ACCIDENT

Aircraft Type and Registration:	Spitfire Mk 26, G-CEPL (80% scale kit-built)
No & Type of Engines:	1 Jabiru 5100A eight cylinder piston engine
Year of Manufacture:	2007
Date & Time (UTC):	19 July 2009 at 1107 hrs
Location:	Knoke Hall Farm, Bulphan, Essex
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Minor) Passengers - N/A
Nature of Damage:	Left wing main and rear spars skin rippled; right landing gear leg failed, propeller blades broken; engine seized
Commander's Licence:	Private Pilot's Licence
Commander's Age:	56 years
Commander's Flying Experience:	2,941 hours (of which 0 were on type) Last 90 days - 3 hours Last 28 days - 0 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot, information supplied by the LAA based on its investigation of the accident, including an engine strip report and AAIB follow-up inquries to the engineers concerned.

Synopsis

During the kit-built aircraft's first test flight, following a two-year period of construction, the engine seriously overheated and failed, and the right landing gear failed to deploy for the landing. The engine failure resulted from an incorrect setting of the carburettors, resulting in a too lean fuel/air mixture. The landing gear failure to deploy occurred because the uplock pin could not be withdrawn, most probably due to it being a tight fit in the receptacle in the leg. This accident was investigated fully by the LAA, with particular emphasis on overall project management, during both the build stages and during the lead-up to the first flight, as well as the conduct of the flight itself. The outcome of their investigations, and lessons drawn from it, form the basis of a case study published in an article in the November 2009 issue of the LAA's "Safety Spot" magazine which can be found on the LAA's website.

Introduction

The accident occurred during the aircraft's first flight, and was being flown by a pilot who had no previous experience on type, but who had been authorised by the Light Aircraft Association (LAA) carry out the post-build test flights of the aircraft in question. This was subject to conditions and advice contained in a letter from the LAA Chief Engineer, who is experienced on the aircraft type. In particular, the pilot was instructed to familiarise himself with the operation of the landing gear system by, first, sitting in the cockpit with the aircraft on jacks and cycling the gear. Although the pilot reports that he had not had sight of this letter, he prepared for the flight over a period of some four months, drawing both on information supplied by the aircraft's designer/kit manufacturer in Australia, and on published reports and pilot's notes from two owners of the type. Particular attention was paid at this stage to the electrically-controlled constant-speed propeller, which was limited to a maximum of operating speed of 2,800 RPM (200 RPM below the engine's RPM limit), and to the operation of the retractable landing gear system.

Landing gear description

The landing gear design is both technically complex and possessed of an unusually complicated operating logic. Each main leg is operated by its own independent retraction and extension system, incorporating an electric motor, to provide the necessary power, together with its own entirely separate set of controls in the cockpit, indicators, and mechanical uplocks and downlocks. The LEFT and RIGHT landing gear controls in the cockpit were arranged side by side and, with appropriate dexterity, may be operated simultaneously to effect a synchronised retraction or extension of the landing gear legs:

The controls themselves comprise, for each leg:

- A toggle switch, used to set the direction of rotation of the actuating motor, to cycle the gear up or down as required. This switch does not, by itself, direct power to the motor.

- A selector lever which, when moved into the fully forward position, operates a mechanical linkage that moves a lock pin into engagement with the leg, to lock it into either the UP or the DOWN position, depending on the leg's physical position when the selector lever is pushed forward. When pulled progressively back, this lever firstly disengages the mechanical lock, allowing the gear to move, and when it reaches the fully aft position, it activates a microswitch. This directs electrical power to the actuating motor via the UP/DOWN selector switch described above, to drive the leg to the selected position. Once this has been achieved, the selector lever is returned to the fully forward position, de-activating the motor and re-engaging the mechanical lock to maintain the leg safely in the selected position.

- An orange light illuminates when the leg is in transit, and a green indicator illuminates when the leg is locked down.

- A mechanical indicator on each wing, visible from the cockpit, provides visual indication of the landing gear's state when retracted.

- A mechanical emergency disconnect mechanism, operated from the cockpit, physically disconnects the landing gear leg from its retraction motor, allowing it to free-fall, provided the selector lever is pulled back sufficiently to withdraw the mechanical lock-pin.

The pilot was given a functional demonstration of the retraction cycle with the aircraft on jacks during a visit to the aircraft's home base airfield some two months before the accident flight. However, he did not actually sit in the aircraft and cycle the gear himself at this time, nor did he do so at any other time prior to the test flight. During this demonstration, the left landing gear would not extend. It is understood that remedial work, involving re-reaming of the lock pin receptacle, was subsequently carried out. During the course of this visit, the pilot was able to familiarise himself with the aircraft's ground handling by taxiing it and carrying out high-speed runs on the runway. During these tests, he noted that the aircraft accelerated well (without takeoff flap selected), but that the wheel brakes were rather ineffective. Work was subsequently carried out by the owner to remedy this. The pilot also reports that, following these ground tests, it was found that the propeller had not been achieving a fully-fine pitch setting, and it was adjusted accordingly.

History of the flight

On the day before the first flight, the pilot met the owner to review the aircraft's documentation and to discuss the weight and balance schedule. The outcome of this was that he decided to carry 20 kg of ballast immediately aft of the pilot's seat; the aircraft is designed to accommodate a passenger. The flight reference cards were also amended at this time, to take account of a recently promulgated reduction in flap limiting speed from 99 kt to 80 kt.

Prior to the initial test flight, the pilot went through a period of more intensive cockpit familiarisation with the assistance of the owner, with particular attention being paid to the flap controls and indicator positions, the engine controls and associated instruments, radio fit and operation, the propeller speed control, and the landing gear operating switches, levers, lights and the emergency disconnect system. The stall warning system was only partially installed at this stage, and its wiring was taped up and securely out of the way on the left side of the cockpit floor.

Following an uneventful engine start and warm-up, full-power engine checks were conducted (with two people holding down the tail), during which manual carburettor heat and magneto checks were carried out at various power settings (with minimal 'RPM drops' being noted in each case) and the aircraft was taxied onto the airfield. A high-speed run was then carried out along Runway 25, with 10° of flap selected, during which the aircraft accelerated well and a tendency to swing was easily contained with use of rudder. Afterwards, the pilot taxied back for a review of some minor issues that had become apparent, including the positioning of the propeller fully-fine pitch indicator light, which was outside the pilot's normal line of sight. None of these items were judged to be of sufficient importance to require postponement of the test flight and, after restarting the engine, the aircraft was taxied to the holding point for Runway 25, where a further power check at 1,500 RPM was carried out; nothing abnormal was noted. As part of the pre-takeoff checks, the engine cowl flap was set to OPEN, the electrical carburettor heat was set to 2, 10° of flap were selected, the landing gear switches were pre-selected to UP, and the pilot states that he set the propeller speed to 2,800 RPM in 'auto' mode[1]. After an uneventful

Footnote

[1] In the LAA Safety Spot article covering this event, it is stated that the pilot set the propeller control to MANUAL.

takeoff, the engine temperatures and pressures were checked, and found to be within limits, and the aircraft climbed at 75 kt to 300ft, when the flaps were retracted, the carburettor heat setting was reduced to 1, and the climb speed increased to 90 kt.

Full power was not used to takeoff, but the rate of climb was still well below that expected and, as the aircraft passed 500 ft, power was increased with the propeller control still set to 2,800 RPM. A climbing turn was then initiated towards the north and, with the aircraft still climbing at 90 kt, and mindful of the gear limiting speed of 110 kt, the landing gear was selected up by pulling both landing gear selector levers fully back. The orange 'gear in transit' light for each leg illuminated as the legs retracted, and the right leg mechanical indicator showed UP, followed shortly afterwards by the left. Both landing gear selector levers were returned to the forward position, both transit lights went out, and the levers were then pushed gently home to engage the uplocks.

After climbing downwind to an altitude of 2,000 ft over a distance of some 5 km, the aircraft was turned back towards the airfield overhead and power was reduced. This power reduction resulted in an immediate reduction in propeller speed to 2,400 RPM. The propeller control was then set to maintain 2,400 RPM, with 20 inches manifold pressure but, with the aircraft in a level attitude at an airspeed of 110 kt, the pilot found that the altitude could not be maintained. Manifold pressure was therefore increased to 24 inches, but this caused the propeller speed to exceed 3,000 RPM. The power was reduced immediately to limit the propeller speed to 2,800 RPM. A series of medium bank turns was then flown over the airfield with the aircraft in this condition, during which its handling was assessed.

At about this stage, fumes began to enter the cockpit via the fresh air vents, and light smoke was seen emanating from the left bank of exhausts stubs. The vents were immediately repositioned in an effort to limit further entry of fumes, engine power was reduced, and the aircraft turned away from the overhead in preparation for a let-down to the north of the airfield. Manual carburettor heat was applied at this time, and the pilot considered shutting down the engine. He rejected this course of action in light of the unknown flight characteristics of the aircraft during the approachand instead, adopted a low power setting.

The landing gear was released by selecting the two switches to DOWN and pulling back on both selector levers. The right gear deployed correctly into the down position and a green light obtained, but the left selector lever was reluctant to move fully aft and the left gear 'in transit' orange light remained illuminated. By this stage, a considerable amount of smoke was entering the cockpit from the exhaust stubs, so the pilot closed the throttle fully and opened the canopy. Thirty degrees of flap was selected and confirmed, the propeller speed was reset to 2,800 RPM in auto mode, and the pilot's shoulder straps were tightened. A further attempt to lower the left gear was made by pulling its selector fully back, recycling its selector switch and, finally, by pulling the its emergency-disconnect toggle but the gear remained up.

The pilot briefly considered retracting the right leg to allow for a 'belly' landing, but he immediately rejected this option because he found flying the aircraft under increasingly difficult circumstances, with smoke continuing to enter the cockpit, quite demanding. A turn on to base leg was initiated at a height of 1,000 ft, approximately 1 km from Runway 25 threshold, but it quickly became apparent that the rate of descent was too great to enable the aircraft to reach the airfield. A judicious increase of throttle produced a temporary power increase but the engine then failed completely; the pilot turned both magnetos off.

Two potentially viable landing fields were identified to the east of the airfield: one, adjacent to the airfield and separated from it by a main road, had a crop of mature standing corn in rows running across the line of flight; the other was closer, and appeared to be mix of soft earth and stubble. The aircraft had descended to a height of about 500 ft at this time, which appeared initially to be too high to permit landing in the nearer field. However, after making a positioning turn to the right and lowering the nose to maintain a 60 kt minimum airspeed, followed by a turn back to the left, the aircraft arrived over the landing spot, into wind, just as the landing flare was initiated. A gentle touchdown was made on the extended right landing gear, and the aircraft tracked gently to the right as the left wing descended and made contact with the ground. At this point, it yawed rapidly left and then slid sideways to the right about 20 metres before coming to rest with the right gear collapsed. The electrical system and fuel cock were turned off, and the pilot vacated the aircraft unaided, having suffered a blow to his left elbow from the cockpit wall and strained neck and shoulder muscles on his right side. The flight lasted just seven minutes.

The pilot was of the opinion that his lack of serious injury was attributable to the combination of low ground speed at touchdown, due to a 15 kt headwind, use of 30° flap, the fine pitch setting of the propeller and the softness of the ground; this had been ploughed the previous day. He commented that the four-point harness had been very effective in restraining him during the landing. Afterwards, he observed that each of the propeller blades had fractured, confirming his recollection that the propeller had continued to rotate until touchdown, and he also noted a great deal of oil on the lower fuselage and around the tailwheel, and signs of burning in the left exhaust stubs.

Observations

The pilot offered the following observations about the flight:

- The propeller pitch appeared never to have moved out of the fully-fine position, but the indicator light which would have shown this condition could be seen only by "ducking" one's head down in the cockpit to obtain line-of-sight. He felt that it would have been more helpful to him had this light been within his normal field view in the cockpit. He also commented that, with hindsight, it might have been possible to restore correct propeller function and reduce its speed by pulling the circuit breaker, setting the propeller control to manual, re-setting the breaker, and readjusting the propeller speed setting.

- Operation of the landing gear actuating motor required the associated selector lever to be pulled fully aft, otherwise it would not engage the microswitch that activates the retraction/ extension system.

- The positioning of the fuel cock on the cockpit floor immediately in front of the control column, and its design which incorporated a central knob that had to be pulled whilst the cock was twisted through 90°, was such as to make it practically impossible to operate in an emergency situation such as that which he encountered.

- Because the aircraft's systems were dependant on an electrical supply, and the flaps had a further two stages available if required (40° and 59°), the battery master was not switched off until after the landing.

- With regard to the engine failure, the pilot stated, "at no point in the flight was the engine speed allowed to approach 3,300 RPM, this being the maximum rated speed for a fixed propeller installation."[2]

Technical investigation

The engine was strip examined at the behest of the aircraft's insurer, and the accident was also the subject of wider investigation by the LAA with a view to promulgating lessons learned through the medium of its 'Safety Spot' publication.

A preliminary inspection of the engine in situ revealed that, whilst it had been installed to a high standard overall, each of the cylinder head temperature (CHT) probes had been fitted under the top cylinder head bolt, instead of beneath the spark plugs as recommended by the manufacturer. It was also noted that no exhaust gas temperature (EGT) or Lambda (fuel-air ratio) sensor had been installed.

After removal of the engine, 4.75 pints of oil were drained from the sump. A preparatory external examination revealed that both front crankcase clamping nuts, and a No 6 cylinder head nut, had split. The No 4 cylinder was missing a nut which was also presumed to have split and fallen off. Removal of the rocker covers released a strong smell of burnt oil, suggesting that the engine had been running very hot.

Footnote

[2] The maximum rated speed for the engine is quoted as 3,000 RPM

Bulk dismantling of the engine revealed the following:

- The No 8 cylinder head, piston, and cylinder were undamaged and functional.

- The Nos 4 and 6 cylinder exhaust valve seats had migrated clear of their seats in the cylinder heads, the pistons were burned, and aluminium deposits from the pistons were evident on the cylinder walls.

- The No 2 cylinder head was apparently undamaged, but there was a large hole in the piston crown and evidence of heat-seizure on the cylinder wall.

- The No 7 cylinder head was apparently undamaged, but evidence of heat-seizure of the piston was apparent on the cylinder wall, and the little end was abnormally tight.

- The No 5 cylinder inlet valve pushrod was dislocated from its rocker arm, but the cylinder head and valves were apparently undamaged. Evidence of heat-seizure was present on the cylinder wall.

- The No 3 cylinder head was burned virtually clean of carbon deposits and the piston showed signs of detonation and heat seizure, with corresponding indications on the cylinder wall.

- The No 1 cylinder head was similarly burned clean of carbon deposits and the piston crown was burned through over a part of its circumference, with corresponding overheat damage and aluminium deposits evident on the cylinder wall.

It was evident the engine failure had been caused by detonation of the mixture and consequential overheating of the engine, resulting in a progressive loss of power due to a combination of piston burn-through and to burning/dislocation of valves seats. This had been exacerbated by power absorption and further generation of heat associated caused by the partial seizure of pistons in their cylinders.

It was concluded that a number of factors potentially caused and/or contributed to the detonation and overheating, including:

- A lean mixture jet and needle set-up in the carburettors, which appeared to be the 'as delivered' setting from the factory, suitable for a fixed pitch propeller sized to give an operating speed range of 2,500 to 3,000 RPM, with a normal cruise speed in the range 2,700 to 2,800 RPM

- The installation of a variable pitch propeller. Had this operated at a more coarse than optimal pitch setting during the flight, an attendant loading of the engine at relatively low speed may have occurred

- The installation of a free-flow extractor exhaust system, which requires a richer mixture setting for correct combustion than a normal exhaust system

Effective monitoring of engine temperatures during both the accident flight and the preceding engine runs and taxi tests was undoubtedly compromised by incorrect installation of the CHT sensors beneath cylinder head bolts, instead of beneath the spark plugs as recommended by the engine manufacturer. Comparative flight tests were carried out subsequently by the engineer who conducted the strip examination, using an aircraft fitted with a six-cylinder Jabiru engine. One of its CHT sensors was relocated to beneath a cylinder head nut, to permit direct comparison with the output from a correctly installed sensor. The incorrectly sited sensor exhibited significant thermal lag and reduced temperature indications compared with the correctly installed sensor. Specifically, the temperature reading from the incorrectly located sensor was only 20% of the reference value following engine start, rising to 50% once warm-up was complete. During takeoff, as a cooling flow through the engine cowl became established, this reading reduced to 16%, and remained at about 16% of the reference value thereafter during the climb and in cruising flight. Based on this data, there is little doubt that the CHT gauge on G-CEPL was so grossly under-reading as to render it useless, a problem that was compounded by the absence of any alternative (EGT) temperature instrumentation.

As regards the indications of an excessively lean mixture, the baseline fuel-air ratio delivered by the Bing "constant depression" type carburettors installed on this engine, will be determined by a combination of:

- the jets sizes installed

- the profile of the metering needle (ie the type of needle)

- the setting of the metering needle in its carrier, ie, which notch it is set to, and the position of its adjustment screw

- the level of fuel in the float chamber, determined by the shut-off setting of the float valve

In addition to these setting-up variations, any induction air leaks and leaks at the cylinder head-to-barrel seals will tend to lean the mixture. Also, different exhaust systems will demand different mixtures, the more free-flowing extractor systems, in particular, requiring a richer mixture than systems producing more back-pressure.

The constant depression-type carburettor is designed to maintain an optimal mixture throughout the engine's operating range by varying the throat geometry to match the engine's operating condition, and is achieved by means of a choke barrel that descends into the choke tube, progressively obstructing it. A tapered metering needle, attached to the base of the choke barrel, moves up and down within the main jet so as to adjust the effective jet size to match the throat area at any given instant. The top of the choke barrel is mounted on the underside of a diaphragm-sealed piston, which moves inside a sealed chamber against a light spring that biases the assembly downwards, towards the restricted throat position and reduced jet area setting. A reduction in pressure above the piston, caused by increasing depression downstream of the throat as the throttle is opened to demand more power, creates a differential pressure across the piston causing it to lift upwards against the bias spring, increasing the throat area and hence the mass flow rate of air through the carburettor. This lifting of the metering needle, increases the effective jet size to match the increased mass-flow of air, maintaining the correct fuel/air ratio. The lower half of the piston chamber is ported to atmospheric pressure which amongst other things, provides altitude compensation.

In practice, matching the carburettor's operating characteristics to actual engine demand requires knowledge and experience, and careful consideration of the loading environment which the engine will encounter in service, in particular, its propeller characteristics. If the jet sizes and the profile of the metering needle and/or its setting are not correctly matched to these characteristics, and especially if the engine is operated under high load at speeds below that for which the needle and jet set-up has been optimised, the engine will run lean with a corresponding risk of overheat damage. The operation and setting up of these carburettors is covered at length in a series of Service Bulletins from the engine manufacturer, issued initially in 2004 and more recently updated as Service Bulletin JSB 018-2 dated 7 May 2009, in which the importance of setting the carburettor's mixture characteristics to match propeller loading is stressed. The setting-up procedures are covered in some detail.

The reason for the left landing gear's failure to extend was not positively established, but the symptoms, including its failure to free-fall after disconnection of its drive motor, imply a failure of the uplock pin to withdraw.

Conclusion

This accident was investigated fully by the LAA, with particular emphasis on overall project management, during both the build stages and during the lead-up to the first flight, as well as the conduct of the flight itself. The outcome of their investigations, and lessons drawn from it, form the basis of a case study published in an article in the November 2009 issue of the LAA's "Safety Spot" magazine (www.lightaircraftassociation.co.uk/Magazine/Nov%2009/Safety_Spot_Nov09.pdf).