ACCIDENT

Aircraft Type and Registration:	Cirrus SR22, G-SRTT
No & Type of Engines:	1 Teledyne Continental IO-550-N46 piston engine
Year of Manufacture:	2007 (Serial no: 2421)
Date & Time (UTC):	9 June 2018 at 1039 hrs
Location:	Benington, Hertfordshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Minor damge to fuselage at the lower left engine mount and where the CAPS cables pulled out of the structure; engine severely damaged
Commander's Licence:	Private Pilot's Licence
Commander's Age:	60 years
Commander's Flying Experience:	284 hours (of which 4 were on type) Last 90 days - 18 hours Last 28 days - 4 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot, AAIB enquires and examination of the engine

Synopsis

Approximately eight minutes into a cross-country flight there was a catastrophic engine failure. At a height of approximately 800 ft agl the pilot successfully operated the aircraft's parachute recovery system and the aircraft descended into a field near the village of Benington (Figure 1). The engine failure most probably occurred because of an insufficient quantity of oil.

History of the flight

The pilot reported that he was conducting a VFR flight from North Weald Airfield to Retford Gamston Airfield and was accompanied by a passenger, who also held a private pilot's licence. The wind was approximately 5 kt from 070°. Approximately six minutes into the flight, and while at a cruise height of approximately 1,500 ft agl, the engine oil low pressure warning light illuminated. The engine oil pressure gauge, which would normally have indicated 45 to 50 psi, indicated approximately 9 psi. The pilot reduced the engine power, which reduced the airspeed from approximately 130 kt to 90 kt, and made a turn with the intention of returning to North Weald.

Figure 1
G-SRTT descending under the parachute
(Photograph used with permission)

Shortly after the pilot informed Farnborough Radar of his engine problem and intentions, the engine started to run rough, there was a loss of power and grey smoke and oil started to come out from the engine cowlings. At this stage the pilot had entered a shallow descent in order to maintain his airspeed. The rough running developed into severe banging, there was a further loss of engine power and the smoke became denser to the extent that the pilot had difficulty in seeing through the windscreen. The aircraft was now at a height of approximately 1,100 ft agl and while there were a number of large fields within glide range, with the smoke obscuring his forward visibility the pilot was not confident that he could make a safe landing. He was also concerned that an engine fire might develop. The passenger, on the pilot's instructions, made a MAYDAY call to Farnborough Radar while the pilot checked that the area below the aircraft was clear and operated the Cirrus Aircraft Parachute System (CAPS) at a height of approximately 800 ft agl.

The CAPS operated normally, and the aircraft descended into a field on the eastern edge of the village of Benington (Figure 2). The pilot and passenger were uninjured.

Figure 2
Accident site

Aircraft information

General

The Cirrus SR22 is a four-seat light aircraft equipped with a single piston engine fitted with an oil-operated variable pitch propeller. The cockpit is equipped with two electronic displays: a Primary Flight Display (PFD) and a Multifunctional Display (MFD). Also mounted on the instrument panel is an annunciator panel that contains a red oil warning light that illuminates when the oil pressure is below 10 psi.

Cirrus Aircraft Parachute System (CAPS)

The Cirrus SR22 is fitted with CAPS, a ballistic parachute recovery system, which is designed to bring the aircraft and occupants to the ground in the event of a life-threatening emergency. Its deployment has been demonstrated in straight and level flight at a speed of 133 kt with a loss of height of 400 ft. In the event of an engine failure, Cirrus Aircraft provide the following advice in their document *'Guide to CAPS'* (Figure 3).

Takeoff Briefing

A Cirrus pilot is more likely to deploy CAPS quickly during a total loss of engine power or other emergency if a takeoff briefing is conducted prior to takeoff.

Height Above Ground Level (AGL)	Recommended Response
0' – 500' (600' G5)	Land Straight Ahead*
500' (600' G5) – 2000'	Deploy CAPS Immediately
2000' or Greater	Troubleshoot, Use CAPS as Required

*Activate CAPS immediately if no other survivable alternative exists.

Figure 3
Extract from Cirrus aircraft document – Guide to CAPS

Engine

General

The aircraft was equipped with a Teledyne Continental IO-550-N46 six-cylinder, fuel-injected engine. The engine had been fitted with two Tornado Alley intercoolers and turbochargers by the aircraft manufacturer under a Supplementary Type Certificate. At the time of the accident the engine had operated for approximately 1,280 hours since new.

The last significant maintenance on the engine occurred during the annual inspection carried out in June 2014, approximately 430 engine hours prior to the accident, when the No 2 and No 4 cylinders were found to be cracked. Both cylinders were replaced without disturbing the piston connecting rods.

The engine was last inspected during the 50-hour servicing carried out approximately two weeks prior to the accident. The inspection revealed no evidence of an oil leak from the engine or propeller, or burnt oil residue in the exhaust system.

Capacity of the engine oil system

The Continental IO-550-N46 engine fitted to the Cirrus SR22 has a certified oil capacity of 8 US quarts, whereas the IO-550 engine used in other aircraft installations has a 12 US quart system with the extra 4 US quarts used for cooling. The aircraft manufacturer advised that the IO-550-N engine was reduced to 8 US quarts (slightly smaller sump) as the SR22 cowling provided better aerodynamic cooling.

Regarding the oil system, the Pilot's Operating Handbook (POH) provides the following caution:

> *'The engine should not be operated with less than six quarts of oil. Seven quarts (dipstick indication) is recommended for extended flight.'*

The pilot on the accident flight informed the AAIB that he checked the oil level during the pre-flight walk round and it was full at 8 US quarts. He also reported that there was no evidence of oil leaks on the outside of the aircraft.

Description of the engine oil system

The engine is provided with a wet-sump, high-pressure oil system for engine lubrication and cooling (Figure 4). The engine oil, which is contained in the oil sump, is drawn through a screen into the oil suction tube to the inlet of the positive displacement oil pump. Pressurised oil from the pump outlet is directed past the oil pressure relief valve to the oil filter. From the oil filter, pressurised oil flows through a crankcase passage to the oil cooler.

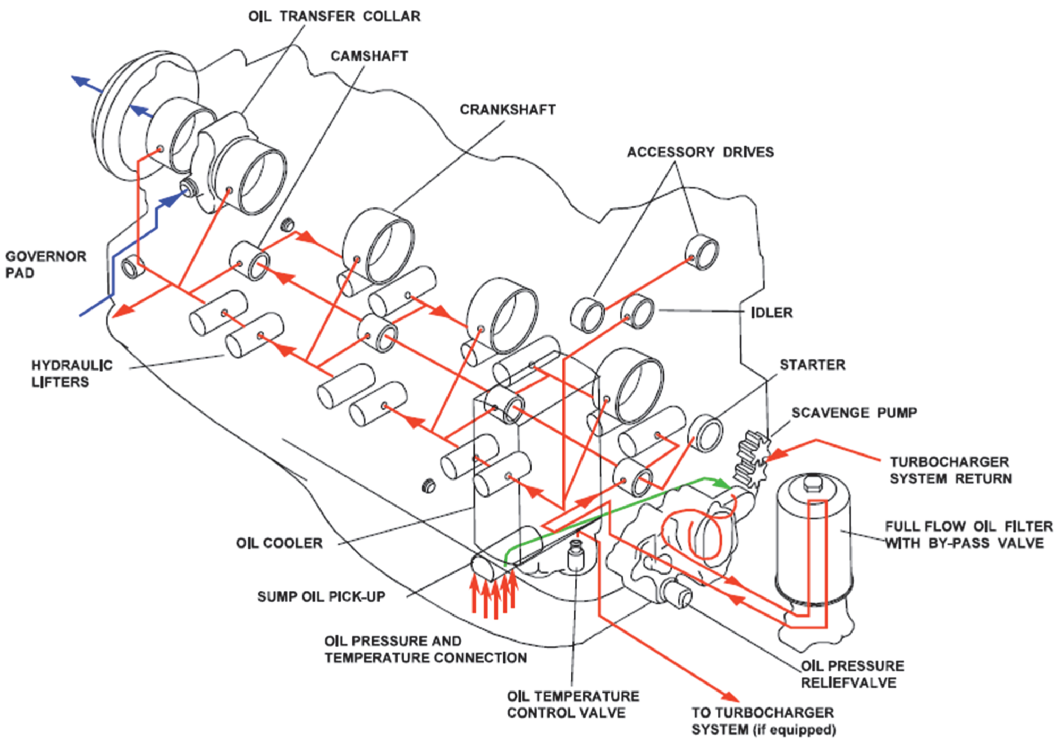

Figure 4

Engine oil system

From the oil cooler the oil is directed to the oil galley in the left side of the crankcase and the camshaft. The oil in the left side of the crankcase is directed to all the main bearings and then feeds through galleys in the crankshaft to each of the connecting rods (Figure 5). The oil lubricating the main bearings is also directed to the oil squirt nozzles that spray a mist of oil onto the bottom side of the pistons to lubricate the cylinder walls and piston pins; gravity returns the oil to the sump. Oil that passes through the left side of the crankcase is also used for the propeller governor operation. Oil is also passed though the camshaft to the right side of the crankcase to lubricate the valve lifters and other cylinder components.

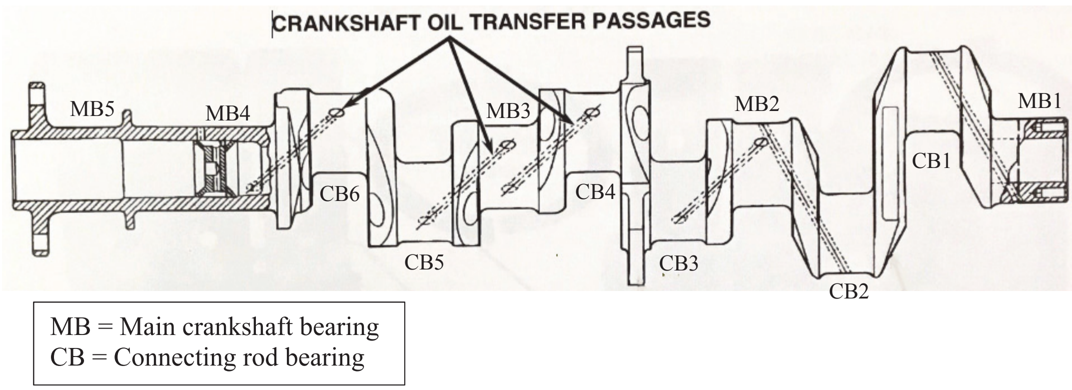

Figure 5

Crankshaft oil transfer passages

The oil pressure is sensed by a transducer located between the oil cooler and crankshaft oil gallery and the oil temperature by a sensor located in the sump.

Engine limitations

The POH provides the following engine operating limitations:

Oil Temperature …………..240°F (115°C) maximum
Minimum oil pressure …….10 psi

Engine indications

The SR22 is equipped with engine instrumentation and warning lights to monitor the engine performance. A data acquisition unit converts analogue signals from the cylinder head temperature (CHT), exhaust gas temperature (EGT), manifold air pressure (MAP), oil pressure, oil temperature and tachometer to digital format which is then transmitted to the MFD and the PFD. The engine oil pressure is continuously displayed in the engine data block located in the lower right corner of the PFD. System health, caution, and warning messages are displayed in colour-coded advisory boxes in the lower right corner of the MFD (Figure 6). In addition, the text of the engine parameters displayed on the PFD changes to the corresponding colour of the advisory box during an annunciation event.

Figure 6

Multi Functional Display

If the oil pressure falls below 30 psi or exceeds 75 psi, the MFD will display '*Check Oil Press*' in a yellow advisory box in the lower right corner of the MFD. If the oil pressure falls below 10 psi or exceeds 99 psi, the MFD will display *'Check Oil Press'* in a red advisory box.

An annunciator panel located in front of the pilot contains an oil warning light which illuminates when either the oil pressure or oil temperature warning messages are generated.

Emergency procedures for low engine oil pressure

Regarding low oil pressure, the POH provides the following guidance to the pilot:

> *'If low oil pressure is accompanied by a rise in oil temperature, the engine has probably lost a significant amount of its oil and engine failure may be imminent. Immediately reduce engine power to idle and selected a suitable forced landing field.*
>
> ***Note***
>
> *If low oil pressure is accompanied by normal oil temperature, it is possible that the oil pressure sensor, gauge, or relief valve is malfunctioning. In any case, land as soon as practical and determine cause.'*

Engine data

The aircraft MFD has a Flight Data Logging feature which automatically stores critical flight and engine data on a compact flash card.

The engine data for the accident flight is plotted in Figure 7. The data shows that the engine had been running for 11 minutes before the rpm and MAP increased for takeoff. During this period the oil temperature rose progressively to 162°F and the oil pressure reduced to approximately 45 psi before peaking at 58 psi as the engine speed was increased to 2,670 rpm. Over the next 13 minutes, the oil temperature continued to increase, peaking at 198°F. Approximately 6 minutes after the start of the takeoff run, the oil pressure reduced to 30 psi (yellow warning) and 2 minutes later reduced to 10 psi (red warning). The engine stopped rotating approximately 13 minutes after the takeoff run commenced. During the flight the CHTs peaked at 346°F, and the EGTs at 1,436°F.

Apart from the reducing oil pressure, all the parameters indicate that the engine was operating normally until 30 seconds before the engine stopped, when the EGTs started to decrease. The engine data for the four flights prior to the accident fight appeared to be normal with the oil pressure remaining at around 50 psi during the cruise. The oil temperature during the previous flights peaked at between 184°F and 195°F; on the accident flight the oil temperature peaked at 198°F.

Examination of the aircraft and engine

Examination of the aircraft at the accident site

The engineering organisation who recovered the aircraft reported that the only significant damage to the aircraft was to the area of the fuselage adjacent to the lower left engine mount and the areas where the cables for the CAPS had been pulled out of the airframe. The CAPS had operated as designed.

Engine oil had leaked onto the ground from the sump, which had been punctured during the impact. There was a hole in the crankcase next to the No 4 cylinder through which the oil had leaked out of the engine in flight. There was no other evidence of an oil leak from the engine or propeller. The engineering organisation also reported there was no evidence of residues in the exhaust to indicate that oil had been burnt in the combustion chambers. The engine could not be rotated by hand.

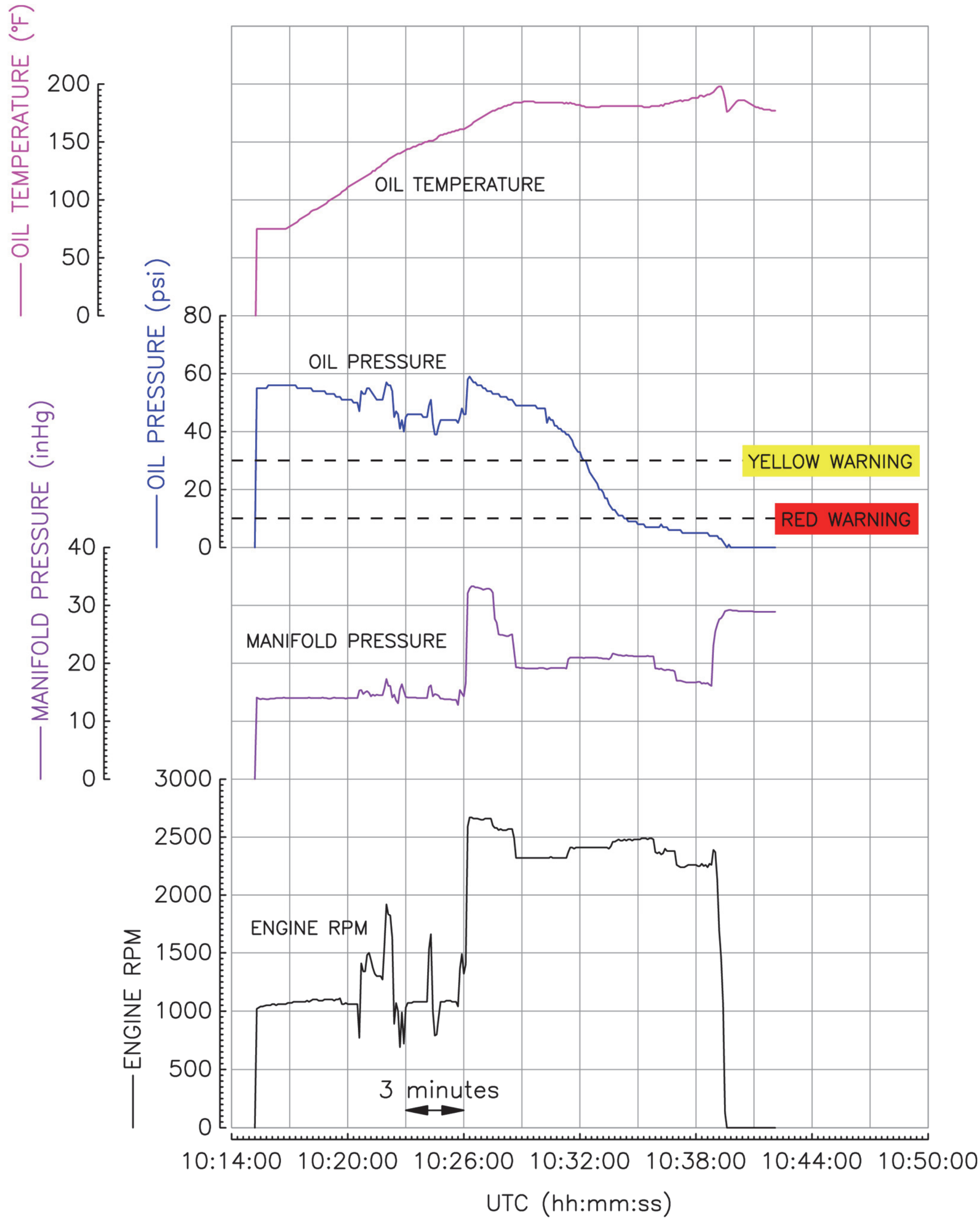

Figure 7

Engine data from accident flight

Examination of the engine by the AAIB

An examination of the engine was carried out by the AAIB at the engine overhaul facility. For reference, the parts of a generic piston and connecting rod assembly are shown at Figure 8.

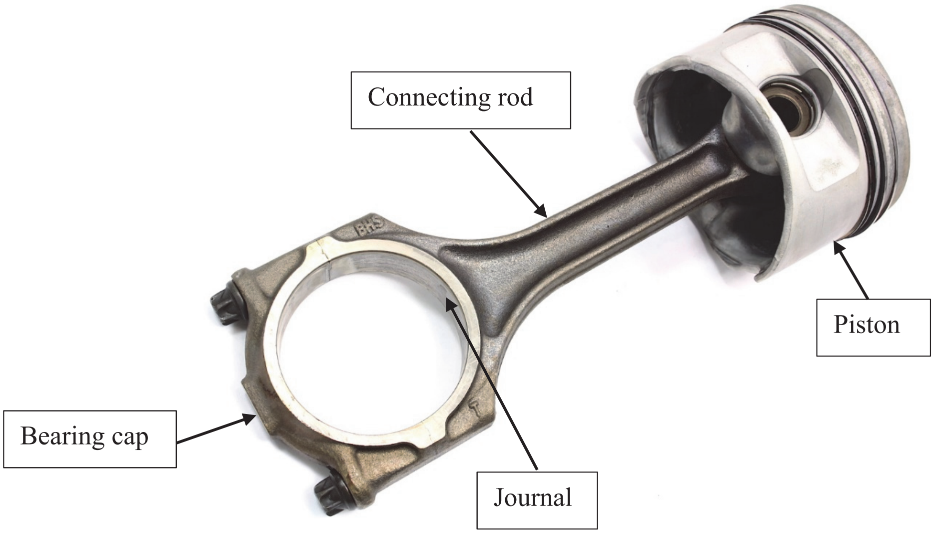

Figure 8
Generic piston and connecting rod

The bearing caps on the No 3 and No 4 piston connecting rods had become disconnected. Damage to the No 4 connecting rod indicated that it had then been struck by the crankshaft with sufficient force for it to knock a hole approximately 10 cm by 8 cm in the crankcase beneath the No 4 cylinder (Figure 9).

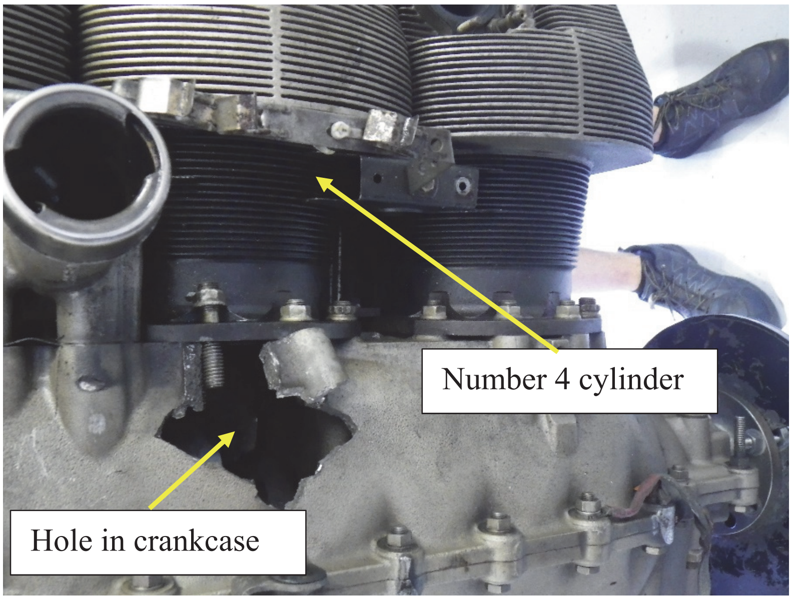

Figure 9
Hole in the crankcase caused by the No 4 connecting rod

The No 2 piston connecting rod was seized on the crankshaft and the No 5 piston connecting rod was partially seized. The No 1 and No 6 connecting rods rotated normally. Except for the No 1 connecting rod, there was discoloration and corrosion on the bottom part of all the connecting rods, which was greatest on the inner four connecting rods (Figure 10). The bearing material on all the overheated connecting rods had extruded out of the bearing caps leaving the connecting rods running on the steel shells. There was no evidence that any of the bearings had rotated in their journals.

The crankshaft counterweights were intact and there was no evidence of overheating on the cylinders, pistons or valve assemblies.

Figure 10

Corrosion and discoloration on connecting rod and bearing cap

The bottom of the No 3 connecting rod and bearing cap had broken into four parts and the remnants of the bolts exhibited failure in overload. The skirt on the piston had also broken off (Figure 11). The No 4 bearing cap was intact, and distorted, and had separated from the connecting rod. The parts of the two bolts that remained in the bearing cap also exhibited necking associated with failure in overload.

Figure 11

Damage to No 3 and No 4 connecting rod and bearing caps

Parts of two bolts, that had failed in overload, a nut containing part of a bolt that had failed in shear and a broken part of a nut where found in the engine (Figure 12).

Figure 12

Parts of failed nuts and bolts recovered from the engine

Overall condition of the engine

There were multiple sites of impact damage within the crankcase and on the bottoms of the pistons, caused by flying debris. The oil galleries in the crankshaft were checked and found to be clear. There was oil throughout the engine and debris from the crankcase was found in the oil filter. The remainder of the oil system, including the bypass and relief vales were intact and operated normally. There was no evidence of an oil leak in the turbochargers.

There was no evidence of overheating in the cylinders or pistons, or at the ends of the crankshaft. All the piston rings and oil scrapers were intact and there was no evidence of oil having been burnt in any of the combustion chambers.

Metallurgist report

Metallurgists from QinetiQ examined the failed bolts, the parts that were recovered from the No 2 and 3 connecting rods, and photographs of the crankshaft taken by the AAIB.

The parts had been badly damaged and based on the evidence available they concluded that the main bearings on the No 3 and 4 connecting rods had overheated sufficiently to cause the bearing material to melt and the strength of the steel bolts to reduce such that they failed in overload.

Engine oil consumption

No complete record had been kept of either the engine oil level or oil replenishments. Pilots of this aircraft on previous flights stated that the engine oil level was satisfactory at the start of the flight, there was no evidence of oil leaks and no additional oil was added to the engine.

Analysis

Engine failure

Examination of the engine revealed that the temperature at the bottom of a number of the connecting rods had been sufficient for the bearing material to melt and for the No 3 and 4 connecting rod cap bolts to fail in overload. There was no evidence of overheating in any other part of the engine and no fault was found in the engine lubrication system. The engine manufacturer advised that the heat damage along the crankshaft and the failure of the connecting rod bearings was consistent with the engine having been operating with a low level of oil.

With insufficient oil to cool and lubricate the bearings, the temperature of the bearing material would increase and start to melt, causing the gap between the bearing surface and the crankshaft to increase. This would result in an increase in vibration and a drop in the oil pressure which would affect the cooling and lubrication of other parts of the engine. Once all the bearing material had melted, the connecting rod would be left running on the steel bearing shell, which would have caused a further increase in temperature sufficient to reduce the tensile strength of the cap bolts so that they failed under normal loads.

The engine data indicates that the rise in temperature at the connecting rod bearings, and subsequent failure of the cap bolts, occurred over a short period of time and before there was sufficient heat transfer from the crankshaft to affect the temperature of the oil in the engine sump where the temperature sensor is located.

Loss of oil

Apart from the oil that had been lost through the hole in the crankcase, caused by the failed No 4 connecting rod, there was no other evidence of the engine having sustained an oil leak during the accident flight. Nor was there any evidence that the engine had been burning oil.

Actions of the pilot

The pilot was aware of the decreasing oil pressure, without a corresponding increase in temperature, and considered that he acted in accordance with the POH to land as soon as practicable. However, once the connecting rod failed he not only had insufficient power to maintain height but his forward visibility was affected by the smoke from the engine. He was also concerned at the possibility of an engine fire. The pilot acted in accordance with the recommendation from Cirrus to operate CAPS immediately if the engine failure occurs between 500 to 2,000 ft agl. The CAPS was deployed at approximately 800 ft agl and the aircraft descended into a field approximately 120 m from the village of Bennington without injury to the pilot or passenger.

Conclusion

The pilot activated the CAPS following an engine failure in accordance with the POH and advice by the aircraft manufacturer. The engine failure was due to overheating of the connecting rod cap bolts as a result of insufficient cooling by the engine oil.

AAIB comment

This accident highlights the importance of understanding the sensitivity of an engine's oil capacity and oil level during flight. The engine in the Cirrus SR22 has a certified oil capacity of 8 US quarts and a drop from the maximum level can increase the risk of the bearings starting to overheat and fail.

It is also worth emphasising that a drop in oil pressure, without a corresponding increase in oil temperature, does not necessarily indicate that the fault is caused by an oil sensor or gauge and, therefore, a pilot should land as soon as safely practical. In considering whether to make a field landing, a pilot would need to consider the risk of continued flight to a suitable airfield against the risk of a precautionary landing in a field.

Bulletin correction

Following further discussion with the pilot, the conclusion to this report now reads:

> **Conclusion**
>
> The pilot activated the CAPS following an engine failure in accordance with the POH and advice by the aircraft manufacturer. The engine failure was due to overheating of the connecting rod cap bolts as a result of insufficient cooling by the engine oil.

The online version of this report was corrected prior to publication.