INCIDENT

Aircraft Type and Registration:	Robinson R22 Beta, G-DERB
No & Type of Engines:	1 Lycoming O-320-B2C piston engine
Year of Manufacture:	1989
Date & Time (UTC):	15 November 2004 at 1400 hrs
Location:	Biggin Hill, Kent
Type of Flight:	Training
Persons on Board:	Crew - 2 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Main rotor blade cracked
Commander's Licence:	Air Transport Pilot's Licence
Commander's Age:	35 years
Commander's Flying Experience:	2,950 hours (of which 2,080 were on type) Last 90 days - 252 hours Last 28 days - 71 hours
Information Source:	AAIB Field Investigation

Synopsis

Following a flight during which an unusual vibration developed, the helicopter landed safely but then experienced intense vibration whilst subsequently hover taxiing to a maintenance organisation. Inspection showed that one of the main rotor blades had cracked from the trailing edge, through approximately 75% of its chord, as far as the spar at about the ⅓ span position. The teeter hinge was found to be extremely stiff, and this had been assembled about 20 hours beforehand without the necessary shims. The cracking was attributed to higher than normal stresses caused by the stiff teeter hinge.

History of the flight

The commander had completed a daily inspection in preparation for a flight from Manston to Biggin Hill. The two crew consisted of the commander and a student preparing for his qualifying cross country for his PPL(H). Shortly before arrival at Biggin Hill the commander noted an unusual vibration. After landing she discussed this with another company pilot and it was eventually decided to hover taxi to a nearby maintenance organisation with experience of the R22. With the commander and student on board, another 0.4 hrs was logged, of which about 0.1 hrs was airborne time.

During the hover taxi, the vibration became intense and the commander landed and shut down. Subsequent examination of the helicopter showed that one of the rotor blades was cracked through about 75% of the chord, from the trailing edge, at about the ⅓ span position. During examination of the rotor system it was found that the teeter hinge, which should be free to pivot, was extremely stiff.

Aircraft details

G-DERB was built in 1989 and had a recorded total of 2,989.9 hours. The main rotor blades carried the part number A016-2, and serial numbers 11646C (the cracked blade) and 11674C. They were fitted on 6 October 1999 and had a total recorded airborne time (as opposed to running time) of 1,205.6 hours. This standard of blade was being phased out of service because of a history of cracking in service, frequently resulting from corrosion damage. On 25 March 2004 the manufacturer issued Service Letter SL-54 in support of FAA AD 2004-06-52 (superseded later that year by FAA AD 2004-19-09). This SL required replacement of A016-2 blades before 10 years calendar life and suggested that, in corrosive environments, these blades should be removed as soon as possible and, in any case, within five years calendar life. For all A016-2 blades with more than 1,000 hours or five years calendar life, additional track and balance of the rotor system was required. On 14 December 2004 the manufacturer issued Service Bulletin SB-94, which required that all A016-2 blades be withdrawn from service by 1 December 2005.

Description of teeter head coning hinges

The Robinson R22 is fitted with a teeter head and coning hinges, Figure 1. In this design, the teeter head allows the rotor disk to take up an attitude appropriate to the flight condition, with the coning hinges allowing the blades to achieve the optimum coning angle appropriate for the flight and loading conditions. In doing so, they remove any bending moment from the blade roots, permitting a lighter blade structure than would otherwise be required. A correctly functioning R22 rotor system in steady state forward flight will therefore experience little or no relative motion between the blade and the head at the coning hinge. The use of a teeter head eliminates the need for flap hinges, and also therefore the need for conventional lead-lag hinges and associated dampers.

Maintenance history

Maintenance records showed that on 24 March 2004, at 2,968.1 airframe hours, various rod ends were renewed in the swashplate/main rotor area. On 31 March 2004, the aircraft was flown to another maintenance organisation to carry out the accomplishment of FAA AD 2004-06-52, which required a main rotor track and balance check, but this could not be completed satisfactorily due to worn bearings in the main rotor head. It was agreed that the blade spindles and main rotor head would be reworked by the agent but, due to delays, the helicopter was transported by road back to its base for the work to be completed there. This included refitting the main rotor head and blades. At this point the helicopter had a total of 2,969.9 hours[1].

On 2 and 3 June 2004, the main rotor head, blades and spindles were reassembled. New spindle bearings had been fitted, the spindles themselves had been inspected and the main rotor head had been re-bushed before being refitted. The mechanic who assembled the main rotor head was studying to obtain a CAA licence and was working as an apprentice under the supervision of the Chief Engineer. He had encountered some difficulties with the assembly and stated that no shims had been returned with the reworked head components. The mechanic also stated that he was told to assemble the head without the shims, as there were none in stock, and therefore did so.

The Maintenance Manual requires that after assembly, the teeter bolt be pre-loaded and the pull-off load[2] be recorded. It remains unclear whether the various parties to this work thought the shims were necessary or not but, when assembled, the mechanic found that the pull-off load was unacceptably high and disassembled the head to investigate. After re-assembly, using the same components, the Chief Engineer witnessed the pull-off load check which, at 15 to 22 lbf, was still high but now within limits, and recorded the values. The main rotor system was then satisfactorily checked with a strobe light, and the work was 'signed off'. The helicopter also received a 50 hour inspection at this time.

The incident occurred 20 flying hours later.

Engineering investigation

Rotor head examination

The rotor system was disassembled and examined, Figure 2. It was found that the cadmium plated surface of the teeter bolt was damaged, that the thrust washers at the teeter hinge and the associated bushes in the main rotor head were deformed. The teeter hinge assembly should be assembled with shim washers, the thickness of which are determined on assembly, but no such washers were found in the assembly from G-DERB when examined by the AAIB. During assembly, the teeter bolt is pre-loaded by torque loading its nut until the extension of the bolt, due to elastic strain[3], achieves a

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[1] The recorded hours must be regarded as suspect because the mechanic confirmed in writing to AAIB that the helicopter had been fitted with an isolation switch, mounted beneath the pilot's seat, which was wired into the Datcon (hours meter). He had been asked to remove this switch, which had apparently been fitted before the aircraft came into the possession of the operator, his employer. Therefore, the hours recorded in the log books before this time may or may not be accurate. In the UK, the Air Navigation Order Article 17 defines the requirement for the keeping of aircraft hours, in that the aircraft log book is to be kept up to date.

[2] A torque value to move the teeter hinge, measured by a spring balance from a special tool.

[3] When the bolt is torque tightened, a tensile load is induced in the bolt, and the bolt stretches elastically. This strain, or extension over its original length, is measured using a dedicated tool. This is a more accurate means of setting the pre-load in a bolt, rather than relying upon a torque value applied to the nut, where variable friction effects may apply.

set value. On disassembly, the residual strain in the bolt was measured and this was found to be sufficiently close to the required value to suggest that the teeter bolt had been correctly pre-loaded. As a consequence of its assembly without the required shims, the bushes on the teeter bolt were not properly clamped, resulting in the thrust washers applying an excessive load directly to the teeter head itself. This caused the teeter motion to occur between the teeter bolt and its bushes rather than, as intended, between the bushes and the head itself. Using information from the Maintenance Manual and the finished dimensions of the detail parts, the required thickness of shims for correct assembly was calculated. It was found that a total of 0.059 inches of shim material was required.

Examination of blade crack

The cracked blade was examined by a specialist laboratory, Figures 3 and 4. Their report concluded that the crack had initiated in the trailing edge of one skin of the blade by a fatigue mechanism, which had then progressed, relatively slowly, forward and into the other skin. It then advanced rapidly through the top and bottom skins forward as far as the blade spar. The spar itself showed no evidence of cracks. The origin of the fatigue crack was not associated with damage, corrosion or material defect, but appeared to be due to higher than normal stresses and was in the area of a local stress concentration at the end of an internal doubler.

Analysis

General

When the head was initially assembled it was rejected by the mechanic, because the teeter hinge was very stiff to move. On inspection of the parts after the incident, it was found that the thrust washers were plastically deformed (bowed) and the mating bushes in the head were distorted to a concave shape. This most probably occurred as the teeter bolt was tightened when first assembled. These plastic deformations would have resulted in changed clearances on re-assembly, even without any shims, and there may also have been some surface grease on the parts which are normally assembled dry. The assembly may have been less stiff after re-assembly for these reasons, resulting in the recorded pull-off values remaining higher than normal due to the absence of the shims, but this time within limits. There was no clear reason established why, over the last 20 flying hours, the teeter hinge had progressively stiffened. It would appear that during this period, it was sufficiently free for the blade tips to be moved down to be inspected from the ground during the daily inspection, although the teeter hinge might have been stiffer than normal. Immediately after the incident, it was found to be extremely stiff. Upon disassembly, damage was observed to the cadmium plated surface of the teeter bolt, about which the teeter motion had been occurring in preference to the bushes and it was found that the bolt did not move freely in the bushes. Cadmium is a soft metal and will 'flow' under heat and pressure. It is likely, therefore, that the soft cadmium was displaced and flowed into the available clearance, causing high friction between the teeter bolt and the bushes.

Fracture mechanism

As described above, there is normally little or no movement of the blades relative to the teeter head at the coning hinges in normal steady forward flight. If, however, the teeter head is stiff or jammed, then the attitude that the rotor disc must adopt relative to the mast, is accommodated by blade flap occurring at the coning hinges. While this may not result in any obvious control difficulties, it will cause the centre of gravity of each blade to move up and down once per revolution, relative to the head. Since the motion occurs about the coning hinge, the centre of gravity of each blade also moves slightly inboard and outboard. Conservation of momentum (the Coriolis effect) thus causes the blade to attempt to change its angular velocity continuously around the rotor disc. Without any lead/lag hinges it is constrained from doing so, and this induces high stresses in the blade itself. This effect is described in many standard text books, for example Newman (1994)[1] states:

> *'The Coriolis forcing will then drive the blades in an in-plane manner. If no allowance for this is made, the loading in the blade will cause damage to the root of the blade or hub…'*

In response to AAIB questions, the helicopter manufacturer responded:

> *'The 'stiff' teeter hinge condition caused by the assembly of the hub to the rotor without proper shims is believed by RHC to have been a major factor in the cracking of the blade…' and.'…The absence of corrosion or other stress riser at the fatigue origin is an indicator of higher than normal loading'.*

Maintenance issues

The pull-off load check, after the rotor head had been assembled for the second time, was within limits and regarded by the mechanic and his Chief Engineer as evidence that the teeter hinge assembly had been assembled satisfactorily. With hindsight, it is apparent that this was not the case and, for this reason, the Chief Engineer has subsequently introduced a stage inspection during assembly to prevent re-occurrence. There are many situations in aircraft maintenance where work cannot be inspected after it is assembled. Where such work is carried out by personnel 'under supervision', it is vital that the responsible licensed signatories assure themselves that all such work has been correctly completed.

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[1] Newman S., (1994) 'The Foundations of Helicopter Flight' p81, pub. Edward Arnold, London, UK, ISBN 0-340-587024

Robinson R22 Main Rotor

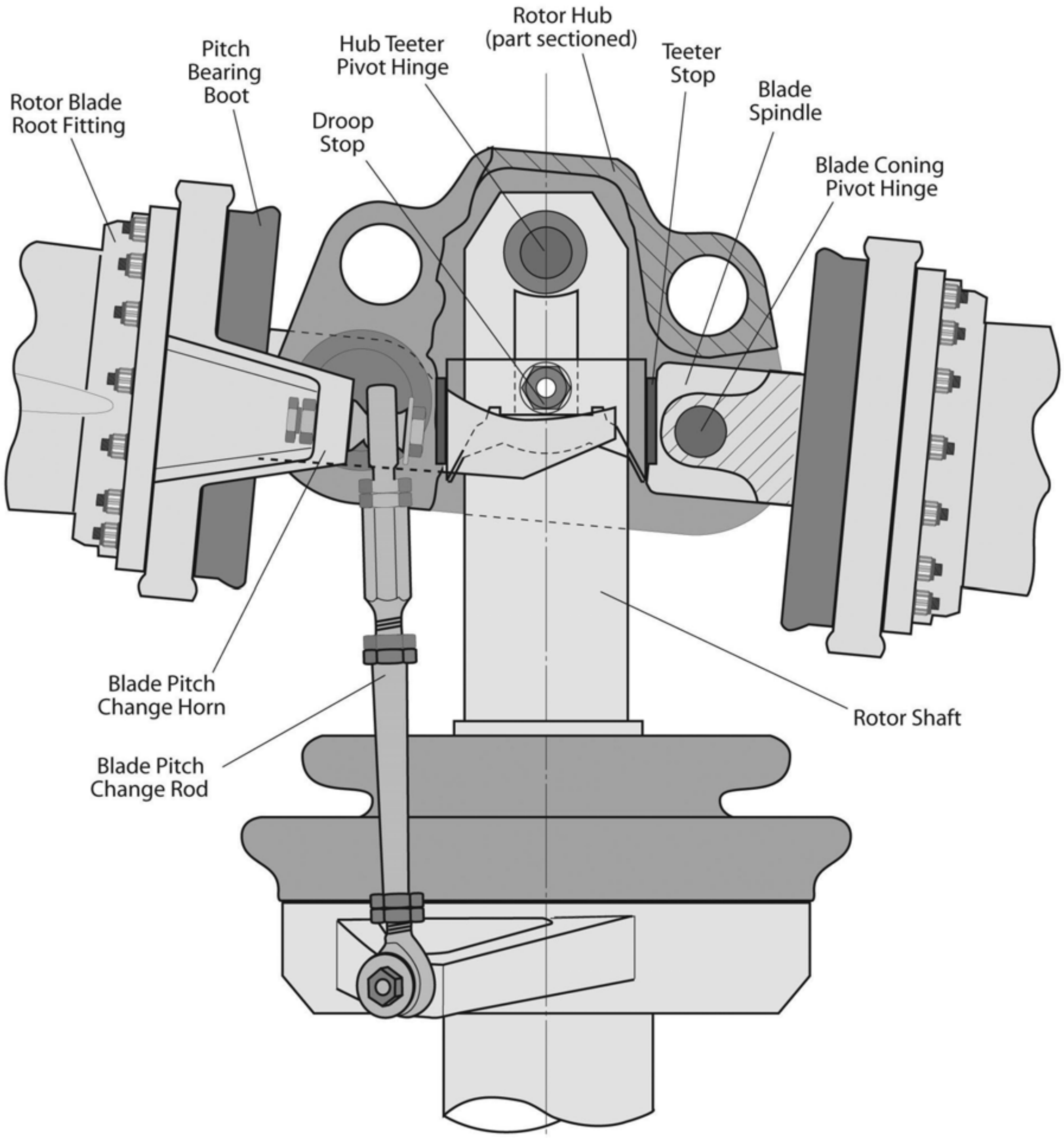

Figure 1

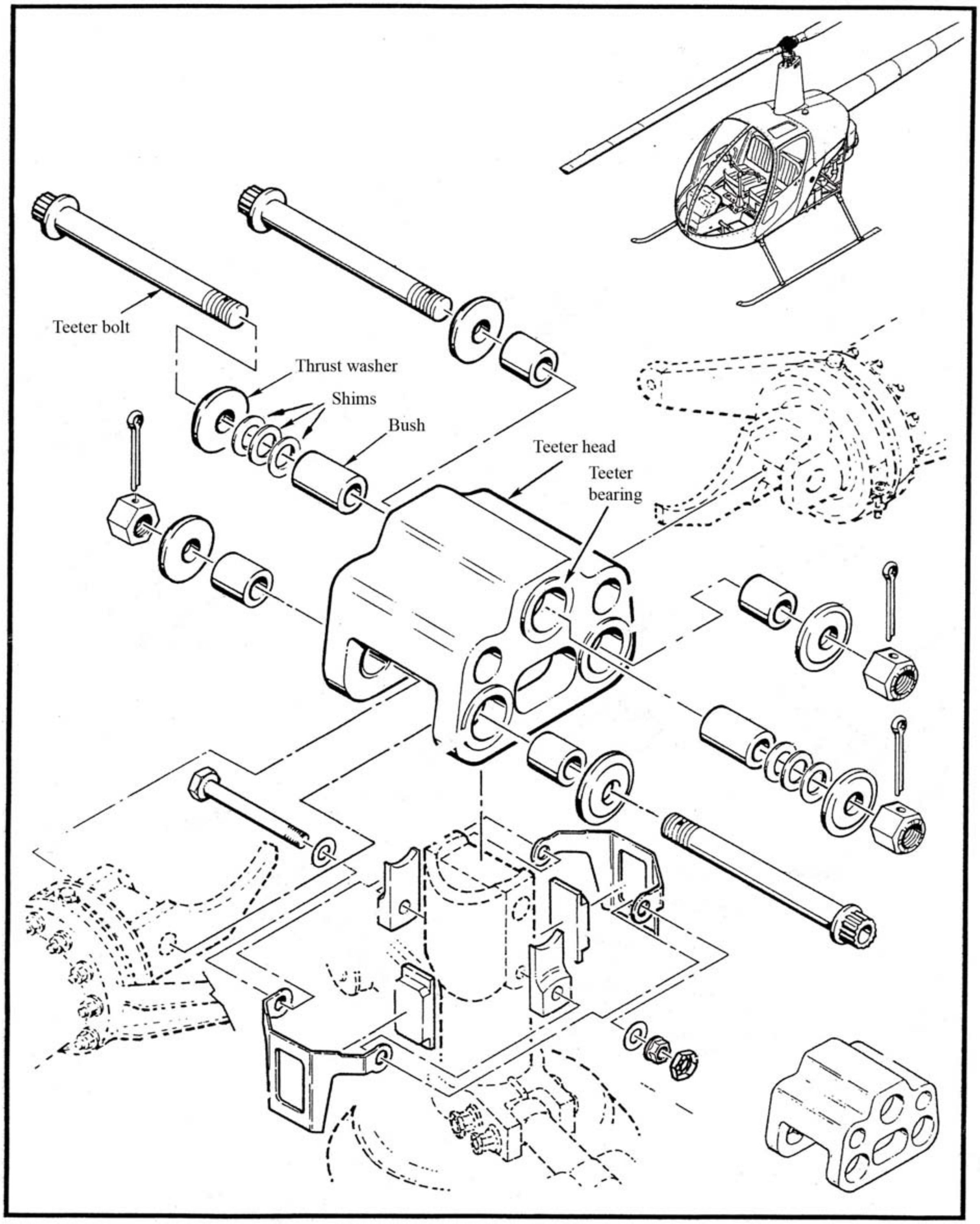

 FIGURE 6-3 MAIN ROTOR HUB

Figure 2

Figure 3
Photograph showing the crack observed on the upper surface of the rotor blade, as received, trailing edge on the left hand side of the photograph

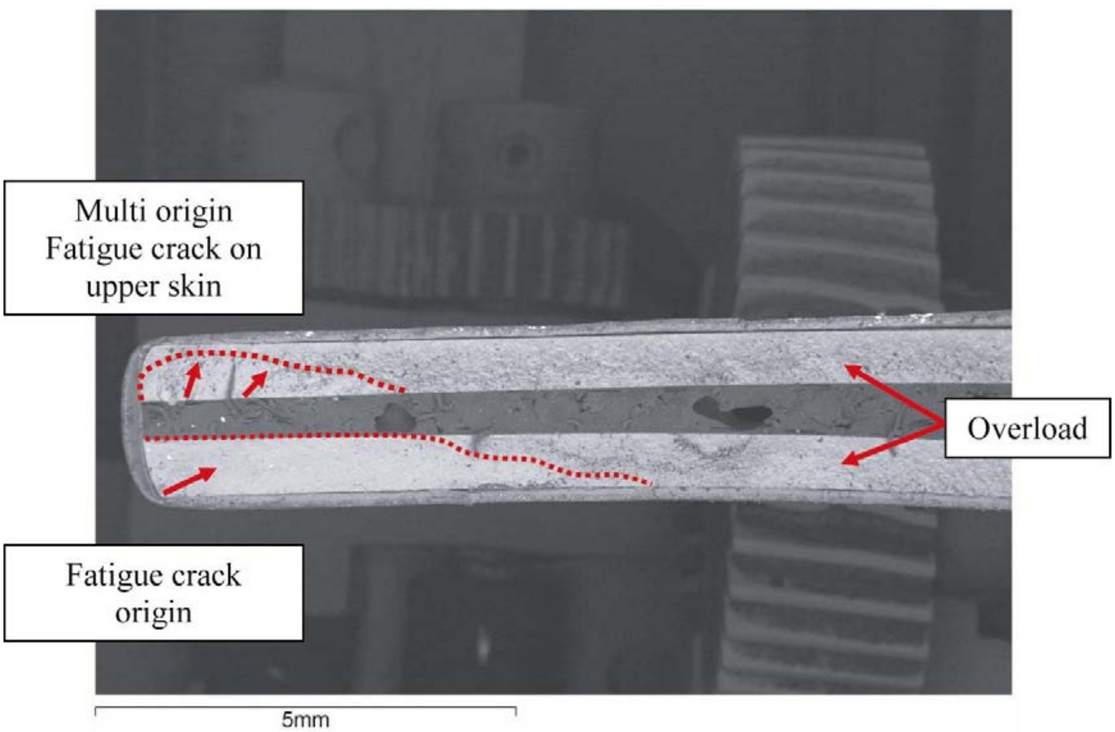

Figure 4
Backscattered electron micrograph of the fracture at the trailing edge location, showing the extent of the fatigue cracks