ACCIDENT

Aircraft Type and Registration:	DH82A Tiger Moth, G-ADXT	
No & Type of Engines:	1 De Havilland Gipsy Major 1H piston engine	
Year of Manufacture:	1935 (Serial no: 3436)	
Date & Time (UTC):	26 August 2017 at 0828 hrs	
Location:	Near Compton Abbas Airfield, Dorset	
Type of Flight:	Introductory Flight	
Persons on Board:	Crew - 1	Passengers - 1
Injuries:	Crew - 1 (Fatal)	Passengers - 1 (Fatal)
Nature of Damage:	Aircraft destroyed	
Commander's Licence:	Private Pilot's Licence	
Commander's Age:	64 years	
Commander's Flying Experience:	22,240 hours (of which 512 were on type) Last 90 days - 50 hours Last 28 days - 24 hours	
Information Source:	AAIB Field Investigation	

Synopsis

The aircraft was carrying out an introductory flight with the pilot and a passenger aboard. As it became airborne from Runway 08, the engine was heard to misfire, but the aircraft continued to climb before making a left turn. Shortly afterwards, the pilot reported an engine problem and his intention to return to the airfield. The aircraft was on the base leg of an approach for Runway 26 when the nose pitched down, and it appeared to enter a steep descending turn to the left from which it did not recover before impact in a crop field. Both occupants were fatally injured.

History of the flight

The flight was intended to be an introductory flight for the passenger, which the operator referred to as an "air experience flight", and was the aircraft's first flight of the day. The pilot arrived at the airfield and was seen to carry out a full pre-flight inspection of the aircraft including checking the fuel tank quantity, which was full, and performing a water check of a fuel sample.

The passenger arrived at the airfield at about 0730 hrs and completed the required documentation before receiving a briefing on the aircraft and associated safety matters. He was then dressed in flying clothing, including a flight suit, leather gloves, flying jacket, goggles, and a helmet with a built-in headset and microphone.

The passenger was taken to the aircraft and assisted into the front cockpit by a member of the ground crew who ensured his safety harness was secure and that the headset lead was connected. He also pointed out the flying controls and other items to remain clear of. The pilot then occupied the rear seat. His normal habit was to carry out his general and safety brief of the passenger. The flight was to last for 30 minutes and was to overfly Shaftsbury, followed by the Steam Fair at Blandford Forum, before returning to the airfield.

The weather at the time of the accident was not recorded but included light and variable wind, clear skies and good visibility with a small amount of fog in the valley to the north of the airfield (Figure 1). The temperature and dew point were not recorded at the airfield.

Another member of the ground crew was responsible for starting the engine by hand swinging the propeller. The normal procedure of priming the fuel line and cylinders was followed and on the second swing of the propeller the engine briefly ran backwards.

With the possibility of an over-primed engine, the propeller was turned backwards several rotations in accordance with the operating manual and a second attempt to start was made but was unsuccessful. On the third start cycle, at the second attempt, the engine started and was warmed up before the magneto checks were performed by the pilot, which sounded normal with no rough running.

The wheel chocks were removed and the aircraft taxied to the threshold of Runway 08. It was seen to accelerate along the runway before becoming airborne at about the 300 m marker. At that point, the engine was heard to misfire but the aircraft continued to climb.

Witness recollections indicate that the aircraft probably made a left turn to the north, which was the intended direction after departure. The airfield does not record radio transmissions on its air/ground frequency but the operator heard the pilot transmit in an apparently calm voice that he had a "rough running engine" and was making a 180º turn to land on Runway 26. The radio operator responded that the wind was light and northerly. The engine could not be heard by witnesses at the airfield.

The perceived direction of turn differed between witnesses, but during the turn or when rolling out of it, the aircraft appeared to be slow and in one witness' description, it appeared slow and became unstable before a wing dropped sharply and the aircraft descended rapidly in a turn which they thought was to the right. One witness thought that as it departed the airfield, it pulled up sharply before making a right turn and descending steeply towards the ground. A witness approximately 1,500 m south of the accident site heard and then saw the aircraft climbing slowly at low airspeed, with the engine "sounding awful and misfiring" before it descended "corkscrewing down".

A flying instructor, who had been speaking to the accident pilot earlier, was next to the radio operator when he heard the transmission indicating engine trouble. He looked out of the window and located the aircraft heading north approximately 1 to 2 nm from the airfield at about 500 feet above airfield elevation. He saw it make a gentle, descending left turn onto a right base leg for Runway 26 and when above some high trees at the eastern end of the field, at about twice their height and some 200 m beyond them, the nose pitched sharply down and the aircraft rolled to the left in a steep descending turn. Shortly afterwards a column of smoke was seen.

Two witnesses at a farm approximately 350 m from the accident site heard the aircraft takeoff. One saw it briefly above trees before losing sight of it behind a barn, after which they heard the engine stop. Driving towards the scene they could see smoke and on arrival at the wreckage they were unable to assist the occupants.

The aircraft had struck the surface of a crop field in a steep nose-down attitude and caught fire. The airfield fire and rescue service attended the scene and controlled the fire using foam and dry powder. Both the pilot and passenger were fatally injured. The police control room log recorded that the accident was reported at 0828 hrs[1]; the first person reporting it thought that they did so approximately 30 seconds after the accident.

Figure 1 below shows the aircraft immediately prior to departure with the weather as described and the fog at the western end of the valley north of the airfield.

Figure 1
G-ADXT before the accident

Footnote

[1] The control room log does not record the exact time in minutes and seconds and, therefore the log was started between 08:28:00 and 08:28:59.

Accident site and initial assessment of the wreckage

The accident site was in a cornfield approximately 0.4 nm east of the threshold of Compton Abbas Runway 26. Examination of the wreckage indicated that the aircraft was structurally intact prior to the accident.

The aircraft struck the ground in a steep nose-down attitude, coming to rest on a heading of approximately 130ºM.

A significant post-crash fire consumed most of the fabric covering of the aircraft and cockpit structure including the seats, instruments, instrument panels and electrical wiring. The steel frame of the fuselage structure was distorted due to loads imparted in the accident. The wooden wing spars and associated structure had burned to varying degrees, with the right wing being more badly affected than the left. The fire had consumed both safety harnesses, but the harness lugs were found to be fully engaged and locked in their respective buckles. The front cockpit shoulder harness attachment cable had failed due to overload.

One of the propeller blades had broken from the hub and its remains were found embedded in the soil beneath the aircraft. The root of the second blade remained attached to the hub but was partially burnt. Both blades had broken approximately mid-span and they had both come to rest to the left of the aircraft centreline.

The investigation determined that the flying controls and their operating mechanisms were intact prior to the accident.

Approximately two litres of residual fuel were siphoned from the aircraft fuel tank, which had ruptured.

The wreckage was recovered to the AAIB at Farnborough for detailed examination.

Aircraft information

General

The De Havilland DH82A Tiger Moth is a single-engine wire-braced biplane with two open cockpits in tandem.

The fuselage is constructed of welded steel tubing covered in fabric and the floor and cockpit decking are of plywood. The engine cowling is of metal construction with hinged side panels, and the wings are primarily constructed from wood with fabric covering.

Flying controls

Dual controls consisting of a conventional control stick and rudder pedals allow the aircraft to be flown from either cockpit, although with a single pilot it is normally flown from the rear cockpit.

The primary flying controls consist of a rudder, elevators and ailerons; the latter on the lower wings only. The control surfaces are of wooden construction with fabric covering but the trailing edges of the elevators and the rudder are made from light alloy tubing.

G-ADXT was fitted with slots on the leading edges of the upper wings which, when unlocked, deploy automatically at high angles of attack. It was not equipped with the optional anti-spin strakes fitted to some Tiger Moths. The strakes were introduced after the Royal Aircraft Establishment studied spin characteristics in 1941 when aircraft were fitted with aileron mass balance weights and bomb racks. Aircraft performance limits are not affected but the aft centre of gravity limit is reduced if strakes are not fitted.

Safety harnesses

The original 'Sutton-type' harness was designed to '*keep the wearer firmly in his seat*' and the specification dated from circa 1940. The harness was not part of an integrated crashworthy aircraft design in which energy absorption and survivable space were considered to the extent that they are for more modern aircraft.

G-ADXT was fitted with 'Z' type harnesses. The shoulder straps were fixed to the aircraft by a cable running across the fuselage, and the lap straps were attached to the fuselage structure. A CAA mandatory airworthiness directive was issued in 2000 to introduce higher strength transverse cables for the attachment of the shoulder straps.

Fuel system

An aerofoil section fuel tank manufactured from tinned steel sheet is fitted above the front cockpit between the upper wings. The tank has a capacity of 19 Imperial gallons (IG) (approximately 86 litres). G-ADXT was not equipped with the optional extended range tank.

Fuel is fed by gravity. It leaves the tank via a shut-off valve and flows through a copper pipe before passing through a filter on the right of the engine compartment. A flexible hose delivers the fuel from the filter to a carburettor.

The fuel shut-off valve can be opened and closed from either cockpit by interconnected push-pull rods. Fuel is turned on and off by moving the control forwards and backwards, respectively. A mandatory airworthiness directive, applicable to all Tiger Moths operating on the UK CAA register, requires the installation of a locking device to ensure that the shut-off valve cannot be closed inadvertently in flight. Compliance with the directive was not recorded in the airframe log book but the locking device was found amongst the wreckage and its condition indicated that it was serviceable prior to the accident.

Oil system

Engine oil is contained in a welded aluminium tank fitted to the outside of the left fuselage immediately behind the engine cowling. The oil tank has a capacity of 2.1 IG (approximately 9.5 litres).

Engine and controls

G-ADXT was equipped with a Gipsy Major 1H engine driving a fixed-pitch, two-bladed, wooden propeller. The Gipsy Major is a four-cylinder, air-cooled, inline inverted engine.

The engine is equipped with two independent ignition systems comprising two magnetos, one on each side of the engine, each feeding four spark plugs. The right magneto is fitted with an impulse coupling, which retards the ignition to aid engine starting. Two pairs of ignition (magneto) switches are fitted outside each cockpit on the left-side of the fuselage. The front switch of each pair controls the right magneto and the rear switch of each pair controls the left magneto.

A control in each cockpit operates the throttle by means of metal control rods. Throttle and magneto controls are interconnected so that when the throttle is closed the ignition is fully retarded. The throttle is moved forward to increase engine power and an engine rpm gauge is fitted in both cockpits.

G-ADXT was equipped with an automatic carburettor heating system, designed to minimise the risk of carburettor icing. The Tiger Moth air intake is of a two-way construction such that cold air can be drawn from an air scoop or warmer air can be drawn from the vicinity of the engine crankcase. The source of the air is determined by the position of a flap valve inside the air intake. The valve is interconnected with the throttle so that when the throttle is fully open cold air is admitted, but at lower power settings, warm air from the engine bay is admitted. A return spring is used to bias the valve to the warm air position when the engine is not running at high power.

Engine starting

G-ADXT was not equipped with an electronic starting mechanism, so the engine was started by hand swinging the propeller. The Bristol Siddeley Gipsy Major handbook, dated December 1958, gave the procedure as follows:

‘1. *Ensure that all oil cocks, if fitted, are turned* ON.

2. *Ensure that both magnetos are switched* OFF.

3. *Turn* ON *the fuel cock.*

4. *Set the throttle lever in the* FULLY CLOSED *position.*

5. *Set the mixture (altitude) control in the* FULLY RICH *position. On some installations a catch on the throttle lever ensures that the mixture control is automatically returned to* RICH *as the throttle is closed.*

6. *Where a manual air-intake control is fitted (Mk.7 embodying Mod. G.1483) set the hot-and-cold air intake control on the* COLD AIR *position.*

7. *Where the fuel supply is by gravity (Tiger Moth 2 installation) depress the carburettor flooder valve knob. Where engine driven pumps are fitted (Magister 1 and Auster T7 installations) operate one of the fuel pumps through the full range of travel whilst holding* OUT *the carburettor flooding device.*

> 8. *Turn the engine through several revolutions by the propeller in order to prime the cylinders.*
> 9. *Move the throttle lever forward about ½ in. from the fully closed position.*
> 10. *Switch ON the starboard magneto.*
> 11. *Swing the propeller cleanly through the compression stroke to start the engine. When the propeller is being swung, it is advisable for a second operator to be ready to adjust the throttle lever setting if required, as the engine starts.*
> 12. *When the engine is running switch on the port magneto.'*

The handbook states:

> *'The engine should start easily in normal weather.'*

and

> *'The most likely cause of trouble is over-priming. If this occurs, switch OFF both magnetos, and with the throttle fully open turn the engine backwards by hand. If the engine still fails to start after two or three successive attempts reference should be made to Chapter 8 and a systematic investigation made.'*

Chapter 8 of the handbook contains a list of possible defects, over-priming and insufficient priming being the first two scenarios to be considered if the engine fails to start.

Weight and balance

The aircraft was estimated to weigh 1,780 lbs at takeoff with a CG position 12 inches aft of the datum[2]. The CG limits were +7.0 inches to +13.5 inches when anti-spinning strips are not fitted as in the case of G-ADXT. The maximum permitted takeoff weight was 1,825 lbs.

Aircraft history

General

G-ADXT was built in 1935 and, according to the airframe logbook, had accumulated approximately 1,245 flying hours. The engine had accrued approximately 862 hours, which was within the defined 1,500 hours between overhauls.

In 2001, the aircraft was involved in an accident in which the engine had stopped during an inverted aerobatic manoeuvre[3]. The aircraft was repaired and returned to service.

Footnote

2 The CG datum for this aircraft was the lower wing leading edge at the root.
3 https://assets.digital.cabinet-office.gov.uk/media/5422f8b9e5274a13140006af/dft_avsafety_pdf_500228.pdf [accessed on 9 August 2018].

At the time of the accident in August 2017, the aircraft had a valid National Certificate of Airworthiness and a current Type Responsibility Agreement[4]. The available records indicated it was maintained in accordance with the Civil Aviation Authority Light Aircraft Maintenance Schedule.

Aircraft log book, technical log and operator's diary

The last 10 days of operations had not been incorporated into the airframe and engine log-books, but the technical log was comprehensive and there were no outstanding faults recorded.

The operator maintained an informal diary to enable the sharing of information within the local team. Diary entries were not attributable to individuals and the content varied. Nevertheless, it provided an insight into the recent operation of G-ADXT and information relating to 137 flights showed that approximately 85% of the engine starts were achieved within five swings of the propeller.

Recent maintenance history

In September 2016, the aircraft underwent a routine 50-hour service. Maintenance records indicate that low compression was identified on two cylinders and all four cylinder heads were removed and returned to an authorised repair organisation. The repair agent stated that he was not told why the components were removed and only the cylinder heads and valves were returned; the aircraft maintenance organisation retained the valve springs and rocker arms. Four new exhaust valve guides were fitted; the valves were reworked and their clearances were checked before the assemblies were recertified and refitted to G-ADXT.

Approximately 25 flying hours later, in February 2017, the aircraft underwent an annual check. Maintenance paperwork referred to a '*report of rough running engine'* and low compression was identified on two cylinders. The number 1 and 2 exhaust valves were found '*stuck open'* and the respective cylinder heads were removed and returned to the repair agent, complete with their valve springs. The repair agent identified that the number two exhaust valve was bent, and a replacement valve was installed; the replacement valve was inspected prior to use and was annotated with a local serial number. The repair agent reworked the assemblies and checked the valve clearances and spring forces before returning the equipment to the aircraft maintenance organisation.

The aircraft underwent its most recent scheduled maintenance in June 2017. The right magneto was removed for repair after difficulties starting the engine. Maintenance records indicate that the timing was adjusted and four new spark plugs were installed.

Footnote

[4] If an aircraft type is no longer supported by a UK Type Certificate Holder, the UK CAA allows an owner to obtain a National Certificate of Airworthiness if a suitably capable organisation has entered into a Type Responsibility Agreement with the CAA. The organisation must be capable of monitoring the continued airworthiness of the type and in the case of a Tiger Moth, this organisation is de Havilland Support Ltd.

When the accident occurred, the aircraft had completed approximately 70 flying hours in 225 flights since the cylinder heads were reworked. It had completed 77 flights since the right magneto was refitted.

Previous report of a rough running engine

Thirteen days before the accident, during the first flight of the day, another pilot encountered a rough running engine while flying G-ADXT. With sufficient performance to maintain altitude he decided to return to Compton Abbas, but the symptoms cleared and he completed the flight in the local area. Six more flights were completed that day with no recurrence and the pilot considered it to have been an isolated event; he did not record it in the technical log. The aircraft completed approximately a further six flying hours in 19 flights before the accident.

Detailed examination of the wreckage

Flying controls

There was evidence the flying controls were connected before the accident, but it was not possible to establish the control surface positions at impact.

Instruments

The cockpit instrumentation was severely damaged in the accident and fire, except for an altimeter which had been thrown clear of the wreckage. The front cockpit engine rpm gauge was found to indicate approximately 1,175 rpm and examination using a computerised axial tomography scanning facility identified that the pointer had disengaged from its drive mechanism. The gauge was disassembled for closer examination, but it was not possible to validate the pointer reading. Typical engine speed in cruising flight is approximately 1,900 rpm, and approximately 2,100 rpm when climbing.

Fuel system

The fuel shut-off valve was found in the OFF position.

The fuel delivery pipe had broken at the filter and the fuel tank had ruptured along the length of one of its joints. The internal construction and cork float showed a combination of impact and fire damage, the varnish coating of the float having been severely degraded or burnt.

Analysis of the fluid that was siphoned from the tank after the accident was inconclusive because of the effects of thermal degradation. The aircraft technical log indicated that the fuel tank was full prior to the flight and a fuel receipt, signed by the accident pilot, showed that 27.78 litres of Avgas 100LL were supplied to G-ADXT on 22 August 2017. This was the last time the aircraft was refuelled prior to the accident and a combined total of 281 litres of Avgas 100LL was supplied to four other aircraft from the same facility on the same day with no reports of problems. Also, prior to the accident, there were another 48 supplies of Avgas 100LL from the same facility with no reports of anomalies. Analysis of a fuel sample retained from 22 August 2017 showed it to be typical of Avgas 100LL, though degraded during storage since the sample was taken.

Engine controls

It was not possible to determine the throttle position at impact because of the damage sustained in the accident.

Both sets of magneto switches were found and all four switches were in the ON position.

Engine

The engine was dismantled under the supervision of the AAIB.

The magnetos and ignition harnesses had been severely damaged and, apart from the impulse coupling, which was found to be in good condition, it was not possible to assess the pre-accident status of these components. The spark plugs in the number 1 cylinder had broken off during the accident. The electrodes of the other six spark plugs appeared normal.

The air intake and carburettor were severely damaged by the fire and their pre-accident status could not be assessed. The carburettor heat return spring arrangement was found to differ from that depicted in the maintenance manuals because two springs were connected in series instead of the correct single spring. The springs remained securely attached, but they were distorted by loads imparted during the accident. The material properties had been affected by the fire and their original stiffness was unknown. An engine test on a representative aircraft showed that when the aircraft was stationary and the spring was disconnected from the flap valve, simulating a spring failure, the valve continued to operate in the correct sense. This replicated the least favourable operating condition that could exist whilst the aircraft was stationary with the engine being warmed up. The CAA could not discount the possibility that they had approved the installation as a minor modification, which should be referenced in the aircraft records. The AAIB could not find a reference to the springs in the maintenance records that were reviewed as part of the investigation, none of which was dated before 2013. Witness evidence indicated that the aircraft had been operating in this condition for several years. The contents of the oil tank had been consumed by the fire but the oil that remained in the engine and filters was clean and free of debris.

The cylinder heads sustained impact damage in the accident and oil had leaked from the rocker covers. However, when the covers were removed the internal surfaces remained wet with oil and it was apparent that they had been adequately lubricated. Except for the No 1 exhaust valve, which was severely bent due to impact damage, the valves could be removed with some difficulty. Most of the valve stems were found to be slightly distorted but there was no evidence of adverse wear or contact with the piston crowns. The distortion would account for the difficulty in removing the valves and, given the damage sustained by the cylinder heads, must have occurred during the accident. Overall, there was no evidence that the engine had suffered a mechanical failure prior to the accident.

Personnel information

The pilot began his flying career in the Royal Air Force where he operated large transport aircraft before moving into commercial aviation at the end of his service career. He flew a number of large aircraft types, retiring from airline operations in 2007 as a Boeing 747 commander.

During that career, he had also flown light aircraft and gained a flying instructor rating. He started flying at Compton Abbas in July 2006. His last flight prior to the accident flight was on the previous day in a DHC-1 Chipmunk aircraft, carrying out 'spin avoidance training' as part of another instructor's annual training requirement.

The passenger had no background of flying training, and no previous experience of controlling an aircraft or flight simulator.

Meteorological information

There was low-level mist and a witness at the airfield, who assisted with starting the aircraft, stated that the aerodrome grass was wet. Another witness, who performed the runway inspection prior to the aircraft being started, stated that the runway and grass area adjacent to the signal square were dry and free of dew. The investigation did not discover any local temperature or dewpoint information.

The METAR for Bournemouth Airport, approximately 16 nm south-east of Compton Abbas, indicated an outside air temperature of 20ºC and a dew point of 14ºC. The METAR for Royal Naval Air Station Yeovilton, approximately 19 nm west of Compton Abbas, indicated an outside air temperature of 18ºC and a dew point of 15ºC.

Aerodrome information

Compton Abbas Airfield has a single grass runway orientated 08/26, 803 m in length. The airfield elevation is 811 ft amsl. Circuits are flown at 800 ft above airfield elevation, left hand on Runway 08 and right hand on Runway 26. To the north of the airfield is a steep sided valley, the bottom of which is some 300 ft below the airfield elevation. To the east of the airfield is a large irregular shaped field approximately 900 m long and 160 m wide, which at the time of the accident, was standing cereal crop of which, two rows had been cut with a combine harvester on the southern edge. (Figure 2)

The airfield has a rescue and firefighting service (RFFS) vehicle which provides initial emergency response to accidents or incidents within the airfield boundary. CAP 168 – '*Licensing of Aerodromes*', Appendix 8C sets out the requirements which cover RFFS at Compton Abbas, which is a Special Category aerodrome. There is no specified time within which the vehicle should reach the occurrence location but the RFFS should achieve '*a response as expeditiously as possible'*.

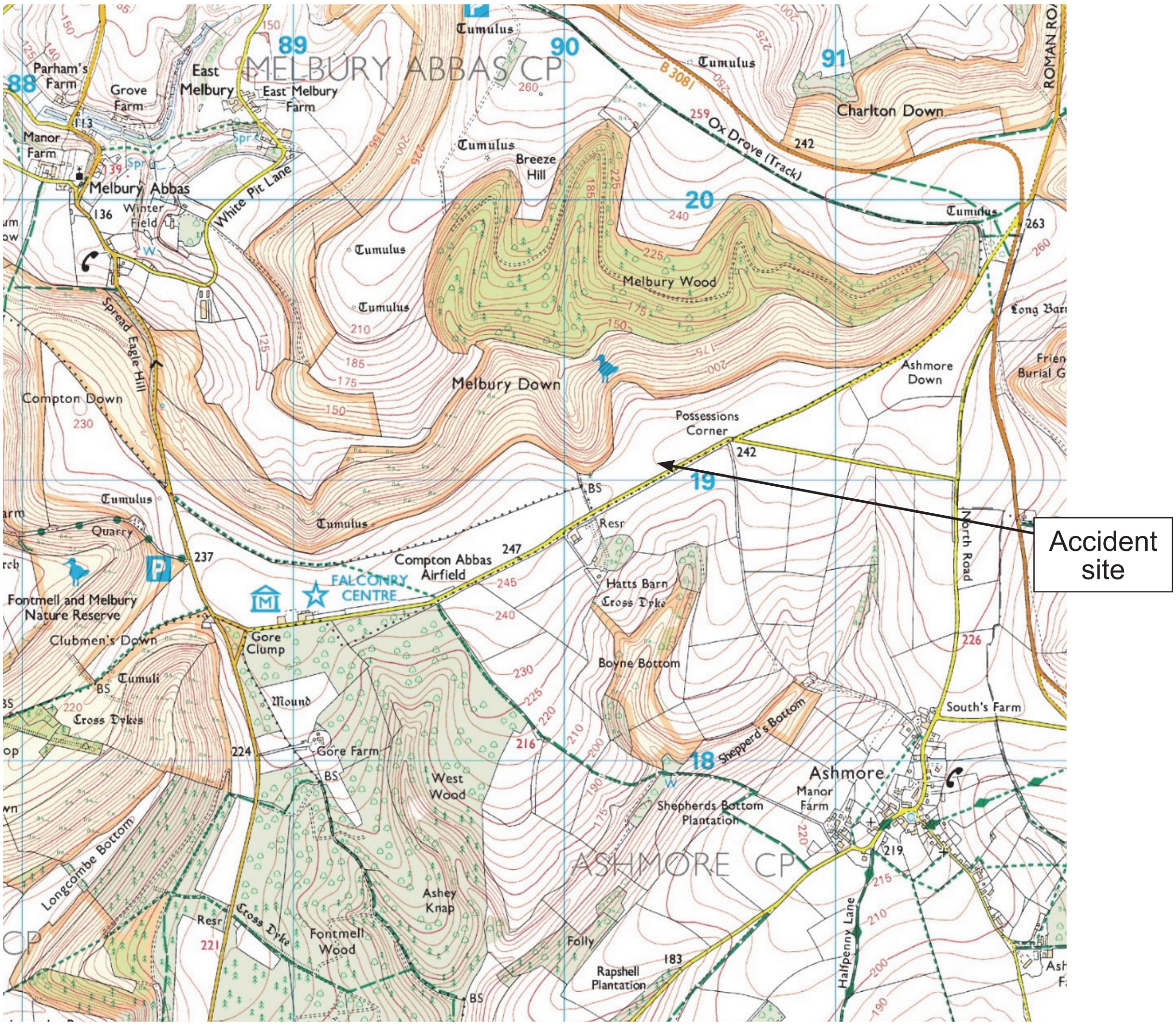

Figure 2

Extract from Ordnance Survey map of the local area

Recorded information

The aircraft was fitted with a video recording system. Remnants of electronic chips that may have related to this system were found in the wreckage but were too damaged for data recovery. A heat damaged USB[5] memory stick was also recovered from the wreckage. Recordings recovered from it were from a previous flight. No other recording devices were fitted.

The accident flight was not captured by radar.

A witness to the takeoff at the airfield provided a series of short video clips[6] taken during the flight preparation, takeoff roll and the initial climb; all while the aircraft was still within the airfield boundary. The video clips had embedded times enabling them to be aligned to each

Footnote

5 Universal serial bus.

6 The video clips were from "live" photographs which are very short video clips, in this case each approximately three seconds long, with an associated photograph.

other with an accuracy of one second. They did not form a complete record of the takeoff and initial climb but provided a basic timeline of events.

The engine was started at some point between two video clips recorded at 0811 hrs and 0819 hrs. The aircraft left its parking position at 0823 hrs. The next clip was just over a minute later, showing the aircraft having started its takeoff roll. There were three more gaps in the remaining sequence, the last clip showing the initial climb and ending at 0825 hrs.

Figure 3

At the beginning of the takeoff run showing the tops of cloud or fog in the valley to the west of the airfield

Figure 4

The cloud or fog conditions are not the same in the valley to the north of the airfield (separated from the westerly valley by a ridge).
The windsock indicates a light crosswind from the north

Figure 5

Abeam the camera location

Figure 6
Lifting off

Figure 7
Initial climb

Figure 8
Last video clip, initial climb

The propeller speeds were established from the images in the video clips. The aircraft engine was running at approximately 2,000 rpm when passing the camera location but had reduced to approximately 1,710 rpm by the end of the video clips.

Spectrum analysis of the video clip audio enabled measurement of the audio frequencies that related to the engine rotating speed, as they reached the camera. The recorded audio also reduced in frequency as the aircraft passed the camera location and flew into the distance. This was partly due to the reducing engine speed as identified using the video images, and partly due to the Doppler effect[7]. The groundspeed was then derived from the measured Doppler effect and the approximate flight path of the aircraft. This indicates that the aircraft took off with a groundspeed of approximately 50 mph, and the groundspeeds for the penultimate and final video clips were in the ranges of 52 to 60 mph and 48 to 56 mph respectively.

Footnote

[7] An example of the Doppler effect is a siren on a police car that appears to drop in tone as it passes you, the faster it is travelling relative to you the bigger the shift in frequency.

No sudden changes in engine behaviour were detected during the video clips. It was not possible to observe throttle position in the imagery.

Previous flights

Video recordings created by the system fitted to the accident aircraft were obtained for two recent previous flights, one in the morning and one in the afternoon, flown by the same pilot on the same aircraft but with different passengers. These recordings had a groundspeed indication embedded in the image. The audio part of the recording provided engine related signatures except during periods of recorded speech. The data for these two flights is compared to the accident flight in Figure 9. The pilot use of the throttle lever was not evident from the videos.

The aftercasts for airfields in the area at the times of the flights indicated similar conditions across all three flights apart from an approximate 8 kt headwind on the day of the previous flights.

Figure 9 shows that during the takeoff of both the previous flights engine speeds were faster than those for the accident flight; there was also a marked difference between the previous two flights. The engine speed for the morning flight showed a reducing trend, which subsequently increased to engine speeds closer to those achieved during the afternoon flight. This was similar in behaviour to the accident flight but with only about half the reduction.

Medical and pathological information

Post mortem examination revealed no pre-existing medical conditions or diseases which might have contributed to the accident, and no drugs or alcohol were present.

Survival aspects

Post mortem

The pathologist considered that the injuries sustained by both pilot and passenger prior to the fire were not survivable.

Safety harnesses

The safety harnesses were consumed by the fire but the harness lugs were found securely locked in the quick release buckles.

The front shoulder harness attachment cable was found to have broken and this would have compromised the restraint of the front seat occupant. The aircraft maintenance records indicated that the higher strength attachment cables for the shoulder straps had been incorporated, but fuselage distortion caused by the accident had loaded the cable beyond its capability.

Fire

First responders from Compton Abbas airfield tackled the post-crash fire using a combination of aqueous film-forming foam (AFFF) and dry powder extinguishers.

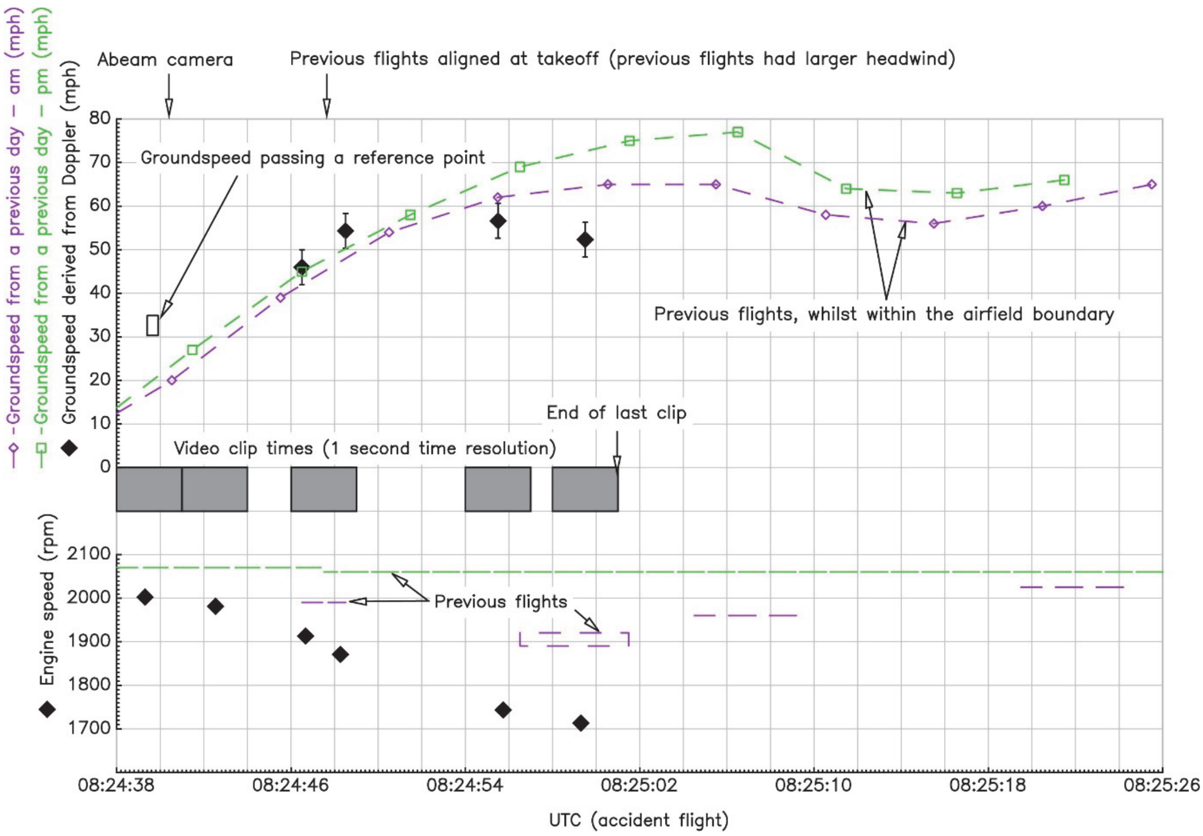

Figure 9

Accident flight parameters compared to previous flights aligned to the point in time of takeoff

Flight trials

The pilot had reported in his transmissions to the airfield that he had a "rough running engine" but did not report an engine failure. He appears to have made a gentle, descending left turn to return to the airfield with the intention of landing on Runway 26. No radar or recorded images of the flight path or performance data for the aircraft type were available to the investigation.

Initially, two trial flights were conducted as part of the investigation to establish takeoff, climb and descent performance at different airspeeds, using full power and throttle closed, with varying angles of bank in the turns. Two Tiger Moths of a similar specification to G-ADXT were used, and data recorded. From this data, height gained or lost against time and/or distance could be calculated. It was not possible to determine the effects, if any, of the "rough running engine" on the performance of the accident aircraft, the rates of climb recorded in these trials were greater than those estimated for the accident flight.

The aircraft used in the trials were as follows:

G-ACDI - TOW 1,760 lbs and CG 12.6 inches aft.
G-ANNG – TOW 1,790 lbs and CG 13.7 inches aft[8].

The indicated engine speed for takeoff and the initial climb was 2,100 rpm for G-ACDI and 2,050 rpm for G-ANNG.

The results are set out in Table 1 below:

Serial	Profile	Data	Remarks
1	Takeoff Run	300 m	Full power
2	Stabilised Climb	650 ft/min G-ACDI 500 ft/min G-ANNG	Full power
3	Climbing Turn	580 ft/min G-ACDI	Full power
4	Descending Turn	At 66 mph 860 ft/min	Throttle closed
5	Stalling – idle power	Approx 40-45 mph	Benign – full back stick no wing drop
6	Turn Back (180º turn)	Height loss 400 ft	Throttle closed
7	Descent at Stall Speed	1,200 ft/min	Throttle closed

Table 1

Consolidated table of results from initial flight trials

The final two test points simulated turn back manoeuvres assuming a worst case in which the power available from the engine was equivalent to idle power. The aircraft was positioned and climbed at 66 mph to 800 ft QFE and the throttle closed. The aircraft nose was promptly lowered to target 66 mph and the aircraft rolled to a 45° angle of bank to commence a simulated turn back to the airfield.

The test pilot conducting the trials considered the aircraft flown to be typical and representative of Tiger Moths registered in the UK. Both had similarly benign stall characteristics at between 45-49 mph IAS[9], adopting a high angle of attack and rate of descent with the stick held full back and no tendency to drop a wing. The measured rates of descent were consistent with other Tiger Moths he had flown, but with a noticeable increase in rate of descent when flown at or just above the stall speed. The aircraft could be turned relatively easily with an increasing rate of turn, with approximately 45° bank being the optimum for a turn back towards an airfield. Height loss in turns through 180° was approximately 400 ft. The test pilot considered that starting such a manoeuvre much below 800 ft, with a total engine failure, would give the pilot little opportunity to manoeuvre onto the reciprocal runway[10].

Footnote

8 G-ANNG had anti spin strakes fitted which increases the aft CofG limit to 15.3 inches aft.
9 The Pilot's Notes state: '*Normal stall from a straight glide, engine off 40 mph (35Kts), engine on 30 mph (25 Kts)*'.
10 A turn to intercept the reciprocal runway would require a combination of turns though more than 180°.

A third trial was undertaken to assess the takeoff and initial climb, using G-ANNG at the same takeoff weight as on the previous flights. The trial was undertaken from Runway 06 at Old Sarum Airfield, which has a grass surface 781 m long that was dry. During the trial the surface wind was calm but with a slight northerly drift. Conditions were CAVOK, with a surface temperature of 15˚C and QNH 1026 hPa.

The test points were:

1. Rejected takeoff performance
2. Climb performance at partial power (low engine rpm)
3. Aircraft attitude in a glide at minimum ROD airspeed

Rejected takeoff

Rejecting the takeoff in the Tiger Moth introduced a number of challenges. The aircraft was not fitted with wheel brakes, had a very crude steerable rear tail skid and was a 'tail dragger' configuration. Rejecting the takeoff when the wheels were still in contact with the runway required the throttle to be closed and the level attitude held initially before allowing the tail to drop gently as the airspeed reduced. During this period there was no braking and steering was entirely aerodynamic and reliant on airflow over the rudder (which was reduced with loss of propeller wash). This technique worked satisfactorily and, from being light on the wheels at 40 KIAS, the aircraft was brought to a halt in approximately 230 m after closing the throttle and following an initial takeoff run of 200 m.

The situation became slightly more problematic once the aircraft had become fully airborne. Typically, the aircraft would be landed in a 'three point' attitude, main wheel and tail skid contacting the runway at the same time in a stalled or semi stalled condition with a minimum ground and airspeed. Rejecting the takeoff once airborne at 40+ KIAS meant that the initial application of aft control stick would have potentially caused the aircraft to climb initially before the 'three point' landing attitude was reached which would have resulted in a heavy landing. The alternative was to retain the level attitude and close the throttle allowing the aircraft to descend back onto the runway initially on the main wheels and then complete the reject as described previously. Any delay in making the decision to reject once airborne would noticeably extend the distance required to complete the manoeuvre. Given the risks of performing such a manoeuvre once airborne it is unlikely that it was practised regularly, if at all.

This type of reject, once airborne, was attempted during the sortie with the aircraft having reached about 20 feet agl and a flying speed of 50KIAS. The test pilot summarised the test as follows:

> *'As the throttle was closed and the nose dropped to a level attitude for landing, it was considered that insufficient runway remained to complete the landing without risk and the power was re-applied to climb away.'*

Partial power

The aircraft was flown at 66 mph (58 KIAS) and a density altitude of 2,000 feet, the power being set using the rpm gauge. The height was noted every 15 seconds until a stable condition and rate of climb or descent could be ascertained. The results of the trial are set out in Table 2 below:

Serial	rpm	Remarks
1	1,700	The aircraft almost was able to remain in level flight but over a minute, indicated a very slight rate of descent of approximately 20 fpm.
2	1,800	The aircraft exhibited a barely discernible rate of climb of approximately 20 fpm.
3	1,900	A rate of climb of 200 fpm was established.
4	2,000	A rate of climb of 400 fpm was established.

Table 2

Consolidated table of partial power climb results

Pitch attitude

A manoeuvre was flown from level flight at 66 mph (58 KIAS). The throttle was closed rapidly and the attitude to glide at 66 mph (58 KIAS) adopted. A nose-down pitch attitude of approximately 10º was required.

It was also noted that the front cockpit of the Tiger Moth was quite confined for a large person of the size of the passenger on the accident flight, whose weight was recorded as 16 stone. All engine and flight controls were operational and accessible to the passenger, and there was nothing to prevent a passenger restricting control stick or rudder movement.

Organisational information

Aircraft operation

The aircraft was owned and operated by an Approved Training Organisation (ATO), which was permitted to carry out introductory flights, referred to by the ATO as 'air experience flights'. The operation of such flights is explained in CAA Information Notice Number IN-2015/029, which refers to such flights as 'introductory flights'. EASA regulations define these as follows:

> *'"Introductory flight"' means any flight against remuneration or other valuable consideration consisting of an air tour of short duration, offered by an approved training organisation or an organisation created with the aim of promoting aerial sport or leisure aviation, for the purpose of attracting new trainees or new members.'*

Guidance material GM1 ARO.OPS.300 (Introductory Flights), published by the EASA, states:

> *'For introductory flights carried out in the territory of the Member State, the competent authority may establish additional conditions such as defined area of the operation, time period during which such operations are to be conducted, safety risk assessments to be accomplished, aircraft to be used, specific operating procedures, notification requirements, maximum distance flown, pilot qualification, maximum number of passengers on-board, further restrictions on the maximum take-off mass.'*

The CAA did not impose such conditions but instead recommended that operators apply their own conditions based on their assessment of the risk to the occupants of the aircraft, which should include:

> '
> - *The experience and currency of the pilot particularly on the aircraft to be used and familiarity with its flight characteristics over the range of planned weight and CofG*.
> - *The pilot's familiarity with proposed route(s), airspace, operational restrictions and emergency procedures*.
> - *Weather minima to be observed, particularly visibility, cloudbase, wind strength and direction*.
> - *Any other criteria which should be considered to achieve the objective of a safe and enjoyable introductory flight for the participant(s*).
>
> ***Important Note**: The exemptions issued under the ANO[11] for national licences and Annex ii aircraft are not valid outside the airspace of the UK unless validated or otherwise accepted by the relevant authority of the State where the flight is to take place.'*

Under these conditions, the approved training organisation was permitted to conduct what they termed 'air experience' flights.

Additional information

Operation of the fuel shut-off valve

Analysis performed by the Civil Aviation Authority of New Zealand after a previous Tiger Moth accident (ZK-DHA) concluded that the fuel shut-off valve on this aircraft type can close because of structural deformation sustained during an accident. Tests that were performed as part of that previous investigation showed that if the valve was turned off with an engine running at full throttle, the engine continued to run for approximately 16 seconds before coming to an immediate stop.

Footnote

[11] Air Navigation Order.

Possible causes of a rough running or misfiring engine

The pilot reported that the engine was running rough and witnesses described it as misfiring.

The Gipsy Major Handbook includes a table of running defects, possible causes and recommended remedial actions. The appropriate sections are reproduced in Table 3 below.

Symptoms	**Possible Defect**
Missing or irregular firing	Defective sparking plugs
	Defective ignition
	Incorrect carburation
	Incorrect tappet clearance
Vibration and rough running	Defective ignition
	Incorrect carburation
	Mechanical defects
	Loss of compression
	Engine loose on mountings
	Induction manifold leakage
	Induction blockage
	Propeller hub loose on crankshaft
	Propeller out of balance
	Spinner out of truth
	Reduced valve spring loads

Table 3

Possible cause of misfiring and rough running

Carburettor icing

Carburettor icing is typically associated with rough running, gradual power loss and, eventually, engine stoppage. CAA Safety Sense Leaflet (SSL) No 14, '*Piston Engine Icing*' gives advice and guidance on how to recognise and avoid carburettor icing. It notes:

> *'the most common, earliest to show, and the most serious, is carburettor (carb) icing caused by a combination of the sudden temperature drop due to fuel vaporisation and pressure reduction as the mixture passes through the carburettor venturi and past the throttle valve.*
>
> *If the temperature drop brings the air below its dew point, condensation results, and if the drop brings the mixture temperature below freezing, the condensed water will form ice on the surfaces of the carburettor. This ice gradually blocks the venturi, which upsets the fuel/air ratio causing a progressive, smooth loss of power and slowly 'strangles' the engine.'*

The leaflet identifies several risk factors, including when the ground is wet (even with dew) and the wind is light; and in clear air where cloud or fog may have recently dispersed.

Previous research

The ATSB carried out an Aviation Research and Analysis, AR-2010-055, and produced a booklet, 'Avoidable Accidents No 3'. The aim of the booklet was to increase awareness among flying instructors and pilots of the issues relating to partial power loss after takeoff in single-engine aircraft.

The booklet set out the issues related to partial power loss as distinct from total loss of power and illustrated the analysis with case studies. It provided the following 'key messages':

> *'Most fatal and serious injury accidents resulting from partial power loss after takeoff are avoidable. This report will show that you can prevent or significantly minimise the risk of bodily harm following a partial or complete engine power loss after takeoff by using the strategies below:*
>
> 1. *Pre-flight decision making and planning for emergencies and abnormal situations for the particular aerodrome*
> 2. *Conducting a thorough pre-flight and engine ground run to reduce the risk of a partial power loss occurring*
> 3. *Taking positive action and maintaining aircraft control either when turning back to the aerodrome or conducting a forced landing until on the ground, while being aware of flare energy and aircraft stall speeds.'*

Analysis

Recorded data

Over the period covered by the video clips, the engine speed reduced from approximately 2,000 rpm to approximately 1,710 rpm. During takeoff on one of the previous two flights reviewed, a reduction in engine speed was also apparent, though to a higher value of approximately 1,900 rpm, before increasing again. Engine speed during the other takeoff reviewed was above 2,050 rpm. This demonstrates that the pattern of engine speeds during takeoff was not consistent. A reducing engine speed during takeoff was not unique to the accident flight and had previously resulted in a successful flight. The investigation did not determine how the pilot operated the throttle. Flight test results showed that the engine speed indicated by the last video clip would have been insufficient for the aircraft to climb, indicating that it did increase after that.

The reduced engine speeds of the recorded parts of the accident flight resulted in a slower groundspeed profile than at similar points in previous flights, even though the previous flights were flown with more headwind.

There was only intermittent video coverage of the initial takeoff and climb. The sound of the engine was not obviously unusual during these clips. Witnessed engine sounds and pilot-reported rough running either occurred between these recordings or after them.

Engine start

The first attempt to start the engine was unsuccessful and witnesses reported that it briefly ran backwards. This indicates the presence of a combustible fuel / air mixture and a source of ignition. As this was the first flight of the day, the possibility of a localised hot-spot inside the engine can be discounted. The only conceivable source of ignition in a cold engine is a spark from a spark plug. This indicates that the left magneto may have been ON, or that there was a timing anomaly with the right magneto or a problem with its impulse coupling. The impulse coupling was found to be in good condition after the accident and the timing of the right magneto could not be checked because of the extent of the damage sustained. If the right magneto timing was incorrect, this would have been the case since it was installed, and the engine would always have been susceptible to running backwards during start-up; the aircraft had completed 77 flights since the magneto was refitted. The engine cannot self-sustain if it runs backwards and when the engine was dismantled there was no evidence of any mechanical failures or damage that could not be attributed to the accident.

The pilot informed the groundcrew that he believed the engine had been over-primed. The appropriate procedures were followed, and the engine started.

Rough running engine

The pilot reported that the engine was “rough running” shortly after takeoff and witnesses described an engine misfire as the aircraft lifted off. The two witnesses at the farm reported that, shortly after they became aware of the aircraft, the engine stopped.

The Tiger Moth Maintenance and Repair Manual states that the engine should be warmed for four minutes prior to the magneto and power checks and the Bristol Siddeley Gipsy Major handbook states that the oil temperature should be at least 15ºC prior to takeoff. Photographic evidence showed that the engine was running at least four minutes before the aircraft left the parking area and witnesses reported that the magneto and power checks sounded normal.

Examination of the engine did not identify any pre-existing defects that would have prevented normal operation but damage sustained in the accident meant that it was not possible to establish the pre-accident status of the magnetos, ignition system and carburettor. The engine handbook states that a problem with any one of these items could result in the symptoms described by the pilot and witnesses.

Both sets of magneto switches were found, and all four switches were in the ON position, which is the normal flight position. The switches are ON when they are in the up position and it is considered unlikely that they changed during the accident.

The fuel shut-off valve was found in the OFF position but it was not possible to determine when the valve was closed. The mandatory locking device was found in the wreckage and its condition indicated that it was serviceable prior to the accident. Analysis performed after a previous Tiger Moth accident concluded that the valve can close because of structural deformation sustained during an accident. The possibility that the pilot closed the valve in preparation for a forced landing cannot be discounted, but this is considered to be less likely. Witnesses who saw the aircraft shortly before the accident reported that the engine was still running and a test conducted as part of a previous investigation established that the engine would run for approximately 16 seconds if the valve was closed when the engine was running at full power.

Both propeller blades had broken approximately mid-span and were embedded in the ground on the same side of the aircraft centreline. This indicates that the propeller was turning when the accident occurred. The fact that the wooden propeller did not shatter and that the broken parts were found close to the wreckage indicates that the propeller was probably turning slowly.

Carburettor icing

G-ADXT was equipped with an automatic carburettor heat system intended to minimise the possibility of carburettor icing. The installation differed from the configuration depicted in the maintenance manual but the aircraft had been operating in this condition for several years. Tests indicated that the air intake flap valve would still operate in the correct sense whilst the aircraft was stationary and the engine was being warmed up. When the pilot selected full power for takeoff, the intake flap would move to the cold air position as designed.

The chart included in SSL No 14 indicates that, at the temperatures recorded at Bournemouth and Yeovilton, moderate icing could be experienced at cruise power and serious icing could be experienced at descent power.

Over the period covered by the video clips, the engine speed reduced from approximately 2,000 rpm to approximately 1,710 rpm, but the cause is unknown. A test flight established that the aircraft could not have climbed at 1,710 rpm so the engine power must have increased after the last video clip.

Post-crash fire

The aircraft struck the ground in a steep nose-down attitude and a post-crash fire began before first responders arrived at the scene.

The fuel delivery pipe was found to have broken at the joint with the fuel filter. This would have given rise to a fuel leak, but the volume of fuel would have been limited because the fuel shut-off valve was closed. The fuel tank, which was full before the flight, was found to have ruptured along the length of a joint. This would have resulted in a significant fuel leak and it is possible that leaking or atomised fuel ignited when it contacted the hot engine.

First responders tackled the fire using a combination of AFFF and dry powder extinguishers. The fire had been extinguished prior to the arrival of the Fire and Rescue Services.

Flying controls

Examination of the flying controls showed no evidence of a pre-accident failure.

Operations

The pilot was properly licensed and qualified to carry out the flight, which was being operated in accordance with the regulations governing 'introductory flights'. The aircraft was being operated within its weight and balance envelope.

The post mortem examination did not identify any pre-existing medical condition that might have led to pilot or passenger incapacitation.

The weather was good with a light and variable wind, which at the time of the accident was given as northerly at less than five knots. No precise time was recorded for the flight but the last photograph showing the aircraft towards the eastern airfield boundary was taken at 0825 hrs and the police incident log commenced at 0828 hrs. This indicates the flight lasted between three and four minutes.

On takeoff, the engine was heard to misfire, but the aircraft continued to climb. It would have been possible to abandon the takeoff closing the throttle and attempting to stop on the runway. If the decision was made promptly, there would have been sufficient space remaining for the aircraft to stop or turn away from the obstacles at the eastern boundary. Once the aircraft was airborne, the pilot would have faced the same situation observed by the test pilot during sortie three of the flight trial.

During the accident takeoff, engine speed reduced to 1,710 rpm. This may have been a result of the pilot reducing throttle in order to reject the takeoff. However, the takeoff continued and he may have concluded that there was insufficient runway or other space on the airfield in which to stop.

Flight trials indicated that power settings, 1,700 and 1,800 rpm would not have been sufficient to achieve the height gained in the time available. Although the pilot had reported "rough running", the engine must have been producing sufficient power to achieve between 1,900 and 2,000 rpm at the best rate of climb speed in order to gain between 300 and 500 feet above airfield level in the time available.

Subsequently, both the turn and descent back towards the airfield were gentle manoeuvres and there were no additional transmissions from the pilot reporting any deterioration in his situation. No radar or GPS positions, heights or ground track were available to the investigation and witness evidence varied regarding the flight path, distance from the airfield and the direction of the turn back towards it. However, the aircraft's final manoeuvre was described consistently as a steep, nose down, rapidly descending turn. This was above and slightly beyond the trees at the eastern end of the airfield and at about twice their height, or approximately 200 ft above airfield elevation.

Up to this point, the gentle rate of descent suggests that the engine was still producing power but was not, and probably could not be, heard from outside the flying club if at reduced power. The pilot either made a normal approach throttling back and descending on the base leg or, if power available had reduced and he was unable to maintain height was forced to let the aircraft descend. With a rough running engine, the possibility of a total or increased loss of power is always a possibility and maintaining height until within gliding distance of the intended landing point is desirable in this situation if it can be achieved whilst maintaining sufficient speed.

The aircraft's nose was seen to pitch positively down some 30º, which when combined with the turn, would have caused the aircraft to lose height rapidly. Flight trials established that the rate of descent could have been at least 1,200 feet per minute if the aircraft was just above the stall at low speed and low power.

One witness had seen the aircraft briefly before the accident and reported hearing the engine "sounding rough". Shortly thereafter that witness and one other witness both heard the engine stop abruptly. Given the location of the witnesses and timings of the observations, the engine stoppage was most likely as a result of the aircraft impact with the ground, rather than an engine failure in flight or the pilot closing the throttle.

Three possible reasons for the final manoeuvre were considered:

1. Low airspeed resulting from trying to maintain height which caused a wing to drop at the stall, as described by one witness.
2. Low airspeed resulting in the need for a large nose down attitude change in order to regain airspeed but resulting in a significant rate of descent.
3. A late decision to change the landing area to the crop field, requiring a tight left turn. This would have required an increase in airspeed, obtained by the significant nose-down attitude change before the turn.

Either (1) or (2) may have caused the aircraft to descend below the minimum glide angle required to land at the airfield. In these cases, the pilot may have recognised that he was not able to return to the airfield and turned towards the large open area of crop field. Alternatively, the angle of the descent placed the aircraft at a height and position from which the pilot decided to change his landing area to the crop field. He may also have been attempting to recover from or avoid a loss of control at low airspeed.

Finally, there was either insufficient height to recover or a restriction of the controls that prevented recovery before impact. The accident aircraft was fitted with dual controls and, although the passenger had received a full cockpit and safety brief, it is possible the flying controls were involuntarily restricted as the passenger reacted to what would have been a very stressful situation.

Conclusion

The accident occurred when the pilot was attempting to return to the airfield after reporting a rough running engine. Damage sustained during the accident prevented an assessment of the magnetos, ignition system and carburettor. A problem with any one of these could have caused the reported symptoms. The possibility of carburettor icing could not be discounted.

At about 200 ft agl, the aircraft pitched suddenly and significantly nose down before descending in a left turn from which it did not recover before striking the surface of a crop field. The reason for this final manoeuvre was not determined.

Aviation Research and Analysis, AR-2010-055, *'Avoidable Accidents No 3'*, published by the Australian Transport Safety Bureau, considers issues related to partial power loss after takeoff in single-engine aircraft and contains valuable guidance when dealing with such an emergency and is potentially relevant to this accident.