ACCIDENT INVESTIGATION REPORT

REPORT ON THE ACCIDENT INVESTIGATION INVOLVING A ROBINSON R44 RAVEN II HELICOPTER REGISTERED A2 – HEX THAT OCCURRED ALONG BORO RIVER (NEXT TO MAUN) ON THE 12th MARCH 2023.

REFERENCE MTPW/AIG/08/23

Name of Operator	Helicopter Horizons
Manufacturer	Robinson Helicopter Company
Model & Serial #	R44 Raven II; S/n: 12444
Nationality & Registration Marks	A2 - HEX
Place of Accident	Boro river
Date & Time of the Accident	12th March 2023 @ 1345hrs Z (approximately.)

All times given in this report are Coordinated Universal Time (UTC) and will be denoted by (Z). (UTC + 2hrs = local time).

Contents

PURPOSE OF THE INVESTIGATION

This investigation was conducted in accordance with the **Civil Aviation (Accident and Incident Investigation) Regulations of 2022**, of the Republic of Botswana, that is in line with *ICAO Annex 13* for the principal purpose of determining the circumstances and causes of the accident with a view to the preservation of life and avoidance of similar accidents in future and not to ascribe blame to any persons.

The Civil Aviation Act of 2011 at Section 75 as amended stipulates that:

The sole objective of the investigation of an accident or incident shall be the prevention of accidents and incidents and not to apportion liability or blame.

Investigation Process:

The Directorate of Accident Investigation (DAI) of the Republic of Botswana categorized this occurrence as an accident and instituted an investigation conducted by an Investigator-in-Charge. It was assigned the following accident investigation file number MTPW/AIG/08/23.

The State of manufacturer and the country of origin of the accident victim were notified of the accident by the State of occurrence which also happens to be the State of registry - Botswana.

Any person with information that might be of help in this investigation should contact DAI or the IIC at jsebineng@gov.bw or mobile (+267) 73005766.

DIRECTORATE OF ACCIDENT INVESTIGATION
Private Bag 007
Gaborone
BOTSWANA

In accordance with regulation 36(1)(b)(i) of the Civil Aviation (Accident and Incident Investigation) regulations of 2022, a draft final report was served to both person and entities of interest in order for them to make significant and substantiated comments. DAI received feedback comments from the stakeholders following their review of the draft final report.

The stakeholder's response to the draft final report forms an annexure to this report. In dealing with the stakeholder comments, DAI adopted some of the comments to amend the report. The amendments will be noted by bolded *italic font style* in the report. Some comments attracted clarification; others were just noted without any action taken.

In view of the raised comments that were not responded to, DAI once more reiterates that the aim of the investigation is to present the analysis of all evidence that was achieved during the investigation process in order for all those concerned with aviation safety to derive lessons from and enhance accident prevention.

It is most unfortunate that in most cases the reader(s), some not all, are more interested as to whether or not individual(s) or action(s) were the probable cause of the occurrence and if anyone was held responsible. That is not the aim of this investigation (or any other air accident/incident investigation for that matter), the main intention of the investigation is to improve upon aviation safety generally in this country.

Investigation by its nature involves gathering, recording and analysing of evidence. The presented facts must not be construed to apportion blame but they serve to raise awareness.

Therefore, usage of this report (or any part thereof) for a purpose other than that which is consistent with the spirit of the Act and other relevant instruments and/or protocols might lead to erroneous interpretations and applications. Apportioning of liability and blame is not the purpose of this report.

GLOSSARY OF ABBREVIATIONS

AOC: Aircraft Operator Certificate

ATC: Air Traffic Control

ATPL: Airline Transport Pilot's License

ATC: Air Traffic Control

ATS: Air Traffic Services

AWOC: Aerial Work Operator Certificate

BPS: Botswana Police Services

CAAB: Civil Aviation Authority of Botswana

CATS: Chief Air Traffic Services

CPL (H): Commercial Pilot Licence (Helicopter)

CoA: Certificate of Airworthiness

CoR: Certificate of Registration

DATCO: Duty Air Traffic Controller

ETA: Estimated Time of Arrival

GPS: Global Positioning System

ICAO: International Civil Aviation Organisation

METAR: Meteorological Aerodrome Report

NM: Nautical Mile

NZCAA: New Zealand Civil Aviation Authority

PIC: Pilot-In-Command

PPL: Private Pilot Licence

R44 II: Robinson Helicopter 44 Raven II

RCC: Rescue Control Centre

TTSN: Total Time Since New

UTC: Universal Time Coordinated (i.e., Local time minus 2 hours) or Zulu time

SYNOPSIS

On the 12th March 2023 at around 1334hrs, a helicopter registered A2 – HEX left Maun airport to Shokomoko camp / Santawani, a tourist area next to the Moremi Game Reserve. The flight duration was supposed to be twelve (12) minutes.

The helicopter belonged to a local company, Helicopter Horizons – a Maun based organisation that holds a CAAB approval certificates for both Aerial Work Operator and Aircraft Operator issued under the number (#063).

A2 - HEX did not reach the intended destination within the expected time and that led to Helicopter Horizons – Head office calling the Maun airport DATCO at 1358hrs to inquire about the status of A2 – HEX. In response, DATCO shared the airborne time and the estimated time of arrival for Santawani.

Helicopter Horizon – base followed with a second call to DATCO at around 1404hrs inquiring on the same subject. It so happened that A2 – HCM, another helicopter belonging to Helicopter Horizon, made a positive confirmation to Maun ATC that A2 – HEX was safe at its destination. DATCO had asked A2 – HCM to reach out to A2 – HEX since the former was operating within the local control zone on a local game flight. The feedback from A2 - HCM was passed onto Helicopter Horizons base (Headquarters).

It was later proved that things were not as reported earlier at 1404hrs as a third call was made to DATCO at 1423hrs by Helicopter Horizon employee informing DATCO that they have no communication contact with A2 – HEX and its whereabouts are still unknown.

DAI received a call from the CATS at SSKIA at around 1525hrs reporting that there was a helicopter missing at the Maun area and already a search has been activated. The search was initially composed of three (3) helicopters belonging to Helicopter Horizon. Another helicopter later joined the search party to increase the number to four (4). As dusk was drawing near, a call to engage other members of the search and rescue unit was made and due to some logistical reasons, it was agreed that only at the break of dawn the following day shall the other units join the search party.

At 1710hrs, DATCO called Helicopter Horizon base where the Accountable Officer confirmed the sad news that an accident site has been located and there was a fatality. Gaborone Control was updated of the latest developments at 1714hrs and rescue coordination centre was deactivated. DAI received the fatal accident report at 1717hrs.

Access to the accident scene was not until around 2200hrs due to vegetation and suspected wild animals. The ground team had to tread with caution as they

navigate a new path to the wreckage. At the accident scene it was discovered that A2 – HEX including the pilot were consumed by post impact fire. The deceased pilot was retrieved from the wreckage at around 0030hrs in the morning and taken to the local hospital where he was certified dead.

The investigation process was prolonged as some key components were taken in for detailed tests and analysis at a metallurgical laboratory. The report of which forms part of the report. Feedback from stakeholders also played a significant role in the investigation by lending some valuable insights.

The gathered evidence points to the probable cause of the accident being heavy mast bumping. DAI came up with five (5) safety recommendations that are aimed at enhancing safety as well as improve the effectiveness of processes related to emergency procedures. The safety recommendations are directed to both the CAAB and the aircraft operator for implementation.

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1. FACTUAL INFORMATION

1.1 History of Flight

1.1.1 A2 – HEX was flying out of Maun Airport to Shokomoko camp / Santawani with one (1) crew and nil passengers. The helicopter had fuel duration of three (3) hours whereas the expected flight time to the intended destination was twelve (12) minutes.

1.1.2 The purpose of the flight was to pick clients (tourists) and bring them back to Maun. A2 – HEX advised Helicopter Horizons base at 1333hrs of its lift off to Shokomoko camp and the estimated arrival time of 1350Hrs at the camp.

1.1.3 A2 – HEX had a Garmin GPS that linked it to Helicopter Horizons base as a mode of flight tracking. The GPS tracker reported at two (2) minutes interval and the last report it sent to base was at 1335hrs. At that time A2 – HEX was flying a north – east course. It recorded a speed of 97 Knots at elevation three thousand four hundred and fifty – nine feet (3 459 ft). The latitude direction of A2 - HEX at the time was 19. 936613 and longitude of 23.452700.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	1	nil	nil
Serious	nil	nil	nil
Minor/None	nil	nil	

1.3 Damage to aircraft

1.3.1 A2 – HEX was extensively destroyed due to ground impact and post impact fire. Some components that appeared to have dislodged from the aircraft before it impacts the ground were left strewn along the helicopter flight – path. Pictures showing the damage can be seen at **Appendix 1** of this report.

1.4 Other damage

1.4.1 The other damage was only limited to a small piece of land that the helicopter fire affected. There were charred trees and shrubs around the wreckage and this was restricted to a very small area.

1.5 Personal information

NATIONALITY	New Zealand	GENDER	Male	AGE	24 years
LICENSE #	CV 324	DATE ISSUED	***15/02/2023***	ENDORSEMENT	CPL (H)
RATING(S)	Flight Radiotelephone Operator	A/C TYPE	Robinson 22 & 44	ENGLISH PROFICIENCY LEVEL	Level 8
MEDICAL	NZCAA Medical Certificate issued 10/09/22 till 10/09/23	LIMITATIONS	Nil	PREVIOUS ACCIDENT INVOLVEMENT	Nil
TOTAL FLYING TIME	175hours	TOTAL FLYING TIME ON TYPE	31hours	TOTAL FLYING TIME IN COMMAND	

1.6 Aircraft Information

MANUFACTURER & MODEL	Robinson Helicopter Company & R44 Raven II	SERIAL NUMBER	12444	YEAR OF MANUFACTURE	5th Jan 2009
DATE OF REGISTRATION	26/08/2020	REGISTRATION CERTIFICATE #	1205	CATEGORY	Commercial
TOTAL TIME @ ACCIDENT	2185.9hrs	C OF M ISSUE DATE	9th March 2023	TOTAL TIME SINCE C OF M	1.4hours
ENGINE CONSTRUCTOR	***Lycoming***	ENGINE TYPE	IO-540-AE1A5F	CONSTRUCTOR # ENGINE	RL – 30816 -48E
CONSTRUCTION DATE	20/01/2020	ENGINE TOTAL TIME SINCE NEW	1298.8hrs	ENGINE TOTAL TIME SINCE OVERHAUL	Factory rebuilt
MAIN ROTOR CONSTRUCTOR	Robinson Helicopter	MAIN ROTOR	CO16 - 7	NUMBER OF ROTOR BLADES	2
ELT MAKE & MODEL	Kannad & 406AF	EMISSION CLASS & FREQUENCY	16K0F3E	RADIO LICENSE #	RL-BOCRA-ASL 3156-2022-20

1.7 Meteorological information

1.7.1 The obtaining weather conditions on the fateful day were as reported by METAR below; FBMN 121000Z 1212/1312 11010KT CAVOK.

1.8 Aids to navigation

1.8.1 Not applicable in this occurrence.

1.9 Communications

1.9.1 Communications between the aircraft and ATC was normal at all times as during the early phase of the flight leading to the accident both parties were communicating with each other without a sign of a hitch.

1.10 Aerodrome information

1.10.1 The helicopter has just departed Maun airport and was assisted in all aspects to embark on its journey. The aerodrome did not play any role in this occurrence.

1.11 Flight recorders

1.11.1 Not applicable

1.12 Wreckage and impact information

1.12.1 A2 – HEX made impact with the ground on the right-hand side of the canopy, with the right side of the nose including the right forward door, at a suspected angle of around forty-five degrees (45°) relative to the ground surface.

1.12.2 The helicopter debris were scattered in an orderly fashion with components that became detached prior to ground impact found at varying distances behind the main wreckage.

1.12.3 A2 - HEX main wreckage ended up next to where it impacted the ground. The other components, such as doors, main rotor blades, tail rotor blades, empennage and tail rotor gearbox that detached prior to ground impact were found some distance from the main wreckage.

1.12.4 The main rotor blades were found resting a short distance behind the main wreckage. Unlike other salvaged components, it is not conclusive whether

the main rotor blades detached prior to ground impact or not, it is also likely that it broke off from the mast at the time the helicopter made impact with the ground.

1.12.5 The pattern formed by the debris location on the ground depicted a scenario of a helicopter flying in a banked angle at the time leading to the crash. The location of debris relative to the of the main wreckage were strewn in a curved like path resembling a shape of letter "C".

1.12.6 The main wreckage consisted of a helicopter fuselage with a tail cone. Its impact with the ground made a one meter squared ($1m^2$) wide and a fifty-centimeter (50cm) deep crater. The helicopter fuselage together with the tail cone bounced off and rested two and a half (2,5 meters) from the center of the crater.

1.12.7 The main rotor blades were found next to the main wreckage lagging at a distance of sixty - nine meters (69m). A further fifteen meters (15m) down behind the main rotor blades laid the empennage. At the point where the tail-boom was found, a large piece of a glass wind-shield from one of the helicopter doors was also discovered.

1.12.8 The empennage was found to be without the tail rotor gear box assembly. After some concerted search effort in the bush, the tail rotor gear box was found a distance of thirty – seven (37m) adjacent to the main wreckage.

1.12.9 The tail rotor gearbox was located in a straight line relative to where the empennage was found. After being detached from the helicopter structure, the tail rotor gearbox continued on a straight path. The main structure appeared to bank at a steep angle to the right where it ended up impacting the ground.

1.12.10 Shredded pieces of the tail rotor blade were located along the flight path. Only three (3) pieces were spotted and they do not compose a single whole blade. The rest of the tail rotor blade pieces were not found.

1.12.11 The broken door pieces were located some distance behind the empennage and in between the two was a piece of a shredded tail rotor blade.

1.12.12 The debris that fell from the helicopter were found laid in a path pattern shaped like a letter "c". The broken door pieces were the first components at the far end to be discovered in the helicopter flight path. They were placed at a point that can be best described as the down end starting point of letter "C". The relative empennage position can be best described to be at the midpoint of the letter with the main wreckage at the top end point

of the letter "C". As described earlier, the tail rotor gearbox was found far ahead of the empennage in a straight-line relative to the tail boom position.

1.13 Medical and pathological information

1.13.1 The post mortem examination report states that the deceased succumbed to the thermal injuries sustained due to post crash fire.

1.14 Fire

1.14.1 Post impact fire consumed the whole helicopter wreckage and a small area of the surrounding bush.

1.15 Survival aspects

1.15.1 The accident was not survival due to impact forces and the resulting post impact fire.

1.16 Tests and research

1.16.1 The engine was taken in for an observed laboratory stripping and analysis though it was charred as a result of post impact fire.

1.16.2 The main oil filter was cooked up with everything inside charred. The accessory components were found to be intact and appeared to have been operational prior to the accident. The oil sump induction housing was intact and the sump was clean of debris but dry of oil due to fire that engulfed the wreckage post impact.

1.16.3 The engine internal components appeared intact with no sign of breakage. The rocker arm assembly for both exhaust and intake valves, both inner and outer valve springs were intact with no distortion. The magneto retainer assembly, oil pump assembly and crankshaft idler gears were all free from damage.

1.16.4 The main rotor mast and the drive shafts for both tail and main rotor did not show any sign of fatigue and failure prior to the accident.

1.16.5 The door attachment components such as ball studs, hinge assembly, end connector and gas spring assembly were inspected ***for serviceability***.

1.17 Organisational and management information

1.17.1 Helicopter Horizon is a CAAB approved aircraft operator that holds approval certificate for Aerial Work in addition. The certificates are issued under the No. 63 and valid until 31st May 2023.

1.17.2 Helicopter Horizon has a maintenance facility that maintains its own fleet. The aircraft maintenance organization is CAAB approved and holds an approval certificate No. 66 valid until 11th July 2023.

1.18 Additional information

1.18.1 The eye witness who happened to be along the Boro River on the fateful day, heading in an easterly direction, stated that A2 – HEX flew overhead him in the same direction. According to the eye witness, within a short period time the helicopter flew back overhead in an opposite direction now heading west.

1.18.2 At both times the helicopter was flying past, the eye witness observed no sign of smoke or any strange noise produced. The eye witness stated that the helicopter was tilted more to the right on its flight heading west.

2. ANALYSIS

2.1 The engine was serviceable and normally functioning prior to the accident.

2.2 The main rotor drive shaft and the tail rotor drive shaft did not reveal any signs of failure whilst in service. (See **Figure 13**; para 6)

2.3 The main rotor blades did not show any signs of impact marks with any structural part from the onset, however after further analysis, it was discovered that they were scratches on the underside of the blades. The blades were found intact on the ground with identical bends on both blades at the tips (2metres from the tip ends). The bended blade tips did not completely detach from the main blades. (Refer to **Figure 13;** para 6)

2.4 The main rotor drive shaft broke close to the main rotor hub assembly. The shaft broke immediately at a point where it exits the mast fairing leading to the swash-plate. (Refer to **Figure 13**; para 6.1.2)

2.5 All the pieces of the three doors that were found on the ground showed signs of being struck by a thin object. The recovered pieces of the doors exhibited imprints (marks) of a thin material at the breakage points (contact

points). The doors had separated inflight probably due to flexing of the airframe as the airframe could have experienced massive vibration.

2.6 A2 – HEX conducted off-door operations for scenic and photography flights in the past. During these flights the helicopter doors were removed totally from the structure (fuselage). The last off-door operation by the helicopter was on the 9th March 2023. (Refer to **Annexure on stakeholder's comments: Stakeholder C** comments in relation to draft final report; para 6.2 – 6.5)

2.7 The door attachments components that were inspected did not provide conclusive evidence of whether there was failure in their operation or not.

2.8 Door attachments hinges are shown to have holes which implies that a cotter-pin or a ring is required to keep the door locked/secured into a hinge. No ring or cotter – pin was found in any of the recovered doors.

2.9 The pilot had small experience of flying this type of helicopter as witnessed by low number of flight hours.

2.10 According to eye witness statements, A2 – HEX was not flying at a very high altitude on its final phase of the flight just before a loud sound was heard followed by a huge ball of black smoke.

3. CONCLUSIONS

Probable Cause

3.1 From the information received after the testing of the helicopter components, (Refer to Figure 13 para 6.1.2); the main rotor hub failed and broke possibly due to severe imbalance during operation which could have been ***mast bumping***. This is supported by evidence on both the main rotor drive-shaft and hub assembly break-up, the damage on the main rotor blades and the inflight door separation.

(i) Paragraph 2.4 above mentions that the main rotor drive shaft broke at the hub end. (Refer to **Annexure;** Comments from Stakeholder B item 3 – noted that the experienced mast separation is a severe form of mast bump). The laboratory test results proved that the shaft separation could be attributed to severe imbalance (out of track) of the MR system during the accident sequence of events. The low altitude at which the helicopter was seen flying by the eye witness was conducive for mast bumping provided the speed was low.

(ii) Paragraph 2.3 above mentions main rotor blades that have fine scratches, which are attributable to the main blades coming into contact with the windows or windscreen of the cockpit. (Refer to **Annexure**; Comments from Stakeholder B after examining additional material as follow-up to the draft final report). The main rotor blades flying low to a point where they end up striking the airframe and even the tail boom. With evidence at hand, it points to the main rotor blades having struck an object and incurring marks similar to those resulting after window collision.

(iii) The inflight doors separation could have been a result of massive vibration that happens during heavy mast bumping. Mast bumping can lead to airframe flexing which causes the doors to separate inflight. (Refer figure 10a, b, 11 – 11a).

Contributing Factors

3.2 The damaged tail rotor blades caused an imbalance which might have led to the tail rotor gearbox tearing from the mount on the tail cone.

3.3 The tail rotor gear-box got disintegrated from the tail and it is suspected that as it separated, it chopped off the tail boom from the helicopter, damaging the both horizontal and vertical stabilizers along the way.

4. SAFETY RECOMMENDATIONS

4.1 It is recommended that CAAB require that compound major emergencies must be rehearsed at set intervals by commercial helicopter pilots. The emergency procedure rehearsals for the pilots who are less experienced and low on flight hours must be conducted at a higher frequency rate.

4.2 It is recommended that the CAAB must require the task of door removal and installation as per procedure (4.130 – Maintenance Manual) by operators be documented.

4.3 It is recommended that the aircraft operator must place emphasis on inspection for integrity of the door attachment components during the process of door removing and fitting for off-door operation purposes.

4.4 It is recommended that both the ATC and AOC holder must amend and enhance their procedures which deal with actions for overdue aircraft. An amended procedure must be implemented outlining definite actions that must be regarded as emergency. These should help in conserving time and

avoid situations whereby opportunity is lost whilst communicating back and forth without elevating the situational status.

4.5 It is recommended that the AOC must enhance its standard operating procedures in regard to information sharing. Specifically, to address the aspect of crew providing information that is not substantiated as was the case about the location of a missing aircraft. The enhanced procedure must key on the above aspect to emphasize the importance of basing reports on facts as that would help in timely decision making and activation of appropriate measures by the relevant parties.

Appendices

Figure 1: The main helicopter wreckage; tail cone assembly and remnants of fuselage with the whole canopy demised and only the engine

Figure 1a: The charred engine above is the only remaining component of the entire fuselage.

Figure 2: The impact point on the ground.

Figure 2a: Crater on the ground at the impact point.

Figure 3: Mast fairing assembly destroyed by the post impact fire.

Figure 4: Part of the tail cone (tail cone root) melted away due to heat by post impact fire.

Figure 5: Main rotor showing breakage on the mast

Figure 6: Main rotor blades still attached to rotor assembly hub but with this perpendicular bend on both blades.

Figure 7: Tail end vertical stabilizer as found along the flight path.

Figure 8: Damage on top of the tail cone that is suspected to be caused by tail rotor gear-box.

Figure 8a: Damage on the horizontal stabilizer

Figure 9: The largest of the only two tail rotor blade fragments that were located.

Figure 9a: The smallest of the two pieces of the tail rotor blade located

Figure 10: A rear door found along the flight path.

Figure 10a: The view of left rear door from the outside.

Figure 10b: Position of the door locking mechanism as found on the rear left door.

Figure 11: A piece of the left front door as found along the flight path. Note the position of the door locking mechanism.

Figure 11a: Closer view of the left front door as found at the scene of the accident.

Figure 11b: View of the door attachment of the rear left door.

Figure 11c: Attachment component (lower door hinge) front left door.

Figure 11d: Frontal view of the door attachment linkage component

Figure 11e: Closer view of the door attachment linking component

Figure 11f: Side view of the door attachment linkage

Figure 12a: The detached tail rotor gear-box as found at the accident scene

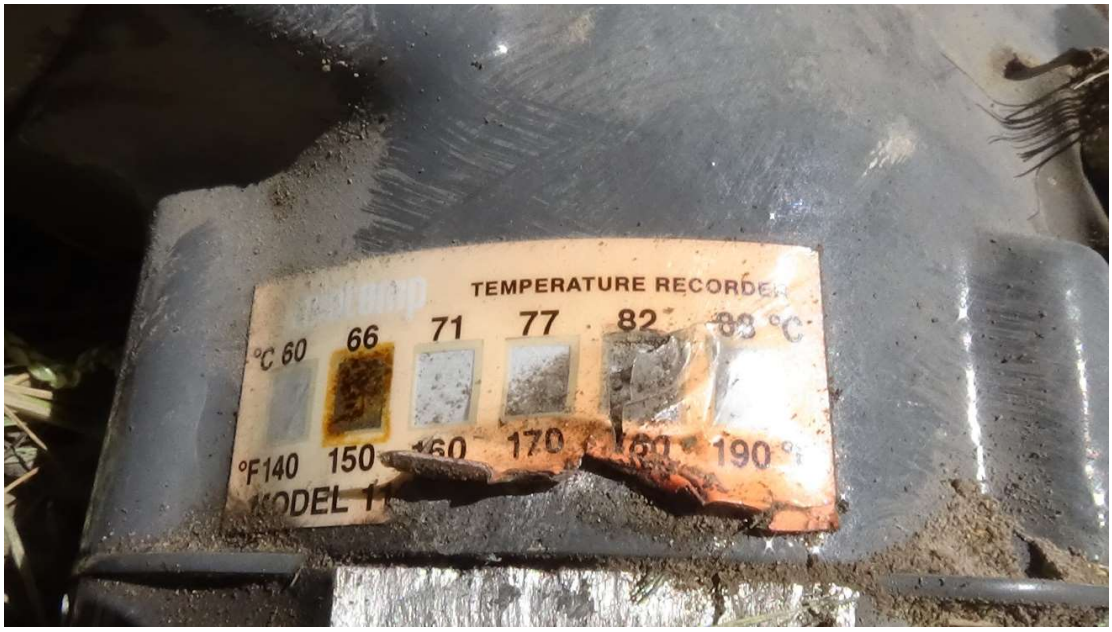


Figure 12b: View of the tail rotor gear-box telatemp sticker (Telatemp – heat sensitive stick-on strip)

Figure 12c: View of the ***<u>oil sight glass of the rotor gear-box</u>***.

Figure 13: Laboratory Report on tested selected components

COMPILED BY:	UNIVERSITEIT VAN PRETORIA UNIVERSITY OF PRETORIA YUNIBESITHI YA PRETORIA **LABORATORY FOR MICROSCOPY & MICROANALYSIS**	**PAGE 1** OF 1	
		DOCUMENT NUMBER FA-008-04-23	
COMPILED FOR: **Botswana Directorate of Accident Investigation**	**PRELIMINARY REPORT:** Impact Analysis: Robinson R44 Raven II Helicopter, Registration No A2-HEX	**DATE** 2024-09-01	ISSUE 1

ITEM: **Selected Components, Robinson R44 Raven II, Registration No A2- HEX**

1. BACKGROUND INFORMATION

1.1. Selected components originating from a Robinson R44 Raven II rotary wing aircraft, registration no A2-HEX, manufacturer's serial no 12444 (Photo1), were supplied to determine the most probable level of serviceability at the time of impact.

1.2. The relevant aircraft was involved in an accident on the 12th of March 2023 involving 1x fatality (Extract 1). The aircraft was totally destroyed and exposed to a post-impact fire. The aft section of the tail boom structure was found separated from the main wreckage[1].

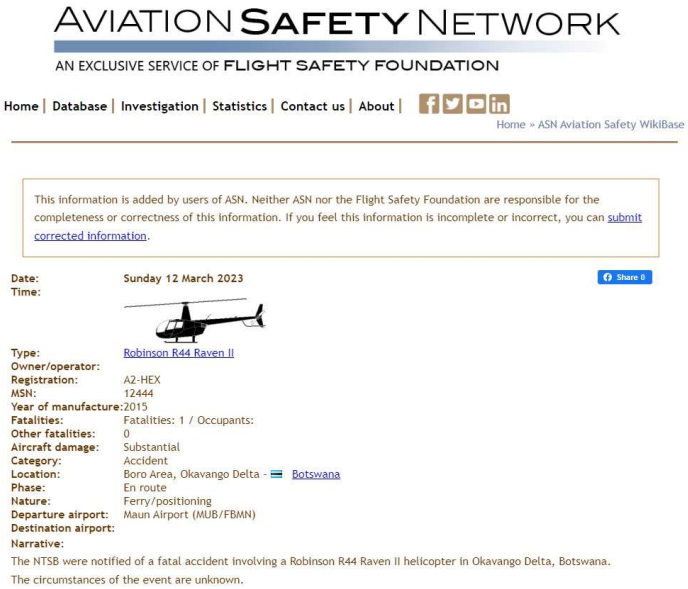
1.3. Supplied Components (Extract 2):

(a) Main Rotor Drive Shaft assembly.
(b) Main Rotor Hub with Blades.
(c) Tail Rotor Driveshaft.
(d) Parts of Tail Rotor and -gearbox assemblies.

Photo 1: Similar aircraft, file photo[2]

1 Courtesy Botswana AID

2 Courtesy Planespotters.com



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Date: Sunday 12 March 2023
Time:

Type: Robinson R44 Raven II
Owner/operator:
Registration: A2-HEX
MSN: 12444
Year of manufacture: 2015
Fatalities: Fatalities: 1 / Occupants:
Other fatalities: 0
Aircraft damage: Substantial
Category: Accident
Location: Boro Area, Okavango Delta - Botswana
Phase: En route
Nature: Ferry/positioning
Departure airport: Maun Airport (MUB/FBMN)
Destination airport:
Narrative:

The NTSB were notified of a fatal accident involving a Robinson R44 Raven II helicopter in Okavango Delta, Botswana.
The circumstances of the event are unknown.

Extract 1: Incident report[3]

Component (S/n #; Part #)	Date Installed	Time at inst.	Component life time	Total Number Service Hours	Total time since last overhaul/Inspection	Previous reported difficulty
Main rotor blade (S/n: 14232; Part # CO16-7)	27/04/22	0	2200	467.9	467.9	Nil
Main rotor blade (CO16-7; S/n: 14233)	27/04/22	0	2200	467.9	467.9	Nil
M/R drive shaft (S/n: R9617; C251-2)	27/04/22	0	4400	467.9	467.9	Nil
Tail rotor drive shaft (s/n: 10438; Part#: D196-1)	27/04/22	0	4400	467.9	467.9	Nil
Main rotor hub (S/n: 12485; C154-1)	27/04/22	0	2200	467.9	467.9	Nil

Extract 2: Supplied components, information[4]

1.4. This report is divided into the following sections:

(a) INTRODUCTION & BACKGROUND Par. 1

3 Courtesy ASN

4 Supplied by Botswana DAI

2. APPLICABLE DOCUMENTS

(a) Botswana DAI Request, ref no MTPW/AIG/08/23
(b) Robinson R44 IPC
(c)

3. DEFINITIONS

AAI	Aircraft Accident Investigation	MPI	Mandatory Parts Inspection
AC	Advisory Circular	NDE	Non-Destructive Evaluation
AD	Airworthiness Directive	NDI	Non-Destructive Inspection
AISI	American Iron and Streel Institute	NDT	Non-Destructive Testing
AME	Aircraft Maintenance Engineer	OEM	Original Equipment Manufacturer
AMO	Aircraft Maintenance Organization	OHSA	Occupational Health and Safety Act
ASI	Air-Speed Indication/or	POD	Probability of Detection
ASTM	American Society for Testing and Materials	QMS	Quality Management System
BE	Big End	RC	Rockwell C-scale
EASA	European Union Aviation Safety Agency	RoD	Rate of Descend
EBSD	Electron Back-Scatter Diffraction	RT	Radiographic Testing

ECSA	Engineering Counsel of SA	SABS	South African Bureau of Standards
ECT	Eddy Current Testing	SACAA	South African Civil Aviation Authority
EDS	Energy-Dispersive X-ray Spectroscopy	SAPS	South African Police Services
FAA	Federal Aviation Authority	SB	Service Bulletin
HE	Hydrogen Embrittlement	SCC	Stress Corrosion Cracking
HIC	Hydrogen Induced Cracking	SE	Small End
HSS	High-Strength Steels	SEM	Scanning Electron Microscope
ICAO	International Civil Aviation Authority	TBO	Time Before Overhaul
IG	Inter-Granular	TG	Trans-Granular
IPC	Illustrated Parts Catalogue	TSO	Time Since Overhaul
IPL	Illustrated Parts List	TTSN	Total Time Since New
IR	Infra-Red or Thermal Testing	UT	Ultra-Sonic Testing
MAUW	Maximum All-Up Weight	VSI	Vertical Speed Indication
MM	Maintenance Manual		

4. PERSONNEL

The investigative member and compiler of this report is Mr C.J.C. Snyman. Mr Snyman is a qualified Physical Metallurgist (Metallurgical Engineering, ECSA Registration: Prof. Eng. Tech. No 201670194), Radiation Protection Officer (RPO, NNR, No 281) and Aircraft Accident Investigator.

5. APPARATUS AND METHODOLOGY

(a) The methodology included visual inspection of the affected part/s, sample preparation and Light, Stereo- and FEGSEM/EDS analysis.

(b) Apparatus:

Type	Make/Model	Operator
Stereo-Microscope	Zeiss Discover V20	C.J.C. Snyman
Scanning Electron Microscope	Zeiss 540 Crossbeam FEGSEM	C.J.C. Snyman
EDS	Oxford Aztec	C.J.C. Snyman

6. INVESTIGATION RESULTS

6.1. Visual- and Low Magnification Inspection

Note 1: The investigation results are based on the supplied parts and information only.

6.1.1. MR Components: MR Blades x2 (serial no's 14232 and 14233):

The visual- and low-magnification inspection (Photo 2; Diagram 1) revealed no clear indications of debonding, pre-impact fracture initiation/s, FOD and/or other discrepancies that could be considered contributory to the accident sequence of events (SoE). The noted damages could be related to a combination of impact and interference with the tail boom structure during the accident SoE. Both pitch horns revealed single overload fractures (Photo 2; Diagram 1, blue arrow).

6.1.2. MR Components: MR Hub (serial no 12485) and Driveshaft (serial no R9617) assemblies (Photo 4):

The visual- and low-magnification inspection of the MR Hub assembly (Photo 3; Diagram 2) revealed no clear indications of pre-impact failure/s or other discrepancies that could be considered contributory to the accident sequence of events (SoE).

The MR driveshaft assembly (Photo2 4 and 6; Diagram 3) revealed no clear pre-impact discrepancies that could be considered contributory to the accident sequence of events (SoE).

The MR Driveshaft (Diagram 3, red arrow) failed close to the MR Hub assembly (Photos 3 and 4, red dashed circles). The disparity between the paint discoloring (induced by the post-impact fire) and the noted rotational surface marks (Photo 4, yellow dashed circle) of the MR Hub end when compared to the MR Driveshaft end (Photo 4, red arrows) suggest that the MR Hub end driveshaft section separated from the bottom driveshaft section during the accident SoE. This could be attributed to severe imbalance (out of track) of the MR system during the accident SoE. This imbalance could have been introduced by (i) the pilot input/s and/or (ii) following the impact with the tail boom structure and/or (iii) due to the separation of the tail boom structure during the accident and/or (iv) impact of the MR blades with ground. The fracture geometry correlates with applied excessive torsional- and bending loads. *The former suggest that the fracture was induced while under power, however it could not conclusively be determined if the applied torsional load was due to engine- or MR inertia loads.*

The MR Pitch Control Links (PCL) revealed fractures within the threaded sections (Photo 5) with no clear indications of pre-impact fracture initiation/s.

6.1.3. TR Components: TR Blades (x2) (serial numbers not supplied):

Note 2: The TR blades were not supplied to this investigation. The analysis is based on the photographic evidence only.

The noted TR blade damages (Photo 6) seemingly correlates with an applied (impact) load while under power. Considering that the aft section of the tail boom structure was located separated from the main wreckage (ref p.1.3.), it can be derived that the damages were inflicted due to interference with the tail boom structure during the accident SoE.

6.1.4. TR Components: TR Driveshaft (serial no 10438), -Gearbox and -Control assembles

The Single-piece (elastomer bearing) TR Hub assembly revealed no clear indications of preimpact discrepancies other than the fractured push-pull tube assembly (Photo 8, red arrow; Diagram 5, red arrow). The fracture surface revealed no clear indications of pre-existing initiation/s and/or other discrepancies.

The TR Gearbox attachment points (Diagram 5) fractured at various locations during the accident SoE (Photo 9). The fracture surface morphologies and geometries correspond with an overload condition attributable to the SoE.

The TR Driveshaft failed at the aft yoke (Photo 10; Diagram 5, blue arrow) from the rear flex plate assembly. The fracture surface geometry and morphology suggest a bending-overload condition while under rotation. This correlates with reported separation of the aft tail boom structure during the accident SoE.

The inspection revealed continuity between the TR Input- and Output Driveshafts supporting the notion of mechanical integrity (support bearings, beveled gears, etc.) within the TR gearbox.

6.2. High Magnification Inspection

6.2.1. MR Components: MR Hub (serial no 12485) Pitch Control Links

The high-magnification inspection of the PCL fracture surfaces revealed no clear indications of fatigue and/or other discrepancies (Photo 11). Secondary fracture initiations within the threaded sections confirmed exceedingly high applied bending loads applied during the accident SoE. The fracture surface morphologies are consistent with a ductile tensile overload (Fractograph 1).

6.2.2. TR Components: TR Hub Push-pull Tube

The high-magnification inspection of the Push-pull Tube fracture surface revealed no clear indications of fatigue and/or other discrepancies. The fracture surface morphology is consistent with a ductile tensile overload (Fractograph 2).

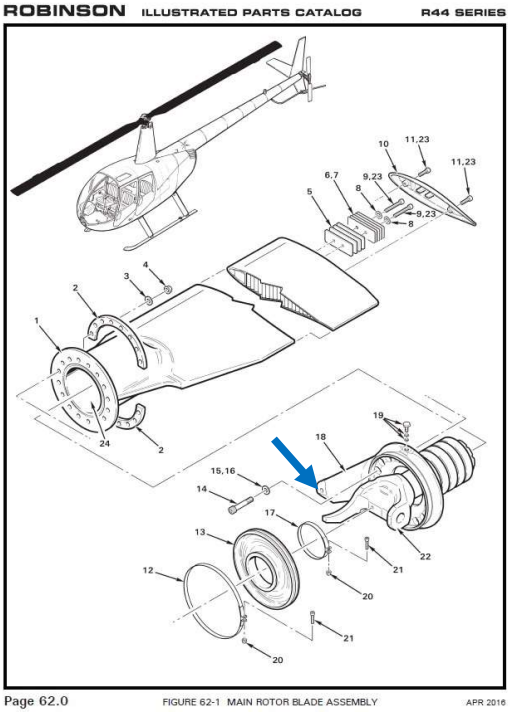


Diagram 1: MR blade assembly [5]

[5] Courtesy RH

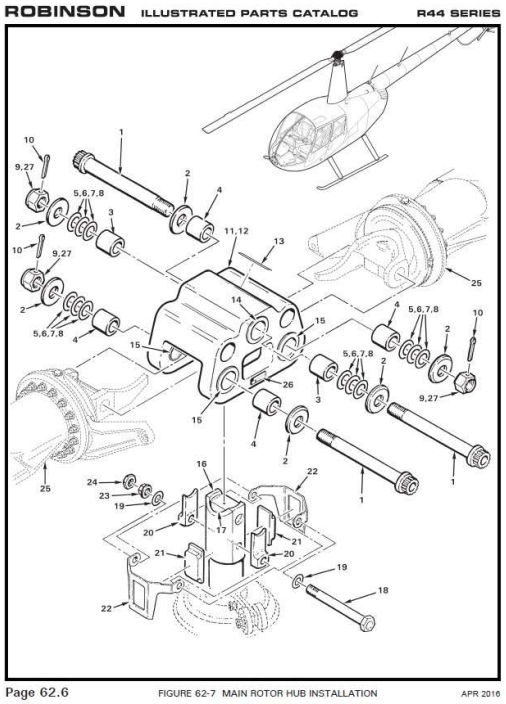


Diagram 2: MR Hub assembly

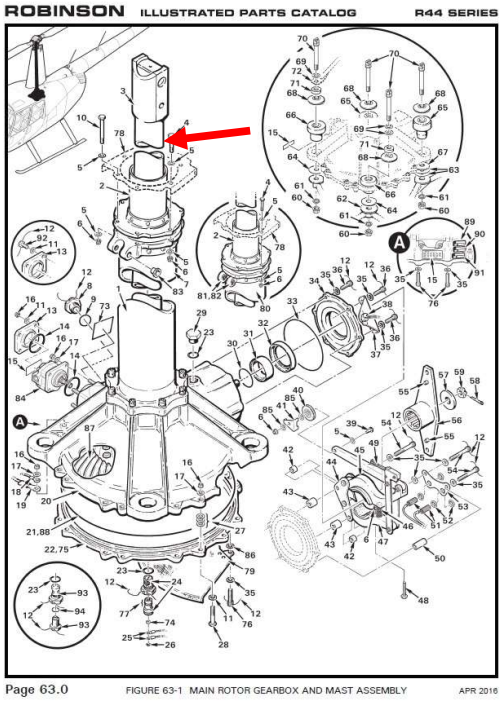
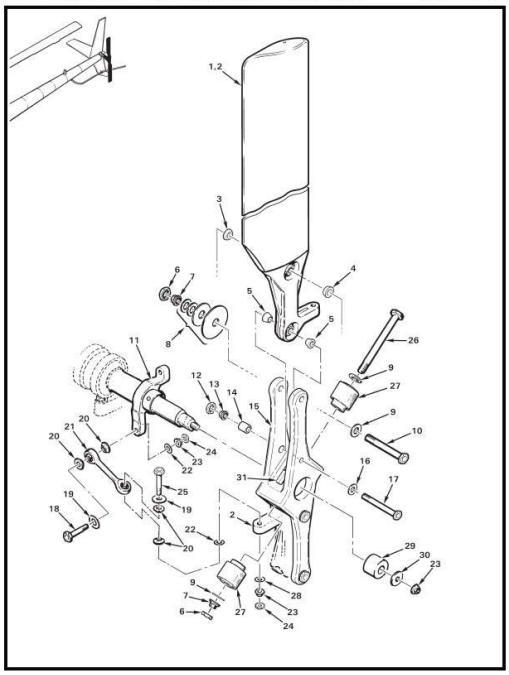


Diagram 3: MR Gearbox and Mast assemblies



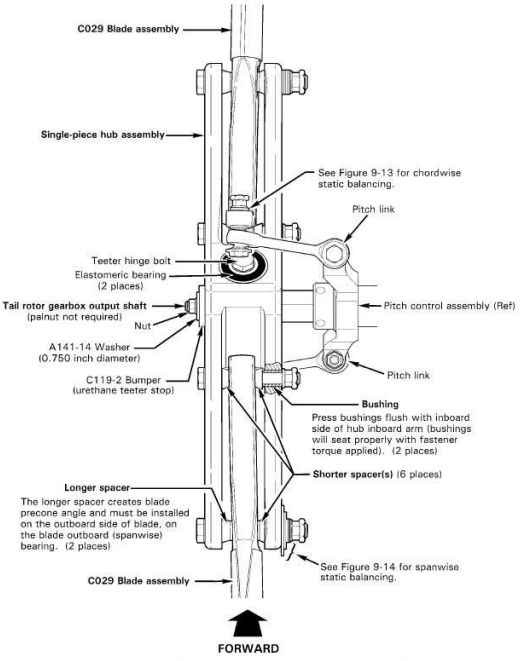
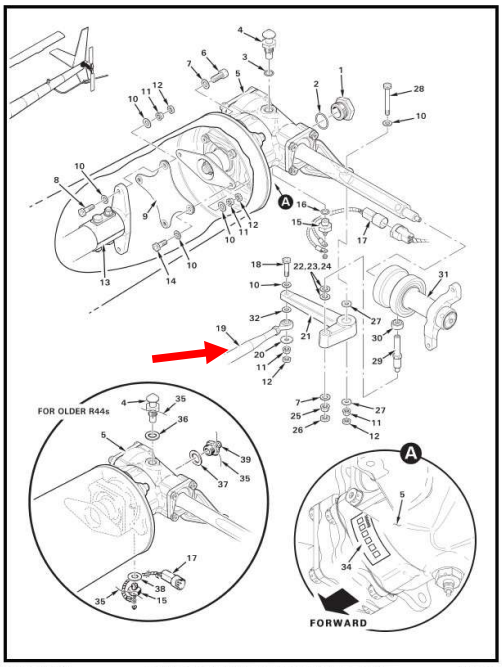


FIGURE 9-11 SINGLE-PIECE HUB TAIL ROTOR ASSEMBLY INSTALLATION

Diagram 4: Single -Piece TR Hub Assembly



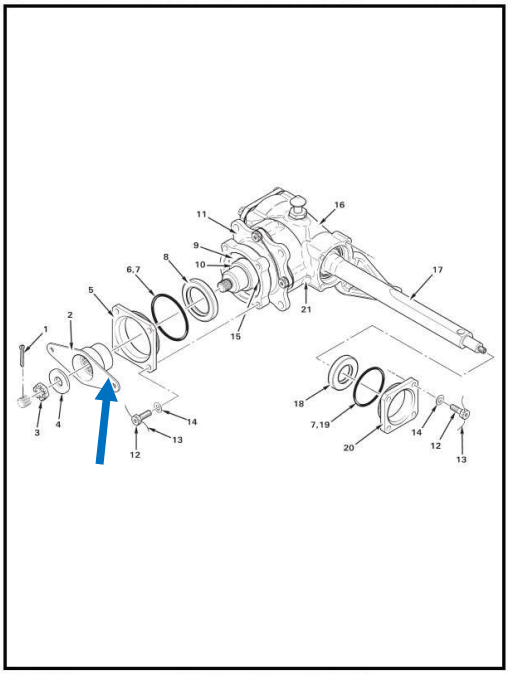


Diagram 5 : TR gearbox assembly

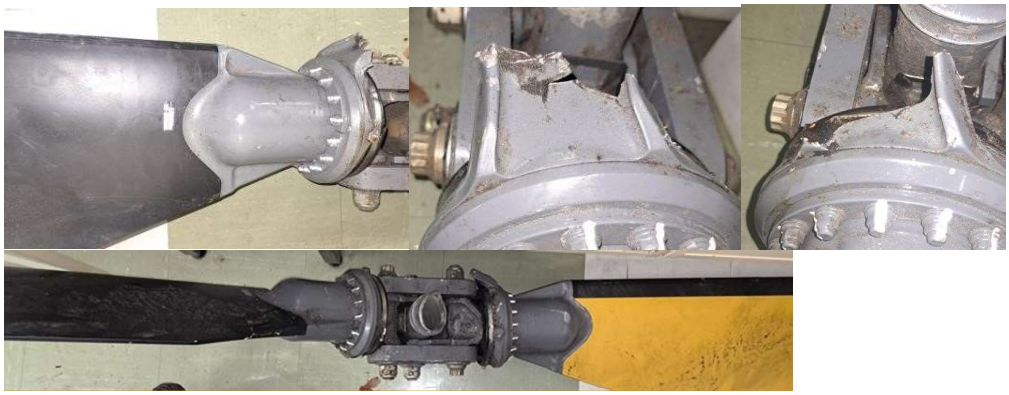


Photo 2: MR blades, as supplied (Dig ital)

Photo 3: MR Hub assembly, as supplied (Digital)

Photo 4: MR drive (mast) assembly, as supplied (Digital)

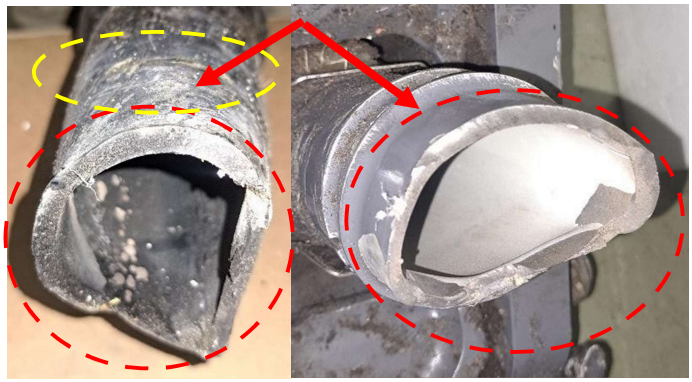
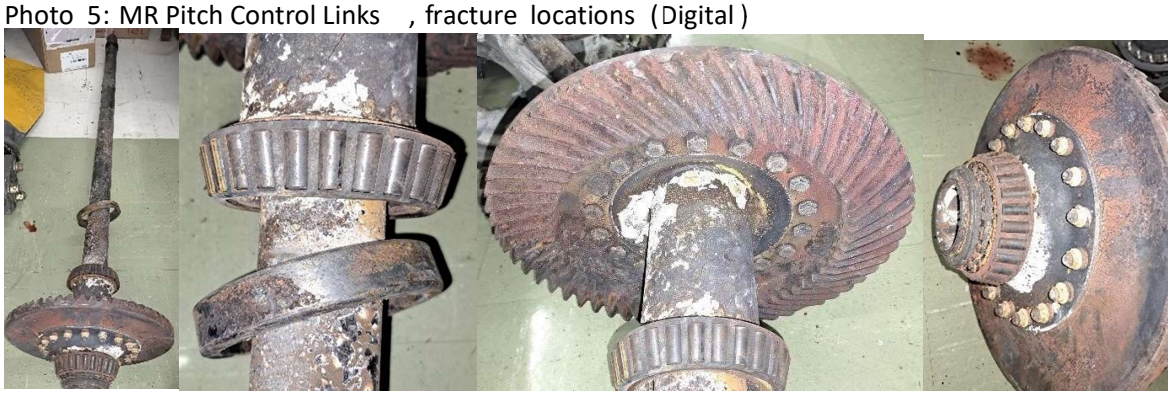


Photo 4: MR Driveshaft primary fracture location (Digital)

Photo 5: MR Pitch Control Links , fracture locations (Digital)



Ph oto 6: MR Driveshaft assembly (Digital)

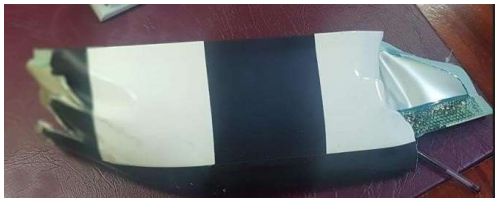


Photo 7: TR Blade conditions [6]

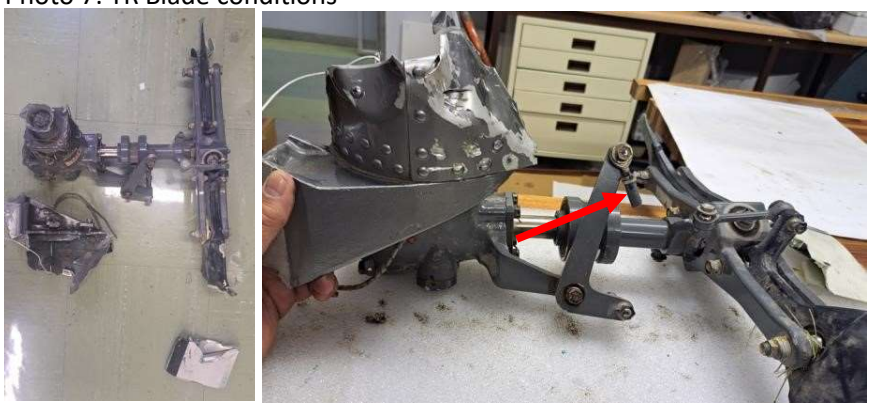


Photo 8: Single -piece TR assembly, as supplied (Digital)

Photo 9: TR Gearbox fractures (Digital)

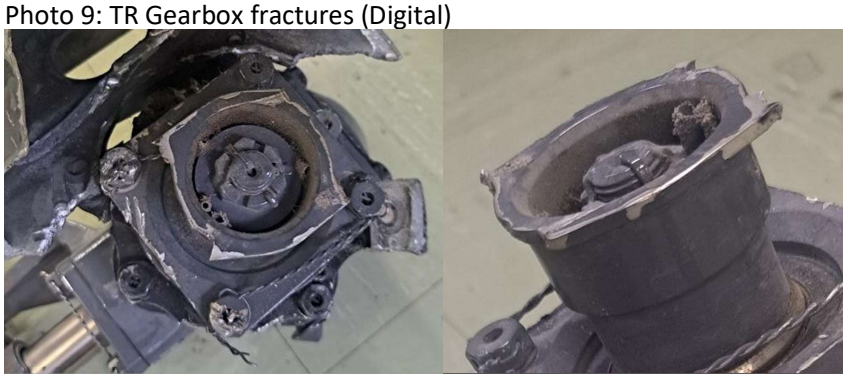
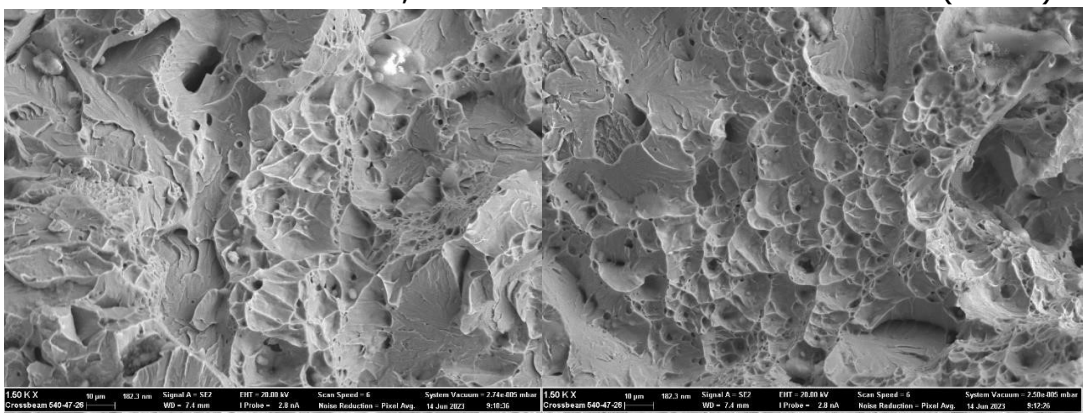


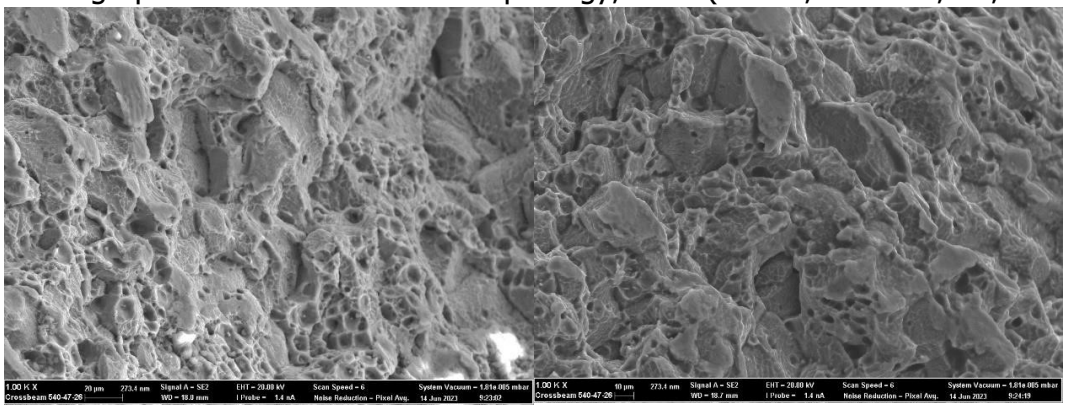
Photo 10: TR Driveshaft Yoke failure (Digital)

[6] Supplied by Botswana AID

Photo 11: Pitch Control Links, fracture surfaces and thread sections (Stereo)



Fractograph 1: Fracture surface morphology, PCLs (1500X, FEGSEM, SE, 20kV)



Fractograph 2: Fracture surface morphology, TR pull-push tube (1000X, FEGSEM, SE, 20kV)

7. DISCUSSION AND CONCLUSIONS

Note 3: The conclusions are based on the investigation results obtained from the supplied parts/components and information only. All information supplied to this investigation from other parties are considered factual.

7.1. The investigation results from the supplied components support the following:

7.1.1. MR Components: MR Blades, -Hub and -Driveshaft assemblies:

No clear indication/s of pre-existing fracture/s and/or other discrepancies were noted that could have contributed to the accident SoE.

7.1.2. TR Components: TR Blades, -Hub, -Driveshaft and -Gearbox Assemblies:

No clear indication/s of pre-existing fracture/s and/or other discrepancies were noted that could have contributed to the accident SoE.

7.2. Most probable Accident SoE:

The investigation results (*ref Notes 1 to 3*) support the notion that the suspected (and reported) interference by the MR Blades with the Tail Boom assembly during flight was most probably induced by the aircraft's control inputs (pilot).

8. RECOMMENDATIONS

8.1. None applicable.

9. DECLARATION

9.1. All digital images have been acquired by the author, unless otherwise stated, and displayed in an un-tampered manner.

ANNEXURE TO THE FINAL REPORT

In accordance with regulation 36(1)(b) of the Republic of Botswana Civil Aviation (Accident and Incident Investigation) Regulations of 2022, a draft final report was served as notice to entities or person whom are directly affected by this report. This was done in order for the served party(s) to submit their significant and substantiated comments.

Following the circulation of the draft final report, the operator submitted their comments to the IIC. After a thorough consideration of the received comments, it was found necessary to adopt some comments and correct the facts as contained in the draft report.

Further comments were received from the representative of the pilot's family as well as the helicopter manufacturer.

This annexure highlights the received submissions and the subsequent action taken as a response to the received comments. Some of the received feedback/comments were of editorial nature to the draft final report and as such, the editorial corrections are made on the report and are denoted by bold font.

The contacted stakeholders are as shown;

1. The helicopter manufacturer (Robinson Helicopter Company) referred to as **Stakeholder A**.
2. The victim's (pilot) family through their representative, who is a renowned helicopter accident investigator from New Zealand, referred to as **Stakeholder B**.
3. Finally, Helicopter Horizon being owner/operators of the occurrence helicopter referred to as **Stakeholder C.**

Editorial comments received:

Page	Para	Fig	COMMENTS RECEIVED
1			**Stakeholder B:** All times in this report are UTC and will be denoted by (Z). The Z is not denoted on any of the timings in the report.
8	1.5		(**Stakeholder B and C:** commented on the erroneous issue date of the Pilot license shown on the draft report)

			Date of license issue 15/03/2023. That can't be right. It is after the accident.
8	1.6		**<u>Stakeholder B noted:</u>** The engine constructor is Lycoming, not Teledyne Continental (Draft final report stated TCM as manufacturer)
13	3.3		Due to inflight separation of the doors severe buffeting in the cabin. NO. The helicopter can routinely fly with doors off.
13	3.4		Auto rotation is not due to loss of tail rotor effect. Loss of directional control is from loss of tail rotor though.
23	11b		Door is upside down in photo. Better to orientate correctly.
27	12c		**Stakeholder B:** It is not hydraulic. Should read <u>oil sight glass of the tail rotor gear box</u>

Stakeholder A's comments relating to the analysis:

Cc: Deepak Joshi <JOSHID@ntsb.gov>

Subject: RE: Links

Hello Joseph,

We have started looking at the photos and information, and there are a couple of questions that immediately come to mind. In photo "out view_ 141156.jpg", we can see the upper portion of the pitch link, that shows exposed female threads. Was the upper portion (rod end) of the pitch link unscrewed from this part as part of the wreckage disassembly/examination, or is this the way it was found?

In photo "TCBc 123029.jpg", we can see some cable wrapped around the tail rotor driveshaft, just forward of the flex coupling. This does not appear to be the wire that is normally inside the tailcone. Do you know where this cable came from? Can you perhaps provide a few more photos of this?

We are continuing to evaluate all of the information we have, but it would help if we could clear up these two questions as we move along.

Thank you,

Ken Martin

Morning Ken..

Those cables were put there by us as we evacuated the wreckage, they were used to tie down the shaft.

From: Ken Martin <investigation@robinsonheli.com>
Sent: Tuesday, March 12, 2024 10:16 PM
To: Joseph Ebineng <jsebineng@gov.bw>
Subject: RE: Links

Hello Mr. Ebineng,

Thank you for that. I'm sorry, I am still not understanding how the cable(s) ended up wrapped around the tail rotor driveshaft. I have added green circles to two of your photos to possibly clarify what I am referring to. I do not see the cables on the shaft in the photo below.

Thank you, and I'm sorry I am not following this yet.

Ken Martin

From: Joseph Ebineng <jsebineng@gov.bw>
Sent: Monday, March 11, 2024 1:26 AM
To: Ken Martin <investigation@robinsonheli.com>
Subject: RE: Links
If you could look closely on the right side, that's where the cables were obtaining. As we were moving the wreckage, somehow the cables were used to tie the shaft. Originally it was not there.

The pitch link (upper portion) was unscrewed for examination purposes, what is contained in the small bag is the associated part.

Stakeholder B's comments in relation to the draft final report:

1. I have studied the report Reference MTPW/AIG/08/23 in detail and acknowledge that the basic investigation has been done well.

2. However, there are a number of areas that require deeper analysis to come to a convincing conclusion. The basics are there, but the detailed work will make the difference. It is common to get this point in an investigation. In helicopter investigations it is often the sequence of events that will get confusing.

3. Mast - The mast separation as in this accident, is not as common as a simple mast bump. Mast separation is a severe form of mast bump. See report fig 5. Close up photos of the mast break would be useful to see if the failure was a singular strike with the ground as noted in report para 1.12.4 or repeated strikes from damage in flight during a break up.

4. Main Rotor Blades - The bending of the main rotor blades noted at report para 2.3 and fig 6 exhibit low energy in the blades. Low energy is when the blades are not being driven by the engine or auto rotation. If a successful auto rotation is not entered into, the main blades will continue to slow down in flight, thus becoming low in energy. A power on strike would have blades bending backwards under power. A mast separation would have allowed the blades to lose their energy before striking the ground.

5. Tail Rotor Blades - There is obvious damage to both tail rotor blades. Something has struck the rotating blades.

6. That damage to the tail rotor blade will cause an imbalance which usually tears the tail rotor gearbox from the mount on the tail cone. (Refer report para 1.12.8) The investigation evidence supports that, but a close-up photo of the fractured mounting face of the gearbox would be helpful to eliminate the possibility of that imbalance being the initial cause of the accident.

7. In New Zealand we have had a case of poorly painted blades causing a gearbox mount failure due to vibration. The considerable vibration, which was not felt in the helicopter, but was caused by different paint layers and therefore different weight to each blade causing the imbalance and subsequent vibration.

8. A photo of the tail rotor driveshaft where it detached from the gearbox would be helpful. The recent maintenance visit raises red flags in some areas such as possible painting.

9. Doors - The door hinges and pins are of very light weight construction. The doors are locked to the hinges by either a spilt pin (sometimes called a cotter pin) through the pin hole or by means of a ring through the pin hole. In order for them to separate there must be some interference damage. I see no evidence of that in the supplied photos.

10. No mention is made of any observed hinge damage in report para 1.16.5 – just that they were inspected. Report para 2.6 notes that the door attachments did not provide conclusive evidence of their failure.

11. The doors may have not been locked, or perhaps massive flexing of the cabin frame allowed the door departure which points back to mast bumping causing that flexing. The possibility exists that the doors were never locked at the hinges after the recent maintenance visit or after a doors-off flight.

13. Where the doors have failed midway near the bottom of the window and above is very common so the assumption that the damage is from the tail rotor is not convincing. Better photos are needed supporting that, although report para 1.12.11 notes the shredded tail rotor blade between two door pieces. I can supply numerous photos from various accidents showing the same door damage and the tail rotor has never been touched during the accident sequence.

14. If the Probable Cause of the accident is an inflight separation of the doors more work needs to be done in that area. I am happy to assist as I have a catalogue of failures of that nature that I have studied and physically have the hinges etc in my workshop or photographic evidence from previous accidents.

SEARCH

15. The time taken to find this helicopter with only a few minutes flying time from the airport is quite extraordinary. This used to occur in New Zealand until about 2008 when, after a number of such accidents, flight tracking devices and 406 emergency beacons came into use.

16. I have a flight tracking device fitted to each of the fifteen aircraft that I am responsible for. Right now, I can see exactly where they are on my mobile phone and what they are doing to the second. It is so accurate, that I can see where they are parked on the tarmac, and I can see when power goes

on at the start of a pilots pre-flight. We use Spider-track devices which are well known internationally.

17. I strongly suggest that Botswana follows New Zealand's lead. This accident would have been even more problematic if a load of injured passengers were involved. This accident site would have been found within minutes of the accident.

18. The Garmin unit fitted to this helicopter is a very basic device, by most standards, more useful in tracking slow moving hikers, not a fast-moving helicopter. A lot of ground is covered in multiple directions in two-minute position intervals.

19. No mention is made of the emergency beacon. A modern ELT was fitted. Kannad 406 AF. Refer report page 8.

20. I am puzzled why this company had the transponders turned off. My review on Flight Radar 24 over the accident period showed me other aircraft moving about but not this company. Surely this rate a mention in the report.

Stakeholder C's comments in relation to the draft final report:

Dear Sirs,

RE: REPRESENTATIONS AND COMMENTS ON DRAFT ACCIDENT INVESTIGATION REPORT: HELICOPTER HORIZONS: A2-HEX

1. We act on the instructions of Simon Little (Pty) Limited t/a Helicopter Horizons.

5. SECTION 1.5 PERSONAL INFORMATION

5.1. The accident occurred on 12th March 2023

5.2. Under Section 1.5 [Personal Information], the date of issue of the deceased Pilot's Licence is reflected as "15/03/2023", which is a date some 3 days after the date of the accident.

6. PROBABLE CAUSE

6.1. The probable cause of the accident as contained in Section 3.1 of the Draft Final report is recorded as being:

"an inflight separation of the doors from the structure for unknown reasons."

6.2. The last off-door operation involving A2-HEX was on 9th March 2023, as confirmed in Section 2.5 of the Accident Investigation Report.

6.3. From 9th March 2023 up to and including the date of the accident (12th March 2023) the doors to A2-HEX were not removed.

6.4. Over the period 9th March to 12th March 2023 A2-HEX had flown 4 hours of flight without any incident involving the doors nor the door attachment linkage or component.

6.5. The doors of A2-HEX, as found at the accident site, are all shown to have been in the "locked" position during flight.

6.6. In the absence of any reasonable finding or explanation as to why the doors may have separated from the structure of the fuselage during flight, it is submitted that:

6.6.1. There was no separation of the doors from the structure of the fuselage in flight (save in the respects suggested below); and

6.6.2. the suggested separation of the doors from the fuselage structure in flight was not the probable cause of the accident.

6.7. SUGGESTED PROBABLE CAUSE

6.7.1. The accident scene and debris field indicate that A2-HEX suffered a main rotor mast failure.

6.7.2. The above is borne out by the photographs appearing as Figure 5 and Figure 6 of the Draft Final Report.

6.7.3. It is suggested that the main rotor mast failure was as a result of the phenomenon known as Mast Bumping.

6.7.4. Mast Bumping occurs when the helicopter's main rotor hub is allowed to make contact with, and deform, the main rotor mast.

6.7.5. Mast Bumping is peculiar to 2-blade rotor systems that use the teetering hinge system on the rotor hub, which system is utilized on the Robinson Helicopter range of aircraft.

6.7.6. The Directorate is respectfully referred to Section 2 of the Robinson Helicopters Pilot Operating Handbook.

6.7.7. In the event of the incorrect application of the cyclic by the Pilot, following a low-G flight situation, this will cause excessive vertical movement or "flapping" of the rotor blades.

6.7.8. In the event of excess flapping of the rotor blades, following the incorrect recovery from a low-G flight condition, the rotor blade(s) may make contact with the aircraft fuselage and the tail cone.

6.7.9. It is suggested that the Pilot encountered a potential bird strike (or other similar condition) requiring the Pilot to undertake an evasive manoeuvre which, in turn, resulted in a low-G flight condition which, in turn, caused excessive "flapping" of the rotor blades during recovery resulting in Mast Bumping.

6.7.10. The rotors then impacted and sliced through the fuselage, accounting for the damage to, and loss (separation) of, the doors.

6.7.1 1. The rotor blades further impacted the tail cone, at or near the tail rotor gearbox which resulted in the tail rotor gearbox becoming detached.

6.7.12. The impact with the fuselage and/or the tail cone resulted in the main rotor mast failure which caused the rotor assembly to separate from

the body of the aircraft, accounting for the distance that the rotor blades and assembly were found from the main wreckage of the helicopter.

6.7.13. The above, in turn, resulted in a complete loss of directional control, causing the helicopter to crash.

6.7.14. The phenomenon of Mast Bumping would further account for the damage (bend) in the rotor blades as a result of the rotor blades impacting the fuselage and/or tail cone.

7. Our client submits that the above is the most probable cause of the accident.

8. Our client requests that the Directorate consider our client's representations and comments detailed above in accordance with the provisions of Regulation 23 (5) of the Civil Aviation (Accident and Accident Investigation) Regulations.

9. Our client further requests service of the Final Report prior to its publication to the Minister.

10. Kindly acknowledge receipt hereof on the duplicate copy of this letter.

Yours sincerely,

Sent electronically hence unsigned

COMMENTS FROM STAKEHOLDER B AFTER EXAMINING ADDITIONAL MATERIALS AS FOLLOW-UP TO DRAFT FINAL REPORT

A. Main rotor hub assessment by the stakeholder arrived to a position below.

Joseph, you will probably have this half - moon mark on the top of your hub and probably on both sides. This indicates that during the mast bump the blades flew up to their maximum height and hit the hub. Massive vibration comes with this and is the reason that the airframe flexes and explains the doors coming off.

Figure A.: Reference hub provided by the stakeholder with the half-moon mark.

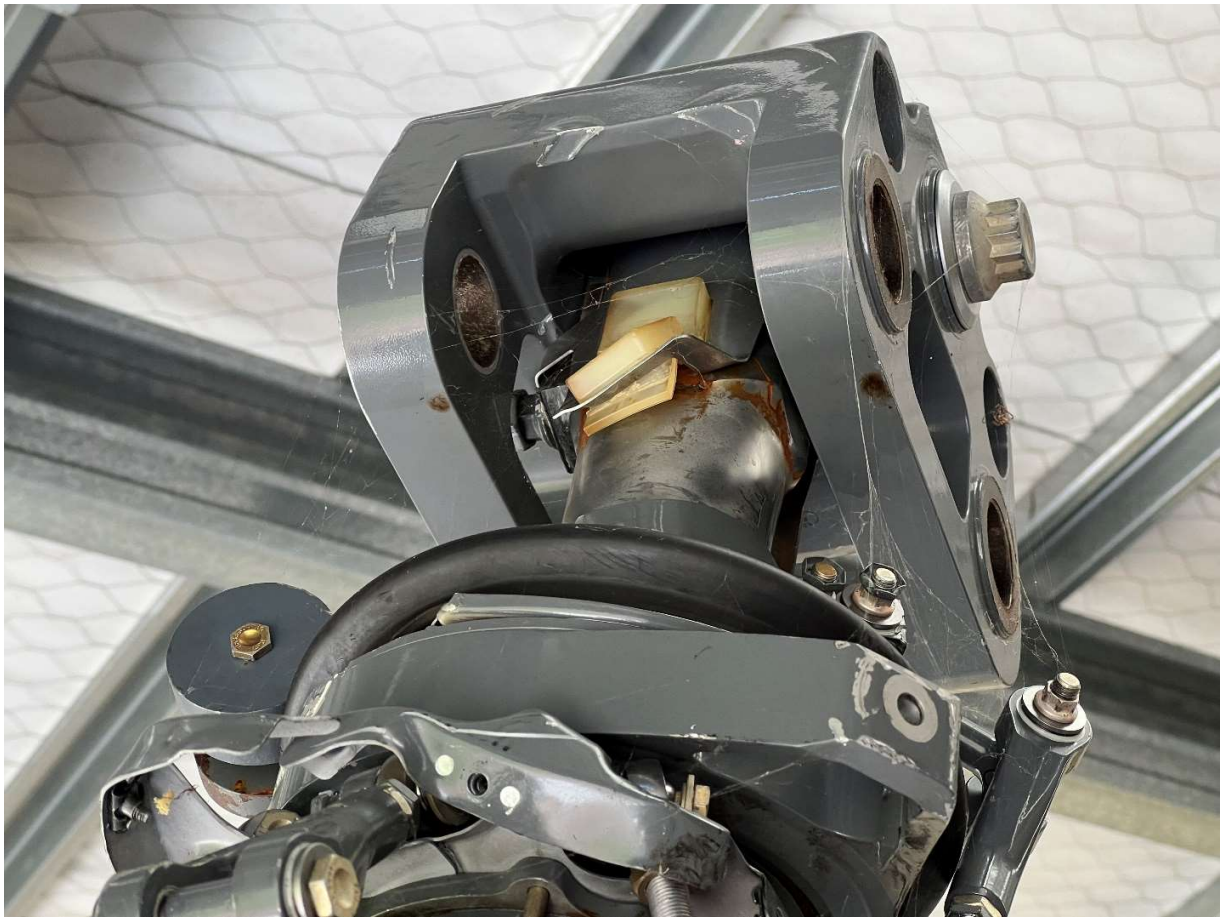


Figure AA: Another example of the main rotor hub with similar scratches provided by the representative.

B. Stakeholder comments following the assessment of the main rotor blades

Main rotor blades

Joseph, have a look on your main rotor blades about half way along. You will see a section that looks like a cat has scratched the furniture. It is in a defined area perhaps about a meter. It is during a mast bump the blade hits the left side front windscreen and shatters the Perspex which causes the scratches on that section of blade. This supports the likelihood of a mast bump.

Figure B: A reference main rotor blade with scratches that resulted from contact with helicopter windows

Figure BB: A2 – HEX main rotor blade with scratches similar to those attributable to contact with windows.