ACCIDENT

Aircraft Type and Registration:	BFC Challenger II, G-BYKU
No & Type of Engines:	1 Rotax 582 piston engine
Year of Manufacture:	2007
Date & Time (UTC):	22 July 2008 at 0950 hrs
Location:	On approach to Runway 25 at Otherton Airfield, Staffordshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Damage to propeller, fuselage fabric and dorsal longeron
Commander's Licence:	Private Pilot's Licence
Commander's Age:	71 years
Commander's Flying Experience:	243 hours (of which 5 were on type) Last 90 days - 22 hours Last 28 days - 5 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and AAIB inquiries

Synopsis

The propeller and hub assembly detached from the aircraft at a late stage on the approach. The pilot was able to continue with a glide approach and landed safely on the runway. The investigation established that thread locking compound had not been applied to the propeller hub mounting bolts, allowing them to vibrate loose. This resulted in fatigue cracks developing in the bolts, causing them to fail.

History of the flight

The aircraft flew uneventfully in the local area for 10 to 15 minutes before the pilot rejoined the circuit to land. At a late stage on the approach he heard a loud "bang" from behind him and assumed that the drive belt to the propeller reduction gearing had failed. Despite the loss of thrust he was able to land the aircraft safely on the runway, where he discovered that the propeller assembly and propeller hub were missing. All the components were subsequently recovered from a tree on the edge of the airfield.

At the time of the accident the aircraft had flown approximately 12.6 hours since August 2007, when its first Permit to Fly was issued.

Aircraft information

The BFC Challenger II is a high-wing aircraft powered by a two-stroke engine mounted above the rear fuselage in the pusher configuration.

The propeller blades are mounted on a reduction drive assembly (Figure 1) which consists of a propeller assembly, propeller hub and top pulley, all of which are manufactured from aluminium alloy. The propeller hub is attached to the top pulley by six steel Allen head bolts, each of which screws into a threaded blind hole in the top pulley. Steel bolts are used to secure the propeller assembly to the hub.

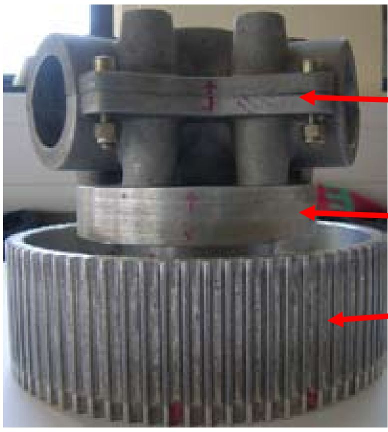

Figure 1

Reduction drive assembly

Examination of the aircraft

The owner of the aircraft reported that the propeller hub had detached from the top pulley and that five of the six hub mounting bolts had broken in two. A report from an Inspector from the Light Aircraft Association (LAA) who examined the aircraft stated that one propeller blade had struck the dorsal longeron area immediately beneath the propeller arc, severely denting the tube and stressing the associated structure forward of the impact area.

Previous occurrences

The LAA informed the AAIB that there had been two previous occurrences of the propeller and hub assembly detaching from this type of aircraft. The first occurred in flight in the USA in 1998, and the second, on the ground in the UK in 2005. The hub mounting bolts were not recovered following either of these occurrences and therefore it was not possible to establish why they had failed.

As a result of these occurrences, the Popular Flying Association (PFA), now the LAA, issued an Airworthiness Information Leaflet[1] on 6 October 2005 requiring owners to check the torque of the propeller hub mounting bolts every 50 hours. Issue 1 of this document referred to the bolts as '*propeller attaching bolts*' and Issue 2, dated 24 January 2006, referred to the bolts as '*propeller adaptor bolt*' and '*counterbored Allen bolts of the drive adaptor plate*'. The manufacturer's build instructions do not use any of these descriptions.

Issue 2 also stated that the bolts should be correctly torqued to '*12 ft/lbs*' in accordance with the manufacturer's specification and any unserviceable bolts should be replaced using '*Red Loctite*'. The manufacturer's build instructions state that the bolts should be torqued to '*15 ft. lbs'*. There are a number of different Loctite products that are coloured red and not all of these are suitable for this application. In the build instructions the manufacturer states that '*#271 Red Loctite*' should be used on the propeller hub mounting bolts.

Build history

The owner started building the aircraft in 1999 and an LAA inspector signed for inspecting the engine assembly on 18 June 2004. The owner was unable to fully recall the activities he undertook in fitting the propeller drive assembly, but believed that he had followed the manufacturer's instructions and had applied a Loctite thread locking compound to the threads on the propeller hub mounting bolts and the corresponding threads in the blind holes in the top pulley.

Footnote

[1] PFA/MOD/177/014.

Examination of the reduction drive assembly

The reduction drive assembly and six propeller hub mounting bolts were inspected by the AAIB and the forensic engineering division of QinetiQ.

Propeller hub mounting bolts

One bolt was recovered intact; the remaining five had all broken between 10 and 16 mm below the bottom of the bolt head. The fracture surfaces of the broken bolts all showed smooth and ductile overload regions indicative of fatigue progression leading to final failure in overload (Figure 2). The threaded portion of the bolts was approximately 29 mm long and the shank approximately 2 mm long.

Top pulley

The top pulley had six blind threaded holes into which the hub mounting bolts were secured. One hole contained part of a bolt that had broken off approximately flush with the surface of the pulley, one hole was in relatively good condition and the remaining holes all showed some damage in the form of stripped threads and ovality. The depths of five of the blind holes were measured and found to range from 33.4 to 34.6 mm. It was not possible to establish accurately the depth of the hole containing the broken bolt.

Propeller hub

There was extensive fretting damage on the face of the propeller hub which was in contact with the top pulley (Figure 3). The clearance holes for the hub mounting bolts were all deformed and an impression of the thread from the bolts had formed on one side of each of the holes. The threads in five of the six holes into which the propeller assembly attachment bolts fit were found to be intact. Part of the thread was missing from the sixth hole.

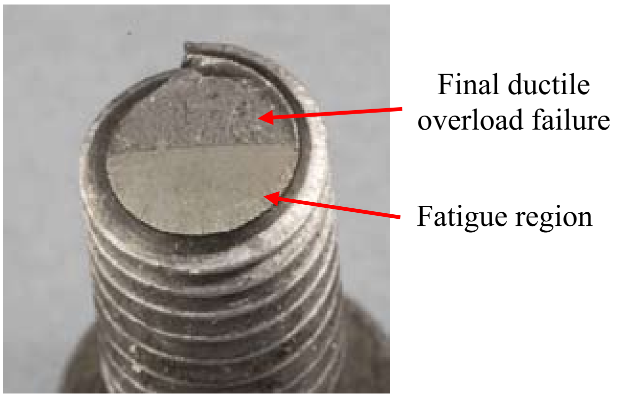

Figure 2

Typical fracture surface on broken Allen head bolt

Integrity of the propeller hub attachment bolt holes

Following this accident, the LAA were concerned that the distance between the side of the threaded hub attachment bolt holes and the edge of the flange of the top pulley might have been insufficient to prevent distortion of the hole and failure of the threads (Figure 4). Therefore, with the permission of the AAIB, the LAA drilled and tapped an additional hole in the flange of the top pulley and established that the threads failed at a torque of 35 lbf ft. This is approximately 2.3 times greater than the torque specified in the build instructions for the hub attachment bolts.

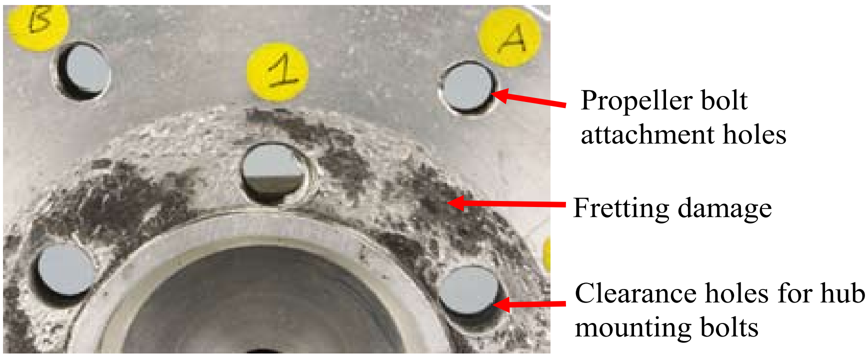

Figure 3

Damage to propeller hub

Testing for the presence of a thread locking compound

Figure 4

Top pulley

The manufacturer of Loctite advised the AAIB that Loctite 271 fluoresces when exposed to ultraviolet light. To determine if Loctite had been applied to the propeller mounting bolts, three test specimens were produced. The first specimen was a clean steel bolt, the second was smeared with a thread cutting fluid and the third had red Loctite 271 applied along its length and a nut wound part way along the thread. The Loctite was left to cure for seven days at a temperature of approximately 20ºC. At the end of this period the Loctite on the portion of the thread not covered by the nut was found to be sticky to the touch, whereas the Loctite in the threads between the nut and bolt had cured and the nut was firmly glued onto the bolt. On unwinding the nut, the cured Loctite was found to be pale pink in colour. The bolts that had been covered with cutting oil and Loctite 271 (cured and uncured) fluoresced when exposed to ultraviolet light; the other bolt did not.

The six propeller hub mounting bolts recovered from the accident aircraft were all exposed to ultraviolet light and, with the exception of a small portion of the thread on the intact bolt, none of the bolts fluoresced. It is suspected that the fluorescence on the sixth bolt was due to cross contamination by the thread cutting oil used during the LAA tests. There was also no physical evidence of any cured or uncured Loctite on any of the bolts. It was not possible to use ultraviolet light to check for the presence of Loctite in the blind holes in the top pulley as the holes had been contaminated with thread cutting oil during the testing by the LAA.

Thread locking compounds

Anaerobic adhesive thread locking compounds such as Loctite form a solid thermoset plastic when they come into contact with metal in the absence of air and work by gluing the threads of the male and female portions of the fastener together. The strength of the locking compound is dependent on the cleanliness of the parts and the curing time, which is dependent on temperature, use of activators and the types of fastener material to be locked together. The technical data sheets for Loctite locking compounds provide information on the strength and curing times for a number of different materials. However, they do not include the combination of steel and aluminium, the materials from which the propeller hub mounting bolts and the top pulley on the BFC Challenger II are manufactured. The manufacturer of Loctite advised the AAIB that this combination of materials can take up to seven days to cure and recommended that tests be carried out to establish the cure time and strength of the adhesive contact before using their products in such applications.

During the investigation the AAIB purchased samples of Loctite 243 and Loctite 271. Whilst the instructions on the bottle of Loctite 243 directed the user to the product technical data sheets there was no such instruction on the Loctite 271. Instead, the instructions on the packaging stated:

> *'Ready for use in 15 minutes. Full strength in 3 hours.'*

The product technical data sheets refer to performance properties such as the 'breakaway torque', 'prevail torque' and 'breakloose torque'. The breakaway torque is the torque that needs to be applied to break the adhesive contact which locks the threads together. Once the adhesive contact has been broken, particles of the cured locking compound remain in the threads and the prevail torque is the torque required to overcome the resistance of these particles. The breakloose torque is the torque required to undo a fastener which has been subject to a pre-torque. As a general rule, the breakloose torque is equivalent to the breakaway torque plus 80% of the pre-torque applied to the fastener but this figure should be established by testing.

The manufacturer advised that Loctite 243 and 271 are both suitable for use in an assembly subject to vibration. Loctite 271 is red in colour and has a breakaway torque of approximately *'22 ft.lb'* and a prevail torque of approximately *'5 ft.lb'*.

The method of applying the locking compound is dependent on whether the bolt is secured by a nut or threaded into a blind hole. If the bolt is secured by a nut, then the locking compound is applied to the threaded portion of the bolt which will be in contact with the nut. However, this technique is not suitable for blind holes, as the introduction of the bolt will compress the air at the bottom of the hole, forcing the locking compound out of the threads. The manufacturer therefore recommends that the locking compound should be applied to the bottom of blind holes so that the escaping air forces it into the threads between the bolt and side of the hole. However, if the reservoir of locking compound at the bottom of the hole is too small, the escaping air may not force the locking compound into the threads. This is a particular problem where there is a relatively large distance between the bottom of the hole and the end of the bolt, as is the case for the propeller hub attachment bolts and holes. In such situations the manufacturer recommends that a plug should be inserted at the bottom of the hole.

Comment

From the available evidence, it is probable that thread locking compound was not applied to the six propeller hub mounting bolts, which subsequently vibrated loose. This led to the initiation of fatigue cracks in the bolts which led to the bolts finally failing in ductile overload during the accident flight.

Although not an issue in this accident, the investigation identified a number of issues concerning the use of thread locking compounds on aircraft.

In order to prevent fatigue failure of the hub mounting bolts, it is necessary to apply a sufficient clamping force to prevent movement between the propeller hub and top pulley. This is achieved by applying the aircraft manufacturer's specified torque of 15 lbf ft to the hub mounting bolts. As the breakaway torque for Loctite 271 is 22 lbf ft, any subsequent torque check of these bolts would only confirm the integrity of the adhesive contact between the threads and would not prove that the clamping force between the components had been correctly applied. There is also a risk, particularly if the thread locking compound has not had sufficient time to reach its full strength, that any subsequent torque check of the hub mounting bolts may break the adhesive contact, thereby rendering the locking compound ineffective. It is for these reasons that torque checks should not be carried out on assemblies where a thread locking compound has been used. As a result of these findings, and given the discrepancies between instructions issued by the aircraft manufacturer and the PFA (now the LAA), the Airworthiness Information Leaflets for the inspection of the Challenger II propeller reduction drive assembly have been amended[2] and the requirement for the routine checking of the torque on the hub mounting bolts has been rescinded.

It is apparent that there are a number of misconceptions regarding the correct use and application of thread locking compounds. The information on the packaging may be ambiguous and therefore the technical data sheets should be consulted before the products are used in a safety-critical application. Moreover, given the number of factors which can affect the strength of the adhesive bond, it would be advisable to prepare a test specimen to establish the curing time and strength before thread locking products are used on aircraft.

The LAA intends to highlight to its members the issues raised in this investigation regarding the use of thread locking compounds in aircraft applications.

Footnote

[2] MOD/177/014 issue 3 dated 6/10/08.