INCIDENT

Aircraft Type and Registration:	Thruster T600N 450, G-CBWJ	
No & Type of Engines:	1 Jabiru Aircraft PTY 2200A piston engine	
Year of Manufacture:	2002	
Date & Time (UTC):	2 August 2010 at 1530 hrs	
Location:	Bradley Lawn Farm, Heathfield, East Sussex	
Type of Flight:	Training	
Persons on Board:	Crew - 2	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Propeller detached	
Commander's Licence:	National Private Pilot's Licence	
Commander's Age:	47 years	
Commander's Flying Experience:	n/k hours (of which n/k were on type) Last 90 days - 55 hours Last 28 days - 11 hours	
Information Source:	AAIB Field Investigation	

Synopsis

At approximately 300 ft agl, just after takeoff, the propeller blades, hub and mounting flange detached from the engine, forcing the pilot to land in a nearby field. Forensic examination of the failed flange mounting screws identified high cycle fatigue, possibly due to relative movement between the flange and crankshaft following loss of clamping load.

History of the flight

The pilot successfully completed a flight to Popham airfield, Hampshire and was on the return leg to his departure farm strip at Bradley Lawn Farm. During the last 5 miles of the flight, the pilot noticed a low frequency vibration, but landed without incident at around 1100 hrs. The propeller blades had recently been replaced, so the pilot checked that the blade pitch angle had not changed. He could find nothing wrong with the aircraft to explain the vibration.

The next flight conducted by the pilot[1] in the aircraft was at 1530 hrs the same day. This was to be a cross-country navigation exercise with a student. The student handled the aircraft and completed the pre-departure checks, with no abnormal indication from the engine. The aircraft lined up on Runway 22 and the student opened the throttle fully and accelerated along the runway at full power. After the aircraft rotated into the air and climbed through 100 ft, the pilot reported that he felt

Footnote

[1] The pilot was a qualified microlight instructor.

heavy vibration through the airframe and took control from the student; he then reduced the engine speed from 2,850 rpm to 2,600 rpm (under normal circumstances, full power is maintained to 700 ft). He commenced a right turn in an effort to fly a low-level circuit to land again; however, with the aircraft at approximately 300 ft agl, the propeller hub and blades detached from the engine, narrowly missing the wing. The pilot shut the engine down and performed a successful forced landing in a field. Despite numerous searches, the propeller could not be located.

Aircraft description

The aircraft is a fixed wing microlight constructed with a steel and aluminium frame, a glass-fibre cabin pod, tricycle landing gear and fabric covered wings and rear fuselage. The engine is mounted on a pole extending forward from the top of the cabin pod and braced by an A-frame. The propeller hub is bolted to a flange, which is secured by cap screws to the front of the engine crankshaft. The incident aircraft was fitted with two individual composite propeller blades, secured in the hub by separate retaining bolts.

Aircraft inspection

The pilot recovered the aircraft from the landing site to a hangar at the farm strip, prior to inspection by the AAIB. No damage was evident on the airframe. The engine propeller hub, flange and blades were detached, though the remains of the shanks from the six flange mounting screws were still present in the engine crankshaft (Figure 1). Replicas of the screw fracture surfaces were taken for forensic analysis and the remains of the screws, following extraction, were submitted for metallurgical examination. Aircraft documentation showed that a manufacturer approved

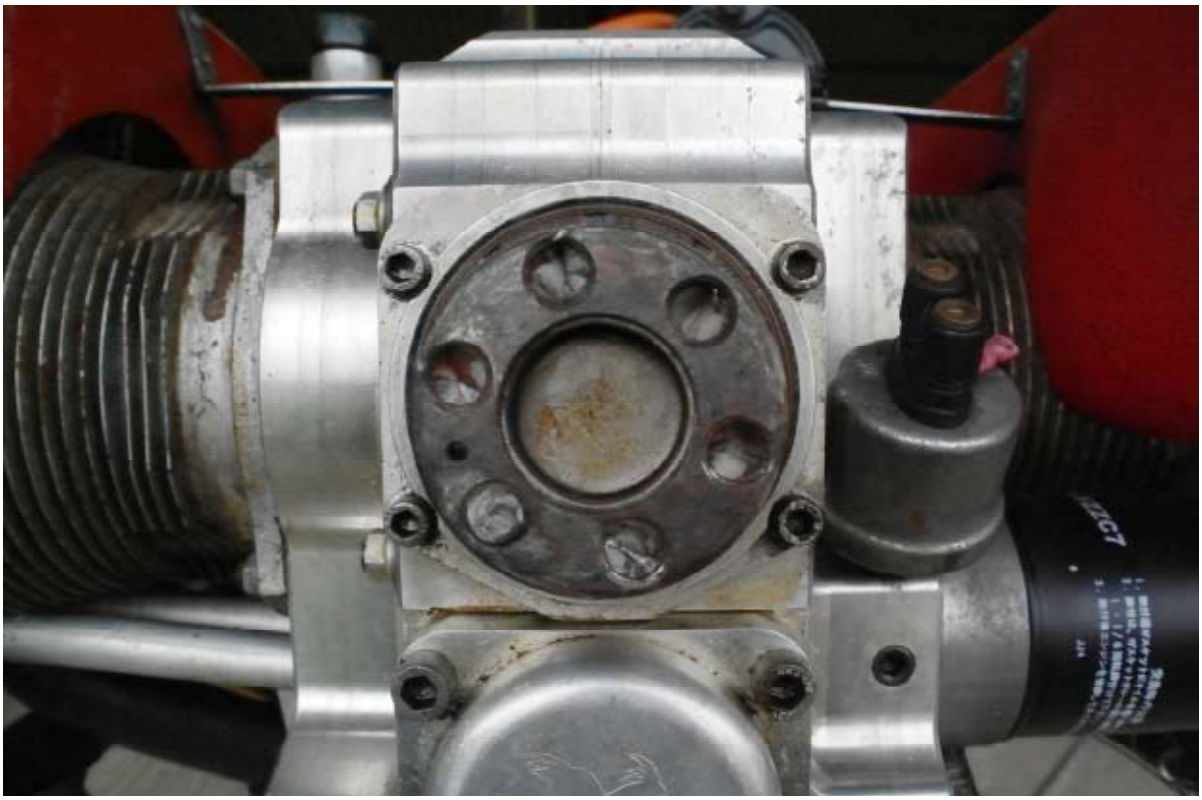

Figure 1

Front face of crankshaft showing shanks of failed screws still in-situ.

propeller hub and blades had been fitted, though it was not possible to confirm this physically due to the loss of these components in the incident.

Manufacturer's documentation

The manufacturer issued service bulletin JSB 022-1 on 28 July 2008. This stated that there had been a number of in-service propeller loss events due to failure of the flange mounting screws, resulting from incorrect installation procedures. The service bulletin highlights the importance of using the correct technique (use of a bonding agent and a specified torque load) to install the screws, and recommends the refitting of any propeller flanges, that are suspected of having been incorrectly installed, within 50 hours.

Service bulletin JSB 014-1 details important information regarding the installation and inspection of propellers and mounting flanges.

Service bulletin JSB 012-1 recommends the replacement of the flywheel mounting bolts, due to the possibility of damage from high propeller vibration due to propeller strikes or the incorrect fitting of the propeller.

Consultation with the engine manufacturer confirmed that they recommend checking the torque of the flange mounting screws every 100 hours for approved propeller types. This advice is included in the maintenance manual, though in a generic manner which covers all propeller related bolts and screws. The maintenance manual also recommends full overhaul of the engine at 2,000 hours, with a 'top end' overhaul at 1,000 hours. Replacement of the flange screws is recommended at full overhaul.

Maintenance history

The pilot advised that the aircraft was normally stored with an engine cover fitted, in an open hangar (roof, but no walls) and typically could be stored for up to a month at a time during the winter period.

At the time of the incident, the aircraft had flown 615.6 hours since new. A manufacturer approved repair organisation had extensively repaired the engine at 424.8 hours since new, due to an oil pump gear attachment failure that damaged the camshaft and timing gear. The invoice for the engine repair did not list new flange screws among the items fitted. The propeller blades were replaced approximately 12 flying hours prior to the incident due to a crack in the collar of one of the blades. There was no evidence from the engine logbook to suggest the failed flange screws had been replaced in-service, so it is likely they were original from first build of the engine.

The engine logbook identified that the repair organisation carried out service bulletin JSB 012-1 during the engine repair in 2006. There was no record of service bulletin JSB 022-1 being completed on the engine.

Detailed inspection findings

Screw 1

Scanning Electron Microscope (SEM) inspection revealed smooth, flat fracture surfaces, which exhibited clear beach marks; these confirmed High Cycle Fatigue (HCF)[2] as the fracture mechanism (Figure 2). Initiation occurred at multiple locations around the thread roots (a region of stress concentration). A region of possible intergranular fracture was found at one of the thread root

Footnote

[2] High Cycle Fatigue is characterised by a large number of load cycles to failure (typically $>10^4$), for example due to a high frequency vibration.

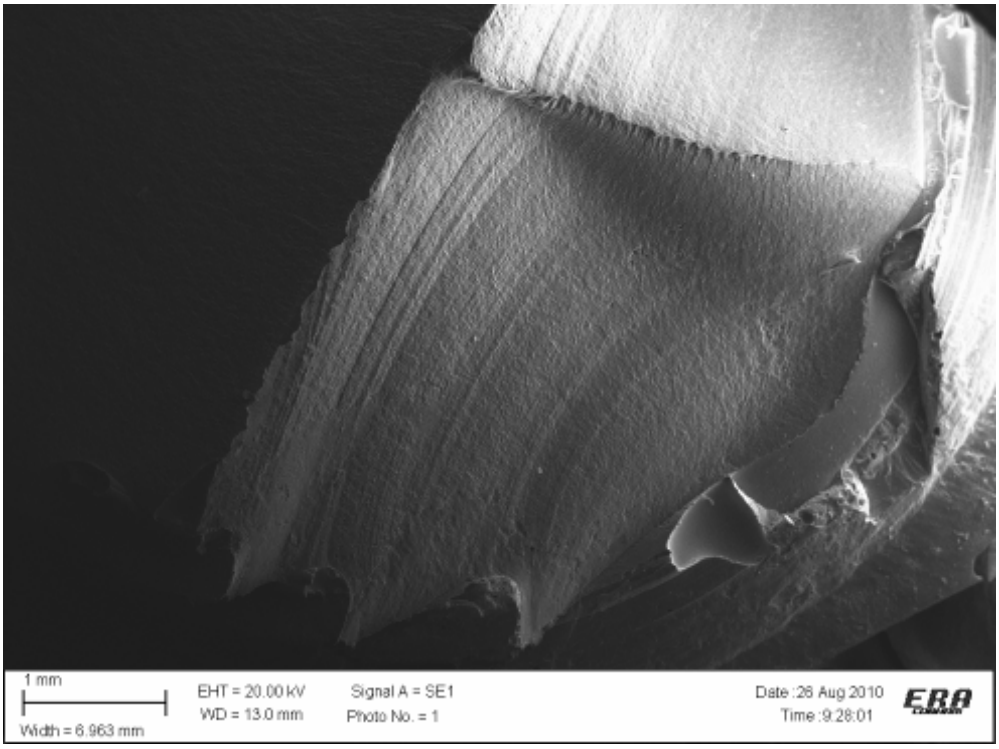

Figure 2

SEM image of beach marks indicating HCF with multiple initiations.

initiation sites, suggesting that some stress-corrosion cracking (SCC) might have contributed to fatigue initiation.

Screw 2

The screw exhibited smooth, flat fracture surfaces as with screw 1, but the beach marks were more difficult to distinguish. Some regions contained features that could have been corrosion. The fatigue appeared to have initiated from the stress concentration of the thread root. The fracture surface consisted of two large flat regions of fatigue that initiated on opposite sides of the screw, with a thin strip of final overload fracture between them.

Screw 3

The screw exhibited two main fatigue regions, which initiated diametrically opposite one another, at the thread roots.

Screw 4

This screw also suffered fatigue in two regions diametrically opposite one another.

Screw 5

In contrast to the other screws examined, there were no large flat regions on this fracture surface. SEM examination revealed some areas of overload and some areas of smeared surface, typical of contact between fracture surfaces during separation from torsional overload.

Screw 6

Beach marks, indicating fatigue, were very clear on this surface and several initiation points were obvious. Again, all initiation sites were at thread roots, with two main areas of initiation diametrically opposite one another.

Metallographic examination and hardness testing

Sectioning revealed that many of the screws contained secondary fatigue cracks, usually initiating at the next thread down from the primary fracture surface. The section through screw 5 showed a crack at a thread root and possible fatigue cracking on the side of the threads. Each screw section was subjected to micro-hardness testing in three locations. The results indicated that all six screws were of similar strength. The microstructure, hardness, strength and chemical composition of the screw material were consistent with the manufacturer's recommendation for use in this application; the testing showed no evidence of manufacturing defects.

Analysis

The forensic analysis indicated that five of the six screws suffered fractures due to HCF. The remaining screw's (screw 5) fracture surface was damaged after failure, though some evidence of fatigue and overload were identifiable.

The cracks within the screws initiated in two regions diametrically opposite one another, suggesting a reversed bending load pattern. However, the orientations of each initiation relative to the crankshaft show that they all aligned tangentially. This may indicate relative rotational movement between the flange and the crankshaft.

Therefore, the most likely cause of failure of the screws was a loss of clamping load on the flange, due to reduced torque load on the mounting screws. This would allow movement between the flange and the crankshaft and create an additional load cycle on the flange screws related to the engine rpm. HCF cracks developed from initiation points in areas of stress concentration within the screw threads, until the critical crack length was reached and the screws failed in overload. The flange and propeller then released during the incident flight.

This incident highlights the importance of installing the propeller mounting flange in accordance with the engine manufacturer's guidance detailed in service bulletin JSB 022-1 and inspecting the flange screws in accordance with the manufacturer's recommended maintenance schedule. Both of these documents are freely available on the manufacturer's website.