SERIOUS INCIDENT

Aircraft Type and Registration:	Piper PA-31-350, G-FCSL
No & Type of Engines:	2 Lycoming TIO-540-J2BD piston engines
Year of Manufacture:	1972 (Serial no: 31-7852052)
Date & Time (UTC):	28 March 2023 at 1330 hrs
Location:	South of Salisbury, Wiltshire
Type of Flight:	Private
Persons on Board:	Crew - 2 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Right engine No 2 cylinder detached, mechanical and superficial fire damage to the engine and cowling
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	57 years
Commander's Flying Experience:	7,244 hours (of which 2,501 were on type) Last 90 days - 49 hours Last 28 days - 7 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and enquiries made by the AAIB

Synopsis

Whilst the aircraft was in the cruise at 2,000 ft agl, there was a loud bang as the right engine failed. The aircraft landed without further incident at Bournemouth. The engine failure was because the Number 2 cylinder had detached from the crankcase. This was caused by a fatigue failure of the cylinder flange attachment studs. It is likely that fatigue was initiated by a loss of preload in three of the studs at the front of the cylinder creating the conditions for the remaining studs and through-bolts to subsequently fail. The reason for the loss of preload could not be determined.

History of the flight

The aircraft was en route from Cardiff to its base at Shoreham, cruising at 2,000 ft agl and was just to the south of Salisbury under a Boscombe Down traffic service. The pilot had just completed routine checks and all the temperatures and pressures were normal with both engines running at 2,200 rpm. A couple of minutes later there was a loud bang and an adverse yaw. It became apparent the right engine had failed. The pilot and co-pilot could see the right engine cowling was covered in oil, the dipstick access flap had opened and there was a dent protruding from the side of the cowling. The pilot carried out shut down checks and feathered the propeller. As this was done, flames were observed emanating from the right engine. The firewall fuel shut off was activated and after about 10 seconds

the fire extinguished. A PAN call was made to Boscombe Down and the pilot declared his intentions to land at Bournemouth Airport which by this time was the closest. The left engine was operating correctly throughout the incident. The pilot made a visual approach to Bournemouth and landed on Runway 26 without incident.

History of the engine

The engine was installed in G-FCSL in 2016 and since then it had accrued 1,000 hours of its 1,800 hour time between overhaul periodicity. Apart from routine servicing, no additional rectification work has been required and there has been no abnormalities that might indicate an impending malfunction or failure.

Engine examination

The front left side cylinder (No 2) had become detached from the crankcase with all six of the attachment studs and both through-bolts[1] broken. A section of crankcase with the remains of two of the studs in place had also detached and was lying in the bottom of the lower cowling. The piston ring damage had caused the piston to jam in the lower part of the cylinder and the connecting rod had separated from the big end bearing half shell. The cylinder inlet and exhaust manifolds were also displaced. The engine and accessories were covered in oil and there were signs of fire on and around the turbocharger. Several components associated with the cylinder and piston were found on and around the engine (Figure 1).

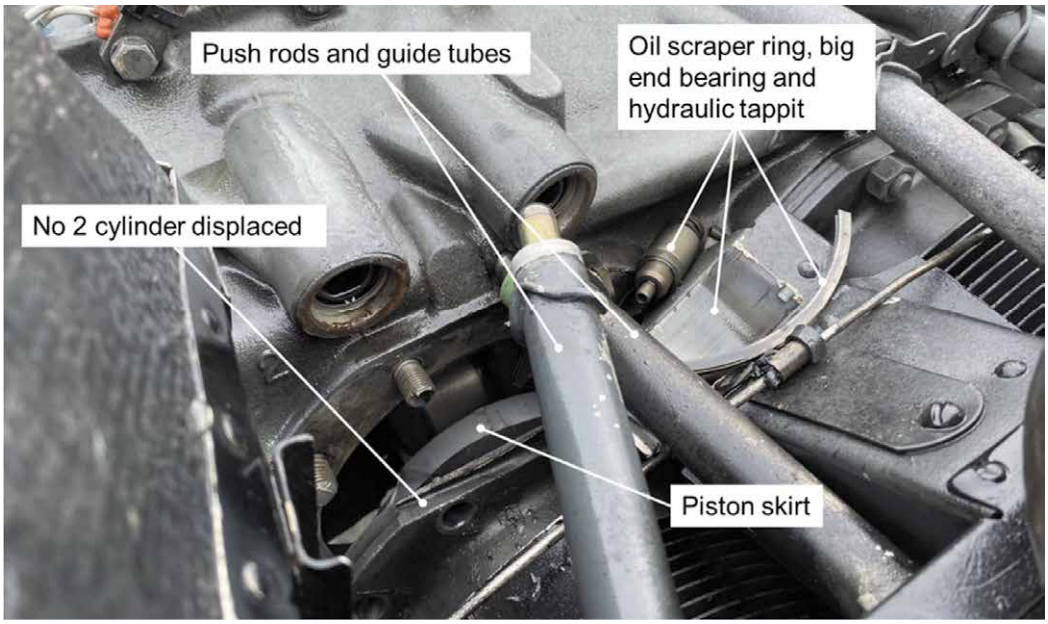

Figure 1

No 2 cylinder and distribution of parts

Footnote

[1] Through-bolts provide additional rigidity within the two halves of the crankcase. Two pairs of through-bolts pass through the crankcase and provide a clamping force to an opposing pair of cylinders. In this case cylinders left No 2 and right No 3, left No 4 and right No 5.

Tests and research

Each cylinder has a flange at the lower end which is held onto the crankcase by six threaded studs and two through-bolts. Four of the studs are 5/16 inch in diameter and the other studs and through bolts are 3/8 inch in diameter. All the studs and through-bolts had failed at the interface between the nut and the flange leaving a piece of each stud and through-bolt in the associated nut. One of the 3/8 inch diameter stud nuts was not found but its corresponding stud had broken in the same position as the other studs. Figure 2 shows the flange and identifies the location of the studs.

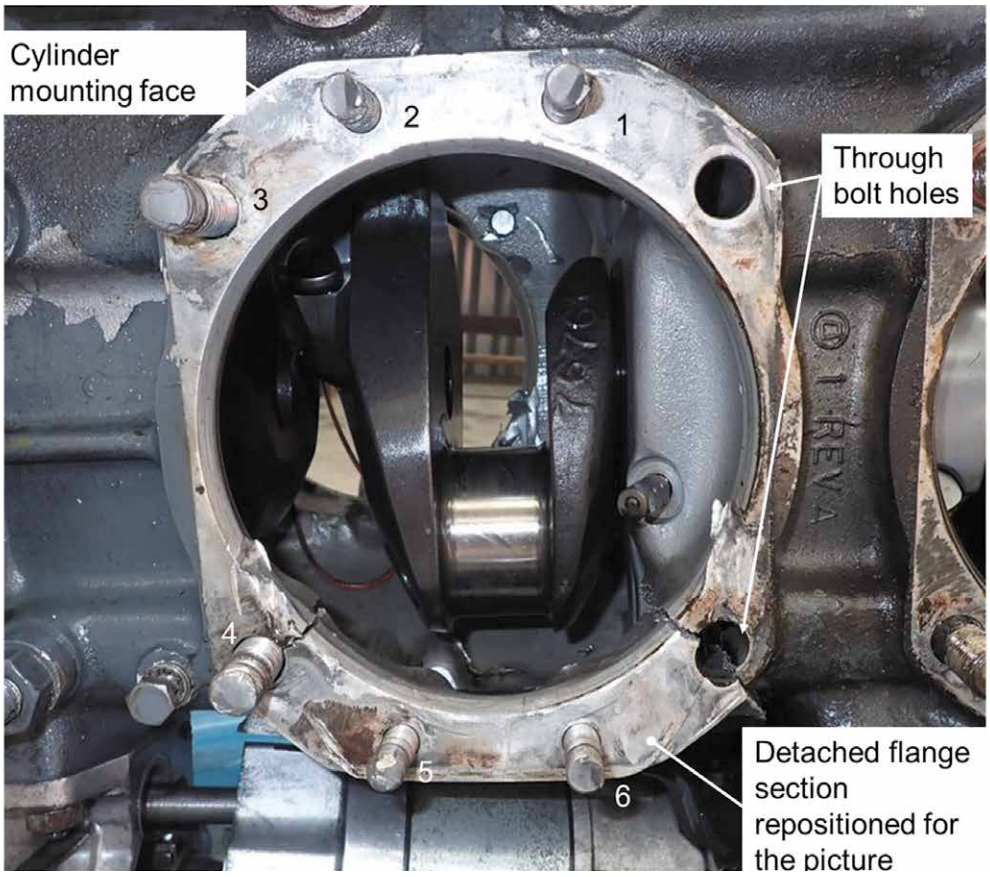

Figure 2

Cylinder mounting flange and location of the studs

The studs and through-bolts were removed from the crankcase using an extraction tool for examination. All were found with the characteristics of a high cycle fatigue failure. The studs numbered in Figure 2 as No 3 and No 5, were found to have different fatigue features than the other studs and through-bolts. The No 4 stud fracture face had suffered mechanical damage which was caused by the piston skirt impacting it during the failure sequence. This was likely to have occurred at the same time as the crankcase section was broken away. The No 4 stud nut was not found. The No 3 and No 5 studs appear to show several fatigue crack faces, initiated from multiple sites from the thread root around the circumference of the stud. Figure 3 shows both No 3 stud facture faces (the portion of the stud that remained within its nut was loose).

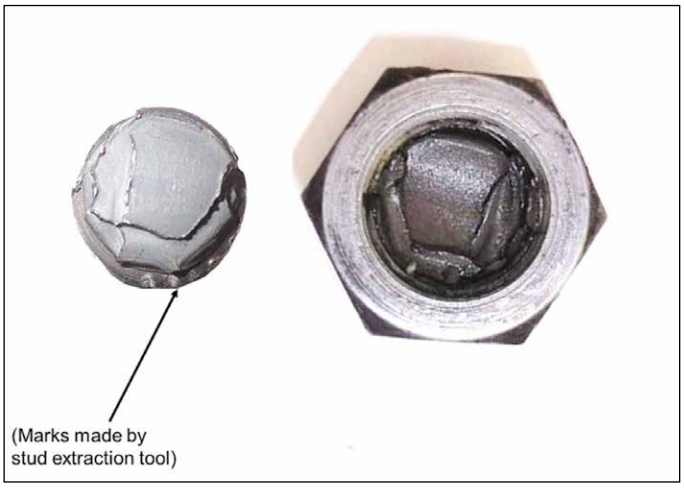

Figure 3
Stud No 3 and associated nut

Under magnification studs No 3 and No 5 exhibited ratchet[2] marks emanating from the thread roots. The through-bolt-fracture faces and those on studs No 1, No 2 and No 6, all show fatigue failure features indicative of unidirectional bending.

Analysis

Mechanical damage to the No 4 stud corrupted the fracture face so a clear identification of its failure mechanism could not be made. However, studs No 3 and No 5 (situated either side of stud No 4) exhibited different fatigue failure characteristics to the other studs and through-bolts. Their fatigue crack features were indicative of a loss of preload[3] or tightness of their nuts. The No 4 stud nut was not found which might suggest that its stud failed earlier, although it is not known how much earlier[4], and was followed by the No 3 and No 5 studs. With these studs failed, the cylinder flange was no longer rigidly attached to the crankcase cylinder mounting face around approximately one third of its circumference at its front edge. This resulted in non-uniform high cycle loads, predominantly tensile bending loads, within the remaining studs (No 1, 2 and 6) and both through-bolts, hence their unidirectional fatigue fracture features.

Conclusion

The Number 2 cylinder detached from the crankcase because of a fatigue failure of its attachment studs and through-bolts. It is likely that the failure sequence was initiated by the front studs of the attachment flange. These studs failed in fatigue and their features suggest a loss of preload within the nuts and studs. The potential cause of a loss of preload could not be determined.

Footnote

[2] Steps or edges which occur as adjacent crack planes coalesce and converge into a single plane.
[3] Although this may not appear as a visible looseness of the nut it describes a relaxation of the clamping load by the nut and stud exerted on the cylinder flange and crankcase.
[4] The location of the No 4 stud on the crankcase behind the alternator, starter motor and cooling air ducting makes it very difficult to see and so an abnormality would be easily overlooked.