ACCIDENT

Aircraft Type and Registration:	1) Grob G115E Tutor, G-BYUB 2) Grob G115E Tutor, G-CGKC
No & Type of Engines:	1 Lycoming AEIO-360-B1F piston engine
Year of Manufacture:	1) 1999 2) 2009
Date & Time (UTC):	1) 23 August 2012 at 0834 hrs 2) 09 Jan 2013 at 1225 hrs
Location:	Fields adjacent to RAF Cranwell, Lincolnshire
Type of Flight:	Military Training
Persons on Board:	Crew - 2 Passengers - N/A
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	(Both aircraft) Propeller counterweight assembly detached and severe damage to corresponding propeller blade and spinner
Commander's Licence:	Both aircraft were being operated by military personnel with service qualifications
Commander's Age:	N/K
Commander's Flying Experience:	N/K
Information Source:	AAIB Field Investigation

Synopsis

Two Grob 115E aircraft suffered detachment of a propeller counterweight assembly during initial climb severely damaging the corresponding propeller blade. Successful forced landings were completed in both cases. Evidence from the second event suggested that the failure was caused by an issue concerning the method of installation of the counterweight assemblies on the affected propeller blades.

History of the flights

On 23 August 2012, following an aerobatic detail and return to RAF Cranwell, G-BYUB carried out a series of touch-and-go landings. Whilst in the initial climb, shortly after the final takeoff, a loud bang was heard; this was followed by severe vibration. The pilot immediately reduced power, lowered the nose and landed in a level field of crops near the airfield. Subsequent examination revealed that one of the propeller blades was severely damaged and missing its counterweight assembly.

Approximately four months later, on 9 January 2013, a second aircraft, G-CGKC, suffered a similar occurrence. Once again, the aircraft landed safely in a field. The damage was found to be similar to that sustained by G-BYUB.

Background information

The Grob G115E aircraft are owned by a civilian contractor, maintained on the civil register, and operated by the UK MoD. The fleet totals 119 aircraft. The airframe/engine/propeller combination is understood to be unique to this fleet.

Component description

The aircraft type is equipped with a Hoffmann HO-V343K-V/183GY three-bladed, constant speed propeller. The blades are manufactured from timber, sheathed in a carbon-composite skin. An aluminium alloy ferrule at the base of each blade engages with the pitch change bearing in the propeller hub. Each blade counterweight assembly (Figure 1) incorporates two semi-circular clamps secured by a pair of nuts and bolts. Tightening the bolts causes the clamps to grip the blade ferrule. Each clamp is extended in one direction and a counterweight is bolted to the extension.

A wide recess is machined circumferentially around each blade ferrule; this accommodates a corresponding semi-circular projection around the inner face of each clamp half. The engagement of the projection into the recess prevents radial movement of the counterweight assembly under the influence of centrifugal force when the propeller is rotating. The relative dimensions of the assembled components leave a gap between the inner faces of the projections of the clamp halves and the base of the circular recess in the ferrule. Thus, the clamping loads act only between the 'shoulders' of the clamp halves and the outer diameter of the ferrule. Ideally, the two clamp halves should be assembled such that their faces are parallel, giving an even gap between the clamp faces on either side of the ferrule. A set screw is threaded through one of the clamp halves and bears on the recessed face of the ferrule.

When the engine is operating, the counterweights each exert a centrifugal turning moment on the blade ferrule to which they are attached. This moment loads the bolt nearest the counterweight on each blade in tension. The tensile load produces a stress when operating, in addition to that created in static conditions by the tension force clamping the assembly to the ferrule.

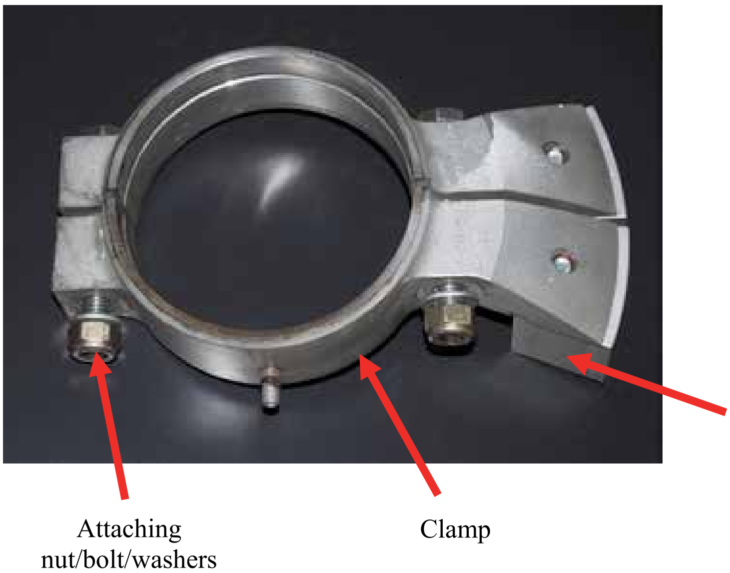

Figure 1

Propeller blade counterweight assembly

G-BYUB investigation findings

General

Post-event examination of the aircraft found that one of the three propeller blades was severely damaged and its counterweight assembly was missing. The spinner was disrupted by the passage of the counterweight assembly as it translated along the pitch change axis of the ferrule and the corresponding axis of the blade. Fragments of the damaged blade and part of the spinner were recovered from the airfield. Despite an extensive search, using military personnel equipped with metal detection equipment, the missing counterweight assembly was not found.

Detailed examination

From detailed examination of the propeller by the AAIB, it was deduced that the two parts of the counterweight assembly had separated sufficiently such that the semi-circular projections had disengaged from the recess in the ferrule, allowing the counterweight assembly to translate radially outwards under the influence of centrifugal force. An 'extruding' effect had removed both timber and carbon composite from the leading and trailing edges of the propeller blade. This had continued until the assembly had reached a radial position at about 50% of the blade span. At this point, the magnitude of its reaction against the blade leading edge, as a result of the acceleration (owing to the rising linear velocity at the greater radius from the propeller axis), caused it to cut through the blade material, completely severing the outer portion of the blade.

Removal of the counterweight assemblies from the two undamaged blades revealed unusual markings in the recess in one of the ferrules. Personnel who had removed and refitted very large numbers of counterweight assemblies during overhauls over a number of years remarked that they had not seen such marks before. It was suggested that they were the consequence of a lightning strike. A check of the magnetic characteristics of the propeller hub provided evidence in support of this suggestion.

The counterweight assembly from the damaged blade was missing so its loss could not be explained. However, it was judged that the evidence of a lightning strike was unique to this particular aircraft and was therefore considered to be of some significance.

Following this event, operation of the G115E fleet was temporarily suspended. All counterweight assemblies were removed, examined and refitted using new nuts and bolts prior to returning the aircraft to service.

G-CGKC investigation findings

General

As in the previous event, it was noted that a single propeller blade was severely damaged, its counterweight assembly was absent and the spinner was badly damaged by the outward passage of the counterweight assembly. The blade damage was virtually identical to that observed on G-BYUB. On this occasion, a fractured threaded portion of a bolt shank with a nut on it was found lying on the ground below the propeller. The nut was of the type used to secure the counterweight clamps to the blade ferrule. It is assumed that this had remained within the rotating spinner and had fallen out after the engine was shut down.

It was determined from flight records that, at the time of the failure, the aircraft had completed approximately 60 flight cycles averaging approximately one hour each since re-installation of the counterweight assemblies with new nuts and bolts.

Following this event the G115E fleet was once again temporarily withdrawn from service.

Detailed examination

Examination of the recovered nut and threaded portion of bolt showed that the bolt had suffered a fatigue fracture in the plane of the face of the nut in contact with the counterweight clamp (Figure 2). The fatigue fracture exhibited multiple origins at the base of the thread form on one side of the bolt. The fatigue cracking had propagated over most of the bolt cross section; the remainder of the cross section had then failed in ductile overload. The nut contact face was confirmed on laboratory examination to be correctly perpendicular to the bolt axis.

A further search was successful in locating a major proportion of one of the missing clamp halves (Figure 3), together with the remainder of the fractured bolt, which was heavily distorted. The section of recovered bolt was from the bolt hole nearest the counterweight. The other clamp half and bolt were not found. The recovered portion of clamp had its curved section deformed plastically to a much straighter, larger radius shape due to the effects of bending.

Examination of the fracture face of the broken bolt in the recovered portion of clamp revealed that it was the matching face to the portion of threaded bolt shank (with nut attached) recovered from beneath the aircraft after the landing. Smearing and damage to the thread forms of the bolt and slight bending of the bolt end were observed; this was consistent with the forces likely to have been imparted to the bolt during the separation sequence. Consideration of the geometry of the clamp and bolt assembly, in conjunction with the thread damage, enabled the rotational orientation of the bolt at the time of the bolt failure/clamp separation to be determined. From this it became clear that the multi-fatigue origin was located on the side of the bolt orientated furthest from the ferrule, ie the side closest to the counterweight.

The laboratory examination of the fatigue fracture face of the bolt revealed prominent beach marks with less prominent marks between them. The area closest to the origin had no clearly defined pattern but ten distinct beach marks were visible between there and the ductile

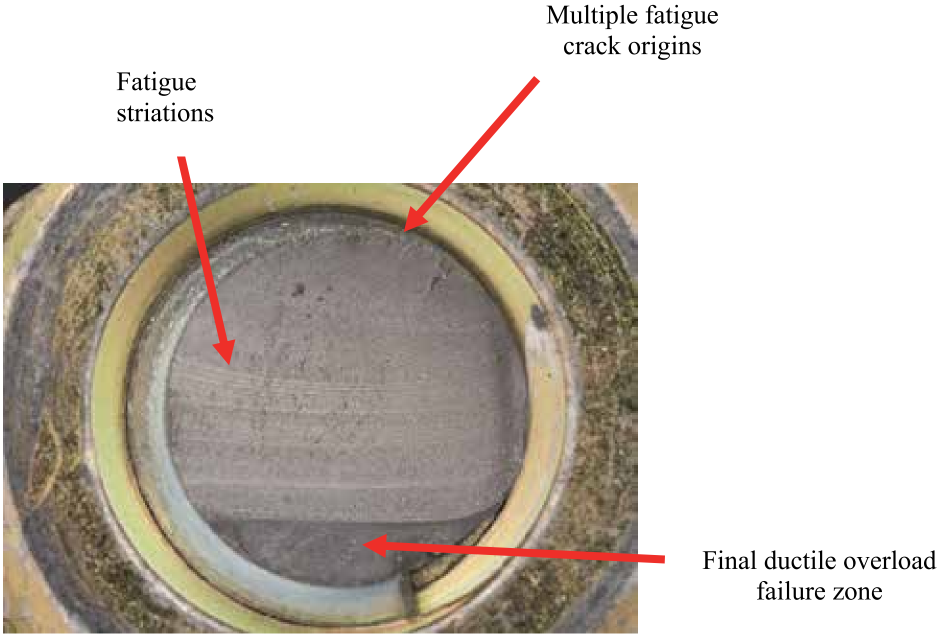

Figure 2

Fracture face of failed counterweight clamp bolt

Figure 3
Recovered portion of counterweight clamp and fractured bolt

failure zone. The most reasonable interpretation of the evidence on the bolt fracture face was that each of the final ten flight cycles had produced a distinct beach mark with lesser marks between these created by smaller load variations.

Qualitative consideration of the loads likely to be experienced by the propeller in normal operation did not identify any high frequency cyclic loads significant enough to result in a fatigue failure of the counterweight attachment bolts.

Discussion

Possible cause of multiple fatigue origins

This aircraft type has, until recently, operated extensively without counterweight clamp bolts fracturing in flight. It is therefore reasonable to assume that those bolts do not normally incur significant fatigue damage within the overhaul life of the propeller. This suggests that the presence of the multi-origin feature from which the fatigue crack on G-CGKC propagated was the critical factor leading to the event on that aircraft. As these origins were concentrated near the base of the thread form on one side of the failed bolt, and no cyclic bending load can be envisaged to have occurred in service, it was reasonable to assume they resulted from a concentrated static tensile load at that location. Elevated local static stress, when combined with the stress due to the centrifugal turning moment, reacted by the clamp bolt in normal propeller operation, may have been sufficient to initiate the fatigue failure mechanism.

A possible way of creating the multi-origin feature would have been to have torque-tightened the nut/bolt combination without the contact faces of the clamp lying parallel. Under such circumstances the tensile stress in the bolt would be distributed eccentrically, thus concentrating a high stress on the one side of the bolt with a significantly lower stress on the opposite side.

The gap between the two assembled clamp halves on each blade permits the assembly bolts to be torque-tightened without the inner clamp faces lying completely parallel (Figure 4). The greatest extent of this loss of parallel orientation is permitted by the clamp geometry if the nut on the bolt furthest from the counterweight is screwed further along its bolt than the nut on the other bolt. Thus with the counterweights ‘spread’ further apart from ‘normal’, an eccentric stress distribution occurs on each bolt and the orientation of the bolt nearest to

Figure 4

Counterweight clamps assembled with faces not parallel
(note the uneven gap either side of ferrule)

the counterweight is such that a stress concentration would occur at the same location as the fatigue origins identified on the failed bolt.

An independent review commissioned by the aircraft operator concluded that the design of the counterweight assembly is such that it is difficult to align both faces exactly parallel to one another around the blade ferrule while ensuring that the torque applied to each bolt is maintained within a tight tolerance band.

Conclusion

In light of the second event, it is now considered that the failure on G-BYUB was probably from the same root cause as that on G-CGKC. However, since the relevant components were not recovered, no further progress with the first investigation is possible. The evidence from the G-CGKC event suggests that the failure may be linked to the method of installation of the counterweight assembly on the propeller ferrule when it was last refitted. More detailed analysis by the propeller manufacturer would be required to confirm this. Since the airframe/engine/propeller combination is unique to this fleet, the AAIB has shared its investigation findings with both the propeller manufacturer and the operator to enable them to develop a 'return-to-service' strategy.