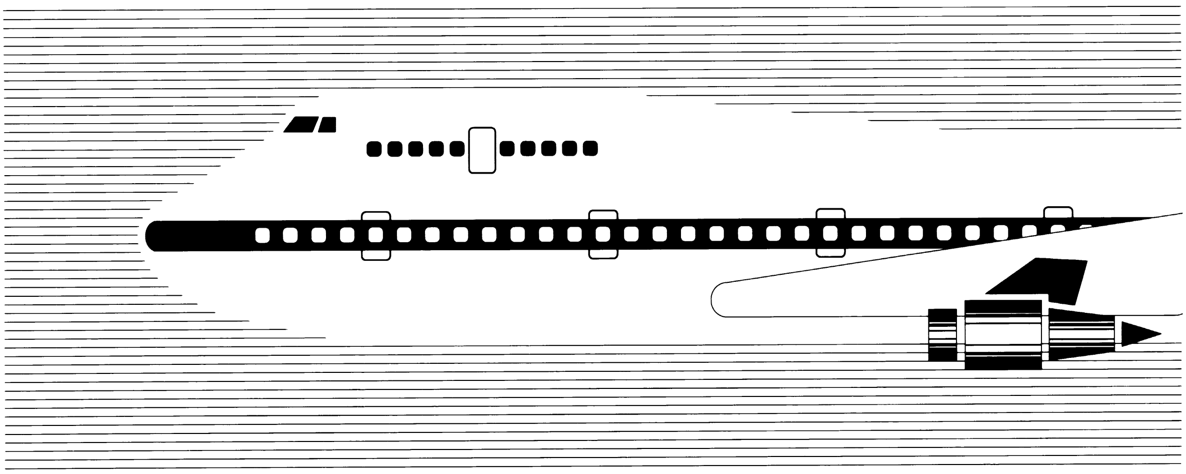

AVIATION OCCURRENCE REPORT

01-005R **Bell UH-1H Iroquois ZK-HJH, in-flight break-up, Taumarunui** **4 June 2001**

TRANSPORT ACCIDENT INVESTIGATION COMMISSION
NEW ZEALAND

Report 01-005R
(Resumed investigation)

Bell (Western International) UH-1H Iroquois

ZK-HJH

in-flight break-up

near Taumarunui

4 June 2001

Abstract

On Monday 4 June 2001 at about 1715, ZK-HJH, a Bell UH-1H Iroquois helicopter, was approaching Taumarunui when it was seen to enter a turn and fall to the ground, killing the 3 occupants. The helicopter was observed to break up before it hit the ground.

This report summarises the results of a resumed investigation of the event and supersedes the original report (Report 01-005).

The investigation was resumed because there was some new and material evidence from 2 other UH-1 helicopter accidents that could have affected the conclusions in the original report. The findings and re-analysis of the accident sequence and its causal factors are based primarily upon evidence found during the resumed investigation. Only the new findings and how they affected the original conclusions are discussed. Many of the original findings remain valid, and text from the original report that is valid is included in this report.

After considerable component and metallurgical testing and examination of all the available evidence, the resumed investigation could not support the original theory that the accident sequence was probably caused by the tail rotor crosshead coming loose, because of incorrect maintenance.

The resumed investigation found that a bent tail rotor blade pitch link and its subsequent fatigue failure during the accident flight brought about a loss of control and in-flight break-up of the helicopter. The link had been bent earlier at some point during the accident flight, which allowed it to crack and eventually fail from bending fatigue. The reason the link was bent could not be determined.

Safety issues concerning the operation and airworthiness of ex-military aircraft were identified.
Safety actions by the Civil Aviation Authority and safety recommendations made to the Director of Civil Aviation address these issues.

Investigation Chronology

The following is a brief chronological overview of the relevant events that led the Commission to resume this investigation.

January 2001

> The Civil Aviation Authority investigates a UH-1 helicopter accident involving ZK-HVY. The accident circumstances were different from that of ZK-HJH.

June 2001

> The Commission investigates the ZK-HJH accident, also a UH-1 helicopter.

December 2001

> The Commission approves its accident report 01-005 involving ZK-HJH for publication.

February 2002

> The Commission releases accident report 01-005 involving ZK-HJH.
>
> The Civil Aviation Authority requests the ZK-HJH wreckage and carries out its own investigation into some aspects of the accident.

June 2002

> A Coroner's inquest into the deaths of the 3 occupants of ZK-HJH is commenced.
>
> During the subsequent inquest hearings, various parties present alternative theories as to the cause of the accident. Some of the parties also raise other issues that criticise the Commission's investigation and its report and some of the report findings. The Civil Aviation Authority, having examined the Commission's report and various parts of the ZK-HJH wreckage, presents evidence during the Coroner's hearing. The Commission's investigator-in-charge is also summoned to give evidence, notwithstanding the constraints of the Commission's legislation.

September 2002

> The Commission and the Civil Aviation Authority have metallurgical testing carried out on a main rotor blade from ZK-HJH.

January 2003

> The Civil Aviation Authority investigates another UH-1 accident, this time involving ZK-IUE. The accident circumstances were different from both the ZK-HVY and ZK-HJH accidents.
>
> The Civil Aviation Authority invites the Commission to examine the tail rotor pitch links and crosshead from ZK-IUE, because the Authority discovered some evidence that could affect the Commission's conclusions on the cause of the ZK-HJH accident.

February 2003

> The Commission meets with the Civil Aviation Authority, which presents the Commission with some new evidence from the tail rotor pitch links and crossheads of both the ZK-HVY and ZK-IUE accidents, which could affect the Commission's conclusions on the cause of the ZK-HJH accident.
>
> The Commission decides to resume the ZK-HJH investigation.
>
> The Civil Aviation Authority attends the disassembly of the main rotor transmission from ZK-HJH conducted by some interested parties, and witnesses a visual inspection of its swash plate. The Authority advises the Commission of the results.

March 2003

The Commission has metallurgical testing done on some tail rotor components from ZK-HJH, including the crosshead bolt, and receives a preliminary report.

April 2003

The Commission requests all the ZK-HJH wreckage from the Civil Aviation Authority.

May 2003

The results of metallurgical testing that some interested parties have had done on the swash plate trunnion bearing housing are released and made available to the Commission.

The Coroner asks that the Civil Aviation Authority maintain custody of the ZK-HJH wreckage until after the inquest.

The Commission decides to postpone its resumed investigation and to not take possession of the wreckage until after the Coroner's hearing is complete, so that it can review the Coroner's findings and the evidence presented during the inquest.

June 2003

The Commission advises the Civil Aviation Authority that it can retain possession of the wreckage until after the inquest, and that it should then return the wreckage to the Commission.

August 2003

The Commission receives the final metallurgical report about the examination of some tail rotor components, including the crosshead bolt.

March 2004

The Coroner releases his findings. He is unable to make a finding as to the cause of the ZK-HJH accident and recommends that, "CAA [Civil Aviation Authority] and/or TAIC [Commission] should reinvestigate this incident as far as resources permit".

The Commission continues with its resumed investigation, after having reviewed the Coroner's findings and evidence presented during the inquest.

June 2004

The Commission appoints an independent forensic engineer, who is trained in aircraft accident investigation, to assist with the resumed investigation.

August 2004

The Commission appoints a new investigator-in-charge to head the resumed investigation, after some of the interested parties object to the original investigator-in-charge heading the resumed investigation.

The Commission decides to involve other overseas agencies in the resumed investigation.

October 2004

The Commission takes custody of all the available wreckage.

The new investigator-in-charge assembles an investigation team, which includes an independent aircraft accident investigator, who is also an engineer and materials failure analyst, from the Canadian Forces Quality Engineering Test Establishment. An aircraft accident investigator, who is a licensed aircraft maintenance engineer and had previously maintained the helicopter type, is seconded from the Civil Aviation Authority. The forensic engineer that the Commission had earlier appointed to assist with the resumed investigation is included in the team.

Bell (Western
International)
UH-1H Iroquois
ZK-HJH

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Abbreviations

AD	airworthiness directive
amsl	above mean sea level
ARA	Annual Review of Airworthiness
CAA	Civil Aviation Authority
CAR	Civil Aviation Rule(s)
EGT	exhaust gas temperature
FAA	Federal Aviation Administration
LAME	licensed aircraft maintenance engineer
m	metre(s)
mm	millimetre(s)
RPM	revolutions per minute
UTC	coordinated universal time

Data Summary

Aircraft type, serial number and registration:	Bell (Western International) UH-1H Iroquois, 4530 (64-13823), ZK-HJH
Type of engine:	Lycoming T53-L-13B
Year of manufacture:	1965
Date and time:	4 June 2001, 1715[1]
Location:	3 nautical miles east of Taumarunui latitude: 38° 51.57′ south longitude: 175° 21′ east
Operator:	Wanganui Aero Work Limited
Type of flight:	positioning for agricultural operations (bait spreading)
Persons on board:	pilot: 1 passengers: 2
Injuries:	3 fatal
Nature of damage:	helicopter destroyed
Pilot's licence:	Commercial Pilot Licence (Helicopter)
Pilot's age:	51
Pilot's flying experience:	13 425 hours total 610 hours on type
Investigator-in-charge:	K A Mathews

Acknowledgements

The Commission acknowledges the assistance provided by the following organisations:
Canadian Forces Quality Engineering Test Establishment; Royal New Zealand Air Force; New Zealand Defence Technology Agency; New Zealand Civil Aviation Authority; Materials Performance Technologies; Prosolve Limited; University of Auckland; Les Bolton and Associates Limited; Heli-fix Limited; Bell Helicopters Textron Limited; United States National Transportation Safety Board; Canadian Transportation Safety Board; Australian Transport Safety Bureau.

[1] All times in this report are New Zealand Standard Time (UTC + 12) and are expressed in the 24-hour mode.

1 Factual Information

1.1 History of the flight

1.1.1 On Monday 4 June 2001 at about 1550, ZK-HJH, a Bell (Western International[2]) UH-1H Iroquois helicopter, lifted off from its base near Pukekohe bound for Taumarunui. On board were the pilot, loader driver and operations coordinator. The helicopter was to position at the operator's airstrip near Taumarunui for bait spreading operations commencing the next day.

1.1.2 At about 1715 some residents of Echolands Road east of Taumarunui saw ZK-HJH approaching from the north-east at a moderate height and flying in the direction of the airstrip. Two witnesses 4 km to the south saw the helicopter over a ridgeline as it approached the area of Echolands Road. None of the witnesses saw anything unusual as the helicopter approached and most of the witnesses reported that the helicopter sounded normal. The helicopter then entered a turn. While several witnesses thought the turn was to the helicopter's left, the majority believed it turned to the right.

1.1.3 The witnesses were able to identify the shape and sound of the helicopter as that of an Iroquois. One witness initially thought the helicopter belonged to another pilot who also had an Iroquois and with whom the witness had worked for several years. He thought it might have been that pilot coming to visit him. The witness then observed what he believed to be several flicks of the helicopter's tail to the left and right before it entered a turn to the right. The witness believed that the pilot had been signalling to him that he intended to land, as the flicks were sharper and more pronounced than usual.

1.1.4 Part-way through the turn, the angle of bank of the helicopter increased and it started to fall towards the ground. Witnesses saw pieces of the helicopter separate as it fell. The helicopter struck the ground about 300 m north of Echolands Road and immediately caught fire.

1.1.5 The first emergency call was received at the Police communications centre at 1719 and the first emergency service person arrived at the scene at 1725. Several local residents had also rushed immediately to the scene but no assistance could be given to the 3 occupants, who had died instantly.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	1	2	-
Serious	-	-	-
Minor/nil	-	-	-

1.3 Damage to aircraft

1.3.1 The helicopter was destroyed.

1.4 Other damage

1.4.1 Nil.

[2] Later changed to Garlick Helicopters, which took over the type certificate.

1.5 Personnel information

1.5.1	Pilot:	male, aged 51 years
	Licence: Ratings:	Commercial Pilot Licence (Helicopter and Aeroplane) agricultural, chemical, D category instructor (helicopter)
	Helicopter type ratings:	Bell 204/205, 206 and 214, Hiller FH1100 and UH12, Hughes 269 and 369HS, Aerospatiale SA-315B and AS-350
	Medical certificate:	Class 1, valid to 5 September 2001
	Last annual pilot competence and agricultural check:	14 November 2000
	Last biennial flight review:	14 November 2000
	Flying experience:	13 425 hours total 12 156 hours helicopter (610 hours on type)
	Duty time:	about 2 hours
	Rest before duty:	more than 18 hours

1.5.2 The pilot had worked for the operator for about 3 years, flying ZK-HJH for that time. He had flown about 54 hours in the previous 3 months and 6.3 hours in the previous 14 days. The pilot would normally fly the helicopter from the left-hand seat[3].

1.5.3 The pilot was known to be cautious in his operation of ZK-HJH. Several people had seen the pilot complete thorough pre-flight inspections of the helicopter. He would use a stepladder, carried on board ZK-HJH, to access difficult places, for example when greasing the tail rotor.

1.5.4 The loader driver and operations coordinator had both worked for the operator and flown with the pilot for several years. During positioning flights it was normal for the loader driver to sit in the front right-hand seat and the coordinator to sit in the centre jump seat behind the 2 front seats.

1.6 Aircraft information

1.6.1 The Bell Helicopter Company manufactured ZK-HJH in the United States in 1965. The helicopter, a UH-1H Iroquois serial number 4530, was produced for the United States Army and allocated the military serial number of 64-13823. The civil equivalent of the UH-1H Iroquois was the Bell 205.

1.6.2 The UH-1H was a 2-bladed, single-engined helicopter designed as a utility aircraft for the carriage of personnel and freight, with underslung load capability. The helicopter was fitted with a 2-bladed tail rotor, which was positioned on the left side of the fin and mounted to a gearbox on top of the fin. ZK-HJH was fitted with a Lycoming T53-L-13B turboshaft engine, serial number LE 14273 B.

[3] ZK-HJH was fitted with a bubble window in the left-hand pilot's door to facilitate operations.

1.6.3 The United States Army sold the helicopter in late 1995, after which Western International Aviation Incorporated (Western International) modified it in accordance with type certificate number H15NM. The United States Federal Aviation Administration (FAA) gave the helicopter a restricted civil certification and brought it onto the United States civil register in January 1996 as N8230H. As part of the airworthiness and type certificate requirements, the FAA directed the helicopter to comply with applicable FAA airworthiness directives (ADs) produced for the Bell 204/205 helicopter.

1.6.4 In March 1996 the helicopter was imported into New Zealand, registered as ZK-HJH and issued with a non-terminating Airworthiness Certificate in the restricted category for use in private and aerial work only. The New Zealand Civil Aviation Authority (CAA) approved maintenance programme for the helicopter was that it continue to be maintained according to the United States Army maintenance regime and applicable ADs, in accordance with its type certificate.

1.6.5 The military maintenance standard included a Preventive Maintenance Daily Inspection of the helicopter, which approved military aircrew members could perform under certain conditions. The daily inspection was a visual examination that included some lubrication, and was more detailed than, but similar to, a pilot's thorough pre-flight inspection. A number of items included in the daily inspection were of rescue equipment or for military application only, and were not relevant to civilian helicopters such as ZK-HJH. The daily inspection and the pilot's pre-flight inspection each called for a thorough visual check of all the visible critical components, such as the tail rotor and main rotor assemblies. Civil Aviation Rule (CAR) 43.51 gave provision for pilots to perform certain limited maintenance, and the operator said he understood that pilots satisfied the need for a daily inspection when they carried out their normal pre-flight inspections.

1.6.6 The pilot had not been specifically approved by the CAA and issued with a certificate to do the daily inspections, so an authorised person or qualified maintenance engineer should have carried out the inspections to satisfy the military standard. However, around the time ZK-HJH was operated there was reportedly some general misunderstanding about the daily inspection, and other operators of restricted category helicopters who maintained their helicopters to the military standard had also carried out daily inspections in a similar manner to the operator.

1.6.7 Following the Commission's original investigation into the accident, the CAA reviewed the operation and maintenance of restricted category helicopters, and found that some were not being maintained to CAA-approved maintenance programmes. The Authority ensured that all operators of such helicopters maintained them as required by CAR Part 91.621 (Maintenance Programmes) in accordance with a CAA-approved maintenance programme. The daily inspection was not a requisite for a programme to be approved. For those operators who opted to follow the military standard, the inspection was included within the programme. The CAA advised that although there was provision before the accident for alternative programmes to have been approved, the various operators had opted only to follow the military standard up to that time.

1.6.8 The operator's engineer and others reported that the pilot's pre-flight inspections were thorough, and that he had regularly lubricated the helicopter components, such as the tail rotor, which the daily inspection included.

1.6.9 ZK-HJH was used in a variety of roles including selective logging, spraying and heavy lift. The helicopter was initially based at Ardmore Aerodrome and generally operated around the central North Island. Part-way through 2000 the operation was moved to a base near Pukekohe and a converted packing shed was used as a hangar. The shed was lockable and fitted with a security system.

1.6.10 ZK-HJH was occasionally used in the spreading of poison, attracting criticism from some quarters. While there were no reports of deliberate damage to ZK-HJH, some tooling was reported stolen from the shed in about March 2001. The theft occurred while the shed was open and unsupervised. There was no report of unauthorised access to the shed while it was locked.

1.6.11 At the time of the accident ZK-HJH had accrued some 12 077 hours since manufacture.

1.6.12 Since 1996 ZK-HJH had been maintained by a variety of licensed aircraft maintenance engineers (LAMEs). Scheduled maintenance was completed at the operator's main base at Wanganui, while short-notice or unscheduled maintenance was often done at Ardmore and latterly at the helicopter's Pukekohe base.

1.6.13 In about October 2000 the operator engaged a helicopter maintenance company (the maintainer) to maintain ZK-HJH. The maintainer consisted of a LAME and a tradesman. The maintainer was familiar with the Bell UH-1 model of helicopter as it also maintained another helicopter similar to ZK-HJH. The LAME in particular was familiar with the UH-1H Iroquois. He became a LAME in 1991, was rated on the helicopter type and had maintained them for several years in New Zealand and overseas.

1.6.14 On 12 March 2001 ZK-HJH was flown to Wanganui for a Phase 1[4] inspection and Annual Review of Airworthiness (ARA). Records indicate the inspection was completed over about 15 days. The tail rotor blades grip bearings were replaced during this period, and a tail rotor balance including tracking was carried out on 27 March 2001.

1.6.15 The CAA had introduced the requirement for an ARA from 1 April 1998. The maintenance records showed that the helicopter had been subject to 3 consecutive reviews before the accident, with the last ARA being completed by the LAME who had an inspection authorisation to carry out such reviews.

1.6.16 From 28 March 2001 to the time of the accident on 4 June 2001, ZK-HJH flew 50 hours.

1.6.17 A review of the maintenance records for ZK-HJH showed that the applicable CAA ADs for the helicopter were recorded as having been complied with. In accordance with the helicopter type certificate, the FAA ADs were recorded as having been reviewed for applicability.

1.7 Meteorological information

1.7.1 The weather on the day of the accident was described by witnesses as clear and calm. Weather observations at Hamilton Aerodrome, located east of the Pukekohe to Taumarunui track, recorded the surface wind as variable at 5 knots at about the time of the accident. The higher-level winds were reported as being light and variable.

1.7.2 Witnesses to the accident reported the weather in the Taumarunui area to be calm with no cloud. The light was fading but visibility was unrestricted.

1.7.3 The sun at the accident site at 1715 on 4 June 2001 was calculated to be 2° below the horizon and on a bearing of 277° magnetic.

1.8 Communications

1.8.1 There were no reports of any radio transmissions from ZK-HJH on the day of the accident.

[4] According to the maintenance manual, TM 55-1520-210-PM, aircraft servicing was based on a 900-hour cycle with a phased servicing every 150 hours.

1.9 Wreckage and impact information

1.9.1 The accident site was on the northern side of Echolands Valley, on hilly farm land about 300 m north of Echolands Road and about 5 km east of Taumarunui. The elevation of the accident site was about 800 feet above mean sea level (amsl).

1.9.2 The wreckage of ZK-HJH that was found was spread over a distance of about 450 m along a slight curve to the right. The bearing from the first item of wreckage located to the main impact point was 099° magnetic (see Figure 1).

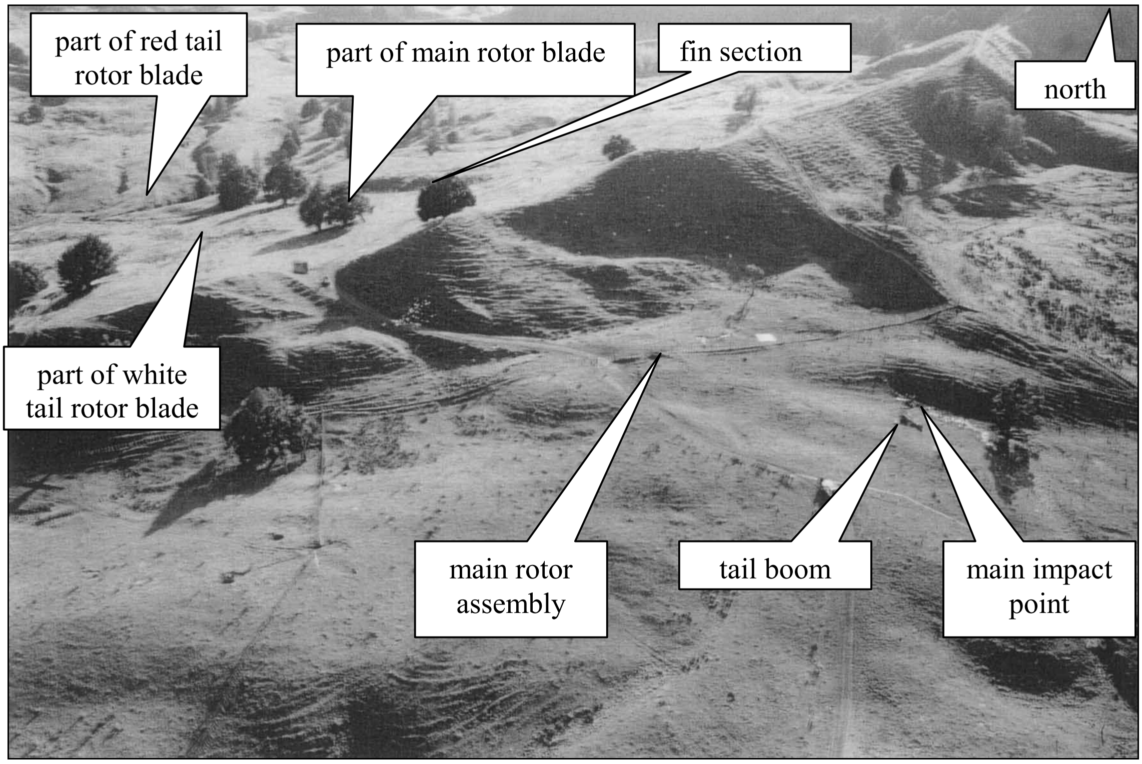

Figure 1
Accident site

1.9.3 The known wreckage trail started with several pieces of helicopter panelling, identified as coming from the area of the tail fin. At the main impact point at 450 m[5] the fuselage had struck the ground in a steep nose-down attitude on a northerly heading. Two of the occupants remained in the fuselage while the third had been thrown clear before impact.

1.9.4 The engine and transmission, including most of the mast, were located with the fuselage but had broken from their mounts. Some foreign objects had been partially ingested into the engine, which was an indication that the engine was operating at least during the initial part of the accident sequence. The tail boom had separated from the fuselage on or shortly before impact and lay next to the remains of the partially burnt wreckage. The fin and tail rotor had separated from the tail boom before impact. Other pieces of debris were scattered around the fuselage.

[5] Distances quoted are measured from the first items found in the wreckage trail.

1.9.5 The main rotor assembly and top section of the mast lay at about 405 m. Indentations on the mast showed that the main rotor hub had struck the mast twice before separating. A main rotor blade, identified as the white blade[6], had broken into 2 pieces about a third of the distance out from the hub. The outer section was located at about 220 m embedded into the ground on its tip end. The area behind the leading-edge spar had compressed about one metre. The compression or crushing was in a span-wise inboard direction, and was consistent with striking the ground on its tip. There was little other damage to this blade section.

1.9.6 The second main rotor blade, the red blade, had sustained significantly more damage, including an area of heavy chordwise scrapes and gouges – mainly along the leading edge and lower surface of the blade. The damage was concentrated around the mid-span of the blade and ran from the front to the rear of the blade. The blade had broken into several pieces, with an inboard section remaining attached to the main rotor hub. The outboard section of the blade lay nearby. An estimated 2-m length of the blade's honeycomb section[7] was located at about 225 m. This section was from about the middle of the blade. The damage, including paint marks and other evidence, was consistent with the red blade entering the cabin area on the right-hand side of the fuselage, the 2-m section breaking off after the blade entered the cabin. All breaks in the blade were examined and determined to be from gross overload. There was no evidence of fatigue.

1.9.7 Located between the main rotor assembly at 405 m and 170 m was a range of items including the right-hand cargo door, windows, quarter door[8], engine cowling and lead ballast weights normally located in the nose of the helicopter. Several of the helicopter's instruments were found between 360 m and 160 m. Three instruments had trapped readings: an altimeter read 2320 feet, a dual tachometer[9] read 6600 revolutions per minute (RPM) and the needle for the exhaust gas temperature (EGT) gauge was able to move between 510° and 740° Celsius[10].

1.9.8 Numerous pieces of the engine-to-transmission drive shaft were found between about 250 m and the impact point. The locations of the drive shaft pieces were an indication that either the engine or the transmission, or both, moved from their mounts before the fuselage struck the ground.

1.9.9 The fin, with 90° gearbox and part of the tail rotor assembly attached, was found at about 260 m[11]. The fin had torn away from the boom towards the right side of the helicopter. There were crush marks along the leading edge of the fin. The 2 pitch links had broken at the jam nuts with the ball-end fittings and jam nut remaining attached to the blade grip pitch horns on the hub assembly. The stack, including the slider and retainer plate, was still attached to the hub assembly and held in place by the split (cotter) pinned nut (item 11 Figure 2).

1.9.10 Inspection of the tail rotor driveshaft in the fin showed that the pitch change control cable and chain had been caught and wrapped around the shaft numerous times, which was consistent with the tail rotor drive continuing to rotate after being struck along its leading edge before the fin separated.

1.9.11 Missing from the tail rotor assembly were the remaining parts (the outboard sections of both pitch links and the crosshead) of the pitch links, the outer sections of the 2 tail rotor blades, broken outboard of the grip doublers, and the crosshead.

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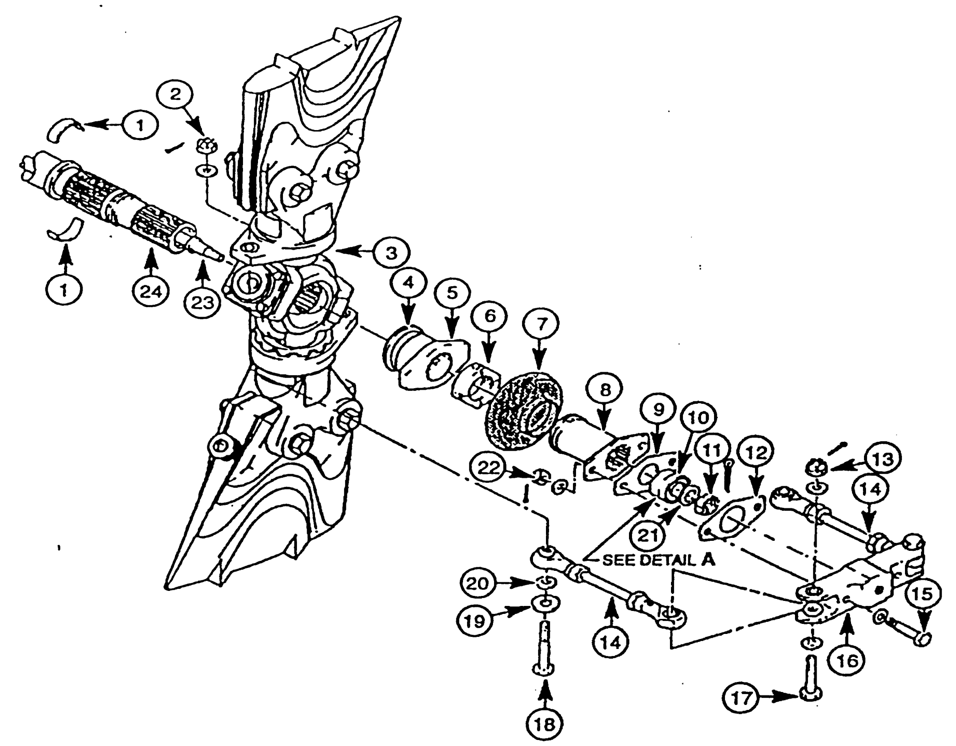
[6] Rotor blades and their associated linkages were colour-coded red or white for identification.
[7] The main rotor blade was constructed of a leading-edge spar with honeycomb material behind it.
[8] A small hinged panel forward of the main cargo door.
[9] The dual tachometer indicates engine output RPM and rotor RPM. During normal operations the engine output reading would be 6600 RPM. On ZK-HJH the needle for rotor RPM was missing following the accident.
[10] During cruise flight the expected EGT reading would be between 470° and 520° Celsius.
[11] For ZK-HJH the tail rotor assembly was mounted on the left-hand side of the fin.



1	Split Cone Set	9	Retainer Plate	17	Bolt
2	Nut	10	Bearing Set	18	Bolt
3	Hub and Blade Assembly	11	Nut	19	Safety Washer
4	Shim	12	Shim	20	Spacer
5	Static Stop	13	Nut	21	Washer
6	Nut, Hub Retaining	14	Pitch Link	22	Nut
7	Boot	15	Bolt	23	Pitch Change Rod
8	Slider	16	Crosshead	24	Gearbox Shaft

Figure 2
Bell UH-1H Iroquois tail rotor assembly

1.9.12 The 2 outer halves of the tail rotor blades were located at about 10 m and 195 m. The tail rotor blade at 10 m, identified as the red tail rotor blade, was missing the tip block and had suffered significant leading-edge damage. A small section of the red tail rotor blade's leading edge was found at the start of the wreckage trail. The white tail rotor blade, found at 195 m, had sustained mainly leading-edge indentations and had transfer of blue paint to its surface. The white tail rotor blade also had a bolt and washer embedded in its inboard side[12].

1.9.13 The damage to the red tail rotor blade and the fin was typical of the blade having flexed inwards and struck the fin before separating. The nature of the break in the white tail rotor blade was consistent with the blade having flexed outwards and away from the fin before separating.

1.9.14 The crosshead and the outboard segments of its 2 pitch links (see Figures 2 and 6) could not be found.

1.10 Medical and pathological information

1.10.1 Post-mortem examination of the occupants revealed they sustained extreme traumatic injuries. The pilot and the person sitting in the centre jump seat suffered injuries that were consistent with having been struck by a main rotor blade or parts of it. Witness marks on the blade supported this conclusion. The third occupant's injuries were probably sustained as the fuselage impacted on the ground.

[12] The side that was closest to the fin.

1.10.2 The examination did not reveal anything that would have affected the ability of the pilot to control the helicopter. There was no medical or pathological evidence of incapacitation or impairment for any of the occupants.

1.10.3 The pilot's most recent medical examination was on 28 February 2001. There were no medical problems identified as relevant to the accident. The 3 occupants were observed to be in good health and spirits and behaving normally before the accident flight.

1.11 Fire

1.11.1 Fire erupted at the main impact point as the fuselage struck the ground. With access to the site difficult, rescue services were unable to extinguish the fire until some 30 minutes after impact. Little additional damage occurred as the fuel burnt off, allowing key aircraft items to be identified. The fire did, however, destroy some of the documentation for the aircraft, including probably the flight manual and aircraft technical log.

1.12 Survival aspects

1.12.1 The accident was not survivable. All occupants sustained immediate fatal injuries as a result of either a main rotor blade entering the cabin or the helicopter striking the ground.

1.13 Tests and research

1.13.1 After inspecting the accident site, some of the wreckage of ZK-HJH was removed to a secure hangar for further examination. The principal air safety investigator for the manufacturer assisted the Commission at this stage.

1.13.2 Inspection of the 2 recovered pieces of pitch link indicated the fracture of the red tail rotor blade pitch link was due to overload. The fracture of the white tail rotor blade pitch link exhibited markings typical of low-cycle (high-stress) reverse bending fatigue. The bushing flange on the red tail rotor blade grip exhibited severe wear on its face.

1.13.3 The bolt and washer found embedded in the white tail rotor blade were extracted. The bolt was identified as a type NAS 1304-20 bolt. The washer appeared to be an AN960 series of washer. According to the manufacturer and aircraft parts manuals, the NAS 1304-20 type bolt was used to attach the pitch links to the blade horns (item 18 Figure 2) and the crosshead to the slider and retainer plate (item 15 Figure 2). The NAS 1304-20 bolt was not used on any other part of the helicopter. On ZK-HJH the 2 bolts attaching the pitch links to the blade horns were still in position and accounted for.

1.13.4 The bolt appeared straight and the threads were intact, although exhibiting some deformation. The hole in the bolt for the split pin was empty. The shank of the bolt displayed a slight wear shadow. The shadow was about 24 mm long, when measured from the washer, flat against the underside of the bolt head, towards the thread.

1.13.5 The pitch change rod (item 23 Figure 2) and stack had been bent over by about 15° at some time during the accident sequence. Some grease was still present on the slider, retainer plate and the end of the pitch change rod where the nut (item 11 Figure 2) was located.

1.13.6 The manufacturer also contended that if one crosshead bolt (item 15 Figure 2) came free, the second bolt assembly should continue to hold the crosshead in place for some time. If the crosshead did start to move and break free, the slider and retainer plate would be damaged in the process.

Resumed investigation

1.13.7 Evidence from an earlier UH-1 accident involving ZK-HVY on 15 January 2001, and a subsequent accident involving ZK-IUE on 3 January 2003, which came about from different circumstances, led the Commission to review its previous conclusions on the ZK-HJH accident. The New Zealand CAA investigated the other 2 accidents.

1.13.8 All the known recovered wreckage of ZK-HJH was taken to the Commission's workshop and was re-examined, along with some components from the 2 other accident helicopters. The investigation team comprised a new investigator-in-charge who was familiar with the helicopter type, a forensic engineer who was trained in aircraft accident investigation, an aircraft accident investigator seconded from the CAA who was a LAME and had previously maintained the helicopter type, and an independent overseas aircraft accident investigator who was an engineer and materials failure analyst. In addition, 4 independent New Zealand metallurgists, the New Zealand Defence Force, a helicopter component overhaul specialist, an overseas laboratory with various metallurgical and other experts, the helicopter manufacturer, and various overseas investigation agencies all provided assistance.

1.13.9 The engine was examined and the top half of the axial flow compressor housing was removed to expose the compressor blades. All the blades showed extensive rotational damage consistent with solid foreign objects having been ingested into the engine while it was rotating at high speed. The engine flexible coupling had failed in overload, consistent with a sudden stoppage when the flexible coupling was being driven under power.

1.13.10 The main transmission had previously been examined, with no evidence of a transmission failure being found. Re-examination of its components did not reveal any defect that could have contributed to the accident. An independent overhaul facility disassembled and examined the sprag clutch. The clutch was shown to be serviceable and displayed evidence that it was being driven normally under power at the time of the accident, and that it had been subject to a sudden stoppage.

1.13.11 The main rotor mast had failed in overload from "mast bump" where the rotor head static stops had contacted each side of the mast.

1.13.12 The tail rotor drive train was examined from the main transmission to the tail rotor 90° gearbox. There were rotational marks on the drive shaft that connected the 42° and 90° gearboxes, caused by contact with the tail rotor pitch change control chain. The lower section of the shaft was not recovered, but there was evidence that a tail rotor blade had struck the shaft. Examination of the 42° and 90° gearboxes revealed no defects. There were also some rotational marks on the drive shaft access cover on the tail boom. The examination did not find any evidence to indicate that a drive train failure had contributed to the accident.

1.13.13 Examination of the white main rotor blade showed that the blade had failed from overload into 2 sections, at about one third span from its hub. The inner section of the blade was inverted and still attached to the main rotor hub. The examination found no evidence to indicate that the blade or any of its components had struck the tail boom, tail fin or tail rotor assembly. There was evidence that the blade had struck some solid object near the point where it had failed. The honeycomb segments aft of the blade main D spar were still attached. The leading-edge abrasion strip was complete but had torn away from the separated inner-blade section. The outer section of blade had been found embedded tip first in the ground along the wreckage trail. Some compression damage to the tip end of the blade was consistent with it having struck the ground. The examination found no evidence to indicate that a white main rotor blade failure had occurred to cause the in-flight break-up.

1.13.14 A metallurgist had previously examined the white main rotor blade and concluded that the failure mode was consistent with overload. He did not find any evidence that fatigue had contributed to the failure.

1.13.15 The red main rotor blade had also failed from overload into 2 sections, at about one third span from its hub. There were numerous scrapes and gouges along the leading edge and lower surface of the blade. The blade inboard section was found inverted and attached to the main rotor hub. The leading-edge abrasion strip was complete but had torn away from the separated inner-blade section. Examination and measurement showed that the entire blade, while turning in its normal direction of rotation, had moved forward 14 cm and struck the top of the wire cutter positioned on top of the cabin. A main rotor blade had struck the battery box in the nose of the helicopter. The red blade had also entered the cabin at a steep angle, after having struck the central support aft of the right pilot door. Three honeycomb blade segments that measured about 1.53 m, 38 cm and 26 cm in length respectively, which fitted aft of the red blade main D spar, had separated from the blade but were accounted for. These had previously been found within the wreckage trail. There was no evidence showing that the red main rotor blade, or any of its honeycomb segments, had struck the tail boom, tail fin or tail rotor assembly. The examination found no evidence to indicate that a red main rotor blade failure had occurred to cause the in-flight break-up.

1.13.16 A metallurgist had previously examined the red main rotor blade visually using low-power magnification aids, and by energy-dispersive X-ray analysis and scanning electron microscopy. The metallurgist's report said that the failure mode was consistent with rapid overload failure, and that a single mechanism had governed the whole failure process. There was no evidence of progressive fracture occurring over a period of time, such as fatigue. The trailing-edge samples (honeycomb segments aft of the main D spar) exhibited a fracture mode typical of overload and no evidence of fatigue was found. The report concluded that the rotor blade had failed from overload during the accident, and that there was no evidence of fatigue on any of the fracture surfaces.

1.13.17 Disassembly of the main rotor head and examination of each main rotor blade tension-torsion strap showed that both straps were twisted but that they had not failed.

1.13.18 A metallurgist had previously examined the swash plate assembly to determine if a fractured trunnion bearing housing had a pre-existing crack centred at a grease nipple hole. The metallurgist's report concluded that while there was no direct evidence of fatigue striations in the fracture surface, consideration of all the evidence and possible factors indicated "… that there was a pre-existing crack in the trunnion bearing housing that had initiated at the outer surface of the trunnion bearing housing centred at the grease nipple hole, and this was present prior to the final fracture of the housing".

1.13.19 An independent metallurgist reviewed the first metallurgist's report, and subjected the swash plate to further examination. Using scanning electron microscopy, he examined the failed trunnion bearing housing. The independent metallurgist concluded that there was no evidence to show the housing had any pre-existing crack, but said that "The fracture surfaces on both sides of the bearing housing were typical of overload of a brittle alloy of this type" and that "… the failure occurred as a result of a single overload event". He concluded that the housing "… failed in overload and probably occurred as a result of impact loading …".

1.13.20 The independent overseas materials failure engineer read the first metallurgist's report, examined the swash plate and trunnion bearing housing and bearing and reviewed the independent metallurgist's evidence. He found no evidence from his examination to suggest that the swash plate failure at the trunnion bearing housing had occurred before the accident, or that a failure of the swash plate contributed to the accident.

1.13.21 Research showed that it was not uncommon for swash plate trunnion bearing housings to crack, and that any cracking was mainly caused by improper maintenance practices during bearing replacement. A crack did not normally lead to a failure, and 2 retaining bolts should prevent the trunnion bearing leaving its housing. Apart from some chipped surface paint, there was no gouging on the 2 drive links that connected to the trunnion bearings, and which were positioned close to and rotated inside the stationary cyclic and collective pitch control horns. Although one horn had failed in overload and was not with the recovered wreckage, neither of the 2 remaining horns showed any gouging. Examination of the swash plate collective sleeve hub assembly showed that the 6 bolts that secured the flange and drive plate to the collective sleeve hub were all sheared, in the direction consistent with a sudden stoppage while the hub was being driven by rotor blade inertia or under power. The resumed investigation examination of the swash plate assembly revealed no evidence to indicate that it had catastrophically failed before the accident, or that its trunnion bearing had been flung outwards from its housing.

1.13.22 The wreckage trail was previously documented as having extended for about 450 m. Flecks of paint from the fin and its panelling, and parts of the red tail rotor blade were the earliest items found along the wreckage trail. The fin was one of the first major items found along the trail, and was located at about 260 m from the first paint flecks. The 90° gearbox was still attached to the top of the fin, but partially separated from it. The skin and spar beneath the gearbox on the left side of the fin had cracked and opened about 2.5 cm. The crack extended about half way across the fin. An initial visual examination of the area by a metallurgist and the materials failure engineer suggested that the area had failed in overload. Further detailed metallurgist examination of the area under a stereoscopic microscope showed that it had failed by overload in shear. The examination found no evidence of fatigue or significant degradation by corrosion.

1.13.23 The tail rotor hub was attached to the 90° gearbox drive shaft. Each tail rotor blade had failed in overload at the outboard end of the doublers, leaving the inner third of each blade attached to the tail rotor hub.

1.13.24 Examination of the fin showed that a tail rotor blade had struck it on its left side, and further examination showed that it was the red tail rotor blade (see Figure 3). The blade had struck the left spar of the fin, cutting it and bending it backwards in the direction of normal blade travel. Measurement showed the position where the blade had struck the spar corresponded to the extent of the normal arc of rotation of the tail rotor blade. The line of the fin damage aft of the spar coincided closely with the normal arc of rotation of the blade. The left spar had been severed, and the fin had failed to the right with its right spar having failed in overload.

1.13.25 The leading edge of the outer portion of the red tail rotor blade was found to be extensively damaged, with its tip missing (see Figure 3). A small section of the outer leading edge of the red blade and its tip block had been found at the start of the wreckage trail. Examination of the blade, including paint transfer evidence, showed the damage was consistent with it having struck the fin while being driven under power.

1.13.26 A broken section of the red tail rotor blade pitch link was attached to the tail rotor blade pitch change horn (item 14 Figure 2, and Figure 4). The pitch link had failed outboard of the jam nut where the link attached to the horn. The outer section of the link was not found, nor was the crosshead to which it attached.

1.13.27 Independent metallurgical analysis of the red tail rotor blade pitch link fracture surface, using optical microscopy, showed that the link had failed from ductile overload. There was no evidence found of any pre-existing cracks or flaws.

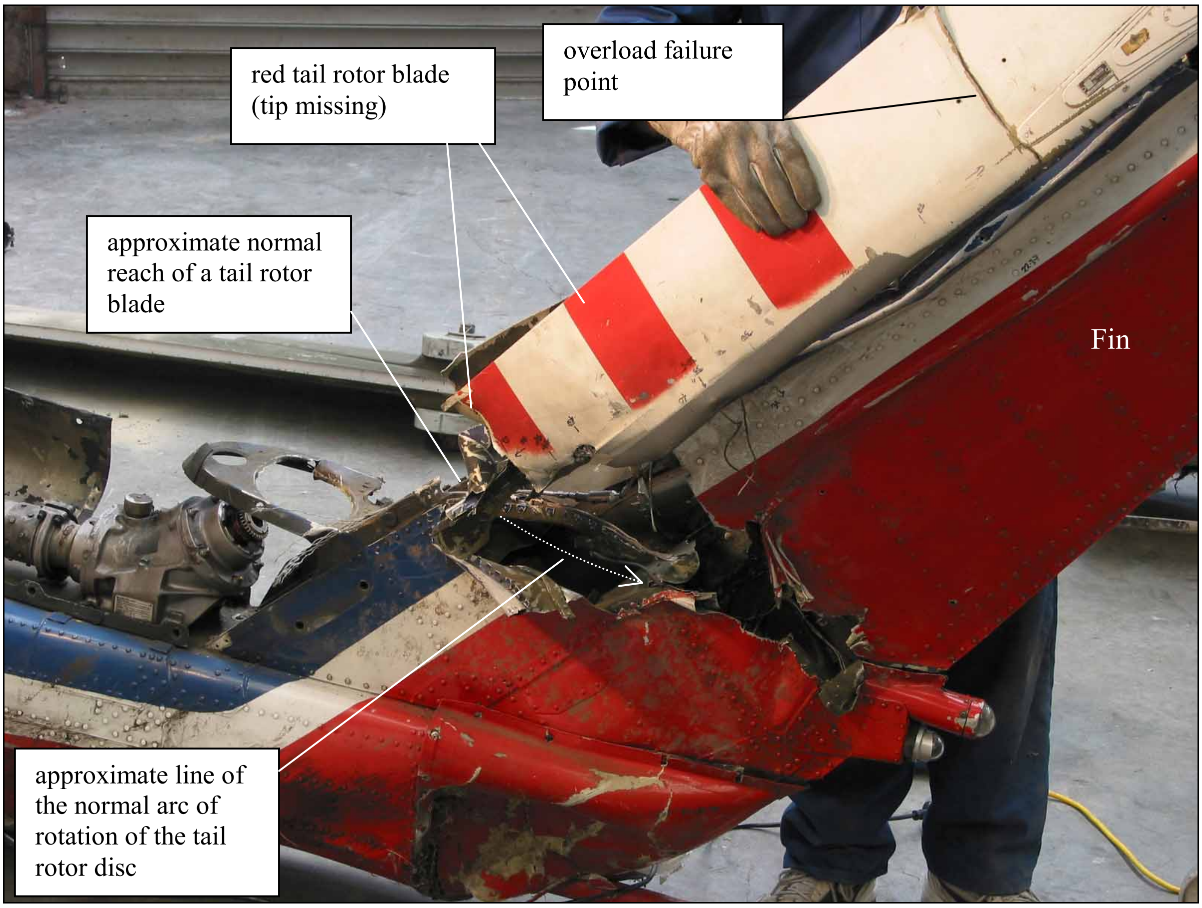


Figure 3
Red tail rotor blade strike on the fin of ZK-HJH

1.13.28 The outer section of the white tail rotor blade had a tear in its inboard side near the tip. As documented previously, an NAS 1304-20 bolt and AN960 washer had been found embedded in the skin of the blade in the area of the tear, and had been identified as being a crosshead bolt and washer. There were some blue paint smears on the blade leading edge that matched the paint on the fin, some chord-wise gouges near the tip, and some minor indentations on the leading edge. A broken section of the white tail rotor blade pitch link was attached to the tail rotor blade pitch change horn (item 14 Figure 2, and Figure 5). The pitch link had fractured outboard of the jam nut where the link attached to the horn. The outer section of the link was not found, nor was the crosshead to which it attached.

1.13.29 Independent metallurgical examination and analysis was carried out, using scanning electron microscopy, of the fracture surface of the failed white tail rotor blade pitch link. The link material was consistent with the correct alloy used to manufacture the links. The fracture surface of the link exhibited 2 pre-existing cracks that featured beach marks typical of fatigue crack propagation (see Figure 5). The position of the cracks indicated in general that the loading action had been reverse bending, and that the cracks had initiated because of this reverse bending. There was evidence of link deformation immediately adjacent to the fracture in the threaded portion of the link outboard of the jam nut. Laboratory tests showed that, for this deformation to occur, the bend was present before cracking. The angular deformation in the first thread was approximately 5° (see Figure 6). Because the rest of the link was not found, it was not possible to determine the degree of any bending beyond what was measured. The 2 fatigue cracks penetrated approximately 35% of the link cross-section, and the remaining cross-section had failed through overload.

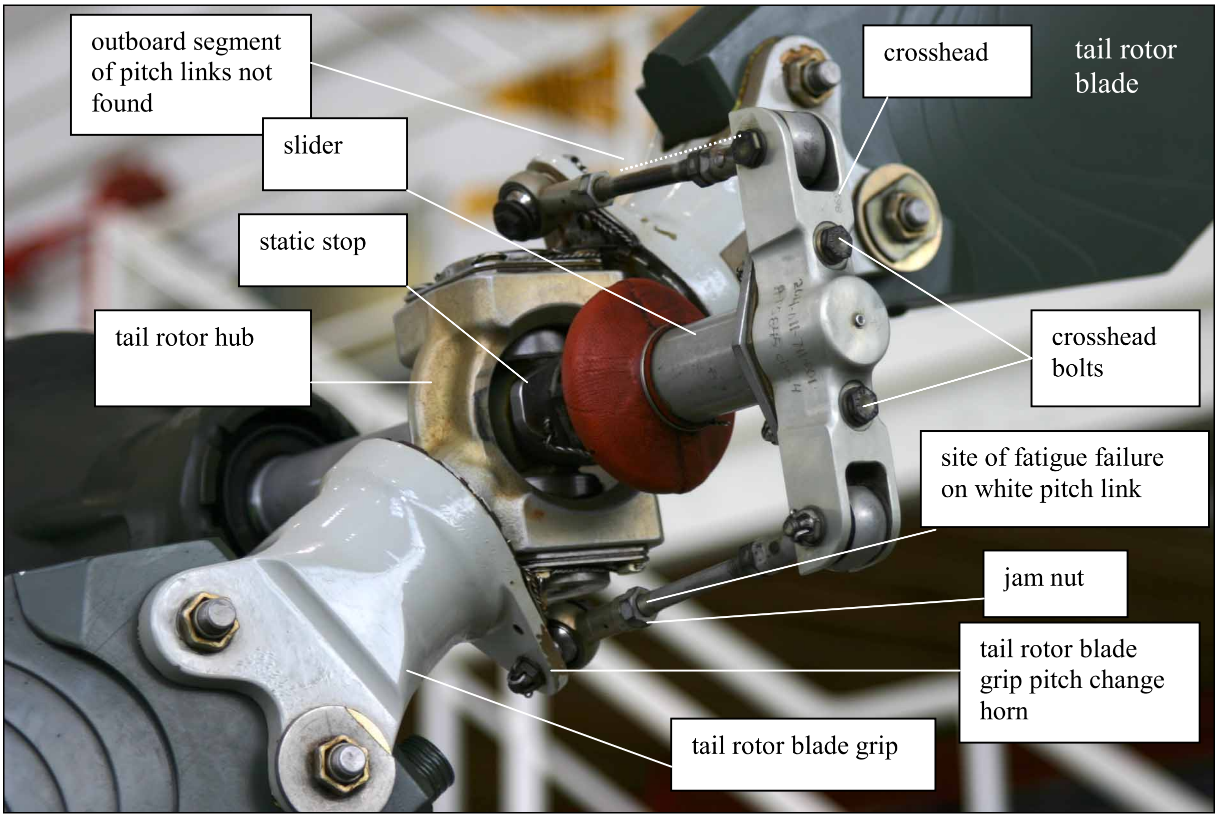


Figure 4
Typical UH-1H tail rotor hub assembly

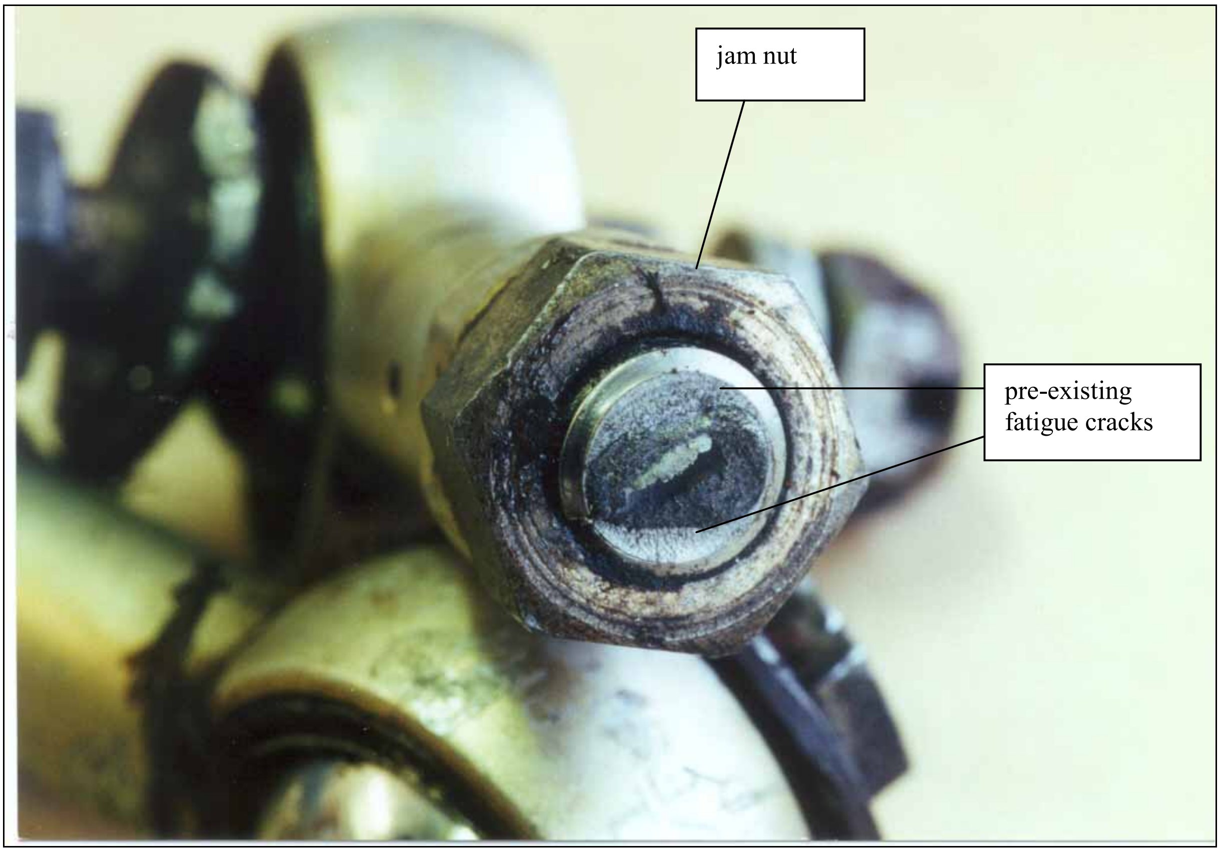
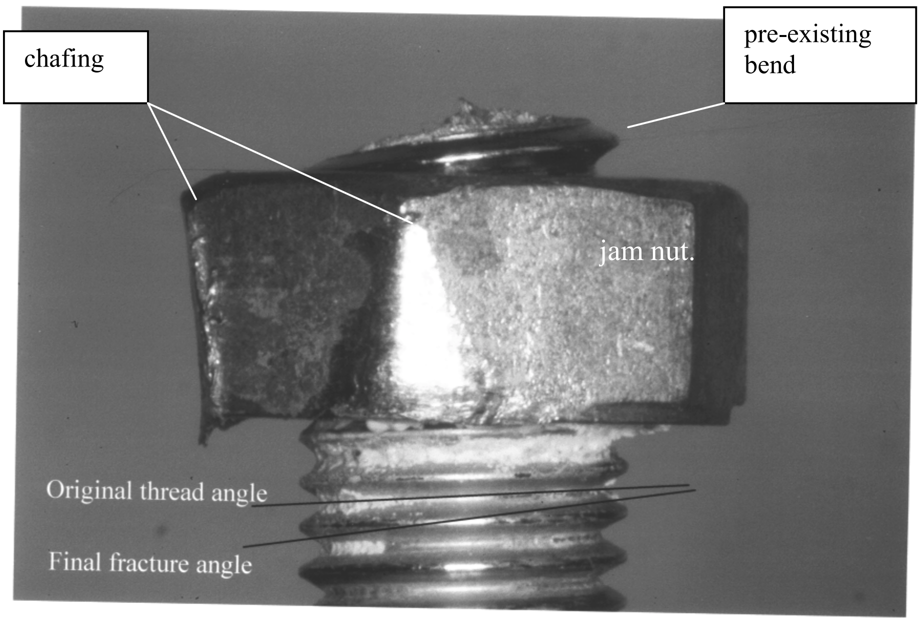


Figure 5
Broken white tail rotor blade pitch link from ZK-HJH



Note: During removal of the broken link piece from its eye end, the jam nut was rotated counter clockwise about 2.5 flats, or 180°, from its original position. This image shows it after removal.

Figure 6
Fractured white tail rotor blade pitch link showing bend

1.13.30 Examination at high scanning electron microscopy magnification showed that much of the surface of the more heavily burnished crack had been damaged by contact with its mating fracture surface. However, sufficient detail existed to identify fatigue crack growth striations[13] typical of fatigue. The striations were relatively regular, indicating that the crack had been growing in response to regular constant amplitude load cycles. The second crack clearly exhibited evidence of fatigue crack propagation. The fracture mode had grown increasingly more ductile as the crack became deeper. Towards the crack tip the cracking was more ductile, indicating that the crack growth had been relatively fast. The evidence on the fracture surface indicated a rapidly rising cyclic stress amplitude that led to failure as soon as the residual material had been unable to sustain the in-service loads.

1.13.31 The tail rotor crosshead assemblies and pitch links from the 2 other UH-1 helicopters that were involved in accidents, ZK-HVY and ZK-IUE with similar tail rotor assemblies to ZK-HJH, were examined for comparative analysis. The pitch link fractures from the tail rotor blades from ZK-HJH occurred at positions consistent with the point on the component where maximum bend deformation had been induced during the accident sequence of one of the other 2 helicopters, and in a position similar to the bend in a link on the other helicopter. The tail rotor assemblies from both these helicopters had been overloaded by blade strikes during their accident sequences, showing that the links could be deformed during blade overloading. One accident occurred during a lifting operation when a rope sling broke and struck the side of a tail rotor blade. Apart from rope witness marks on the blade there was little other evidence of a blade strike, but the strike was sufficient to cause the pitch link to bend in a similar position to the link from ZK-HJH, and the 90° gearbox to separate from the top of the fin. The other helicopter blade strike occurred in the accident sequence, during which the blade struck the ground.

[13] Linear marks on a surface showing each time a crack stops and starts.

1.13.32 Investigative evidence and information from the helicopter manufacturer showed that while a tail rotor strike could cause the 90° gearbox to fracture and separate from the fin, separation depended upon where in the arc of rotation the strike occurred. With ZK-HJH, the gearbox remained intact but had partially separated from the fin.

1.13.33 The metallurgical examinations found that the failure of the red tail rotor blade pitch link on ZK-HJH was explainable by overload, of the type that might be expected when the blade struck the fin, but did not find evidence of pre-existing cracking. However, while the final failure of the white tail rotor blade pitch link was from overload, its cracks were not consistent with them having occurred during the break-up sequence. The fatigue loading in the pitch links would normally be low. Bending fatigue in a link with ball-end fittings was not usually possible unless:

- the link was exposed to very high fatigue loads sufficient to elastically bow the rod in compression during part of the load cycle; or
- the ball joint seized; or
- the link had been previously bent.

1.13.34 Laboratory testing and examination did not reveal any evidence to show that either of the first 2 possibilities contributed to the bending fatigue found in the white tail rotor blade pitch link. However, the metallurgist found the third possibility was the most likely because of evidence that the link had a pre-existing bend before the formation of deep fatigue cracks. The presence of the 2 fatigue cracks with one loaded primarily in tension and the second with a burnished surface, implying a compressive element, also implied the presence of a pre-existing bend in the link.

1.13.35 The metallurgical examinations showed a narrow ductile shear crack existed around much of the circumference of the white tail rotor blade pitch link thread root. Fatigue cracking appeared to have grown out of this ductile shear crack in the thread root after it became enlarged when the link bent. The examinations and research showed that the short ductile cracks in the pitch link thread roots would have acted as stress-raisers and provided initiation sites for fatigue cracking where local stressors were above the threshold for fatigue crack growth.

1.13.36 The metallurgical examinations found that the reason for the fatigue cracks could be some unexplained loading event that was sufficient to induce yielding in the thread root stress concentration, but not sufficient to cause a fracture. Such an event could cause link deformation and possibly in-flight tail rotor vibration, and high fatigue loads in the link. Another possibility was a defect from manufacture during the thread forming process, but cracks of this type were not evident elsewhere in the link screw threads and normal operational loads would not have been sufficient to bend the link even with any small cracks present. There was no evidence that any small manufacturing defects arising from the thread forming process contributed to the link failure.

1.13.37 The metallurgical examinations found an unknown, but significant, period (probably some minutes) of flight had led to the fatigue crack growth in the white tail rotor blade pitch link. Examination of the tail rotor hub showed that the white tail rotor blade pitch link jam nut had been held against the hub, and chafed for a period before it finally failed (see Figure 7). Comparative analysis with a bent pitch link from one of the accident helicopters previously mentioned showed that for this to occur, the pitch link would have had to bend to about 45°. The possibility was considered that the chafing between the pitch link jam nut and the hub occurred after the fracture of the pitch link. However, the chafing on the hub was only present at the point where contact would occur with a bent but intact pitch link. A broken pitch link, on the other hand, would have been free to flail and thus only chafe lightly against the hub at random locations, but there was no evidence of this.

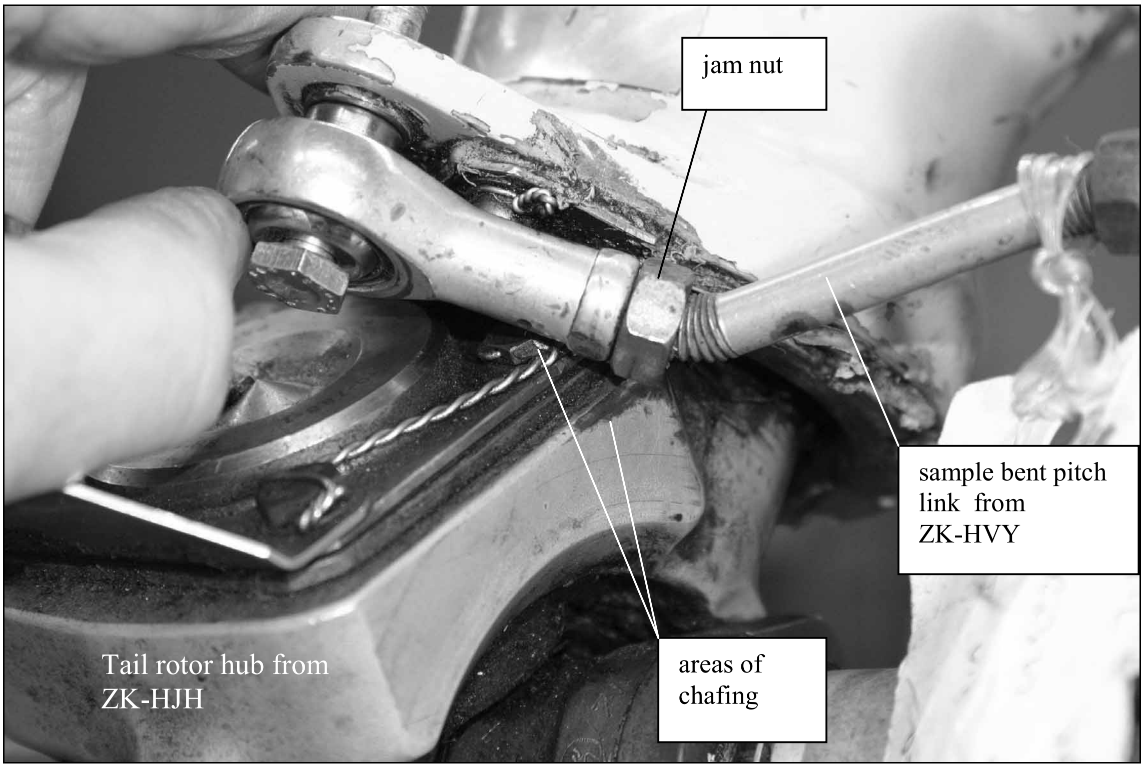


Figure 7
Illustration of bent white tail rotor blade pitch link contacting tail rotor hub

1.13.38 Another metallurgist in an overseas laboratory examined the fractured white tail rotor blade pitch link using scanning electron microscopy, and reached the same conclusions as the first examination analysis. In addition, the fracture surface of the link was subject to examination and a detailed striation count using transmission electron microscopy. That examination and striation count revealed low-cycle[14] bending fatigue and 8000 striations. The striations showed the growth of the cracks after they had formed. Taking the more likely situation of one striation per cycle of tail rotor blade rotation, or the less likely situation of 2 per rotation, the result showed that the cracks in the link had been propagating because of reverse bending fatigue for a few minutes before the link failed.

1.13.39 The tail rotor crosshead bolt that had been found embedded in the white tail rotor blade was documented in the original report as probably not having its castellated nut secured by a cotter (or split) pin. The conclusion reached in the report was that this had allowed the nut to loosen and eventually detach from the bolt, and that its corresponding unfound bolt was probably similarly not secured. The conclusion reached was that the loose crosshead then brought about the accident.

1.13.40 Two independent metallurgists separately examined the tail rotor crosshead bolt threads to see if there was any evidence that a nut had been fastened to the bolt and secured with a cotter pin, and if the nut had been stripped from the bolt threads. To assist the examinations, a number of other sample bolts were provided for comparison, including 2 tail rotor crosshead bolts from one of the other accident UH-1 helicopters where the cotter pins were known to have originally been in place. Sample testing of several crosshead bolts and nuts showed that, because the nut was softer than the bolt, it was possible to strip a nut from the bolt threads, which remained relatively undamaged.

[14] The helicopter manufacturer considered anything fewer than 50 000 cycles to be low cycle.

1.13.41 The crosshead bolt from ZK-HJH was examined using scanning electron microscopy and X-ray energy-dispersive spectroscopy. Sufficient compositional difference existed between the bolt and the corrosion-resistant cotter pins manufactured for fitment through the bolt, for detection of any transferred material.

1.13.42 The bolt and washer were also examined to see if there was any evidence that the bolt had been loose. Severe fretting damage would normally be expected on a loose bolt. No significant fretting damage to the head or shank of the bolt, or to the washer, was found.

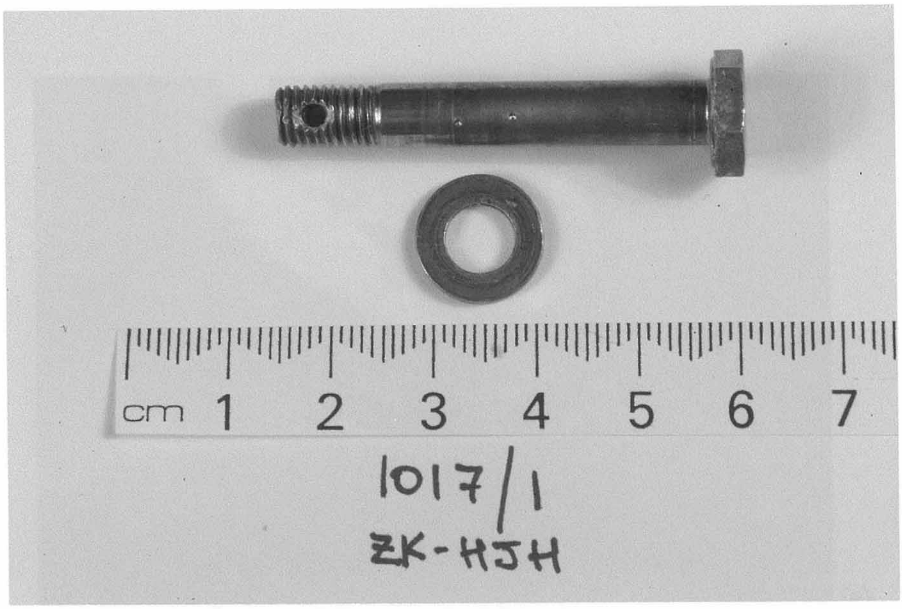
1.13.43 The examinations showed bolt thread deformation, suggesting that a nut had been in place and stripped from the bolt (see Figures 8 and 9). In addition, there were indentations on the crosshead bolt threads, which closely matched the dimensions of the cotter pins manufactured for fitment through the bolts. A crosshead bolt from one of the 2 other UH-1 accident helicopters, where the nut had been stripped from the bolt, exhibited a similar degree of overall damage, including an indentation in a position similar to that found on the bolt from ZK-HJH. The indentation closely matched the cotter pin dimensions, and was in a position that would be expected if a nut had sheared the cotter pin as the nut was stripped from the bolt. Several test piece bolts, with a cotter pin installed, had their nuts stripped from the bolts. These test pieces displayed similar features, which included similar indentations in the bolt.

1.13.44 In addition to the crosshead bolt thread damage and indentations, the second independent metallurgist found a deposit of cotter pin corrosion-resistant steel on the threads of the crosshead bolt from ZK-HJH. The corrosion-resistant steel material transfer was in a position that would be expected from a mechanically sheared cotter pin.

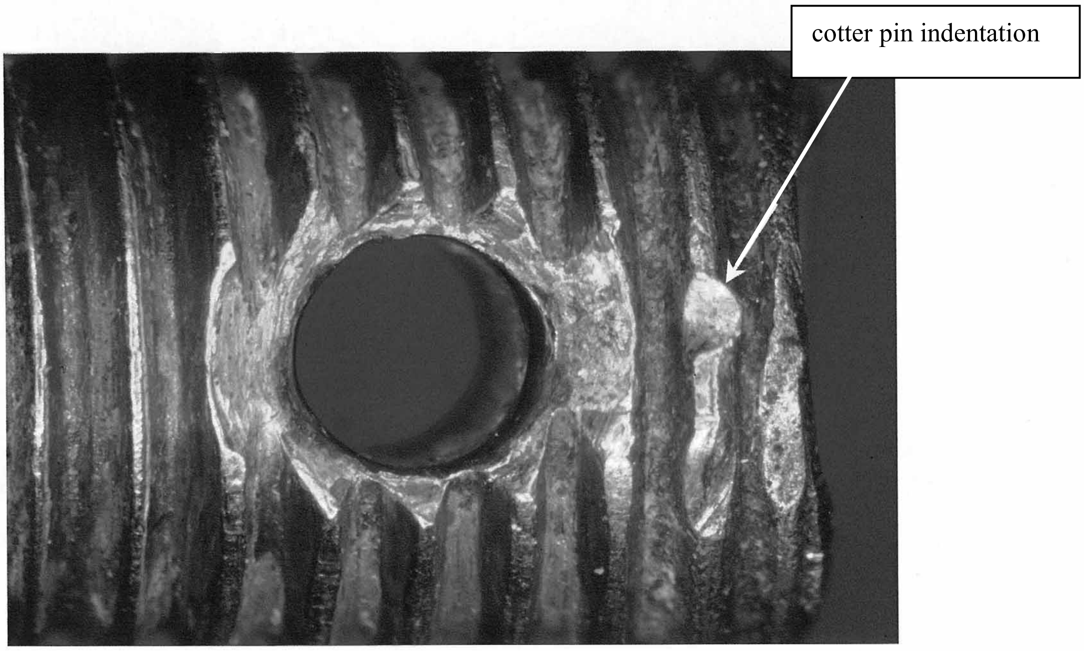
1.13.45 The independent metallurgists concluded that the physical evidence of indentations on the bolt, and particularly the chemical evidence of cotter pin metal transfer, showed that a cotter pin had been present in the crosshead bolt that was recovered from the white tail rotor blade on ZK-HJH. There was not sufficient evidence to suggest that the bolt had been loose.

1.13.46 During examination of the tail rotor blade hub assembly the white tail rotor blade grip would randomly lock, during normal pitch change rotation. Examination and dismantling of the hub assembly took place at an independent overhaul facility. Evidence was found showing that the tail rotor hub and each of the 2 tail rotor grips had been correctly assembled and lubricated with the correct type of grease. The 2 bearings on each yoke that fitted into each blade grip had been replaced with new bearings at the last servicing, 50 flying hours before the accident. The bearings were the manufacturer's specified components with the correct part numbers. They had been fitted and shimmed correctly to their respective hub yokes. Examination of the bearings showed that one ball in the inner bearing from the red tail rotor blade had fractured, and that 2 balls in the inner bearing from the white tail rotor blade had fractured.

1.13.47 A bearings expert in an overseas laboratory and the materials failure analyst disassembled and examined the bearings in detail. Their examination did not reveal any evidence of pre-accident bearing failure. Their examination found that all 4 bearings showed normal wear patterns in the correct locations. Their examination also revealed that all 4 bearings had severe impact brinelling on the load shoulder of the ball race, and some deep dents, indicating a one-time catastrophic event. The red blade inboard bearing showed a heavy wear pattern, superimposed over the normal wear pattern, over about one third of the circumference where the bearing was normally loaded. The wear pattern had the appearance of being produced by heavy loads over a short period of time, but longer than the duration of the accident break-up sequence. Laboratory analysis of the bearing grease showed that it met the correct specifications. Some organic and inorganic foreign material particles were washed from the grease during examination at the independent overhaul facility. Examination of the bearings and particles did not reveal any evidence that the particles had affected the normal operation of the bearings.

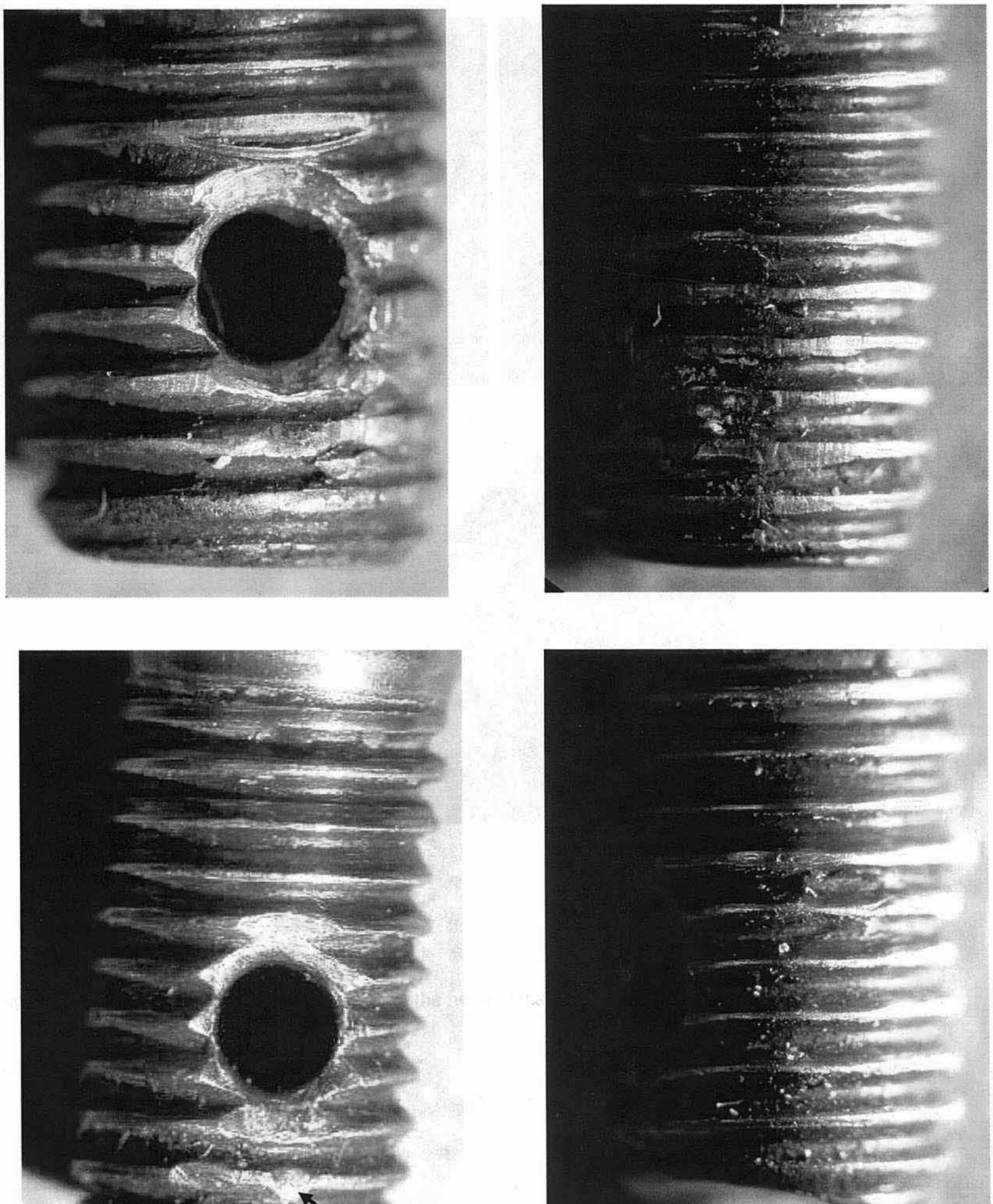


General view of the tail rotor crosshead bolt from ZK-HJH.



Close-up view of the area around the split pin hole of the bolt from ZK-HJH. Note the deformation and scoring of some of the threads and the indentations.

Figure 8
ZK-HJH crosshead bolt thread damage



The bolt from ZK-HJH viewed every 90 degree around it showing the deformation to the crests of the threads and longitudinal score marks along the crests of some of the threads. A mark where the head of the split pin was probably pushed into the threads during the failure is arrowed.

Figure 9
ZK-HJH crosshead bolt thread damage

1.13.48 Examination of the tail rotor hub static stop (see item 5 Figure 1, Figure 4, Figure 10 and Figure 11) showed that the ear on the white tail rotor blade static stop was deformed and bent noticeably outwards, away from the fin. The white side of the tail rotor hub showed corresponding evidence that it had struck the static stop. The tail rotor hub retaining nut, which tightened against the stop, was also deformed noticeably and bent outwards. Examination showed that because of the deformation to the ear of the white blade static stop, the red tail rotor blade could contact the fin. An undamaged static stop on a correctly rigged tail rotor assembly would mechanically limit the degree of tail rotor blade flapping and prevent the tail rotor blades contacting the fin, by limiting their travel to 2.5 inches (6.35 centimetres) from the fin. Also, normal rigidity of the blades would not allow them to flex enough to strike the fin. During normal in-flight operation, the tail rotor hub would not contact the static stop.

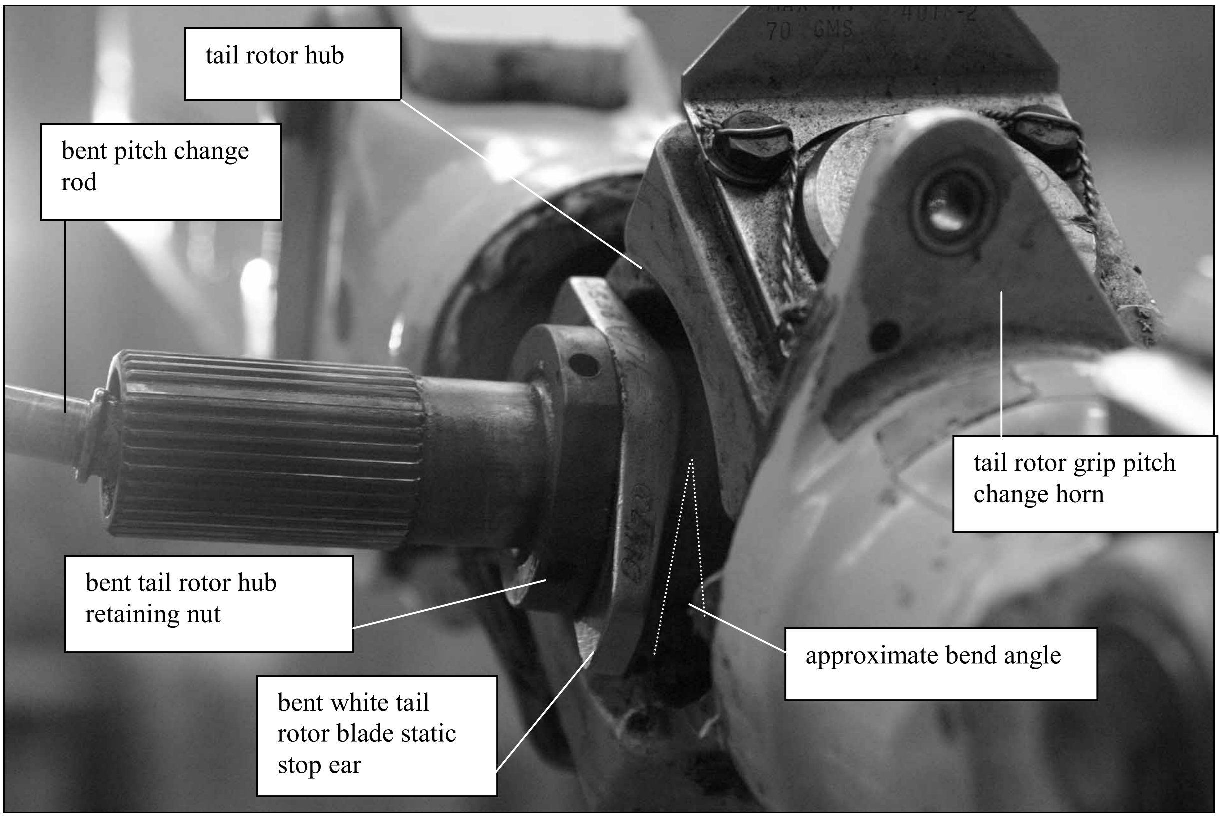


Figure 10
Bent static stop and tail rotor hub retaining nut from ZK-HJH

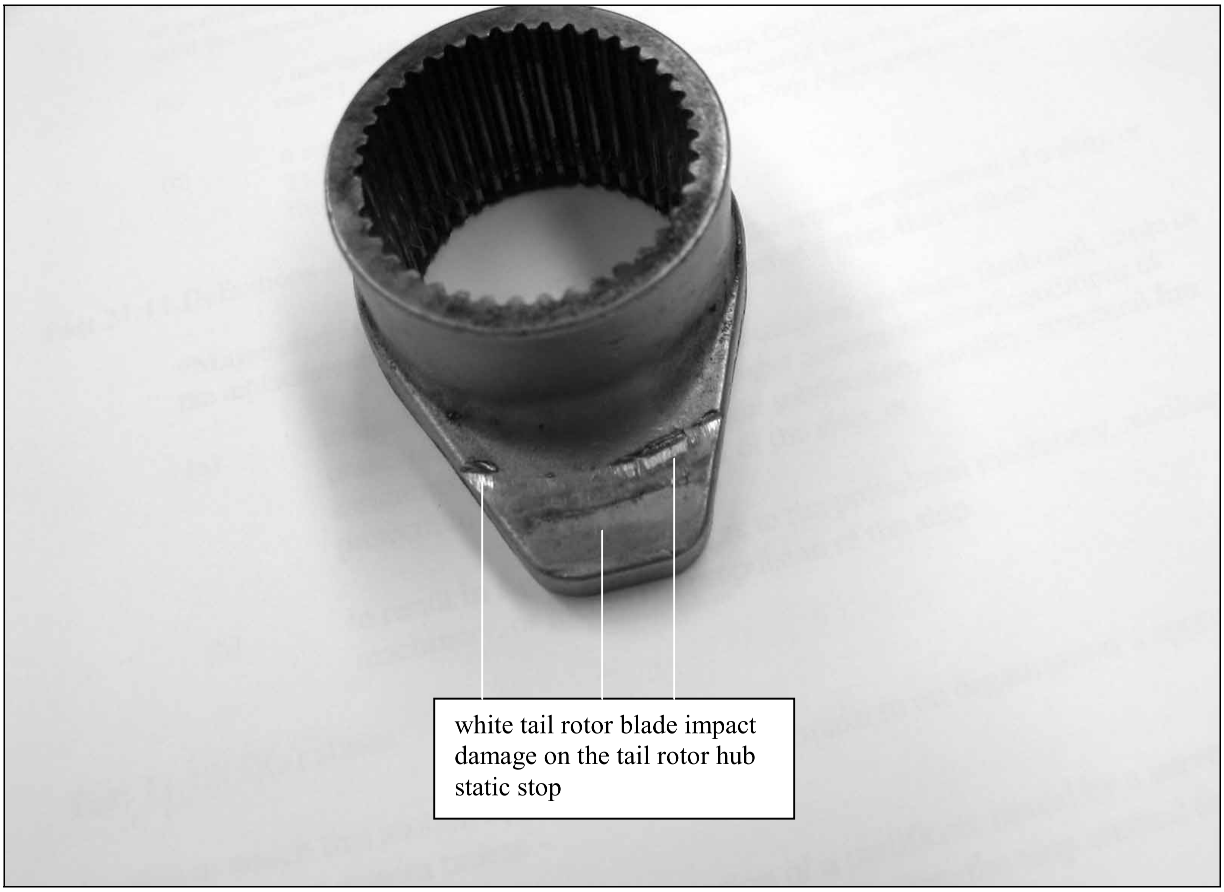


Figure 11
Bent tail rotor hub static stop ear from ZK-HJH

1.13.49 Examination of the tail rotor hub crosshead slider (see item 8 Figure 2, and Figure 4) showed that the slider ear on the red tail rotor blade side, where the crosshead bolt attached, was bent outwards away from the tail rotor hub. The corresponding slider ear, on the white tail rotor blade side, was bent inwards towards the tail rotor hub (Figure 12). The retainer plate that fitted between the slider and crosshead (see item 9 Figure 2) was bowed away from the slider and had some rotational scoring marks on its outer face. The end of the pitch change rod (see item 23 Figure 1, and Figure 10), which passed through the tail rotor drive shaft and connected to the crosshead, was bent away from the red blade slider ear.

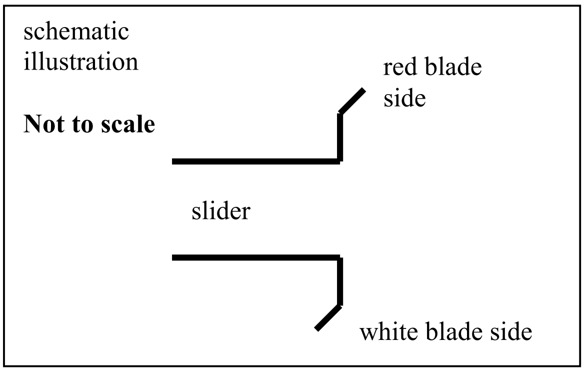


Figure 12
Schematic illustration exaggerating bent crosshead slider ears

1.13.50 Overseas experience showed that a pitch link failure in a UH-1 helicopter could lead to a fin strike by a tail rotor blade, and that jamming of a pitch link ball joint bearing could lead to a link failure. In one case, an incorrect bolt had been installed through the pitch link ball joint bearing to the tail rotor blade grip, and had dislodged during flight. Another case involved the seizure of a ball joint bearing and the subsequent failure of its pitch link near the jam nut. In another case, the pilot heard a banging noise coming from the tail area as he applied yaw pedal control during forward flight. Examination found that one pitch link was not connected to its tail rotor blade control horn because its connecting bolt was missing. A tail rotor blade had struck the side of the fin several times, causing significant damage and the banging noise the pilot heard.

1.13.51 The helicopter manufacturer said that if a tail rotor blade was unrestrained in pitch, it would tend toward a flat pitch setting but be unstable. During forward flight the blades must flap to equalise the lift, and if there were different pitch settings between the blades they would flap excessively. The amount of flapping was dependent upon the degree of lift dissymmetry (which would be exacerbated in the case of a pitch link failure), and increased as the airspeed increased.

1.14 Organisational and management information

1.14.1 The operator was subject to routine annual CAA audits, which sampled various aspects of the operator's activities and its aircraft. Over a period of time, the audits would cover all of an operator's activities. The helicopter came within the agricultural flight operations audit cycle, and the last such audit before the accident was completed in July 2000. The audit report noted that there were no concerns regarding the standard of maintenance being performed, and the report indicated that ZK-HJH had not been inspected during the audit. A separate CAA spot check around the time of the audit had checked the helicopter for any unauthorised parts, with none being found. The previous audit report also indicated that the helicopter had not been inspected as part of the audit sample, or suggest that it should be.

1.15 Additional information

1.15.1 The Commission has investigated a number of accidents in recent years where documents carried on board an aircraft have not been recovered, often due to fire. This means that items such as the flight manual and aircraft technical log have not been available to investigators after an accident. One copy of the aircraft technical log is required to be made and held on board the aircraft.

1.15.2 In the first 6 months of 2001 there were 3 fatal accidents involving ex-military helicopters in New Zealand. In addition to this accident, there was one involving a Bell UH-1F in Wellington on 15 January, and another involving a Wessex near Motueka on 12 February.

2 Analysis

Excerpts from the original analysis

2.1 The flight was a positioning flight from the helicopter's base near Pukekohe to Taumarunui, to start bait spreading operations the next day. The direction of approach to Taumarunui and the estimated flight time were consistent with ZK-HJH flying over the area to be poisoned, before continuing on to Taumarunui. Witnesses reported nothing unusual as the helicopter approached Echolands Valley. A witness located further down the valley and another who heard but did not see the helicopter, reported changes in the noise of the helicopter as it approached or turned. However, the majority of witnesses, especially those located under the flight path and nearby, reported that the helicopter sounded normal until part way through the turn. The inference, therefore, is that the flight was proceeding normally before entering the turn.

2.2 The weather enroute and at Taumarunui was good and not considered to be a factor in the accident. The sun was setting and would have been to the pilot's right as he flew towards Taumarunui.

2.3 Estimates of ZK-HJH's altitude over Echolands Valley varied significantly. However, the helicopter would have been at least 1400 feet amsl, or 600 feet above the local terrain, when the eyewitnesses to the south of the ridgeline saw it disappear from view. The trapped altimeter reading of 2320 feet would provide a reasonable estimate of the helicopter's altitude for the early part of the accident sequence.

2.4 The trapped tachometer and EGT readings indicated that the engine was functioning at the onset of the accident. The readings correspond to a cruise power setting and would have been typical for that stage of the flight.

2.5 No transmissions from ZK-HJH were reported during the flight. This could suggest the onset of the emergency was rapid and did not give the pilot enough time to make an emergency radio transmission.

2.6 The wreckage trail and eyewitness accounts confirmed that there was an in-flight break-up of ZK-HJH. The distribution of wreckage, the damage and the injuries sustained indicated that the inception of the accident sequence included some form of tail rotor control loss.

2.7 Alternative theories on what initiated the break-up, including a failure of a main rotor blade, cannot account for the presence of the bolt in the tail rotor blade. Further, witness marks on the red blade, including the broken section found at 225 m and the remainder of the blade found at 405 m, confirm that the red blade entered the cabin area intact and then failed owing to overload, and not fatigue. Also, there was no evidence to indicate that either of the main blades had struck the fin, causing a loss of tail rotor control.

2.8 The tail of ZK-HJH flicking back and forth before the helicopter turned or yawed to the right, was possibly when the pilot started to have tail rotor control problems. A turn to the right is symptomatic of a loss of tail rotor thrust for the Iroquois if a pilot does not immediately reduce power to counter the torque effect of the main rotor when the failure occurs. However, many witnesses observed the helicopter to remain about level for the early part of the turn. After entering the right turn ZK-HJH probably continued to turn through about 270° – the helicopter becoming uncontrollable part way through the turn.

Resumed investigation analysis

2.9 The following re-analysis of the accident sequence and its causal factors is based primarily upon evidence found during the resumed investigation. Much of the factual information that had previously been documented remains valid and is not re-analysed. Only the new findings and how they affected the original conclusions are discussed.

2.10 The wreckage trail that had been documented previously showed that the earliest items found along the wreckage trail came from the tail end of the helicopter. This included paint flecks, a piece from the tip of the red tail rotor blade, separated parts of the tail rotor blades and then the fin. Because there was very little wind at the time, the items would not have been dispersed by this means. During an in-flight break-up of an aircraft, as was the case with ZK-HJH, the wreckage trail, which unfolds itself along the surface, can be taken as a very good indicator of the sequence of events.

2.11 The resumed investigation found a number of consistent indicators that pointed to the break-up starting at the tail end of the helicopter, in particular the tail rotor and fin. The conclusion reached was that the wreckage trail layout was an accurate depiction of the actual in-flight break-up sequence.

2.12 The previous investigation had already determined this, and had argued that the tail rotor crosshead had probably come loose and initiated a loss of control and the break-up sequence, because the castellated nut on each of the 2 crosshead bolts had probably not been secured with a split pin (cotter pin).

2.13 The resumed investigation determined, through extensive component and metallurgical testing and other evidence from the tail rotor assembly, that the original theory of the crosshead coming loose and causing the break-up sequence could not be supported. The resumed investigation found that the crosshead bolt found embedded in the white tail rotor blade had its castellated nut stripped from the bolt early in the break-up sequence. The resumed investigation determined that a cotter pin had been fitted through the nut and bolt, and that the nut had mechanically sheared the cotter pin when the nut was stripped from the bolt. Although the crosshead itself was not recovered, the resumed investigation could also not support the original theory that the crosshead bolts had loosened during flight and separated from the crosshead.

2.14 The resumed investigation examined all other possibilities, including those that had been put forward during and since the original investigation, such as a main rotor blade failure or strike on the boom or tail rotor assembly, a swash plate failure, or a transmission or engine failure.

2.15 There was no evidence found to indicate that any maintenance practices had contributed to the accident. Examination and disassembly of the tail rotor assembly showed that it had been correctly assembled and greased, and records showed it had been balanced and tracked at the last servicing.

2.16 The resumed investigation examined the tail rotor drive train and tail rotor assembly. Other than the cracking and failure of the white tail rotor blade pitch link, no evidence was found to indicate that any other pre-accident defect contributed to the accident.

2.17 Various independent experts examined the white tail rotor blade pitch link in detail and concluded that the link had 2 fatigue cracks, which grew over a period of time until the residual strength was reduced to the point where complete fracture occurred, before the break-up sequence. The link had been subject to low-cycle bending fatigue cracking before it fractured completely. The fracture surface of the more heavily burnished crack had been damaged over much of its surface by contact with its mating fracture surface, which showed that the crack had been present for some time and had been subject to compression.

2.18 Although examination of the white tail rotor blade pitch link showed that there was a pre-existing bend of about 5° near the point where it failed, the examination only measured the bend at one threaded portion of the link and could not account for any progressive bend on the rest of the link that was not found. Each thread on the rest of the link could have been similarly bent. However, a bend was necessary for the fatigue to occur, and the measurement clearly showed that there was a bend. The evidence also showed that the link end and its jam nut had been held firmly against the tail rotor hub and chafed for a period before the link finally failed. Comparative analysis with a bent pitch link from ZK-HVY showed that the link had to have been bent significantly more than 5° for this to occur. The striation count on the fracture surfaces of the link showed that the growth of the cracks, from reverse bending fatigue, took place over a short period, probably a few minutes, before failure.

2.19 The resumed investigation concluded that the link bending probably occurred in its entirety during one event at some point during the accident flight, thus bending the link to its final shape that was necessary for it to be held against the tail rotor hub, and chafe. This bend then brought about the reverse bending stresses that made the fatigue cracks initiate and progress, and for the link to finally fail. Had reverse bending occurred over a longer period, such as throughout the duration of the accident flight, more striations should have been present. The nature of the fatigue growth also showed that it occurred relatively quickly. The unusual wear pattern observed in the tail rotor hub bearings also indicated that the wear was not progressive over a longer period of time, but during a shorter period.

2.20 Why the pitch link had a pre-existing bend could not be determined. Because the tail rotor assembly had been worked on during the last servicing 50 flying hours before the accident, any 5° or larger bend at that time would have been evident and rectified by the maintenance personnel, indicating that it was not present at the time of the servicing. Also, had a bend been present some hours before the accident, a greater number of striations would have been evident. The low number of striations confirmed that the bend occurred during the later stage of the accident flight.

2.21 Although there was no evidence found to suggest that either an object from the helicopter or an external object had struck the tail rotor assembly during the accident flight, this possibility cannot be ruled out. There was also no evidence of foul play found. There was no evidence found to suggest that a segment of main rotor blade, or other helicopter component, had failed earlier in the flight and struck the tail rotor assembly. Because all the main rotor blade segments were accounted for along the wreckage trail, this also helped rule out the possibility that a segment had failed earlier and struck the tail rotor assembly or a tail rotor blade. There was also no evidence to suggest that any engine, transmission or swash plate failure had caused the accident.

2.22 After the pitch link was bent and held against the tail rotor hub, the pilot would probably have experienced some vibration and tail rotor control problems, especially if he had slowed the helicopter. With the white tail rotor blade pitch link shortened by the bend, the blade would have moved toward a lesser pitch angle, but the red blade would have been at the pitch setting selected by the pilot. This would have created a different pitch setting and an out-of-track situation between the blades, and they would have flapped more than normal to try to equalise their lift. With the helicopter in forward cruise flight, the fin would have offloaded the tail rotor and provided the necessary directional stability, which may have masked the problem from the pilot. Even so, the pilot probably realised that he had a vibration and some sort of tail rotor control problem and might have adjusted the helicopter power, as would be expected, in attempting to analyse the nature of the problem in order to regain control.

2.23 With a loss of some tail rotor authority, pilots would normally keep their helicopter at a speed that maintained directional stability, and attempt a run-on landing at a suitable site, only slowing the helicopter when a landing was assured and then using throttle control to help maintain direction. Any power or speed variation could possibly account for the unexplained level right turn, with an accompanying loss of some directional control, shortly before the link finally failed. Given the nature of the failure, which restricted or prevented positive left yaw pedal control, a right turn would be expected whether induced by the helicopter or initiated by the pilot.

2.24 The random locking of the white tail rotor blade grip found during the resumed investigation, because of its damaged grip bearing, was investigated to see if it could have contributed to the bent pitch link. However, detailed examination showed the majority of the damage to the 4 tail rotor blade grip bearings occurred when the tail rotor was subject to a one-time catastrophic event, which probably was when the red tail rotor blade struck the fin. There was the possibility that some damage occurred from extreme dynamic loads from excessive flapping, when the blade struck the static stop. The heavy wear pattern observed on the inboard bearing of the red blade suggested that something significant happened at some point, which caused the functioning of the tail rotor to produce abnormal loads. This bearing wear was most likely brought about by abnormal loading, and possibly extreme dynamic loads from excessive flapping, on the tail rotor resulting from the bent white tail rotor blade pitch link. A bend would have shortened the link and moved the blade to a flatter pitch. The pilot could have compensated for the subsequent loss of tail rotor authority by making larger inputs, putting more thrust on the red blade and causing it to fly closer to the fin. The red blade at this time could have been held against the flapping (static) stop, which would have put high side loads on the blade grip bearings. Thus, the abnormal bearing wear was most likely caused by the same events that ultimately led to the failure of the white tail rotor blade pitch link through fatigue. These 2 observations, the bent pitch link and abnormal bearing wear, appear to be correlated.

Likely break-up sequence

2.25 The break-up began after the white tail rotor blade pitch link, having been earlier bent by an unknown event, failed and the red tail rotor blade struck the fin.

2.26 Once the pitch link failed, the white tail rotor blade was no longer restrained along its feathering (pitch change) axis, but was free to move in pitch and rotate about the hub yoke. Although the blade would have tended to go to a flat (feathered) pitch because of centrifugal twisting force, it would have been relatively unstable and oscillated back and forth, at least for a short time. This could be related to the "tail flicking" that was observed shortly before the accident. Rapidly changing pitch settings between the 2 tail rotor blades would have resulted, and extreme tail rotor flapping would have occurred to try to compensate and equalise the lift (thrust) between the blades. The fast forward speed of the helicopter would have accentuated this flapping as the blades would have tried to flap to equality to equalise the lift between them.

2.27 During the extreme flapping of the unrestrained white tail rotor blade, it struck the ear on its flapping (static) stop with sufficient force to bend it away from the fin. For this to have occurred, the white tail rotor blade had to flap away from the fin and the red tail rotor blade towards the fin. The bent static stop would then have allowed the red tail rotor blade to move beyond its normal limit and strike the side of the fin. The examination of the fin and red tail rotor blade clearly showed that the blade, while being driven under power, had struck the fin with sufficient force and depth to sever the left fin spar, probably during its first strike. This would have weakened the blade, and the evidence showed a second deeper strike across the top of the fin, which probably was when the red blade failed in overload.

2.28 Once the red tail rotor blade struck the fin, sufficient force would have been applied back through the red pitch link to the crosshead, and thus to the head of its crosshead bolt, to cause the crosshead bolt to pull through its castellated nut, shearing the cotter pin and ejecting the bolt from the crosshead. At the same time, the crosshead would have been levered about the white blade crosshead bolt, causing it to also fail in a similar manner. Examination of the slider, to which the crosshead attached, showed that the slider ears were bent outwards away from the red blade, and inwards toward the white blade, confirming the levering direction. The outwards bow in the more flexible retaining plate, and the bend in the pitch change rod, also helped show the levering direction.

2.29 An ejected crosshead bolt was struck and picked up by the inside face of the white tail rotor blade, and embedded in the blade. For this to have occurred, the unrestrained blade had to have moved to a negative pitch angle beyond its normal limit. Probably at about that time, the blade failed in overload near its doublers from aerodynamic loading.

2.30 After the crosshead had detached from the slider, the unrestrained crosshead would have flailed about the weakened red blade pitch link, which finally failed by dynamic overload.

2.31 The fin failed to the right in overload a short time after the red tail rotor blade had cut through its left spar. Once the fin and its attached gearbox detached from the tail boom, there would have been no directional stability and a substantial rapid forward shift in the centre of gravity, because of the loss of weight. At this point, the helicopter would have become uncontrollable and would have pitched down, yawed right and rolled from gyroscopic effect to the left. This would have induced the double main rotor mast bump, aided by the pilot's natural reaction to apply aft and right cyclic to counter the forward pitch and left roll.

2.32 The mast would have failed because of the double mast bump, and the main rotor would then have been separated from the mast. The wreckage plot indicated that the mast bump occurred at about the time the fin failed. The then unrestrained rotating main rotor spiralled forwards and struck the cabin, causing significant disruption and further break-up, before the various components finally came to rest on the ground along the wreckage trail.

Additional excerpts from the original analysis

2.33 Witness marks on the red tail rotor blade and fin were consistent with the fin being struck by the blade while it was still attached to the tail rotor assembly and rotating under power. The blue paint transfer marks on the blade match the colour of the top surface of the fin. The crush marks on the fin panelling found at the start of the wreckage trail (refer paragraph 1.9.3) also correspond with the fin having been struck by a tail rotor blade that had flexed inwards during rotation. After being struck by the red tail rotor blade, pieces of the fin were dislodged and hit by the white tail rotor blade, causing the damage and blue paint marks to the second blade. The tail rotor control cables wrapped around the drive shaft confirmed that the tail rotor continued to rotate after the initial strike.

2.34 The striking of the fin by the red tail rotor blade was not sufficient to sever the fin immediately. However, the damage inflicted by the strikes was enough to weaken the structure of the fin so that it separated a short time later.

2.35 The bolt found in the white tail rotor blade originated from the crosshead on the tail rotor assembly. The bolt matched the type used on the crosshead and the shadow wear markings corresponded to the dimensions of the crosshead. Records confirm that the crosshead bolts on ZK-HJH had not been replaced during the time the helicopter had been owned by the operator. The only other likely source for the bolt were the pitch links attachments, and these were accounted for in the wreckage.

2.36 The fin and 90° tail rotor gearbox, weighing about 50 kilograms and located 8 m aft of the helicopter's centre of gravity, had numerous functions including assisting in directional control during forward flight, thereby reducing the amount of power required by the tail rotor to counter the torque effect of the main rotor system. The effect of losing the fin, coincidental with or shortly after the loss of tail rotor thrust, would have made it very difficult, if not impossible, for the pilot to maintain control. This difficulty was probably compounded by the sudden shift forward in the helicopter's centre of gravity owing to the loss of weight and the long moment arm. The tendency would then have been for the nose of the helicopter initially to pitch down relative to the plane of rotation of the main rotor blades, and to bring about a mast bump.

Other matters

2.37 Because of the operator's misunderstanding that the requirement for a Preventive Maintenance Daily Inspection was satisfied during a pilot's normal pre-flight inspection, the daily inspection had not been carried out as prescribed. However, the daily inspection was designed for military requirements, and operators' subsequent CAA-approved alternative maintenance programmes did not necessarily include the inspection, unless the programmes required it. Because of the similarities in the 2 inspections, the pilot would have routinely examined the critical daily inspection items during his normal pre-flight inspections, especially the tail rotor and main rotor components. The pilot also did regular lubricating, which the daily inspection included. Notwithstanding this, there was no evidence that the disparity between the daily inspection and the pre-flight inspection contributed to the accident.

2.38 Because audits only sampled various activities, the CAA audits of the operator had by the time of the last audit before the accident not then specifically sampled ZK-HJH and found the daily inspection anomaly. From the audits that had been carried out, there was no prompt or concern to have caused further examination, including any inspection of the helicopter.

2.39 Although there was no evidence that the operator's misunderstanding and hence omission to comply with the military daily inspection requirement contributed to the accident, this disparity was an issue that the CAA addressed during its review after the accident, by ensuring that all operators of restricted or special category aircraft had CAA-approved maintenance programmes to follow.

2.40 When dealing with "one-off" aircraft types, especially ex-military aircraft, some flexibility was called for. The term "applicable ADs" was open to interpretation and it was often up to a LAME to determine the relevance of an AD without external guidance.

2.41 The aircraft technical log contained current technical information relevant to the aircraft. Much of the information would be repeated in other documents and remain available should the technical log be lost. However, some information, for example maintenance carried out and certified between inspections, may not be available from other sources. This information could be relevant to an investigation should an accident occur.

2.42 Ex-military aircraft can provide a cost-effective alternative to using purpose-designed or equivalent civil aircraft. However, ex-military aircraft do require specialist maintenance to continue flying.

2.43 Ex-military helicopters can be used in operations for which they were never intended. For example, while the Iroquois has an underslung load capability it was not intended for logging operations where there are repetitive large and rapid power changes. The control and maintenance requirements of these aircraft therefore need to be strictly adhered to, and reviewed from time to time to ensure the maintenance programme is appropriate and the aircraft remain airworthy.

3 Findings

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

3.1 The pilot was appropriately licensed and medically fit to conduct the flight, and there was no evidence that medical or fatigue factors contributed to the accident.

3.2 The requirement for an authorised person to do a daily inspection of the helicopter to meet the military standard had not been satisfied, because the operator had misunderstood who could satisfy that requirement.

3.3 ZK-HJH was required to be maintained to its former military schedule, and apart from a daily inspection anomaly the records indicated that it had been maintained to that schedule and its appropriate ADs.

3.4 There was no evidence to suggest that any maintenance practices had contributed to the accident.

3.5 The ZK-HJH aircraft technical log information could not be examined, because the only copy of the technical log was on board the helicopter and was destroyed in the accident by fire.

3.6 The helicopter was probably functioning normally until shortly before the accident, and was being flown at a safe height above the terrain.

3.7 There was no evidence to suggest that the conduct of the flight contributed to the accident.

3.8 The resumed investigation could not support the original investigation theory, which promoted a loss of tail rotor control that was probably caused when the crosshead had loosened, because the castellated nut on each crosshead bolt had probably not been secured.

3.9 The resumed investigation determined that there was a loss of control and subsequent in-flight break-up of the helicopter, which began when the white tail rotor blade pitch link was bent by some event and then later failed from fatigue.

3.10 The bend in the pitch link had initiated its fatigue.

3.11 The reason the pitch link was bent could not be determined; therefore the initiating cause of the accident is unknown.

3.12 Once the pitch link failed it set off a final chain of events that followed in quick succession.

3.13 Once the vertical fin failed the helicopter quickly became uncontrollable, and it is unlikely that the pilot could have recovered control of the aircraft.

3.14 Although not contributing to the accident, the term "applicable ADs" did not provide sufficient guidance for aircraft engineers to ensure that an isolated aircraft type was correctly maintained.

4 Safety Actions from the Original Investigation

4.1 As a result of the recent accidents involving ex-military helicopters, the CAA initiated a review of the certification, operational use, supply of parts and components, and oversight of this category of aircraft. The Commission supports the objects of the review, however any recommendations that may result are beyond the scope of this report.

4.2 The CAA review of restricted and special category aircraft in 2002 ensured that all such operators had an approved maintenance programme, civilian or military.

5 Safety Recommendations from the Original Investigation

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

5.1 On 10 December 2001 the Commission recommended to the Director of Civil Aviation that he:

5.1.1 review the operation of the aircraft technical log to ensure critical information is duplicated and held separately from the log, possibly with the aircraft's maintenance documents. (064/01)

5.1.2 educate licensed aircraft engineers who are holders of an Inspection Authorisation, particularly those maintaining ex-military aircraft, on airworthiness directives and the requirement for the aircraft to conform to its type certificate. (065/01)

5.1.3 ensure the New Zealand airworthiness directive schedule specifies applicable airworthiness directives called up in the ex-military type certificates data sheets. (066/01)

5.2 On 9 January 2002 the Director of Civil Aviation replied:

> All 3 recommendations are accepted as worded, and will be implemented as follows:
>
> 064/01: The review will be completed within 6 months (target date 30 June 2002), but any changes to the Rule requirements will depend on negotiations between the CAA and the Ministry of Transport.
>
> 065/01: This will be addressed in the renewal training for Inspection Authorisation holders that starts in 2002, with a letter to be sent to each Inspection Authorisation holder by 31 January 2002.
>
> 066/01: I will ensure that the Airworthiness Directive schedule specifies the appropriate Airworthiness Directives by 28 February 2002

Approved on 27 April 2006 for publication

Hon W P Jeffries
Chief Commissioner

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03-007	Hughes 369HS, ZK-HCC, in-flight power loss and emergency landing, Fox Glacier, 30 November 2003
03-006	Convair 580, ZK-KFU, loss of control and in-flight break-up, Kapiti Coast, 3 October 2003
03-004	Piper PA 31-350 Navajo Chieftain ZK-NCA, controlled flight into terrain, near Christchurch Aerodrome, 6 June 2003

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