Australian Government
Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY REPORT

Aviation Occurrence Investigation – AO-2006-006

Final

Loss of control
21 km NE Mount Gambier, SA
20 December 2006
Kawasaki KH4
VH-LFK

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Figure 1 image source: Google Earth™ mapping service

Abstract

On 20 December 2006, a Kawasaki KH4 helicopter lost collective pitch control and impacted terrain while performing agricultural aerial spray operations approximately 21 km NE of Mount Gambier, SA. The helicopter was substantially damaged but the pilot was uninjured. When the accident site was surveyed, the main rotor mast and main rotor blade assembly were found to have separated from the helicopter. They were located a short distance away.

Examination of the wreckage revealed that the helicopter's main rotor mast thrust bearing had failed catastrophically in flight. That bearing was a critical item for safe operation and continued airworthiness of the KH4. It supported the full weight of the helicopter and transferred thrust loads generated by the main rotor blades during flight.

The investigation was unable to conclusively establish the factors that led to failure of the mast bearing. No evidence was found of manufacturing or material defects. Nor was there any evidence of improper installation procedures or maintenance practice. Based on the inspection of aviation databases in Australia and North America, the main rotor mast thrust bearing failure appears to be an isolated event for the KH4-series helicopter.

Despite the low probability associated with a mast bearing failure of this type, the consequences of such an event could have been fatal for the pilot onboard. This report has been provided to Australian operators and maintainers of Kawasaki KH4 and Bell 47G3 series helicopters as a future alert for this type of occurrence.

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

The Australian Transport Safety Bureau (ATSB) is an operationally independent multi-modal bureau within the Australian Government Department of Infrastructure, Transport, Regional Development and Local Government. ATSB investigations are independent of regulatory, operator or other external organisations.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia that fall within Commonwealth jurisdiction, as well as participating in overseas investigations involving Australian registered aircraft and ships. A primary concern is the safety of commercial transport, with particular regard to fare-paying passenger operations.

The ATSB performs its functions in accordance with the provisions of the *Transport Safety Investigation Act 2003* and Regulations and, where applicable, relevant international agreements.

Purpose of safety investigations

The object of a safety investigation is to enhance safety. To reduce safety-related risk, ATSB investigations determine and communicate the safety factors related to the transport safety matter being investigated.

It is not the object of an investigation to determine blame or liability. However, an investigation report must include factual material of sufficient weight to support the analysis and findings. At all times the ATSB endeavours to balance the use of material that could imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner.

Developing safety action

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues in the transport environment. The ATSB prefers to encourage the relevant organisation(s) to proactively initiate safety action rather than release formal recommendations. However, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organisation, a recommendation may be issued either during or at the end of an investigation.

The ATSB has decided that when safety recommendations are issued, they will focus on clearly describing the safety issue of concern, rather than providing instructions or opinions on the method of corrective action. As with equivalent overseas organisations, the ATSB has no power to implement its recommendations. It is a matter for the body to which an ATSB recommendation is directed (for example the relevant regulator in consultation with industry) to assess the costs and benefits of any particular means of addressing a safety issue.

About ATSB investigation reports: How investigation reports are organised and definitions of terms used in ATSB reports, such as safety factor, contributing safety factor and safety issue, are provided on the ATSB web site www.atsb.gov.au.

FACTUAL INFORMATION

History of the flight

On 20 December 2006, at approximately 0915 Central Daylight-saving Time[1], while performing agricultural aerial spray operations, the pilot of a Kawasaki KH4 helicopter, registered VH-LFK (LFK), encountered flight control difficulties that resulted in the helicopter impacting terrain approximately 21 km NE of Mount Gambier, SA. The pilot was uninjured.

The pilot reported that he first encountered control difficulties while turning at about 20 ft above ground level during the final phase of a clean-up run[2] around the potato crop that he had been spraying (Figure 1). A loud bang was heard followed by airframe vibration and a complete loss of the helicopter's collective pitch control. At that instant, the helicopter immediately began to descend. The pilot was able to guide the helicopter as it descended using inputs to the cyclic control stick and the tail rotor control pedals. The helicopter landed heavily, tail first, and was substantially damaged from exposure to ground impact forces.

The pilot also reported that after completing the clean-up run, he had planned to climb to 500 ft for a ferry flight to the next property to be sprayed.

After consultation with investigators from the Australian Transport Safety Bureau (ATSB), the helicopter was recovered by the pilot/owner and transported and stored in a neighbouring farm machinery shed for later examination not far from where the crash occurred.

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1 The 24-hour clock is used in this report to describe the local time of day, Central Daylight-saving Time (CDT), as particular events occurred. Central Daylight-saving Time was Coordinated Universal Time (UTC) + 10.5 hours.

2 The clean-up run is the action performed during agricultural aerial spray operations whereby the crop boundary/perimeter and any areas that were missed during the normal run are resprayed to ensure complete coverage of the product being applied.

Figure 1: Satellite image of the paddock that was being sprayed, overlaid with LFK's reported track prior to impacting the ground

Image Source: Google Earth™ mapping service

Wreckage and impact information

Accident site

A survey of the accident site showed that the helicopter had impacted an irrigated[3], soft-soil potato crop (Figure 2). Ground scars from the helicopter skids were located just within the paddock fence line. A ground mark to the rear of the skid impressions was consistent with a tail rotor impact.

A second set of skid impressions was found within the paddock approximately 4 m forward of the first set. This indicated that the helicopter had bounced after initially impacting the ground, and then travelled a short distance forward before coming to rest in the soft soil.

Discussions with the pilot revealed that the main rotor assembly, including the main rotor blades, the hub and the mast, had detached from the helicopter during the accident sequence. These items were found by the pilot during the recovery, approximately 14 m from where the helicopter had come to rest.

Numerous small freshly broken branches were observed in the nearby eucalyptus tree plantation adjacent to the accident site. The broken foliage, which was approximately 5 m above the ground, indicated that LFK had made minor contact with the tree foliage during the final few seconds of flight. A thorough search of the

3 A centre pivot irrigation system had been used to irrigate the paddock using a long-wheeled arm which rotated around a pivot. A circular area centred on the pivot was irrigated, and created a circular pattern in the crop when viewed from above.

site found no further evidence of installations or component assemblies from the helicopter. All items had been recovered by the operator.

Figure 2: The accident site showing skid impressions (arrowed) where LFK first impacted terrain

Aircraft information

The accident helicopter was a Kawasaki Heavy Industries Limited model 47G3B-KH4 (KH4), serial number 2133, powered by a non-turbo Lycoming VO-435 six cylinder engine. The helicopter had been manufactured in 1972 and had subsequently accumulated 12,288 hours total time in service (TTIS).

The KH4-series helicopter had originally been made in Japan under licence based on the three-seat, Bell Helicopter Company Bell 47G-3 design. Although virtually identical to the Bell 47G-3, changes to the KH4 included a larger cabin that increased the passenger seating capacity to three, the addition of a modified Lycoming engine, and a larger fuel tank.

The helicopter had first been placed on the Australian civil aviation register in May 1990. It had been owned and operated throughout northern Australia performing work in both charter and aerial roles for 11 years. In June 2001, it was bought by the South Australian operator involved in this occurrence.

In August 2001, among other maintenance, a modified control system that removed the stabiliser bar from the main rotor system and a full-flow engine oil filter were fitted. In December 2002, an Isolair aerial spray distribution system was fitted for agricultural aerial work. That spray system consisted of two side-mounted liquid storage hoppers and an underslung extendable spray boom.

In August 2003 the operator was granted approval by the Civil Aviation Safety Authority to operate the helicopter under a restricted category of airworthiness for the purpose of agricultural operations.

The current operator had been utilizing the helicopter for agricultural aerial spray work that involved a duty cycle of, on average, around four flights per hour. Each flight consisted of filling the spray hoppers to full, followed by a transit flight to the client's crop, and then a return flight back to base to replenish the hoppers.

Damage

Examination of the helicopter was performed inside a machinery shed on a neighbouring property with it still loaded on the back of the recovery truck (Figure 3).

Body and landing gear

The helicopter's main cabin structure and landing gear was relatively undamaged. Both the left and right skids displayed evidence of minor upward bending. The tail boom frame had completely separated just forward of the centre fuselage frame assembly with buckling of the supporting cross tubes and main tubes evident. All damage to the airframe was characteristic of a moderately hard landing whereby the tail section had impacted the ground first.

Figure 3: LFK as recovered from the accident site

Main rotor assembly

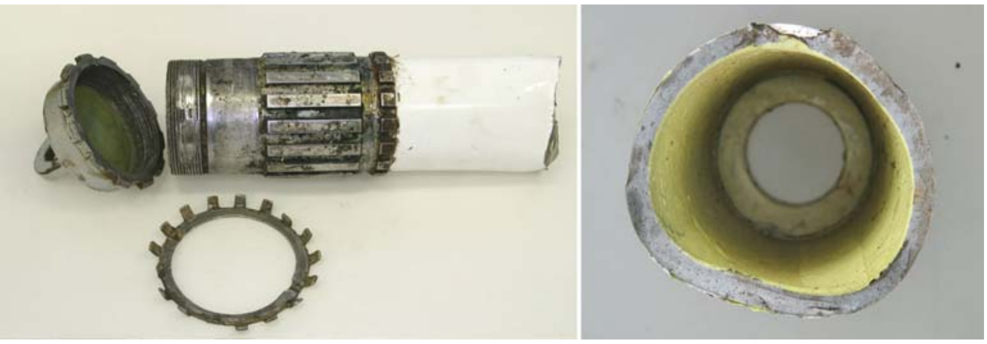
The main rotor blades, head and mast assembly had separated from the helicopter during the accident sequence and were found embedded in soil approximately 14 m from the helicopter fuselage. Both main rotor blades were damaged, with combined chord-wise buckling and longitudinal bending clearly apparent. No evidence was found to indicate that the blade damage had been produced in-flight prior to the accident.

Main rotor mast and controls

Examination of the main rotor mast showed that it had fractured toward the upper end of the assembly (Figure 4). The mast, which was tubular in section, was deformed out-of-round at the point of fracture. The fracture surfaces were clean and fresh with no visible evidence of pre-existing defects or progressive cracking.

The mast cover nut, which normally clamped the main rotor hub and blades to the main rotor mast, had detached from the upper portion of the broken mast. The internal threads of the cover nut had stripped from shear overload. Corresponding damage to the mating threads on the uppermost end of the fractured mast where the cover nut had been secured was also found. Such thread damage, coupled with the mast deformation at the point of fracture, was indicative that these components had been subject to considerable forces throughout the accident sequence.

Figure 4: The detached mast cover nut (left) and fractured upper portion of the main rotor mast (right)



Note the substantial deformation to the tubular mast section at the point of fracture

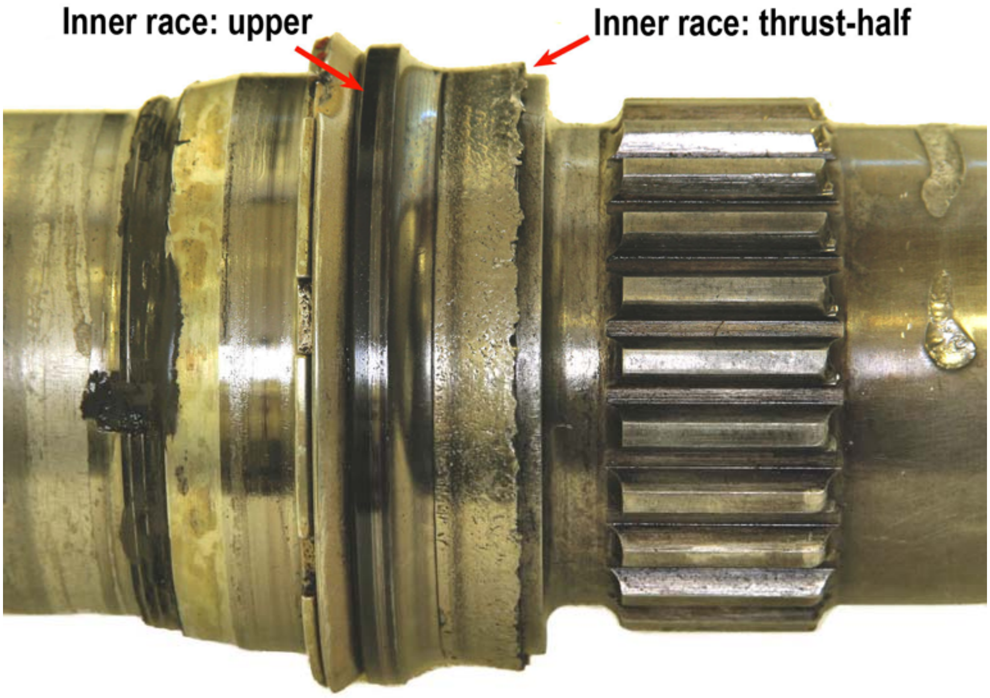
Main rotor mast thrust bearing

Further examination of the main rotor mast revealed that the mast thrust bearing had catastrophically failed. The bearing outer race, which was still secured within the upper throat of the transmission housing, displayed many contact marks around the running surfaces. The split inner race, which was still secured to the mast, was severely disrupted with gross physical damage to the thrust-half section (Figure 5). Examination of the recovered spherical bearing balls from the mast bearing showed a worn and irregular surface similar in texture to the rolling surfaces observed on the split inner lower race.

The general features of the damaged mast bearing indicated that gross degradation had occurred during main rotor operation.

The prime function of the mast bearing was to provide support to the main rotor mast and support the axial thrust loads generated from the main rotor system during service. Moreover, the gross weight of the helicopter while in flight was suspended from the mast bearing, meaning that a serviceable mast bearing was integral for continued airworthiness and safe operation of the KH4 helicopter during flight.

Figure 5: Close-up of LFK's mast as-recovered noting the extensive loss of curvature and physical damage to the thrust-half section of the inner race



The split inner race of the main rotor mast thrust bearing was secured to the mast using a lock nut and fingered lock washer. When the mast was disassembled[4], the breakaway torque required to unfasten the mast bearing retaining nut measured approximately 4800 in-lbs.

Instructions listed by the manufacturer stated that during reassembly, the mast bearing retaining nut should have been fastened to a final torque ranging between 3000-3300 in-lbs[5]. While the breakaway torque value for the lock nut was not consistent with the manufacturer's specifications, the lock nut threads had been covered with sealant and the mast had been exposed to significant distress as a result of the accident. Such factors are known to raise the breakaway torque measurement.

The mast disassembly also revealed that the 'O' identifiers that had been stamped onto the upper/lower faces of each race were aligned together. In part, the manufacturer stated that during mast bearing reassembly[6]:

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4 The mast disassembly was performed under supervision of the ATSB at a Brisbane helicopter maintenance facility, with representatives from both CASA and the helicopter operator present.

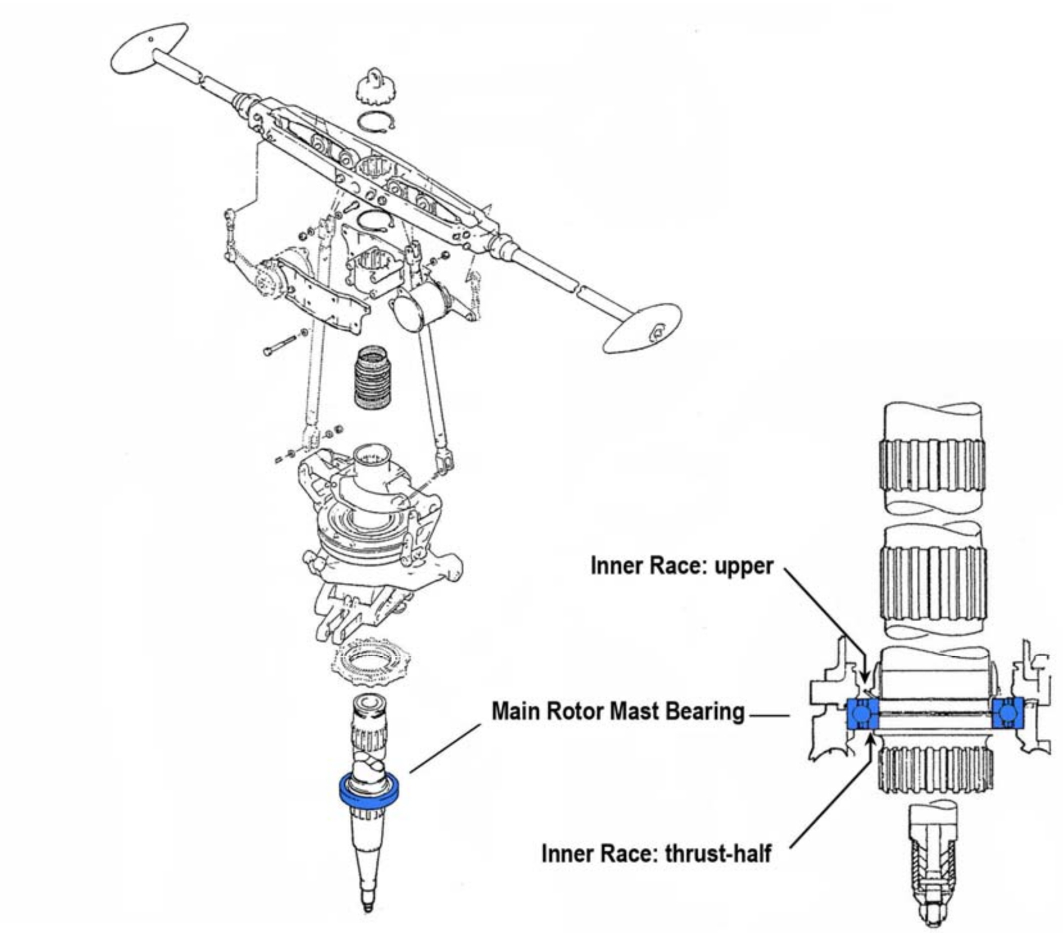
5 Kawasaki Heavy Industries Ltd, Model 47G3B-KH4 Maintenance and Overhaul Instructions, Section 3, Paragraph B, Page 3-24.

6 Kawasaki Heavy Industries Ltd, Model 47G3B-KH4 Maintenance and Overhaul Instructions, Section 3-53, Paragraph A, Page 3-24.

> …In installing the bearing care should be taken to align the "O" marks on the inner race within ±5 degrees of each other. Adherence will ensure that the high and low points in the split inner race groove have been mated. This will provide a smoother operating bearing and hence provide longer bearing life...

Proper alignment of the bearing identifiers indicated that the mast bearing had been installed in accordance with the manufacturer's instruction. Figure 6 illustrates the KH4 mast controls and the position of the mast bearing.

Figure 6: Illustration of the KH4 mast controls showing the main rotor mast and the mast thrust bearing in detail



Note: LFK was not fitted with a stabiliser bar

Flight controls – pitch mechanism

On-site examination of the flight controls established complete mechanical continuity between the collective pitch stick/throttle and the upper swashplate yoke. Manipulation of the collective stick failed to reveal any connectivity defects to any of the components comprising the pitch control assembly (such as the bell cranks, control rods, eye ends, linkage bolts) that could have contributed to the accident. However, connectivity at the point between the swashplate yoke and the rest of the swashplate assembly had been disrupted. Both arms of the yoke had fractured during the accident at the innermost bearing where the left and right swashplate connecting link had been bolted.

Other damage included break up of the pitch control swashplate support housing. A complete circumferential fracture had occurred through the mounting flange above where it had been bolted to the upper throat of the transmission. Another area of the support housing that had fractured was adjacent to where the pitch control yoke bearing was installed. At this location, the housing had fractured in a vertical orientation allowing the pitch control yoke and yoke bearing to detach.

The fracture surfaces from each section of the broken support housing and swashplate yoke arms were examined and only features consistent with that of a gross overload event were observed.

It was noted that the collapse of the main rotor mast thrust bearing, combined with fragmentation of the swashplate support housing where it had been mated to the transmission housing, would have resulted in unrestrained vertical movement of the main rotor mast and blade assembly.

Flight controls – cyclic mechanism

Mechanical continuity was established with the cyclic system. Manipulation of the cyclic control sticks did not reveal any defects to the components that could have contributed to the accident.

Transmission

Several bearing balls from the collapsed main rotor mast thrust bearing had fallen into the upper planetary gears of the transmission. Three of the balls had been caught between the upper transmission gear pack and the transmission housing. As a result, each ball had been partially punched outward through the case from inside the transmission.

Disassembly[7] of the transmission revealed that a piece of the mast bearing cage and five bearing balls were lodged between the upper ring and spider gear pack assembly. Some of the teeth within the spider gears had sustained damage due to obvious contact with the loose bearing elements. Despite the tooth damage, the entire transmission gear train could be rotated by hand. No evidence was found of a transmission gear failure or condition that might have otherwise contributed to the occurrence.

It was noted that all components within the transmission were lightly coated with oil. The oil galley within the upper transmission housing that supplied lubricating oil from the engine to the mast bearing was examined. No blockage within the main mast bearing oil jet was found.

Powerplant related systems

The KH4 oil lubrication system lubricated both the engine and transmission components. Oil was supplied from an external tank to the engine oil pump and fed to the upper transmission by an external pressure line that directed oil to the main

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7 The transmission disassembly was performed under supervision of the ATSB at a Brisbane helicopter maintenance facility, with representatives from both CASA and the helicopter operator present.

mast thrust bearing. The oil system incorporated a full-flow oil filter. A non-electrified magnetic single-pole chip detector that was designed to remove and collect ferrous particles from the oil supply, had been incorporated into the sump drain plug. A significant quantity of accumulated metallic chips was found on the plug (Figure 7).

Subsequent analysis[8] of the magnetic debris revealed a chemical composition that was consistent with that of high-carbon SAE-AISI M-50 alloy steel, which was the specified material for the mast bearing steel.

Figure 7: The magnetic drain plug showing metallic particles amassed around the tip

ATSB metallurgical examination – mast bearing

A detailed metallurgical examination of the failed main rotor mast thrust bearing was performed at the ATSB engineering facilities in Canberra. The bearing was a ‘thrust-type’ design that incorporated a two-piece split inner race, a machined bearing cage and 20 spherical bearing balls. Identifiers indicated the bearing to be manufactured by Fafnir (Torrington Bearings) with Kawasaki part number 47.620.973.1 and serial number 4690 engraved on the non-contact surfaces.

Magnified examination of the thrust-half inner race revealed that a major section of the raceway curvature had collapsed. While most of the damage had been over rolled through contact with the bearing balls, a small section of inner raceway spalling was found (Figure 8). Similar spalling was found on the outer race.

Examination of the fractured bearing cage revealed elongation and wear to the cage pockets. Such deformation signalled unstable bearing ball and cage interaction had occurred during the final phase of the bearing life. Close examination of the bearing balls showed extensive spalling and over-rolling of the surfaces (Figure 9).

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8 Chemical analysis of the debris was performed at the ATSB Canberra engineering facility using a scanning electron microscope equipped with an energy dispersive spectrometer.

Chemical analysis[9] and hardness testing of each bearing element was performed and no anomalies were found with respect to the manufacturer's specifications. The hardness ranged between 741 and 769 Vickers[10] (~62 Rockwell C [11]) and the chemistry was consistent with that for AISI-SAE M-50 high-carbon alloy steel. Metallographic examination of the microstructure from each bearing element revealed a through-hardened steel microstructure of uniform finely tempered martensite. No irregularities or material defects such as non-metallic inclusions[12] were observed that could have otherwise contributed to the bearing failure.

Figure 8: Close view of the thrust-half inner race showing a location of spalling (arrowed) along the rolling surface

9 Spectrometer Services Pty. Ltd. Report Reference Number 27146, 16 February 2007.

10 The Vickers Hardness number is a standard method for measuring the hardness of a material.

11 Rockwell C (HRC) refers to the Rockwell Hardness number and is a standard method for measuring the hardness of a material.

12 An inclusion is a particle of foreign material in a metal matrix and is considered undesirable.

Figure 9: The fragmented cage and some of the bearing balls as-recovered from the mast bearing assembly

Maintenance

Kawasaki KH4 maintenance requirements – mast bearing

In support of ongoing airworthiness and continued safe operation, the manufacturer's maintenance and overhaul manual[13] provided guidance to operators and maintainers for servicing the KH4 helicopter. The main rotor mast was maintained on-condition, requiring a periodic inspection and replacement if found unserviceable. Maintenance on the KH4 helicopter consisted of the following schedule:

1. Daily inspection – required prior to the first flight of each day
2. Periodic inspection – required at the 50, 100, 300, 600 and 1,200-hour intervals
3. Special inspections – required for unusual events, such as a hard landing or sudden rotor stoppage
4. Mandatory retirement schedule – for life limited components.

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13 Kawasaki Heavy Industries Limited, Maintenance and Overhaul Instructions, Model 47G3B-KH4, Section 1-15.

With particular regard to the main rotor mast thrust bearing, the 50-hour inspection[14] required the engine oil to be changed and the engine oil filter to be inspected and cleaned. If metal particles were found, the manual mentioned the following:

> …If metal particles are found, locate and remove the cause. In such a case, inspect thrust bearing of main rotor mast carefully. If it is found unserviceable, replace it.

Aside from the accomplishment instructions listed for the 50-hour inspection, the 100 and 300-hour inspections contained no specific reference for examination of the mast bearing.

The 600-hour inspection[15] added further detail to the 50, 100 and 300-hour inspections, with the need for closer inspection of the mast bearing. Paragraph 5, under the heading Mast and Controls, stated:

> Visually inspect, all areas of the mast, for indication of damage. Remove the retaining bolts of transmission cap and raise swashplate support and transmission cap sufficiently to rotate and carefully check main rotor mast bearing for smoothness of operation, excessive radial and/or axial looseness and verification that the retaining nut is secured properly.

The 1,200-hour inspection[16] was the most rigorous inspection schedule, and in addition to the requirements of the 50, 100, 300 and 600-hour schedule, listed the following part quotation in regard to the main mast bearing:

> MAST AND CONTROLS
>
> 1. Remove, disassemble and visually inspect all parts in accordance with the following steps:
>
> c. Inspect mast and mast bearing for wear, cracks, foreign matter, brinelling, and smooth operation.

The maintenance and overhaul manual also listed special instructions for inspection of the mast bearing in the event of a hard landing. For such an occurrence, the main rotor mast was required to be removed and the mast thrust bearing inspected for damage.

VH-LFK maintenance

LFK had accumulated 12,288 hours total time in service (TTIS) up until the accident. In June 2001 shortly after the ownership of LFK was transferred to the current operator, a 1,200 hour inspection and complete overhaul of the helicopter was performed (10,873.6 hours TTIS). The reported amount of work completed during that period was significant with complete disassembly and inspection of the helicopter having been carried out. The records indicated that at that time, the main rotor transmission was overhauled and numerous new components were installed,

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14 Kawasaki Heavy Industries Limited, Maintenance and Overhaul Instructions, Model 47G3B-KH4, Section 1-37/1-38.

15 Kawasaki Heavy Industries Limited, Maintenance and Overhaul Instructions, Model 47G3B-KH4, Section 1-43.

16 Kawasaki Heavy Industries Limited, Maintenance and Overhaul Instructions, Model 47G3B-KH4, Section 1-48.

including a new main rotor mast thrust bearing, serial number (S/N) 4190. That bearing accumulated a further 1414.8 hours of service before its failure led to the accident.

The component worksheets covering the maintenance performed during the June 2001 overhaul activities indicated that a mast bearing with S/N 3082 was inspected and was eligible for installation into the upper transmission of the helicopter (VH-LFK). The mast bearing that had failed was identified as S/N 4190. It could not be established why a discrepancy in the written records existed between the bearing that was intended to be installed (S/N 3082) and the bearing that had been installed (S/N 4190). While the serial number mismatch discrepancy existed, it was not considered to be a contributing factor in the failure event.

The last service performed in the mast area of the helicopter was shortly after the most recent 1,200 hour service when at 11,994 hours TTIS, oil was found leaking from the mast seal. The leak was stopped after the replacement and installation of a new mast seal, washer and mast nut.

The last recorded maintenance activity prior to the accident was the 300-hour scheduled service on 20 October 2006, some 24 operating hours prior to the accident. The presence of metal flakes in the oil filter at this check would have been a good indicator that internal engine damage had been occurring. However, the maintenance release for the helicopter contained no mention of any irregularities when the oil was changed and the oil filter was inspected.

History of related mast bearing failures

In response to this occurrence, a search of Australian and North American safety databases[17] was performed for evidence of similar failures (Kawasaki part number 47.620.973.1). No records involving failure of other main rotor mast thrust bearings were found, which indicated that this may be an isolated event.

As previously discussed, the Kawasaki KH4 had been originally designed from the Bell 47G-3 series helicopter. Many parts were commonly shared between both helicopter types. The main rotor mast thrust bearing was one such item with the same detail and design as the Kawasaki bearing. Bell was consulted and their databases searched which revealed that three Bell 47 mast bearing failures had occurred (1972, 1976 and 2001). No specific detail was available regarding each event.

17 Australian Civil Aviation Safety Authority (CASA), the Australian Transport Safety Bureau (ATSB), United States Federal Aviation Administration (FAA), U.S. National Transportation Safety Board (NTSB) and Transportation Safety Board of Canada (TSB).

ANALYSIS

Accident sequence

The pilot flying the helicopter was fortunate that the main rotor mast thrust bearing failure occurred at relatively low altitude. He was preparing to climb from 20 ft to 500 ft to ferry the helicopter to another property when the failure took place. Had the loss of control occurred at higher altitude, the consequences of the accident would almost certainly have been more severe.

The ATSB investigation established that a catastrophic failure of the main rotor mast thrust bearing (Kawasaki part number 47.620.973.1) was the primary contributing factor that led to the KH4 helicopter's loss of control and subsequent ground impact. The mast bearing was a critical item for continued airworthiness and safe operation of the KH4. That bearing supported the gross weight of the helicopter during flight, and also transferred main rotor thrust loads from the mast to the upper case of the transmission.

Once the bearing failed, the main rotor mast was able to disengage from the transmission, which allowed the full weight of the helicopter to be transferred onto the control rods that connected the swashplate to the main rotor assembly. At that point during the flight, the pilot's control of the helicopter's main rotor control, which included the collective pitch and cyclic mechanisms, would have been lost.

The mast and main rotor blade assembly were found some 14 m from the body of the helicopter. It was evident that separation of the mast and rotor assembly had occurred as a result of the mast bearing failure. Once the mast bearing had failed, the loss of vertical and lateral support normally provided by the bearing would have allowed severe out-of-balance forces to develop within the rotor system. While it was reported by the pilot that the main rotor blade assembly had separated from the helicopter immediately prior to impacting the ground, it was also considered possible that separation of the main rotor blade assembly had occurred as a physical response to the helicopter impacting the ground.

Bearing failure

The investigation was unable to conclusively identify all the contributing factors that could explain the mast bearing failure. Such a failure appeared to be an infrequent event within the long serving worldwide KH4-series helicopter fleet. The bearing had performed satisfactorily for a considerable time in service and it was not considered a premature failure. The contributing factors that produce bearing failures are often difficult to identify. Due to the severe damage to the bearing, the evidence that might have indicated what happened in the early stages of the failure was lost.

The thrust-half of the inner race had sustained gross physical damage and dimensional changes which led to the collapse. Some spalling was found on the raceway surfaces and signified that the bearing had reached the end of its rolling-contact fatigue life.

Metallurgical analysis of the bearing found it to conform to the manufacturer's engineering specifications. No evidence was found of any material or manufacturing defect that could have contributed to the failure. There was no evidence found to suggest that the bearings had been improperly installed.

The service life of a bearing can be influenced by numerous factors including; misalignment during installation, poor handling, contamination, extremes of temperature and moisture, and insufficient/inadequate lubrication. The dynamic loading imparted during service is also known to have a considerable effect on bearing life. Increased loads will result in a reduction in service life. The duty cycle for the accident helicopter consisted of approximately four flights per hour and a high gross weight was carried by the helicopter during those aerial spray flights. While the magnitude and frequency of loading from such service may have affected the life of the mast bearing, no evidence was found to link the type of helicopter operation and the failure occurrence.

Helicopter maintenance

In terms of regular maintenance activity, the operator's records indicated that the 50-hour recommended oil change and oil filter inspection had been performed prior to the occurrence. While the investigation could not determine the veracity of these actions, and indeed the adequacy of previous maintenance and inspections, the available evidence indicated the failure was not related to poor maintenance practice.

The 50-hour oil change and oil filter inspection is a relatively frequent event with regard to maintenance activity for the KH4 helicopter. In the absence of an electrified cabin-mounted metal chip warning system, the oil filter inspection carried out at the 50-hour interval is the primary method for operators and maintainers to assess the serviceability of the helicopter's internal engine components. The detection of metallic debris during that service indicates that engine components are failing. The KH4 maintenance manual provided a specific recommendation to inspect the main rotor mast thrust bearing if such debris was found within the oil filter. The value of that filter inspection should not be underestimated. The timely detection of any metallic debris may signify a damaged main rotor mast thrust bearing, which is a critical item required for continued safe flight.

In view of the apparent absence of other similar failures in the inspected databases, and the absence of any evidence of material or manufacturing anomalies in the failed bearing, the failure appears to be an isolated event and unlikely to be an indicator of an airworthiness issue with the helicopter type.

FINDINGS

From the evidence available, the following findings are made with respect to the loss of control of the Kawasaki KH4 helicopter, and should not be read as apportioning blame or liability to any particular organisation or individual.

Contributing safety factors

- While flying at low altitude, the pilot encountered flight control difficulties and was unable to stop the helicopter impacting the ground.
- The flight control difficulties were a direct consequence of the catastrophic failure of the helicopter's main rotor mast thrust bearing, which allowed the main rotor mast to disengage from the transmission and negate the effectiveness of the pitch and cyclic change mechanisms.

Other key findings

- The investigation was unable to conclusively identify the directly contributing factors that led to the mast thrust bearing failure. In view of the apparent absence of other similar failures in the inspected databases, and the absence of any evidence of material, maintenance or manufacturing defects, the failure appears to be an isolated event and unlikely to be an indicator of an airworthiness issue with the helicopter type.