Accident

Aircraft Type and Registration:	Jabiru UL-450, G-CDFK
No & Type of Engines:	1 Jabiru 2200A piston engine
Year of Manufacture:	2006 (Serial no: PFA 274A-14144)
Date & Time (UTC):	4 April 2023 at 1107 hrs
Location:	Damyns Hall Aerodrome, Upminster, Essex
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - 1 (Serious) Passengers - 1 (Serious)
Nature of Damage:	Extensive
Commander's Licence:	National Private Pilot's Licence
Commander's Age:	57 years
Commander's Flying Experience:	230 hours (of which 173 were on type) Last 90 days - 1.5 hours Last 28 days - 0.5 hours
Information Source:	AAIB Field Investigation

Synopsis

During the climb after what was thought to be a normal takeoff the aircraft did not climb as expected. When at 300 ft, the pilot identified that the engine was not developing full power. With insufficient height or speed to return to the runway, and no suitable landing sites immediately available, the pilot attempted to remain airborne. The engine then stopped, the aircraft stalled and entered a spin before striking the ground.

The loss of engine power was probably caused by an age-related split in the rubber coupling attaching the carburettor to the engine's plenum chamber. No issues with the engine were identified during a 100-hour engine service or the subsequent check flight, carried out in January 2023. The location of the coupling and its mounting clips made inspection problematic. The engine manufacturer's manual for the engine stated that the coupling had a 1,000 hour, or five-year life but there was no evidence that the coupling had been replaced since the aircraft had been built in 2006.

The Light Aircraft Association (LAA) are revising its documents to clarify the processes and responsibilities of owners and LAA inspectors to make judgements about the management of life-limited components on LAA aircraft.

The UK Civil Aviation Authority (CAA), in addition to the information published in Safety Sense Leaflets 02, 07 and 12 regarding stall/spin awareness and aircraft performance, have hosted a workshop to discuss what to do in the event of an engine failure after takeoff

and provide some guidance on staying safe. They also intend to produce a podcast about engine failures after takeoff and a communication campaign to promote the workshop and podcast.

Two Safety Recommendations have been made to the CAA to mandate a life limit for the Jabiru carburettor coupling and consider mandating a life limit for similar components used on other engine and aircraft types.

History of the flight

The pilot had arranged to take a friend on a couple of sightseeing flights from Damyns Hall Aerodrome where he kept his aircraft (G-CDFK). It was a clear day with a surface wind varying between 070° and 140° at approximately 10 kt giving a crosswind on Runway 03. The temperature was 10°C and dew point was 1°C.

After completing the necessary pre-flight inspections and pre-takeoff checklist, the aircraft took off from Runway 03 at 1018 hrs and flew to Hannningfield Reservoir. During the flight the pilot noticed the engine was "struggling a little". As the aircraft crossed the M25 the pilot noted they were only at 900 ft when he would expect them to be at 1,200 ft. The pilot also saw the cylinder head temperature was slightly higher than usual. However, as the aircraft had recently been serviced at an approved facility with experience of the aircraft and engine type, he was not unduly concerned and decided to see how the engine performed on the second flight. The aircraft returned to Damyns Hall, landing at 1043 hrs.

The pilot refuelled the aircraft and prepared for the second flight. He intended to fly to the Queen Elizabeth II Bridge then to Brands Hatch before returning to the aerodrome.

The pilot taxied from the refuelling pump to Runway 03. He was conscious that another aircraft was on the downwind leg of the circuit so planned to expedite his takeoff. Before takeoff he recalled he checked the "hatches and latches", engine temperatures and increased the engine power then reduced it back to idle to check that it didn't cut out. He remembered it "all sounded alright and the temperatures and pressures were all in the green". He elected to start his takeoff roll from a position inset from the full length as he had done on the first flight. He recalled making the radio call "*G-CDFK lined-up 03, immediate takeoff*". He commenced the takeoff at 1105 hrs.

His recollection of the accident flight is blurred but he remembered that the takeoff was normal. He recalled that the engine note sounded normal, but during the climb identified that he was lower than he would have expected, realising that when he should have been at 400 ft agl he was actually at approximately 300 ft agl. He recalled seeing the airspeed reducing rapidly from "60 [kt] to 50 [kt]" and put the flaps up to see if that helped him gain airspeed. He remembered "it all going quiet" and the speed reducing. He thought he may have started to turn to the right to parallel the power cables. He then remembered "the wings waggled a bit" and the aircraft "just dropped". Reflecting afterwards, he felt the engine must have stopped running when it went quiet. He did not recall hearing the stall warner before entering the descent.

A flight instructor, who was on the ground at the aerodrome, saw G-CDFK climbing away from the runway and witnessed the accident. They reported seeing the aircraft flying slowly with a nose-high attitude. They described seeing the aircraft "wobbling" or "waffling" in what they described as "classic slow flight". They then saw the aircraft stall and enter a spin, rolling to the right. They saw the aircraft descend and heard the impact with the ground and immediately called the emergency services. The pilots of the aircraft that were on the downwind leg also witnessed the accident but were too far away to see what happened. They contacted Southend Radar to report the accident and were able to give the location.

The pilot remained conscious after the accident and attempted to make a MAYDAY call. He was able to speak to his passenger who was able to walk away from the accident despite having broken several ribs and bones in her back and received a severe laceration to her knee.

The emergency services arrived at the site and sedated the pilot before he was airlifted to hospital having received serious chest and leg injuries. He was in hospital for several weeks but was eventually able to return home to continue his recovery.

The passenger recalled that the takeoff and initial climb had appeared normal to her. She had not noticed anything different to the first takeoff until the aircraft started to roll to the right then "fell out of the sky". She did not recall hearing any abnormal noises before the accident.

When asked about his normal pre-takeoff engine checks the pilot stated that he normally increased the throttle to 2,000 rpm for a few seconds to let it warm up, then increased up to full power for a couple of seconds, then reduce to idle then back to 2,000 rpm. He would check for "smooth operation and no popping or banging". He did not know a figure for the maximum rpm he would expect but he thought he knew what normal looked like. He recalled that before the accident flight the engine all seemed to be normal, the engine indications were in the right place and it sounded normal.

The pilot also stated that he did not normally use the transponder fitted to his aircraft on local flight as he found it difficult to use due to a previous hand injury.

Accident site

The accident site was in a wooded area (Figure 1) approximately 900 m from the start of the aircraft's takeoff roll and 390 m from the upwind threshold of Runway 21 at Damyns Hall Aerodrome. Damage to the trees indicated that it had entered them nearly vertically, striking the trunk of a mature tree before coming to the ground.

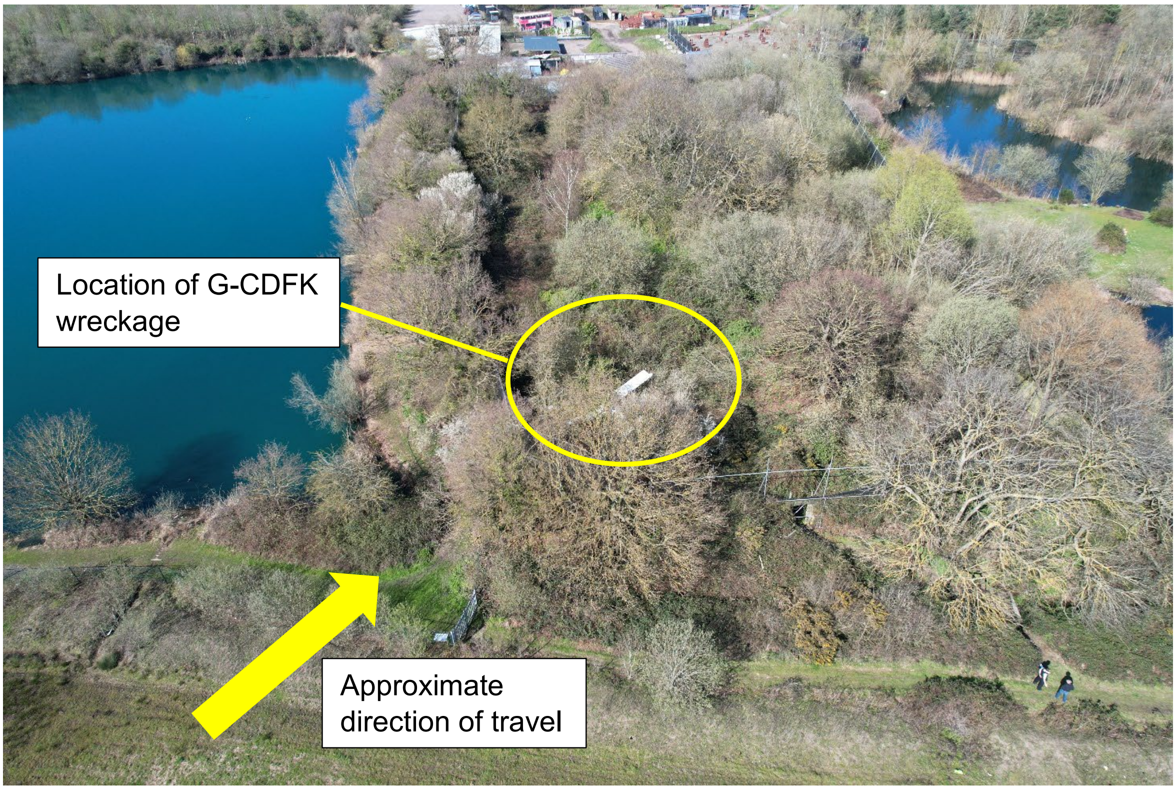

Figure 1

Area of woodland in which G-CDFK came to rest (courtesy of London Fire Brigade)

The aircraft came to rest upright with its right wing supported by foliage and the left wing on the ground. The cockpit floor had crumpled, as had the engine mounts.

One of the propeller blades was mainly intact with its tip missing, however the other blade had fractured at the hub. Fragments of propeller blade material remained close to the accident location. The condition of the propeller indicated that the propeller was not rotating, or was rotating slowly, when it struck the trees.

Control continuity was confirmed for the ailerons and elevator. Due to the cockpit floor damage and associated rudder pedal damage, rudder system continuity could only be confirmed up to the forward end of the control cable. The wing flaps were retracted with the flap lever positively located in that position.

When the AAIB arrived on site, all switches on the instrument panel were in the OFF position. The position of the engine throttle levers could not be positively determined.

Although some fuel had leaked from the aircraft, the fuel tank remained intact and contained approximately 30 litres of fuel. The fuel was later analysed and was found to be consistent with Aviation Gasoline, 100LL, and was free from contaminants. The fuel line to the engine was continuous and was filled with fuel. The fuel valve was in the ON position.

Recorded information

The aircraft was not fitted with any recording or logging devices. A transponder was fitted but was not operating[1]. No external flight tracking services recorded the flying activity.

No CCTV or local traffic dashcam recordings of the accident flight were found.

The pilot was using an aviation app on a tablet which recorded many flights including the first flight on the day of the accident and the subsequent accident flight. For both flight recordings on the day of the accident, the quality of the altitude data was poor in the vicinity of the airfield. The pilot later reported this was often the case.

The recording of the accident flight started at 1101:01 hrs. At 1101:40 hrs the aircraft moved from the fuel bowser location and taxied back to the south-western area of the airfield, turned onto the runway, and at 1105:00 hrs, immediately accelerated for takeoff. The start of the takeoff roll was approximately 50 m further into the runway than the previous takeoff. The altitude data did not allow analysis of the climb.

Aircraft information

The Jabiru UL450 is a two-seat high-wing light aircraft of composite construction with a maximum all up weight of 450 kg. It is powered by a Jabiru 2200A engine with a directly-driven, two-bladed, fixed-pitch wooden propeller.

Pitch and roll control are from a centrally mounted control column, yaw control is from rudder pedals in both the left and right footwells. A lever mounted on the roof to the left of the pilot's seat operates the flaps. An engine throttle lever is provided for each occupant. The throttle levers extend from below the seat to occupy a position between the occupant's legs.

The aircraft is fitted with a stall warning system which consists of a hole in the leading edge of the left wing that is connected, by a flexible pipe, to a horn positioned in the ceiling of the cockpit. When the wing is approaching the stall, low pressure around the hole draws air through the horn, vibrating a reed within it. The noise generated is intended to alert the pilot that the aircraft is approaching the point of stall so that they can take avoiding action to prevent a stall occurring. The noise should commence approximately 5 to 10 kt above the stall speed and sound continuously if the speed is further reduced.

The Jabiru 2200A engine is an uncertified four cylinder, four stroke naturally aspirated engine with a single carburettor and electronic ignition system. The carburettor is mounted on the engine's plenum chamber using a rubber coupling and secured by jubilee clips at each end. Carburettor heating is activated using a lever in the cockpit. This is accomplished by

Footnote

[1] The UK AIP Part 2 En-route section 1.6 part 2 states the requirements for transponder use in UK airspace. It states that 'when a serviceable SSR transponder is carried, a pilot shall operate the transponder at all times during flight, regardless of whether the aircraft is within or outside airspace where SSR is used for ATS purposes […] and should enable pressure-altitude reporting if available, in order to facilitate detection of their aircraft by collision avoidance systems and ATS surveillance equipment'.

moving a baffle in the air intake box, so the intake air is passed through a heat exchanger around the engine exhaust before entering the carburettor. In addition to conventional carburettor heating the carburettor fitted to G-CDFK had inbuilt electrical heating, which was controlled by switches in the cockpit.

G-CDFK was built from a kit and made its first flight in 2006. The aircraft then changed ownership in 2012, 2015 and 2020. At the time of the accident the pilot was the fourth owner and had owned the aircraft for nearly three years.

The aircraft's LAA administered Permit to Fly was revalidated on 6 January 2023 at a maintenance facility familiar with the aircraft and engine type, but had not serviced or maintained G-CDFK previously. At the time of the permit revalidation it had flown 706 hours. At that time several items, including the nose landing gear leg, an elevator hinge pin and main landing gear rubber top hats were replaced. A 100-hour engine service was also carried out in which the spark plugs, distributor rotor arms, oil, oil filter and fuel filter were replaced. The aircraft was re-weighed and a new weight and balance report was issued.

During the permit renewal check flight, the aircraft performance was satisfactory and only differed slightly from previous years' results (Table 1). The stall characteristics were also consistent with previous test flights. It was noted that there was no discernible buffet prior to the stall, but the stall warning horn did alert the pilot of impending stall commencing at 48 kt, 4 kt minimum airspeed achieved.

Date of test flight	Loaded weight (kg)	Time to climb from 1000 to 2000 ft (s)	Climb speed (kt)	Engine rpm during climb (rpm)
10 Feb 2023	450	61	65	3,050
5 Jan 2022	386	53	65	3,100
15 Oct 2020	386	53	65	3,100
5 Oct 2019	386	47	65	3,100
8 Oct 2018	363	63	70	3,100
30 Oct 2017	390	63	62	3,150
30 Aug 2016	390	60	62	3,150
9 Sep 2015	448	68	62	3,000

Table 1

Permit revalidation flight test climb performance data for previous eight years

The aircraft had flown approximately 1 hour 40 minutes between the permit renewal test flight and the accident flight.

Pilots operating handbook and checklists

The Pilot's operating handbook (POH) among other things provides normal and emergency procedures when operating the aircraft. A printed version of the POH, dated 6 July 1999, was provided to the investigation by the pilot.

Under normal procedures, the before takeoff checklist identifies the following procedure:

1	**Brakes**	**CHECK**
2	Cabin Doors	CLOSED & LATCHED
3	Flight Controls	FREE & CORRECT
4	Flight Instruments	SET
5	Fuel Shutoff Valve	ON
6	Elevator Trim	NEUTRAL
7	Flaps	SET FOR TAKEOFF
8	Ignition Check	Throttle to 2000 rpm. Hold this engine speed for 10 seconds. Switch OFF No 1 Ignition and watch for RPM drop Switch ON the No 1 Ignition & switch OFF the No 2. Ignition watching for the rpm drop. RPM drop should not exceed 100 rpm on either system. If drop is excessive, shut down & determine the reason. Switch No 2 Ignition ON.
	NOTE During the check with one system only, the inactive sparkplugs may tend to load up slightly. To clean the plugs, run the engine with both ignitions for a few seconds, then recheck the second system.	
9	Power Check	Throttle to 2850 rpm. Open the throttle fully & slowly to check the maximum RPM being produced. Wind conditions may effect, but as an average 2,850 should be seen.
	NOTE If the RPM is found to be more that 150 rpm lower than normal, the engine should be examined to determine the reason.	
10	Idle Check	Throttle back to idle position & check that the engine runs smoothly. With too low an idle speed, or rough running, the cause must be located & corrected to avoid the potential for an in-flight stoppage.
11	Carburettor Heat Check	Throttle up to 2,000 rpm. Pull out the carburettor Heat Control & look for an rpm drop. Return the Carburettor Heat Control to the Full IN or cold position.

Whereas a laminated sheet in the aircraft's door pocket had the following list for pre-takeoff checks:

- Controls full and free;
- Hatches / Harnesses;
- Instruments set and working;
- Fuel sufficient / pump on;
- 1 stage of flap / trim for takeoff;
- Set power 2,000 rpm;
- Check mags;
- Full power check;
- Wind strength & direction;
- All clear runway and approach;
- Use full power to 500 ft;
- Keep CHT[2] out of the red.

The POH also explained, within the '*Emergency Procedures*' section, the importance of using carburettor heat, and highlighted the causes of carburettor icing as well as when to apply carburettor heat. The explanation also identifies that carburettor icing can occur when on the ground, particularly when the aircraft and engine have become damp. It also identifies a procedure to check for carburettor icing after taxiing.

Aircraft examination

The aircraft wreckage was transported to the AAIB in Farnborough for detailed assessment. The stall warning system functioned correctly and the dynamic pressure tapping from the pitot probe for the ASI was connected. The static pressure tubing had become dislodged behind the instrument panel. This is likely to have been because of the impact.

Although the engine mounts had buckled resulting in the firewall contacting the rear of the engine and the oil cooler had broken off, most of the engine was intact. The spark plugs were clean and undamaged and in a condition commensurate with their few hours of operation. The internal appearance of the cylinders was good, and the engine could be turned over. The coupling that connects the carburettor to the plenum chamber inlet was found to be split. The coupling was removed, and a new coupling fitted to the engine. The engine was then run on a test stand with the oil cooler bypassed and a donor propeller fitted. The engine ran through the operating range, with no indication of a loss of power or any other issues. A subsequent engine teardown found no issues that could have resulted in an engine failure in-flight.

Footnote

2 Cylinder Head Temperature (CHT).

The nitrile rubber coupling (Figure 2), part number 4691084, removed from the engine was examined in a laboratory. A 360° crack radiating from the inner diameter outward through most of the coupling was found. Additionally, cracks were present radiating inboard from the outer diameter that met the 360° crack. The coupling had a through crack around 65% of the circumference.

Figure 2

Split carburettor coupling from G-CDFK

Assessment of the fracture surfaces indicated that the main crack from the inner diameter had been present for some time and exhibited fatigue striations (Figure 3). It could not be determined for certain whether the external cracks were present during the accident flight, as a result of the impact or during later manipulation when the coupling was removed, but there were five distinct areas of different external crack morphology, two of which exhibited fracture surfaces consistent with overload, leaving the remaining three areas likely to have been present during the accident flight. This suggests that at least 30% of the circumference was fractured during the flight. External cracks were also present in the coupling that had not joined with the main inner crack.

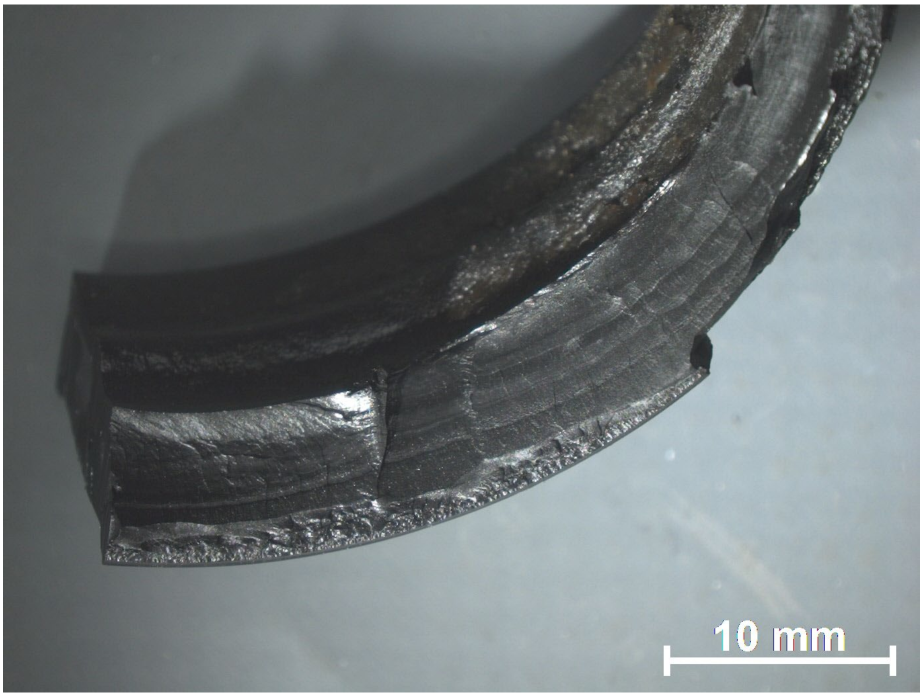

Figure 3

Cracks in coupling wall, showing fatigue propagation from inner diameter

The laboratory examination identified that the rubber showed signs of age-related degradation and embrittlement.

The rear face of the inlet to the plenum chamber showed staining (Figure 4), possibly indicating the location of the split in the coupling,

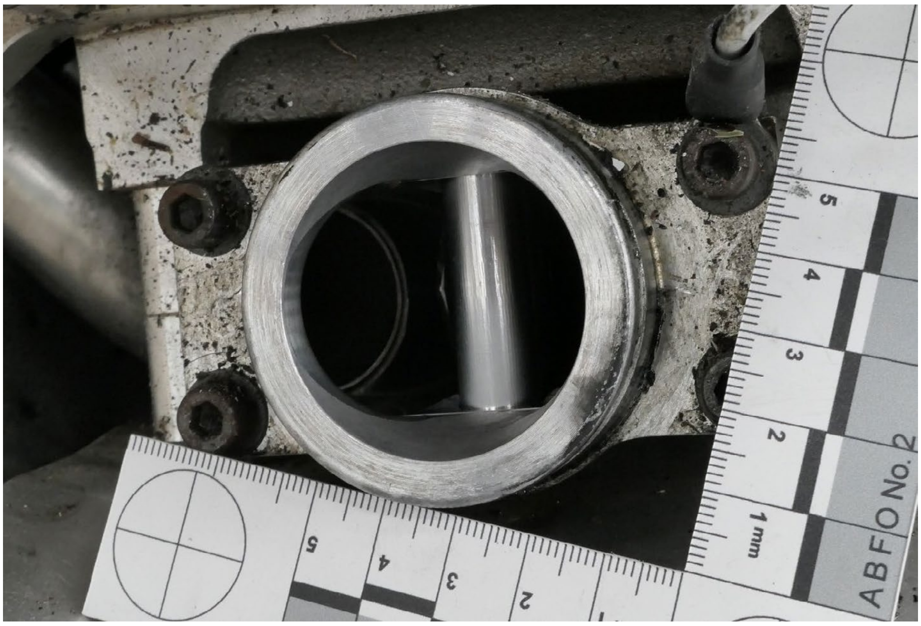

Figure 4

Inlet to plenum chamber showing marking indicating leak in coupling

Technical documentation

LAA documents

The LAA publish Type Acceptance Data Sheets (TADS) for both aircraft and engines which provide:

> *'a summary of the available information about the aircraft [or engine] type and should be used during the build, operation and permit revalidation phases to help owners and inspectors.'*

They also advise that it is:

> *'hoped that the information is as complete as possible, other sources such as the manufacturer's website may contain more up to date information.'*

TADS are normally written in three sections.

> *'Section 1 contains general information about the type.*
>
> *Section 2 contains information about the type that is MANDATORY and must be complied with.*
>
> *Section 3 contains advisory information that owners and inspectors should review to help them maintain the aircraft in an airworthy condition. If due consideration and circumstances suggest that compliance with the requirements in this section can safely be deferred, is not required or not applicable, then this is a permitted judgement call. This section also provides a useful repository for advisory information gathered through defect reports and experience.'*

The first paragraph within section 2 of the TADS states:

> *'At all times, responsibility for the maintenance and airworthiness of an aircraft rests with the owner. A condition stated on a Permit to Fly requires that: "the aircraft shall be maintained in an airworthy condition".'*

TADS 274A Issue 6 Revision D for the Jabiru UL-430 and UL-450 was published on 2 June 2021 and was valid at the time of the accident.

Section 3 advised that the aircraft kit manufacturer supplied an Operators Manual which contains a maintenance schedule, but a link to a relevant manual or specific reference to one was not provided. The manufacturer's website allows anyone to access and download their manuals, however there were no manuals specific to the UL-450 type on the site.

TADS E03 issue 3, for Jabiru engines was current at the time of the accident. Within section '*2.1 Lifed Items*', the LAA Technical leaflet TL 2.23 *'Engine Overhaul Life and Operating 'On Condition'* described providing:

> *'a large amount of information on dealing with engine life for engines installed in LAA administered aircraft.'*

TADS E03 went on to link to the manufacturer's website for relevant service bulletins and manuals and within section *'2.2 Operator's manual'* a link to a copy of the Jabiru J2200 and J3300 engine Maintenance Manual (JEM0002-9) was provided.

Within section '*3.4 Operational Issues'* of TADS E03 a number of previously report operational issues are listed, the fourth item listed is the '*carburettor connection to rubber mounting.'*

TL 2.23 gave guidance to owners and LAA inspectors of ways to operate engines beyond manufacturer's life limits on an 'on-condition'[3] basis. The guidance included advice about how to track an engine's performance over time which provides an indication of certain aspects the engine's internal condition and in some circumstances provides an early warning that a failure condition is developing. There was no guidance on how to manage calendar-lifed components within this or any other LAA document reviewed by the AAIB in relation to this investigation.

Engine manufacturer

The Jabiru engine maintenance manual JEM0002-11, published on 25 October 2021 and overhaul manual JEM0001-23, published on 30 April 2020 were downloadable from the manufacturer's website. *'Section 8.4, Mandatory Inspections & Lifed Items'* within the maintenance manual detailed limitations on various components fitted to the engine and stated flexible hoses '*should be replaced at engine overhaul or every 2 years whichever comes first'* and in paragraph 8.4.2 the carburettor rubber mount was referred to:

> *'The rubber connector attaching the carburettor to the plenum chamber must be replaced at overhaul or every 5 years whichever comes first. Connectors which show deterioration (cracking, splitting etc) must be replaced irrespective of age.'*

Section 8.5 of the manual provided the engine maintenance schedule in tabular form, identifying all inspection and maintenance items due at each 25-hour, 50-hour, 100-hour, 200-hour and Annual Inspection. The carburettor mount was not identified in this table.

The engine overhaul manual stated:

> *'2.8.1 Operating engine "On Condition"*
>
> *Under no circumstances is it deemed acceptable to operate any model Jabiru Engine in aircraft of any certification type (be it type certified, LSA or experimental categories) beyond the previously stated top end and full overhaul intervals, without the appropriate overhaul being conducted on the engine.*
>
> *Jabiru Engine MUST NOT be operated "on condition" beyond the engine overhaul intervals prescribed.'*

Footnote

[3] On-condition describes how an engine or component is sometimes able to continue in use past its manufacturer-stated time between overhaul provided it is judged to remain in good airworthy condition.

LAA requirements for lifed components

The requirements provided by the engine manufacturer regarding replacement of calendar-lifed components and the LAA documentation regarding the management of engines on-condition were discussed with the LAA. Although it is not explicitly stated in the LAA documentation, for aircraft operated on an LAA permit, the LAA considers their advice to take precedence over that provided by manufacturers unless limits are specified in the Operating Limitations document or a Mandatory Permit Directive (MPD), Airworthiness Directive (AD) or similar is available stating a requirement. In this particular case, the LAA would support any owner who maintained their engine as specified in the manufacturer's manuals but would allow extending the life of the engine on-condition if the processes defined in TL2.23 were followed.

Aircraft logbook

There was no record within G-CDFK's aircraft or engine logbook of the carburettor coupling having been replaced during the life of the aircraft. It is therefore assumed that the coupling was over 16 years old at the time of the accident and some 11 years over the 5-year life limit set by the manufacturer.

Weight and balance

Fuel receipts showed the pilot uplifted 37.63 l of AVGAS fuel when he refuelled before the accident flight. He estimated the aircraft had 7-10 l left before he refuelled so would have had approximately 45 l onboard before the flight. An assessment of the weight and balance of the aircraft completed by the AAIB which included approximate weights of the occupants indicated that the aircraft would have been within balance limits and would have been close to the maximum takeoff weight.

Aircraft performance

The altitude the aircraft achieved on the accident flight was not recorded. However, based on the maximum rate of climb demonstrated on the aircraft's last flight test and the approximate lift-off position the maximum height the aircraft could have achieved was estimated to be 370 ft agl. The pilot remembered seeing 300 ft on the altimeter. The altimeter was set to the local QNH so this equates to approximately 244 ft agl.

Airfield information

Damyns Hall is an unlicensed airfield with a main grass runway orientated 030°/210° and 650 m long (Figure 5 runway highlighted in blue). The runway slopes down towards the threshold on Runway 03. Pylon power cables run 0.7 nm to the north-east of the airfield as shown in Figure 5.

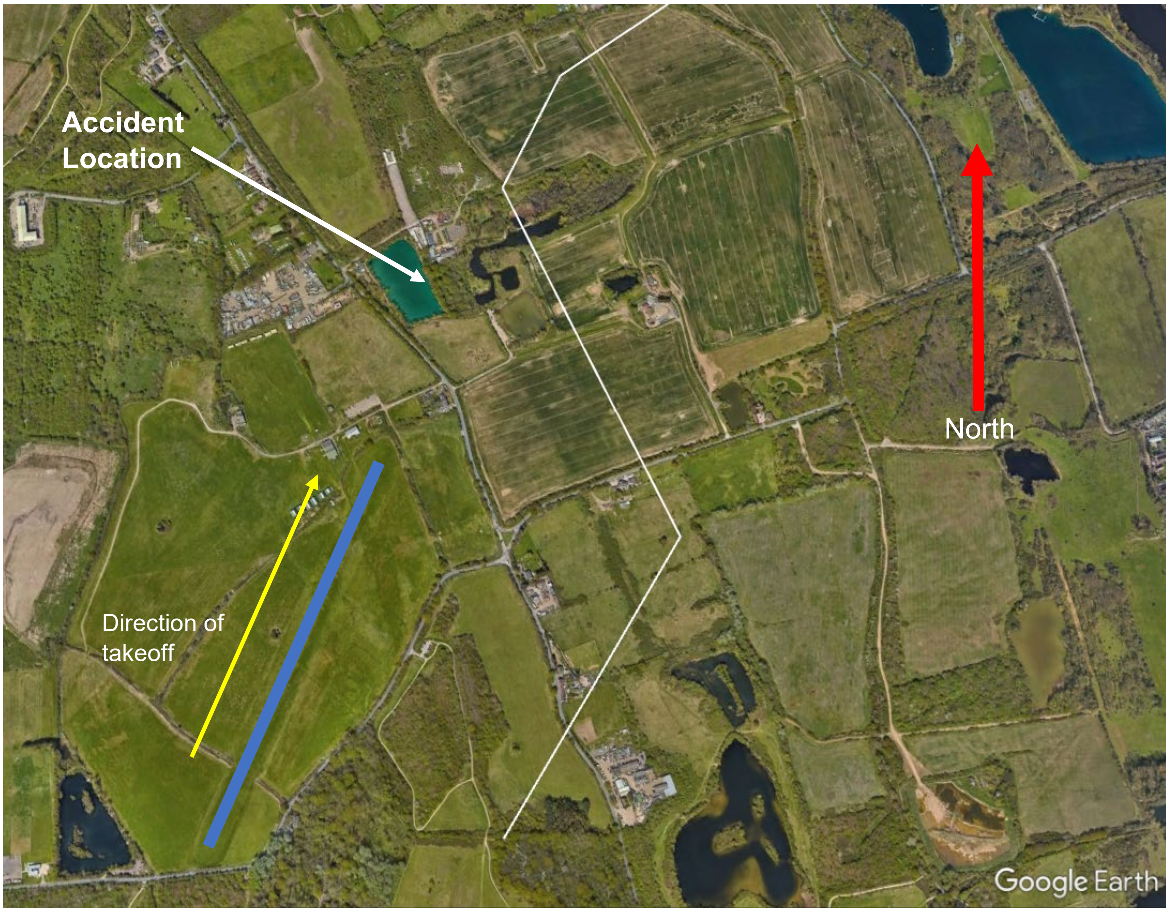

Figure 5

Aerial view of Damyns Hall Aerodrome highlighting the power cables to the northeast (highlighted in white). Runway 03/21 is marked in blue

There are limited options for a forced landing after takeoff from Runway 03 before reaching the power cables. Ahead on the runway centreline after crossing a road is a small lake and woodland, to the left is a field with livestock and to the right is a field with the powerlines across the middle. One local flight instructor reported they preferred to use Runway 21, even with a slight tailwind, for this reason.

Pilot information

The pilot held a National Private Pilot's Licence with a valid microlight rating (expiry 30 April 2023). He had completed a self-declared medical. His last flight with an instructor was on 12 April 2021 when he revalidated his microlight rating.

He started flying in June 2014 and had accumulated a total of 230 flying hours including 173 hours in G-CDFK. His last flight before the day of the accident was on 27 February 2023.

Tests and research

An engine test was conducted using a similar Jabiru 2200A engine fitted with the carburettor from the accident aircraft. The test took a previously used coupling which had been operated for approximately five years. A baseline test run was completed with the coupling intact followed by tests using the coupling with a series of scalpel cuts made in the rubber to attempt to mimic a split. The testing showed that the engine performance was unaffected by splits of up to 60% of the circumference, but whilst the engine was operating with a large split, the engine stopped immediately when rearward pressure was applied to the carburettor, moving it away from the plenum chamber and opening the split.

Examination of the carburettor icing chart in CAA Safety Sense Leaflet 14- Piston Engine Icing[4] suggested that, given the conditions of the day, carburettor icing could occur at low engine power. The possibility of ice build-up during pre-takeoff taxiing prior to the second takeoff was considered but dismissed as the first takeoff from Damyns Hall showed no evidence of carburettor icing and the intervening time between the first flight and the accident flight would have allowed any moisture present on the grass to further dissipate.

Other information

Previous similar accidents

The AAIB have investigated many previous accidents which involved a partial or complete power loss leading to a loss of control of the aircraft. During the period 2011 - 2021 the AAIB completed 16 field investigations in which partial loss of power was involved. Arising from those 16 accidents, there were 15 fatalities and 9 serious or life-threatening injuries. In two of these accidents there were no injuries, and both were as a result of flying the aircraft under control to a successful forced landing or ditching.

On 16 June 2022 the AAIB published a report into an accident involving G-BBSA, a Grumman AA5 which suffered a partial power loss shortly after takeoff followed by a loss of control[5]. This report made three recommendations to the CAA to include training about partial power loss for new pilots and pilots renewing or revalidating their licence. The CAA is working to address these recommendations.

On 13 October 2022 the AAIB published a report into an accident involving G-REJP, a Europa XS[6]. The aircraft developed a significant left yawing tendency during its takeoff roll resulting in the pilot rotating the aircraft early to avoid a lateral runway excursion, probably causing the wing to stall. The aircraft than struck a raised earth bank. The report highlighted the benefits of pilots self-briefing when and how they would abort a takeoff before they start the takeoff roll.

CAA publications

The CAA have published a number of documents intended to provide information which will assist pilots. Safety Sense Leaflet 02- Stall/Spin Awareness provides guidance on stall avoidance and recovery, Safety Sense Leaflet 07- Aircraft Performance deals with aircraft

Footnote

4 https://www.caa.co.uk/publication/download/12659 [accessed 03 June 2024].
5 G-BBSA report available at https://www.gov.uk/aaib-reports/aaib-investigation-to-grumman-aa-5-g-bbsa [accessed 03 June 2024].
6 G-REJP report available at https://www.gov.uk/aaib-reports/aaib-investigation-to-europa-xs-g-rejp [accessed 03 June 2024].

performance including loss of power after takeoff and Safety Sense Leaflet 12-Strip Flying provides information regarding operating from small airstrips.

The emergencies section of CAA CAP 1512 The Skyway Code[7] also provides guidance for managing power loss after takeoff. It states:

- 'Know your best glide speed and procedures for your aircraft.
- Particularly at low level, focus on maintaining speed and control. Provided you keep the aircraft at flying speed and under control, engine failures are unlikely to be fatal.
- If a failure happens shortly after take-off, landing ahead is safer than attempting to turn back. Assess the area immediately in front of you and pick the place that is likely to cause the least damage.'

Inattentional deafness

It is likely that the aircraft's stall warning sounded as the aircraft's speed reduced and the wing approached the critical stalling angle of attack. However, neither the pilot nor the passenger reported hearing the warning. Research[8 9] has shown that in high workload situations it is common that auditory alerts do not capture people's attention. This is known as inattentional deafness.

Analysis

On takeoff the aircraft initially suffered a partial power loss followed by a total power loss. Control of the aircraft was then lost and the aircraft stalled and entered a spin. This analysis first considers why the engine lost power and secondly why control was lost.

Engine power loss

Apart from the split coupling between the carburettor and plenum chamber, there were no issues identified with the engine that could have resulted in a power loss. Fuel was present in the fuel lines and the fuel in the tank was 100LL the normal fuel for this engine. No issues were identified with the quality of the fuel.

A test of the engine that was fitted to the aircraft with its coupling replaced with a serviceable one confirmed that it was able to produce power and ran normally without issue. An engine strip also confirmed that there were no issues internally.

Footnote

7 CAA Skyway Code (CAP1535) available at https://www.caa.co.uk/our-work/publications/documents/content/cap1535/ [accessed 03 June 2024].

8 Dehais, F., Causse, M., Vachon, F., Régis, N., Menant, E., & Tremblay, S. (2014). Failure to Detect Critical Auditory Alerts in the Cockpit: Evidence for Inattentional Deafness. Human Factors, 56(4), 631-644. https://doi.org/10.1177/0018720813510735 [accessed 03 June 2024].

9 Dalton P, Fraenkel N. (2012). Gorillas we have missed: sustained inattentional deafness for dynamic events. Cognition, 124(3), 367-372. https://doi.org/10.1016/j.cognition.2012.05.012 [accessed 03 June 2024].

The coupling from the accident engine was assessed in a laboratory and confirmed that it showed signs of age-related degradation and embrittlement, and that there were pre-existing through-cracks present at the time of the accident. The main crack had initiated on the internal surface around 360° propagating outwards before it combined with smaller cracks propagating inwards from the outer surfaces. The location of the main crack means that its presence cannot be detected without the coupling being removed from the engine.

Review of the aircraft logbook did not find an entry to suggest that the coupling had been replaced during the life of the aircraft and was therefore likely to have been over 16 years old, an age commensurate with the condition reported by the laboratory.

The rubber coupling mounts the carburettor onto the engine and allows the air/fuel mixture to pass through it into the engine. This air/fuel mixture is then directed through the inlet manifolds to the cylinders where combustion takes place. When the engine is running, the movement of the pistons draws air and fuel through the induction system and establishes a low pressure region inside the coupling. With a split in the coupling additional air can be drawn into the plenum chamber, downstream of the carburettor resulting in the mixture becoming leaner. As a split develops it may go un-noticed, especially at high power, as engines are designed to run rich at high power, the additional fuel provided acting as a coolant. With a leaner mixture at high engine power settings, the engine performance will often improve, however the exhaust temperatures will likely increase. As the mixture is leaned further, the engine performance will diminish until the air to fuel ratio is insufficient to support combustion.

As shown by the engine test conducted as part of the investigation the low pressure may force the split closed resulting in the engine running without indicating a performance issue. This was likely to be associated with the cut made in the rubber being with a scalpel, leaving a clean pair of surfaces which, when drawn together, acted as a one-way valve. The coupling fitted to the engine at the time of the accident was old, brittle and had lost elasticity so, although would have had some ability to act as a seal, was unlikely to perform like the test piece.

Evidence of staining in an arc on the rear face of the plenum chamber union indicates that there was disrupted airflow in that location. This suggests a split in the coupling had been present for some time.

Although it is likely that a split was present for some time, its length may not have been sufficient to cause a performance issue with the engine. It was not possible to determine the size of the split in the coupling at the time of the accident as the split was likely to have extended during the accident sequence and when the coupling was removed from the engine. However, it will have been sufficiently large to allow the carburettor to move away from the engine to open the gap and cause the engine to stop.

Although the engine had been serviced recently, and only operated for a few hours after the service, it did not show any symptoms of the split during the test runs and permit revalidation test flight. It is likely that at the time of the last engine service, the coupling would have been showing signs of degradation, however the location of the coupling and the position of the mounting clips obscure the outer surfaces making inspection challenging.

The engine maintenance manual specifies that the coupling has a calendar life and should be replaced at overhaul (1,000 operational hours) or every 5 years whichever comes first. It goes on to specify that couplings which show deterioration (cracking, splitting etc) must be replaced irrespective of age. In addition, the Jabiru engine maintenance manual identifies that the engine should not be operated on-condition.

Although the LAA TADS identified the engine manufacturer's documentation within section 2 which were identified as mandatory, the same document also referred to the management of engines on-condition in the mandatory section. There was no guidance within the LAA documents to instruct owners which documents take precedence where contradiction, such as managing engines on-condition, are present, but the LAA intent is that their technical documentation takes precedence over manufacturers' instruction in the UK.

Although the engine was below the overhaul life of 1,000 hours and therefore not being managed on-condition due to operating hours, with a component past its calendar life limit it should have been managed with these principles in mind. As a result of AAIB enquiries with the LAA in relation to managing calendar-lifed components, the LAA published an article in the November 2023 edition of Light Aviation Magazine[10], highlighting the importance of managing the lifed components in accordance with LAA guidance.

The LAA is also working to revise their TADS to remove any inconsistencies regarding the treatment of manufacturers' stated component life limits. This will coincide with the LAA's interpretation that life limits are mandatory if imposed by a MPD, in the approved data relating to the aircraft or an AD, for previously certified aircraft. Approved data includes any life limitations stated on the aircraft's Permit to Fly Operating Limitations document, or within other documents referenced on the Operating Limitations document, or on approved modification or approved repair documentation relating to the aircraft. The LAA have advised the AAIB that the TADS will reflect the fact that, other than for critical components where the limits are mandated by the LAA (and/or the CAA) by one of the mechanisms above, decisions about the embodiment of manufacturers' stated life limitations should be dealt with locally by the owner and inspector involved.

Although the TADS are being revised by the LAA, they maintain that in line with BCAR section A, chapter A3-7 the '*responsibility for the maintenance and airworthiness of an aircraft rests with the owner'* and that an '*aircraft shall be maintained in an airworthy condition'.* This places the responsibility of ensuring that the aircraft remains in an airworthy condition on the owner of the aircraft. This includes the replacement of any life-limited components mandated by the regulator.

Footnote

[10] Page 46 of November 2023 Light Aviation "Rubber components and other engine bits with a 'life'" https://issuu.com/sharpey/docs/nov_23?fr=sMGI2YjcwMzAwNjI [accessed 03 June 2024].

Since G-CDFK's permit revalidation, the LAA have revised the process through which the revalidation is completed. Within the new Permit to Fly Airworthiness Review Report process, section 3 *'Airworthiness Review Declaration'* part 3a now requires the LAA inspector to state the Aircraft Maintenance Programme under which the owner is having the aircraft maintained. Additionally in section 3d, the inspector is required to state whether mandatory service life-limited components installed on the aircraft have been properly identified and recorded, and whether or not they have exceeded their approved service life limit.

This process change now requires that a maintenance programme under which the aircraft is being maintained is defined. For those aircraft where the LAA does not specify a maintenance programme that must be followed, when available, the content of the manufacturers' suggested maintenance schedule should be considered. Where there is no manufacturers' suggested maintenance schedule, the LAA recommends that the LAA's Generic Maintenance Schedule is used as a starting point for developing the individual aircraft's schedule. Whichever programme is being used this may give the owner opportunity to identify life-limited components that need to be inspected or replaced. Similarly, the need to declare any mandatory life-limited items in part 3d of the form may also prompt the owner to review whether components need to be assessed.

Although the LAA processes have been clarified to help prompt the owner to review whether any life-limited components are fitted to their aircraft, unless a component has a mandated life limit it could be operated on-condition indefinitely. With the knowledge that the carburettor coupling in question cracks from the inner diameter and is therefore not able to be inspected in situ and to prevent cracking associated with age-related degradation and subsequent partial or complete loss of power, the following Safety Recommendations are made:

Safety Recommendation 2024-013

It is recommended that the UK Civil Aviation Authority mandate a suitable life limit for the carburettor to plenum chamber coupling, Jabiru part number 4691084 (or equivalent parts), to ensure the couplings are removed from use before a crack can propagate.

Safety Recommendation 2024-014

It is recommended that the UK Civil Aviation Authority consider mandating a suitable life limit for components used in similar applications to the Jabiru carburettor to plenum chamber coupling on other engine and aircraft types, to ensure the components are removed from use before their condition deteriorate beyond an airworthy condition.

Loss of control

The pilot increased the engine power to confirm it was operating normally before commencing the takeoff. The pilot's recollection was blurred, but recalled a normal takeoff with no signs that the engine was underperforming until he reached approximately 300 ft agl where he realised he was lower than he would normally have expected.

Once in the climb the pilot realised he did not have enough engine power to continue climbing but did not have enough altitude to turn back. Looking ahead he could not see anywhere suitable to attempt a forced landing. The pilot showed characteristics of startle and surprise as the aircraft was not performing as would have been expected. As the speed was reducing he selected the flaps up to reduce the drag, but this would have reduced lift and is likely to have made the situation worse. The pilot did not recall hearing the stall warning although the evidence suggests this was working. This was possibly due to inattentional deafness caused by the high workload situation.

The AAIB have investigated numerous previous accidents where control has been lost after an engine has lost power. The emergencies section of the CAA skyway code gives guidance for managing this situation.

The CAA Safety Sense leaflet titled 'strip flying' gives the following guidance:

- *'You should review the options in the event of an engine failure on takeoff. The obstacle environment may require turning in a particular direction. Have a picture in your head of what the area in front of you will look like in the event of a low level engine failure.'*

The CAA are also undertaking work to address the three recommendations made in the G-BBSA report relating to partial power loss.

However, neither of these give any guidance about what to do if there are no suitable landing areas ahead. Once at a safe altitude a single engine aircraft can be flown such that suitable landing areas are within gliding range. However, immediately after takeoff from many UK airfields there are limited options. The CAA agreed that it would be helpful to provide more information to pilots about how to manage this situation. On 13 December 2023 the CAA hosted a workshop to discuss what to do in the event of an engine failure after takeoff and provide some guidance on staying safe.

The CAA also intend to produce a podcast about engine failures after takeoff which will include discussion of this issue and reference the workshop.

Checklist

For non-certified aircraft there are no requirements for pilots to use approved checklists and therefore there is no requirement for owner-produced checklists to be written to a particular standard or checked against a manufacturer-provided checklist.

Comparing the manufacturer's checklist against the laminated pre-takeoff checks found in the aircraft's door pocket, it was apparent that the POH had not been accurately translated in the laminated checklist available to the pilot. The checklist in the aircraft didn't provide a target rpm for maximum rpm during the power check and didn't identify the idle or carburettor heat functionality checks. As a result of the injuries he sustained in the accident, the pilot was unable to recall the rpm that the engine achieved when set to maximum during takeoff so it is not possible to determine whether use of a checklist that more closely represented the POH would have prevented the pilot from commencing the accident flight if he had used it. Although the likelihood of carburettor icing was ruled out as a possibility for this accident, the fact that the checklist did not have the carburettor heat checks on it highlights the risk that where personalised checklists don't represent the manufacturer defined checks there is a possibility that crucial checks are missed that could lead to complications.

Conclusion

Before commencing the takeoff, the pilot increased the engine power to confirm it was operating normally. As he climbed through 300 ft agl he realised that the aircraft had not climbed away normally. With insufficient height, or speed, to return to Damyns Hall and no suitable landing sites immediately available the pilot attempted to remain airborne. The aircraft stalled and entered a spin at a height where a recovery could not be carried out before striking the ground.

The loss of engine power was probably caused by a split in the rubber coupling attaching the carburettor to the engine's plenum chamber. Examination of the coupling confirmed that it had suffered from age-related degradation and embrittlement and staining on the rear face of the plenum chamber union indicated that a split in the coupling had been present for some time. There was no evidence from the aircraft or engine logbooks that the coupling had been replaced since the aircraft had been built in 2006.

No issues with the engine were identified during a 100-hour engine service, carried out on 6 January 2023, but the location of the coupling and its mounting clips makes inspection problematic. During the permit renewal check flight, the aircraft performance was satisfactory and only differed slightly from previous check flights.

The engine maintenance manual specified that the coupling was a lifed item and should be replaced at overhaul (1,000 operational hours) or every 5 years whichever came first. Although the LAA TADS identified the engine manufacturer's documentation as mandatory, the same document highlighted the management of engines on-condition within the mandatory section. There was no guidance within the LAA documents to instruct owners which documents took precedence.

The LAA is revising the TADS to remove any conflicting statements and clarify the circumstances in which it is mandatory to maintain engines in accordance with the manufacturer's advice regarding limited-life components. Since G-CDFK's Permit to Fly revalidation the LAA have revised the process through which these are completed. A declaration is required of the aircraft's maintenance programme and that all mandatory life-limited components have been properly identified and recorded and have not exceeded their approved service life limit, which should improve the ability of LAA inspectors to identify components which may be close to or have exceeded life limits.

The CAA, in addition to the information already published in Safety Sense Leaflets 02, 07 and 12 regarding stall/spin awareness and the management of a loss of engine power after takeoff, have hosted a workshop to discuss what to do in the event of an engine failure after takeoff and provide some guidance on staying safe. They also intend to produce a podcast about engine failures after takeoff and a communication campaign to promote the workshop and podcast.

Safety actions taken

On 13 December 2023 the CAA hosted a workshop discuss what to do in the event of an engine failure after takeoff and provide some guidance on staying safe.

The LAA has revised the Permit to Fly revalidation process to require declarations of the maintenance programme and that all mandatory life limited components have been properly identified and recorded and have not exceed their approved service life limit and have improved their guidance regarding the appropriate treatment of life-limited components specified by the manufacturer, but not mandated by the LAA or CAA. This is designed to improve the ability of LAA owners and Inspectors to identify components needing replacement before they become unairworthy.

The LAA is revising the Type Acceptance Data Sheet to remove any conflicting statements and clarify the circumstances in which it is mandatory to maintain the engine in accordance with the manufacturer's advice regarding limited-life components when the engine is operating in an LAA-supervised aircraft.

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