ACCIDENT

Aircraft Type and Registration:	Piper PA-28R-201T Turbo Cherokee Arrow III, G-BFLI
No & Type of Engines:	1 Teledyne Continental Motors TSIO-360-FB piston engine
Year of Manufacture:	1977
Date & Time (UTC):	25 June 2008 at 1748 hrs
Location:	Bradford Leigh, Bradford-on-Avon, Wiltshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - 1 (Minor) Passengers - N/A
Nature of Damage:	Aircraft damaged beyond economic repair
Commander's Licence:	Private Pilot's Licence
Commander's Age:	59 years
Commander's Flying Experience:	1,273 hours (of which 1,098 were on type) Last 90 days - 14 hours Last 28 days - 6 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and subsequent AAIB investigation

Synopsis

The aircraft was on its first flight after having had two new cylinders fitted to the engine. After approximately 90 minutes the engine started making an unusual sound and, fearing an imminent catastrophic engine failure or fire, the pilot elected to shut it down and make a forced landing. The aircraft came to rest in a lake; the pilot escaped with only minor injuries.

The engine problem was attributed to the rocker for the No 4 cylinder inlet valve becoming detached due to failure of the stud bolts, causing the inlet valve to remain closed. Metallurgical examination of the fractures revealed evidence of a fatigue-initiated failure mechanism in both bolts; this could not be attributed to any deficiency in the bolt material.

History of the flight

The aircraft was on its first flight after having had two new cylinders fitted to the engine. Two ground runs were completed satisfactorily prior to the accident flight.

About 90 minutes into the flight, at an altitude of 4,000 ft, the engine started to make what the pilot described as a "fluttering" noise and began to lose power. The engine oil temperature and pressure appeared normal and he varied the throttle setting slightly to see if the unusual

noise would change. A few seconds later the No 2, 4 and 6 cylinder exhaust gas temperature (EGT) readings on the engine data management system dropped. The pilot, fearing that a serious engine problem or fire might develop, elected to shut down the engine, put out a MAYDAY call, and carry out a forced landing.

The pilot reported that there was a tailwind of approximately 30-40 kt during the descent. As he turned onto final for his chosen field, he realised that with the given headwind he would be unable to reach the field and was likely to collide with some trees. He elected not to lower the landing gear, selected full flap and attempted to reduce his airspeed as far as possible, making a late turn onto a downwind heading. The aircraft struck a hedge, which caused the left wing to detach at the root, passed through the hedge and came to rest almost entirely submerged in a lake. The pilot, who was wearing a three-point harness, was able to exit the aircraft unaided, and sustained only minor injuries.

Engine information

The aircraft was fitted with a zero-lifed factory-overhauled engine in June 2007 which had logged 71 flying hours at the time of the accident. The aircraft was on its first flight after having had two new cylinders (No 2 and No 4) fitted to the engine because of low compression in the original cylinders.

The six cylinder engine has a horizontally-opposed layout, and the air induction system is divided such that the 'even' cylinders 2, 4 and 6 (on the left side of the aircraft) are fed from one inlet pipe and the 'odd' cylinders 1, 3 and 5 (on the right) are fed from the other inlet pipe.

The aircraft was fitted with a JPI engine data management system which provides real time display of engine parameters to the pilot, and also records the parameters for later analysis. The cylinder head and the exhaust gas temperature (EGT) were recorded for each cylinder.

Each cylinder has an inlet and an exhaust valve, operated by separate pushrods and rockers. Each rocker assembly is attached to the cylinder head by two stud bolts and tie-down nuts. The specified torque range for the nuts is 110-120 in-lbs, which places the bolts at 70% of their yield strength. As the rocker assemblies must be removed when replacing a cylinder, it would have been necessary to disturb the tie-down nuts during the recent replacement of the two cylinders. Replacement cylinders are supplied by the manufacturer with the rocker stud bolts already installed.

Aircraft information – Pilot's Operating Handbook

The PA-28 Pilot's Operating Handbook covers various emergency situations. In the section entitled 'Engine power loss in flight' it states that:

> *'complete engine power loss is usually caused by fuel flow interruption and power will be restored shortly after fuel flow is restored.'*

and:

> *'...if power is not regained, proceed with the power off landing procedure.'*

In the section entitled 'Engine roughness' it states:

> *'...engine roughness may be caused by dirt in the injector nozzles, induction system icing, or ignition problems.'*

It further states:

> *'...if roughness persists, prepare for a precautionary landing at pilot's discretion.'*

A precautionary landing is one that is conducted with engine power available and may be preceded by a circuit, or circuits, being flown to assess the suitability of the chosen landing site.

Engineering investigation

The JPI system and engine were recovered to AAIB headquarters. The JPI unit was dried slowly and the data downloaded. Figure 1 shows the EGT for all six cylinders at the time of the engine problem; it can be seen that the EGT for the No 4 cylinder dropped markedly, with the EGTs for the No 2 and 6 cylinders following shortly afterwards. Several seconds later the EGTs for the remaining cylinders decreased rapidly, consistent with the engine being shut down.

The engine was strip-examined with a representative from the manufacturer present. The two stud bolts that attached the inlet valve rocker assembly to the No 4 cylinder head were found to have failed (Figures 2 and 3), leaving the inlet valve closed. The valve opened satisfactorily when tested. Witness marks were present inside the rocker cover which appeared to have been made by the tie-down nuts from the failed stud bolts.

There were no other significant findings during the engine inspection and the engine manufacturer was confident that the engine was capable of running and developing significant power even with the failed rocker. However, it would probably have sounded and felt unusual to the pilot.

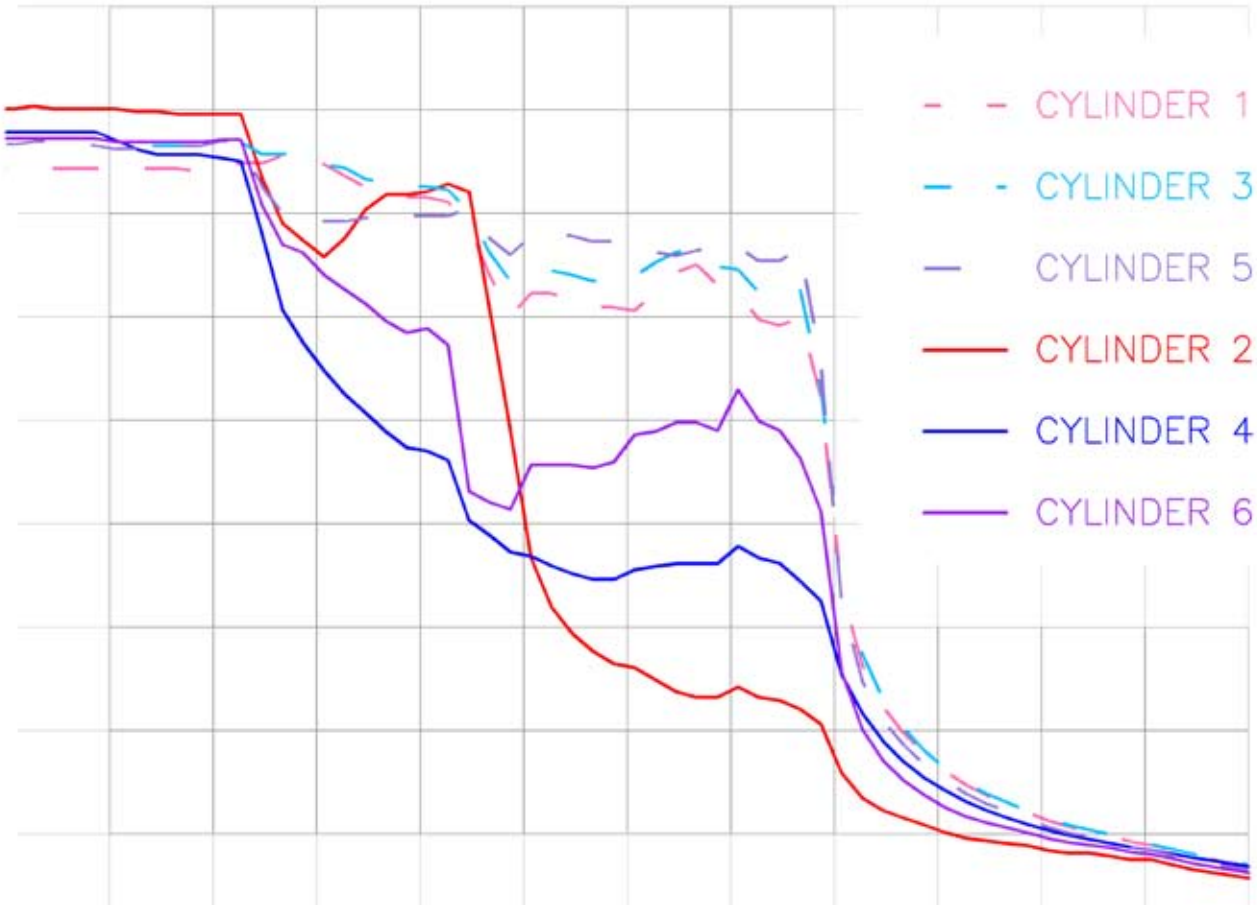

Figure 1

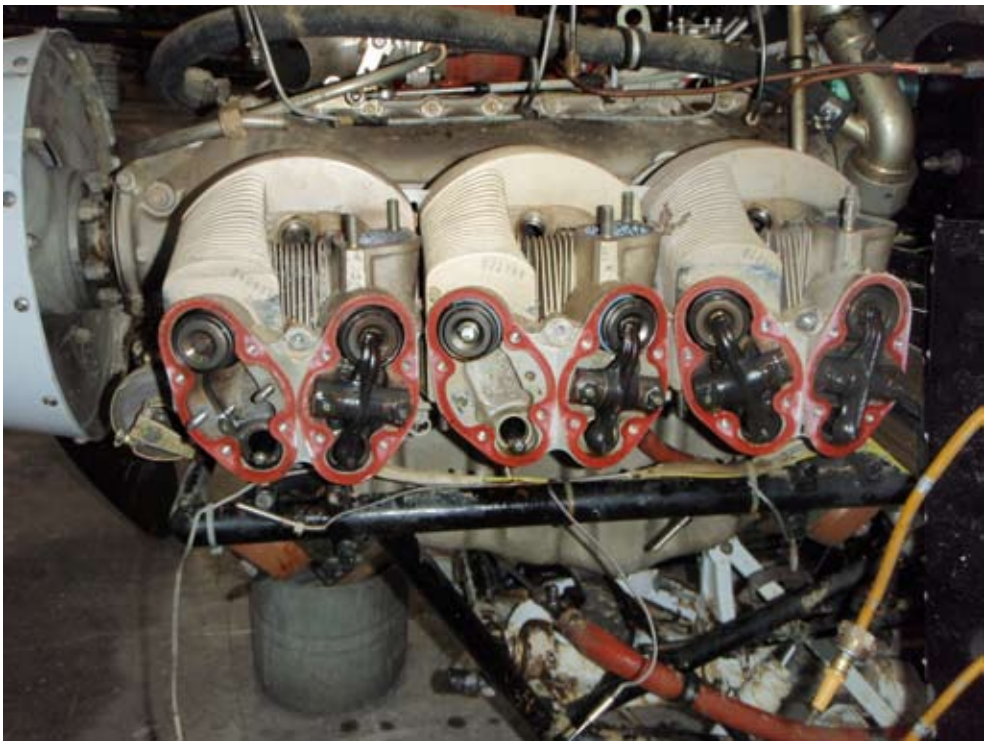

Figure 2

Figure 3

The No 4 cylinder was one of two new cylinders that had recently been fitted. The torque settings of the rocker tie-down nuts were checked on the three remaining rockers on the recently replaced cylinders and on the rockers on the other, undisturbed cylinders. These all appeared to have been correctly torqued.

The two failed stud bolts (bolt 'A', Figure 4 and bolt 'B', Figure 5) were sent to a metallurgist for detailed examination. Both showed evidence of fatigue, although no material defect that could have initiated the fatigue was found in either bolt. The hardness value of each bolt was checked; one was found to be 33 and the other 35 on the Rockwell 'C' hardness scale (HRC) the specified hardness range for this type of bolt being 28-32 HRC. The slightly high hardness values were not considered to be significant.

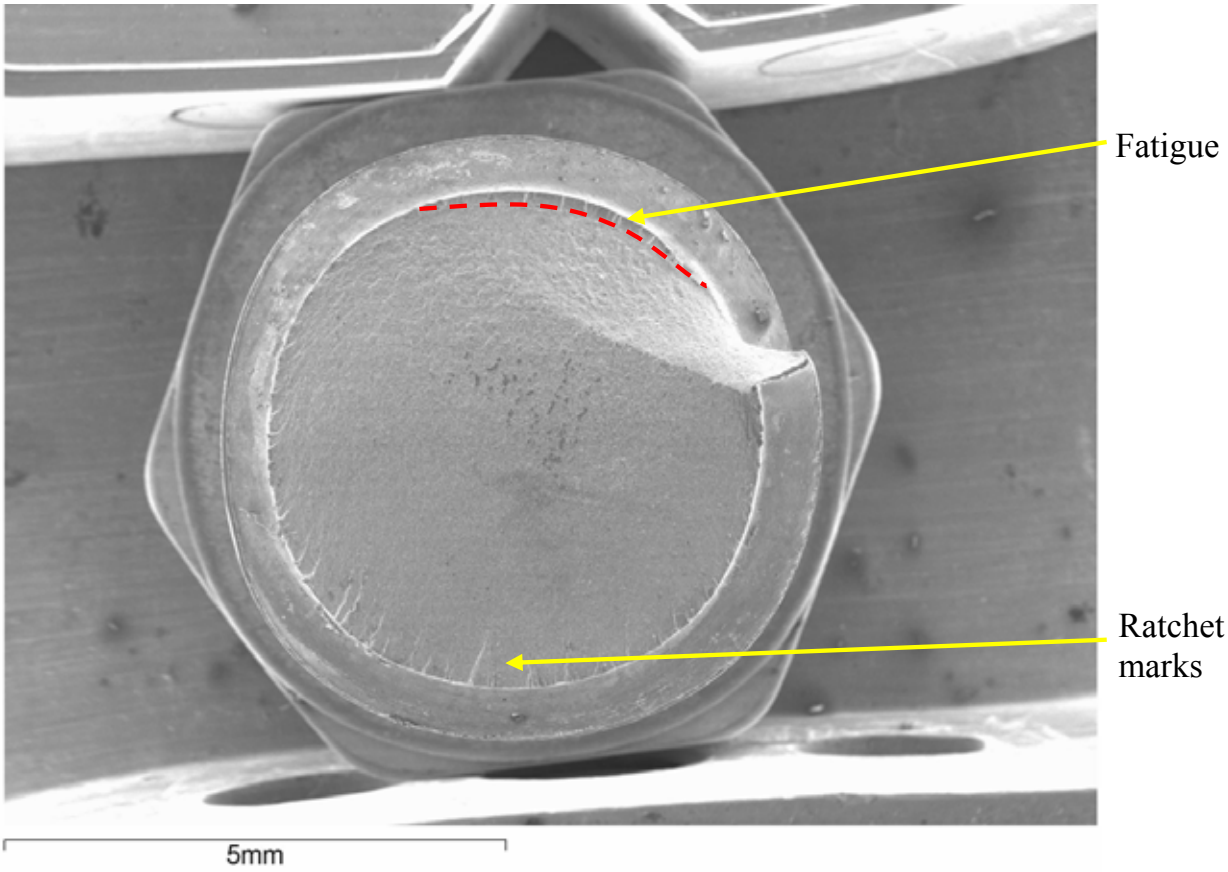

Figure 4

Fracture surface of bolt A

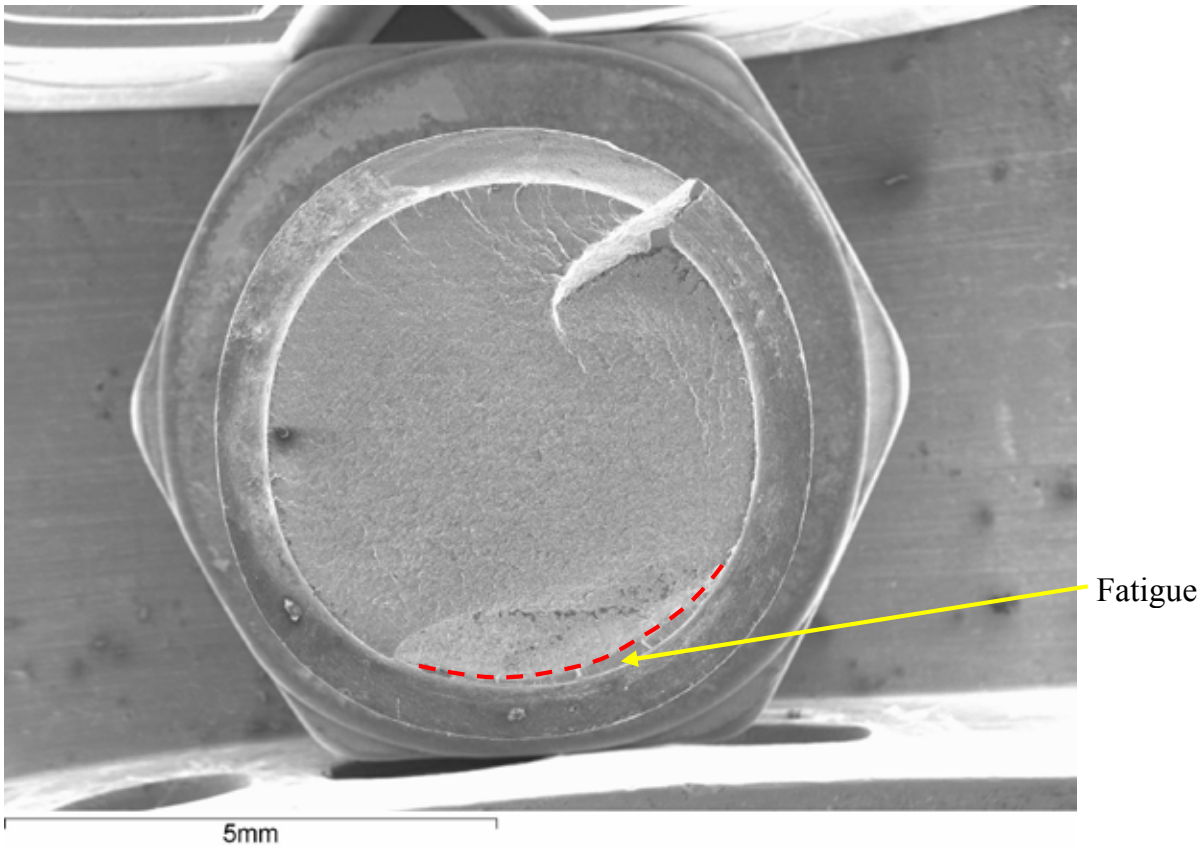

Figure 5

Fracture surface of bolt B

Discussion

The engine inspection revealed that the engine was probably capable of running and developing sufficient power for continued flight, albeit sounding unusual and with some vibration. The guidance provided in the Pilot's Operating Handbook for engine rough running is to execute a precautionary landing. By deciding to shut down the engine, the pilot was left with no other option than to carry out a forced landing without power. The pilot had been active for most of the day and felt that tiredness might have been a factor in his decision making.

No material defects were found in the failed stud bolts that could account for their failure. Given the recent replacement of the No 2 and No 4 cylinders, the possibility that the No 4 cylinder inlet valve rocker tie-down nuts had been incorrectly torqued on reinstallation could not be ruled out, but this could not be concluded with any degree of certainty.