CAA OCCURRENCE 14/1159

MD HELICOPTERS INC. 500N

ZK-HQP

Collision With Terrain Following Engine Failure

Wharerata Forest, Gisborne

20 MARCH 2014

Source: Operators Web Site

Foreword

New Zealand's legislative mandate to investigate an accident or incident are prescribed in the Transport Accident Investigation Commission Act 1990 (the TAIC Act) and Civil Aviation Act 1990 (the CAA Act).

Following notification of an accident or incident, the Transport Accident Investigation Commission (TAIC) may conduct an investigation. The Civil Aviation Authority (CAA) may also investigate subject to Section 72B(2)(d) of the CAA Act which prescribes the following:

> **72B Functions of Authority**
>
> (2) The Authority has the following functions:
>
> > (d) To investigate and review civil aviation accidents and incidents in its capacity as the responsible safety and security authority, subject to the limitations set out in section 14(3) of the Transport Accident Investigation Commission Act 1990

The purpose of a CAA safety investigation is to determine the circumstances and identify contributory factors of an accident or incident with the purpose of minimising or reducing the risk to an acceptable level of a similar occurrence arising in the future. The investigation does not seek to ascribe responsibility to any person but to establish the contributory factors of the accident or incident based on the balance of probability.

A CAA safety investigation seeks to provide the Director of CAA with the information required to assess which, if any, risk-based regulatory intervention tools may be required to attain CAA safety objectives.

Contents

Page Number

Table

Figures

Glossary of abbreviations

CAA	Civil Aviation Authority
CAR(s)	Civil Aviation Rule(s)
CMM	Coordinate Measuring Machine
CPL(H)	Commercial Pilot Licence (Helicopter)
ELT	Emergency Locator Transmitter
FAA	Federal Aviation Administration
HCF	high cycle fatigue
hp	horsepower
hr(s)	hour(s)
m	metre(s)
NM	nautical miles
NTSB	National Transportation Safety Board
NZDT	New Zealand Daylight Time
P/N	part number
S/N	serial number
SW	southwest
SSW	south southwest
TSN	Time Since New
TSO	Time Since Overhaul
USA	United States of America
UTC	Coordinated Universal Time
VFR	Visual Flight Rules
WGS 84	World Geodetic System 1984

Data summary

Aircraft type, serial number and registration:	MD Helicopters Inc. Model 500N, S/N LN093, ZK-HQP
Number and type of engines:	1 Rolls Royce Model 250-C20R/2, 450 hp turbo-shaft engine
Year of manufacture:	2000
Date and time of accident:	20 March 2014, approximately 1005 hrs[1]
Location:	Wharerata Forest, approximately 19 NM SSW of Gisborne Latitude[2]: S 38º 57′ 57.6″ Longitude: E 177º 52′ 34.6″
Type of flight:	Commercial, Day, VFR
Persons on board:	Crew: 1 Passenger: 1
Injuries:	Crew: 1 Seriously Injured Passenger: 1 Fatal
Nature of damage:	Aircraft destroyed
Pilot's licence:	CPL(H)
Pilot's age:	49 years
Pilot's total flying experience:	13,621 hours total flight time 2,470.1 hours flight time on type
Information sources:	Civil Aviation Authority Field Investigation
Investigator in charge:	Mr M Harris

[1] All times are NZDT (UTC + 13 hrs).
[2] World Geodetic System (WGS 84) co-ordinates.

Executive summary

The Civil Aviation Authority (CAA) was notified of the accident by the Rescue Coordination Centre of New Zealand at 1100 hours (hrs), 20 March 2014. The Transport Accident Investigation Commission were notified and elected not to investigate. The CAA initiated a safety investigation the same day.

The helicopter, ZK-HQP, an MD Helicopters Inc. 500N, was engaged in a commercial external sling load operation in the Wharerata Forest approximately 19 nautical miles (NM) south southwest (SSW) of Gisborne. The pilot and passenger, a forestry foreman, were to ferry equipment into an area where forestry contractors were preparing for a controlled burn-off operation. After dropping off the equipment, the helicopter began the return journey to the loading site.

As the helicopter climbed out of a valley, the helicopter lost engine power and the pilot immediately executed an autorotation, releasing both the long line and cargo net from the helicopter. During the autorotation the pilot was unable to clear the steep sloping terrain and the helicopter struck the side of the ridge, facing downhill, coming to rest approximately 60 metres (m) down the slope.

The CAA safety investigation determined that the loss of engine power was caused by a catastrophic compressor failure. The compressor failure was caused by the release of a single compressor blade on the first stage compressor wheel, due to a high cycle fatigue crack.

The accident highlights the hazards involved in low level operations and the considerations that operators and pilots should take into account when conducting risk assessments and determining the safest way of accomplishing the task.

As a result of this accident, four safety actions have been raised.

1. Factual information

1.1 History of flight

1.1.1 On 20 March 2014, the pilot of ZK-HQP, was required to conduct an external sling load operation, to ferry equipment into an area of the Wharerata Forest, so that forestry workers could set up for a controlled burn-off operation.

1.1.2 At approximately 0800 hrs the operator's ground crewman fuelled the helicopter and positioned it in the hangar. The pilot then commenced the pre-flight checks.

1.1.3 Once the pre-flight checks had been completed the helicopter was moved to the lift off area and the pilot started the engine. Upon start up the engine chip detector indicator was illuminated and the helicopter was subsequently shut down.

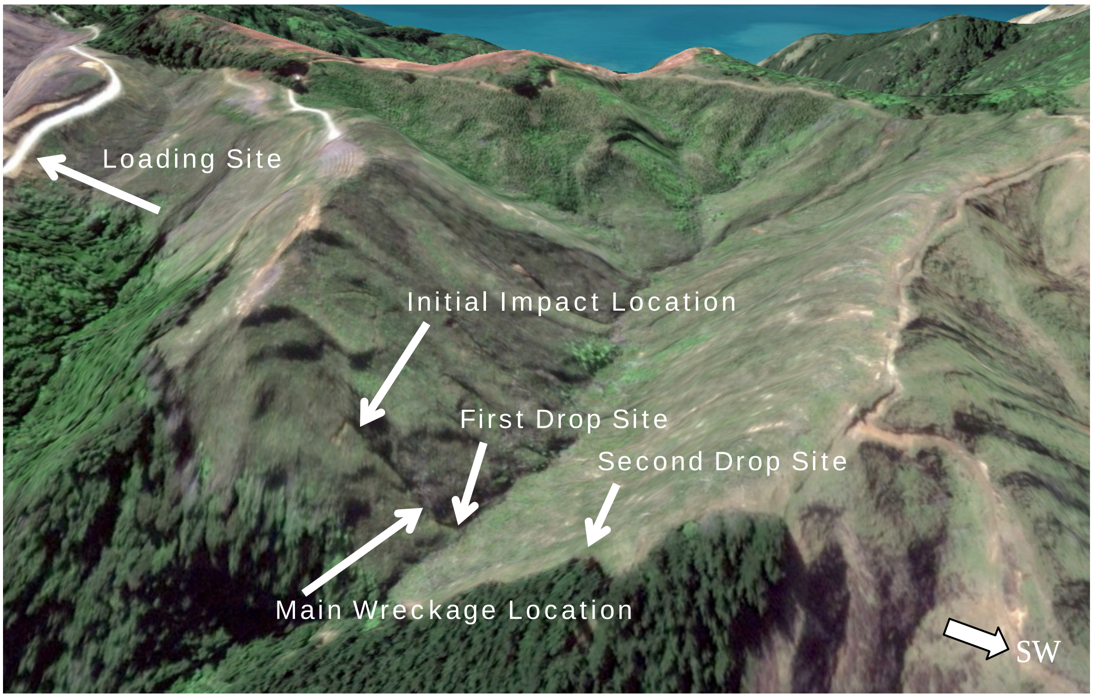
1.1.4 The pilot accessed the engine compartment and removed the engine chip detector magnetic plug. The magnetic plug was visually inspected, cleaned of metallic material and the cloth retained for the maintenance engineer. After refitting the magnetic plug and confirming the engine chip detector indicator had extinguished, the helicopter was restarted. The helicopter was ground run and then the pilot brought the helicopter into a hover. The engine chip detector indicator remained unlit so the pilot elected to continue with the planned operation.

1.1.5 At 0908 hrs the helicopter departed Gisborne Aerodrome and headed for the Wharerata Forest and the designated loading site. The flight took approximately 15 minutes with no unusual indications noted by the crewman or the pilot during the flight.

1.1.6 After landing at the loading site, the equipment was loaded into a cargo net and the crewman attached the cargo net to the helicopter using a 150 foot long line. Once the external sling load was secured and the release mechanisms tested, the crewman assisted the passenger into the right seat of the helicopter, next to the pilot who was occupying the left seat. The passenger secured himself into the right seat with the waist belt.

1.1.7 The crewman and other witnesses observed the helicopter lift off at approximately 0950 hrs and depart toward the first drop site at the bottom of a valley approximately half a nautical mile to the southwest (SW) of the loading site.

1.1.8 Forestry contractors reported the helicopter arriving a short time later at their location in the valley, the first drop site (see Figure 1). Once this first drop had been completed the helicopter flew the rest of the equipment up to the second drop site. The second drop site was approximately 70m further to the SW, on the face of the ridge, near a tree line. A forestry contractor unloaded the rest of the equipment at this site. After the cargo net was detached from the long line the pilot maneuvered the helicopter away from the drop site so that the remote hook did not pose a hazard to the contractors on the ground.



Source: Google Earth

Figure 1:
ZK-HQP approximate drop sites and wreckage locations.

1.1.9 Once all the equipment had been unloaded from the cargo net the helicopter returned and the empty cargo net was re-secured to the long line. The helicopter was now facing the tree line on a SW heading with tall trees to the pilot's right. Considering these trees a hazard, the pilot initiated a climbing left hand turn until the helicopter was facing approximately 180 degrees from where it started, to head back across the valley towards the loading site.

1.1.10 As the helicopter climbed out of the valley, various witnesses described hearing the helicopter make a bang sound similar to a backfire, accompanied by an audible slowing-down of the rotor blades. The witnesses noted 'it was obviously in trouble'.

1.1.11 The pilot stated that he heard a loud bang, felt the helicopter oscillate and yaw to the left. The pilot immediately entered into autorotation and activated the emergency cargo hook release mechanism. The long line and cargo net departed the helicopter, with both dropping onto the face of the ridge.

1.1.12 Witnesses also described the helicopter continuing to yaw to the left while descending. During the descent the pilot was unable to clear the steep sloping terrain and the helicopter struck the face of the ridge, facing downhill and subsequently rolled a number of times.

1.1.13 Once the helicopter had come to rest, the pilot egressed the wreckage and was assisted by the forestry contractors until medical assistance arrived. The passenger did not survive the accident and was found in the helicopter, still strapped into the seat.

1.1.14 The accident occurred at approximately 1005 hrs, approximately 19 NM SSW of Gisborne, in the Wharerata Forest, Latitude S 38º 57′ 57.6″ Longitude E 177º 52′ 34.6″.

1.2 Injuries to persons

Injuries	*Crew*	*Passengers*
Fatal	0	1
Serious	1	0

Table 1:
Injuries to persons

1.3 Damage to aircraft

1.3.1 The helicopter was destroyed.

1.4 Other damage

1.4.1 None.

1.5 Personnel information

1.5.1 At the time of the accident the pilot held a Commercial Pilot Licence (Helicopter) with a Grade 1 agricultural rating, issued by the CAA in 2013. The pilot held a current Class 1 Medical Certificate for single pilot air operations carrying passengers valid until May 2014. The pilot was appropriately rated for the helicopter type.

1.5.2 A review of the Pilot's Logbook showed that at the time of the accident the pilot had accrued 13,621.3 hrs total flying time, of which 2,470.1 hrs was on type.

1.5.3 The pilot had conducted a Biennial Flight Review and an Annual Agriculture Competency Check in October 2013.

1.5.4 Several colleagues reported that the pilot kept current with emergency procedures and was always practising autorotation. Pilot experience or currency was not considered a contributing factor in this accident.

1.6 Aircraft information

1.6.1 MD Helicopters Inc. 500N, serial number LN093 was manufactured in the United States of America (USA) in 2000. The helicopter was registered in New Zealand as ZK-HQP in May 2005 and issued with a Certificate of Airworthiness by the CAA.

1.6.2 At the time of the accident the helicopter airframe and engine had both accrued approximately 3,603 total hrs.

1.6.3 It was determined by calculation that at the time of the accident, the helicopter was being operated within published weight and balance limitations.

1.6.4 The last airframe 100 hour inspection was performed on 11 March 2014 at 3,588.3 hrs. The maintenance records indicated it was maintained in accordance with the operator's maintenance program.

1.6.5 The helicopter was powered by a Rolls-Royce Model 250-C20R/2, 450 hp turbo-shaft engine, serial number (S/N) CAE-295811. The last engine 100 hour inspection was performed on 11 March 2014 at 3,588.3 hrs.

1.6.6 On 27 November 2013 at 3,487.8 airframe/engine hrs (115.5 hrs prior to the accident), compressor assembly, part number (P/N) 23050833, S/N CAC-15817 was installed on ZK-HQP, replacing compressor assembly, P/N 23050833, S/N CAC-28213 due to that compressor assembly reaching overhaul limits.

1.6.7 Compressor assembly, P/N 23050833, S/N CAC-15817 was an overhauled assembly having a Time Since Overhaul (TSO) of zero hrs and a Time Since New (TSN) of 3,941 hrs at the time of installation on ZK-HQP.

1.6.8 The compressor assembly, P/N 23050833, S/N CAC-15817 was overhauled by a CAA approved Aircraft Maintenance Organisation and the overhaul was completed in July 2013, with the overhauled compressor being issued a CAA Form One.

1.6.9 Prior to being removed for overhaul in January 2013, compressor assembly, P/N 23050833, S/N CAC-15817 had been leased to an operator in Indonesia, where the compressor assembly had accrued approximately 700 hrs.

1.7 Meteorological information

1.7.1 At the time of the accident the prevailing wind in the vicinity of the Wharerata Forest was a north-westerly air flow of approximately three knots. The temperature was approximately 20 degrees Celsius and visibility was good.

1.7.2 Weather was not considered to be a contributing factor in this accident.

1.8 Aids to navigation

1.8.1 N/A

1.9 Communications

1.9.1 The helicopter was fitted with appropriate aviation radios. The forestry contractors had been in radio communication with the pilot prior to the accident via hand-held radio transmitter.

1.9.2 An emergency call was heard by the crewman over his portable radio transmitter stating ‘emergency, emergency, emergency, chopper has gone down’. The safety investigation determined this radio call came from one of the forestry contractors who witnessed the accident.

1.10 Aerodrome information.

1.10.1 N/A

1.11 Flight recorders.

1.11.1 N/A

1.12 Wreckage and impact information

1.12.1 Shortly after the accident occurred, a local helicopter operator overflew the accident site at low level, the resultant downdraft disturbed the wreckage. After landing the pilot of this helicopter accessed the aircraft wreckage with the intention of deactivating the ELT. Due to these actions the integrity of the wreckage trail and accurate location of items could not be positively established.

1.12.2 Civil Aviation Rule (CAR) 12.101 *Access to aircraft involved in an accident,* states that no persons shall access or interfere with an aircraft or its contents that is involved in an accident unless authorised to do so by the CAA. The pilot who accessed the accident site of ZK-HQP had not been authorised by the CAA.

1.12.3 Aircraft accident sites are inherently hazardous and the integrity and preservation of evidence is of upmost importance to the safety investigation. As a result, a CAA safety action (CAA 17A529) was raised on the CAA Communication and Safety Promotion Unit to remind aviation participants of the hazards associated with accident sites and the requirements of CAR 12.101. This was accepted and completed via the publication of an article titled *'Hands Off the Accident Scene'*, published in the May/June 2017 edition of the CAA *Vector* magazine.

1.12.4 The accident occurred on 32 degree sloping terrain. The helicopter aft tail section struck the terrain first, followed by the skids, in a level attitude. The vertical stabilisers and both skids separated during this initial sequence.

1.12.5 The helicopter slid before it turned to the left and rolled down the valley. A large amount of Perspex from the helicopter canopy was found at the bottom of an approximate 3m drop, just after the initial impact location. Damage to the forward right side of the helicopter fuselage and the Perspex indicates the helicopter dropped onto the forward right side of the fuselage at this point, before continuing to roll down the slope coming to rest approximately 60m further on. During this phase the tail boom, horizontal stabiliser and two main rotor blade sections detached.

1.12.6 The main fuselage came to rest on its right side facing up the slope.

1.12.7 Due to the difficult terrain, which limited the onsite examination, the wreckage was recovered to a secure CAA facility. A technical investigation was carried out at this facility with the assistance of MD Helicopters and Rolls-Royce Air Safety Investigators.

1.12.8 The Field Investigation Notes, supplied by the MD Helicopters Air Safety Investigator noted:

> *'The forward fuselage including the cockpit area and canopy frames suffered major impact damage. The helicopter belly was relatively undamaged. The majority of damage was to the fuselage's right side. The aft fuselage section was twisted and distorted from impact. The landing gear struts, skid tubes and braces were broken or deformed.*
>
> *The cockpit floor, door frames, instrument panel mounting, and canopy glass were severely damaged from impact.*
>
> *Damage to the main rotor blades and hub are consistent with a power off, low rotor RPM.*

Control continuity was verified for the collective, cyclic and Notar controls. All fractures in the controls were consistent with overload fractures corresponding to impact damage.'

1.12.9 The Wreckage Examination section of the Rolls-Royce Engine Investigation Report supplied by the Rolls-Royce Air Safety Investigator noted:

'The engine remained secured within the engine compartment, although the port-side engine mount was fractured. Initial inspection of the engine exterior did not reveal any evidence of uncontained engine failure or fire. Minor impact damage and paint transfer (presumably from the interior of the engine bay doors) was noted on the starboard side of the engine's outer combustion case (OCC).

Drive continuity was confirmed visually from the engines power output shaft to the helicopters main transmission; however the shaft could not be rotated by hand.

All B-Nuts and fittings were checked by hand for torque. All were found to be at least hand tight and marked with light-blue torque paint.

A vacuum check of the engine's fuel system was completed. The system held the requisite 8 PSIV for two minutes.

The aircraft was equipped with a particle separator and barrier filter at the engine inlet. The engine-side face of the filter exhibited a grey, powdery coating, typical of having been subjected to an engine surge.'

1.12.10 During the technical investigation of the engine, visual inspection of the compressor assembly found that the compressor blades on all four compressor wheels had fractured at the blade root area. All four stator vane stages were also damaged and the compressor blade track liners were extensively damaged by debris. The engine inlet plenum area was inspected for foreign objects that could have caused damage to the compressor, with none being found.

1.12.11 Further inspection of the compressor wheel identified evidence of a high cycle fatigue (HCF) crack on the convex (suction) side of a single blade on the first stage compressor wheel (see Figure 2).

Source: technical investigation

Figure 2:
ZK-HQP high cycle fatigue crack in first stage blade.

1.12.12 The engine was removed and sent to Rolls-Royce for a detailed examination and analysis.

1.13 Medical and pathological information

1.13.1 The results of toxicological testing showed no alcohol or drugs present in the pilot's or passenger's blood.

1.13.2 Post-mortem examination showed the passenger suffered fatal injuries as a result of the accident.

1.14 Fire

1.14.1 Witnesses describe a small shrub fire, most likely started by the hot exhaust ducts. This was extinguished by the first responders. There was no evidence of fire damage to the aircraft.

1.15 Survival Aspects

1.15.1 The airframe structure is designed to be energy absorbing and fails progressively in the event of impact. The helicopter fuselage incorporates a rigid, three-dimensional truss type structure, with an integral roll-bar design. During the accident sequence, the right side of the helicopter fuselage and cockpit area sustained extensive damage, see Figure 3.

Source: Field Investigation

Figure 3:
Front View of ZK-HQP Showing Pilot and Passenger Occupiable Space.

1.15.2 Shoulder harnesses and seat belts are attached to the aircraft structure rather than to the seats themselves and as noted in the MD Helicopters Air Safety Investigator's Field Investigation Notes:

> *'The pilot's and co-pilot's seat were of the mesh seat design and were damaged and crushed. The crew's seat belts and shoulder harnesses functioned normally.'*

1.15.3 The pilot was wearing a helmet, seat belt across the waist and shoulder harness. The passenger was wearing a headset and seat belt across the waist.

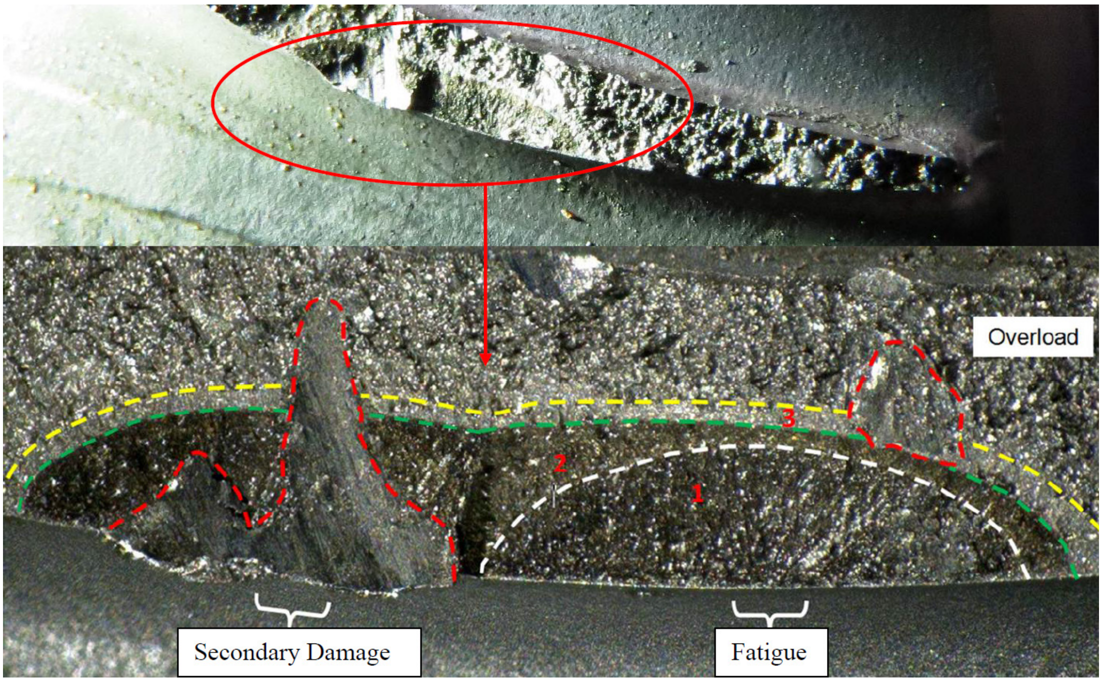
1.15.4 The pilot sustained serious injuries but was able to egress the aircraft with assistance from the forestry contractors. The passenger sustained multiple impact injuries and did not survive the accident.

1.16 Test and research

1.16.1 The Rolls-Royce Engine Investigation Report stated that the fracture surface of the compressor blade on the first stage compressor wheel exhibited a single fatigue crack, with two points of origin. Secondary damage to the fracture surface, associated with the blade release, however, resulted in only one of the origin points being able to be analysed further (see Figure 4). Examination of the intact origin point by scanning electron microscopy identified that the fracture originated subsurface and noted a delta ferrite island at the origin of the fatigue crack.

1.16.2 Due to varying amounts of coked oil accumulated on the fracture surface three distinct zones were identified (see Figure 4). This signature is considered consistent with the crack propagating over a period of time. The exact amount of time required for the crack to progress until failure in overload could not be conclusively determined.

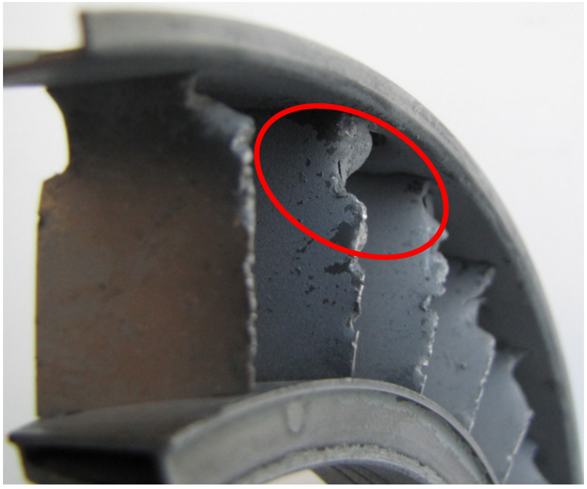
1.16.3 Further examination of the fracture surface identified no traces of fluorescent dye penetrant. The compressor wheels were non-destructively tested using a fluorescent dye penetrant inspection during overhaul. This inspection identified no defects or cracks in the first stage compressor wheel at the time.



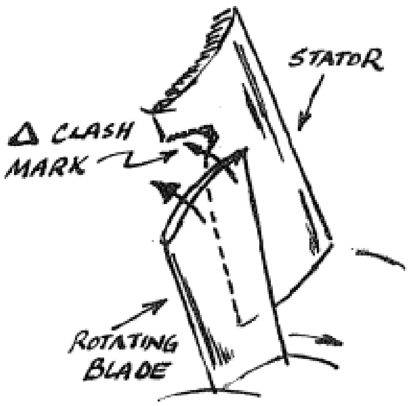
Source: Rolls-Royce Engine Investigation Report

Figure 4:
Three zones exhibited on fracture surface and secondary damage.

1.16.4 Examination of the first stage stator vanes identified triangular impact fractures on the trailing edge of the stator vanes (see Figure 5(a)). Blade clash is a term given to stator-blade contact due to high blade deflections caused by a surge event. The rotating blades clash with the trailing edges of the prior stator vanes. This often results in a characteristic triangular impact mark on the vane (see Figure 5(b)).



a) Impact damage on first stage stator vane – ZK-HQP



b) Blade Clash Diagram[3]

Figure 5:
Indication of blade clash on first stage stator vane from ZK-HQP.

1.16.5 The material removed by the pilot from the engine chip detector was sent to a specialist facility for material analysis. The material was identified as steel M50 bearing material.

1.16.6 During the engine strip the power turbine #2 ½ bearing was found to have unusual wear. It is not uncommon for metallic material to collect on engine chip detectors and usually indicates bearing wear. The safety investigation determined it likely that the M50 bearing material on the chip detector came from this bearing and that the wear was unlikely to have contributed to the cause of the accident.

1.16.7 In 2006/07 Rolls-Royce achieved Federal Aviation Administration (FAA) certification of new and improved compressor wheels for the Model 250-C20R/2 turbo-shaft engine. Rolls-Royce released the new machined compressor wheels to replace the current cast compressor wheels by commercial service letter in February 2007. The compressor wheels installed in the compressor on ZK-HQP were the cast type. The specific reason for the design change could not be conclusively determined.

[3] Cyrus B. Meher-Homji; George Gabriles (1998). *Gas Turbine Blade Failures - Causes, Avoidance, and Troubleshooting*, page 141. 27th Turbomachinery Symposium.

1.16.8 Review of similar Model 250-C20R/2 turbo-shaft engine compressor wheel failures, identified an Aviation Investigation Report by the Transportation Safety Board of Canada[4]. This report refers to the new machined compressor wheels and describes the reason for the change being that the new design was expected to increase longevity and reduce operating costs. This is likely due to the new wheels not needing the protective aluminide coating the cast type require. It also states that the new wheels may provide better fatigue performance compared to the cast wheels.

1.16.9 As the aircraft and engine were both manufactured in the USA, the National Transportation Safety Board (NTSB) assisted in appointing representatives from the aircraft and engine manufactures to participate in the investigation. Specialist resources were also obtained from the NTSB themselves. The input from the respective individuals and organisations is acknowledged.

1.17 Organisational and management information

1.17.1 The safety investigation examined the compressor overhaul process carried out by the CAA approved Aircraft Maintenance Organisation, that conducted the overhaul of compressor assembly, P/N 23050833, S/N CAC-15817. Encompassed in this examination was the compressor inspection and assembly, replacement of the compressor case halves and the blade track liner repair carried out by a third party supplier, also New Zealand based.

1.17.2 During the compressor overhaul, the compressor case halves were also replaced with re-worked case halves, S/N 43119 from the Aircraft Maintenance Organisation's rotable stock. (Compressor case halves are manufactured as a match-set, and share a single serial number.) The re-worked case halves, S/N 43119 were installed on ZK-HQP at the time of the accident.

1.17.3 Manufactured in 1999, case halves, S/N 43119 had blade track liners made of Metco-52C. In November 2010, Rolls-Royce Issued a Commercial Engine Bulletin 72-4099, which calls for replacing Metco-52C blade track liner with a softer, more abradable XPT-268 liner. In 2011 the case halves were dispatched by the Aircraft Maintenance Organisation to a third party supplier and reworked in accordance with

[4] Aviation Investigation Report A06O0150, Engine Failure – Collision With Terrain, 21 June 2006, Transportation Safety Board of Canada.

Technical Directive, to replace the Metco-52C liner with XPT-268 liner. The case halves were subsequently issued a CAA Form One in October 2013.

1.17.4 Examination of the compressor case halves post-accident, found that the case halves did not conform to dimensional design specifications, exhibiting an out-of-round characteristic. The Rolls-Royce Engine Investigation Report stated that the case halves could only be deformed in this manner by an external clamping force.

1.17.5 During review of the compressor assembly process by the CAA, it was identified that when the case halves were received by the Aircraft Maintenance Organisation, post the blade track liner replacement, they underwent an inward inspection. This inward inspection consisted of a visual check for damage only and the Technical Directive, issued by the Aircraft Maintenance Organisation, did not specifically stipulate an inspection requirement.

1.17.6 The Technical Directive did not specifically require the subcontractor to inspect and measure the part for overall dimensional conformity post blade track liner replacement, only requiring the specific blade track dimensions be assessed.

1.17.7 The safety investigation of the Aircraft Maintenance Organisation and third party supplier identified no process or tooling which could have applied an external clamping force on the case halves.

1.17.8 In February/March 2015 the third party supplier commissioned a Co-Ordinate Measuring Machine (CMM) to measure the case halves post machining.

1.18 Additional Information

1.18.1 External sling load operations are conducted under Civil Aviation Rule (CAR) Parts 133 Helicopter *External Load Operations* and 91 *General Operating and Flight Rules*.

1.18.2 Rule 133.53 *Carriage of persons* states that unless a person is carrying out work directly associated with the sling load and necessary to accomplish the work activity a pilot-in-command shall not carry a person inside the helicopter.

1.18.3 The passenger's function on board ZK-HQP was to indicate to the pilot where the loads were required to be positioned. The pilot stated that "I couldn't have found them [forestry contractors] without [the passenger's] directions" as it was difficult to see them due to the terrain.

1.18.4 Rule 91.207 *Occupation of seats and wearing of restraints* stipulates that a pilot-in-command of an aircraft may permit a passenger to unfasten a shoulder harness or a single diagonal shoulder belt, when the aircraft is flying at a height of less than 1000 feet above the surface, if the pilot-in-command is satisfied that such action is necessary for the passenger's performance of an essential function associated with the purpose of the flight.

1.18.5 CARs do not mandate the wearing of safety helmets for pilots or passengers due to the range and complexity of helicopter operations and the specific considerations that need to be taken into account when selecting and using helmets, such as the standard of protection and appropriate fitment. Operators and pilots should however, conduct risk assessments for the type of operation and select the appropriate mitigations. This accident highlights the hazards involved in low level operations and the considerations that should be taken into account when deciding what the safety way of accomplishing the task is.

1.18.6 The accident however provides a reminder of the benefits of wearing safety helmets, especially during low level operations. An article titled *'Flight Helmets are Good Insurance'* was published in the September/October 2013 edition of the CAA *Vector* magazine. The article highlights the benefits of wearing a safety helmet and also the considerations to be taken into account.

1.18.7 Although CARs do not mandate the use of a shoulder harness or safety helmet for passengers, it may be prudent to ensure that passengers have the maximum safety measures available to them. As such a CAA action (CAA 17A530) has been raised, recommending the CAA Health and Safety Unit engage with high risk industries such as agricultural and forestry, etc. to raise awareness and provide guidance to determine the safest way of accomplishing the tasks.

1.18.8 Rule 43.51 *Persons to perform maintenance* provides that a pilot with a type rating and specific approval from the owner/organisation may conduct specific maintenance operations. The organisation had approved the pilot of ZK-HQP to conduct specific maintenance operations on company helicopters. This did not extend to the removal of engine chip detectors and this is not an approved pilot maintenance action listed in Part 43 Appendix A.1 *General Maintenance Rules.*

1.18.9 Neither the airframe or engine manufacturer provide guidelines for the removal and checking of engine chip detector magnetic plugs by pilots, requiring the action be undertaken by maintenance personnel. In addition, the engine's Operations and Maintenance manual specifies a 30 minute ground run be carried out following any engine chip light indications.

1.18.10 The CAA facilitate Maintenance Controllers Courses for owners and operators who wish to increase their understanding of the requirements for the maintenance of their aircraft. The course is attended by a wide range of aviation participants, from airline maintenance planners to private aircraft owners. The aim being to introduce and refresh participants' knowledge of the CARs relating to the maintenance of their aircraft, including the requirements of Rule 43.51 *Persons to perform maintenance*. The Maintenance Controllers Course is held several times a year in various locations across New Zealand.

2. Analysis

2.1 The accident occurred due to a sudden loss of engine power and an attempted autorotation landing onto steep sloping terrain. The autorotation landing was attempted on steep sloping terrain due to limited suitable emergency landing sites, given the altitude at which the helicopter lost engine power. The angle of the slope and the terrain led to the helicopter sliding and rolling after impact with the ground.

2.2 The loss of engine power was caused by a catastrophic compressor failure. The cause of the compressor failure was traced to the release of a single compressor blade on the first stage compressor wheel. The release of this compressor blade ultimately resulted in the fracture of all remaining compressor blades.

2.3 The first stage compressor blade failed due to a HCF crack propagating in the convex (suction) side of the compressor blade, ultimately leading to the blade fracturing in overload.

2.4 The fracture was determined to originate subsurface, which eliminates the possibility of foreign object damage or corrosion pitting as a stress riser and fracture origin.

2.5 During the overhaul of the compressor the first stage compressor wheel underwent fluorescent dye penetrant inspection. At the time of the inspection no defects were noted and during fracture surface analysis carried out by Rolls-Royce, no traces of fluorescent dye penetrant was found. This confirms the crack was not present during the inspection at overhaul.

2.6 Evidence of tip rub could not be conclusively determined due to the extensive damage to the compressor blade track liners, however neither the pilot, operator nor maintenance provider stated any prior indications of tip rub, or noise associated with tip rub. Tip rub was therefore not considered to be a contributing factor.

2.7 Other similar type failures (suction side HCF crack) identified by research have been associated with airflow issues, air blockage/surge situations. The particle separator and barrier filter installed at the engine inlet exhibited a grey, powdery coating on the engine-side face of the filter, typical of having been subjected to an engine surge. It could not however, be conclusively established if this occurred pre or post blade release.

2.8 The triangular impact marks on the trailing edges of the first stage stator vanes indicate "clash" has occurred with the second stage compressor wheel blades and further suggests an engine surge occurred. The safety investigation could not conclusively determine if this particular damage occurred pre or post blade release, however it is unlikely to be associated with a recovered surge event.

2.9 The reason for the initiation of the HCF crack in the compressor blade could not be conclusively determined but it is considered possible that it was due to one or more of the following factors:

- the compressor assembly has experienced an air blockage/surge event at some time in the life of the first stage compressor wheel, which has initiated a subsurface fatigue crack in the first stage compressor wheel blade; and/or
- A subsurface anomaly, associated with one of the two crack origin points, has led to a fatigue crack in the first stage compressor wheel blade.

2.10 It should be noted that the engine’s Operations and Maintenance manual stipulates the mandatory immediate removal of the compressor module for inspection and repair following a compressor inlet air blockage event.

2.11 The compressor wheels installed in the compressor on ZK-HQP at the time of the accident were the cast type and these cast wheels have since been superseded by machined compressor wheels. Although there is no evidence to indicate that the improved wheels are a response to any fault of the original wheel, the new design is expected to offer over higher strength, improved corrosion resistance and may provide better fatigue performance than the cast wheels.

2.12 The safety investigation therefore highlights the potential issue, that the first stage cast compressor wheel may be sensitive to engine surge/fatigue. As a result CAA safety action (17A530) has been raised to bring to the attention of the FAA the potential of a surge/fatigue sensitivity issue with the first stage cast compressor wheel of the Model 250-C20R/2 turbo-shaft engine.

2.13 Additional technical analysis carried out by the CAA determined that the out of round characteristic observed in the compressor case halves was significantly more pronounced in the region of the first stage blade track. A fragment of compressor blade was also imbedded into the compressor inlet housing in a location that corresponded to the general orientation of the major diameter of the out of round characteristic. Review of the overhaul and assembly processes identified no processes or tooling which could have applied an external clamping force on the case halves. The safety investigation determined that it is likely that this deformation was a consequence of the blade release and subsequent destructive forces.

2.14 At the time of installation on the engine, however, no overall geometric dimensions of the compressor case halves were documented by the Aircraft Maintenance Organisation. This was due to the inward inspection consisting of a visual check for damage and the Technical Directive not specifying an inspection requirement to check overall part geometry. Therefore the safety investigation was not able to categorically determine the dimensional status of the compressor case halves at the time of installation.

2.15 The safety investigation concluded that, although not contributing to the cause of the accident, at the time of overhaul of the case halves, an opportunity was lost to record and document information. This information may have aided in the quality assurance of work carried out by the Aircraft Maintenance Organisation. A CAA safety action (CAA 17A531) was therefore raised to recommend that the Aircraft Maintenance Organisation put procedures in place to ensure dimensional inspection of parts critical to airworthiness and/or of critical dimensions for correct operation, be recorded.

2.16 The Aircraft Maintenance Organisation accepted this action and has since conducted a full audit of their third party supplier process and implemented CMM inspection procedures to measure the case halves post machining and record detailed dimensional reports for verification. All compressors case halves inspected subsequent to the new CMM inspection procedures being put in place, without change to the repair process itself, have been shown to be consistently concentric.

2.17 During the accident sequence the helicopter sustained significant damage, with the right side sustaining the majority of the impact forces. The left side maintained its structural integrity throughout the accident sequence, aided by the truss type structure and integral roll-bar design. The survival of the pilot was in part due to the design of the helicopter, the use of both waist and shoulder harnesses, the integrity of the harnesses, the wearing of a safety helmet and the predominate forces of the accident sequence being to the right side of the helicopter.

2.18 The reason the pilot removed and checked the engine chip detector magnetic plug on ZK-HQP prior to the first flight of the day was likely due to this practice being 'normalised' by the pilot. The pilot stated that during 20 plus years of flying 18-20 chip light indications had been experienced and the pilot had always followed the procedure of, checking and cleaning the engine chip detector magnetic plug and monitoring the chip light. When questioned, the pilot was unaware that this was an unapproved practice. The amount of debris observed on the engine chip detector magnetic plug of ZK-HQP on the morning of the accident was considered by the pilot to be minimal, with the pilot stating "I have seen much worse, continued flying and nothing happened".

2.19 These types of deviation from formal operating procedures are referred to as routine violations and are often perceived by those performing them to involve little risk. Through repetition without any negative consequences, routine violations can become a habitual part of an individual's operating practice, the normal way of doing the job. The actions of the pilot are not considered to be a contributing factor in this accident, however, serve as a reminder regarding the limitations of the authority of the pilot-in-command to perform maintenance actions, and also for pilots and operators to be mindful of the latent risk that normalised routine violation can pose.

3. Conclusions

3.1 The helicopter experienced a sudden loss of power as a result of a catastrophic compressor failure due to the release of a single first stage compressor blade.

3.2 The first stage compressor blade failed due to initiation of a HCF crack.

3.3 The reason for the HCF crack initiation could not be conclusively determined but it is considered possible that it was due to one or more of the following factors:

- The compressor module experiencing an air blockage/surge event at some point in the life of the compressor wheel; and/or,
- A subsurface anomaly, associated with one of the two crack origin points.

3.4 During the autorotation the helicopter struck steep sloping terrain, resulting in the helicopter, sliding and rolling after initial impact.

3.5 The cockpit area and canopy frames received major impact damage with the majority of the damage sustained by the right side (passenger side) of the fuselage.

3.6 Due to the dynamics of the accident sequence, the accident was survivable for the pilot, unfortunately it was un-survivable for the passenger.

3.7 This accident highlights the hazards involved in low level operations and the considerations that operators and pilots should take into account when conducting risk assessments and determining the safest way of accomplishing the task.

3.8 The dimensional status of the compressor case halves at the time of installation could not be conclusively determined and although not contributing to the accident, part geometry records may have aided in the quality assurance of work carried out by the Aircraft Maintenance Organisation.

3.9 The pilot was appropriately rated and licensed to conduct the flight.

4. Safety actions

4.1 CAA Safety Action (CAA 17A529) has been accepted and completed by the CAA Communication and Safety Promotion Unit, to remind aviation participants of the requirements of CAR 12.101 *Access to aircraft involved in an accident* and to highlight inherent hazards associated with aircraft accident sites, via an article titled

'Hands Off the Accident Scene', published in the May/June 2017 edition of the CAA *Vector* magazine.

4.2 CAA Safety Action (CAA 17A530) has been raised for the CAA Health and Safety Unit to review the safety mitigations afforded to passengers of helicopters, regularly engaged in low level operations for high risk industries such as agricultural and forestry, etc. with a view to inform and provide guidance to those industries.

4.3 CAA Safety Action (CAA 17A531) has been raised to bring to the attention of the FAA, a potential surge/fatigue sensitivity issue of the first stage cast compressor wheel of the Model 250-C20R/2 turbo-shaft engine.

4.4 CAA Safety Action (CAA 17A532) has been accepted and completed by the Aircraft Maintenance Organisation to review their procedures and ensure adequate documentation of parts critical to airworthiness and/or of critical dimensions for correct operation are held for quality and safety assurance purposes.

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