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ATSB TRANSPORT SAFETY REPORT
Aviation Occurrence Investigation AO-2009-081
Final

Loss of tailrotor control, VH-UHD Nangar National Park, New South Wales 23 December 2009

Abstract

On 23 December 2009, a Garlick Helicopters Incorporated TH-1F helicopter, registered VH-UHD, was engaged in aerial firefighting operations in the Nangar National Park, New South Wales. At about 200 ft above ground level, the nose of the helicopter unexpectedly yawed to the right. The pilot made a corrective input on the tailrotor pedals, but was unable to stop the yaw and the helicopter began to rotate. The pilot guided the helicopter to a less-timbered area for an emergency landing. The helicopter descended into the trees and was seriously damaged. The pilot, the sole occupant, was seriously injured.

The loss of directional control was due to a structural failure in the helicopter's tailrotor control system, likely precipitated by the failure of an attachment bolt.

The investigation identified a safety issue with the maintenance and operation of ex-military helicopters being used in repetitive heavy lift operations. In response, on 5 July 2011, the Civil Aviation Safety Authority published Airworthiness Bulletin 02-40 Issue 1 to advise operators and maintainers to investigate the basis for, and the correct implementation of, the continuing airworthiness requirements of the applicable type certificate data sheet and incorporated supplemental type certificates, particularly in regard to the retirement lives of all life-limited components.

FACTUAL INFORMATION

History of the flight

On 23 December 2009, a Garlick Helicopters Incorporated TH-1F (TH-1F) helicopter, registered VH-UHD (UHD), was engaged in aerial firefighting operations in the Nangar National Park, New South Wales. That included water dropping operations in the later part of the afternoon, during which the pilot flew the helicopter to the fire ground, landed next to the water source and used a 'long line' to hook-up the water bucket.

The weather conditions were reported as being good for water dropping operations. The temperature was about 25 °C with light and variable winds of about 5 kts. The pilot recalled that the helicopter was operating normally and that he had plenty of power reserve for the water uplifts.

The pilot completed seven water drops before temporarily stopping dropping operations to provide directions via radio to a bulldozer driver to enable the driver to reach the fire ground safely. The helicopter was about 200 ft above ground level and at low forward speed at that time.

The pilot reported that, without any warning, abnormal vibration or other indication of a problem, the nose of the helicopter yawed unexpectedly to the right. The pilot attempted to correct the right turn by applying a correcting input on the tailrotor pedals but was unable to stop the yaw and developing rotation.

The pilot recalled attempting to gain height to reach a cleared area of ground nearby, but the helicopter started to pitch nose-down. To prevent losing control of the helicopter and reduce the rate of fuselage rotation, the pilot reduced engine power by partially rolling off the throttle, lowered the collective[1] and sideslipped the helicopter towards a less-timbered area for an emergency landing.

As the helicopter descended through the tree canopy, the pilot rolled the throttle to idle and increased collective pitch to cushion the ground impact. The helicopter impacted the ground at low forward speed and came to rest on its left side (Figure 1). A nearby firefighter witnessed the accident and helped the pilot from the wreckage.

The pilot sustained serious back injuries and the helicopter was seriously damaged[2].

Figure 1: Accident site

Photo courtesy of the Department of Environment, Climate Change and Water

Personnel information

The pilot held a Commercial Pilot (Helicopter) Licence issued by the Civil Aviation Safety Authority (CASA) and a current Class 1 Aviation Medical Certificate. He had logged about 12,500 hours flying experience in a mix of light and medium single-engine and large twin-engine helicopters. The pilot had about 350 hours in the TH-1F helicopter type, including 120 hours in UHD.

The pilot recalled being free of duty for the 5 days prior to the accident. He considered that he was well rested and fit for duty.

Aircraft information

The helicopter was manufactured in 1966 as a utility helicopter (TH-1F)[3] and was operated by the United States Air Force (USAF). Following its retirement from military service and a period of storage, it was purchased by a civilian operator and placed on the United States (US) civilian aircraft register. The holder of the type certificate was Garlick Helicopters Incorporated.

The helicopter was imported into Australia in 2001 and placed on the Australian aircraft register as a 'Limited Category'[4] (ex-military) aircraft.

Operator records indicated that, at the time of the accident, the helicopter's total time in service (TTIS) was 9,323 hours.

Helicopter modification

During 2008, the helicopter underwent significant modification, including the:

- fitment of a 'Fast Fin' kit to the helicopter's vertical fin that improved the efficiency of the tailrotor
- installation of the more powerful Textron Lycoming T53-L13B engine, which increased the available power margin for use in operations such as firefighting
- fitment of a 'Strake' kit to the tail boom that modified the effect of the main rotor downwash on the tail boom to increase the available yaw control
- fitment of lighter, wide-chord tailrotor blades that were manufactured from composite

1 Lowering the collective decreases the pitch on the main rotor blades, decreasing the total rotor thrust (effectively lift) being produced by the main rotor, and reducing any main rotor torque-induced fuselage rotation.

2 The *Transport Safety Investigation Regulations 2003* define 'serious damage' as including the 'destruction of the transport vehicle'.

3 The TH-1F was a variant of the 'UH-1' model utility helicopter.

4 Limited category, ex-military aircraft were not required to comply with any specific civil airworthiness standards or design codes but could be approved to carry passengers.

material and improved the efficiency and authority of the tailrotor.

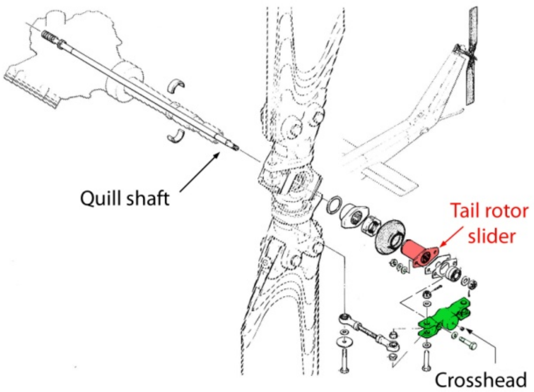
It was reported that those modifications were installed in accordance with the appropriate supplemental type certificates. Due to the extensive modifications, the helicopter was issued a special certificate of airworthiness and registered in the 'Restricted Category'[5].

Tailrotor and pitch change mechanism description

The helicopter's tailrotor counteracted the torque reaction on the helicopter that was produced by the rotation of the main rotor. The pilot controlled the helicopter's direction in yaw by using the tailrotor pedals to change the pitch of the tailrotor blades and therefore the tailrotor thrust.

The tailrotor pitch control mechanism included a 'crosshead' and 'slider' assembly (Figure 2), which translated linear movement of the quill shaft into a tailrotor blade pitch change. The crosshead was secured to the slider by two National Aerospace Standards (NAS) 1304[6] attachment bolts and castellated nuts that were torqued to a specified value and locked by split pins.

Figure 2: Tailrotor slider and crosshead



System of maintenance

The owner reported that the helicopter was being maintained in accordance with the UH-1 Series Inspection Planning Guide (IPG). That document was compiled by the United States Interagency Committee for Aviation Policy[7] and was applicable to a standard UH-1 series helicopter that was being operated in a flight profile similar to that in the US military.

The IPG included a requirement that UH-1 helicopters that were being used for repetitive heavy lift and other unique operations '...shall require additional and/or more frequent inspections as deemed necessary based on operational experience and/or alert service bulletins and/or airworthiness directives.' Those operations included logging, water bucket, and long line operations,

The aircraft's logbook statement indicated that the helicopter was to be maintained in accordance with the USAF Technical Orders or other CASA-approved inspection program. There was no record of CASA approving an alternative inspection program for the helicopter. The helicopter owner believed that the logbook statement allowed the helicopter to be maintained in accordance with the IPG.

The aircraft's logbook statement also indicated that the helicopter's engine was the original General Electric T-58-GE-3. Although the helicopter owner believed that CASA had issued an amended logbook statement after the engine change, neither the owner nor CASA could locate a copy of that document in their records.

The helicopter's maintenance records did not document the conduct of additional or more frequent inspections of the helicopter as a result of its use in a repetitive lift environment. However, the total number of lifts was recorded on the maintenance release, and that data was used for main rotor mast and trunnion fatigue calculations, as mandated by CASA Airworthiness Directive AD/UH1/6.

Tailrotor inspection requirements

The IPG stipulated various inspections and maintenance to assure the aircraft's ongoing airworthiness. Those inspections and maintenance requirements are discussed in the following paragraphs.

5 Certificated for special purpose operations, including firefighting, but not for the carriage of passengers.

6 A designation of the design and material that was used to manufacture the bolt.

7 Established by the US Government to provide support to various government agencies that used aviation services.

The tailrotor control mechanism, including the slider, was subject to repeated visual inspection as part of the daily pre- and post-flight inspection schedules. Those inspections could be performed either by a pilot, who was authorised to carry out the maintenance in the aircraft's approved system of maintenance, or by a licensed aircraft maintenance engineer (LAME).

In addition to those inspection requirements, the tailrotor was also subject to 50-, 100- and 150-hourly scheduled maintenance inspections. Those inspections were required to be carried out by a LAME.

The IPG stipulated a preventative maintenance inspection (PMI) that was to be accomplished every 10 flying hours or 14 calendar days, whichever came first. That PMI included an inspection of the tailrotor crosshead for axial and radial movement. The owner advised that this inspection was listed on the maintenance release, requiring the PMI to be conducted as part of the daily inspection, and that he had trained the pilots in its performance.

Recent maintenance

Maintenance records indicated that in July 2009, the tailrotor was removed from the helicopter and disassembled to fit a new yoke[8]. The reassembled tailrotor was refitted to the helicopter and dynamically balanced. Records indicated that the helicopter had flown 209 hours between that maintenance and the time of the accident.

Maintenance engineers conducted a scheduled inspection of the helicopter on 3 December 2009 and completed the IPG requirements for the 50- and 100-hourly inspections. The maintenance records indicated that the tailrotor pitch control link and inboard rod end bearings were replaced at that time. The crosshead/slider was also measured for wear before the tailrotor was tracked and balanced.[9]

An aircraft maintenance release was issued at 9,254.1 hours TTIS that certified the completion of the required maintenance inspection and PMI. The helicopter had flown 69 hours between the completion of that maintenance and the accident.

On 16 December 2009, 19 flight hours prior to the accident, the helicopter underwent a further IPG 50-hourly inspection. That inspection included another measurement of the crosshead/slider for excessive wear. No anomalies were recorded.

Daily inspections

Another pilot flew the helicopter earlier that day and performed the daily inspection. That pilot also performed a post-flight inspection,[10] including a grease and inspection of the main and tailrotors.[11] The accident pilot conducted a pre-flight inspection before taking off.

Both pilots advised that they carried out those inspections in accordance with the approved (USAF) flight and technical manuals. Each inspection included visual and tactile checks for tailrotor crosshead wear.

Both pilots stated that they did not know about, and had not been trained to perform the PMI. After reviewing the requirements of the PMI, the pilots reported that the inspection required a number of documentation and other checks that were not feasible in the field operating environment. They indicated that their inability to comply with those requirements would have prevented them from certifying the completion of the PMI. In any event, the PMI was not completed as part of their daily inspections that day.

Wreckage examination

The ATSB did not carry out an on-site examination of the wreckage. The following wreckage report is based on the operator's report and on photographs of the wreckage.

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8 A structural member that is normally loaded in tension and links the tailrotor blade to the tailrotor hub.

9 A maintenance activity to ensure that successive tailrotor blades exactly follow their predecessor (track), and that the mass of the blades is evenly distributed about the axis of rotation (balance).

10 The post-flight inspection was called for in the USAF technical manual and included an inspection of the tailrotor.

11 A purge re-grease of the main and tail rotor assemblies that was undertaken by suitably-qualified pilots while away from home base.

Tailrotor and pitch change mechanism

The tailrotor blades struck the helicopter's vertical fin twice, destroying the tailrotor driveshaft cover and severing that section of the driveshaft. Those impacts also shattered the 'red'[12] tailrotor blade (Figure 3). The 'white' tailrotor blade had failed structurally at its tip.

Figure 3: Shattered tailrotor blade

Photo courtesy of an agent for the helicopter's insurer

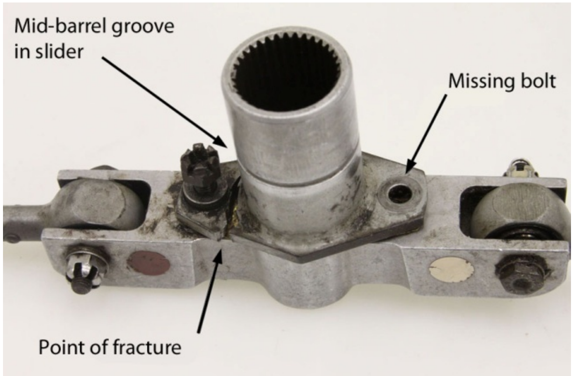
Representatives of the helicopter owner examined the tailrotor on-site and found that the pitch change slider had fractured at the flange-to-barrel transition on the red side of the slider. In addition, one attachment bolt was missing from the slider-to-crosshead attachment (Figures 4 and 5). A search of the accident site by the owner's representatives did not locate the missing bolt.

12 Rotating components are colour-coded for ease of identification. In this case, one blade and the associated control linkages were designated 'red', and the other blade and linkages 'white'.

Figure 4: Slider and crosshead

Photo courtesy of the owner of the helicopter

Figure 5: Slider showing missing bolt and fracture



The crosshead and slider assembly was removed from the helicopter by the owner's representatives and forwarded to the Australian Transport Safety Bureau (ATSB) for technical examination. A number of other tailrotor control mechanism and drivetrain components were also recovered for later examination.

Technical examination of recovered components

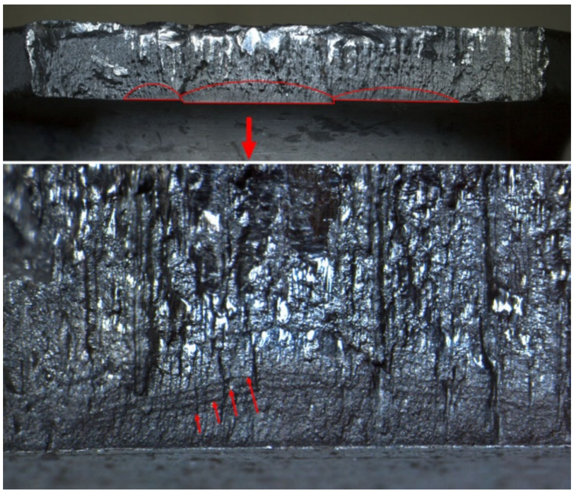
The tailrotor slider fracture at the flange-to-barrel transition followed a circumferential path around the barrel, where the effect of the change in thickness of the structure was greatest. The fracture surfaces were examined at varying magnifications using an optical microscope.

The bulk of the slider flange had failed in a manner consistent with ductile overstress; however, there was evidence of cyclic fatigue cracking in the form of beach marks on the fracture surfaces. Those semi-circular fatigue cracks had initiated in the transition radius of the flange at three separate origins, and had propagated perpendicularly inward through the flange toward the clamping interface with the crosshead.

Measurements indicated that the deepest fatigue crack had grown approximately 25% through the flange, to a maximum depth of 1.2 mm. The existence of multiple fatigue cracks, together with the relatively small size of the fatigue zone in relation to the region of overstress, indicated that the slider most probably failed through bending under low-cycle, high-stress conditions. Examination of the fracture surfaces with a scanning electron microscope found no material anomalies at any of the three crack origins that might have contributed to the crack initiation.

Some smearing of the fracture surfaces had occurred, consistent with metal-to-metal contact during the accident sequence. At the time of the examination, the fracture surfaces appeared to have been newly created, with no evidence of corrosion or polished features (Figure 6).

Figure 6: Fracture surfaces



Other features of relevance on the slider body included localised surface fretting under the washer associated with each slider/crosshead bolt (Figure 7). Fretting of that nature indicated that the bolts had been moving during service. Additionally, as observed by the helicopter owner's representatives on-site, only one of the two NAS1304 attachment bolts that secured the slider and crosshead remained installed within the assembly.

Figure 7: Fretting wear on slider flange

There was no manufacturer's part or serial number on the body of the slider. The absence of those details suggested that the tailrotor slider may not have been manufactured by the original equipment manufacturer (OEM).[13]

The slider was identified visually and was a different part number to that specified in the manufacturer's illustrated parts catalogue. However, the OEM and 'after-market' sliders were similar in physical appearance and dimension, the only difference being a different location for the lockwire retaining groove.

A review of the aircraft's maintenance documentation found no evidence to indicate that the tailrotor slider had been replaced since the aircraft was imported to Australia.

Chemical analysis of the slider confirmed that it was manufactured from the material specified by the OEM. Metallographic analysis found no evidence of intermetallic particles or other anomalous features within the microstructure that might have otherwise affected the fatigue life of the component.

Examination of the slider and the recovered crosshead attachment bolt using a fluorescent magnetic particle inspection technique found no indication of cracking on the intact slider flange, along the length of the attachment bolt, under the bolt head, or in the thread roots. The markings on the attachment bolt identified it as being the correct part for that assembly. Both rod ends that were fitted to the pitch control links at either end of the crosshead were in near-new condition,

13 OEM parts were vibro-etched on the slider body with the respective item's part and serial numbers, together with the company's trademark.

consistent with the maintenance documentation that indicated their recent installation.

Additional information

Slider airworthiness directive

The US Federal Aviation Administration (FAA) issued an airworthiness directive (AD)[14] in September 2006 that addressed the potential for fatigue failure of non-OEM sliders in UH-1 series helicopters. The AD warned of the potential for failure of tailrotor sliders as a result of fatigue cracking. That cracking initiated from rough machining marks at multiple locations in the slider flange-to-barrel radius.[15]

In October 2006, CASA issued airworthiness directive AD/UH-1/19 to owners/operators of Australian-registered UH-1 and TH-1 helicopters. That directive required an examination of the slider fitted to each helicopter to identify non-OEM sliders manufactured by a number of approved parts manufacturers. Those manufacturers' sliders were subjected to a 25-hour inspection requirement and retirement from service within 1,000 flight hours or 12 months, whichever came first.

A LAME inspected the helicopter's slider on 26 November 2006, which was about 470 flight hours prior to the accident, and determined that the slider was not affected by the CASA AD. The LAME reported the understanding that the results of that inspection meant that the slider did not require further inspection or retirement from service.

The investigation confirmed that the requirements of the CASA AD did not apply to the slider that was fitted to UHD at the time.

Specified slider service life

A retirement life was not specified by the USAF for the tailrotor slider during the operation of the helicopter by that Service. However, the US Army issued a technical bulletin in 1998 that specified a 3,000 hour service life for tailrotor sliders in UH-1 series helicopters. The USAF was no longer operating the TH-1F helicopter at that time, so no equivalent bulletin was issued for that model.

The CASA-approved maintenance organisation that was responsible for maintaining the helicopter when first registered in Australia assigned a 3,000 hour service life to the helicopter's tailrotor slider. That was consistent with the maintenance requirements applied to other ex-military UH/TH-1 helicopters operated or maintained by that organisation at the time.

A review of the aircraft's maintenance documentation found that, at the time of the accident, the slider had about 1,300 hours TTIS.

Fatigue management of flight critical components

Original equipment manufacturer

The OEM had, for a number of years, used the retirement index number (RIN) system to track cycle-lifed[16] components. The RIN system had effect on the drive train and other dynamic components that were most affected by cyclical and repetitive loading. The system was based on the number of 'torque events', or significant changes of power affecting the component being monitored. Those events included operations that relied on the use of the helicopter's cargo hook, such as water dropping and the airborne replenishment of fixed internal or external reservoirs - for example, firefighting tanks.

Torque events were recorded against the affected components and factored according to different fatigue requirements. The manufacturer believed that the RIN factoring approach moderated the unnecessary retirement of otherwise lifed components.

Australian context

In the Australian civil environment, ex-military helicopters (usually of US origin) continue to be used in specialist firefighting and other repetitive

14 FAA AD 2006-19-05, requiring the identification of non-OEM sliders, their repetitive inspection and retirement from service within 1,000 flight hours/12 months.

15 US National Transportation Safety Board (NTSB) accident investigation report SEA04LA043.

16 A cycle is one complete sequence of events that makes up a portion of the fatigue life of a machine or component. For example: start, taxi, take off, climb, cruise, descent, landing, taxi in and shut down.

lifting tasks.[17] However, the nature of those tasks is frequently different from those considered in the design and certification of those helicopters, and in the calculation of the service life of various components.

At the time of the accident, the helicopter's main rotor mast and trunnion were the only components that were subject to the OEM's RIN methodology, with the retirement life for the main rotor trunnion being determined by the number of torque events and total flight hours. There was no Australian requirement for any additional inspection or maintenance of ex-military helicopters during specialist firefighting and other repetitive lifting operations.

ANALYSIS

Loss of control

The loss of directional control was the result of a failure of the tailrotor slider, which allowed the tailrotor blades to diverge from their normal plane of rotation. In turn, the tailrotor blades struck the helicopter's vertical fin, severing the tailrotor driveshaft. The resulting loss of tailrotor thrust allowed the helicopter to commence rotating.

The fatigue cracking in the flange-to-barrel transition of the slider was a result of low-cycle, high-stress conditions. The final fracture of the slider was due to overstress of the component from the application of bending forces.

In the context of the missing attachment bolt, the abnormal fretting wear under each slider/crosshead attachment bearing surface was consistent with relative movement in the slider/crosshead attachment area during service. That movement was likely the consequence of insufficient clamping force, as produced by the fastening torque of the castellated nuts onto each attachment bolt. The lack of clamping force in the slider/crosshead assembly created additional dynamic stresses on the components, with associated fatigue cracking in the barrel-to-flange transition. Although not able to be confirmed by examination of the missing bolt, such dynamic stresses could be expected to create ideal conditions for fatigue cracking and the in-service failure of the bolt.

Although the slider was technically the incorrect part for the TH-1F helicopter, it was of an identical geometric design to the correct part and made of the correct material as specified by the original equipment manufacturer. There was no evidence that a material defect had initiated the fatigue cracking.

Component fatigue management

The additional and/or more frequent inspections that were called for in the Inspection Planning Guide recognised the potential effect on a number of the helicopter's components of repetitive heavy lift operations. Those requirements addressed the potential for the cyclical and repetitive loading during such operations to adversely affect the safe service life of various aircraft components.

Whereas the monitoring of lift cycles required by AD/UH1/6 addressed the risk of fatigue in the main rotor mast and trunnion, the lack of similar monitoring of a number of the helicopter's other components increased the risk of their premature failure due to fatigue, when using those helicopters in repetitive heavy lift operations.

The lack of more inclusive fatigue monitoring of critical components in helicopters used for repetitive heavy lift operations increased the risk that those components would exceed their safe service life. Accounting for those increased cycles, and their potential effect on the fatigue life of relevant components, would assure the ongoing airworthiness of those aircraft.

FINDINGS

From the evidence available, the following findings are made with respect to the loss of tailrotor control in Nangar National Park, New South Wales on 23 December 2009 involving Garlick Helicopters Incorporated TH-1F helicopter, registered VH-UHD. They should not be read as apportioning blame or liability to any particular organisation or individual.

Contributing safety factors

- The tailrotor pitch control slider fractured at the attachment to the crosshead, resulting in a

17 At the time of writing this report, there were 17 UH-1 series helicopters in Australia being operated by 13 operators.

loss of blade pitch control and the tailrotor blades striking the fin and severing the tailrotor drive.

- The tailrotor pitch control slider fractured as a consequence of bending under low-cycle, high-stress conditions that were likely produced by a slider/crosshead attachment bolt failure.
- The attachment bolt probably failed as a result of metal fatigue that was produced by excessive stresses associated with relative movement in the slider/crosshead attachment area.

Other safety factors

- The scheduled maintenance requirements for ex-military UH-1 series helicopters may not adequately address the increased risk of fatigue failures associated with repetitive heavy lifting operations that were not considered in the original design fatigue calculations. *[Minor safety issue]*

SAFETY ACTION

The safety issues identified during this investigation are listed in the Findings and Safety Actions sections of this report. The Australian Transport Safety Bureau (ATSB) expects that all safety issues identified by the investigation should be addressed by the relevant organisation(s). In addressing those issues, the ATSB prefers to encourage relevant organisation(s) to proactively initiate safety action, rather than to issue formal safety recommendations or safety advisory notices.

All of the responsible organisations for the safety issues identified during this investigation were given a draft report and invited to provide submissions. As part of that process, each organisation was asked to communicate what safety actions, if any, they had carried out or were planning to carry out in relation to each safety issue relevant to their organisation.

Civil Aviation Safety Authority

Component fatigue management

Minor safety issue

The scheduled maintenance requirements for ex-military UH-1 series helicopters may not adequately address the increased risk of fatigue failures associated with repetitive heavy lifting operations that were not considered in the original design fatigue calculations.

Action taken by the Civil Aviation Safety Authority

On 5 July 2011, the Civil Aviation Safety Authority (CASA) published Airworthiness Bulletin 02-40 Issue 1 to:

> ...advise operators and maintainers to investigate the basis for and the correct implementation of the continuing airworthiness requirements of the applicable type certificate data sheet (TCDS) and incorporated supplemental type certificates (STC), particularly in regard to the retirement lives of all life-limited components.

ATSB assessment of action

The ATSB is satisfied that the action taken by CASA adequately addresses the safety issue.

SOURCES AND SUBMISSIONS

Sources of Information

The sources of information during the investigation included the:

- pilots who flew the helicopter on the day of the accident
- owner and maintainer of the helicopter
- helicopter manufacturer.

Submissions

Under Part 4, Division 2 (Investigation Reports), Section 26 of the *Transport Safety Investigation Act 2003* (the Act), the Australian Transport Safety Bureau (ATSB) may provide a draft report, on a confidential basis, to any person whom the ATSB considers appropriate. Section 26(1)(a) of the Act allows a person receiving a draft report to make submissions to the ATSB about the draft report.

A draft of this report was provided to the pilot, the helicopter owner/maintainer, the helicopter manufacturer and the Civil Aviation Safety Authority.

Submissions were received from the pilot and the helicopter owner. The submissions were reviewed and where considered appropriate, the text of the report was amended accordingly