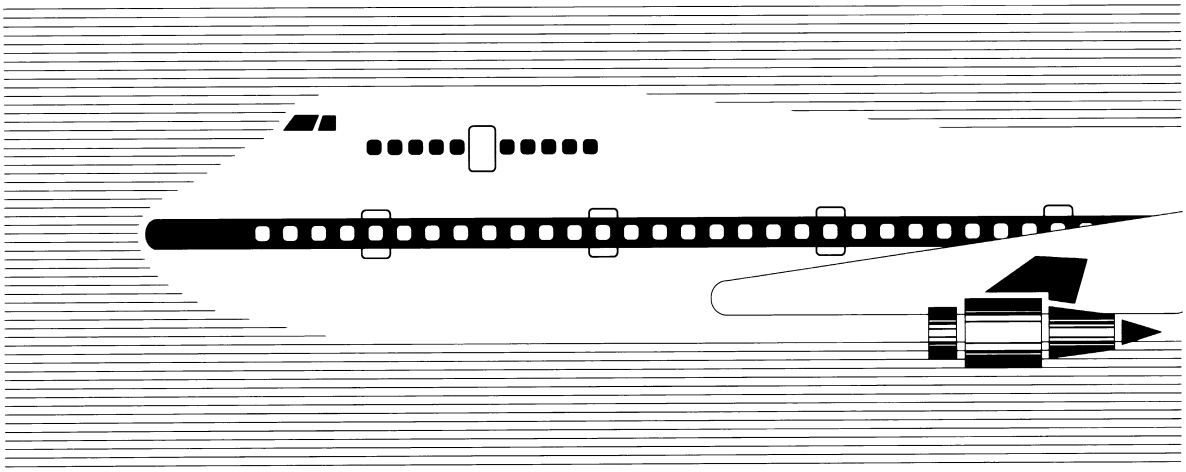
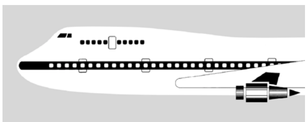
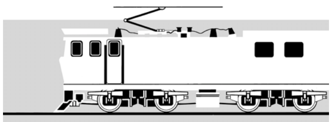
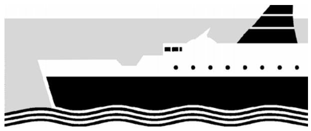


# A V I A T I O N   O C C U R R E N C E   R E P O R T

**04-003** **Bell/Garlick UH1B Iroquois helicopter, ZK-HSF, in-flight break-up, near Mokoreta, Southland** **23 April 2004**

**TRANSPORT ACCIDENT INVESTIGATION COMMISSION**
**NEW ZEALAND**

The Transport Accident Investigation Commission is an independent Crown entity established to determine the circumstances and causes of accidents and incidents with a view to avoiding similar occurrences in the future. Accordingly it is inappropriate that reports should be used to assign fault or blame or determine liability, since neither the investigation nor the reporting process has been undertaken for that purpose.

The Commission may make recommendations to improve transport safety. The cost of implementing any recommendation must always be balanced against its benefits. Such analysis is a matter for the regulator and the industry.

**Report 04-003**

# Bell/Garlick UH-1B Iroquois helicopter ZK-HSF

## in-flight break-up

## near Mokoreta, Southland

## 23 April 2004


## Abstract

On Friday 23 April 2004, Helicopter Services UH-1B helicopter ZK-HSF was on a ferry flight to Gore to facilitate maintenance work. En route near Mokoreta a main rotor blade separated, the helicopter broke up and fell to the ground. The pilot, the sole occupant, was killed and the helicopter was destroyed.

The accident resulted from fatigue failure of a tension-torsion (TT) strap, a critical rotor hub component. The fatigue cracking had probably been initiated by an unreported rotor overspeed event.

Safety issues identified included:

- the need for pilots to understand the importance of reporting a rotor overspeed event
- the need for FAA and CAA airworthiness personnel and licensed maintenance engineers to recognise and respond to documented improper identification of critical finite-life components such as the TT straps

Safety recommendations to address these issues were made to the Director of Civil Aviation, and to the Administrator of the United States Federal Aviation Administration.

# Contents



# Figures

## Abbreviations

| | |
|---|---|
| CAA | NZ Civil Aviation Authority |
| FAA | US Federal Aviation Administration |
| GPS | global positioning system |
| km | kilometre |
| m | metre |
| mm | millimetre |
| RPM | revolutions per minute |
| TT strap | tension-torsion strap |

## Data Summary

| | |
|---|---|
| **Aircraft registration:** | ZK-HSF |
| **Type and serial number:** | Bell/Garlick UH-1B Iroquois helicopter, 62-2090 |
| **Number and type of engines:** | one Lycoming T53-L-13B |
| **Year of manufacture:** | 1963 |
| **Operator:** | B A and J C Emeny Limited (Helicopter Services) |
| **Date and time:** | 23 April 2004, about 0850 |
| **Location:** | near Mokoreta, Southland<br>latitude: 46° 22´ south<br>longitude: 168° 59´ east |
| **Type of flight:** | agricultural - ferry |
| **Persons on board:** | crew: 1<br>passengers: nil |
| **Injuries:** | crew: 1 fatal<br>passengers: nil |
| **Nature of damage:** | helicopter destroyed |
| **Pilot's licence:** | commercial pilot licence - helicopter |
| **Pilot's age:** | 48 |
| **Pilot's total flying experience:** | about 3780 hours<br>about 566 hours on UH-1B type |
| **Investigator-in-charge:** | J J Goddard |

# 1 Factual Information

## 1.1 History of the flight

1.1.1 On Thursday, 22 April 2004, the day before the accident, Bell/Garlick UH-1B Iroquois helicopter ZK-HSF was flown from a farm at Moa Flat to the pilot's home near Gore, then to a farm in the Waikawa Valley where fertilizer spraying work was to be done. After arriving mid-afternoon, the pilot took two local farmers for a short flight in the helicopter to survey the areas to be sprayed. The loader-driver arrived shortly after, with the loader vehicle, and he and the pilot set up the equipment for preparing and loading the fertilizer mixture.

1.1.2 About 5 loads were sown before the pilot decided to stop flying at about 1700. The pilot and loader-driver secured the helicopter on the farm, and returned to Gore in the loader vehicle. On the way home the pilot said to the loader-driver that a temperature gauge reading (probably the engine oil temperature) was higher than normal, "getting a bit close to the red line", and also a vertical bounce or vibration from the main rotor, particularly when the helicopter was hovering, had become more pronounced.

1.1.3 After the pilot arrived home he telephoned the Chief Pilot of Helicopter Services, the operating company based in Inglewood, Taranaki, to discuss the increased vibration. The Chief Pilot and Chief Engineer had planned to fly to Gore on the following day to replace some components on ZK-HSF in order to rectify the problem, which they had become aware of earlier in the week during some other maintenance work on the helicopter. The pilot arranged with the Chief Pilot that in the morning he would ferry the helicopter from the farm in the Waikawa Valley to his home near Gore, to facilitate the maintenance work. The Chief Pilot would fly his aeroplane to Gore Aerodrome. They agreed that the helicopter could be flown for the ferry flight, but not for more spraying.

1.1.4 On Friday, 23 April, the pilot left home alone at about 0650, driving the loader vehicle to the Waikawa Valley farm. A local farmer heard the helicopter start at about 0830, and a few minutes later depart towards the northwest, flying away out of earshot. Nobody saw the pilot, or the departure of the helicopter from the Waikawa Valley farm.

1.1.5 A group of 3 witnesses were on a farm near Mokoreta, on the south side of the Wyndham-Mokoreta road, some 22 km northwest of the Waikawa Valley. They were standing outside at about 0850 when they heard the helicopter approaching from the east. They recognised the sound as characteristic of the Iroquois type of helicopter, but thought it sounded as though it was working hard and flying slowly since they heard it approach for a long time before it came into their view, which was restricted by nearby trees. When the helicopter came into their view it was flying past, straight and level about 500 m north of them, at an estimated height of 500 feet. Some 2 or 3 seconds after the helicopter came into view they heard a loud bang, and saw pieces fall from it. The helicopter fell in a spiral to the ground, impacting with a second loud bang.

1.1.6 These witnesses straight away drove across to the accident site. One witness was able to drag the pilot from the cabin wreckage, but found that he had been killed in the accident. They checked the wreckage for further occupants, but found none. Another of the witnesses drove back up the road to a position where his cellphone would work, and reported the accident to the Police at 0859.

1.1.7 A separate witness was also outside, about 3 km east of the previous witnesses, when he heard and saw the helicopter approach from the south-east, and fly past him to the north-west. He described the helicopter as flying on a steady level course, about 500 feet high, and fairly loud. When it was about 2 km west, he saw the main rotor fly off in pieces, and a cloud of smoke. The helicopter quickly spiralled straight down.

1.1.8 Witnesses described the weather at the time as dead calm, overcast skies, and some patches of fog.

1.1.9 Police and ambulance services arrived about 15 minutes after the accident, and confirmed that the only occupant was the deceased pilot.

## 1.2 Injuries to persons

1.2.1 The pilot received fatal injuries at ground impact.

## 1.3 Damage to aircraft

1.3.1 The helicopter was destroyed in the in-flight break-up and ground impact.

## 1.4 Other damage

1.4.1 Minor surface damage to open farmland.

## 1.5 Personnel information

1.5.1

| | |
|---|---|
| Pilot: | Male, aged 48 years |
| Licence and ratings: | Commercial pilot licence (helicopter), pilot's agrichemical rating |
| Aircraft type ratings: | UH-1B, Sikorsky S55, Bell 47, Bell 206, Hughes 269, Robinson R22 |
| Medical certificate: | Class 1, valid to 17 August 2004 |
| Last agricultural operational competency assessment: | 10 January 2004 |
| Last biennial flight review: | 10 January 2004 |
| Flying experience: | about 3780 hours on helicopters |
| | about 566 hours on UH-1B type |
| Duty time: | about 2 hours |
| Rest before duty: | about 12 hours |

1.5.2 The pilot worked as a self-employed contractor pilot for the operator, Helicopter Services, and had done so since 1994.

1.5.3 He had started helicopter flying training in 1989, and had completed his commercial pilot licence in 1990. From 1992, while working for the operator as a loader-driver, he flew various helicopters on ferry flights until 1994, when he completed a course of agricultural pilot training with the operator. All his subsequent flying was for the operator, on agricultural operations, flying Hughes 269, Bell 206, Sikorsky S55, and UH-1B helicopters.

1.5.4 His routine annual competency checks and biennial flight reviews had been conducted by the Chief Pilot, and had been satisfactory.

1.5.5 The last routine medical examination for the renewal of the pilot's class 1 medical certificate was on 18 August 2003. There were no endorsements on his medical certificate.

1.5.6 The last entry in his pilot logbook had been made on 28 April 2003. His total flying time has been estimated using company records after this date.

## 1.6 Aircraft information

1.6.1 The Bell UH-1B Iroquois type was a single-turbine-engine, single-rotor, medium-size utility helicopter designed in the 1950s to a military specification, and produced from 1961. The Bell 204B, produced from 1963, was a substantially similar helicopter but which was certificated by the US Federal Aviation Administration (FAA) for civil use. After some years of military service, some UH-1B helicopters became surplus to US Army requirements and were sold. In order for these ex-military helicopters to be used, some form of US civil type certification was needed. This was undertaken by Garlick Helicopters Incorporated, who became the holder of FAA type certificate H13WE. UH-1B helicopters meeting its specifications could be issued with a Restricted Category Certificate of Airworthiness, allowing private and aerial work operations only.

1.6.2 ZK-HSF was manufactured by Bell Helicopter in 1963 as a military UH-1B helicopter, serial number 62-2190, for the US armed forces. The detail of its operational history with the US Army was not found, but a total time in service of 2140 hours was recorded in a new Bell helicopter logbook on 12 January 1989 as transferred from its computerized Army logbooks. It was also recorded at that time with the FAA civil registration of N80WF. The new logbook entries indicate that it was operated from that time in Nicaragua by the Nicaraguan Air Force until 12 April 1990, at 2378.4 hours.

1.6.3 Logbook entries on 11 March 1989, at 2157 hours total time, record the replacement of the transmission, mast, swashplate, scissor and sleeve, and main rotor hub assembly. These changes were supported by US Army component record cards which carried historical sub-assembly data and time details. These components remained fitted to the helicopter at the time of the accident. Similar changes of tail boom and tail rotor components, and main rotor stabiliser bar items were recorded on 12 February 1990.


**Figure 1**
**UH-1B main rotor head**

1.6.4 After the 12 April 1990 logbook entry, no further flying was recorded. The next entry, on 1 September 1994, was for refurbishment, repainting and maintenance work, and inspection of the helicopter for compliance with Garlick type certificate H13WE. The last entry, on 9 September 1994 was made by an FAA representative, and recorded that the aircraft met the requirements and that a restricted FAA airworthiness certificate had been issued.

1.6.5 An FAA Export Certificate of Airworthiness was issued on 10 September 1994 for the export of the helicopter to New Zealand. This recorded the helicopter total time as 2378.4 hours, and 0.0 hours since annual inspection. The main rotor blades, mast and hub assemblies, which were removed for shipment, were recorded by part and serial numbers. The US registration of N80WF was to be removed when it was deregistered.

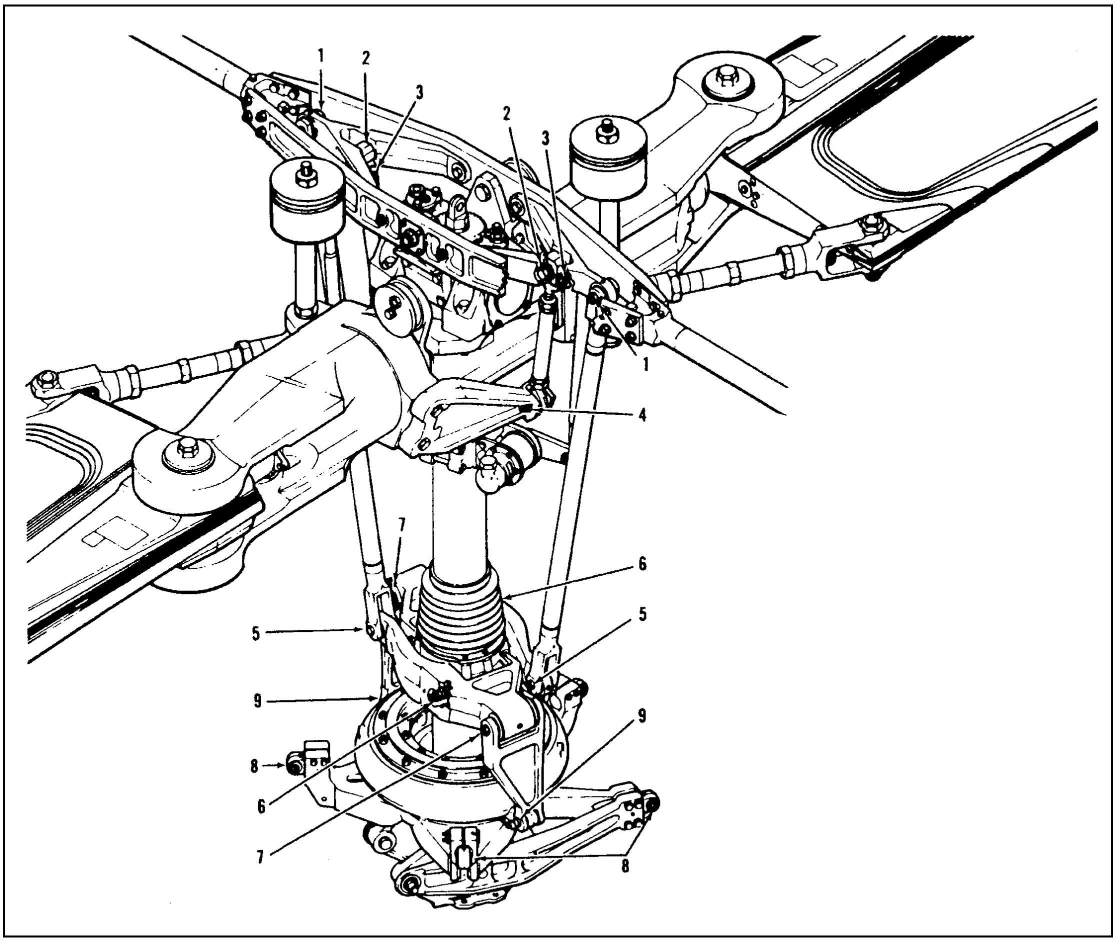


**Figure 2**
**UH-1B main rotor head and mast**

1.6.6 After importation to New Zealand the helicopter was registered ZK-HSF. A new logbook commenced on 23 September 1995 with an entry recording its reassembly, compliance checks to meet NZ Civil Airworthiness Requirements and all applicable Airworthiness Directives, reweighing and numerous maintenance items. One item was a magnetic particle inspection of the main rotor yoke, which involved the removal of the TT straps. ZK-HSF was inspected by the Civil Aviation Authority (CAA) and issued an Airworthiness Certificate in the restricted category, for private and aerial work operations only, on 26 September 1995.

1.6.7 Over the next 5 years the helicopter was flown for a few hours each year, and received routine maintenance. It was repainted and re-upholstered. In August 2000, at 2462 hours, it suffered heavy landing damage, requiring repair to the landing gear and fuselage. The main rotor blades were replaced with new blades for company convenience, and it was returned to service in August 2001.

1.6.8 The agricultural spray system, comprising a metal tank in the rear cabin, spray booms, external pump, pneumatic controls, and associated plumbing was installed in December 2001, in accordance with an approved local modification, at a total time of 2528 hours, and the helicopter was used thereafter in the agricultural spray role. The pilot commenced flying ZK-HSF in July 2002 from his Gore base at a total time of 2605 hours, and had flown it for the majority of its subsequent time.

1.6.9 In December 2002 an electrical fire occurred in the engine bay of ZK-HSF. Electrical wiring and oil and fuel line repairs were carried out, along with routine maintenance, and the aircraft was returned to service on 14 August 2003. At that time the engine was replaced with a T53-L-13B version, which was more powerful than the original T53-L-11D engine.

1.6.10 On 31 March 2004 the Chief Engineer had replaced the main rotor blade pitch links, because some play in the end bearings was causing out-of-track vibrations. Tracking adjustments were made, and the helicopter returned to service.

1.6.11 The unscheduled maintenance work which the Chief Engineer had carried out on Tuesday 20 April had arisen on the job at Moa Flat, when the pilot reported that he was unable to control the engine RPM with the "beep" switch; the caution light was illuminating intermittently, and the torque gauge was indicating intermittently. These defects were traced to an electrical wiring problem, and to corrosion inside an electrical connector on the engine deck. After these problems were rectified, the Chief Pilot flew the helicopter and concluded that the main rotor was slightly out-of-track, and that a vertical vibration in the hover was present. A tracking adjustment was made to the main rotor, which improved the problem, but a close inspection of the control linkages indicated that some play was present in bearings on the collective scissor and sleeve assembly, causing the vertical vibration. The helicopter was released to service providing the vibration did not increase, and the Chief Pilot and Chief Engineer planned to return on Friday 23 April with new bearings and shims for the collective sleeve.

1.6.12 The pilot was reported to have carried out some maintenance on ZK-HSF at the Moa Flat site before the Chief Engineer's visit. This included replacing a pneumatic hose which took bleed air from the engine to the spray equipment, and also replacing a clamp bolt on a control lever on the engine fuel control unit. He also tried cleaning the electrical connector without success. Other reports from that time indicated that he had flown the helicopter on spray work with the engine producing lower than normal RPM and power, resulting in reduced take-off performance and high engine oil temperature.

1.6.13 The last routine maintenance recorded in the aircraft logbooks was on 24 December 2003, at 2864.6 hours. This had included 100 hour and annual inspections, replacement of bearings in the tail rotor pitch links and the main rotor damper links, and in the swashplate trunnion. The next scheduled maintenance was a 600-hour inspection, due at 2964.6 hours. The next annual inspection was due on 24 December 2004. The last recorded total time in service was 2907.7 hours, on 14 April 2004. Time flown after that date, but not recorded, was approximately 5 hours.

1.6.14 The helicopter component record cards, which showed when those components with finite lives had been installed and were due for replacement, indicated that none was in service beyond its allocated life. The main rotor hub assembly, which included the torsion-tension straps (TT straps) and their retention pins, was due off at 3299 hours. The TT straps had a finite life of 1200 hours, of which 384 hours remained. No calendar life was specified. The TT straps and pins, normally components with manufacturers' serial numbers, were identified only as " red" and "white" on the component record card.

1.6.15 The function of the TT straps was to retain the main rotor blades in place in the rotor hub against the large centrifugal forces developed at normal rotor RPM, while allowing the blades to pivot on their feathering axes as required by the control inputs from the swashplate. The TT straps were contained within the arms of the yoke part of the hub assembly, with each outboard end attached to a main rotor blade grip. The blade grips were supported on bearings on the outside of the yoke arms. The yoke arms were filled with oil.

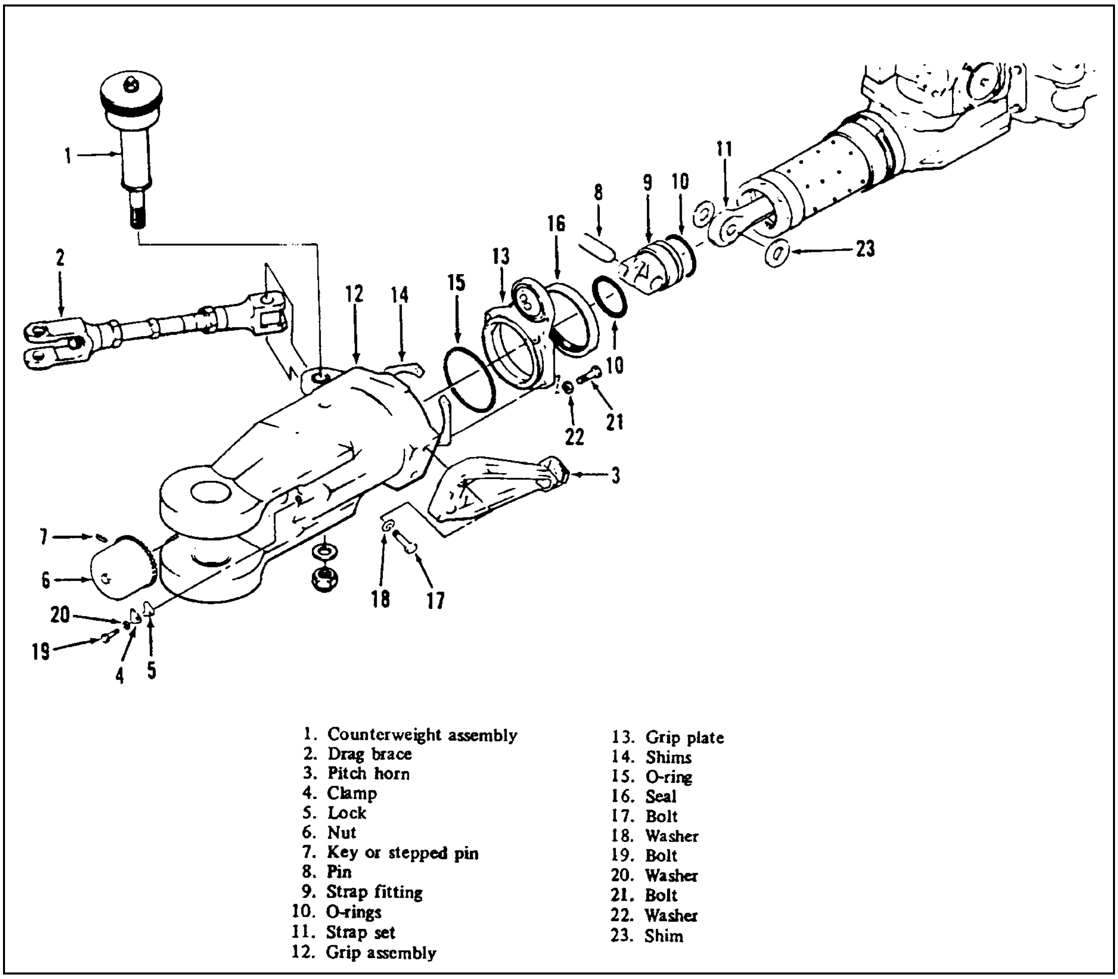



**Figure 3**
**UH-1B grip assembly, showing TT strap**

1.6.16 Each TT strap, Bell Helicopter part number 204-011-113-1, consisted of a one-inch (25.4 mm) stack of 50 stainless steel laminates 0.020 inch (0.50 mm) thick. The laminates were 16 inches (406 mm) long, measured between the retaining pin holes at each end. The centre 30 laminates were 1.6 inches (40.7 mm) wide, with 10 narrow laminates, 0.8 inch (20.3 mm) wide on each side.

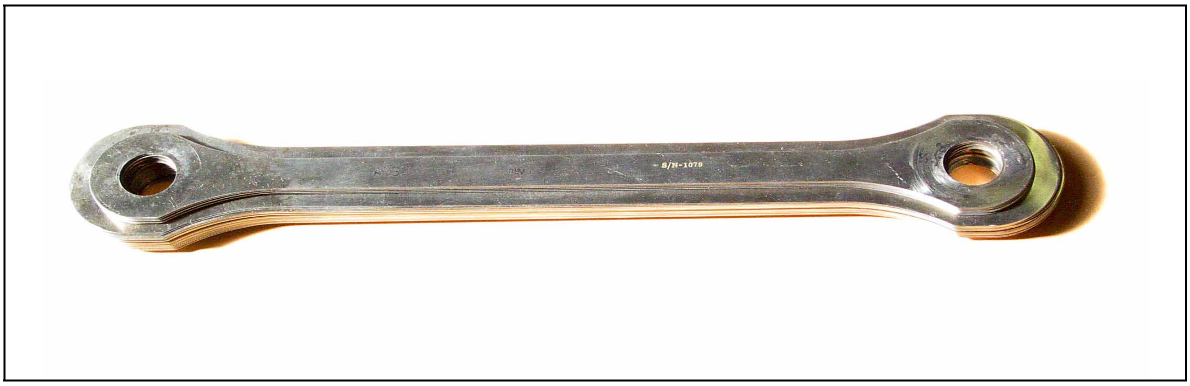


**Figure 4**
**Time-expired TT strap**

1.6.17 The US Army UH-1B Operator's Manual TM 55-1520-219-10, which was part of the CAA flight manual for ZK-HSF, stated that the normal operating range of the main rotor was 294 to 324 RPM, while the maximum main rotor speed during autorotation was 339 RPM. Any main rotor speed in excess of 339 was required to be logged.

1.6.18 The US Army Maintenance Manual TM 55-1520-219-23-1 specified special inspections for main rotor overspeed events. For an overspeed of less than 356 RPM it required:

Inspect:

a. main rotor blades for damage, bond separation, and distortion
b. tail rotor blades…
c. tail rotor blades…

For an overspeed exceeding 356 RPM it required:

a. remove main rotor hub and return to overhaul facility for evaluation
b. examine bolts…
c. inspect main rotor blades…
d. inspect tail rotor blades…
e. replace bolts…
f. tail rotor …
g. parts which may remain in service after thorough inspection…

## 1.7 Meteorological information

1.7.1 A large slow-moving high-pressure area centred east of South Island extended a ridge over most of New Zealand. This gave a period of several days of settled weather in Southland, with generally clear skies, calm or light northerly winds, and areas of early morning fog.

1.7.2 Witnesses to the accident described the weather at the time as dead calm, overcast, and with some patches of fog.

## 1.8 Aids to navigation

1.8.1 Not applicable.

## 1.9 Communication

1.9.1 No radio communications to or from ZK-HSF were recorded, and none were expected or required.

## 1.10 Aerodrome information

1.10.1 Not applicable.

## 1.11 Flight recorders

1.11.1 The helicopter was equipped with a Trimble AgGPS TrimFlight 3 system which could record a log of the aircraft flight path. A study of the data on its memory showed that no data had been recorded on 23 April 2004, indicating that the equipment was not switched on for the accident flight.

## 1.12 Wreckage and impact information

1.12.1 The general area of the accident was a broad, shallow valley oriented south-east/north-west, comprising mostly rolling farmland. The helicopter had been flying on the north side of the valley on an approximately north-westerly track.

1.12.2 The fuselage and tail of ZK-HSF had fallen vertically in a nose-down and inverted attitude, to collide with a scrub-covered slope which separated two farm paddocks. Three major items had fallen some distance from the fuselage. These were the main transmission, which was 172 m south-south-west, the white main rotor blade, which was 352 m east, and the red main rotor blade and main rotor hub, which were 76 m west-north-west of the fuselage. Several minor items of wreckage had fallen nearby and into the small stream at the base of the slope. All significant dynamic items of the helicopter were located in the vicinity, with the exception of the main rotor stabiliser bars. These items may have been thrown some distance in the rotor separation sequence, to be lost in the scrub. The rest of the stabiliser bar assembly was found, broken in a manner consistent with the rotor blade separation.

1.12.3 The tail boom had separated from the fuselage on ground impact, and the tail fin had fractured at its junction with the tail boom. The tail rotor assembly was substantially intact. Damage to the tail rotor control system and drive system components was consistent with the ground impact, and no pre-impact failure was evident. There was no evidence of a main rotor blade strike on the tail boom.

1.12.4 The complete white main rotor blade was found separated from the rotor hub, with the broken stainless steel laminates of the TT strap protruding from the blade grip. Damage to the blade was consistent with its ground impact only.

1.12.5 The complete red main rotor blade remained attached to the rotor hub. The hub included the top piece of the main rotor mast, which had broken from a massive impact from the hub as the rotor pivoted abnormally. The white blade end of the hub yoke had broken laminates from the white TT strap protruding from it. Damage to the red blade was consistent with its ground impact only.

1.12.6 The main transmission was buried in the ground from its impact. It was attached to substantial broken pieces of aircraft structure which normally carried major flight loads. The main rotor swashplate was in place on the mast, with all control linkages broken in a manner consistent with gross overload. The transmission showed no evidence of any malfunction having occurred before it was forcibly separated from its input and output shafts by the break-up sequence.

1.12.7 The engine remained in place in the fuselage, and was subjected to downward crushing forces in the ground impact. Damage to compressor blades was indicative of some rotation at impact, but there was little ingestion of foreign matter through the engine, consistent with the engine not developing significant power, and running down but not completely stopped.

1.12.8 There was no significant evidence from the instrument panel or from any switch or control position in the cockpit.

### 1.13 Medical and pathological information

1.13.1 The post-mortem and toxicological examinations of the pilot did not disclose any abnormalities that might have affected his ability to conduct the flight.

### 1.14 Fire

1.14.1 Fire did not occur.

### 1.15 Survival aspects

1.15.1 The severe ground impact of the helicopter fuselage after a free fall of some 500 feet, and the collapse of the cabin structure made this accident unsurvivable.

1.15.2 The quick actions of the witnesses and the prompt response of emergency services were noteworthy, but unable to affect the outcome of the accident.

### 1.16 Tests and research

1.16.1 Both TT straps were taken to a consultant metallurgist for detailed examination of the material and the fractures, along with a similar TT strap, serial number 1079, which had been removed from another UH-1B helicopter at the end of its service life (1200 hours in service) for comparison. Neither the red nor the white TT strap had any serial number or part number marked on it.

1.16.2 Specimens were taken from laminates from each TT strap, and subjected to tensile testing to establish the mechanical properties of the steel. These tests confirmed that the samples were similar, and complied with the specifications of the part (Mil-S-5059).

1.16.3 Microscopic examination of the laminates from ZK-HSF showed that the steel material contained an appreciable quantity of non-metallic intrusions, both plastic and solid. Qualitative analysis of one such intrusion particle indicated high levels of chromium, manganese, iron and titanium, with a trace of calcium and therefore derived from the steel-making process. The metallurgist's opinion was that the number and length of these intrusions would be excessive if the steel was employed under other stress conditions, but for the almost pure tensile major stress experienced by these parts, the direction of the inclusions presented little opportunity for reduction of mechanical properties in the longitudinal direction.

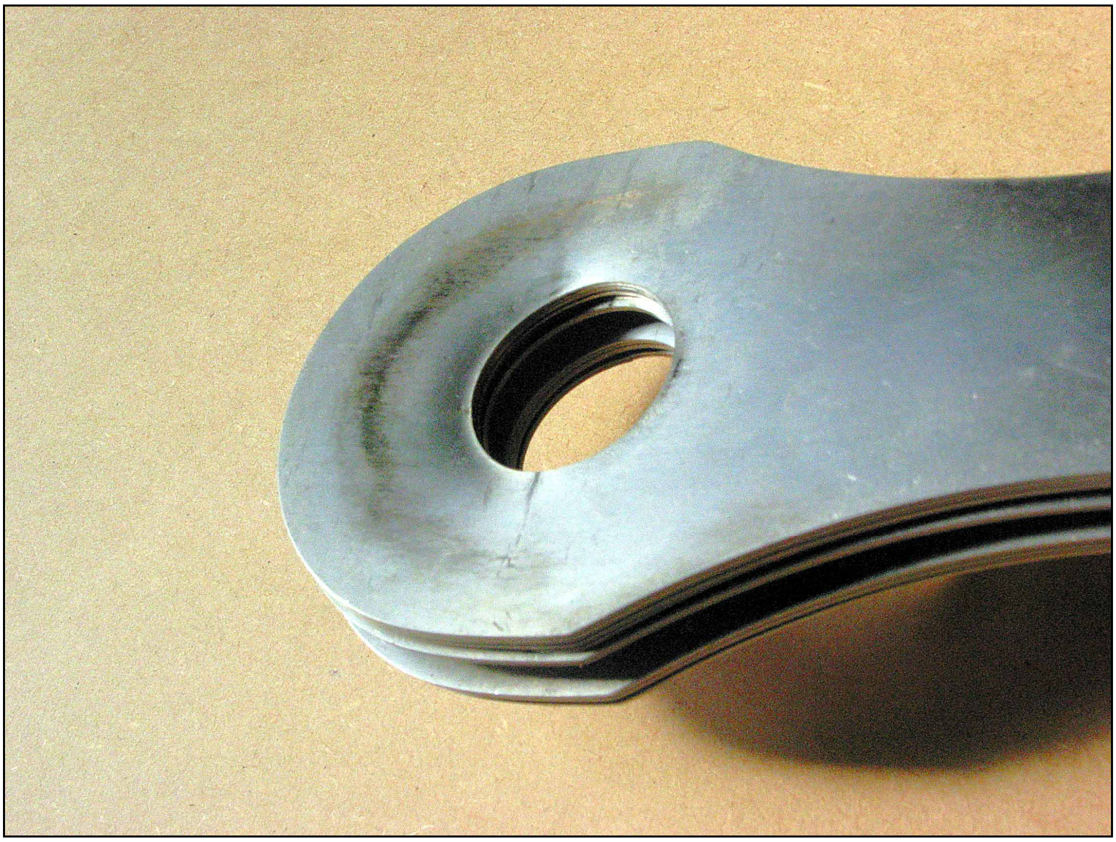


**Figure 5**
**Red TT strap detail, showing buckling and crack**

1.16.4 The fracture surfaces of the laminates from the white (failed) TT strap were all examined by microscope, and selected specimens of fracture surfaces by scanning electron microscope. The majority showed a low-cycle high-load fatigue mechanism initiating at the anchor pin holes and spreading across the strap. A few of the narrow laminates had fractured with no fatigue striations, at approximately 45° in a mid-span position, indicating overload failures. These narrow laminates had stretched by up to 40 mm before failing. All of the laminates showed buckling of varying severity due to overload at the anchor pin holes; those which showed less buckling also showed about 80% of fatigue striations across the fracture surfaces, indicating their failure had occurred before the final overload event.

1.16.5 The red (unfailed) TT strap had 2 laminates which had failed, and several which had visible cracks. The fracture surfaces showed low-cycle high-load fatigue similar to the white strap. All the laminates showed buckling due to overload at the anchor pin holes. While this was less than the most buckled laminates from the white TT strap, it was uniform between laminates.

1.16.6 The anchor pins from both TT straps showed patterns of fretting on the surface sides supporting the tensile loads from the laminations. These patterns were of shallow parallel grooves matching the laminates, and included clusters of corrosion pits. While fretted surfaces can readily initiate fatigue cracking, the subject surfaces of the laminate anchor pin holes were towards the ends of the straps, whereas the fatigue initiation positions observed were at 90°. This indicated that the fatigue initiation was from major tensile loads, and not from fretting.

1.16.7 The laminates from the other comparison (time-expired) TT strap were examined. All laminates were flat, with no evidence of buckling or other distortion. No laminates were cracked. Some discoloration on adjacent surfaces due to slight relative movement was apparent in the anchor pin areas.

1.16.8 The consultant metallurgist concluded:

- There was no evidence of metallurgical defects in either of the TT straps from ZK-HSF.
- Both TT straps had been exposed to very high fluctuating, predominantly tensile loads resulting in low-cycle fatigue cracking of laminates and ultimately the failure of the white assembly.
- Similar damage (low-cycle fatigue cracking) had occurred to the red strap although the prior failure of the other strap prevented further damage.

## 1.17 Additional information

1.17.1 Some members of the pilot's family stated that he had told them that the Chief Pilot of the company had asked him to record less than the actual flight times; they suggested that he was only recording a half to a third of the actual hours flown, and that other pilots in the company had been asked to do the same.

1.17.2 The Chief Pilot stated that with the larger UH-1B helicopter, the company was concerned to minimize any unproductive flying. As a result, the helicopter was usually left at a job site, then ferried on to the next, rather than being flown home each day. With the smaller helicopters, there was a tendency for some pilots to do unnecessary non-revenue flying, which was uneconomic with ZK-HSF.

1.17.3 The fuel uplift records for ZK-HSF between July 2003 and May 2004 were compared with the relevant operational flight time records for ZK-HSF, using consumption rates of 400 litres/hour for flying and 200 litres/hour for ground running (loading). No gross discrepancy was indicated.

1.17.4 The current technical log for the aircraft, where the pilot had entered the daily flight times up to 14 April 2004, did not include the times for his flight check on 10 January 2004, or for the ferry flight from Inglewood to Gore.

1.17.5 Inquiries made to other company pilots did not indicate that under-recording of flight times was normal practice.

1.17.6 The Chief Engineer, who completed the maintenance work on 23 September 1995, recalled that the TT straps were inspected and found serviceable, and were refitted to the main rotor yoke. He was unsurprised that the TT straps carried no serial numbers, because of his previous experience with similar components on various types of older Bell helicopters.

1.17.7 A similar accident occurred in 1997, in the United States, with an ex-military UH-1B helicopter. In that case, the helicopter was hovering a few feet above the ground on a maintenance test flight when a main rotor blade separated following a TT strap failure. The occupants survived, although the helicopter was similarly destroyed. The investigation reported similar fatigue failures to laminates in both TT straps, but did not address the initiation of the fatigue fractures, or observe any evidence of overload. The TT straps involved had been in service for 649 hours.

# 2 Analysis

2.1 The in-flight break-up of ZK-HSF occurred while it was being flown straight and level, at a normal height and airspeed, and in calm weather conditions. The helicopter was being flown at a light weight, with the spray tank empty as was appropriate for a ferry flight. The witness accounts indicate that no manoeuvring occurred before the break-up event; the approach of the helicopter was apparently normal. No unusual noises were reported to attract their attention; just the loud sound of the helicopter in the quiet countryside on a calm morning.

2.2 The separation of the white main rotor blade evidently resulted directly from the failure of the white TT strap – fatigue cracking had progressively spread across more and more laminates, with each laminate failure causing the load to fall on the dwindling remainder until the final 10 or so laminates were overloaded and failed. The TT straps were enclosed within the yoke and blade grip, preventing any opportunity for visual inspection beforehand. Probably no symptoms of an impending failure would have occurred to warn of the event. There was nothing to suggest that the recent maintenance work, or that planned for that day, was associated with the TT strap failure.

2.3 Following the rotor blade separation, the gross out-of-balance forces from the remaining blade would have wrenched the transmission from the airframe structure, while asymmetric lift from the remaining blade would have immediately caused the hub to strike and break the mast. The distances these heavy components were thrown were indicative of the large forces involved. After the transmission detached, the tail rotor would have slowed quickly, with little rotation remaining at ground impact. The engine would probably also have run down because of control disruption.

2.4 The metallurgical study of the TT straps, in particular the red TT strap, showed clear evidence that tensile forces had occurred which were in excess of those developed at normal rotor speeds. The design of the rotor hub ensured that the only loads supported by the TT straps in normal operation are tensile loads resulting from centrifugal forces on the blades. All other lift, drag and manoeuvring forces from the blades are supported by the blade grip and yoke components of the hub. The time-expired comparison TT strap demonstrated that normal operations over the component life do not produce any evidence of overstress, such as the buckling on the red strap from ZK-HSF. The conclusion from this is that the main rotor of ZK-HSF had been operated at a speed exceeding the maximum permitted 339 RPM, and probably exceeding 356 RPM (when removal of the hub assembly is mandated) at some unknown time before the accident.

2.5 The overstress on the TT straps which resulted from this overspeed was clearly beyond the fatigue limit for the material, because of the visible buckling it produced, and probably resulted in the fatigue initiation sites at the anchor pin holes of each laminate. Once the fatigue process had been started by such abnormal loads, cracks would continue to propagate under normal load conditions, probably at each flight cycle when the rotor was brought up to speed before take-off.

2.6 No attempt by metallurgical analysis was made to determine how long before the accident the rotor overspeed event (or events) had occurred, because of the difficulty of determining what operational load cycle might have produced each striation (incremental growth in the fatigue crack), and also of correlating the overall fatigue history across the multiple strap laminates before failure occurred. However the metallurgist classified the fractures as low-cycle fatigue, which infers cycles of hundreds of striations rather than tens of thousands. The best estimate from this is that the overspeed may have occurred within the previous 100 hours flight time, and most probably within the helicopter's operation in New Zealand.

2.7 The UH-1B type of helicopter is not known to be particularly susceptible to rotor overspeed but, as with any helicopter, this can occur. In normal flight the rotor is driven by the engine, which is governed to control the RPM within close limits. In autorotation the rotor is driven by the airflow, and is not governed. While the collective control rigging is adjusted to produce autorotational RPM within the normal range, the helicopter weight, airspeed and manoeuvring by the pilot will cause the RPM to vary, and may require pilot action with the collective control to avoid an overspeed. Turbulence and gusting winds can also produce a rotor overspeed in some circumstances.

2.8 The rotor can be driven to overspeed by the engine if the fuel control malfunctions, or the governor is switched off by the pilot. The governor switch is to enable the pilot to manually control the RPM with the twist grip throttle on the collective lever, in the event of a malfunction. The emergency procedure requires the pilot to first lower the collective, retard the throttle, then move the governor switch to the emergency position, then finally advance the throttle to obtain operating RPM. Overspeed incidents have been reported in military service where a pilot, or engineer ground-running a helicopter, has inadvertently moved the governor switch while the throttle was advanced to its normal detent position. This action can result in a rapid acceleration of engine and rotor unless prompt remedial action is taken.

2.9 No overspeed event involving ZK-HSF had been reported or logged. While the metallurgical evidence of an overspeed having occurred is strong, without any report of such an event it is not possible to reach a conclusion about its circumstances. The problems with the helicopter which occurred the previous week while working at Moa Flat, and the pilot's attempts to diagnose and rectify them, including flying the helicopter with reduced RPM, could have also led to his experimenting with the governor switch in the emergency position, with the attendant risk of overspeed. This possibility, however, is only conjecture without further evidence.

2.10 If the pilot had been aware of an overspeed event, he should have ceased flying the helicopter and reported to the company, to enable appropriate maintenance to be done. The absence of such a report meant that an invisible and latent defect would progress to a catastrophic conclusion. While an overspeed event could have involved another pilot, the pilot involved in the accident had done the majority of the flying in ZK-HSF in New Zealand, so it is likely that he knew that an overspeed had occurred.

2.11 It is possible that the pilot did not appreciate the significance of a rotor overspeed, or perhaps thought that if an occurrence was brief or transient, then no damage would ensue, and reporting it would not be necessary. In fact, an overspeed of any duration was likely to compromise the integrity of structural components such as the TT straps, and set in train an early component failure. While it could not be determined what the pilot knew about the significance of rotor overspeed events, it was considered an essential topic for helicopter pilot education, and a safety recommendation was made to The Director of Civil Aviation to promulgate advice about what action to take should an overspeed occur.

2.12 Many crucial structural components of helicopters, such as the TT straps, have a finite life (flight hours and/or calendar time) specified because engineering design and tests have determined that, given normal operations, they are safe from mechanical failure within that time. As a result, careful maintenance record keeping and scrupulous flight time logging are necessary to ensure that critical components do not exceed their life in service. Component record cards for each part are normally used, along with maintenance log books, to keep track of remaining life and to plan for component replacement.

2.13 Two items of concern arose with ZK-HSF; these were:

- the absence of identification markings on the TT straps and on the appropriate record card, and
- the suggestion that the pilot had been under-recording flight times.

2.14 The US army component record card for the main rotor hub, dating from 1989, clearly showed the TT straps identified only as "red" and "white", designations commonly used in maintenance to refer to individual blades and their associated components. The absence of serial number identification on the records meant that these TT straps could never be uniquely identified, and hence no times in service could properly refer to them. These records plainly showing this lack of identification had subsequently been in the hands of numerous parties, who each had a duty of care, and who should have been expected to note the discrepancy and respond to it. These parties included:

- the US maintenance organisation which refurbished the helicopter in 1994
- the FAA, which issued the restricted Airworthiness Certificate and the Export Certificate of Airworthiness in 1994
- the Operator, or its agent, who assayed the helicopter before its purchase and import to New Zealand
- the Operator's Chief Engineer who reassembled the helicopter in New Zealand, and subsequently maintained it
- the CAA, which issued the New Zealand Airworthiness Certificate in the restricted category.

2.15 The presence of components without the maker's serial numbers could give rise to suspicion that they were bogus parts. In this case there was no evidence either way, and the material of the TT straps was consistent with the specifications. The absence of any attempt to record a serial number, rather than a counterfeit number, may indicate that they were genuine parts which had lost their identification.

2.16 While it was surprising that all these parties who were expected to be knowledgeable and responsible should overlook or miss this documented inadequacy, the fact remains that it occurred. Such a widespread shortcoming indicates that some remedial education is necessary, and that it should include Administrator of the United States Federal Aviation Administration and the Director of Civil Aviation airworthiness personnel as well as industry licensed maintenance engineers. A safety recommendation to this effect was made to the Administrator of the United States Federal Aviation Administration and to the Director of Civil Aviation.

2.17 The main rotor hub had not been disassembled for maintenance since 1995, a period of 10 years. While calendar-period-based maintenance was not required for the hub or its included components such as the TT straps, it was unlikely that such a long period, resulting from low utilisation of the helicopter, had been anticipated when the maintenance schedule was created. There was no evidence that long-term deterioration effects, such as corrosion, were a factor in this accident, but the inaccessibility for inspection over a long period of such critical components as the TT straps was of concern.

2.18 Any under-recording of flight times had the potential to cause components to exceed their specified finite lives without this being apparent from maintenance records, which is unsafe. The suggestion that this might have occurred was not substantiated because the only available check, by comparing fuel uplift records with logged flight times did not show gross discrepancy. The pilot had not made entries in his pilot logbook for the last year, so that was not available as a check. It was apparent, however that he had not entered some non-revenue flights on the technical log, such as the ferry flight from Inglewood to Gore.

2.19 While some under-recording of flight times was exemplified by these absent entries, it probably was not sufficient to have caused the TT straps to exceed their life during the period since ZK-HSF was deployed in the agricultural spray role. This was because since then about 385 hours had been logged, leaving the TT straps with 384 hours life remaining. Under-recording by as much as 100% was not consistent with the fuel record evidence.

2.20 This analysis of component identification and flight time recording was because safety issues were involved which could have led to this accident. The conclusion that they probably did not do so was because of the evidence that the fatigue fractures in the TT straps had originated from main rotor overspeeding.

2.21 Before the accident the pilot was reported to have attempted sundry items of defect rectification on the helicopter which were beyond the scope of pilot maintenance, or daily inspection, lubrication and cleaning. While there is nothing to suggest that they were a factor in the accident, the operator should be aware that the pilot had seen fit to take such action without reference to the operator, and that this could be contrary to safety, or operational efficiency. Safety recommendations were made to the operator that he ensures that other company pilots properly record flight times in aircraft documents and their pilot logbooks, and that they do not attempt tasks of aircraft maintenance that are beyond the scope of approved pilot maintenance.

# 3 Findings

Findings are listed in order of development and not in order of priority.

3.1 The helicopter was being flown normally on a ferry flight for maintenance when separation of a main rotor blade occurred, causing break-up of the helicopter.

3.2 The rotor blade separated because of fatigue failure of the TT strap which retained the blade in the rotor hub.

3.3 The fatigue cracking in the TT straps was initiated by a main rotor overspeed event which occurred at an unknown time before the accident.

3.4 The rotor overspeed event had probably occurred while the pilot was operating the helicopter.

3.5 The rotor overspeed event had not been reported by the pilot, or by any other pilot, with the result that no maintenance action was taken to prevent the subsequent failure.

3.6 The TT straps did not carry proper identification marking, and this was recorded on the component record cards for all to see.

3.7 Numerous parties who should have noted and responded to the TT strap identification deficiency did not do so.

3.8 The TT strap identification deficiency probably was not a factor in the accident.

3.9 Some under-recording of flight times had occurred, but probably was not a factor in the accident.

3.10 The pilot’s attempts at defect rectification were beyond the scope of pilot maintenance, but probably were not factors in the accident.

# 4 Safety actions

4.1 On 26 May 2004 CAA issued Airworthiness Directive (AD) DCA/HELI/4 titled "Ex-military helicopters – finite life recording". It stated:

> To prevent finite life components inadvertently exceeding their safe lives accomplish the following:
>
> Examine aircraft records and verify that all finite-life limited components, as listed in the applicable instructions for continued airworthiness, maintenance manual or schedule of retirement lives, are being tracked.
> Ensure all finite life components have a serial number recorded in the aircraft records. Any finite life components which are not identified by serial number must be removed from service.

4.2 On 1 June 2004 CAA cancelled the above AD, because it did not take into account life-limited components that are not provided with a serial number by the manufacturer (such as some rotating bolts), and issued AD DCA/UH1/14 titled "Tension–torsion straps – tracking by S/N and retirement life". It stated:

> To prevent failure of a tension-torsion (TT) strap, loss of a main rotor blade, and subsequent loss of the helicopter, accomplish the following:
>
> Record the S/N of each TT strap (including those held as spares) and track the history of each since first installation from new. Remove from service before further flight any TT strap that has exceeded its retirement life.

# 5 Safety Recommendations

Safety recommendations are listed in order of development and not in order of priority.

5.1 On 21 November 2005 the Commission recommended to the Director of Civil Aviation that he:

5.1.1 develop educational material to ensure that helicopter pilots understand the significance of a rotor overspeed event, and what action should be taken (084/05).

5.1.2 develop educational material for CAA airworthiness personnel and licensed maintenance engineers to raise awareness of the need for them to recognise and respond to documented inadequate identification of critical lifed components when checking aircraft maintenance documents (085/05).

5.2 On 17 October 2005 the Director of Civil Aviation Authority responded to the preliminary safety recommendation, which was subsequently adopted unchanged as the Commission's final safety recommendation as follows:

> The Director will accept this recommendation and will publish an article in the March 2006 issue of Vector magazine concerning the significance of a helicopter rotor over speed event and what action should be taken. (084/05)
>
> The Director will accept this recommendation and will publish an article in the March 2006 issue of Vector magazine concerning the significance of licensed maintenance engineer's identification of critical lifted components when checking aircraft maintenance documents. The CAA is currently reviewing its procedures for the issue of an Airworthiness Certificate and this matter will be addressed as part of the review. (085/05)

5.3 On 26 September 2005 the Commission recommended to the Administrator of the United States Federal Aviation Administration that they:

5.3.1 develop educational material for FAA airworthiness personnel to raise awareness of the need for them to recognise and respond to documented inadequate identification of critical lifed components when checking aircraft maintenance documents (087/05).

5.4 On 8 November 2005 the Administrator of United States Federal Aviation Administration replied in part:

> The Office of Accident Investigation was tasked with disseminating the draft report for comment our Aircraft Certification Office and our Flight Standards Office. Both offices have reviewed this draft report and have no comment. (087/05

5.5 On 21 November 2005 the Commission recommended to the Chief Executive of Helicopter Services that he:

5.5.1 ensures that other company pilots properly record flight times in aircraft documents and their pilot logbooks. (088/05).

5.5.2 ensures that company pilots do not attempt tasks of aircraft maintenance that are beyond the scope of approved pilot maintenance. (089/05).

5.6 On 18 November 2005 the Chief Executive of Helicopter Services responded to the preliminary safety recommendation, which was subsequently adopted unchanged as the Commission's final safety recommendation as follows:

> company/contracted pilots have been reminded of their responsibility to properly record flight times in aircraft documents and in their pilot logbooks as is specified in their pilot contracts. (088/05)

> company/contracted pilots have been reminded not to attempt any aircraft maintenance tasks beyond the scope of approved pilot maintenance and that any defects affecting aircraft airworthiness are to be reported to the company chief engineer. (089/05)

Approved on 17 November 2005 for publication

Hon W P Jeffries
**Chief Commissioner**

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