ACCIDENT

Aircraft Type and Registration:	Cirrus SR22T, 2-RORO
No & Type of Engines:	1 Continental Motors TSI0-550-K piston engine
Year of Manufacture:	2014 (Serial no: 701)
Date & Time (UTC):	12 May 2019 at 0950 hrs
Location:	A40, near Abergavenny, Wales
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 2
Injuries:	Crew - 1 (Minor) Passengers - 2 (Minor)
Nature of Damage:	Aircraft destroyed
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	52 years
Commander's Flying Experience:	1,600 hours (of which 700 were on type) Last 90 days - 70 hours Last 28 days - 30 hours
Information Source:	AAIB field investigation

Synopsis

On takeoff from Abergavenny Airfield the engine of 2-RORO started to produce varying amounts of power, which the pilot and witnesses described as the engine "surging". The power available was insufficient to allow the aircraft to climb away, and it contacted power lines before pitching down and striking a dual carriageway. The aircraft came to rest inverted and was quickly consumed by fire. All three occupants were helped to escape by a passing motorist.

The loss of engine power was probably caused by too much fuel being delivered to the cylinders. Due to the significant damage to the aircraft and parts of the engine, the investigation was unable to determine the cause of the over-fuelling.

History of the flight

The pilot had flown 2-RORO from Denham Aerodrome to Abergavenny Airfield to pick up two passengers. The group would then fly to Manchester for an event later that day. They arrived in Abergavenny around 0930 hrs and were ready to depart at around 0950 hrs; the aircraft was not refuelled. As the pilot prepared for departure, he noted that all the engine indications were normal and completed his pre-takeoff checks, including selecting the electric fuel booster pump ON.

The aircraft accelerated normally along the runway and at around 75 kt lifted off as normal and began to climb. Almost instantly the pilot recognised that the engine was not delivering the expected power. He could hear the sound of the engine rising and falling like it was "surging", and this sound was also confirmed by other witnesses at the airfield. The pilot felt there was insufficient runway remaining ahead on which to land the aircraft so decided there was little option but to continue the departure, climb away from the ground and carry out a forced landing at the earliest opportunity.

The pilot was aiming to land the aircraft on the dual carriageway, which runs parallel to the airfield, if he could clear the trees running parallel to the runway. However, the aircraft struck the trees and a power cable with its landing gear and this pitched it down rapidly so that it struck the road heavily. Either the initial impact or contact with the central barrier caused the aircraft to invert, and it came to rest against the central barriers on the far carriageway. A fire started during the accident sequence. Figure 1 shows the accident site with the airfield in the background.

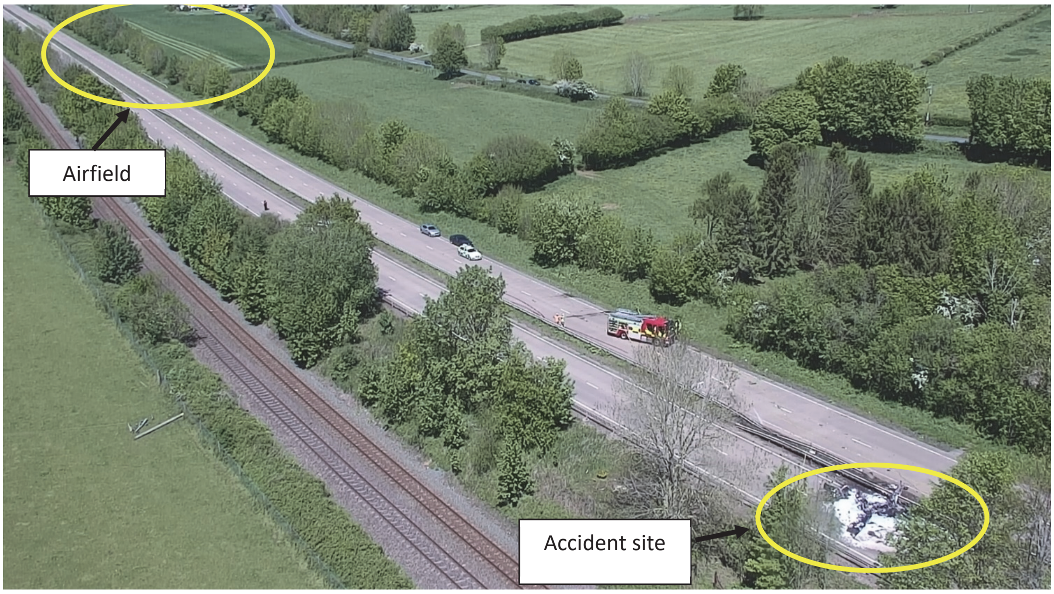

Figure 1

Accident site with Abergavenny Airfield in the background

All three occupants were trapped in the aircraft due to the inverted attitude jamming the doors closed. Whilst the aircraft is equipped with a hammer to break the windows during such an event, the occupants were unable to find it in the confusion and disorientation of being upside down. One of the passengers and a passer-by who rushed to help were able to break one of the windows. The passer-by pulled out the three occupants one by one who were then able to run away from the fierce fire. The occupants suffered only minor injuries. Figure 2 shows the aircraft on fire after the occupants escaped. The pilot estimated that the flight time from lift off to striking the road was less than 30 seconds.

The aircraft was equipped with a ballistic recovery system (BRS) as well as an oxygen bottle and both items were consumed in the fire. The oxygen bottle caused a significant explosion shortly after all the occupants had been assisted from the wreckage. On arrival at the scene the fire brigade was advised about the BRS by the pilot and as a result, once the fire was under control, they contacted the AAIB for advice to ensure that the BRS was safe and that no additional precautions were needed.

Figure 2
Aircraft fire after the occupants' escape

Accident site

The aircraft came to rest against the central reservation barriers of the northbound carriageway of the A40 approximately one mile south of Abergavenny, Monmouthshire. There were clear witness marks on the carriageway indicating that the aircraft slid from the initial impact point to its final resting place. Figure 3 shows the accident site and the marks on the road.

The majority of the aircraft was consumed by fire, with little behind the engine firewall surviving. The engine, however, was relatively intact. The wreckage was recovered by the emergency services so that the road could be re-opened, it was then moved to the AAIB at Farnborough for further examination.

Figure 3
Accident site showing the ground marks

Recorded information

2-RORO was fitted with a recoverable data module (RDM) in the tail. However, neither the recorder nor the protected memory module within it could be located. The wreckage had been recovered from the roadside and moved to a storage yard before subsequently being transported to the AAIB. It could not be established if the memory module had not survived the intense fire in the area of the tail, or if it was lost in the subsequent movements of the wreckage. The RDM would have recorded flight and engine data.

The aircraft was fitted with a Mode S transponder, but the aircraft did not reach a height at which its transmissions were picked up by any receiver.

Aircraft information

The Cirrus SR22T is a four-seat aircraft largely constructed from composite material. The aircraft is fitted with a Continental TSIO-550-K1B six-cylinder twin turbocharged piston engine. The cylinders are numbered one to six[1]. The ignition system consists of two engine-driven magnetos and two spark plugs per cylinder. Ignition and magnetos are controlled by a four-position switch in the cockpit. The engine drives a three-blade, composite, variable-pitch constant speed propeller.

Aircraft fuel system

The SR22T is fitted with an integral fuel tank in each wing. Fuel is fed by gravity to the associated tank collector sump, where an engine-driven pump draws fuel through a filter and a selector valve (with positions LEFT/RIGHT/OFF) to pressure feed the engine fuel injection

Footnote

[1] No 1,3 and 5 cylinders are on the right side of the engine as seen from the pilot seat with No 2,4 and 6 on the left side of the engine. No 1 and 2 cylinders are closest to the pilot at the back of the engine.

system. An electric fuel pump is fitted upstream of the engine-driven pump to provide fuel for engine priming and for vapour suppression. A schematic diagram of the aircraft fuel system can be found in Figure 4.

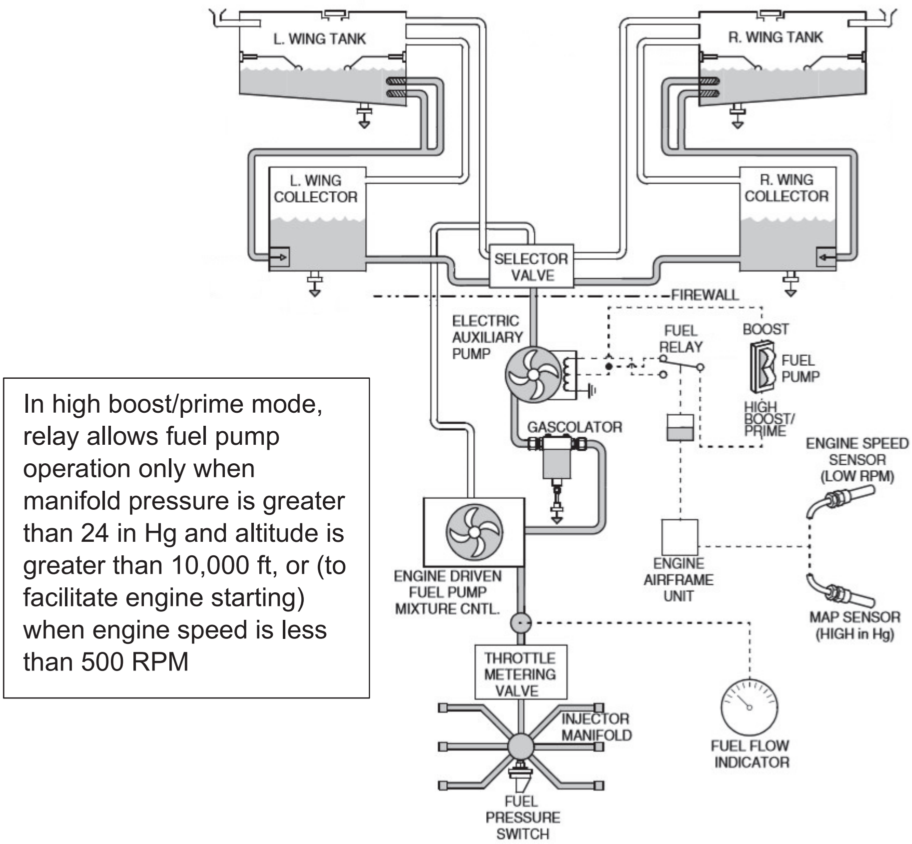

Figure 4

Cirrus SR22T fuel system incorporating software update v0764.36

Electric fuel pump operation is controlled through a fuel pump rocker switch in the cockpit. The switch has a lower pressure BOOST position and a higher-pressure HIGH BOOST/PRIME position. Selecting BOOST energizes the fuel pump in low-speed mode regardless of engine speed or manifold pressure to deliver a continuous 4-6 psi boost to the fuel flow for vapour suppression in a hot fuel condition. The manufacturer's checklist suggests selecting the pump to BOOST before engine start (HIGH BOOST/PRIME before BOOST for a cold weather start) and leaving it at BOOST until the aircraft reaches cruise altitude. The pump should then be selected to BOOST before landing. The manufacturer also recommends the pump be selected to BOOST for any manoeuvring flight. The system is fitted with a lockout relay to ensure that HIGH BOOST/PRIME is only used for engine start (when the engine speed is less than 500 rpm) or for operation at high power settings (when the manifold pressure is greater than 24 in Hg). A software modification was introduced in November 2018 which also locked out the high boost setting below 10,000 ft. This software update was embodied in 2-RORO in January 2019.

The lockout relay limits the electric fuel pump to the lower pressure BOOST even if the switch is selected to HIGH BOOST/PRIME. During takeoff, although the manifold pressure would have been in excess of 24 in Hg, the aircraft was below 10,000 ft altitude and therefore the lockout relay should have limited the fuel flow. The altitude restriction was introduced by a software update after several incidents with this aircraft type where the electrical fuel boost system was suspected of causing over-fuelling[2] to the engine resulting in black soot deposits and reported engine “surging”.

The fuel supply is metered in the throttle metering valve which selects the appropriate fuel flow for the demanded power and environmental conditions. Excess fuel is then returned to the selected tank via the return line. The metered fuel passes to a flow divider and is delivered to the individual cylinders.

Ballistic recovery system

The SR22T is fitted with a BRS that can be deployed in the event of loss of control, failure of the aircraft structure, or other in-flight emergencies. Once deployed, a large parachute lowers the aircraft to the ground. The aircraft did not reach a height at which deployment of the system would have been a successful option.

Maintenance history

2-RORO held a valid Certificate of Airworthiness and had been maintained in accordance with an approved maintenance programme. The aircraft had its last Annual Inspection on 8 August 2018. This included a magneto timing check and an inspection of the spark plugs, which were all recorded as serviceable and within limits.

The pilot had flown the aircraft during the previous week and noted no anomalies with, or adverse performance from the engine. The flight to Abergavenny on the morning of the accident was also normal.

Survivability

The pilot reported that because the aircraft was inverted he found it difficult to locate the emergency egress hammer, which was in the central armrest, to break the windows. Disorientation when an aircraft is in an abnormal attitude can mean people find it difficult to locate seat belt releases and emergency equipment. The cabin space remained intact through the accident sequence, and once the window had been broken the occupants found they could escape relatively easily despite being inverted.

Weight and balance

The aircraft was under its maximum takeoff weight and within its centre of gravity limits.

Footnote

2 Over-fuelling is where the fuel-to-air mixture delivered to the engine is too rich in fuel for the conditions.

Aircraft performance

Calculations of the aircraft takeoff performance, using figures provided by the aircraft manufacturer and assuming a normally operating engine, indicated that the runway available was more than adequate for the takeoff distance required. These calculations also showed that the aircraft should have had no difficulty in clearing the trees in the departure route.

Meteorology

Weather conditions at the airfield are automatically recorded. At the time of the accident the wind was from 140° at 5 kt, with a temperature of 13°C. There was no cloud below 5,000 ft aal and the QNH was 1033 HPa. There had been no rain in the previous 24 hours and the grass was dry.

Engine examination

The engine was examined externally prior to strip down. Although it sustained thermal damage from the post-accident fire, this was concentrated at its bottom and rear. There were no external pre-accident anomalies visible with any of the components. The spark plugs were removed and examined. All were coated in a dark black soot with oil also coating all but the No 2 top and No 5 bottom sparkplugs (Figure 5). The No 1 top, No 4 bottom and the No 6 bottom sparkplugs had fractured centre insulators. All the sparkplugs displayed what the engine manufacturer described as a '*severe worn-out wear condition*', as the central electrodes on all sparkplugs had eroded to an elliptical or diamond shape. The sparkplugs were tested and the ones with the cracked insulators failed to produce a spark.

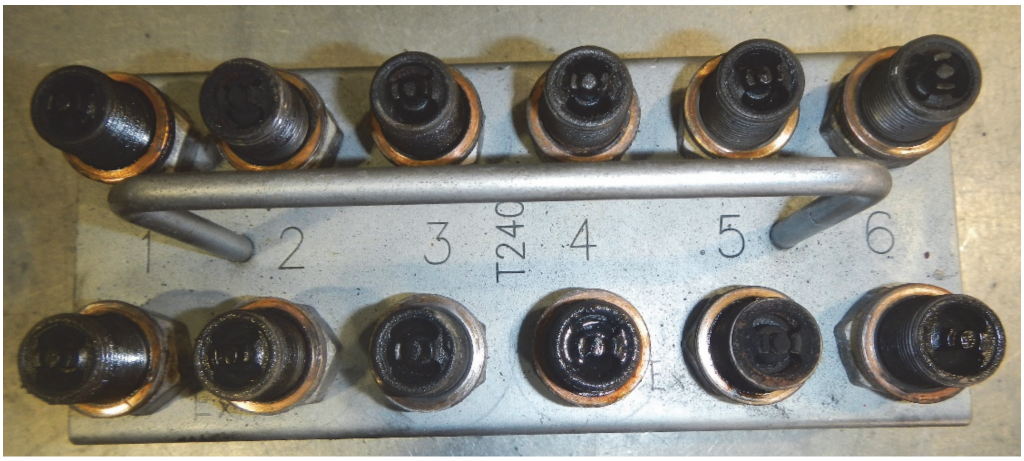

Figure 5

Spark plugs removed during engine strip

The engine exhaust system risers and manifolds remained attached to the engine. The turbochargers and wastegates were removed and examined. No pre-accident anomalies were evident. The turbocharger turbines and their respective impellers rotated normally.

Both magnetos remained secured to the engine. Examination showed that the magneto-to-engine timing was not to specification. It was not established if this was also the case before the accident. However, on removal from the engine both the left and right magneto internal timing were also not to specification. The magnetos were placed on a test stand and functionally tested. Both produced a spark from each lead in the correct firing order throughout the operational speed range.

The engine-driven fuel pump had sustained significant thermal damage and it was not possible to functionally test it. Disassembly revealed there were no pre-accident anomalies with its internal components. The throttle body was intact and after removal from the engine it was tested against the production specifications. Although the results showed that it was not calibrated to the Aircraft Maintenance Manual specification, the differences were slight with a somewhat leaner condition in the mid-throttle range. The fuel manifold valve functioned as designed. All the fuel nozzles were clear and free from obstructions. The engine oil system was normal with no signs of pre-accident anomalies. Neither the fuel pump rocker switch nor the electric fuel pump and its associated lockout relay were located in the wreckage, and it was considered likely that they had been destroyed in the post-accident fire.

All six cylinders remained attached to the crankcase and produced compression when the crankshaft was manually rotated, and all rockers/valves moved normally. None of the cylinders' internal components showed any significant combustion deposits. On removal it was seen that all cylinder heads and intake valves were covered in black soot. Cylinder No 5 also displayed evidence of lean-mixture piston head and cylinder head erosion as shown in Figure 6.

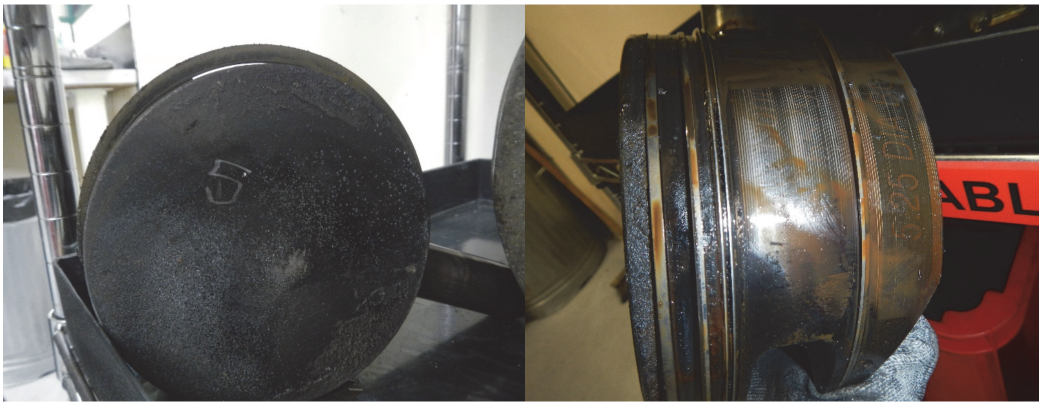

Figure 6

Cylinder No 5 showing the dark soot deposit and the lean-mixture piston face and cylinder head erosion

The crankcase, crankshaft, connecting rods, camshaft and assessor gears were all intact and showed no mechanical anomalies.

The propeller governor was stripped, and it showed no pre-accident anomalies and that the propeller was rotating when the aircraft struck the ground. Assessment of the propeller pitch change mechanism confirmed that the propeller was in fine pitch at the time it struck the ground.

Analysis

On takeoff from Abergavenny Airfield, 2-RORO suffered a loss of engine power and could not climb away adequately. The aircraft struck power cables, pitching it down onto the dual carriageway which runs alongside the airfield. The aircraft came to rest inverted and a fire developed which quickly consumed much of the aircraft. The pilot and two passengers were helped from the aircraft by a passing motorist.

The pilot and witnesses described the engine sounding like it was "surging" with varying power. The propeller and its governing system were examined and considered not to exhibit any pre-impact damage, and therefore the governing system was ruled out as a possible cause of the loss of power.

The pilot's description, together with the soot on the cylinders and intake valves, suggested the engine was running with a rich fuel mixture (over-fuelling). However, the engine itself revealed a longer-term issue with magneto timing, lean running (under-fuelling) and spark plug damage. These longer-term faults could all be linked with the magneto timing issues causing both the spark plug damage and the cylinder damage but could not explain the engine malfunction on the day of the accident. The longer-term faults may have eventually caused a loss of power on the engine, but they were not the cause of the failure on the accident flight.

Rich running could have been caused by a malfunction in the electric fuel pump system or fuel metering system, or by a blockage or restriction in the fuel return lines, possibly elevating the fuel delivery pressures and flows to the engine. The electric fuel pump and its associated lockout relay were destroyed in the post-accident fire so could not be examined or tested. The throttle body was tested and found to be outside production specifications, although the differences were slight and tended towards lean running rather than rich. 2-RORO had software which, to prevent over-fuelling on takeoff, added an altitude restriction to the conditions in which the HIGH BOOST/PRIME relay would allow increased fuel flow. It should not therefore have been possible for over-fuelling from the electric fuel pump to occur even if the switch had been selected to HIGH BOOST/PRIME. The aircraft and engine examination did not establish if there was any fault or malfunction in the relay or the rest of the fuel system. It was not therefore possible to identify the cause of the over-fuelling on the takeoff at Abergavenny.

Had the memory module of the recorder been recovered, it would have helped the investigation understand the accident flight and the long-term health of the engine through trends in temperatures and pressures over time. Without it, the investigation was left with physical evidence in the engine of longer-term issues related to lean running (under-fuelling) and short-term issues related to over-fuelling. It became clear from the engine examination that the loss of power on the accident flight was unrelated to the longer-term engine issues.

Conclusion

The loss of power after takeoff experienced by 2-RORO was probably caused by over-fuelling leading to a mixture too rich for the engine. Both the engine and aircraft manufacturers have investigated cases where an engine has been over-fuelled when the aircraft is at a low altitude but with a high power setting, such as with the accident takeoff. The manufacturer developed a software modification to remove this risk by preventing the HIGH BOOST/PRIME function being active below 10,000 ft altitude with the manifold pressure above 24 in Hg. This software modification was embodied on 2-RORO at the time of the accident. The cause of the over-fuelling was not determined because many components of the fuel system as well as the data recorder were not located or were destroyed in the post-impact fire.

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