	Newtownards Airport, County Down	
Type of Flight:	Training	
Persons on Board:	Crew - 2	Passengers - None
Injuries:	Crew - 2 (Minor)	Passengers - N/A
Nature of Damage:	Shattered windscreen and skylight. Right door damaged and cuts in the Dacron fuselage covering	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	75 years	
Commander's Flying Experience:	7,627 hours (of which 10 were on type) Last 90 days - 51 hours Last 28 days - 24 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot and further AAIB enquiries	

Synopsis

The examiner landed the aircraft successfully after the windscreen and skylight assemblies shattered and detached in flight. The cause was not determined but photographs indicated that the skylight installation did not comply with the aircraft build manuals. There is no definitive link between this anomaly and the failure, but this accident is a good reminder to be prepared for the unexpected and to concentrate on maintaining control of the aircraft.

The Light Aircraft Association (LAA) will publish an article highlighting the effects of startle and the need to comply with aircraft manufacturer's construction drawings and assembly methods.

History of the flight

The aircraft had recently undergone an annual check, and the flight was a general skills test to revalidate the owner's licence. The flight was uneventful until the windscreen and skylight shattered without warning shortly after the aircraft recovered from an intentional spiral dive. This startled both pilots, and the in-rush of air blew their headsets off, preventing them from communicating verbally. The examiner checked that the aircraft was controllable and indicated his intention to return to the airfield, which was approximately 10 miles away. The aircraft owner managed to recover the examiner's headset from the baggage compartment, and he made radio calls to the airfield every 30 to 60 seconds. He used his

jacket to shield the microphone against the effect of the wind and, as they got closer to the airfield, they could see the emergency services were prepared for their arrival. The landing was successful, and both occupants were helped from the aircraft having sustained minor injuries. No third parties were reported to have been injured.

Aircraft examination

The owner said that the windscreen and skylight broke into numerous pieces and the majority had departed from the aircraft. The right door was damaged, and the Dacron fuselage material was torn in a few areas where it had been hit by broken parts. Figures 1 and 2 show the aircraft and some of the damage after landing.



Figures 1 and 2

Broken windscreen and torn fuselage coating

The owner's headset was reported to have been found in the rear fuselage, having apparently entered through a hole in the damaged fuselage cover. The owner visited the area where they had been flying and recovered several broken parts from the ground. He said there were no obvious indications of a bird strike.

Aircraft history

The aircraft was first registered in 2000, and the current owner purchased it in 2017. It was repaired by an agency which used LAA inspectors after a forced landing in the same year, and it was returned to the owner in 2018. The invoice showed that the repairs included a replacement skylight and the part number indicated that this was an original equipment manufacturer's part. The owner said the aircraft had accrued around 250 flying hours since the repairs.

Windscreen and skylight information

The windscreen and skylight assemblies are made of Lexan¹. The current aircraft parts catalogue and the build manual show the assemblies are rivetted to the aircraft framework, but 'sandwiched' between foam strips and metallic trim strips (Figure 3). The trim strips under the rivet heads spread the loads over a larger surface area, which reduces the risk of the Lexan cracking around the rivet holes. Photographs of G-BZKO after the accident showed that neither the foam strips nor the trim strips were fitted.

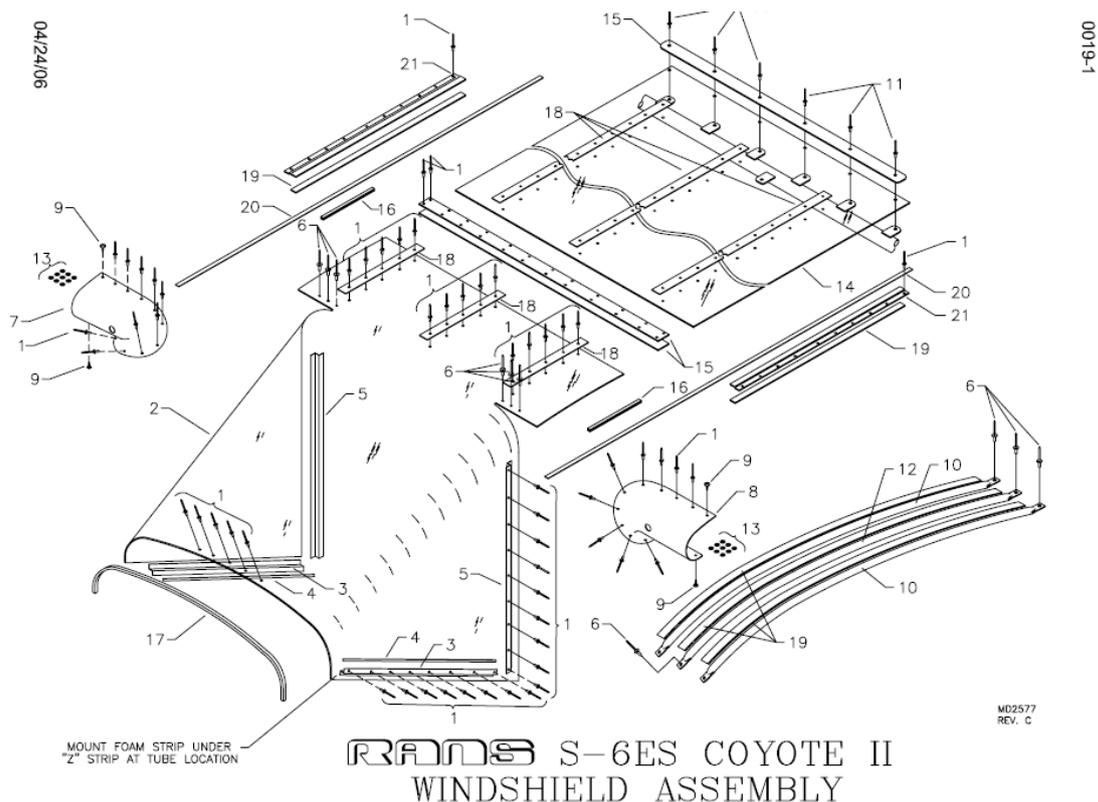


Figure 3

Parts catalogue showing the foam strips (items 19) and the trim strips (items 18)

A build manual from 1991 included a requirement for the foam strips, but there was no requirement for the trim strips. The aircraft manufacturer advised that the trim strips were introduced in 1995 when larger engines were installed, and cruise speeds increased.

Aircraft manufacturer's comments

The aircraft manufacturer said they were not aware of any similar failures in the Coyote aircraft series or any other models they produce with similar glazing installations. They suggested several factors that they believed could contribute to such a failure. These included incorrect rivet hole size, incorrect or embrittled glazing material, incorrect rivets, operating outside the specification (weight and engine performance) and fuel / solvent spills. The aircraft build

Footnote

¹ Lexan is a brand name for a specific polycarbonate product.

manual contains a cautionary note in the general information section: “*CAUTION: Do not allow fuel, acetone, lacquer thinner or Loctite to come in contact with the Lexan glazing. These and some other solvents will destroy the Lexan.*”

LAA's records

The LAA had no records of previous failures in the UK Coyote fleet, or other similar type of aircraft.

Analysis

The indications are that the pilots worked well together after the initial startle effect with the examiner concentrating on flying the aircraft whilst the owner did his best to alert the airfield of their problem. Using a jacket to protect the microphone from the effects of the wind blast may have helped to make the transmissions clearer to personnel at the airport.

Neither pilot could discount the possibility of a bird strike, but there was no obvious evidence. Similarly, the possibility of the windscreen shattering for another reason could not be discounted. Photographs showed that foam strips and trim strips, intended to reduce localised stresses in the acrylic, were not fitted. The trim strips were introduced in 1995, but the foam strips were a requirement from the original design. The absence of the foam strips could potentially have contributed to the failure if their omission caused localised cracking in the Lexan.

Conclusion

The windscreen and skylight shattered during the flight for an unknown reason. The pilots were startled but were successful in alerting the airfield before completing a successful landing. This accident is a reminder of the importance of being prepared for the unexpected and concentrating on maintaining control of the aircraft.

Safety promotion

The LAA will publish an article in their Light Aviation magazine to highlight the potential consequences of a windscreen shattering in flight, and the need to comply with manufacturer's construction drawings and assembly methods.

Accident

Aircraft Type and Registration:	LBL 90A, G-JEMI	
No & Type of Engines:	None	
Year of Manufacture:	2007 (Serial no: 1,189)	
Date & Time (UTC):	10 August 2024 at 2000 hrs	
Location:	Forngett End, Norfolk	
Type of Flight:	Private	
Persons on Board:	Crew - 2	Passengers - 1
Injuries:	Crew - None	Passengers - 1 (Serious)
Nature of Damage:	None	
Commander's Licence:	Other	
Commander's Age:	71 years	
Commander's Flying Experience:	267 hours (of which 252 were on type) Last 90 days - 4 hours Last 28 days - 3 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot	

The pilot reported making an approach into a "large field" where several other balloons had already landed. During the initial stage of the approach, they saw a horse in a field below them and elected to delay their descent until they had passed it. They then commenced a steep approach into the target field. When the pilot attempted to reduce the descent rate using one of the balloon's burners, they thought it "sounded different," ie not firing correctly, so fired the other burner instead. While the second burner worked normally, the need to switch burners reduced the time available to slow the descent rate and the pilot was not able to arrest it sufficiently before touchdown. This resulted in a heavy landing, during which a passenger suffered a broken collarbone after banging their shoulder against one of the gas canisters. The pilot reported that the passenger was an experienced flyer who was seated in "the correct landing position" before touchdown and that they have since made a full recovery.

AAIB Record-Only Investigations

This section provides details of accidents and incidents which were not subject to a Field or full Correspondence Investigation.

They are wholly, or largely, based on information provided by the aircraft commander at the time of reporting and in some cases additional information from other sources.

The accuracy of the information provided cannot be assured.

Record-only investigations reviewed: September - October 2024

- 30 Jan 2024** **MW6-S** **G-MZHG** Kernan Airfield, County Armagh
(Modified SS)
As the pilot came into land, he elected to go-around. He increased engine power after which the engine failed and the aircraft struck trees to the north-east. The pilot sustained minor injuries; the aircraft was severely damaged.
- 12 Jun 2024** **Cirrus SR22T** **G-GWOW** Gloucestershire Airport
The aircraft was being collected by its owner to be flown back to Turweston from Gloucester. During the takeoff run, at approximately 65 kt, the aircraft rapidly slewed to the left which the pilot was unable to correct. It then ran off the runway into the grass where the pilot brought the aircraft to a stop. Whilst transiting the grass near the edge of the runway, the aircraft struck an airfield sign which resulted in damage to the aircraft wing.
- 21 Jun 2024** **Sherwood** **G-SWAB** Near Norwich Airport
Ranger XP
The aircraft experienced a loss of engine power approximately 3 nm from Norwich Airport so the pilot executed a forced landing in a nearby field. During the subsequent ground roll the aircraft tipped over, coming to rest inverted.
- 25 Jun 2024** **Eurofox 2K** **G-CMOT** Chilbolton Airfield, Hampshire
The aircraft drifted to the right and failed to climb during takeoff, resulting in the aircraft striking the ground to the right of the runway. The cause of the loss of climb performance was not established.
- 30 Jun 2024** **Jodel D18** **G-BUPR** Heveningham Hall, Suffolk
The pilot recalled that the approach appeared normal until he encountered some "windshear" associated with some trees. The wing dropped and struck the ground and the aircraft came to rest inverted.
- 17 Jul 2024** **Piper PA-12** **G-AWPW** Wadswick Airstrip, Wiltshire
The aircraft drifted to the right during a crosswind landing, and the right wing struts contacted long grass to the side of the runway. The aircraft slewed to the right, decelerated rapidly, and nosed over. The pilot recognises that forward visibility whilst in the three-point attitude and flare is restricted by the cowling and engine, and that he had not realised how close he had become to the edge of the runway.

Record-only investigations reviewed: September - October 2024 cont

- 17 Jul 2024 Luscombe 8A G-BRJA** Bodmin Airfield, Cornwall
En route to Bodmin the aircraft suffered a temporary loss of radio. Regaining contact 4 nm out the pilot set up for a crosswind join for Runway 31. Bodmin Radio informed the pilot that the wind was “all over the place” and with no other traffic Runway 13 might be a better option. The pilot misunderstood this information and made an approach for Runway 21. He was also momentarily distracted by another aircraft holding to the left of the runway, and subsequently misjudged the approach, touching down too fast. The aircraft bounced, veered off into long grass to the side of the runway and tipped over.
- 17 Jul 2024 Plumb BGP-1A G-FUNN** Near Woodchurch, Kent
The aircraft was being flown on a permit renewal test flight, with no defects noted prior to takeoff. Shortly after becoming airborne the aircraft yawed to the right, requiring the pilot to apply full left rudder to fly straight. The pilot continued to apply full power and the aircraft climbed slowly to 500 ft agl, at which point the engine failed. The pilot felt the aircraft stall, so pushed the stick forward to regain best glide speed and picked a grass field to land in but during the ground roll the left mainwheel caught in a rut, causing the aircraft to groundloop. The pilot stated that the cause of the right yaw and engine failure were not identified.
- 19 Jul 2024 Robinson R22 G-CDBG** Enniskillen Airport, County Fermanagh
Beta
A student pilot was practising an engine failure in the hover and, after a short countdown, the instructor slowly closed the throttle. The student raised the collective lever, which caused a drop in the rotor rpm, and the helicopter settled onto the ground while drifting to the left. The helicopter rolled left around the skid and came to rest on its side. The student climbed out of the helicopter through the right door, followed by the instructor.
- 12 Aug 2024 Cirrus SR22 G6 N70DE** Elmsett Airfield, Suffolk
After an uneventful approach and landing on grass Runway 23 at Elmsett Airfield, the aircraft became momentarily airborne after hitting a bump in the runway. As the remaining runway was downhill, and it was too late to conduct a baulked landing, the aircraft overran the end of the runway into a field at about 20 kt.
- 16 Aug 2024 Piper PA-18-150 G-OFER** Near Bicester, Oxfordshire
The pilot reported that the engine lost power and, being unable to rectify the situation, he decided to land in a field of wheat. The landing gear caught the top of the crop and the aircraft came to rest inverted. The pilot was able to exit the aircraft without assistance.

Record-only investigations reviewed: September - October 2024 cont

26 Aug 2024 **Clipper-100** **G-CHJJ** Old Park Farm Airfield (Margam), Neath Port Talbot

In a south-westerly wind of 9-15 kt, the aircraft touched down heavily on the left mainwheel on grass Runway 36 and the pilot executed a go-around. He was advised, by radio, that the left gear was damaged and so flew two practice approaches to Runway 30 before a final approach to land. With 50% flap set, upon reducing engine power to idle, the nose dropped, and the aircraft struck a hedge short of the threshold before sliding onto the airfield perimeter track. The pilot considered that the aircraft had been affected by wind effects in the lee of the trees during the original approach to Runway 36.

27 Aug 2024 **Robinson R44 II** **G-RMYD** Headcorn Aerodrome, Kent

Having flown a circuit accompanied by an instructor, the student pilot was cleared to fly his first solo circuit. The initial lift into the hover was normal, but the helicopter then yawed to the left which the student stated surprised him and he was slow in responding with corrective right pedal. The helicopter subsequently rolled to the right and the main rotors struck the ground with the helicopter coming to rest on its side.

30 Aug 2024 **Quik GTR** **G-CIHZ** Near Leyburn, North Yorkshire

The pilot diverted to a farm strip as one of the aircraft he was flying with needed to make a precautionary landing due to an engine issue. As the pilot attempted to flare for landing the aircraft pitched nose down and sank, striking the ground with its nose gear. The aircraft bounced before striking the ground a second time. It then pitched forward, severely damaging the wing as it struck the ground. The trike turned 180° and came to rest on its side facing the direction it had come from. The pilot commented that he only sustained minor injuries and felt this was a result of wearing his shoulder harness.

31 Aug 2024 **Pierre Robin** **G-CROI** Crowfield Airfield, Suffolk
HR200/120B

As the aircraft touched down it bounced, and, rather than going around, the pilot continued with the landing. This resulted in the nosewheel hitting the ground first. The nose leg broke and caused the propeller to strike the ground and shock load the engine.

12 Sep 2024 **Beagle B121** **G-AXPN** Lyde Court Airstrip, Herefordshire
Series 2

During the takeoff run the passenger door opened. The pilot aborted the takeoff, but was unable to stop the aircraft before it overran the end of the grass strip and struck a hedge.

Record-only investigations reviewed: September - October 2024 cont

- 15 Sep 2024** **Europa** **G-ODJG** Mill House Farm Strip, South Lanarkshire
While landing at his own private grass airstrip, the pilot selected a deeper than normal aiming point. After the aircraft was flared it bounced before touching down. Because of trees at end of the runway a baulked landing was not an option. Braking was commenced almost halfway along the runway. However, the aircraft subsequently overran the runway at about 10 kt coming to rest in a ditch. The aircraft sustained damage to its nosewheel and lower engine cowling.
- 21 Sep 2024** **Skyranger 912(2)** **EI-ERL** High Halden, Kent
The pilot increased altitude to avoid some sheep that were on the runway. The aircraft subsequently struck a hedge at the end of the runway, and then flipped upside down.
- 28 Sep 2024** **Cherry BX-2** **G-BXUX** Headcorn Aerodrome, Kent
When the landing gear was lowered during the approach, the landing gear lights did not illuminate to indicate the landing gear was down and locked. The pilot recycled the landing gear and performed a go-around, during which all three gear were confirmed down from the ground. During the subsequent landing, the left landing gear retracted and the pilot maintained control on the remaining landing gear. Towards the end of the landing roll, the left wing dropped and touched the ground causing the aircraft to depart the runway at slow speed. After the accident, the pilot noted a sheared nose landing gear attachment bolt, which he considered may have affected the operation of the landing gear.
- 3 Oct 2024** **Pegasus** **G-MYZJ** Athey's Moor Airfield, Northumberland
Quantum 15
With the aircraft battery flat, the pilot decided to hand start the engine from outside the aircraft. The engine started but the aircraft accelerated away from the pilot and took off. It was subsequently tracked by radar as it flew over the coast north of Newcastle and flew out to sea. It was presumed to have subsequently crashed into the sea.
- 10 Oct 2024** **Piper PA-28-161** **G-BODE** Leicester Airport
The pilot was instructed to park on a stand but was not familiar with the airfield. Whilst trying to decide where best to park, the aircraft struck a fuel kiosk which damaged the wing.

Record-only investigations reviewed: September - October 2024 cont

11 Oct 2024 **Robinson R44** **G-HYND** Cotswold Airport, Gloucestershire

The aircraft was being flown by a student conducting his first solo flight. As the student raised the collective lever to take off the nose raised more than usual due the reduced crew complement, somewhat distracting the student. The helicopter was on soft ground and as the student continued to raise the collective it rolled rapidly to the right and the main rotors struck the ground.

17 Oct 2024 **Aeroprakt** **G-EOID** Batchley Farm Airstrip, Hampshire
A22-L Foxbat

On approach to land on Runway 24, the pilot was dazzled by the sun making it difficult to see and the aircraft contacted a hedge. It spun round and came to rest in the hedge.

Miscellaneous

This section contains Addenda, Corrections and a list of the ten most recent Aircraft Accident ('Formal') Reports published by the AAIB.

The complete reports can be downloaded from the AAIB website (www.aaib.gov.uk).

TEN MOST RECENTLY PUBLISHED FORMAL REPORTS ISSUED BY THE AIR ACCIDENTS INVESTIGATION BRANCH

- | | |
|---|--|
| 3/2015 Eurocopter (Deutschland)
EC135 T2+, G-SPAO
Glasgow City Centre, Scotland
on 29 November 2013.
Published October 2015. | 2/2018 Boeing 737-86J, C-FWGH
Belfast International Airport
on 21 July 2017.
Published November 2018. |
| 1/2016 AS332 L2 Super Puma, G-WNSB
on approach to Sumburgh Airport
on 23 August 2013.
Published March 2016. | 1/2020 Piper PA-46-310P Malibu, N264DB
22 nm north-north-west of Guernsey
on 21 January 2019.
Published March 2020. |
| 2/2016 Saab 2000, G-LGNO
approximately 7 nm east of
Sumburgh Airport, Shetland
on 15 December 2014.
Published September 2016. | 1/2021 Airbus A321-211, G-POWN
London Gatwick Airport
on 26 February 2020.
Published May 2021. |
| 1/2017 Hawker Hunter T7, G-BXFI
near Shoreham Airport
on 22 August 2015.
Published March 2017. | 1/2023 Leonardo AW169, G-VSKP
King Power Stadium, Leicester
on 27 October 2018.
Published September 2023. |
| 1/2018 Sikorsky S-92A, G-WNSR
West Franklin wellhead platform,
North Sea
on 28 December 2016.
Published March 2018. | 2/2023 Sikorsky S-92A, G-MCGY
Derriford Hospital, Plymouth,
Devon
on 4 March 2022.
Published November 2023. |

Unabridged versions of all AAIB Formal Reports, published back to and including 1971,
are available in full on the AAIB Website

<http://www.aaib.gov.uk>

GLOSSARY OF ABBREVIATIONS

aal	above airfield level	kt	knot(s)
ACAS	Airborne Collision Avoidance System	lb	pound(s)
ACARS	Automatic Communications And Reporting System	LP	low pressure
ADF	Automatic Direction Finding equipment	LAA	Light Aircraft Association
AFIS(O)	Aerodrome Flight Information Service (Officer)	LDA	Landing Distance Available
agl	above ground level	LPC	Licence Proficiency Check
AIC	Aeronautical Information Circular	m	metre(s)
amsl	above mean sea level	mb	millibar(s)
AOM	Aerodrome Operating Minima	MDA	Minimum Descent Altitude
APU	Auxiliary Power Unit	METAR	a timed aerodrome meteorological report
ASI	airspeed indicator	min	minutes
ATC(C)(O)	Air Traffic Control (Centre)(Officer)	mm	millimetre(s)
ATIS	Automatic Terminal Information Service	mph	miles per hour
ATPL	Airline Transport Pilot's Licence	MTWA	Maximum Total Weight Authorised
BMAA	British Microlight Aircraft Association	N	Newtons
BGA	British Gliding Association	N_R	Main rotor rotation speed (rotorcraft)
BBAC	British Balloon and Airship Club	N_g	Gas generator rotation speed (rotorcraft)
BHPA	British Hang Gliding & Paragliding Association	N_i	engine fan or LP compressor speed
CAA	Civil Aviation Authority	NDB	Non-Directional radio Beacon
CAVOK	Ceiling And Visibility OK (for VFR flight)	nm	nautical mile(s)
CAS	calibrated airspeed	NOTAM	Notice to Airmen
cc	cubic centimetres	OAT	Outside Air Temperature
CG	Centre of Gravity	OPC	Operator Proficiency Check
cm	centimetre(s)	PAPI	Precision Approach Path Indicator
CPL	Commercial Pilot's Licence	PF	Pilot Flying
°C,F,M,T	Celsius, Fahrenheit, magnetic, true	PIC	Pilot in Command
CVR	Cockpit Voice Recorder	PM	Pilot Monitoring
DME	Distance Measuring Equipment	POH	Pilot's Operating Handbook
EAS	equivalent airspeed	PPL	Private Pilot's Licence
EASA	European Union Aviation Safety Agency	psi	pounds per square inch
ECAM	Electronic Centralised Aircraft Monitoring	QFE	altimeter pressure setting to indicate height above aerodrome
EGPWS	Enhanced GPWS	QNH	altimeter pressure setting to indicate elevation amsl
EGT	Exhaust Gas Temperature	RA	Resolution Advisory
EICAS	Engine Indication and Crew Alerting System	RFFS	Rescue and Fire Fighting Service
EPR	Engine Pressure Ratio	rpm	revolutions per minute
ETA	Estimated Time of Arrival	RTF	radiotelephony
ETD	Estimated Time of Departure	RVR	Runway Visual Range
FAA	Federal Aviation Administration (USA)	SAR	Search and Rescue
FDR	Flight Data Recorder	SB	Service Bulletin
FIR	Flight Information Region	SSR	Secondary Surveillance Radar
FL	Flight Level	TA	Traffic Advisory
ft	feet	TAF	Terminal Aerodrome Forecast
ft/min	feet per minute	TAS	true airspeed
g	acceleration due to Earth's gravity	TAWS	Terrain Awareness and Warning System
GNSS	Global Navigation Satellite System	TCAS	Traffic Collision Avoidance System
GPS	Global Positioning System	TODA	Takeoff Distance Available
GPWS	Ground Proximity Warning System	UA	Unmanned Aircraft
hrs	hours (clock time as in 1200 hrs)	UAS	Unmanned Aircraft System
HP	high pressure	USG	US gallons
hPa	hectopascal (equivalent unit to mb)	UTC	Co-ordinated Universal Time (GMT)
IAS	indicated airspeed	V	Volt(s)
IFR	Instrument Flight Rules	V_1	Takeoff decision speed
ILS	Instrument Landing System	V_2	Takeoff safety speed
IMC	Instrument Meteorological Conditions	V_R	Rotation speed
IP	Intermediate Pressure	V_{REF}	Reference airspeed (approach)
IR	Instrument Rating	V_{NE}	Never Exceed airspeed
ISA	International Standard Atmosphere	VASI	Visual Approach Slope Indicator
kg	kilogram(s)	VFR	Visual Flight Rules
KCAS	knots calibrated airspeed	VHF	Very High Frequency
KIAS	knots indicated airspeed	VMC	Visual Meteorological Conditions
KTAS	knots true airspeed	VOR	VHF Omnidirectional radio Range
km	kilometre(s)		
