ACCIDENT

Aircraft Type and Registration:	Aeronca 65C, G-BTRG
No & Type of Engines:	1 Verner Scarlett 7Hi piston engine
Year of Manufacture:	1939 (Serial no: C4149)
Date & Time (UTC):	21 October 2021 at 1435 hrs
Location:	Birchwood Airfield, North Yorkshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Aircraft extensively damaged and missing propeller
Commander's Licence:	Private Pilot's Licence
Commander's Age:	58 years
Commander's Flying Experience:	568 hours (of which 387 were on type) Last 90 days - 4 hours Last 28 days - 4 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot

Synopsis

Shortly after takeoff the propeller departed the aircraft and then the engine over sped. All six propeller bolts failed in fatigue due to a lack of pre-load. It is possible that a misinterpretation of an engine manufacturer's requirement resulted in the incorrect bolt length being chosen. When the bolts were tightened to the correct torque they shanked, no pre-load was applied and failed due to normal propeller loads in fatigue. The aircraft was extensively damaged and the propeller was not recovered.

History of the flight

The aircraft, with the pilot and one passenger, took off from Runway 26 at Birchwood private airstrip for a short flight. It was the first flight after completion of a Permit-to-Fly renewal flight following annual maintenance. The aircraft climbed through 450 ft and as the pilot went to reduce the engine power, it suddenly over sped. The pilot does not recall any abnormal indications such as noises or vibration prior to the engine over speeding. The pilot immediately closed the throttle and flew the aircraft to maintain its best gliding speed of 65 to 70 mph. He evaluated possible landing sites ahead but chose to return to the airfield as he felt his options were limited. He lined up on Runway (RWY) 03 and slide slipped to lose height as he was closer than he had anticipated. The pilot felt that the aircraft was going too fast to stop on RWY 03, so realigned to RWY 08 and landed on the main wheels. Despite the use of braking, the aircraft went through a hedge at the far end of the runway (Figure 1). The pilot turned the fuel and electrical master off and vacated through the left door with the passenger. It was then that they noticed that the propeller was missing. The propeller has not been recovered.

Figure 1

Accident site with close-up of propeller flange
(Photographs used with permission)

Aircraft information

The Aeronca Chief is a family of American high-winged light touring aircraft, designed and built from the late 1930s by Aeronca Aircraft. G-BTRG was a 65C model made in 1939 and was originally fitted with a Continental A-65 engine. The A-65 is a horizontally opposed four-cylinder 65 hp engine. The aircraft was restored in 2017 and the A-65 was replaced with Verner Motor Scarlett 7-cylinder radial 124 hp engine. The conversion was accomplished under the CAA E-conditions and the aircraft was operated under an LAA Permit-to-Fly.

Propeller information

G-BTRG was fitted with a 76” wooden propeller (Figure 2 left) and was attached to the engine propeller flange with six M8 x 110 mm, 8.8 steel bolts. The heads were drilled, wire locked in pairs and the threaded part had been shortened. Under the head of each bolt was a plain washer and a 8 mm thick recessed crush plate (Figure 2 centre and right). The bolts thread into inserts which are press fitted into the attachment flange. The full thread started approximately 1 mm inside the insert from the propeller side.

Prior to the Permit-to-Fly renewal flight the propeller had been removed and returned to manufacturer as there was evidence of cracks and disbonding of the surface lacquer finish. The propeller was refurbished by stripping it back to bare wood and the moisture content checked. No additional drying was required so the propeller was re-lacquered, balanced and returned. The newly refurbished propeller was re-fitted for the renewal flight and was to be torque checked after 25 flight hours. The propeller manufacturer recommended a torque check after the first flight, after 25 hours and every 50 hours thereafter.

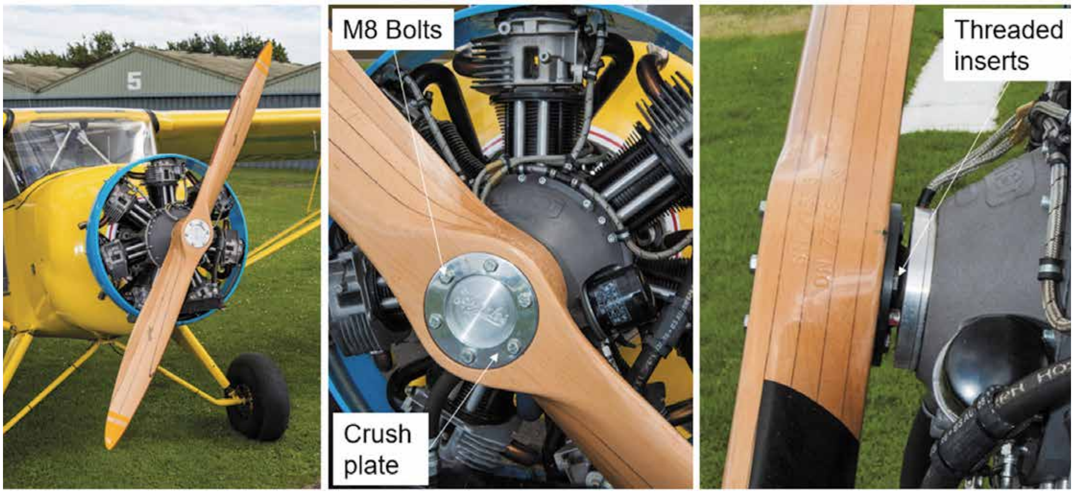

Figure 2

G-BTRG with Hercules propeller (left), detail of the attachment (centre and right)
(Photograph credit: FLYER - Ed Hicks)

Propeller flange examination

The propeller attachment flange was removed from the aircraft (Figure 3 left) and sent to AAIB where the threaded inserts were removed and sent for metallurgical examination (Figure 3 centre and right).

Figure 3

Attachment flange (left), example threaded insert removed (centre),
remaining bolt thread in the insert (right)
(Photographs used with permission)

After an initial optical examination at magnifications up to x 45 the threaded inserts were cut to remove the remaining threaded part of the bolt. The rust deposits were removed from the fracture surfaces and then examined using a Scanning Electron Microscope at magnifications up to x 5,000.

Examination of the fracture faces showed that all the bolts had similar characteristics of failure. Multiple fatigue cracks had propagated inwards from initiation sites around the circumference of the bolt, coalescing to form two major cracks (Figure 4). This is consistent with reverse-bending fatigue and the fine spacing of the crack growth indicated loading under high frequency vibration. No pre-existing mechanical or material defects could be found at the initiation sites. Sample bolts were strength tested and they conformed to all specification requirements.

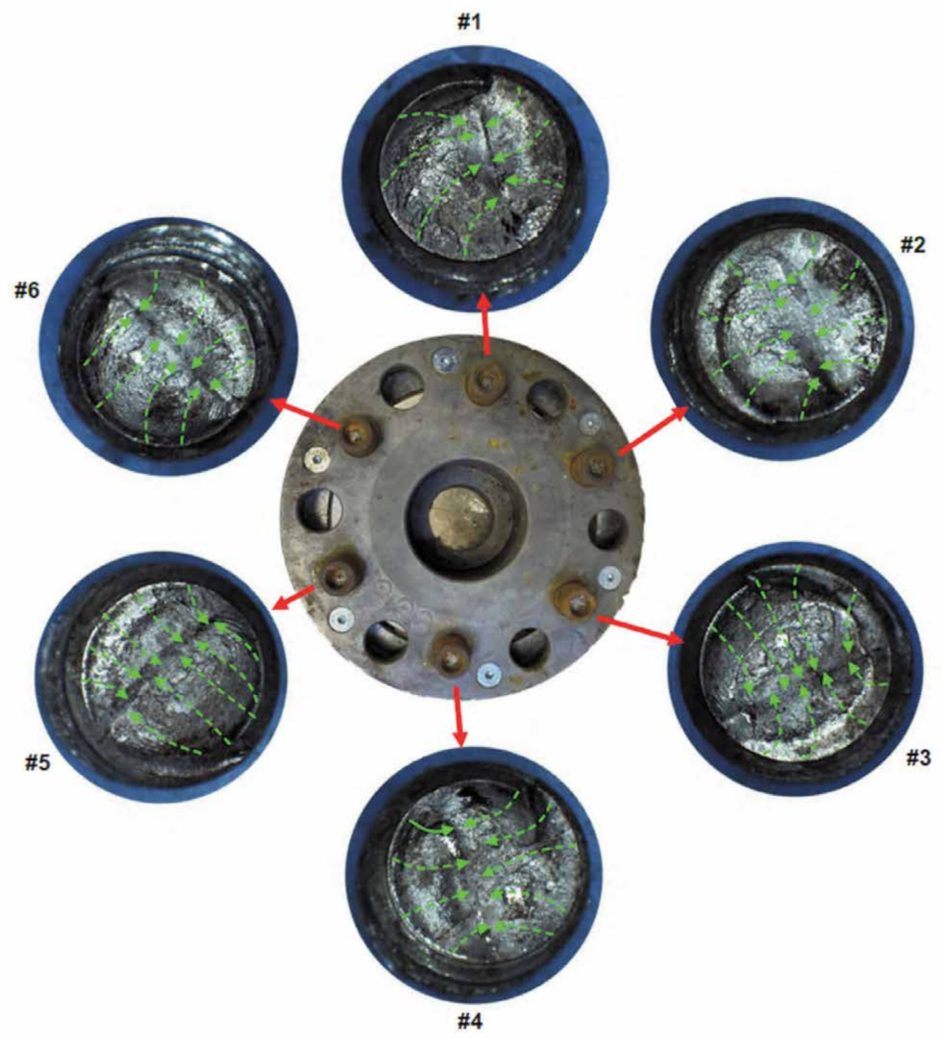

Figure 4

Fracture faces of all bolts showing propagation direction.
(Photograph used with permission)

The tail of all the bolts showed evidence of grinding marks consistent with the bolts being shortened and chamfered (Figure 5). The bolt standard states the full thread length of the bolt is 22 mm minimum and the average length of full thread documented on the batch certificate of conformance was 23.2 mm. The thread transition was approximately 1 mm. The part of the bolt removed from the threaded insert was 18 mm and as the thread transition was visible, approximately 5 mm had been removed from the bolt tail.

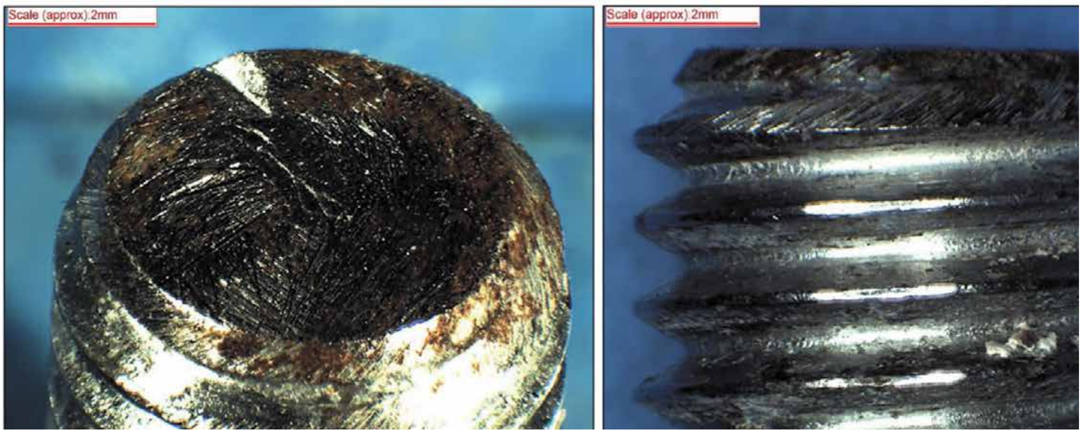

Figure 5

Detail of the bolt tail showing grinding marks and chamfering.
(Photographs used with permission)

There was evidence on two of the threaded inserts of a circular imprint and helical machining marks on the surface on the non-flanged end, ie the end adjacent to the propeller (Figure 6). It was considered possible that these imprints were a result of the shank of the bolt having been pressed into the insert. This situation is called 'shanking', where the bolt is tightened to the specified torque but the pre-load tension in the bolt is lower than specified. Insufficient pre-load is a common cause of fatigue failure of threaded fasteners.

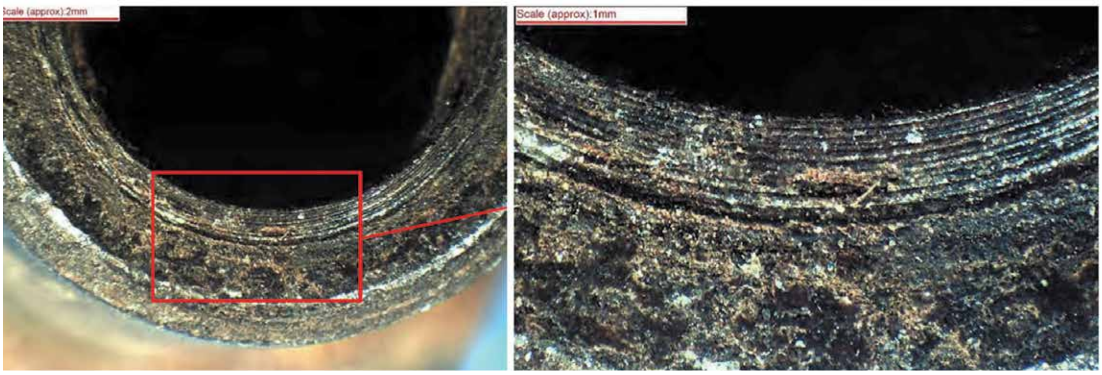

Figure 6

Detail of the circular imprint and helical machining marks on a threaded insert.
(Photographs used with permission)

Bolt length

The cross section shown in Figure 7 shows the propeller, flange and threaded insert arrangement. The recessed crush plate and the washer under the head of the bolt are also included. The M8 x 110 mm bolt has a shank length of 86.6 mm (110 – 23.2 = 86.6 mm). It was assumed that the full thread would start 2 mm inside the insert due to the overlapping thread transitions and this was supported by the fracture faces being approximately 2 mm inside the insert (Figure 3 right).

The stack of components in the joint is 82.6 mm (2 - 20 + 9 + 91 + 1.6 = 83.6 mm) thereby leaving a gap of 3 mm. The installed bolt would have shanked before pre-load had been applied. The engineer stated that when the propeller was installed the crush plate "was proud by 2 to 3 millimetres" which he accepted as correct.

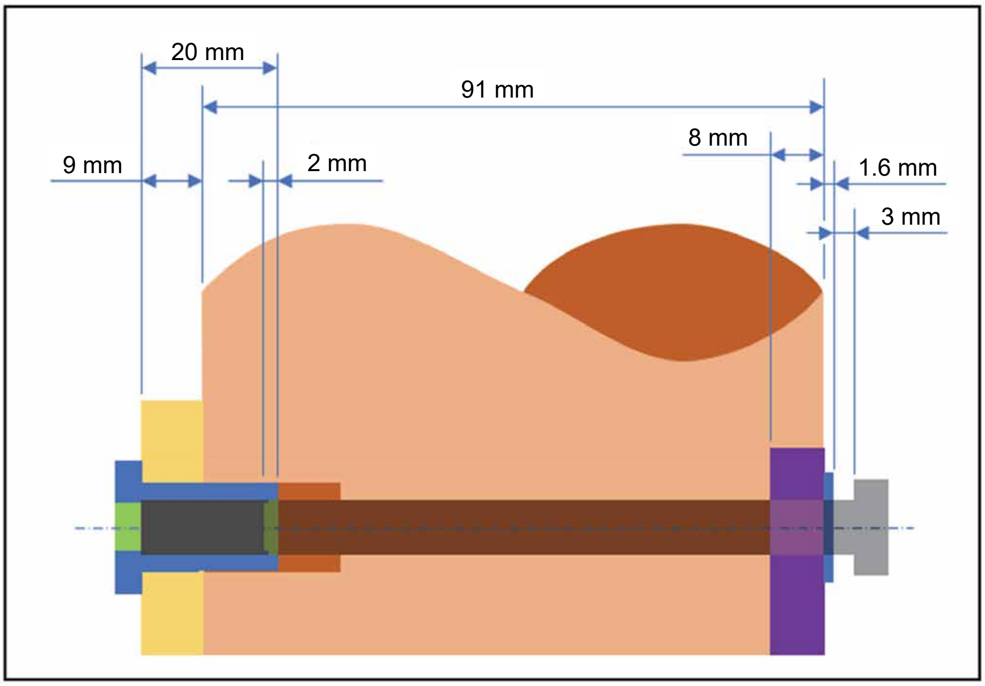

Figure 7

Cross section of the propeller to flange bolted joint

In the engine manufacturer's installation documentation, there is a requirement that no more than 10 mm of bolt is to protrude through the propeller to ensure clearance of the alternator windings which are located just behind the propeller flange (Figure 8).

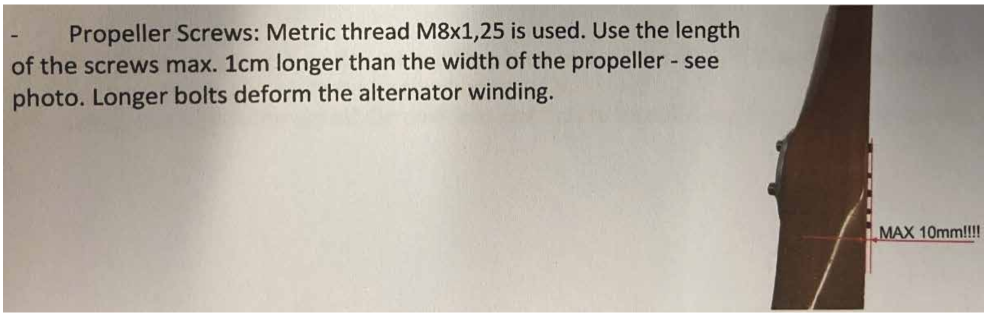

Figure 8

Engine manufacturer's installation documentation regarding propeller bolting

The engineer responsible for the installation of the propeller stated that an M8 x 100 mm bolt was too short and that a 110 mm was required. The propeller, crush plate (3 mm proud) and washer had a combined stack of 96 mm (91 + 1.6 + 3 = 95.6 mm) and a 100 mm bolt would have had 4 mm of thread protruding through the rear face of the propeller whereas a 110 mm bolt would have had 14 mm. The length of thread remaining in the threaded insert after the accident was 18 mm which equates to a standard thread length with 5 mm removed thereby leaving just less than 10 mm protruding through the propeller. The engineer stated he had cut "less than 10 mm" from the tail of the bolts before installing them to ensure the clearance to the alternator windings as per the installation documentation.

Analysis

Shortly after takeoff all six propeller bolts failed, resulting in the propeller departing the aircraft. There were no indications prior to the failure and the first symptom was the engine over speeding. The pilot closed the throttle and made a forced landing which resulted in the aircraft being extensively damaged.

Examination of the failed bolts revealed that they had failed from high cycle, reverse-bending fatigue. This failure is consistent with normal loads applied by the propeller to bolts which have insufficient pre-load. This loss of pre-load was possibly due to the bolts having shanked. On installation the correct torque was applied however as the bolt shank was too long no axial pre-load was applied to the bolt.

It is possible that the length of bolt was chosen based upon a misinterpretation of the installation document from the engine manufacturer. A bolt length was chosen which protruded more than 10 mm and was then shortened so that just less than 10 mm protruded. This resulted in a shank length which was too long for the stack by approximately 3 mm. A 100 mm bolt would have had full thread engagement without shanking and protruded approximately 4 mm from the rear face of the propeller.

When the propeller was installed, it is possible that no gaps where visible after the bolts were fully torqued due to the crush plate not fully seating into the rebate as new surface lacquer had just been applied. The propeller manufacturer recommended a re-check after the first flight which was not done.

As a result of this accident the engine manufacturer has taken safety action to revise the information in the installation document to include a drawing to aid the correct length of bolt to be selected.

Conclusion

Lack of pre-load in the propeller bolts resulted in their failure by reverse-bending fatigue shortly after takeoff. The bolts had shanked but were correctly torqued without applying a pre-load. It is possible that the incorrect bolt length was chosen due to a misinterpretation of the engine manufacturer's installation document.

The engine manufacturer has taken the following safety action:

> To revise the propeller installation document to include a drawing to aid the correct length of propeller bolt to be selected.