ACCIDENT

Aircraft Type and Registration:	Savannah Jabiru, G-CEED
No & Type of Engines:	1 Jabiru Aircraft Pty 2200 piston engine
Year of Manufacture:	August 2006
Date & Time (UTC):	20 October 2007 at 1030 hrs
Location:	Near Mergate Hall, Bracon, Norfolk
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Nose landing gear bent backwards, slight indentation on the underside of the engine cowling and forward fuselage
Commander's Licence:	Private Pilot's Licence
Commander's Age:	51 years
Commander's Flying Experience:	247 hours (of which 11 were on type) Last 90 days - 4 hours Last 28 days - 1 hour
Information Source:	AAIB Field Investigation

This investigation was conducted in parallel with the investigation into G-JAAB, also published in this AAIB Bulletin, 5/2010.

Synopsis

About 5 minutes after takeoff the pilot of G-CEED performed a 'FREDA' check and saw that the engine indications were normal. Immediately after completing this check she saw smoke in the cabin and less than a minute later the engine seized. The pilot established the aircraft in a glide and landed in a nearby field. The approach and landing were smooth but the surface was rough, causing the nose landing gear to fold backwards. The pilot and passenger exited the aircraft without injury and there was no fire.

Another aircraft (G-CEFY) with a Jabiru 2200 engine suffered a similar engine failure. Both engines had less than 50 hours of usage since manufacture and the failures were caused by high temperatures generated within the cylinders, softening the piston material which led to the piston rings becoming trapped in their grooves. This allowed engine lubricating oil (or vapour) to enter the combustion chamber, which allowing pre-ignition to occur, leading to burn-through of the piston crown and for oil to be expelled overboard.

Both engines had been modified at manufacture to comply with Jabiru Service Letter JSL 002-1 titled '*Jabiru Engine Economy Tuning'* which introduced lean burn jets into the carburettor.

History of the flight – G-CEED

The pilot of G-CEED carried out a pre-flight inspection and topped up the fuel tank with premium unleaded Mogas. She noticed that the engine oil level was within limits. About 5 minutes after takeoff the pilot carried out an after-takeoff/cruise 'FREDA' check and saw that all the engine indications were normal. Immediately after completing this check she saw smoke in the cabin and less than a minute later the engine seized. The pilot established the aircraft in a glide and landed in a nearby field. The approach was smooth but the landing was into a rough agricultural field, which caused the nose landing gear to fold backwards. The pilot and passenger exited the aircraft without injury and there was no fire.

Engine description

The Jabiru 2200 is a four-stroke horizontally-opposed four cylinder piston engine, normally aspirated and air cooled. The displacement is 2,200 cc which produces nominally 85 hp at 3,300 rpm. The fuel specified is either Avgas 100/130 (preferred) or Mogas with an octane rating of 95 or above. The carburettor is pressure compensated and is mounted to a plenum chamber in the sump casing by a flexible rubber coupling. From the plenum chamber the fuel/air mixture is delivered to the cylinders via individual inlet pipes. There is no fuel mixture control in the cockpit. The fuel/air mixture is set up during manufacture, installation or maintenance. There is one cylinder head temperature sensor, mounted under the No 4 cylinder spark plug, which is connected to a gauge in the cockpit.

The engine is fitted to a wide range of manufactured and home-built Light Sport Aircraft worldwide.

Engineering examination – G-CEED

The engine was taken to the manufacturer's UK agent where a strip examination was carried out under AAIB supervision. When the engine was stripped the No 3 piston was found to have burnt through from top to bottom (Figure 1). There was evidence of piston seizure and partial seizures within the cylinders and excessive heat discolouration of the crankshaft and connecting rod bearings, indicative of the engine having run with insufficient lubricating oil. External examination of the engine did not reveal evidence of an oil leak but there was evidence of oil having been blown out of the engine breather pipe.

All four pistons and cylinders were submitted to the Materials Department at QinetiQ for a detailed metallurgical examination. Examination of the No 3 piston showed pre-ignition to be the most likely cause of the burn-through; pre-ignition occurs when the fuel/air mixture in the cylinder ignites before the plug sparks. The fuel burns and expands before the piston is in the correct position, which causes large stresses in the engine and can cause localised heating sufficient to burn through the piston crown as was seen in this case. The QinetiQ report stated that common causes of heat build-up are:

- Carbon deposits.
- Wrong spark plug heat range.
- Lean fuel mixture.
- Combustible contaminants within the combustion area (oil, diesel, kerosene).
- Insufficient engine cooling (air or oil).

Carbon deposits were unlikely to be the cause in this case; no carbon build-up was observed in the cylinders and the engine was relatively new (43 hours since manufacture). The spark plugs in the cylinders received

Courtesy of QinetiQ

Figure 1

No 3 piston from G-CEED showing pre-ignition damage and burn-through

were NGK D9EA, those specified by the manufacturer. For the pistons to seize, the excessive heat must have been present prior to the piston crown burning-through, possibly caused by a lean fuel mixture and/or insufficient engine cooling. Excessive heat can cause pre-ignition. After the piston rings seized, engine oil could have entered the combustion chamber causing, or contributing to, pre-ignition.

Metallurgical checks carried out on pistons 2 and 3 indicated that they had been overheated. Energy dispersive X-ray (EDX) analysis showed that the pistons were manufactured from a high-silicon aluminium alloy, typical of automotive pistons. Hardness testing indicated that both pistons Nos 2 and 3 had been affected by overheating, which had reduced their strength and piston No 3 had been affected more than piston No 2. The piston rings of pistons Nos 1, 3 and 4 were all seized in the grooves. It is possible that a loss of strength in the pistons allowed the grooves to close up, trapping the rings.

The examination of the four exhaust valves did not identify thermal cracking or corrosion, associated with hotter than typical exhaust gases, seen in other Jabiru engines. As the engine in G-CEED was virtually new, it may be that the exhaust gases were hotter than typical, but it was too early in the valves lives to develop fatigue cracks.

Other information – G-CEED

The engineering examination did not show indications of significant leaks at the cylinder head seals, inlet or exhaust systems and no restriction within the engine oil supply system. The engine had a total of 43 hours in use since it was installed into the aircraft as a new unit and had a 25-hour maintenance check carried out in accordance with the manufacturer's requirements.

The engine was found to have been configured in accordance with Service Letter JSL 002-1 titled '*Jabiru Engine Economy Tuning'* which was issued in December 2004. A fuel sample was taken from the aircraft and analysis showed that it was 95 octane unleaded gasoline (ULGAS, BS EN 228:2004), with no evidence of contamination from another fuel product.

Incident to Jabiru 2200 engine fitted to G-CEFY

This incident occurred 3 February 2008 at Brookfarm airfield, Lancashire. Following an uneventful pre-flight inspection by the pilot/owner, which included checking the engine oil level, the engine was started and power checks carried out. After a normal taxi, takeoff and climb to 500 ft at full power, the pilot lowered the nose, reduced the power to 2,600 rpm and continued in a shallow climb to 1,000 ft. Following a gentle turn the engine 'tone' suddenly changed, as if a spark plug had failed. The pilot returned to the airfield and landed safely. Two witnesses at the airfield are reported to have said that they observed a trail of smoke behind the aircraft.

Engineering examination – G-CEFY

The engine, which had completed 48.9 hours since manufacture, was removed from the aircraft and sent to an aircraft engineering organisation for examination. The examination did not show any evidence of an oil leak, significant leaks at the cylinder head seals, inlet or exhaust manifold systems and no restriction within the engine oil supply system. There was, however, good evidence of the onset of piston seizure within the cylinders and burn-through of the No 3 piston (Figure 2).

Three cylinders and their associated pistons were taken to the Materials Department at QinetiQ for detailed metallurgical examination. Examination of the three cylinders showed that No 3 piston and cylinder exhibited characteristics similar to the No 3 piston and cylinder from G-CEED. The piston/cylinder head interface exhibited sooting on one side of the cylinder, with the corresponding edge of the piston exhibiting burn-through (Figure 2). The internal surface of the cylinder showed evidence of minor wear and material pick-up from the piston at the point of the piston burn-through. Skirt wear was observed on the piston similar to that observed in the examination of the engine from G-CEED. Minor wear was observed below the burn-through with the opposite skirt exhibiting more severe wear. The other two pistons both exhibited skirt wear similar to the No 3 piston. One of the pistons showed evidence of damage to the edge of the piston crown with reciprocating wear and material pick-up on the internal surface of the cylinder. The damage appeared to be purely mechanical, with no evidence of burn-through as seen in the No 3 piston.

Examination of the piston rings and oil scraper rings showed that the lower piston ring was seized in the closed position on one of the pistons and on another the upper ring was seized at the area of the damage, so that it was flush with the piston edge. The other end of the piston ring was free to move. On the No 3 piston both the lower piston ring and oil scraper ring were seized in the closed position.

Courtesy of QinetiQ

Figure 2

No 3 piston from G-CEFY showing pre-ignition damage and burn-through

The visual examination of the three pistons and cylinders showed that an engine failure similar to that of G-CEED. In both cases the engines exhibited seized piston and oil scraper rings, piston skirt wear and burn-through.

The engine in G-CEFY was found to have been configured in accordance with Service Letter JSL 002-1 titled '*Jabiru Engine Economy Tuning'* which was issued in December 2004. Jabiru Service Bulletin JSB 018-1 titled '*Jabiru Engine Tuning*' had not been installed and was not a mandatory requirement. The aircraft's owner stated that only 95 octane unleaded Mogas had been used since the engine was installed as a new unit.

Jabiru Service Letter JSL 002-1

Jabiru JSL 002-1 was issued on 13 December 2004, titled '*Jabiru Engine Economy Tuning'* which introduced the '*Economic Tuning Kit'*. This kit contained new idle, needle and main carburettor jets, a new needle and fitting instructions. This Service Letter introduced 'lean burn' jets into the carburettor to improve fuel consumption at cruise power.

Jabiru Service Bulletin JSB 018-1

Jabiru JSB 018-1 was issued on 5 October 2007, titled '*Jabiru Engine Tuning*'. The Service Bulletin introduced richer running jets into the carburettor to replace those introduced by Service Letter JSL 002-1.

Carburettor mounting effect on cylinder head temperature

A UK CAA-Licensed Aircraft Maintenance Engineer, and owner of a Jabiru-engined aircraft, conducted tests with differing angles of mounting the carburettor to the plenum chamber, and at the same time monitoring cylinder head temperatures (CHT) and exhaust gas temperatures (EGT). He found that by tilting the carburettor 10° to 15° left and right he could obtain a rise and fall in CHTs between Nos 1 & 3 cylinders and Nos 2 & 4 of up to 50°C and EGTs up to 120°C.

Discussion – G-CEED and G-CEFY

This investigation was conducted in parallel with the investigation into G-JAAB, also published in this AAIB Bulletin, 5/2010. The evidence from the valve failures in the Jabiru 2200 engines in G-JAAB and G-BCIP indicated that overheating of the valves was at least a contributory factor and this was consistent with the timing of Jabiru JSL 002-1, which had introduced 'lean burn' jets into the carburettor to improve fuel consumption at cruise power. However, Jabiru JSB 018-1, issued in October 2007, introduced richer running jets into the carburettor to replace those introduced by Service Letter JSL 002-1.

From the similarity of the events and their timing, it is likely that the same overheating mechanism that appeared to have affected the valves in G-JAAB and G-BCIP was present in the piston failures in G-CEED and G-CEFY.

Safety action

Following the failures of a number of Jabiru 2200 engines in the UK (including G-CEED (10/07), G-CEFY (2/08) and G-JAAB (9/07)) the AAIB informed the engine manufacturer. A number of overheat-related failures occurred in France at about the same time. The engine manufacturer has a continuing programme of product quality improvement and the number of such events reported to the AAIB and the LAA (Light Aircraft Association) has decreased since that period.