INCIDENT

Aircraft Type and Registration:	Sikorsky S-92A, G-CHCK
No & Type of Engines:	2 General Electric CT7-8A turboshaft engines
Year of Manufacture:	2006
Date & Time (UTC):	23 April 2007 at 0750 hrs
Location:	Approximately 65 nm north-east of Aberdeen
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 2 Passengers - 15
Injuries:	Crew - None Passengers - None
Nature of Damage:	In-flight separation of a tail rotor pivot bearing
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	52 years
Commander's Flying Experience:	16,390 hours (of which 214 were on type) Last 90 days - 113 hours Last 28 days - 37 hours
Information Source:	AAIB Field Investigation

Synopsis

The helicopter was on a public transport flight to offshore platforms in the North Sea and was over water, approximately 65 nm north-east of Aberdeen, when a heavy vibration began, which continued until the end of the flight. The crew turned back towards the coast and a successful run-on landing was completed about 30 minutes later.

The vibration was found to have been caused by the detachment of a tail rotor blade pivot bearing following a disbond of the bearing retainer from the flexible spar of the blade. Inspections of other S-92 helicopters highlighted other disbonded bearing retainers. Until a final fix is implemented, the helicopter manufacturer has increased the pivot bearing inspection frequency and provided more detailed instructions for inspecting the bearings.

History of the flight

The helicopter departed Aberdeen Airport at 0642 hrs on an Instrument Flight Rules (IFR) flight to transport personnel to offshore platforms in the Forties Field, in the North Sea. Weather conditions en-route were good Visual Meteorological Conditions (VMC), with nil weather, visibility in excess of 10 km and cloud base around 4,000 ft amsl.

The crew reported that at 0710 hrs, when the helicopter was approximately 65 nm north-east of Aberdeen and at an altitude of 3,000 ft in the cruise, a heavy vibration suddenly started. The commander took control, turned the helicopter back towards Aberdeen and initiated a descent from 3,000 ft, whilst the co-pilot radioed Aberdeen Airport to inform them of their intention to return. On noticing the helicopter's descent, Air Traffic Control (ATC) asked if they wished to declare an emergency; the co-pilot responded, stating that they had a technical problem.

The commander descended the helicopter to 1,000 ft and slowed it to below 120 kt. As the vibration had not diminished, he directed the co-pilot to make a 'PAN' call. The descent was continued down to 500 ft and the airspeed reduced to 85 kt, so that the helicopter could be ditched quickly if necessary. ATC advised that a Search And Rescue (SAR) helicopter would be sent to accompany them and asked if they wished to route towards the nearest coastline. The crew agreed that this was the most prudent action and turned the helicopter towards Peterhead. The passengers were kept appraised of developments and the crew's intentions, and the co-pilot reviewed the ditching drill in case this should become necessary.

The Stability Augmentation System (SAS) mode of the Automatic Flight Control System[1] (AFCS) continued to operate normally, but the autopilot hold functions of the AFCS were unavailable and the co-pilot's attempts to re-engage the autopilot proved unsuccessful. When the helicopter was approximately 15 nm from the coast, the Active Vibration Control[2] (AVC) system went into degraded mode. The co-pilot switched off the system in accordance with the checklist actions, but the crew's perception was that the level of vibration increased considerably and so it was switched back on again. At about this time, the Crash Position Indicator signalled that it had deployed and was transmitting.

ATC asked the crew if they wished to land at Longside and with further systems showing distress, this was considered the best option. A successful run-on landing was completed at Longside at 0748 hrs.

Recorded information

Multi Purpose Flight Recorder (MPFR)

The helicopter was fitted with a Penny & Giles Multi Purpose Flight Recorder (MPFR) that recorded the last two hours of flight crew speech and cockpit area microphone sounds and was capable of recording over ten hours of flight data. No data, however, was recorded due to a configuration mismatch between the installed MPFR and the Data Acquisition Unit (DAU), resulting in all the data from the DAU being misinterpreted by the MPFR as a continuous stream of '1's (in the binary format in which the data is stored). The lack of FDR data is discussed later in this report.

Health and Usage Monitoring System (HUMS)

HUMS data was available which showed that during the incident flight, from 0725 hrs onwards, there was a marked increase in the vibration level of the tail rotor. The mean vibration level measured increased from 0.2g to 0.5g and doubled approximately in peak-to-peak amplitude. From the CVR, it was at this time that the crew first felt the vibration. HUMS trend data recorded a single sample of the tail rotor balance during the flight of over 4.5 inches/second, 10 times more than the samples from the previous flight on 20 April, and in excess of the 0.8 inches/second service limit.

Footnote

1 The AFCS performs flight stability, attitude hold and trim functions, reducing the pilot's workload.

2 The AVC system controls the level of vibration at the 4-per-revolution main rotor blade passing frequency. It is an electro-mechanical system which employs sensors to measure the levels of vibration in different parts of the helicopter and commands inertial force generating devices which provide controlled vibratory loads to reduce fuselage vibration.

Helicopter information

General

The S-92 is a medium-lift, twin-engine, multi-role helicopter. It is equipped with four-bladed main and tail rotors. This helicopter, serial number 920030, was manufactured in 2006 and at the time of the incident had flown approximately 1,030 hours and completed 1,881 landings since new. The previous scheduled tail rotor inspection was performed 53 flying hours prior to the incident, with no reported defects. The helicopter was not carrying any relevant deferred defects at the time of the incident.

Tail rotor blade construction

The tail rotor blade construction is illustrated in Figure 1. The rotor comprises four individual composite blades attached to a central hub. The main load bearing structure of the tail rotor blade comprises an elliptically-shaped graphite-epoxy torque tube. The leading edge aerofoil contour of the blade is formed by a nickel sheath bonded to the front of the torque tube. The aft part of the aerofoil section consists of a honeycomb structure sandwiched between fibreglass-epoxy skins. The blade is attached to a graphite flexible spar, sometimes called a flex beam, which is inserted inside the torque tube and is attached to it at the mid-span location with four fasteners. The free end of the flexible spar is bolted to the tail rotor hub. The open, root end of the torque tube is covered with a boot to prevent moisture and debris from entering the blade.

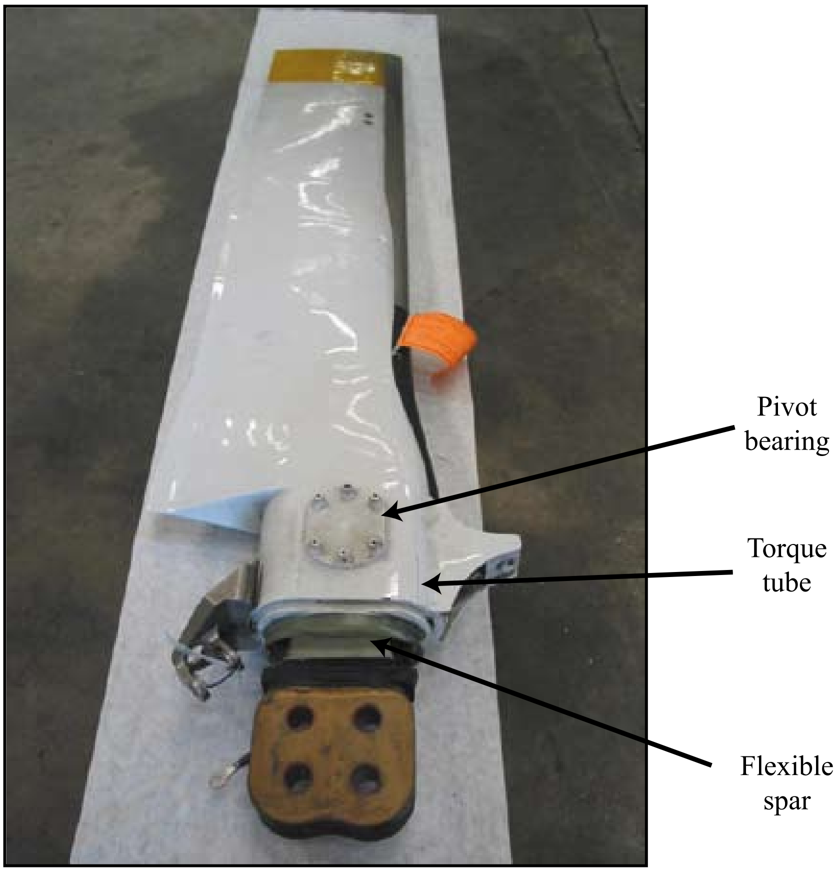

Figure 1

S-92 tail rotor blade

Elastomeric pivot bearing

Two pivot bearings are located on either side of the flexible spar, towards the root of the blade (Figure 2). These are fixed to the torque tube and protrude into the hollow centre section of the blade. The bearings butt up against the flexible spar, which is clamped between them. The bearings are manufactured from an elastomeric material to allow some degree of movement between the flexible spar and the blade, in specific directions. One end of the bearing is bonded to a nut plate, which is attached to the torque tube with six fasteners. An end plate, comprising a metal disc with a central recess, is bonded to the other end of the bearing. This locates on to a retainer, comprising a metal disc with a central spigot, bonded to the surface of the flexible spar. The retainer further constrains the movement of the blade.

G-CHCK tail rotor blade details

The tail rotor blade assembly, part number 92170-11000-044 and serial number A111-00210, was manufactured on 22 November 2005 and installed on G-CHCK at helicopter build. At the time of this incident, it had completed approximately 1,030 flight hours since new. In early 2007, the trailing edge of the blade tip suffered minor damage from contact with staging whilst the helicopter was being manoeuvred in a hangar. The damage was repaired in accordance with a repair scheme approved by the helicopter manufacturer and a tail rotor balance check was performed after reinstalling the blade.

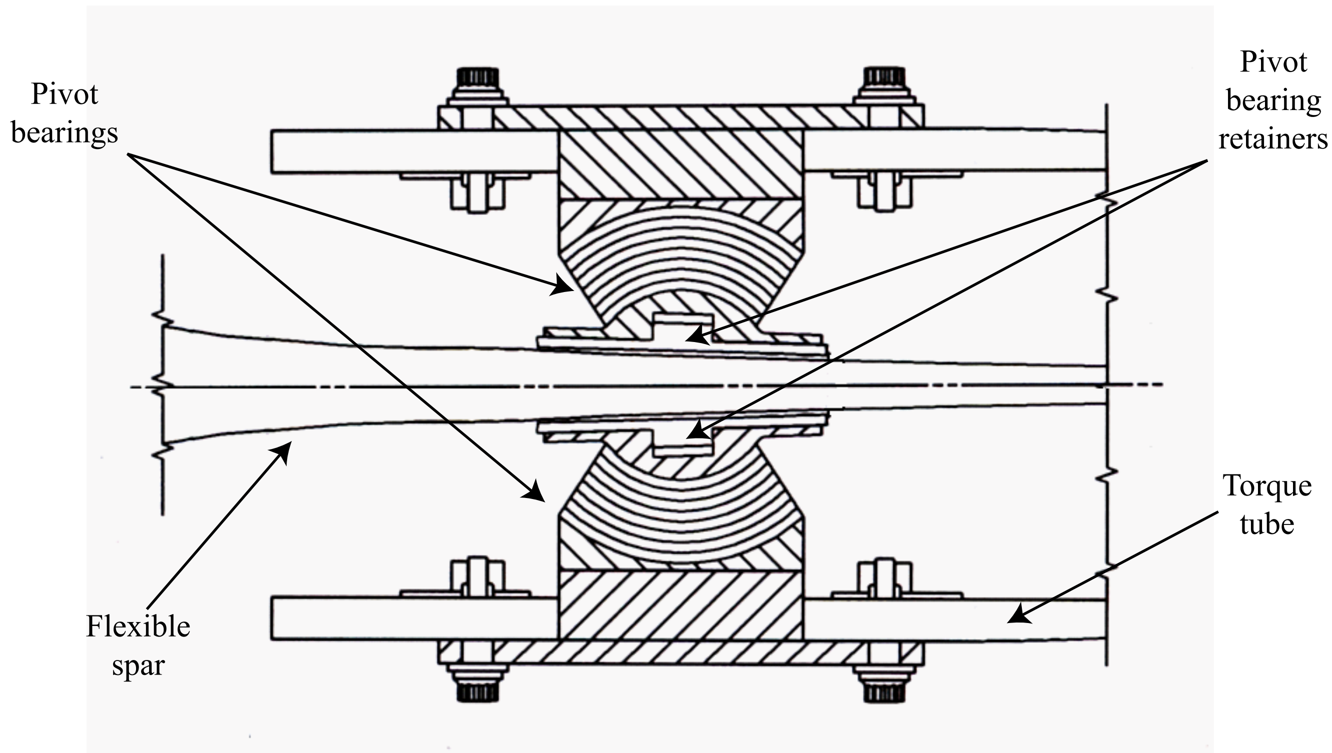

Figure 2

Longitudinal section through tail rotor pivot bearing

Tail rotor blade examination

The affected tail rotor blade was removed from G-CHCK and sent to the AAIB for preliminary examination prior to being forwarded to the helicopter manufacturer for more detailed examination.

It was evident that the larger part of the outboard pivot bearing and its retainer had detached (Figure 3) and migrated outwards inside the torque tube under centrifugal loading, becoming jammed between the torque tube and the flexible spar (Figure 4). The inboard bearing retainer had also detached from the flexible spar and travelled up inside the torque tube, but the inboard bearing was undamaged (Figure 5). Overlapping circular witness marks were visible on both sides of the flexible spar (Figures 5 and 6), corresponding to the original position of each bearing retainer and the newly adopted positions after the retainers had disbonded from the flexible spar. Similar witness marks were found on the flexible spar of another of the operator's S-92 helicopter, serial number 920013, which had also suffered a disbond of a bearing retainer. This blade was also removed and sent to the helicopter manufacturer for examination.

Figure 3 (left)

View inside G-CHCK tail rotor blade torque tube showing missing pivot bearing

Figure 4 (right)

View inside torque tube of G-CHCK tail rotor blade showing detached outboard pivot bearing trapped between torque tube and flexible spar

Figure 5 (left)

G-CHCK tail rotor inboard pivot bearing showing missing bearing retainer and overlapping circular witness marks

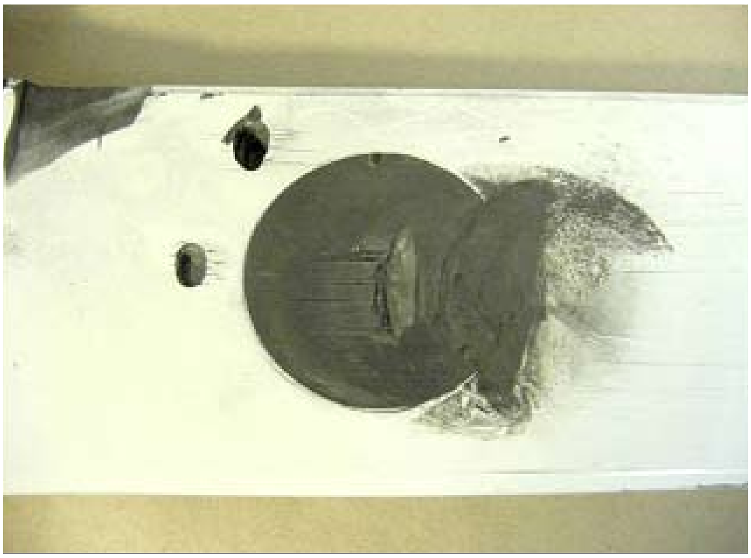

Figure 6 (right)

G-CHCK flexible beam outboard side showing witness marks produced by bearing retainer

Tail rotor inspection requirements

Scheduled inspection requirements

The helicopter inspection requirements are included in the Airworthiness Limitations section of the S-92 Maintenance Manual. The inspection interval for the tail rotor pivot bearing was originally 50 flying hours, but this was later increased to 250 flying hours, as no defects were being reported by operators.

The inspection of the pivot bearing was covered by Item 9 of the 250-Hour Inspection: *'Inspect tail rotor blade elastomeric pivot bearing and retention plate.'* The task cross-referred to the instructions contained in Maintenance Manual task 64-10-01. However these are instructions for an external inspection of the condition of the blade and not an internal inspection of the pivot bearings. Specific instructions for inspecting the pivot bearings are contained in Maintenance Manual section 64-10-06, '*Inspection of Tail Rotor Pivot Bearing*.' Following this incident, the helicopter manufacturer moved the pivot bearing inspection on to the 50-Hour Inspection schedule and amended the Maintenance Manual cross-reference to call up the correct inspection procedure contained in section 64-10-06.

Pivot bearing inspection instructions

Prior to the incident the instructions contained in Maintenance Manual 64-10-06, as listed below, were brief and did not provide specific instructions on inspecting the pivot bearings:

> '…(2) *Visually inspect inside of tail rotor blade.*
>
> (3) *Make sure that the upper and lower pivot bearing retainers are bonded to the flex beam.*
>
> (4) *Make sure pivot bearing is properly seated on pivot bearing retainer.'*

With the tail rotor blade installed on the helicopter, there is limited access to the root of the blade due to the proximity of the tail rotor hub.

The helicopter manufacturer has since issued Temporary Revision (TR) 64-03 to the Maintenance Manual, to provide more comprehensive instructions for inspecting the pivot bearings and, in particular, how to detect a disbonded bearing retainer. It is now recommended that a borescope is used to inspect the pivot bearings if the inspection is performed with the blade installed on the helicopter.

To date there have been a total of 16 cases of disbonded pivot bearing retainers, nine of which have occurred since this event. With the exception of this event, all have been found during inspection.

Fleet inspection of pivot bearings

After the G-CHCK incident, the operator inspected the tail rotor pivot bearings on other helicopters in its S-92 fleets. One other helicopter, serial number 920013, was found with a disbonded pivot bearing retainer, but the pivot bearing was still intact. This helicopter had flown 2,286 hours since new and the most recent scheduled pivot bearing inspection was completed 116 flying hours previously.

On 23 May 2007, the helicopter manufacturer issued Alert Service Bulletin (ASB) No 92-64-001 to direct operators to perform a one-time visual inspection of the tail rotor pivot bearing retainers within 50 flying hours, or 30 days from the date of issue of the ASB. The inspection required the removal of the pivot bearings to allow access to the bearing retainers for a visual and tactile check of the integrity of the bonding of the retainer to the flexible spar. The AAIB is aware of one helicopter in Denmark that was found with a disbonded pivot bearing retainer when performing the ASB. The affected tail rotor blade, serial number A111-00282, had completed 152 flying hours since new.

MPFR installation

On 18 April 2007, the annual download check of the MPFR fitted to G-CHCK was due to be carried out. However, connections problems between the MPFR and the laptop PC used for the download prevented the check from happening, and in order for the helicopter to return to commercial operations, a replacement MPFR was installed instead. Unfortunately, the replacement MPFR was configured to record at the data rate of 128 words per second (wps) compared with the Data Acquisition Unit's (DAU) rate of 256 wps. This MPFR remained installed until the time of incident, during which G-CHCK had flown a total of 12.5 hours.

Sikorsky Maintenance Manual SA S92A-AMM-000 (Aug 31/05)

Both the removal and the installation of the MPFRs was carried out in accordance with the Sikorsky Maintenance Manual, SA S92A-AMM-000 (31-31-01 Pages 401-404 dated Aug 31/05), which refers to the MPFR by its part number D51615-102. This practice is quite normal as flight recorders in general that share the same part number are usually interchangeable, with predefined configurations matched to the aircraft's flight recorder system.

Penny & Giles MPFR

The MPFR can, however, be reconfigured via its PC interface, allowing, for example, different recording data rates to be set on different recorders that share the same part number. As there is nothing externally on the recorder to indicate the FDR data rate configuration, the uniqueness of the part number no longer ensures the interchangeability of the MPFR in the aircraft's flight recorder system.

As a result of this incident, Penny & Giles issued a Service Information Leaflet (sil51615-XXX-02) and Service Bulletin (D51615-31-5) to all known customers of the MPFR requiring an FDR Data Rate label (P/N: 111053), illustrated in Figure 7, to be attached to the outer casing onto which the current data rate of the recorder can be marked. This label is also now attached to all new MPFRs.

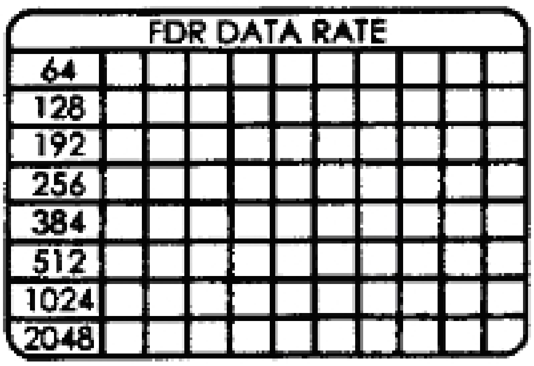

Figure 7

MPFR Data Rate label

Flight recorder system – monitoring of proper operation

The design and installation of the MPFR was made in accordance with the EUROCAE document ED-112 (Minimum Operational Performance Specification for Crash Protected Airborne Recorder Systems) that specify the continuous monitoring of the data recording system for proper recording of the information in the recording medium. In particular it states in paragraph 2-1.4.2 that:

> *'An acceptable means of compliance would be to provide system status monitor(s) and built-in test functions which would detect and indicate to the flight crew a failure of the flight recorder system due to any of the following:*
>
> *a. Loss of system electrical power,*
>
> *b. Failure of the acquisition and processing equipment,*
>
> *c. Failure of the recording medium,*
>
> *d. Failure of the recorder to store the information in the recording medium as shown by checks of the recorded material including, if reasonably practicable, correct correspondence with the inputs,*
>
> *e. The absence of the recorder and/or the acquisition unit.'*

To meet this requirement, the helicopter is fitted with an FDR fail light, positioned within the cockpit to the left of the left-seat collective control. From the above list of failure cases, it could be argued that if a data recorder were configured to a specific data rate but received data from the acquisition at a different rate, this difference, if detectable, should be interpreted as a '*failure of the acquisition unit*'.

MPFR built-in-test equipment (BITE)

The MPFR, as part of its BITE, is designed to make a data rate check at recorder start-up. If set to the wrong rate a BITE should be identified and flag an FDR fault via the FDR fail light. The FDR fail light, however, did not illuminate. This was due to the MPFR interpreting two consecutive 'zeros' sent from the DAU (set to 256 wps) as 'ones' when the MPFR was set to 128 wps.

CHC Scotia aircraft fleet using the MPFR

CHC Scotia has a mixed fleet of aircraft that each use the MPFR as part of their flight recorder system: the Sikorsky S-92; the AgustaWestland AW139 and the Eurocopter AS332L2. The systems do not, however, share a common data rate. Of the fleet, only the S-92 and the AW139 come fitted with the MPFR as standard fit, and configured for a 256 wps data rate. The AS332L2 has the MPFR installed as a retro-fit (using a CHC Heli-One modification), and configured for a 128 wps data rate.

MPFR functionality checks post-installation

The Sikorsky Maintenance Manual 31-31-01 (Aug 31/05) did not require a functionality check of the MPFR post-installation. A check of this nature would provide a means of capturing an MPFR configured to a different data rate compared to the flight recorder system requirements. As such, Sikorsky have issued a Temporary Revision (No 31-03 dated Sep 30/07) to 31-31-01 (Aug 31/05) that requires a post-installation test to be performed as part of the installation procedure. (Similarly, the AgustaWestland AW139 MPFR installation procedures do not include a functional check of the FDR side of the MPFR post-installation. The CHC Heli-One AS332L installation procedures require a functional check of the MPFR to be carried out, but a specific check of the data rate is not required. AgustaWestland have, however, indicated that they intend to revise their procedure to include such a check.)

Analysis

The sudden onset of vibration during the flight suggests that a rapid in-flight separation of the outboard pivot bearing occurred, causing the greater part of the bearing to detach and migrate further up the torque tube under centrifugal force. The resultant change in the centre of mass of the blade would have caused the tail rotor to become out of balance, producing the reported high vibration levels.

The overlapping circular witness marks on both sides of the flexible spar represented the initial position where the retainer was bonded to the spar and the new relaxed position of the bearing after the retainer had disbonded. Inspections of other S-92 helicopters since this incident have identified other retainers that had disbonded, producing similar witness marks on the flexible spar.

All of the above suggests that the bearing separation on G-CHCK was probably preceded by the disbond of either one or both of the bearing retainers from the flexible spar. This would have caused the inner end of the pivot bearing to become unrestrained, allowing it to deflect outwards in a spanwise direction under centrifugal loading when the tail rotor was rotating. This would place the elastomer under considerable strain. In this case, the elastomer eventually separated, allowing the greater part of the outboard pivot bearing to detach and to be centrifuged up inside the blade torque tube.

It is possible that the impact on the tail rotor blade sustained in the hangar could have compromised the integrity of the bond on the bearing retainer, making it more likely to fail. However, the damage to the blade was very localised and the loads transmitted to the pivot bearings were likely to have been less than those they would be exposed to in normal service. Furthermore, disbonded retainers were found on tail rotor blades without any previous damage, suggesting that the root cause is not damage-related.

It is possible that the tail rotor pivot bearings may not have been adequately inspected prior to this incident, given the incorrect Maintenance Manual cross-reference and the very basic instructions previously contained in Maintenance Manual task 64-10-06. This may have been exacerbated by the difficulties in accessing the inside of the blade when installed on the helicopter. These issues have been addressed by the helicopter manufacturer in recent amendments to the manual. The amended inspection has proved to be effective in identifying disbonded bearing retainers.

The helicopter manufacturer is continuing its investigation into the root cause of retainer disbond. A final fix will be implemented once the root cause has been identified. In the meantime, the more frequent inspections of the pivot bearings and more comprehensive inspection instructions should ensure that disbonded retainers are identified before bearing separation occurs.

The issue concerning MPFR data rate configuration control has been expediently and satisfactorily resolved by the airframe and recorder manufacturers. Therefore it is not considered necessary to make any safety recommendations on this matter.

Conclusions

The helicopter experienced a sudden onset of vibration due to the detachment of a large part of the outboard pivot bearing on one of the tail rotor blades. The separation of the pivot bearing was probably the consequence of the bearing retainer becoming disbonded from the flexible spar, allowing the inner end of the bearing to become unsupported. This would have exposed the bearing to loads for which it had not been designed, causing it to eventually separate in flight.